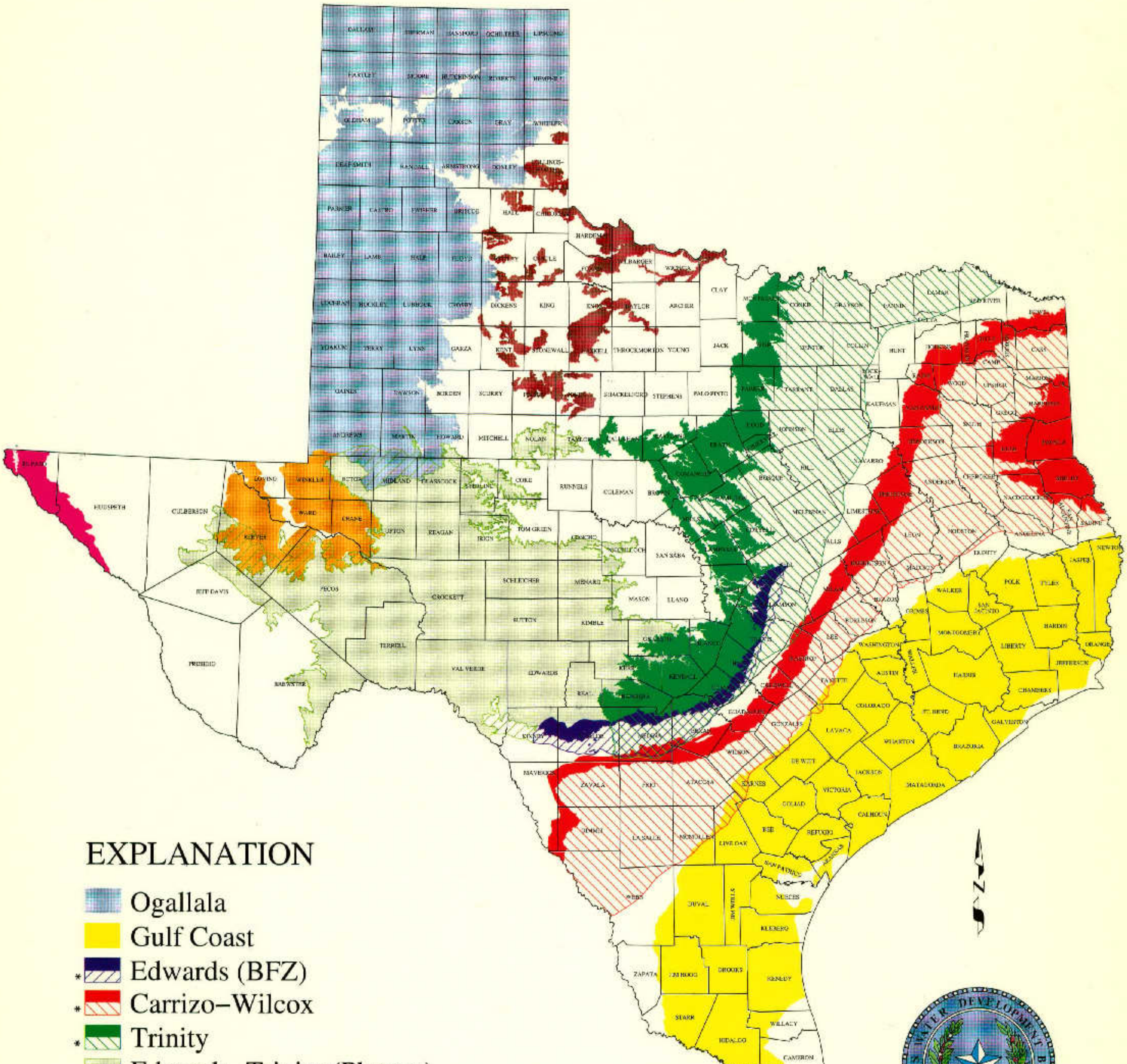
Water, Water Conservation & The Edwards Aquifer

Student Workbook

MAJOR AQUIFERS OF TEXAS



EXPLANATION

- Ogallala
- Gulf Coast
- * Edwards (BFZ)
- * Carrizo–Wilcox
- * Trinity
- * Edwards–Trinity (Plateau)
- Seymour
- Hueco–Mesilla Bolson
- Cenozoic Pecos Alluvium

OUTCROP (That part of a water-bearing rock layer which appears at the land surface.)

* DOWNDIP (That part of a water-bearing rock layer which dips below other rock layers.)

Miles

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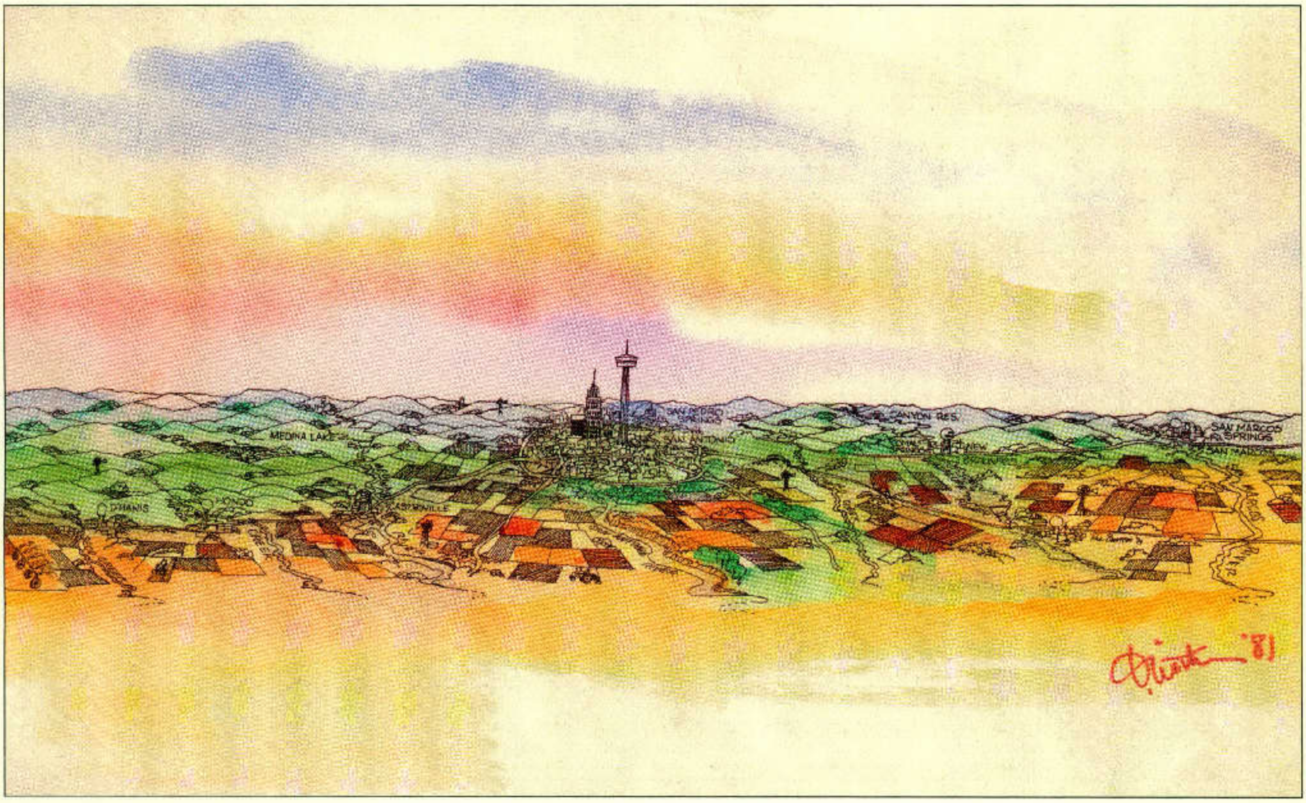
January 1994

Water, Water Conservation & The Edwards Aquifer



Edwards Underground Water District
Edwards Aquifer Research and Data Center

Editor's note: *Water, Water Conservation and the Edwards Aquifer* was originally printed in 1981. It was produced under an interagency agreement between the Edwards Underground Water District (EUWD) and the Edwards Aquifer Research and Data Center (EARDC), Southwest Texas State University. It was produced because of the obvious need to educate young people of this region about the Edwards Aquifer and water conservation. The workbook was updated, revised and reprinted in 1994 because of its popularity with area science teachers and students.

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The text was written principally by Edmund A. Marek, Ph.D., then Assistant Director of the EARDC (Education Center); Thomas P. Fox, then General Manager of the EUWD; and Glenn Longley, Ph.D., Director of the EARDC . Science teachers from Kerrville, Castroville, Seguin, San Marcos and San Antonio participated in workshops for the initial planning and preparation of the student book and teacher's guide. Contributions by the staff of the High Plains Underground Water District No. 1 in Lubbock were invaluable. Teachers involved in the pilot study of the student's book and teacher's guide were: Patti Martin, Goodnight Junior High School, San Marcos; Elizabeth Pipkin, Hobby Middle School, San Antonio; Gerald Haby, Uvalde Junior High, Uvalde.

Herb Grubb, Ph.D. and Tommy Knowles, Ph.D., with the Texas Department of Water Resources, reviewed the manuscript for technical accuracy. The staff of the Texas Education Agency reviewed the book for utility and appropriateness at the eighth grade Earth Science level.

Many others assisted in various capacities during the original preparation and editing of this book. Included were Michael Vivion, Ph.D., SWTSU Assistant Professor of English, editing; Shelly Wiseman and Cristina Stricklen, research assistants, Steve Dockal, Shelly Wiseman, Pat Thomas and Wayne Pearce, artwork and graphics, Corine Krueger and Judy Sturdivant, typing; Jo Cullinane, Russell L. Masters, Bobby Bader, Dick Reeves and Cathy Raley, review of the manuscript.

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THE IMPORTANCE OF WATER

America is a country richly endowed with natural resources: fertile land, extensive and varied forest, an abundance of mineral wealth beneath the soil. All these things are gifts of nature, which our people have used to build a civilization unmatched in human history for its material productivity. From the products of our land, our forests, our mines and oil fields, we have raised great cities and spanned a continent with railroads and automobile highways. But without one key resource, water, none of these miracles of human achievement would have been possible.

Water has unique characteristics. Time does not change it. It is the same today as it was 10,000 years ago. Water is active, and affects all other things. It has molded our mountains, carved our great valleys, nourished our forests, created our alluvial plains, played a major part in creating the fertility of our land, and carried off our topsoil. Changes in its quality are only temporary; it does not change in quantity but only in its location and form as it pursues nature's eternal cycle from the raindrop to the land, thence to the sea, and back again to the clouds.[1]

Our study of water, water conservation and the Edwards Aquifer begins with an introduction to the importance of water, an examination of the water cycle, and definitions of surface and groundwater. These concepts of hydrology are then applied to the water system known as the Edwards Aquifer. Next, we examine the hydrology, geology and history of water in Central Texas; the uses of water in the Edwards Aquifer; and the future of this precious natural resource. Concluding our study of water is a look at water conservation and water resource planning.

[1] *National Water Resources Policy*

Water and air are the most important basic ingredients in your life. Inside your body, water helps transport food, oxygen and waste products. It aids in regulating your body temperature. It is an essential ingredient for many of the chemical reactions in your body. Without water you could survive for only a few days. Just as you cannot exist without water, all living things must have water to exist. ALL LIVING THINGS DEPEND ON WATER!

Approximately 70% of your body and your pets' body is water.

Water is an essential part of all community activities. It is used to grow food for your community and, in fact, is used in manufacturing almost everything in your community. In addition to this work, water is also used to transport human and industrial wastes for treatment and disposal.

Can you think of how water is used to make so many products?

Of all the water on this planet, only freshwater is directly usable for man's survival. The vast oceans of salt water cannot, as yet, economically be used to quench your thirst or water your lawn. Frozen water at the poles cannot be used until it is melted. Only liquid freshwater can supply the basic needs of life on land.

National Geographic refers to water as the "wonder fluid" in a revealing article titled "Our Most Precious Resource, Water."

For a brew that's colorless, tasteless, odorless, and calorie free, water packs a punch.

It is the only substance necessary for all life; many organisms can live without oxygen, but none can live without water.

It comes closest to being the universal solvent; while you drink from a tumbler, the water is busily dissolving molecules from your glass.

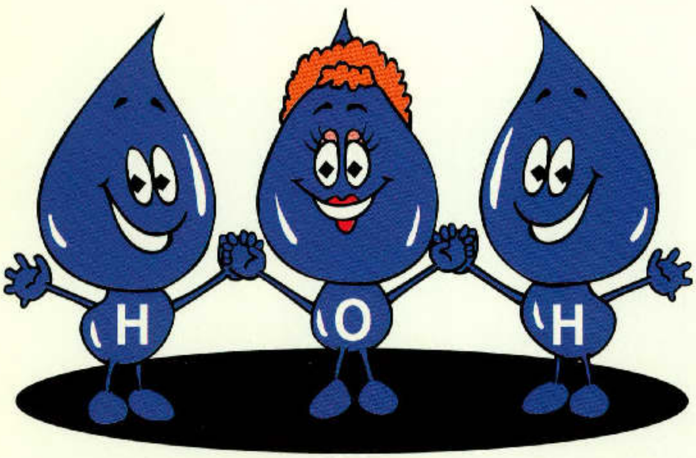
It travels upwards in defiance of gravity. So strongly do water molecules adhere to one another that when one evaporates, from the leaf of a tree, it pulls up those behind like links of a chain. This molecular attraction forms the surface film on which water bugs race without wetting their feet, and which permits you to float a darning needle atop a glass of water.

All of the water on earth is either saltwater, freshwater, or frozen water.

THE WATER CYCLE

Water, the wonder fluid with its own unique properties, also has its own cycle of existence.

Water is made of hydrogen and oxygen. Separately, the components of water are gases and have quite different characteristics than water. But when two parts (atoms) of hydrogen are combined with one part (atom) of oxygen, water, symbolized as H_2O, is produced.

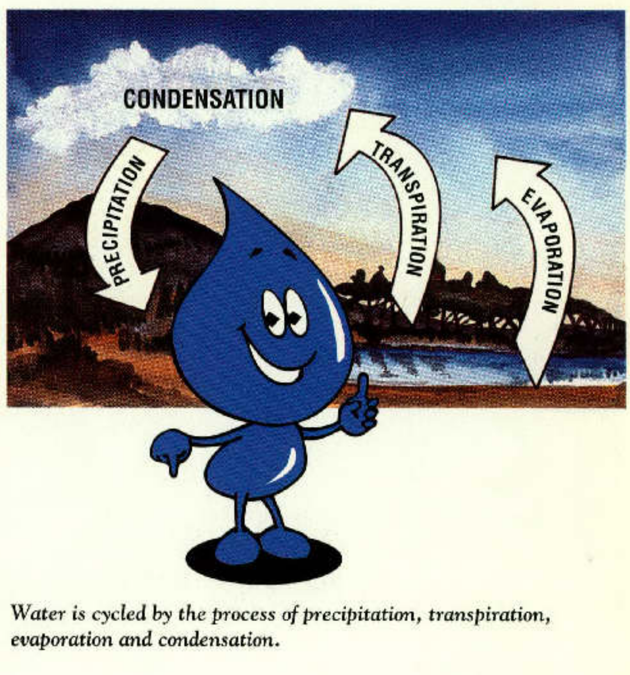


A molecule of water is made of two hydrogen atoms and one oxygen atom.

Man has known for a long time that there is a water cycle – a series of repeating events. In the water cycle, water circulates naturally through five principal realms: oceans, lakes and rivers, icecaps and glaciers, underground, and the atmosphere.

Water is cycled by the processes of *evaporation*, *transpiration*, *condensation*, and *precipitation*. Remember that evaporation means changing a liquid (water) into a gas (water vapor); transpiration is the loss of water to the air from plants; condensation means changing a gas (water vapor) into a liquid (water); and precipitation is the discharge of water from the air.

Since there is no beginning in a cycle, let's start with the evaporation process. Heat from the sun is the driving force of the water cycle and causes water to evaporate from the oceans, lakes, rivers and soil. Also, plants use water from the ground and give off water vapor to the air in a process called transpiration. The water vapor in the air near the earth's surface is warmed and rises; as it rises, it cools and condenses into water droplets. You can see the results of this condensation process in the form of clouds, fog, frost, and dew. When the water droplets in a cloud become too large and too heavy, the cloud loses some of the moisture as precipitation in the form of rain, snow, sleet or hail.



Water is cycled by the process of precipitation, transpiration, evaporation and condensation.

About seventy-five percent of all precipitation falls on the oceans. The twenty-five percent that falls on land has several pathways before it eventually makes its way back to the ocean. 1) Some precipitation goes into rivers that carry it quickly to the ocean. 2) Some is slowed in its journey when it is trapped in lakes and swamps. 3) Some water seeps downward into the soil and either becomes groundwater or is absorbed by plants, which return a portion to the air. Eventually, most water makes its way to the ocean and the cycle continues.

Events of the water cycle in any part of the world are affected by events in all other parts of the world. The water cycle is a complex set of steps involving all parts of the world. Evaporation occurring from our lakes and rivers in Central Texas may fall as precipitation in Oklahoma or China, for example. Precipitation in this area of Texas could come from the Gulf of Mexico or be brought by winds from distant seas.

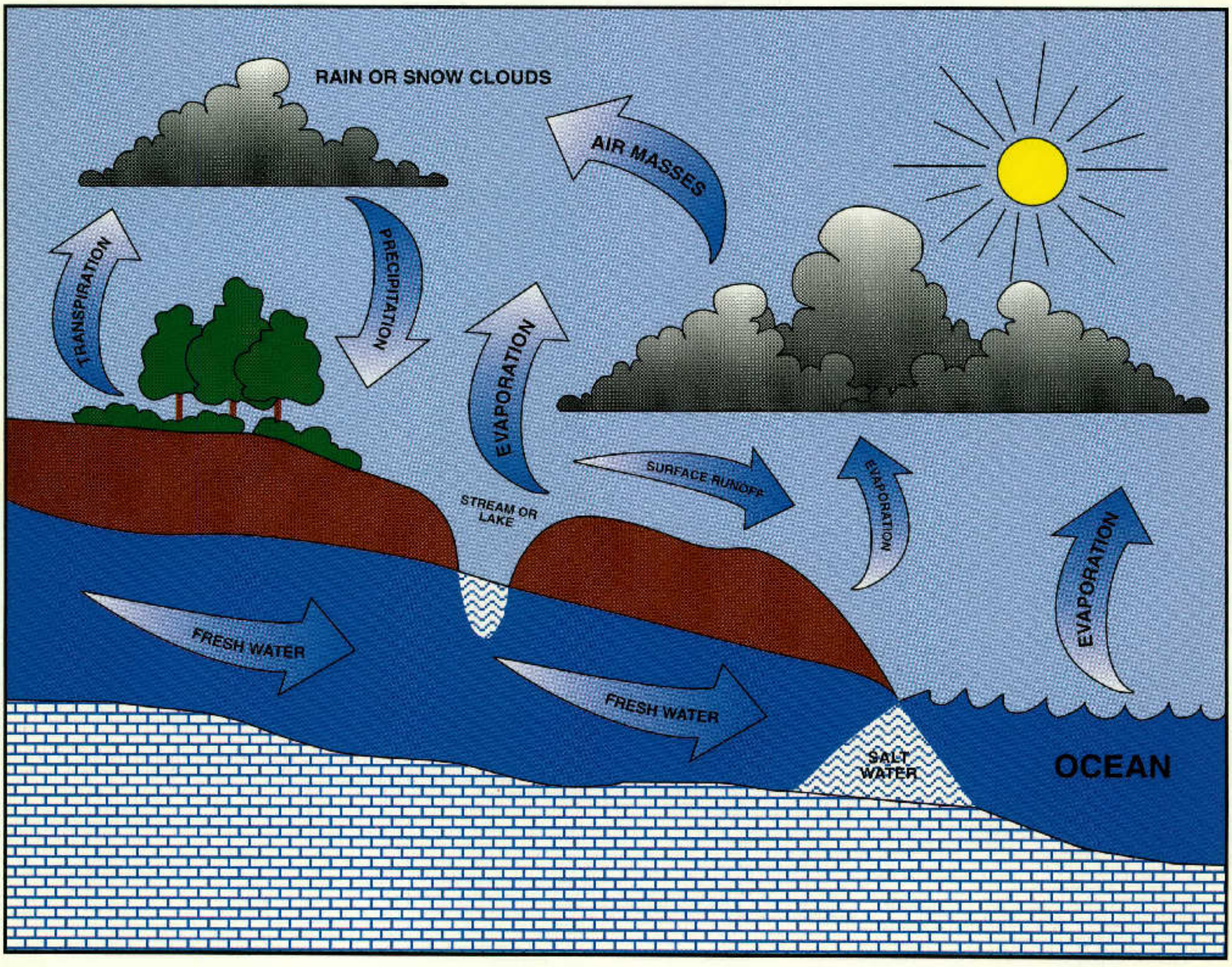


Figure 1. The Water Cycle.

SURFACE WATER AND GROUNDWATER

III

Separate names for surface water and groundwater are used to describe where the water is, not because it is different. Surface water is the water on the land's surface. This includes lakes, streams, rivers and glaciers. As shown in the water cycle, streams carry runoff water from precipitation back to the oceans. Groundwater is water found under the surface of the land. It includes water trapped in the tiny pores of rocks and soil and water trapped in large caves and cavities underground. When surface water enters the ground, it becomes groundwater.

Surface Water

Surface water begins as runoff from rains, melting snow and springs. These combine to form streams, rivers and lakes. There is a continuous interchange between surface and groundwater.

In our area, water drains from the Edwards Plateau, forming rivers and streams that flow through the Hill Country to lower elevations and eventually to the coast. The rivers are the West Nueces, Nueces, Frio, Sabinal, Medina, Guadalupe, Blanco and other smaller ones.

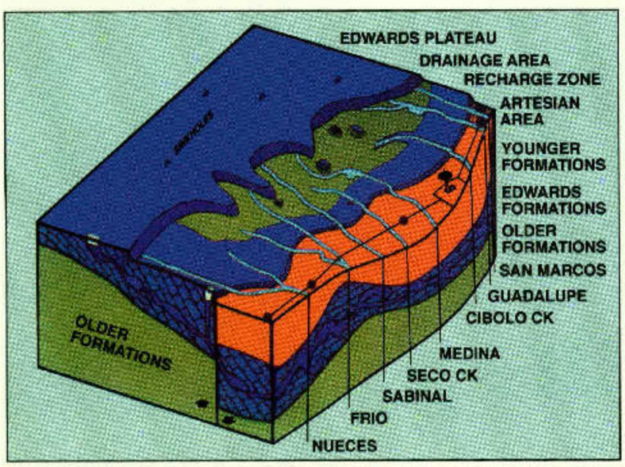


Figure 2. Streams flowing from the Hill Country. What happens to the water in these streams?

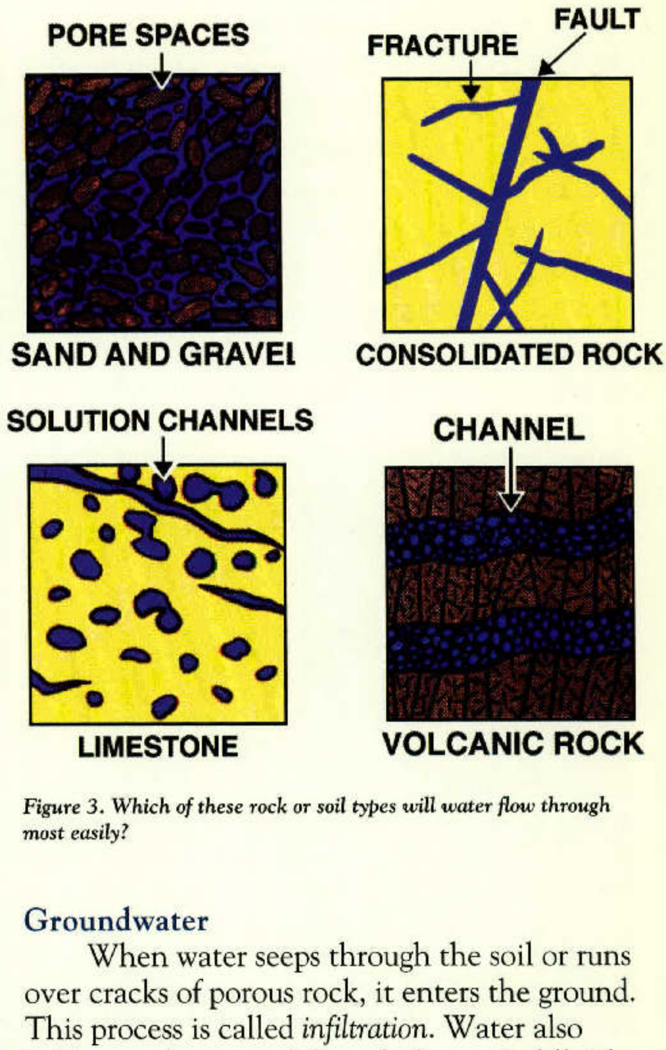


Figure 3. Which of these rock or soil types will water flow through most easily?

Groundwater

When water seeps through the soil or runs over cracks of porous rock, it enters the ground. This process is called *infiltration*. Water also infiltrates the ground directly from rainfall. The amount of water entering the ground is especially large in the Edwards Aquifer area where the openings are extensive and numerous.

Water may enter the ground through cracks in the soil or through pores between soil particles. Some rocks have spaces or cracks between the crystals or grains. These pore spaces allow water to flow into the rock. This condition of rock and soil is called *porosity*. The size and arrangement of the pore spaces determines how easily water will travel through the rock.

Rocks with large pore spaces through which water or other liquids flow freely are said to be *permeable*. Sandstone is a good example of permeable rock. Layers of sand and gravel are also very permeable. Material that will not permit liquid or water to flow through it is said to be *impermeable*. Shale, slate and clay are good examples of impermeable materials.

Water travels downward into the ground through the soil and continues through permeable layers until reaching the impermeable layers. The water continues to collect in the porous rock and fills the pores. This is known as the *zone of saturation* because the pores are filled with water. The area above the zone of saturation is the *zone of aeration*. In this area the pores are partially filled with air. The junction of the two zones is the *water table*.

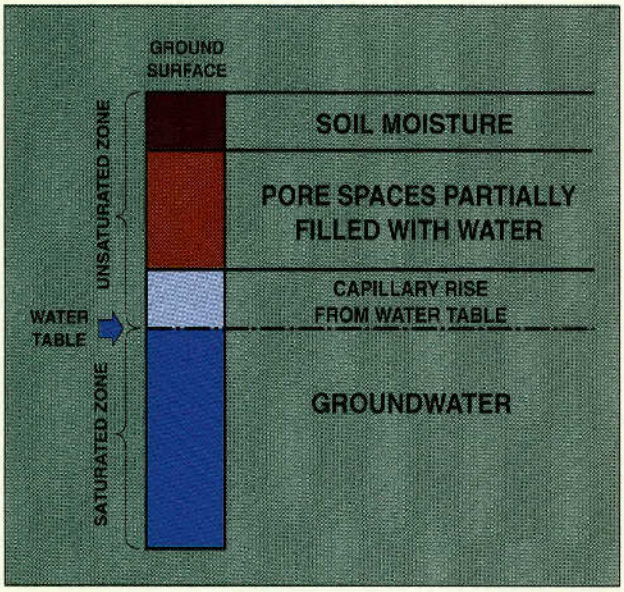


Figure 4. Which area is an aquifer?

The name for a rock or soil layer which contains and transmits water is *aquifer*. *Aqua* means water in Latin, and *fere* means to bring. An aquifer is an underground zone or layer that is the source of usable quantities of water. An aquifer may be in gravel or sand, a layer of sandstone, a zone of highly shattered or cracked rock, or a layer of cavernous limestone. The *Edwards Aquifer* is a water bearing layer of cavernous, fractured and cracked limestone.

The area where most of the water enters the ground is called the *recharge zone* because water refills or recharges the groundwater supply below the surface. Water flowing into an aquifer is said to be recharging the aquifer. For the Edwards Aquifer, most of the recharge

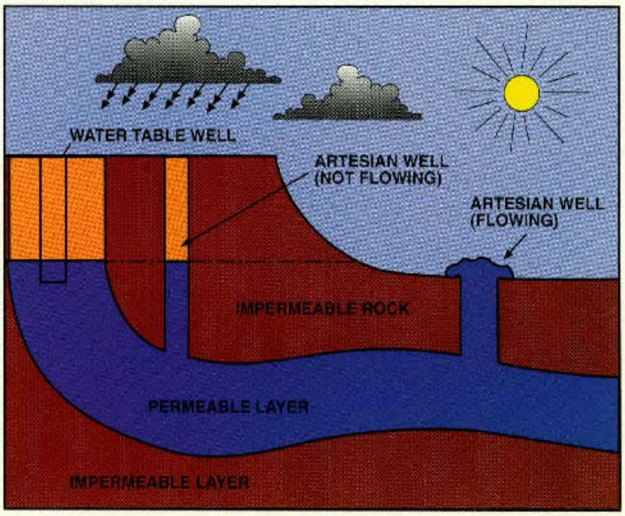


Figure 5. What causes some wells to flow while others don't?

occurs at the outcrop of the water bearing layer at land surface (See Figure 7). Water leaving the aquifer is referred to as *discharge*. Discharge occurs through wells or springs. Most wells require pumping to produce water; however some wells are in *artesian aquifers*. An artesian aquifer occurs when the water, which is confined by impermeable layers, rises or has the potential to rise above the aquifer. Artesian wells may or may not flow at the surface.

Figure 6. Comal Springs in New Braunfels.

A *spring* is defined as a natural discharge of water from an aquifer. Some springs occur where water under artesian pressure rises through a crack in the earth's surface. Artesian springs, located on the *Balcones Fault Zone*, discharge water from the Edwards Aquifer. Leona Springs near Uvalde, San Antonio and San Pedro Springs in San Antonio, Comal Springs in New Braunfels, and San Marcos Springs in San Marcos are such springs. Other springs occur along the sides of valleys that have been eroded below the level of the water table. This type of spring is found in the Edwards Plateau area and supplies water to the streams which eventually cross the recharge zone. Many of these streams lose their normal base flow into the recharge zone.

Water is also discharged through water supply wells. If more water is discharged than recharged, the water level will be lowered, and if discharge exceeds recharge for a long enough period, the springs will cease flowing.

Water used by man comes from lakes, rivers and aquifers. In our part of Texas, however, the Edwards Aquifer is our **primary** source of water.

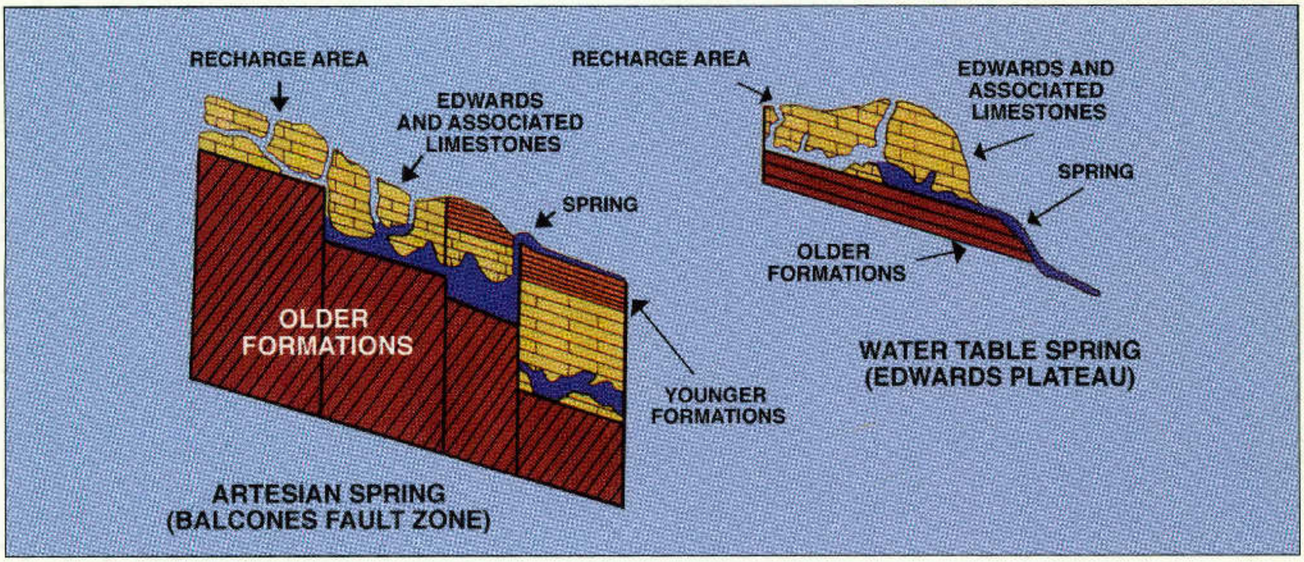


Figure 7. Cross-sections of the Edwards Aquifer showing water table and artesian conditions.

THE EDWARDS AQUIFER

IV

This chapter will present more detailed information on the geology, hydrology and biology of the Edwards Aquifer.

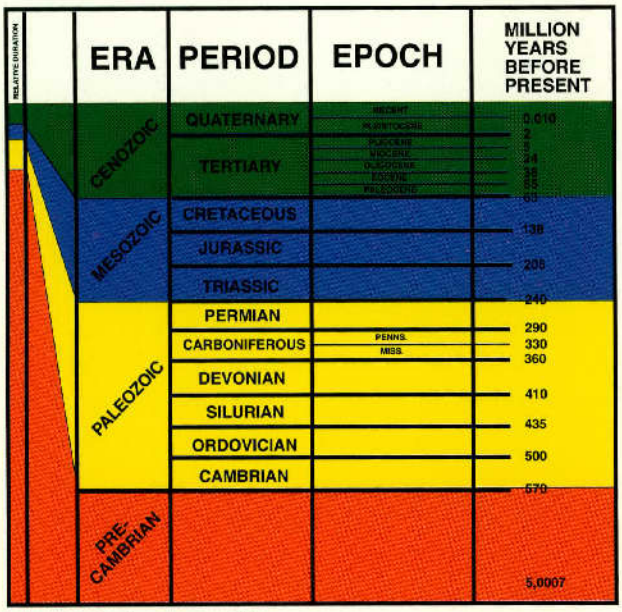


Figure 8. Geologic time table.

Geology

The story of the Edwards Aquifer began approximately 100 million years ago when much of Central Texas was covered by an ocean. Remains of marine organisms, mainly shells and coral, were deposited on the floor of the ancient ocean in layers. These layers became limestone rock, known today as the *Edwards and Associated Limestone Formations*. These layers were deposited during the Cretaceous Period of the Mesozoic Era.

Figure 9a. 100 million years ago Central Texas was a shallow sea.

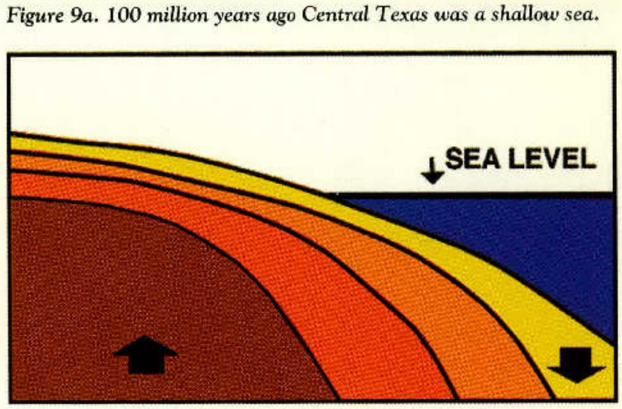


Figure 9b. As the waters receded, Central Texas rose above the surface of the sea.

Major faulting formed the *Balcones Escarpment* approximately 17 million years ago during the Miocene epoch. A shifting of the earth's crust caused Central Texas to be uplifted, resulting in this faulting.

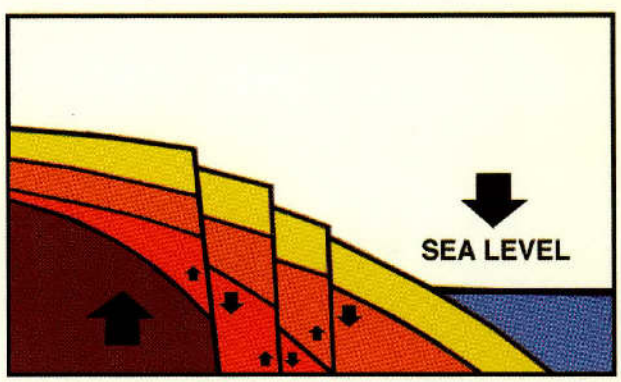


Figure 10. Faulting that produced the Balcones Escarpment.

Then the Edwards Formation underwent a long process of dissolution which led to the porous, cavernous state present today.

Figure 11a. Cliff on Cibolo Creek, Bexar-Comal County Line.

Figure 11b. Porous Limestone.

The creation of caverns in Edwards Limestone has been enhanced by one of water's characteristics. Water (H_2O) is known as the universal solvent because of its ability to dissolve many materials. Carbon dioxide (CO_2) is a gas present in the air and soil. This gas combines readily with water to form carbonic acid (H_2CO_3), a weak acid that has the ability to dissolve limestone ($CaCO_3$) easily. The formula for this process is written:

$$H_2O + CO_2 = H_2CO_3$$

Water + Carbon dioxide = Carbonic acid

Dissolving limestone produces calcium ions (Ca^{++}) and bicarbonate ions (HCO_3^-). The formula for this process is:

$$H_2CO_3 + CaCO_3 = Ca^{++} + 2HCO_3^-$$

Carbonic acid + Calcium Carbonate (limestone) = Calcium ions + Bicarbonate ions

Through the years, cavities and finally caves formed along *faults*, *fractures* and *joints* in the limestone. Since many of the major faults occur parallel to the Balcones Escarpment, much of the water is transmitted through caves along these faults. Large quantities of water are also contained in the dense limestone rock that remains undissolved. This water is relatively unavailable.

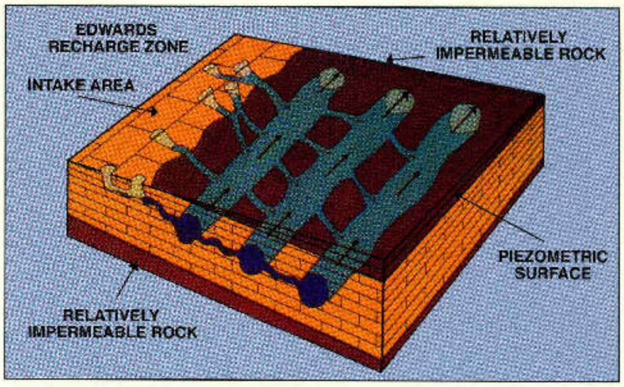


Figure 12. Hypothetical diagram showing how water in the cavernous Edwards may flow (adapted from Arnow 1959).

In the northeastern part of the aquifer (present-day Guadalupe River Basin), rapid cutting by streams was increased by greater fault displacement. The stream cuts in this area penetrated the Edwards Formation creating the first aquifer discharge sites. During the early Cretaceous period, as discharge occurred, caverns enlarged. As time passed, overlying rock in the drainage area continued eroding. This produced numerous recharge caverns in the area known as the recharge zone.

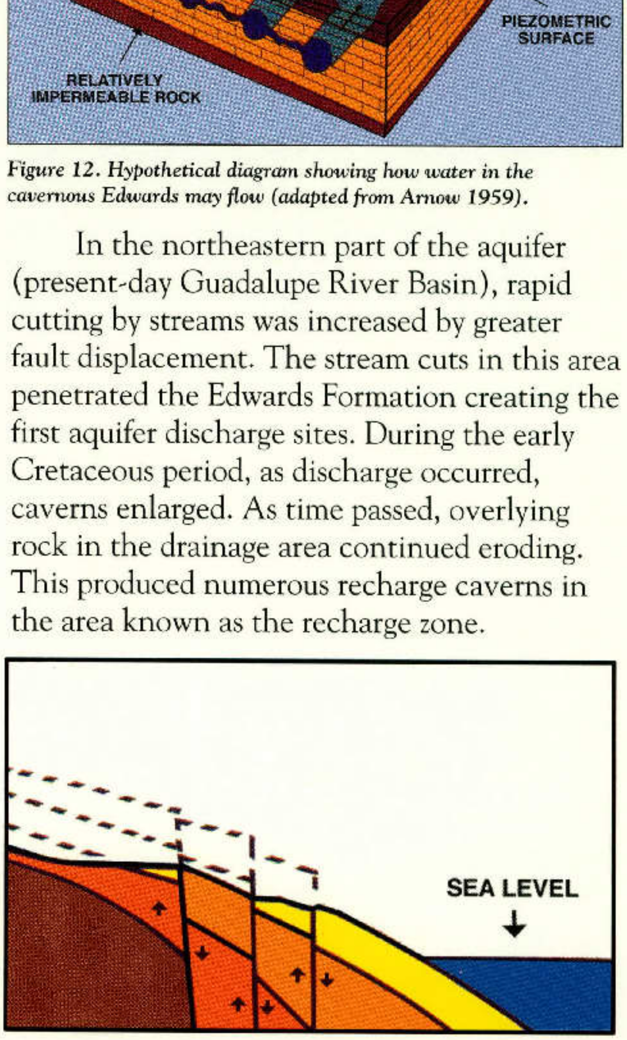


Figure 13. The dotted lines represent erosion of soils to the lower elevations.

This honeycombed, cavernous formation can hold vast quantities of water, which may be obtained by drilling a well into the aquifer. The wells in the Edwards Limestone that produce the greatest quantities of water are shown by well drillers' records (logs) to have penetrated the fractured, or cavernous areas in the limestone.

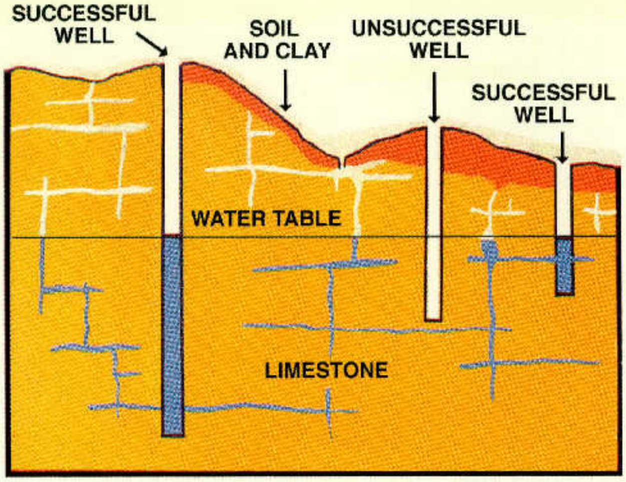


Figure 14. Groundwater in a limestone system.

Hydrology

The Edwards Aquifer "system" is a very complex geologic and hydrologic unit. The system as it is understood today has distinct physical and geologic boundaries and components.

The upper or northern boundary of the San Antonio Region of the Fault Zone Aquifer includes the drainage areas of the Nueces, San Antonio and Guadalupe River Basins. In the drainage or watershed area of these rivers, the Edwards Formation is exposed on the surface throughout much of the area. This exposed area is located on the *Edwards Plateau.*

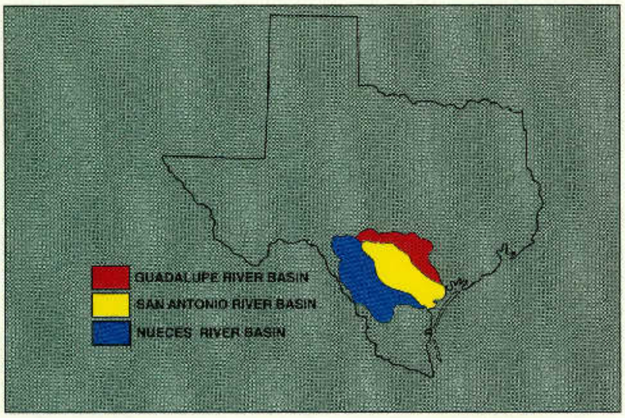


Figure 15. Nueces, San Antonio and Guadalupe River Basins.

The *Edwards Plateau Aquifer* is a water table aquifer which furnishes water for springs that form the base flow of rivers such as the Nueces, Sabinal, Guadalupe, Frio, Medina and Blanco. These rivers flow south to the recharge zone of the *Balcones Fault Zone Aquifer.* The recharge zone roughly coincides with the fault zone. The recharge zone is where the water, primarily from the rivers and streams, enters the Balcones Fault Zone Aquifer. Recharge is concentrated in this zone because the Edwards Formation is exposed on the surface in the fault zone area. The section of Edwards we are most concerned with is the Balcones Fault Zone Aquifer.

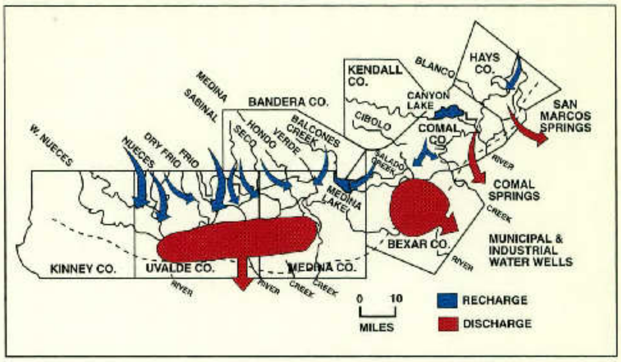


Figure 16a. Recharge and discharge of the Edwards Aquifer.

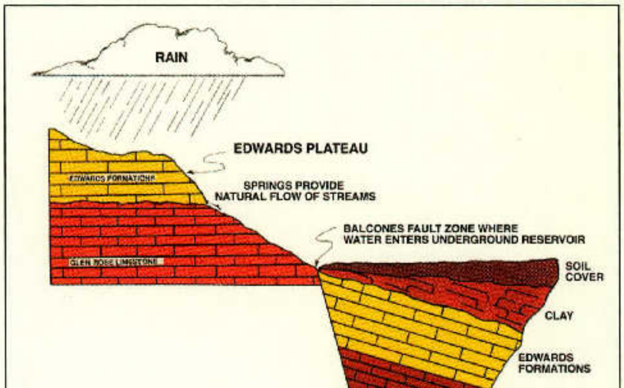


Figure 16b. Cross-section of the Edwards Aquifer.

In the Balcones Fault Zone Aquifer there are two main areas: the artesian zone and the recharge zone (see Figure 17). The artesian zone is so named because the water is confined to the Edwards Formation by clay layers. In most areas, the Del Rio Clay is located directly above the Edwards and Associated Formations. The water is confined in the Edwards Formation by the lower, denser layers of Glen Rose Limestone. Refer to Figure 18, on page 14.

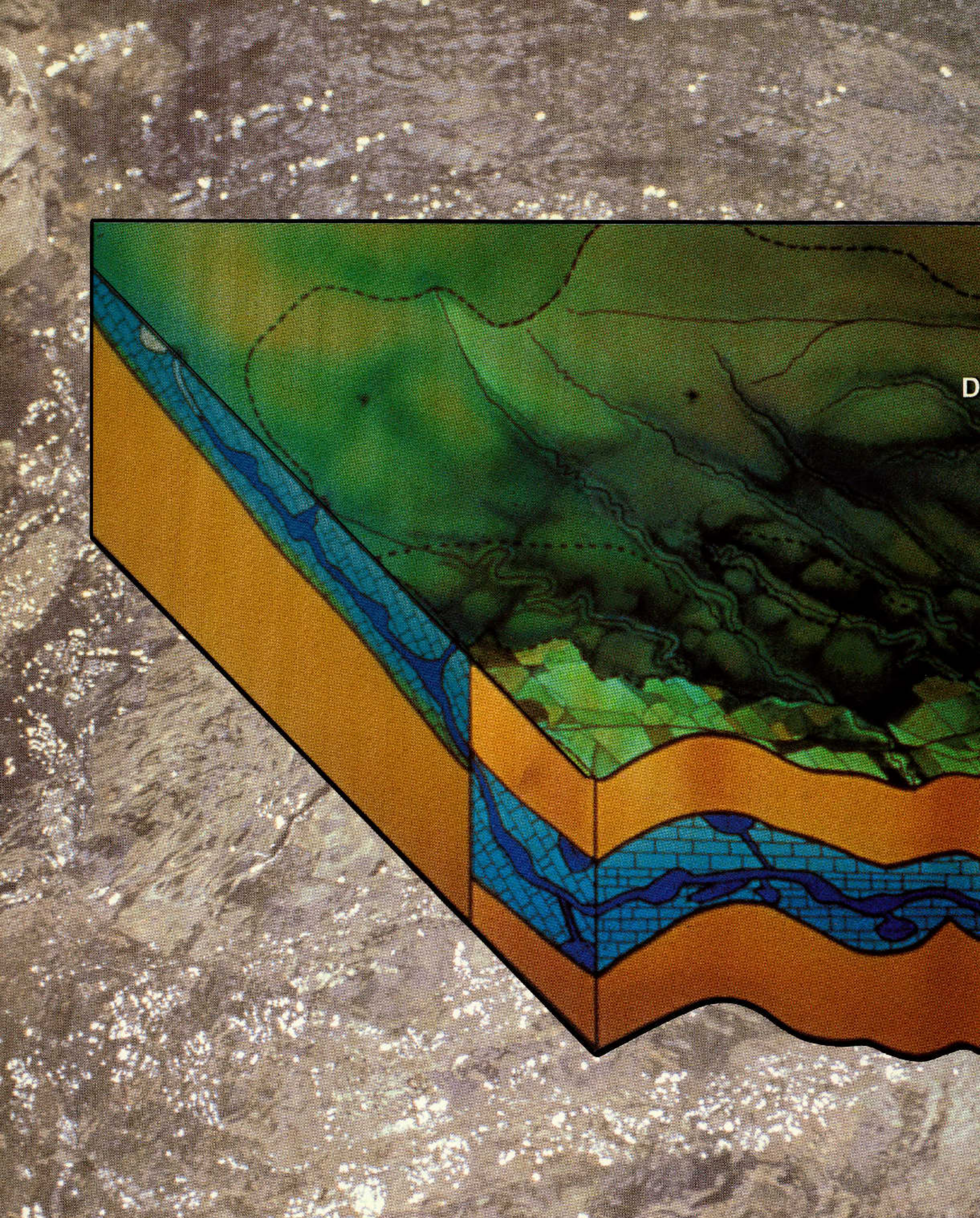


Figure 17. Since the Edwards Formation yields large quantities of water in many areas, it is referred to as the Edwards Aquifer.

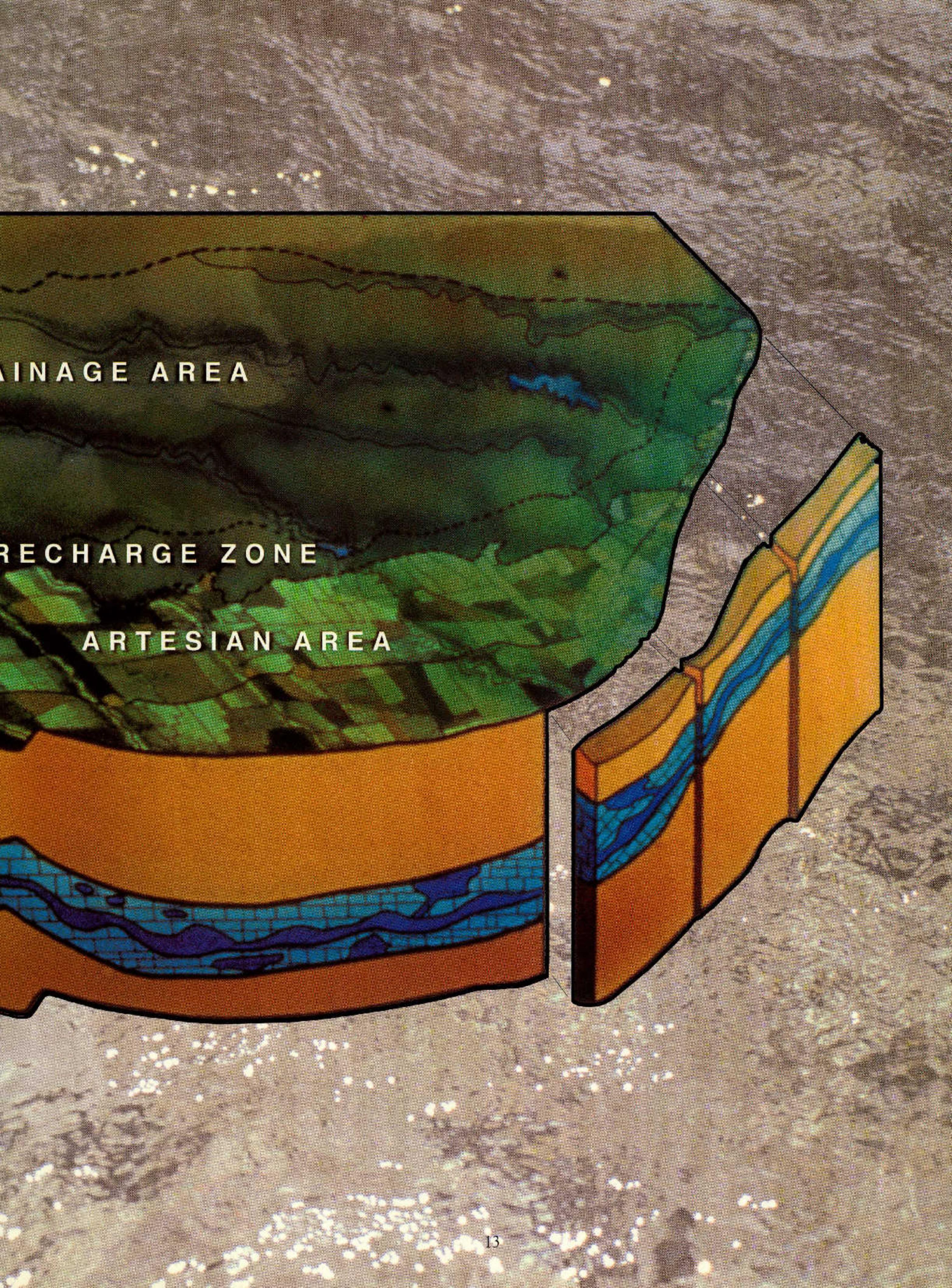

AINAGE AREA
RECHARGE ZONE
ARTESIAN AREA

Figure 18. Geologic strata of the Edwards Aquifer.

Within the fault zone, the aquifer's western and eastern boundaries are *groundwater divides*. A groundwater divide is a physical feature that separates water flow in the aquifer. The area located between Brackettville in Kinney County in the west, and Buda in Hays County in the east, is generally referred to as the San Antonio region. The area from Buda in Hays County, to Salado in Bell County, is generally referred to as the Austin region. Edwards and Associated Formations extend beyond the groundwater divide at Brackettville to the west toward Del Rio.

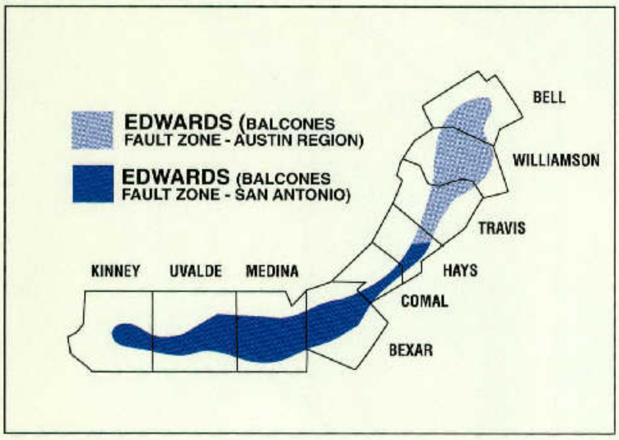


Figure 19. Regions of the Edwards Aquifer.

The Edwards "system" is a very complex hydrologic unit. Movement of the earth's layers produced differences in elevation between the Nueces River Basin and the Guadalupe River Basin (see Figure 2). This is one reason most recharge occurs in the Nueces River Basin and the major discharge occurs in the Guadalupe River Basin. Another reason is that the recharge zone is larger in the Nueces River Basin than in the Guadalupe River Basin.

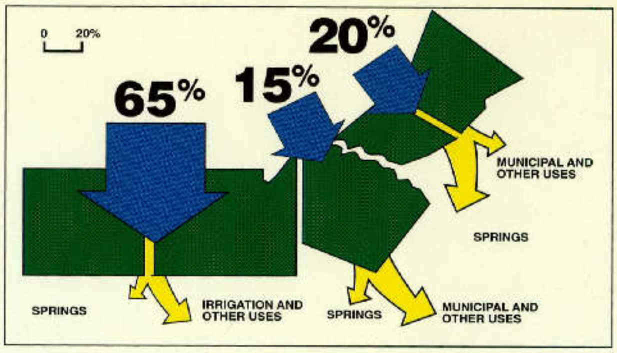


Figure 20. Water balance of the Edwards Aquifer, San Antonio Region. (Approximate, as of 1993)

The spring openings occur at progressively lower elevations from Leona Springs (approximately 870 feet above sea level) in Uvalde to San Marcos Springs (approximately 575 feet) in the northeastern part of the aquifer. The largest springs, Comal Springs, located in New Braunfels, issue from openings approximately 623 feet above sea level. As a point of reference, the lowest recorded water level (612.5 feet) in a San Antonio indicator well occurred during the summer of 1956. The highest water level (703.3 feet) at this well occurred in 1992. The approximate water level in the Kinney County area is 1300 feet above sea level, contrasting with approximately 600 feet above sea level at San Marcos (Hays County). The lower water level in Hays County is the reason water flows from southwest to northeast in the aquifer.

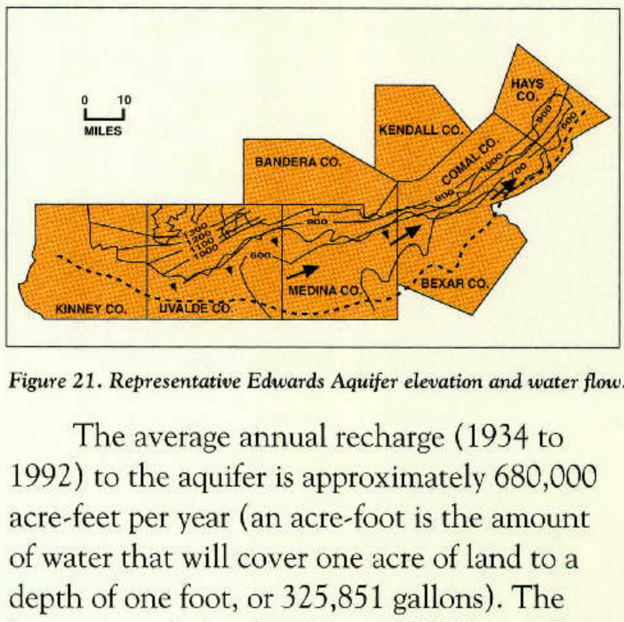


Figure 21. Representative Edwards Aquifer elevation and water flow.

The average annual recharge (1934 to 1992) to the aquifer is approximately 680,000 acre-feet per year (an acre-foot is the amount of water that will cover one acre of land to a depth of one foot, or 325,851 gallons). The lowest recorded recharge was 44,000 acre-feet in 1956; the highest was 2,486,000 in 1992.

This represents one acre-foot of water.

Recharge has been increased by the construction of recharge dams. These dams, or flood-retarding structures, slow the flood flows and allow the water to infiltrate. Thus, much of the water that would have gone past the recharge zone is added to the aquifer.

The first recharge dams were built by Uvalde County in the 1950's. Most recharge projects have been developed by the Edwards Underground Water District in cooperation with the counties, the Soil Conservation service, and other local governments. Medina Dam, while not built as a recharge dam, is now a major recharge point.

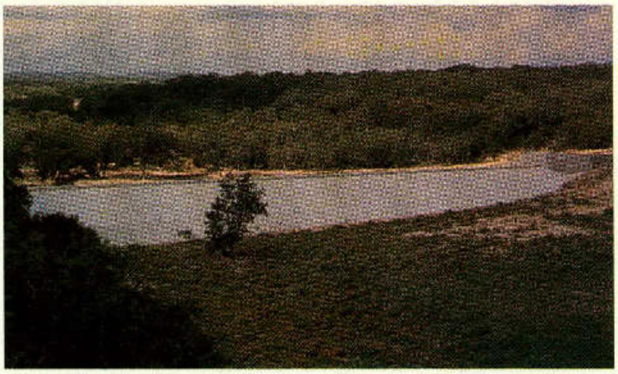


Figure 22a. San Geronimo Recharge Dam, before storm runoff.


Figure 22b. San Geronimo Recharge Dam, after storm runoff.

The southern boundary of good water in the Edwards Aquifer is called the "bad water line," or "fresh/saline water interface." "Bad" or "saline" water is water which has more than 1000 milligrams per liter (mg/l) of dissolved solids, and usually has a bad odor, a higher temperature, and is lower in dissolved oxygen. (Figure 23.)

The quality of water in the Plateau and Fault Zone Aquifers is excellent because the drainage and recharge areas are relatively undeveloped (meaning there are few existing buildings such as homes, businesses, or factories). Recall that normal flow of the streams from the plateau (drainage area) is supplied with water from springs. This flow is important in supplying the excellent quality water for recharge at the fault zone.

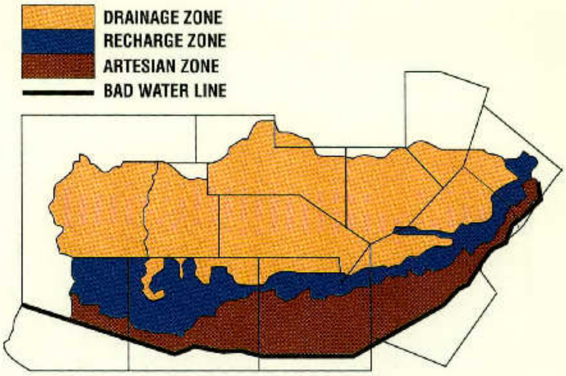


Figure 23. Fresh/Saline Water Interface (Bad water line).

Organic material, including plant and animal matter, enters the aquifer along with recharge. This organic matter is used as a food source by the organisms living in the aquifer. Aquifer organisms include bacteria, crustaceans (including shrimp, amphipods, copepods, isopods, and ostracods), flat worms, snails, beetles, salamanders, and catfish. Approximately forty known species live in the San Antonio Balcones Fault Zone Aquifer.


Figure 24. Texas Blind Salamander.

Through thousands of years of living in darkness, the aquifer organisms have developed characteristics unlike their surface relatives. Eyes have degenerated or disappeared. Pigment in the skin is virtually absent.

Figure 25a. Texas Blind Shrimp.

Figure 25b. Toothless Catfish.

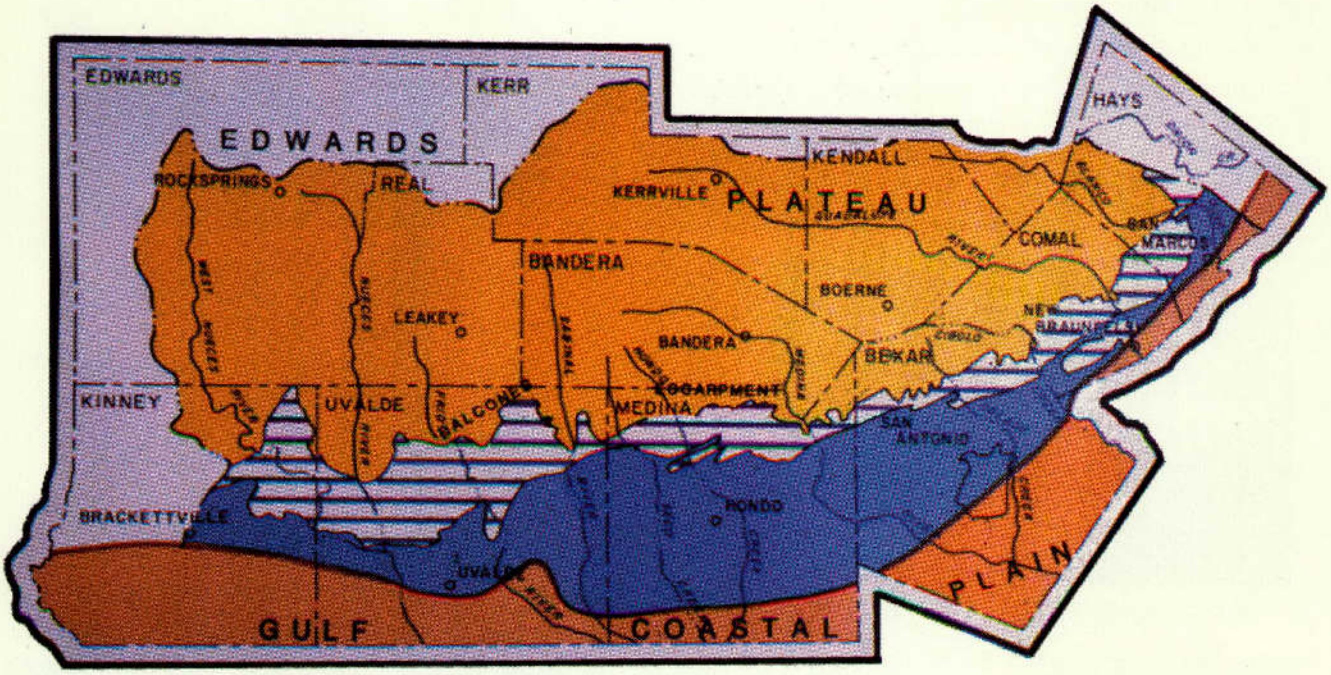


Figure 26. Edwards Aquifer Region: Drainage, Recharge and Artesian Areas.

The Edwards Aquifer is a complex and interesting system. It is unique geologically, hydrologically and biologically.

EDWARDS AQUIFER WATER USE

V

Historic Water Use

The Edwards Aquifer and its springs were the reason for the historic development of the region. Water from the springs was vital to the survival of the area's earliest inhabitants. Archaeological investigations at San Marcos Springs indicate that man lived by the springs as early as 13,000 years ago. Indications of his presence are flint tools, pottery and other handcrafted items around the springs. Archaeologists have discovered numerous sites near San Marcos Springs that date from the time period 6,000 B.C. to 500 B.C. During this period, chert and flint for making tools were taken from exposed Edwards Formations.

Early travels of the Spanish explorers brought them by the major springs flowing from the Edwards Aquifer. The "Camino Real," or King's Highway was completed by the Spanish in 1697 from Natchitoches, Louisiana to San Antonio and Mexico. It passed near San Marcos, Comal and San Antonio Springs. Cabeza de Vaca passed San Antonio Springs on his expedition of 1532-36. St. Denis, a Frenchman from Louisiana, started a small trading village near San Antonio Springs in 1714. By 1716 a military post had been established there. Settlers used the springwater for irrigation.

The history of early San Antonio is composed of numerous accounts of man and his relationship to the San Antonio River, a stream fed by the San Antonio and San Pedro Springs which flow from the Edwards Aquifer. An elaborate system of ditches was constructed for diversion of river water for cooking, drinking and irrigation. Mission San Jose also used the ditches to carry water to power a mill for grinding grain, and to fill a swimming pool for mission residents. The old water ditches, or acequias as they were called, played an essential role in the city's history for over 150 years. The first major acequia was built in 1730 and the last was abandoned around 1899. San Antonio has a rich history centered around the springs located in the city.

Other areas where springs issued from the aquifer also became historically significant. The old Spanish Trail led west from San Antonio through Uvalde, Brackettville and Del Rio.

Figure 27. Early San Antonio Acequia System, 1730-1800.

These cities were founded around springs issuing from the Edwards Aquifer. Between 1867-1895 the Chisholm Cattle Trail led north from San Marcos, passed by Barton Springs in Austin, then through Georgetown and Salado, and continued north. In the mid-1800's German immigrants were attracted to the area around Comal Springs in New Braunfels. Today, people looking for a good place to establish a business, industry or to retire find the water of the Edwards Aquifer a strong attraction and a fine recreational resource. Water is a key factor in the economy of this region.

Current Water Use

There are many uses of water. In our area of the Edwards Aquifer, the primary uses of water are:

1. Agricultural (irrigation, food processing, stock raising)
2. Municipal (drinking and household uses, commercial businesses)
3. Industrial (power generation, mining, manufacturing)
4. Recreational (tourism, parks, riverwalks)
5. Natural (maintenance of ecosystems)

	UVALDE	MEDINA	BEXAR	COMAL	HAYS	TOTAL
Municipal Supply & Military Use	4.0	4.0	211.4	3.7	10.1	233.2
Irrigation	18.7	4.7	2.8	.2	.1	26.5
Industrial Use	.7	------	15.2	12.8	.2	28.9
Domestic Supply Stock & Misc.	2.7	.7	29.1	.7	1.4	34.6
Total	26.1	9.4	258.5	17.4	11.8	323.2

Figures represent thousand acre-feet per year.

Figure 28. Calculated pumpage from the Edwards Aquifer by county and water use, 1992, Report 93-05, Edwards Underground Water District.

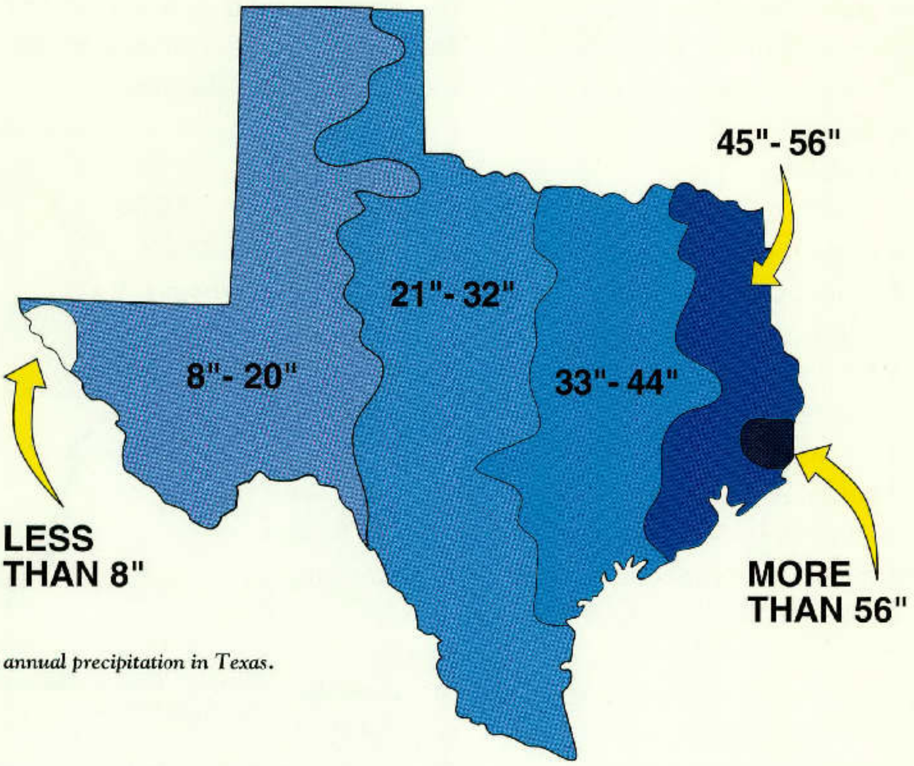


Figure 29. Mean annual precipitation in Texas.

Water is pumped from the Edwards Aquifer to aid in growing crops. This practice is called *irrigation*. Farming and ranching are very important to the economy of this area. Farmers use precipitation as the basic water supply for their crops. In the San Antonio region of the Edwards Aquifer, the annual rainfall averages about 20 inches in the far western region, to about 34 inches in the eastern region.

Most of the crops grown in the area require 24 to 36 inches of water per year. In the practice of irrigation, supplemental water is used to make up the difference between the amount of water available as rain after evaporation loss and the amount needed by the crops. Most of the best crop land in our area is located in the western area (Uvalde and Medina Counties). Therefore, this is where a great amount of irrigation occurs. The objective of efficient irrigation is to improve the water availability to a crop in order to produce a desired crop yield. Furthermore, efficient irrigation must minimize the energy required; minimize water, soil and plant nutrient losses; and protect the quality of the soil and water resources.

Figure 30. Irrigation in Medina County.

Historically, approximately 16% of the water discharged from the aquifer is used for irrigated agriculture. Pumping this water from the ground takes energy. This energy is usually in the form of electric, diesel, gasoline, or natural gas engines. As water levels go down, more energy, and therefore more money is required to pump the water. Farmers have learned that they can save water and money by using available conservation techniques.

Figure 31. Irrigation well.

Much of the Edwards Aquifer water being pumped is used for municipal and industrial purposes. Most of this use occurs in San Antonio. Other important users are Uvalde, Knippa, Sabinal, D'Hanis, Hondo, Castroville, LaCoste, New Braunfels, San Marcos, and Kyle. Edwards Aquifer water is used because of its excellent quality and low cost. There are numerous rural water supply districts using Edwards Aquifer water for the same reasons.

In the city of San Antonio, approximately 170 gallons of water per person (capita) per day is used. This amount is typical of water use in other municipal areas. The figure includes

Figure 32. Pump station.

water used for household purposes, commercial facilities and some industry.

In a typical city, the daily per capita use can be divided into the following categories:

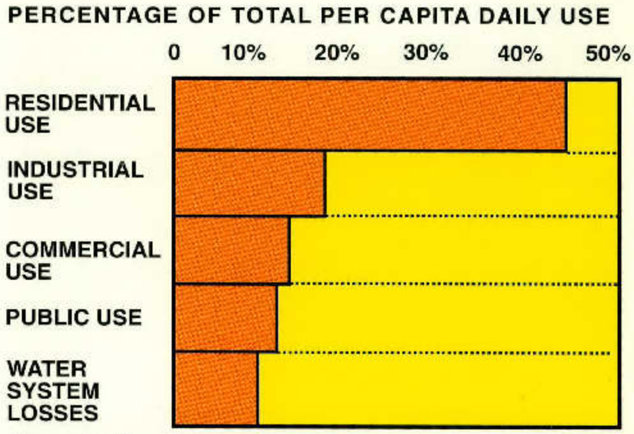


Figure 33. Water use in our area.

Percentages may vary somewhat but are representative of our area. If you use 100 gallons of water/person/day at your home and there are four people in your home, your typical water use is presented in Figure 34.

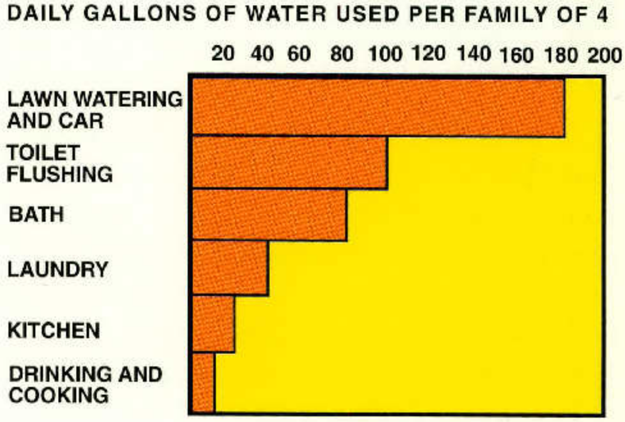


Figure 34. Water use in the home.

Water for cooking and drinking is the smallest portion of your daily use. The largest water uses at your home (lawn watering, car washing and toilet flushing) are among the best targets for water savings in a city.

Recreation is another important use of Edwards Aquifer water. Water flowing from streams which originate in the Edwards Plateau is frequently used for boating and swimming. Water flowing from the springs such as Leona Springs near Uvalde, San Pedro and San Antonio Springs in San Antonio, Comal Springs in New Braunfels, and San Marcos Springs in San Marcos has become important for recreation.

Figure 35a. Floating the San Marcos River.

Figure 35b. The River Walk in San Antonio.

Water emerging from Comal Springs and San Marcos Springs is not only important to recreational users. This springflow makes up a large percentage of the Guadalupe River flow as the river makes its way to the coast. Cities and rural areas along the Guadalupe River between the springs and the coast rely on this water for municipal, industrial, hydroelectric, and agricultural uses.

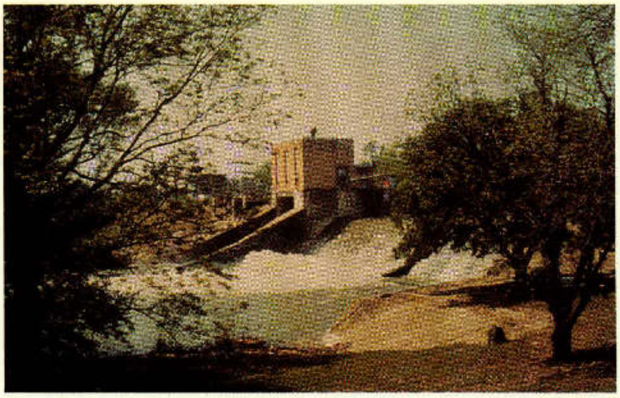


Figure 36. Hydroelectric plant in Sequin.

Edwards Aquifer water is also essential to the maintenance of ecosystems. An often neglected consideration of springflow is that it helps maintain the base or normal flow of certain river systems. Much of the flow in the San Antonio River is maintained by pumping when the water levels in the aquifer are too low for natural flow.

A large portion of the base flow of the Guadalupe River is springflow from Comal and San Marcos Springs. This water not only maintains the environment along the river, but it also provides fresh water flow into a major bay and estuarine system on the Texas coast. Estuarine water is a mixture of fresh and salt water. During droughts, the estuaries depend even more heavily on the flow of good quality fresh water from these springs. Many important fish and shellfish species depend upon the estuarine waters to complete their life cycles. Commercial and sport fishing, a major industry on the coast, could be detrimentally affected if natural springflows ceased.

Figure 37. Aerial view of the Guadalupe estuary on the Texas coast.

The Future Of The Edwards Aquifer

VI

The population in the Edwards Aquifer region is growing and is expected to continue to increase. The major concentration of this growth is between San Antonio and Kyle. This population increase presents two direct threats to the aquifer: contamination and depletion.

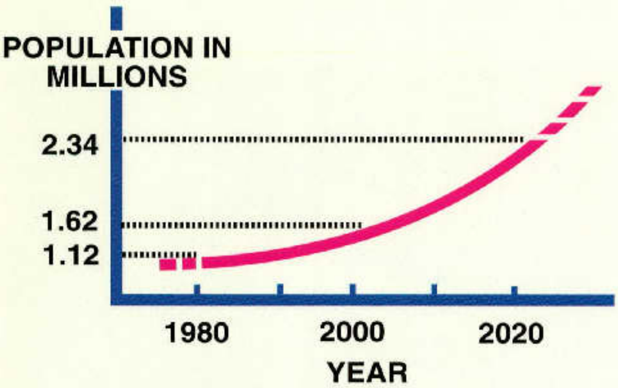


Figure 38. Population growth for Uvalde, Medina, Bexar, Comal and Hays Counties.

Contamination

One point of concern for the future is the effect of "man-made" contaminants on the quality of water in the aquifer. Pollution specialists have recently called for an awareness of **nonpoint source pollution,** or pollution that cannot be traced to any one particular source. For example, pesticides and fertilizers placed on yards and gardens can become part of the surface runoff. Car emissions and leaks from automobile gas tanks may become part of runoff from urbanized areas. Wastewater from septic tanks in the recharge zone can carry diseases into the aquifer through the limestone's fissures and cracks. Underground hydrocarbon and hazardous materials storage tanks have also been recognized as a significant threat to the aquifer.

As the density of human habitation increases over the recharge zone, the potential for contamination increases. It has been demonstrated numerous times that contamination of aquifers is a very real possibility if care is not taken to protect against it. Contamination of limestone aquifers, such as the Edwards Aquifer, is quite simple because the recharge water flows directly into the aquifer through large cracks and crevices without being filtered through layers of soil and sand. Once contaminants enter the aquifer, they may be extremely difficult to trace back to their source and eliminate. Remediation of the aquifer would be exhausting because of the the rapid movement of water and contaminants within the aquifer and a limited ability to remove contaminants.

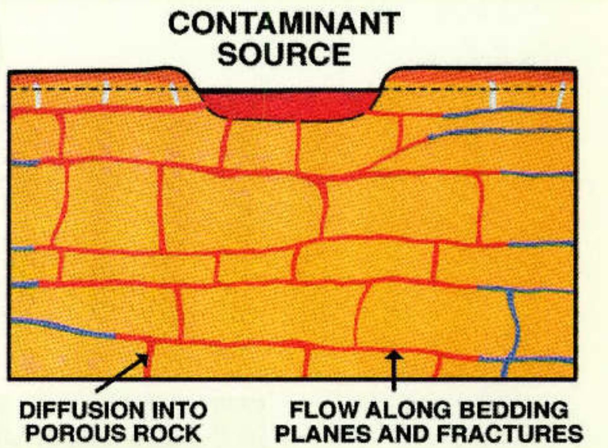
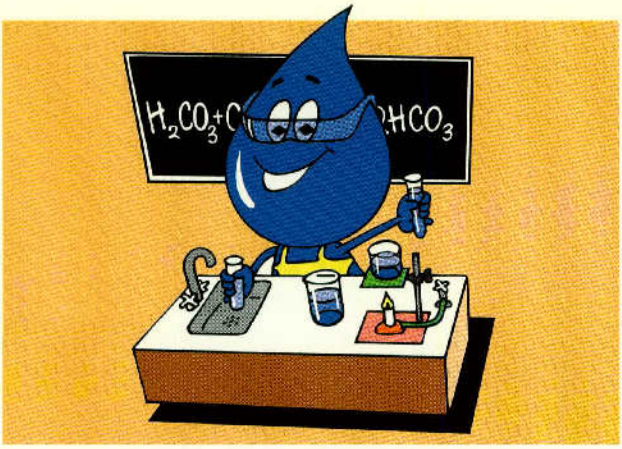


Figure 39. Contaminant migration from surface source through fractured porous limestone.

In an effort to protect the Edwards Aquifer, the Texas Natural Resource Conservation Commission imposed supplemental regulations for hydrocarbon storage facilities located on the Edwards Aquifer recharge and transition zones. These restrictions, known as the Edwards Rules, apply to hydrocarbon and hazardous materials storage facilities, and also address development over the recharge zone.



Is this water any good?

In the Edwards Aquifer area, the potential for contamination has been recognized and steps have been taken to minimize contamination. The Edwards Underground Water District, the U.S. Geological Survey, the Texas Natural Resource Conservation Commission, the Texas Department of Health, and river authorities conduct **water quality monitoring**. This monitoring involves sampling water and scientifically measuring the concentration of many different chemical, biological, and physical elements (parameters).

Water samples are taken from the major streams providing recharge to the aquifer. After these samples are analyzed, the data are reviewed to determine if any changes have occurred in the water quality. These data indicate that the major streams providing recharge have excellent water quality.

Water samples are also taken from over 90 wells located throughout the area. Some of these wells are located in urban areas within the recharge zone. Analyses of these data indicate that there is no evidence of significant decline in water quality in the Edwards Aquifer, nor any trend of decline in the San Antonio region. There are cases of isolated wells being contaminated, generally as a result of inadequate or improper well construction.

The Edwards Underground Water District and the City of San Antonio have an ongoing program of stormwater quality monitoring from urban areas. This information may be used to suggest new and better methods of protecting the aquifer.

The Texas Natural Resource Conservation Commission also has rules for specific construction activities over the recharge zone. These activities include construction of septic tanks, sewer systems, and gasoline storage facilities. Such rules and regulations, with proper enforcement, will help us protect the aquifer's water quality. New methods for determining water quality changes are being studied at the Edwards Aquifer Research and Data Center located at Southwest Texas State University.

Figure 40. Widemouth Catfish (Top Carnivore).

Researchers have discovered a large community of organisms living in the aquifer. The diversity found in this subterranean aquatic community is greater than any other similar system known in the world today. By understanding the community of organisms living in the aquifer, insight may be gained about water movement and potential contamination occurring in the aquifer. Scientists are studying the "*Top Carnivores*" of the biological community to see if contamination exists. Materials are often concentrated up the *food chain* by a process known as *biological magnification*. These investigations may allow early detection of contamination in the aquifer.

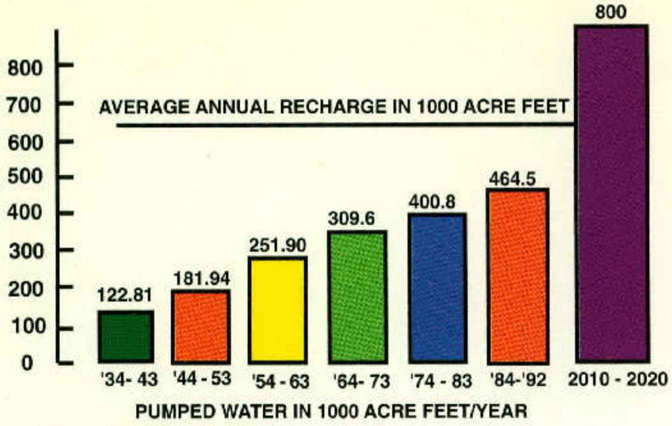


Figure 41. Historic water use.

Depletion

The most immediate threat to the aquifer, however, is depletion. As you can see from Figure 41, the demand for water in the San Antonio region is increasing, and the trend will continue. As more people move into the region, more water will be required for personal, commercial and industrial needs. Demands for agricultural products will also increase as the population of the area increases. Although more efficient methods of using water for agriculture are currently being developed, the increased population will need more land to produce food and fiber. Consequently, we will need even more water. What will happen to the Edwards Aquifer when water use exceeds recharge?

This and similar projections show the future demands for water will **exceed** the average annual recharge of water to the Edwards Aquifer. If the only source of water for the region continues to be the Edwards Aquifer, then the groundwater supply will be *mined.* Mining means more water is removed than is being replaced by recharge. Mining would result in decreased average water levels, thus increasing pumping costs and reducing springflow. Springs would eventually cease flowing. Although these conditions might not affect all users at the same time, eventually all areas relying on Edwards Aquifer water would be adversely affected. The future prosperity of cities, agriculture, industry, and recreation within this region will depend greatly on the future of the Edwards Aquifer.

Public Awareness

Water resource planners can forecast future water needs. These planners attempt to anticipate future water needs and develop adequate supplies of good quality water. These future supplies are essential if continued economic prosperity and future growth of cities is to occur.

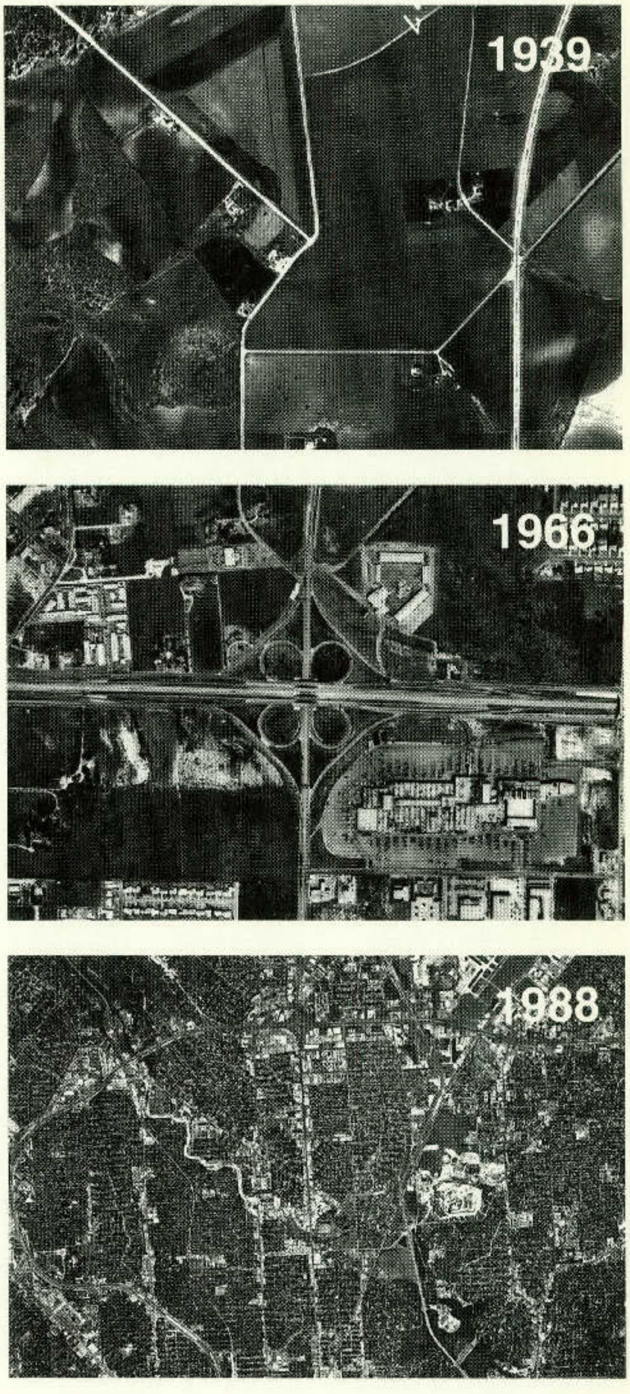
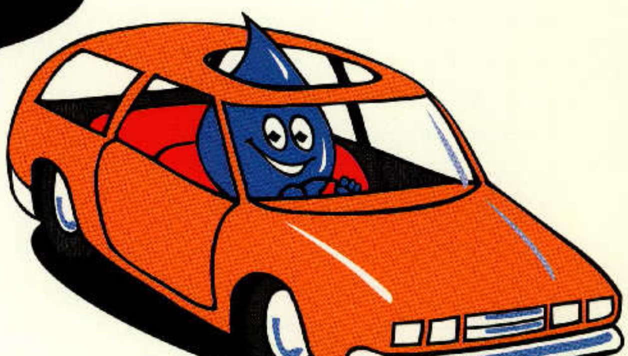


Figure 42. Intersection of Interstate 410 and San Pedro Ave., San Antonio, illustrates population growth in Bexar County.

Times have changed.



Many people in the region do not realize the need for water planning and conservation because of the current low cost and abundance of water. Future generations using the Edwards Aquifer, however, will find they are in a water crisis if more steps are not taken soon to plan for the future. The effort for this long range planning and conservation should involve all persons using the Edwards Aquifer. They must first become knowledgeable about our water supply. This must involve more than knowing what happens when a faucet is opened. To be without water one time is to remember the experience!

In the past, people were unconcerned with the thought of an energy crisis. However, when gasoline costs increased to more than a dollar a gallon and electricity costs rose, people became concerned. It is unfortunate that an economic crisis is needed before people realize that problems exist. The alternatives available to provide water for the future will cost more but can prevent a crisis. Sound management techniques can both increase the quantity and maintain the current high quality of our water supply. Plans are now being made to protect our source of water and assure proper management of the resource for the future. Without everyone's participation in conservation, it will be difficult to keep up with the increased demand for water.

Knowing the importance of a precious water resource is not only the responsibility of governmental agencies, departments and water planners but is also the responsibility of every person living in the area. Adequate protection of our main source of water must begin now, with extensive conservation measures and the development of alternative sources.

WATER CONSERVATION AND WATER RESOURCE PLANNING

VII

One of the first steps in planning for the future is WATER CONSERVATION. Conserving a resource means managing it so that it lasts longer than it would without management. Conserving means reducing waste to a minimum and increasing reuse to a maximum. Water conservation is defined as any beneficial reduction in water use or water loss. Texas has had nine significant droughts since records have been kept. The last drought ended in 1957 and Texas probably has a major drought in its near future.

As the water level in the aquifer declines, the first springs to cease flowing are Leona Springs, then San Antonio and San Pedro Springs. The Texas Natural Resource Conservation Commission predicts that if use continues to increase at the present rate, springs at San Marcos and New Braunfels will probably flow intermittently in the future and cease flowing by the year 2020.

Every user of Edwards Aquifer water, and most especially you, must understand the reasons for our water problems. Furthermore, you must understand the steps that have to be taken to conserve both ground and surface water supplies. Your future and the future of the Edwards Aquifer area depends upon every water user in the region...

NOT WASTING WATER.

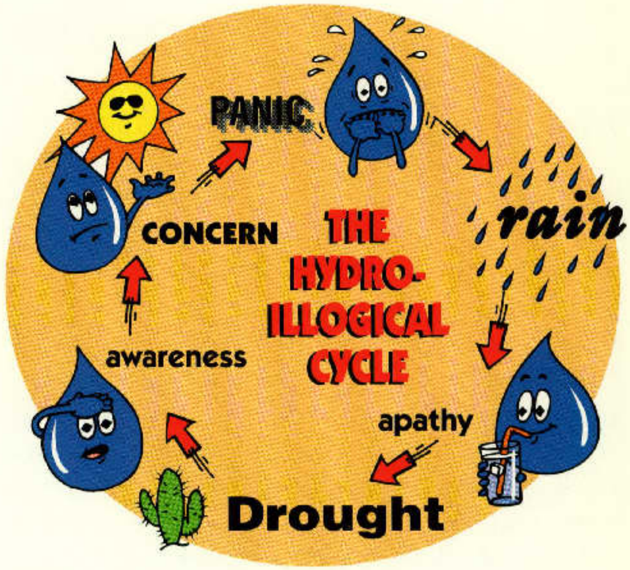


Figure 43. The Hydro-Illogical Cycle. (Adapted from Water for Texas, vol. 5, no. 10)

Individual Efforts

Water conservation is an attitude. You can do two things:

* personally conserve water
* teach others about the aquifer and the need to conserve water.

You, as an individual, can be a water educator. By now, you know more about water than most people in our region. You can tell your family about the need for conserving water. You can supply enough background information so that they will understand the problem, and you can teach them ways to conserve.

You can convince them that water conservation is not simply an emergency measure but rather a necessary way of life for **all** Texans. We must not wait for a crisis or a catastrophe, such as a severe, prolonged drought. We need to change our traditional attitudes and habits before such a crisis, not after the fact, when it may be too late.

Water is used for almost everything.

Home Conservation

Yard watering uses the largest percentage of household water and thus offers the greatest opportunity for saving water. Our soil can hold only one or two inches of water for every foot of soil. Most landscape plants (grass, flowers and shrubs) use the water from the top two feet of soil. One or two inches of water per application will usually fill this area of the soil to capacity. Any additional water applied to the landscape will be wasted. It will either move too deep in the soil for plant roots or it will run off. To determine the amount of water you are applying to your lawn, set a small jar or can under the sprinkler. Turn off the sprinkler at 30 minute intervals and measure with a ruler the amount of water collected in the container. When the container has collected one to two inches of water, move the sprinkler to another location.

Here are some other effective ways to save water outside:

- If your family is putting in a new landscape, suggest native or adaptive plants rather than grasses, trees, and shrubs that use a lot of water. A local garden center or nursery can give you detailed suggestions on specific plants.
- Do not water your established landscape regularly during the first cool weeks of spring. If you encourage deeper rooting, your grass will better withstand the hot, dry weather.
- Water your landscape only as a last resort.

If you must water, do not overdo it. One and one-half inches of water once a week during hot, dry spells will keep most Texas landscapes healthy.

- Avoid all runoff. Watering streets, side walks, and driveways will not make your grass greener, but will cost more.
- Avoid watering at windy times and during the heat of the day. Early morning or late afternoon watering will reduce evaporation.
- Use a sprinkler that throws large drops rather than a fine spray or use a soaker hose with the holes on the bottom not the top.
- Wait to water until your grass has turned a dull gray-green or until your footprints remain visible as you walk across it.
- Keep your grass fairly long rather than scalped. Taller grass holds moisture better. Cut grass fairly often so than only one-half to three-fourths of an inch is trimmed off.
- Mulch flowers, vegetables, and shrub areas so that they hold moisture longer.
- Never "sweep" your walks and driveways with a hose. Use a broom instead.
- When washing the car, use a bucket of soapy water and use the hose only for rinsing.

Here are some ways to conserve water in the home:

- Take quick showers rather than baths, and wash your hair in the shower. Turn the water off while soaping and shampooing, turn it on to rinse.
- Install a low-flow shower head to slow the flow from five gallons to two and one-half gallons per minute.
- Fill the sink with water for face washing or shaving rather than running the water.
- Turn off the water while brushing your teeth.
- Attach water-saving devices to toilets and faucets.
- Repair all leaking faucets. A slow drip can waste as much as 170 gallons of water each day, or 5,000 gallons per month, and can add unnecessary costs to your bill.
- Repair leaking toilets. If food coloring drops placed in the water tank appear in the toilet bowl before flushing, you have a toilet to repair.

- Always load your washing machine and dishwasher to capacity. If you are buying new models, look for those that are water savers. Use the light load setting whenever possible.
- Don't wash dishes with running water. Fill a dishpan for washing and one for rinsing.
- Run the disposal once for accumulated garbage.
- Keep a container of drinking water in the refrigerator or keep a thermos of ice water on the counter.
- Use a small pan of water for cleaning vegetables rather than running the water.
- Keep the thermostat on your hot water heater at a moderate temperature.
- Insulate all water pipes to avoid long delays and wasted water while you wait for the water to run hot.
- Turn off all water outlets, inside and out, and check your water meter. If it's still running, you probably have a leak between the house and the meter.

Your individual efforts can save water. If your household reduced the amount of water used for lawn watering by 10% through improved efficiency, the yearly water savings might be as much as 6,500 gallons. If your family used low flush toilets, the yearly water savings might be 11,700 gallons. With these relatively simple steps, it might be possible to save approximately 18,000 gallons per year per household. So, you see, individual efforts can save water and money. If all homes in the Edwards Aquifer region reduced water consumption by this amount, a significant amount of water could be saved. Additional money would be saved by reducing pumping costs for the water and the costs of treating the water at the waste treatment plants.

How much money can you save from wasting less water?

Municipal and Industrial Conservation

Cities can encourage water conservation by:

- Informing the public about the 1) need to save water and 2) methods to accomplish water savings.
- Developing recycling systems to reuse treated wastewater and encourage industry to do the same. Treated wastewater could be used for irrigation of non-food crops, watering parks, golf courses and for industrial use.
- Establishing water pricing policies that encourage water conservation. High volume commercial and domestic water users in many cities pay a higher per unit cost than low volume water users. In some cities high volume water users are provided with lower water rates which encourages more water use.
- Developing a leak detection and repair program to reduce the amount of water wasted from leaks.

Figure 44. Leak Detection study provided by the Edwards Underground Water District.

Light industry which relies on the Edwards Aquifer is concentrated in and around San Antonio. These companies are primarily involved in petroleum and natural gas production, brewing of beer, brick and tile manufacturing, gravel quarrying and cement production. Due to the agreeable climate, abundant work force, and inexpensive, clean water, more and more industry is coming to the area.

Industries are usually very much aware of the costs involved in their production and may use many methods to conserve water.

Agricultural Conservation

Farmers realize that efficient water use is valuable. As water levels in the aquifer decline, pumping costs increase. Conservation minded farmers take advantage of every advance in technology as it becomes practical.

Figure 45. Field Water Conservation Laboratory for irrigation efficiency evaluation provided by the Edwards Underground Water District.

The Edwards Underground Water District, the Edwards Aquifer Research and Data Center, the Texas Agriculture Extension Service, and colleges and universities in the area have worked on research and development projects aimed at making the most efficient use of water available for agriculture. One such project of the Edwards Underground Water District, the Soil Conservation Service, and local Soil and Water Conservation Districts involves evaluating irrigation efficiency with portable equipment used at the irrigation sites. This equipment and these evaluation procedures assist farmers in using their water more efficiently.

Improvements in water use efficiency will continue to be made as researchers and farmers seek methods to increase crop yields per unit of water and reduce overall water needs.

Surface Water Alternatives

There is never any one single "best" solution to water resource needs. An alternative may cost less money initially, but may cost more in other ways such as in lifestyle changes, economic hindrances, or environmental consequences. The job of the engineers, planners and decision-makers is 1) to understand and account for **all** costs of various alternatives, 2) to select and combine alternatives, and 3) to balance the benefits and costs of these plans in order to maximize the benefits.

We know that water from the Edwards Aquifer is limited; that is, our growth and demand will someday exceed the "safe yield" or average annual recharge. We also know that conservation will extend the life of that supply and allow for growth. However, in order to have enough water available for the growth that is expected to occur in our area, the total amount of water available to use must be increased. An increase in the amount of water available to us can only be accomplished by developing and using surface water. This can be done by selecting suitable sites on rivers and constructing large dams across rivers to create reservoirs. A reservoir does not actually increase the amount of water in a river, but it stores water that would have gone downstream. A reservoir also allows large amounts of flood water to be stored for future use.

Water resource planners have identified several sites for reservoirs in our area. Some reservoirs have been built, others are in the process of being developed, but others will be needed. A dam and reservoir cost a lot of money and take as much as ten years to build. Each of us should consider the development of necessary reservoirs. Each of us will also pay for these reservoirs, either directly or indirectly, through increased costs of goods and services. These reservoirs are not without their consequences. Large sums of money and energy are committed to their construction and operation. They change the character and environment of a river and reduce the volume of water which reaches the bays and estuaries. Dams and reservoirs take land out of production. We can, however, compare these consequences to the benefits of water supply, recreation and flood protection. These comparisons will be used, and only those reservoirs identified as being necessary and having a beneficial impact on the area will be recommended.

☛ Whatever our motivation, we must support every means available to make certain we have usable water supplies for the future. We must:

Capture And Save More Of The Water That Falls As Rain.

Conserve Our Current Water Supply.

APPENDIX

Edwards Underground Water District

Edwards Aquifer Research and Data Center

Glossary

Bibliography

Edwards Underground Water District
1615 N. St. Mary's
P.O. Box 15830
San Antonio, Texas 78212-9030
(210) 222-2204; 1-800-292-1047

Creation of the Edwards Underground Water District:

The creation of the Edwards Underground Water District in 1959 was a manifestation of the region's concern for the protection and preservation of the Edwards Aquifer. Following the devastating drought of the 1950's, the Texas State Legislature, working in cooperation with concerned area citizens, created the Edwards Underground Water District (District) to provide for local protection of this indispensable source of fresh water. The Edwards Aquifer remains one of the nation's unique groundwater resources, as well as this region's most valuable natural resource.

Goals and Purpose:

The District's mission of stewardship is to "conserve . . . to preserve and protect . . . to prevent waste and pollution . . . to develop comprehensive plans . . . to publish plans and information . . . to increase recharge . . ." for present and future generations.

The Board of Directors of the District:

The original enabling legislation that created the District included the five principal counties which rely on the aquifer: Uvalde, Medina, Bexar, Comal and Hays. The board was then comprised of fifteen directors representing those counties. Thirty years later, in 1989, the two western counties (Uvalde and Medina) pulled out of the District. Since that time, the District's boundaries have included the remaining counties (Bexar, Comal and Hays) and its affairs are governed by a 12-member board elected by popular vote representing qualified voters in those counties.

Activities of the District:

- Maintaining a program of data collection which is considered to be one of the best for an underground water supply.
- Identifying the potential threats and associated risks to water quality.
- Providing expert testimony to the regulatory process and monitoring the implementation and enforcement of the regulatory procedures so that potential threats and risks can be controlled and minimized.
- Identifying and funding the development and construction of surface water recharge projects that result in increased recharge at a cost that does not exceed benefit.
- Identifying and funding research programs aimed at increasing water use efficiency.
- Fostering a water conservation ethic among future water users through public education initiatives.

Edwards Aquifer Research and Data Center
Southwest Texas State University
San Marcos, TX 78666 (512) 245-2329
Fax: (512) 245-2669; e-mail: gl01@al.swt.edu

Purpose:
To provide public service in the study, understanding and use of the Edwards Aquifer.

Services:
The EARDC has four centers which provide various services.

DATA CENTER collects and makes available sources of information about the Edwards Aquifer. This information is available to all users. Special capabilities involve obtaining information from state and federal data bases on-line, including full internet capabilities for data acquisition. Specialists in on-line information services are available to help users. An example of a specialized service would be downloading current satellite photos.

EDUCATION CENTER provides inservice seminars, conferences and workshops at their location or at Southwest Texas State University. Topics include: geology, hydrology, biology, conservation, demography and economics of the Edwards Aquifer. Aquatic Studies field days and week-long summer camps offer more intensive learning experiences.

RESEARCH CENTER conducts research in biology, hydrology, hydrochemistry, geology, water quality, and groundwater modeling.

TECHNICAL SERVICES CENTER is primarily a full service water and environmental media laboratory. The laboratory is certified as a Drinking Water Laboratory by the Texas Department of Health. All necessary analyses required by state and federal agencies are available from the laboratory. These include biomonitoring, toxicity testing, and rapid bioassessment studies. The laboratory has modern instrumentation including a H.P. GC/MS, three additional GC's and two AA Spectrophotometers (including Graphite Furnace). In addition an Alpkem RFAnalyser provides for high volume analyses. Regular QA/QC is done with USEPA check standards.

GLOSSARY

Acequias-Water ditches of early San Antonio. Acequias were built to divert river water for cooking, drinking, and irrigation.
Aquifer-Any zone below the surface of the earth which stores, transmits, and yields water in sufficient quantities for human use.
Artesian Aquifer-One type of aquifer in which two impermeable layers surround one permeable water-bearing layer. The water is confined and stored under pressure and will rise above the top of the aquifer when penetrated by a well.
Bad Water (Saline Water)-Characterized by having more than 1000 mg/l of dissolved solids. It may be low in dissolved oxygen, high in sulfates and have a higher temperature. The bad water line (fresh/saline water interface) is the southern boundary of good water in the Edwards Aquifer.
Balcones Escarpment-A steep series of fault-formed hills which divide the higher plateau from lower coastal prairies. Escarpments can be formed by erosion, or as with the Balcones, by faulting.
Balcones Fault Zone-The area bounding the Edwards Plateau having extensive cracks and faults caused by the force of crustal movement.
Base Flow-A theoretical minimum flow of water down rivers.
Calcium Carbonate-($CaCO_3$)-The common mineral causing the hard water of the Edwards Aquifer. It is the main component of limestone.
Carbonic Acid-(H_2CO_3)-The acid formed by the combination of water, supplied by rainfall, and carbon dioxide produced in the atmosphere. This weak acid dissolves the Edwards limestone.
Condensation-The transformation of the gaseous water vapor into liquid water.
Contaminate-To make unfit for use by the introduction of undesirable substances.
Discharge-Water which leaves the aquifer by way of springs, flowing artesian wells, or pumping.
Discharge Area-An area where groundwater is lost from the aquifer to surface water.
Dissolution-the process of dissolving.
Drought-A long period of time without sufficient rain.
Ecosystem-The natural unit that includes a community of organisms and all of the environmental factors effecting the community.
Edwards Aquifer-Water bearing zone comprised of Edwards and Associated Limestones.
Edwards & Associated Limestone-(Edwards Formation)-Layers of sediment deposited during the Cretaceous period which later became limestone rock.
Edwards Aquifer Region-Region of Texas which obtains its water from the Edwards Aquifer. This area consists of the recharge zone and the artesian zone of the Edwards Aquifer.
Edwards Plateau-The area west and northwest of the Balcones Fault Zone where the Edwards Formation is essentially flat-lying and is the principal aquifer of the region.
Estuary-An area where fresh water from rivers mixes with salt water from the sea and is characterized by reduced salinity. Estuaries are important nurseries for many marine species.
Evaporation-The process by which liquid water is transformed into gaseous water vapor due to the heat of the sun.

Fault Zone- A region containing several breaks in the earth's crust along which slippage has taken place.
Fault Zone Aquifer-An aquifer developed in association with a zone of faulting. i.e. Balcones fault zone and the resulting Balcones Escarpment with the associated Edwards Fault Zone Aquifer.
Faults-Fracture of the earth's crust accompanied by movement.
Food Chain-Series of organisms usually starting with green plants in which each organism serves as a source of energy for the next one in the series.
Fracture-Breaks in rocks due to intense folding and faulting; a simple break in which no movement is involved.
Geologist-A scientist who studies the history of the earth, especially as it is recorded in the rocks.
Groundwater-Water that is stored under the earth's surface.
Hydrology-A science dealing with the properties, distribution and circulation of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere.
Impermeable-Material (such as dense rock) that will not permit liquid or water to flow through it.
Infiltration-The process of water entering the ground through cracks, soil or porous rock.
Irrigation-To supply water by artificial means to crops.
Joints-Lines of weakness in rock along which weathering occurs.
MG/L-Milligrams per liter.
Municipalities-Self-governing urban political units having corporate status.
Nonpoint Source Pollution-Pollution whose source cannot be readily identified. Nonpoint source pollution relates to land use activities.
Permeable-Having a texture that permits liquid to move through the pores.
Piezometric Surface-The imaginary surface to which water will rise from a confined aquifer.
Point Source Pollution-Pollution that can be traced to an identifiable single source. That source could be a pipe, a ditch, industrial plants, or sewage outlets.
Pollutant-Any substance which restricts or eliminates the use of a natural resource.
Porosity-Any property of geologic formations which has the ability to hold and yield water due to the spaces between particles.
Porous-Having openings which may or may not be connected.
Precipitation-Discharge of water from the air in the form of rain, ice or snow.
Recharge-Process by which water is added to an aquifer.
Reservoir-A man-made body of water contained behind a dam.
Sediment-Solid material (mineral or organic) which has been transported from its site of origin by air, water or ice and has been deposited either on the land's surface or on the sea floor.
Spring-A place where water flows from rock or soil upon the land or into a body of surface water.
Subterranean-Being or lying under the surface of the earth.
Surface Water-Water on the land's surface including lakes, streams, rivers and glaciers.
Transpiration-Loss of water vapor to the air from plants.
Unsaturated Zone-The layer of soil and rock above the water table but below the top layer of earth. This area is also known as the zone of aeration because the spaces between the rock particles are partially filled with air.
Water Table-The part of the aquifer nearest the surface or the upper surface of the zone of saturation.

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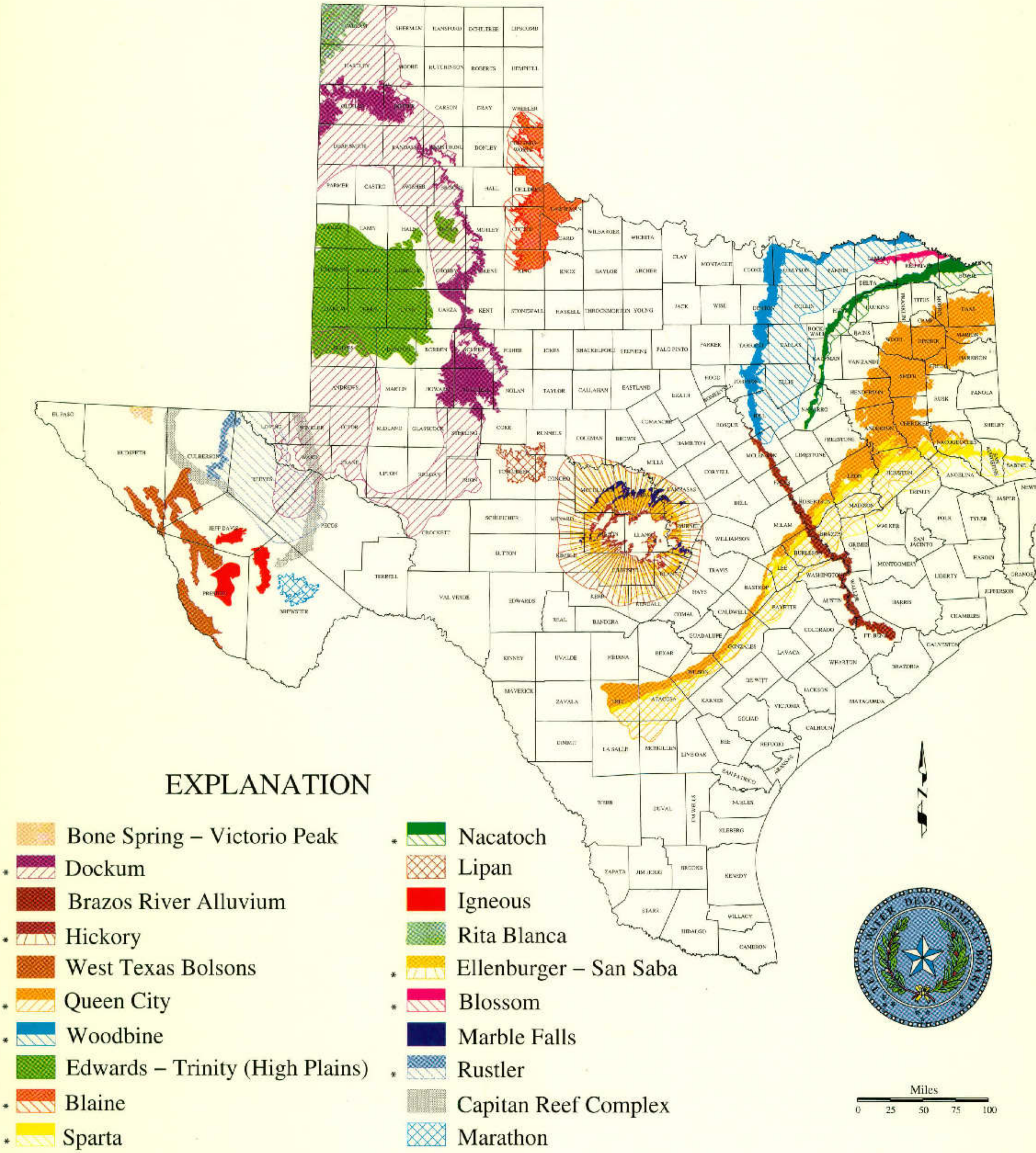
MINOR AQUIFERS OF TEXAS



OUTCROP (That part of a water-bearing rock layer which appears at the land surface.)
* DOWNDIP (That part of a water-bearing rock layer which dips below other rock layers.)

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Edwards Underground
Water District