ARTIFICIAL RECHARGE TO
THE EDWARDS LIMESTONE AQUIFER IN
SOUTH TEXAS

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ABSTRACT

The Edwards limestone aquifer is located in south central Texas along a portion of three major river basins. Ground-water divides, outcrops, and a highly mineralized water limit the portion of the aquifer under study to a length of about 175 miles and a width of 5 to 40 miles. The underground reservoir is the area’s prime natural water resource, providing the only existing water supply to an estimated 850,000 people.

Recharge to the aquifer is furnished by the streams which have their inception in the hill country to the north and flow southerly across the outcrop of the Edwards limestone in the Balcones fault zone. The aquifer recharge averages 423,200 acre-feet annually, but is relieved by discharge from springs located down gradient making the aquifer comparable to a conduit with open ends. The balance between recharge and discharge has been disrupted by some 4,000 wells which have been drilled since the late 1800’s. This resulting imbalance has placed the aquifer on a depletion schedule and, unless additional recharge is supplied, the reservoir will soon be unable to meet its water demands.

Because of this critical condition the Fort Worth District Corps of Engineers, in cooperation with proper state agencies, was authorized to investigate the feasibility of providing recharge to the aquifer as part of plans for flood control and water conservation. The study consisted of: (1) a survey of available water for recharge and the effects of evaporation in surface reservoirs; (2) the determination of maximum infiltration rates along the streams; (3) a further development of the hydrology and geology of the Edwards limestone; (4) utilization of a radioactive tracer to study the ground-water movement; (5) fluctuation of the "bad-water" line; (6) methods to control the spring flow; (7) the feasibility of reducing leakage from an existing reservoir built in the Balcones fault zone; and (8) geologic investigation of ten dam sites.

The proposed plan of improvement resulting from the study would provide for the construction of five dams. Three dams, to be constructed primarily for recharge, flood control, and recreation, will provide an additional 63,900 acre-feet of water annually for recharge. In these reservoirs the excess runoff, i.e., that which otherwise would escape across the recharge areas in the streambeds, will be stored and released at the maximum infiltration capacity of the rock. Two water conservation dams, designed to provide a supplemental surface water supply for the aquifer, will provide an additional 89,100 acre-feet annually. The proposed plan of improvement will meet all of the water demands in the area to approximately the year 2000.

Réalimentation artificielle de l’aquifère calcaire d’Edwards dans le sud du Texas

L’aquifère calcaire d’Edwards se trouve dans le sud de la partie centrale du Texas. Il longe une partie de trois grands bassins hydrographiques. Des lignes de partage des eaux souterraines, des affleurements et une eau fortement minéralisée limitent la section étudiée à une zone longue d’environ 265 km et large de 8 à 60 km. Ce réservoir souterrain constitue la principale ressource naturelle en eau de cette région, et même la seule source d’alimentation en eau d’une population d’environ 850 000 personnes.

L’alimentation de cet aquifère est assurée par des cours d’eau qui prennent naissance dans la région accidentée du nord et qui se dirigent vers le sud, à travers l’affleurement calcaire d’Edwards, dans la zone faillée de Balcones. Ces rivières apportent en moyenne, annuellement, 508 millions de m³ par acre (0,40 hectare); mais des sources situées à une altitude inférieure réduisent ce volume d’eau, ce qui fait ressembler l’aquifère à une conduite ouverte aux deux bouts. L’équilibre établi entre les apports et les pertes a été rompu par le forage de quelque 4 000 puits depuis la fin du siècle dernier. Le déséquilibre qui en est résulté tend à épuiser la nappe; à moins qu’un apport d’eau supplémentaire ne lui soit fourni, le réservoir sera bientôt incapable de répondre à la demande actuelle.
En raison de cette situation critique, le corps des ingénieurs du district de Fort Worth, en liaison avec les organismes d'État compétents, a été autorisé à rechercher la possibilité d'assurer la réalimentation de la nappe dans le cadre des plans de lutte contre les crues et de conservation des eaux. Les études effectuées ont porté sur les points suivants:

1) Recherche des eaux pouvant être utilisées pour la réalimentation et étude des effets de l'évaporation dans le cas des réservoirs de surface;
2) Détermination du taux maximum d'infiltration le long des cours d'eau;
3) Étude hydrologique et géologique plus détaillée du calcaire d'Edwards;
4) Emploi de traceurs radio-actifs pour suivre le cheminement de l'eau sous terre;
5) Fluxuations de la limite des eaux inutilisables (bad water);
6) Méthodes de régulation de l'écoulement des sources;
7) Possibilité de réduire les fuites d'un réservoir déjà construit dans la zone faillée de Balcones;
8) Étude géologique de dix emplacements de barrages.

Le plan d'amélioration proposé à la suite de ces études prévoit la construction de cinq barrages. Trois de ces barrages, construits principalement pour la réalimentation de la nappe, la lutte contre les inondations, ainsi que les activités de loisirs fourniront chaque année à la nappe un supplément de 77 millions de m$^3$ d'eau par acre (0,40 hectare). Dans ces réservoirs, l'excédent du ruissellement (c'est-à-dire la quantité d'eau qui, autrement, traverserait en pure perte la zone d'alimentation) sera emmagasiné pour s'écouler au taux maximum d'infiltration dans la roche. Deux barrages construits pour la conservation de l'eau et conçus pour fournir un apport supplémentaire d'eau superficielle à l'aquifère assureront un supplément annuel de 110 millions de m$^3$ par acre (0,40 hectare). Ce plan d'amélioration permettra de satisfaire toutes les demandes en eau de la région jusqu'à l'année 2000 environ.
GEOLOGY

Three formations, considered as a single hydrologic unit and referred to as the Edwards and associated limestones, make up the aquifer. They are, from oldest to youngest, the Comanche Peak, Edwards, and Georgetown limestones, all a part of the Comanche series of Lower Cretaceous age. Together they average between 350 and 500 feet in thickness in the artesian portion of the underground reservoir, but thicken considerably downdip toward the Gulf Coast. The hard, dense, light grey limestone rock is highly solutioned, as evidenced by the large number of caves of considerable vertical and horizontal extent found throughout the area. The Grayson shale, a blue-grey clay and clayey shale, overlies the Edwards limestone aquifer, forming the upper confining bed. The Glen Rose limestone, an argillaceous limestone, shale and dolomite, underlies the aquifer and forms the lower confining bed.

The Balcones fault zone, a variable width zone of moderate to intense faulting featuring normal or gravity-type faults downthrown to the south or south east, is the dominant structural feature in the area. The zone extends east-west across the State, forming a prominent escarpment at the foot of the Edwards Plateau. Although displacements vary greatly, single faults within the system exhibit displacements up to 700 feet and are traceable for about 50 miles. The maximum displacement across the zone, about 1,500 feet, occurs in Comal County, north of San Antonio. The faulting, significant in that it has broken and fractured the competent Edwards limestone, provides ideal avenues for circulating groundwater and accompanying solution activity. Figure 3 shows generalized geologic sections along and normal to the centre line of the underground reservoir.

The strata in the Edwards Plateau dip south and southeasterly toward the Gulf of Mexico at a rate of 10 to 20 feet per mile. South of the plateau in the Coastal Plain the average dip steepens to about 100 to 150 feet per mile.

RECHARGE

Recharge to the Edwards limestone aquifer occurs as rainfall on the Edwards Plateau filters down through the Edwards and associated limestones to the top of the Glen Rose limestone. The water then moves by gravity flow laterally through the limestone to reappear as springflow in the valleys that have been formed by the erosive action of the streams. These springs form the base flow of the streams that drain the area. Because of the impermeable nature of the Glen Rose limestone, very little water is lost until the streams begin their flow across the Edwards limestone in the Balcones fault zone. Along this zone the streams lose virtually all their base flow and much of their flood flow to the Edwards limestone. Once the water enters the artesian aquifer, the normal southerly flow is blocked by a combination of major faults and reduced permeability, causing the water to flow in an easterly direction, generally along the lines of major faulting, toward San Antonio.

Streams that flow through the area and contribute to the aquifer recharge are in the Nueces, San Antonio, and Guadelupe River Basins. Eight streams in the Nueces River Basin, with a drainage area of 3,112 square miles, contributed an average of 321,500 acre-feet of recharge annually for the period 1935-1956. (This 1935-1956 period was used throughout the study because it represents one complete cycle from a period of high runoff through a period of critical drought). Four streams in the San Antonio River Basin, with 1,158 square miles of drainage area, contributed an average of 145,800 acre-feet of recharge water annually. The three streams in the Guadalupe River Basin drain an area of 2,114 square miles and, although they have the highest average annual water resources above the Balcones fault zone, 374,400 acre-feet, they contributed only
APPROXIMATE LOCATION OF NORTHERN LIMITS OF THE BALENCES FAULT ZONE

LEGEND

EDWARDS UNDERGROUND RESERVOIR

EXISTING RESERVOIR

PROPOSED MULTIPLE-PURPOSE RESERVOIR

PROPOSED WATER CONSERVATION RESERVOIR

PROPOSED MULTIPLE-PURPOSE RESERVOIR WITH RECHARGE STORAGE

EDWARDS UNDERGROUND WATER DISTRICT BOUNDARY

EXISTING SCS DAM (JULY 1964)

AUTHORIZED SCS DAM

LOCATION AND PLAN OF IMPROVEMENT

SCALE IN MILES

FIGURE 1
45,900 acre-feet of recharge water to the aquifer. The principal river in the basin, the Guadalupe, does not contribute. Combined, the streams in the three river basins drain an area of 6,384 square miles, have estimated total average annual resources of 940,700 acre-feet upstream of the southern edge of the Edwards outcrop, and contribute an estimated 423,200 acre-feet of recharge to the Edwards limestone aquifer.

**Discharge**

The Edwards Plateau, along with the Balcones fault zone, is one of the principal spring-producing regions in the United States. Within the plateau region hundreds of springs form the base flow of the streams that drain the area. The most spectacular springs, however, occur in the Balcones fault zone where six major springs serve as natural outlets for the underground reservoir. The principal springs are, from west to east, Leona, San Antonio, San Pedro, Hueco, Comal and San Marcos Springs. Their average annual combined discharge is approximately 352,400 acre-feet, or 67% of the total aquifer discharge. Two of the springs, Comal and San Marcos, are listed among the 65 springs of first magnitude in the United States (1)*. The volume of flow from these springs is dependent on the water level in the underground reservoir.

The remainder of the discharge from the aquifer is through wells. The first well was drilled into the Edwards limestone in 1884 for a water supply for the city of San Antonio. By 1907 there were over 100 artesian wells in Bexar County alone, some with a natural flow of about 30 million gallons per day. Today there are about 4,000 wells drawing water from the reservoir in the five-county area which includes Uvalde, Medina, Bexar, Comal, and Hays Counties. The 1962 use from wells was 268,200 acre-feet, of which 212,000 acre-feet were pumped in Bexar County.

**Aquifer Storage**

The total capacity of the underground reservoir is unknown, but by use of the water budget equation "inflow minus outflow equals change in storage", a reasonable estimate of the storage within the historic high and historic low stages of the reservoir was obtained. Water levels have been observed and recorded for the last several years over the entire length of the underground reservoir. A study of these water levels has shown that a good correlation exists between the average elevations in these wells and the elevation of a single well, H-26, located in San Antonio. The lower water level (elevation 612) was recorded in well H-26 in August 1956, at which time all the springs except San Marcos ceased to flow. The highest level (elevation 685) was recorded in October 1942. Studies have indicated that, above elevation 612, a change of one foot in the water level in this well reflects an average change of storage in the aquifer of about 38,400 acre-feet. In the recorded range of elevation (612 to 685), it is estimated that about 2,800,000 acre-feet of water is in storage. There is no way to accurately determine the storage in the aquifer below the recorded low of 612; however, an extrapolation of the lower part of the curve, the accumulated annual differences in recharge and discharge versus the year and elevation of well H-26, shows that about 30,000 acre-feet of water per foot of drawdown are available.

**Investigations and Studies**

Investigations and studies included: (1) Geologic studies of the area in general and the Edwards limestone aquifer in particular; (2) locating and investigating ten potential

* The number (1), etc. pertain to specific references in the bibliography.

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EAST-WEST GEOLOGIC CROSS-SECTION

MEDINA COUNTY

BEXAR COUNTY

GOMAL COUNTY

NOTE
Data from U.S. Geological Survey
Texas Water Commission Bulletin No 9408

NORTH-SOUTH GEOLOGIC CROSS-SECTIONS
(LOCATION OF SECTIONS SHOWN ON FIGURE 2)

CROSS SECTIONS THROUGH THE
EDWARDS AQUIFER

FIGURE 3
dam and reservoir sites for flood control, recharge, water conservation, and recreation purposes; (3) investigation of an existing dam on the Medina River; (4) radioactive tracer studies to study groundwater movement in the aquifer; (5) hydrologic investigations to determine the quantity of additional water resources for recharge and other water conservation purposes and to determine the flood-control and structure requirements; (6) the effects of evaporation in surface storage reservoirs; (7) methods to control flow from the large springs issuing from the aquifer; and (8) fluctuation of the "bad water" line.

**GEOLOGIC STUDIES**

Approximately 18 miles northeast of San Antonio the Edwards Underground Reservoir narrows to a width of about five miles between the outcrop area and the "bad water" line. Since virtually all the springflow from Comal and San Marcos Springs must pass through this restriction, it was decided to explore the zone by core boring through the Edwards limestone. After completion of drilling, the boring was electric logged and photographed with a bore hole camera. The investigation showed a total thickness of 482.5 feet of Edwards limestone. The rock was found to be highly broken and solutioned with cavities up to two feet in diameter, separated by intervals of relatively impermeable limestone. The bore hole camera was used in the boring to supplement the information obtained from the cores and to show the condition of the rock in place.

To further study and define the limits of the Edwards aquifer electric logs were made in the exploration borings at all the investigated dam sites and in a number of old and new water wells in the area. Local water well drillers co-operated in the investigation by supplying pertinent data on new wells drilled in the area.

Geologic mapping was completed on portions of the major rivers and streams that drain the Edwards Plateau and contribute recharge to the Edwards limestone aquifer. This mapping was necessary to locate suitable dam sites, as well as evaluate the recharge capabilities of the streams. The requirements of the various proposed structures (i.e. water conservation or recharge and flood control) controlled the final selection of the site. Proposed dams with water conservation requirements were located above the heavy seepage loss areas in the Balcones fault zone. Other recharge structures proposed for operation as "dry pool reservoirs" were located in the Balcones fault zone on the Edwards outcrop.

Geologic conditions at ten dam sites were investigated by core drilling, electric logging, pressure testing, and geologic mapping. Seven of the sites, located in the Nueces and San Antonio River Basins, were investigated primarily as sites to provide artificial recharge. The remaining three sites, located in the Guadalupe River Basin, were investigated primarily for flood control and for water conservation rather than direct recharge.

**MEDINA DAM**

Medina Dam, a concrete gravity structure on the Medina River about 25 miles northwest of San Antonio, is the only structure in the area located within the Balcones fault zones. The dam and a diversion dam, located some four miles downstream, were constructed in 1911 for irrigation and water conservation; however, due to excessive leakage to the Edwards Underground Reservoir, estimated at 42,700 acre-feet annually, the project has never had a dependable yield. Because the project is essentially a prototype of those planned by the Corps for artificial recharge to the Edwards aquifer, detai-
Total discharge 525.9 MGD
589,500 AC. FT./YR

Domestic, Stock, Misc. 25.7 MGD
(28,800 AC. FT./YR)

Industry 20.4 MGD
(22,900 AC. FT./YR)

Military 13.5 MGD
(15,100 AC. FT./YR)

Irrigation 64.9 MGD
(72,700 AC. FT./YR)

Springs 286.6 MGD
(321,300 AC. FT./YR)

Municipal 114.8 MGD
(128,700 AC. FT./YR)


For purposes

Discharge from the Edwards Underground Reservoir (1962)
led geologic and hydrologic investigations were conducted. From these investigations the following conclusions were reached: (1) the Edwards limestones, if properly explored and treated, is a suitable foundation rock for the size structures proposed; (2) leakage from the reservoir through the abutments and foundation occurs through well-developed joints and fractures resulting from the faulting in the Balcones fault zone. This leakage could possibly be controlled if necessary by extensive grouting; (3) sedimentation in the reservoirs has not affected the capability of the rock to accept recharge water; (4) a project in the Balcones fault zone is well suited for a flood control structure as well as recharge; (5) an additional 20,900 acre-feet of recharge water per year could be realized if the Edwards Underground Water District could obtain the structure and cease diversion for irrigation.

RADIOACTIVE TRACER STUDY

An investigation of scientific methods for obtaining information regarding movement of underground waters revealed that satisfactory results had been found in somewhat similar circumstances by the "tritium analysis method". This method involves the laboratory analysis of natural water molecules. Tritium, a natural isotope of the hydrogen atom, is present in the atmosphere and in water at all times, due to the interaction of the atmosphere with cosmic rays from the sun. In recent years its concentration has been increased by the nuclear bomb testing programme.

A small scale pilot programme designed only to test the feasibility of the use of tritium was initiated in 1963 by completing analysis on samples collected from 100 wells, streams, and springs throughout the aquifer area. The results of the programme were encouraging but not conclusive. Only about one-third of the water samples collected showed tritium activities high enough to be measured without an enrichment process. The range of activity in the river samples varied from 118 to 441 T.U. (Tritium Units). This wide range of tritium activity is surprising since all the streams receive essentially the same rainfall. It was felt the range indicated a more complete mixing of the precipitation and base flow in some streams than in others. The only wells containing water with measurable tritium activities are located in Medina County. These wells produce from a depth greater than 600 feet, indicating the runoff water in that portion of the aquifer proceeds to considerable depths with little dilution. On the basis of the initial programme, it is believed that detailed tritium tracer studies could be very useful in defining the groundwater movement in the aquifer, especially with the new refined methods of laboratory analysis.

HYDROLOGIC INVESTIGATIONS

Hydrologic investigations were made to determine the quantity of additional water resources that could be developed for recharge of the Edwards aquifer and other water conservation purposes by the construction of surface reservoirs on the streams of the Edwards Plateau. Studies were made to determine the best method of regulating the surface reservoirs for recharge. They included holding the water in surface conservation pools and the rapid release of all storage following each runoff period. A number of hydrologic routings of water resources through the aquifer were made under existing and modified conditions to determine the dependable yield of the aquifer and to evaluate the effects of the recharge structures. To determine the yield of the aquifer which might be associated with various levels of drawdown, routings were made assuming several constant pumping rates. However, because of the risk of pollution of the aquifer if the water level is drawn down below its historic low of elevation 612, this minimum control elevation was adopted.
Other hydrologic investigations were made to determine the storage requirements for all investigated projects to control the floods of record on the individual streams and to determine structure requirements for spillways and outlet works.

THE EFFECTS OF EVAPORATION ON SURFACE RESERVOIRS

The very high evaporation rate in the semi-arid Edwards Plateau precludes the storage of any large body of water for an extended period of time for efficient recharge. This condition is especially true in the western portion of the area where the net annual loss from surface reservoirs varies from 35.7 inches at San Antonio to 55.3 inches on the Rio Grande at Del Rio. A surface reservoir in this region covering an area of 5,000 acres would lose from 15,000 to 23,000 acre-feet per year by evaporation.

CONTROL OF SPRINGFLOW

Although the Edwards limestone aquifer is a vast complex of relatively permeable strata receiving recharge from several drainage basins, the high rate of uncontrolled springflow at the lower end preclude it from being classified as an ideal groundwater reservoir. Approximately 65% of the discharge from the aquifer during the period 1936 to 1956 has been through major springs located in the Balcones fault zone. Two of the springs, Comal and San Marcos, account for about 83% of the total spring discharge. If the flow from these two springs could be regulated, an additional 292,900 acre-feet annually would be available for pumping.

Ideally the most logical way to control the springflow would be to control the recharge, thereby controlling the water level in the underground reservoir. However, this would require impounding water in surface reservoirs upstream from the Balcones fault zone and controlling releases. As previously noted, evaporation losses are too great for this type reservoir regulation. Evaporation losses also preclude a similar method whereby large pump stations located “up-reservoir” between Comal Springs and San Antonio could intercept the water and store it in “pump-up” reservoirs before it emits from the springs.

Physical methods of controlling the springflow are equally problematical. Comal Springs, for example, is the largest volume-wise of any known spring in the southwestern part of the United States. Water issues from openings in the Edwards limestone along the trace of the Comal Springs fault for a distance of about 500 yards. Conceivably, ring dikes could be constructed around the springs to equalize the hydrostatic head, but eventually breakouts would probably occur elsewhere along the fault. A grout curtain across the Edwards limestone aquifer a few miles “up-reservoir” from the springs at a location where the underground reservoir narrows to a width of about five miles was also considered. However, information from the boring through the Edwards limestone located in the general area showed the rock to be so intensely broken and permeable that grouting would be ineffective. In addition, hydrostatic pressure within the aquifer would prevent a successful grouting programme.

“BAD WATER” LINE

The historic low of elevation 612 in the Edwards limestone aquifer is significant in many respects. If the reservoir could be drawn down to a point where the major springs would stop flowing, then the entire recharge would be available for pumping. However, the presence of highly mineralized water in the reservoir to the south and southeast is a major deterrent factor. A study by the US Geological Survey of this transition zone
between the good and bad water has shown that there is a correlation between the change in the water quality and the storage change in the aquifer (4). From 1955 to 1962 the water level fluctuated from its historic low to a near record high and during this period, a close survey of wells along or adjacent to the “bad water” line was maintained. Three zones of different quality water were sampled. Zone 1 was in an area of good quality water (about 300 ppm), Zone 2 was near the “bad water” line and contained water with about 1,000 ppm, and Zone 3 was in an area downdip with highly mineralized water (+3,000 ppm). The water from Zone 1 showed no significant quality change during the study period. In Zone 2 the quality of water became poorer during the pumping seasons from May through October, but improved as pumping diminished during November through April. Overall, the quality of the water in Zone 2 changed almost 13% from the median. The quality of water in Zone 3 exhibited opposite results from those achieved in Zone 2. In this case, the water quality improved with increased pumping and became poorer when pumping was lightest. The total chemical quality change in Zone 3 was less than 5%.

It is not known to what extent the reservoir can be lowered before the intrusion of poor quality water would begin. However, in view of the possible serious consequence and possible permanent loss of the uncontaminated portion of the aquifer, it is considered that the water level should not be lowered appreciably beyond its historic low.

**PLAN OF OPERATION**

From extensive studies and investigations made over the past 65 years by a number of Federal, State, and local governmental agencies, consulting engineers, and groundwater hydrologists, and from investigations and studies by the Corps, it has been concluded that additional recharge can best be provided by a system of dams on the principal streams in the drainage area that contribute to the Edwards limestone aquifer. The base flow of most of the streams in the Edwards Plateau is lost to the underground reservoir where the streambeds cross the outcrop of the Edwards limestone in the Balcones fault zone. Additional water for recharge, therefore, must come from the flood flows which cannot be absorbed into the underground reservoir as they flow past the loss zone. From gauge records it has been estimated that the infiltration rate along the streams in the Nueces River Basin where they cross the fault zone varies from about 500 to more than 1,000 second-feet. Along the streams in this basin, which contribute about 64% of their flow to the natural recharge of the aquifer, about 128,000 acre-feet per year of water resources pass the lower edge of the loss zone. In the San Antonio River Basin only about 8%, or 15,900 acre-feet per year, of the average annual resources pass the lower edge of the loss area. In the Guadalupe River Basin only one stream is a major contributor to the underground reservoir. This stream has an average of only 8,400 acre-feet annually of its resources passing the loss area. Surface water reservoirs, constructed upstream from and in the Balcones fault zone, would provide regulation of the recharge to the underground reservoir. The water would be released from the surface reservoirs at rates not to exceed the infiltration rates along the streams and allowed to enter the aquifer through existing natural recharge channels downstream from the dams. Under this plan of operation evaporation losses would be held to a minimum. Since only a very small percentage of water resources of the San Antonio River Basin passes the lower edge of the Balcones fault zone and since there are no appreciable flood damages in this area, no additional water resource development could be justified at this time. However, in the Guadalupe River Basin, although it contributes very little recharge to the Edwards limestone aquifer, two projects were found to be economically justified for purposes other than recharge. Water conservation storage potential was computed for both these reservoirs in order to present the complete picture of both the
surface and groundwater resources which are possible of development within the study
area.
To provide controlled recharge storage for the underground reservoir, additional
water supply storage and recreation facilities for the people of the Edwards Reservoir
area, and to provide flood protection for the downstream areas of the Guadalupe and
Nueces River Basins, the following plan of improvement has been found to be justified
at this time.

(a) For authorization and construction by the Federal Government

1. Montell Reservoir on the Nueces River (Nueces River Basin) for flood control,
water supply, recharge, and for recreation and fish and wildlife purposes. The reservoir
would have a total controlled storage of 252,300 acre-feet and would increase the average
annual recharge to the aquifer by about 26,600 acre-feet.

2. Concan Reservoir on the Frio River (Nueces River Basin) for flood control,
recharge, and recreation purposes. Total controlled storage would be 149,000 acre-feet
and would provide about 21,500 acre-feet of increased recharge annually.

3. Sabinal Reservoir on the Sabinal River (Nueces River Basin) for flood control,
recharge, and recreation purposes. Total controlled storage would be 93,300 acre-feet
and would provide about 15,800 acre-feet of increased recharge annually.

4. Clopton Crossing Reservoir on the Blanco River (Guadalupe River Basin) for
flood control, water conservation, and for recreation and fish and wildlife purposes.
The proposed reservoir would have a total controlled storage of 403,000 acre-feet with
274,900 acre-feet of that amount to be water conservation storage. The water conserv-
ation provision would fully develop the resources of the Blanco River upstream from
the site and provide a dependable yield of 42,700 acre-feet yearly (38 million gallons
per day).

(b) For construction by local interests

Dam no. 7 Reservoir on the Guadalupe River for water conservation. This project,
having a total controlled storage of 658,000 acre-feet and operated in conjunction with
the existing Corps of Engineers Canyon Reservoir some 48 miles downstream, would
fully develop the resources of the river above the lower dam. Dam no. 7 would increase
the dependable yield about 46,000 acre-feet per year over that of the existing project.

It should be noted the development of the recharge was limited to streams where it
was considered feasible to justify flood control for Federal interest. Additional recharge
can be realized if local interests desire to expand the programme to provide small,
locally-financed structures to control the runoff in the small streams in the areas.

Physical effects of the plan on the Edwards limestone aquifer

Construction of Montell, Concan, and Sabinal Reservoirs in the Nueces River Basin
and operation of the projects as proposed would result in a net increase in recharge to the
Edwards limestone aquifer of about 63,000 acre-feet per year (57 million gallons
per day).

For analysing the effect of the increased recharge on yield and water levels of the
underground reservoir, hydrologic routings were made of the recharge through reservoir
storage in the aquifer for the period 1935-1962. These routings were made under existing and modified recharge conditions. As graphically shown (fig. 5), the safe yield for pumping may be increased from 234,000 to 263,000 acre-feet per year (235 million gallons per day) without depleting storage in the underground reservoir below elevation 612 at San Antonio. This represents an increase of 29,000 acre-feet per year (26 mgd). The remainder of the increased recharge, 34,900 acre-feet per year (31 mgd) under this
NOTE
For Hydrologic Routing above EL 682,
Springflow Curves were extended.

EFFECTS OF CONSTANT PUMPAGE ON WATER LEVELS
IN THE EDWARDS UNDERGROUND RESERVOIR
MONTELL, CONCEA, & SABAL RESERVOIRS IN OPERATION

FIGURE 5
plan, would be discharged from the aquifer principally through the major springs. Under assumed conditions of constant pumping of 234,000 acre-feet per year during the 1935-1956 period, the average annual springflow would be about 292,900 acre-feet. With the recharge projects in operation, this quantity would be increased to 327,800 acre-feet.

**Effects of Surface Storage for Dependable Water Supply**

Three reservoir projects, Montell, Cloptin Crossing, and Dam no. 7 are proposed to provide conservation storage. Montell would contain 1,000 acre-feet of conservation storage to meet downstream commitments. Cloptin Crossing and Dam no. 7 would provide a total of 915,400 acre-feet additional conservation storage in the Edwards area. These projects could supplement the groundwater supply and prevent its rapid depletion if area-wide agreement on development of water resources can be obtained.

**Conclusions**

The proposed plan of improvement would meet the municipal, rural, industrial, military, thermal power, and irrigation demands of the area to about the year 2,000. To meet the anticipated future water demands beyond these dates will require more adequate use of return flows and development of additional water supplies outside the Edwards Reservoir area.

**Background Bibliography**