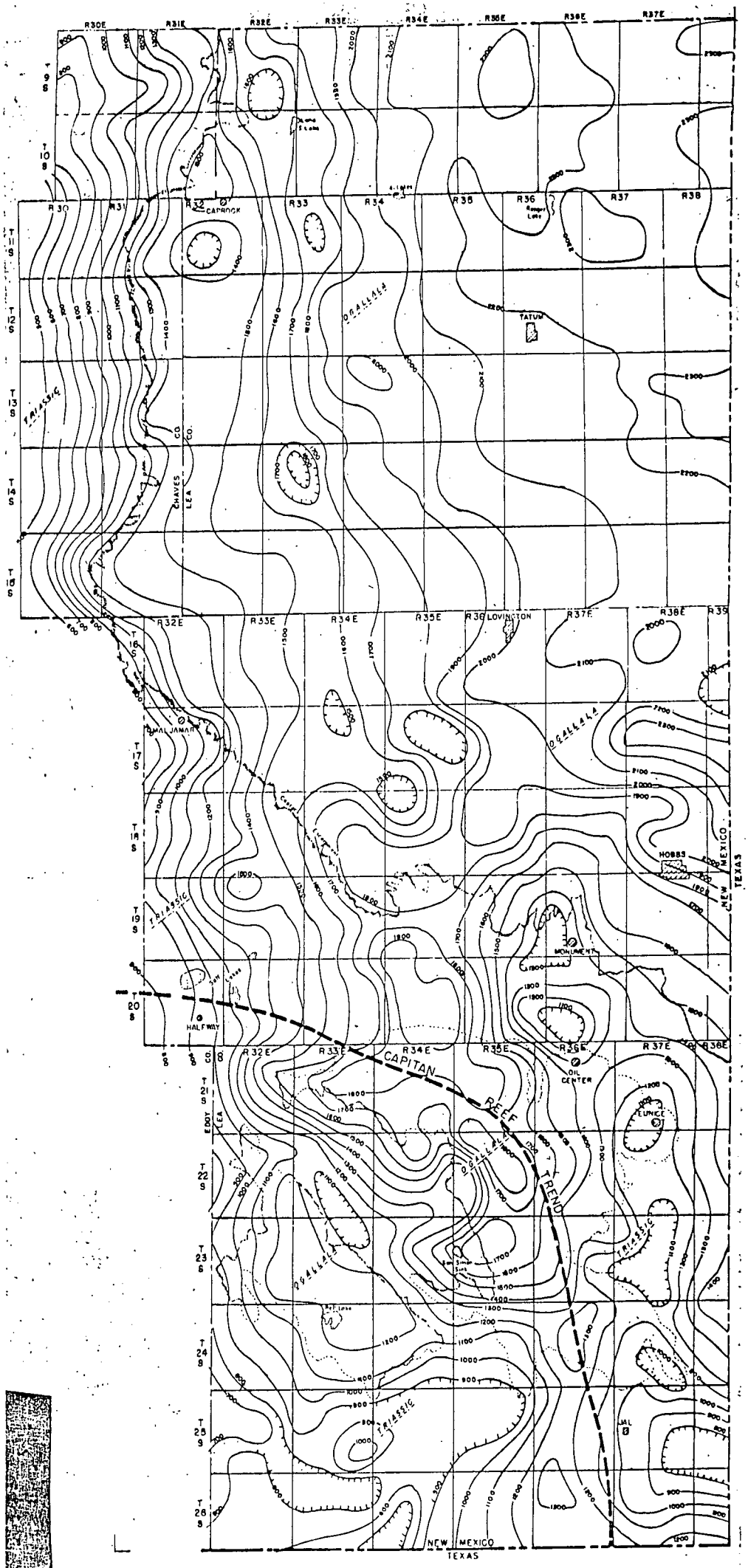
RECR - 10
Windmill Oil

Hobbs Area
Aquifer Study

Final Figures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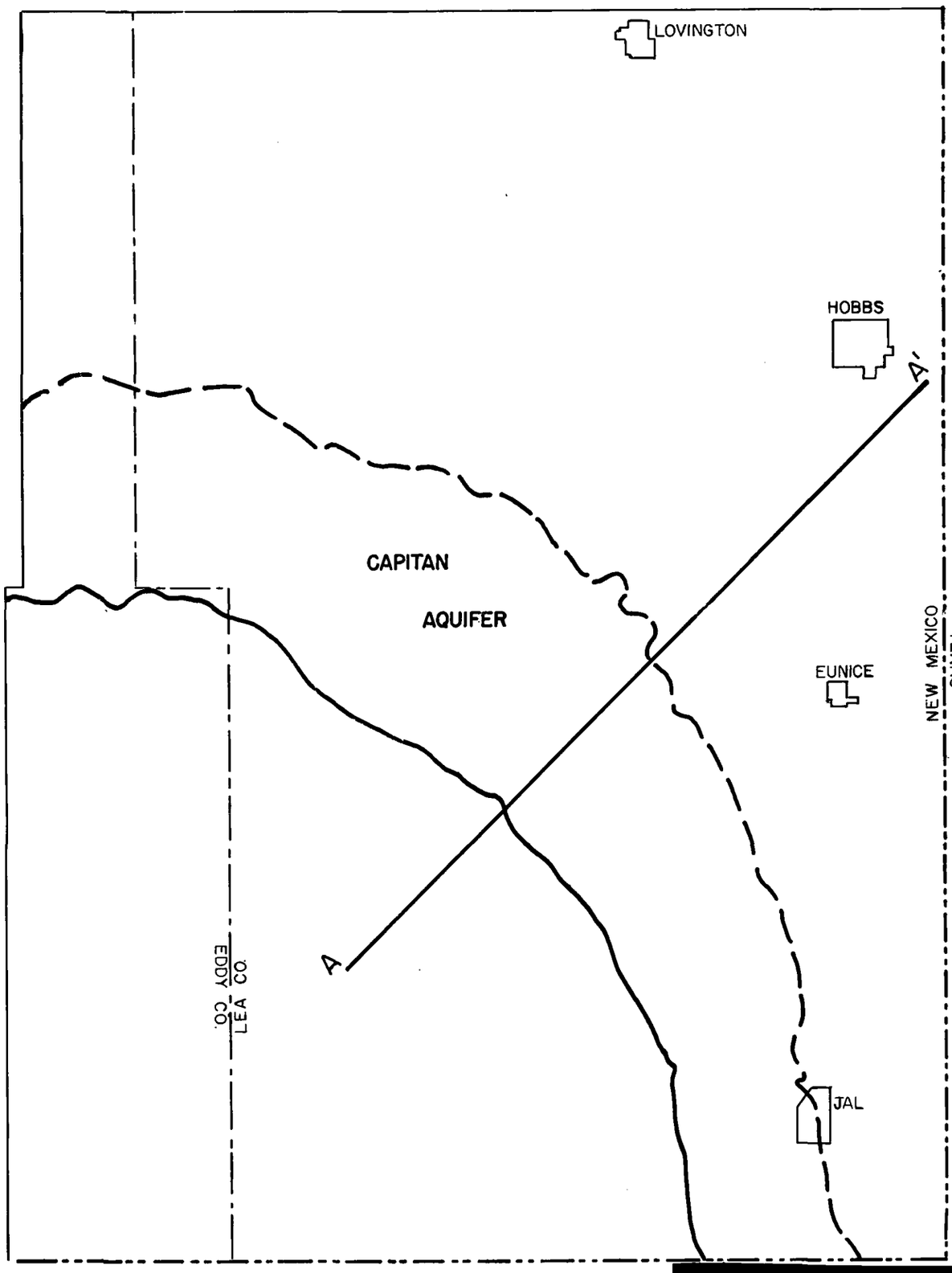
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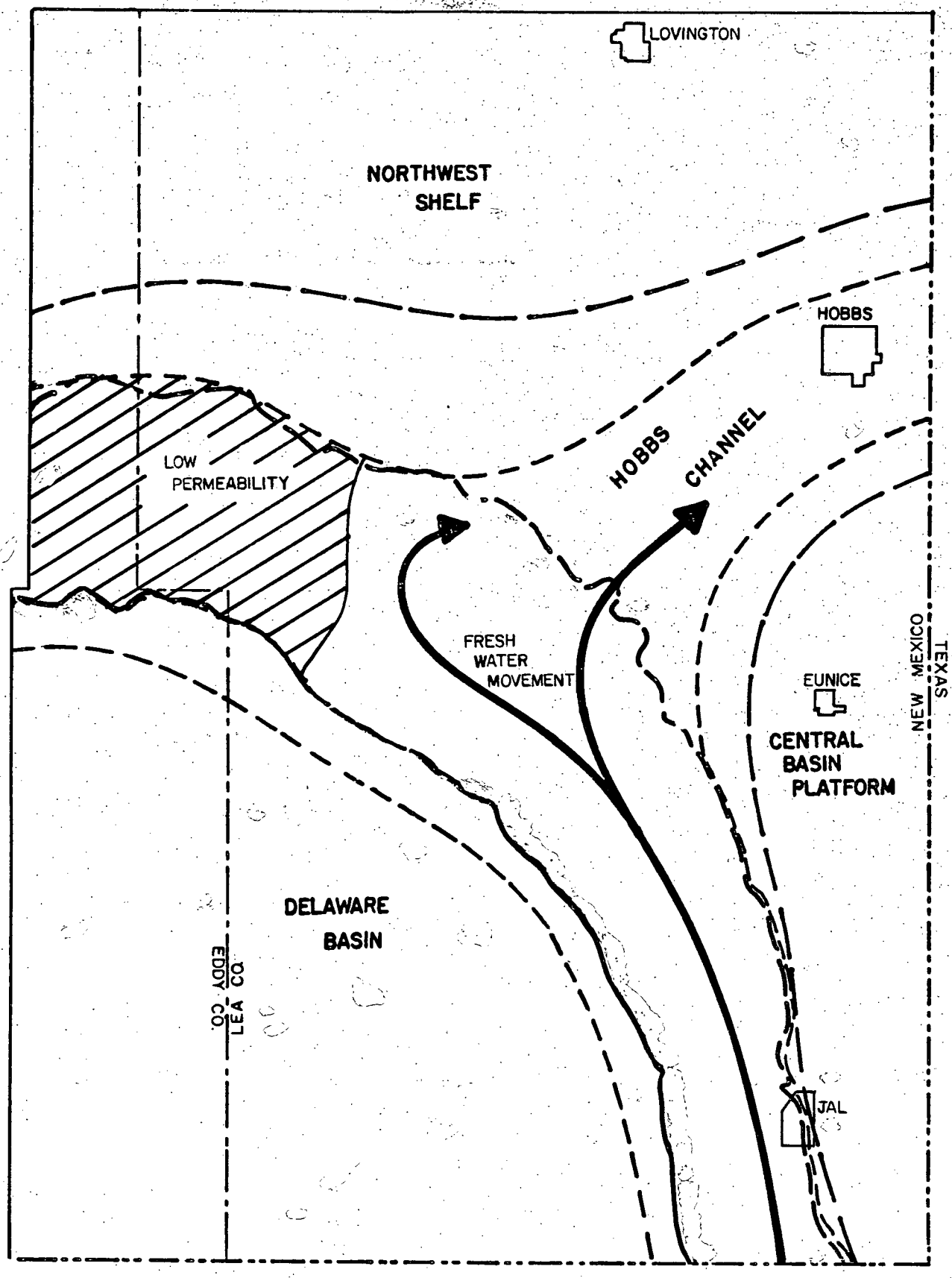
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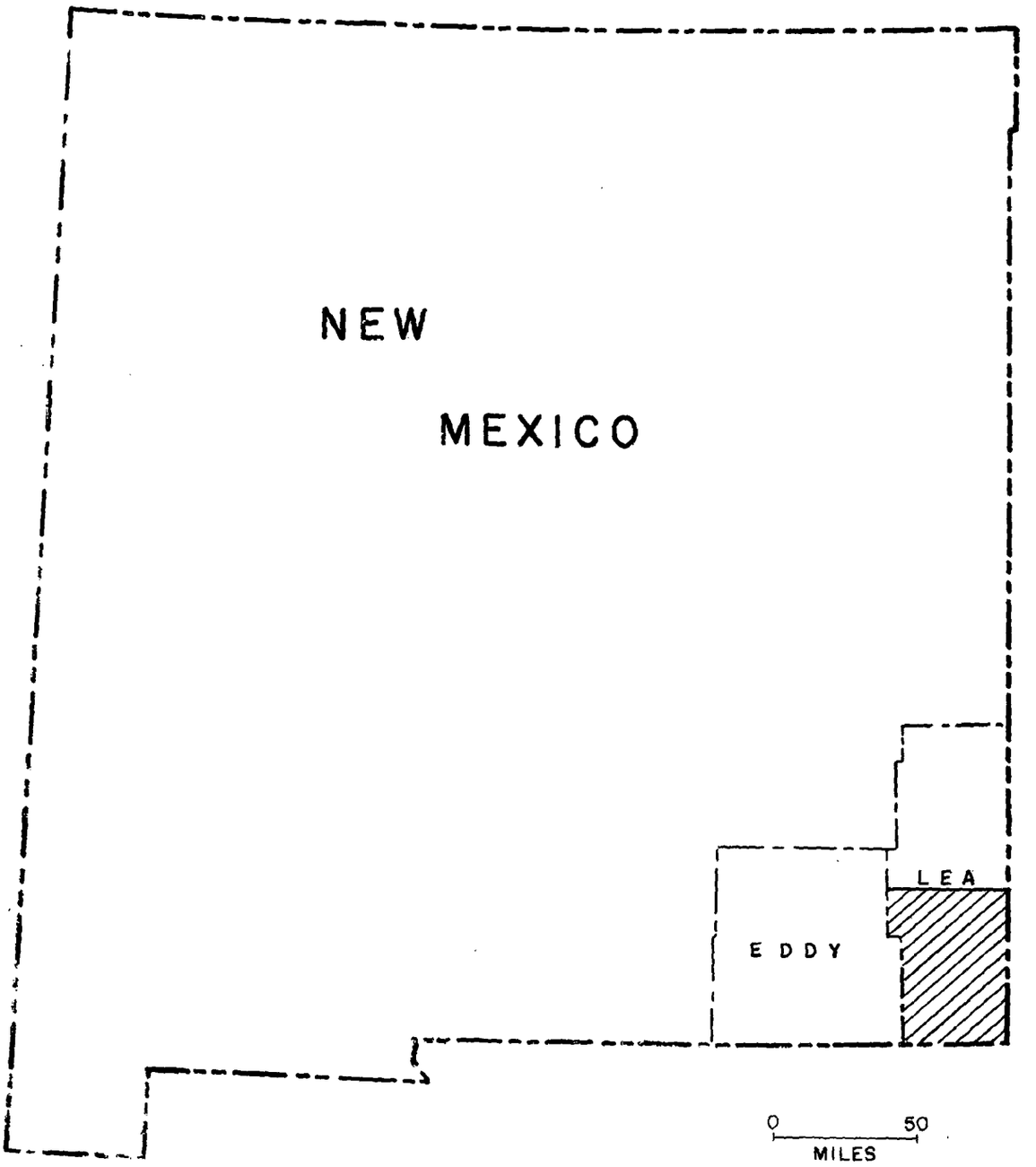
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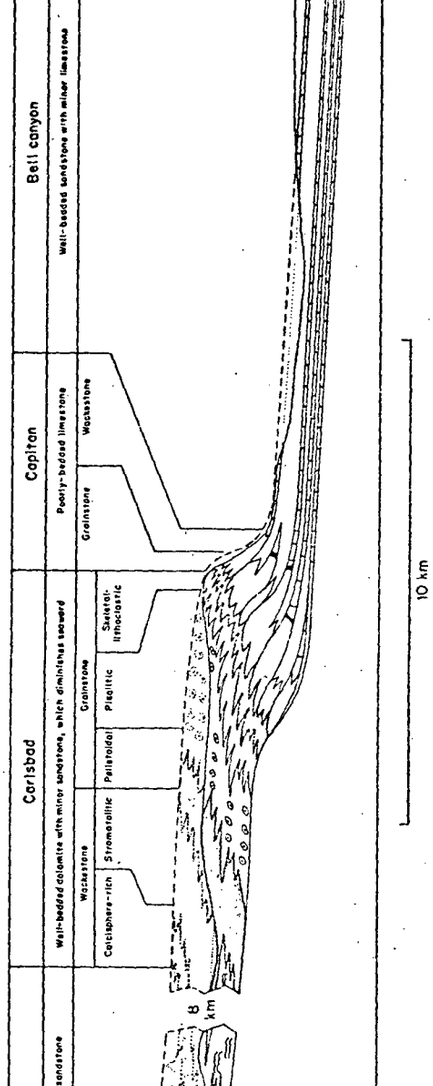

Figure 13.12 Sedimentary facies of Upper Guadalupian (Permian) carbonate rocks in the Guadalupe Mountains and surrounding area. (After Dunham, 1972.)

AQUIFER EVALUATION FOR UIC:
SEARCH FOR A SIMPLE PROCEDURE

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INTRODUCTION

Regulations adopted by the U.S. Environmental Protection Agency (EPA) as part of the Federal Underground Injection Control (UIC) program require protection of aquifers which are currently used for drinking water or which have a total dissolved solids (TDS) content of less than 10,000 mg/l (see 40 CFR Part 122). However, aquifers may be exempted from protection if they are or will be used for mineral, oil or geothermal energy production, or if they cannot provide drinking water for reason of economics, technology, gross contamination, or location above a zone which, due to well-related mining, is subject to subsidence or catastrophic collapse (40 CFR 146.04).

Procedures for identifying aquifers to be protected can be inferred from the Federal Register. Figure 1 is a flow chart which summarizes these procedures, which can be termed the "aquifer evaluation process". Application of Figure 1 to an area where injection is of concern will result in the classification of all rock units into one of four categories: protected aquifer, salt-water aquifer, exempted aquifer or non-aquifer. A protected aquifer is a rock unit which is a present or future underground source of drinking water. If the unit is not presently a drinking water resource, then by definition it has the following characteristics: it is capable of yielding significant amounts of water to a well or spring; the water is fresh (total dissolved solids or TDS no greater than 10,000 mg/l); and there are no economic or technical reasons for exempting it from protection. All rock units must be so defined unless they can be shown to fit into one of the other

of good porosity within the Artesia Group and San Andres Formation, and confirmed fluids having less than 10,000 mg/l TDS in some wells. However, neither the water-quality nor resistivity data were sufficient to show definite boundaries for the fresh water. This is because precise delineation of the lateral and vertical extent of the fresh water zones is inhibited by the complexity of the carbonate stratigraphy and close proximity to oil producing zones. Rapid gradation of lithologies within the Capitan Reef complex makes correlation of characteristic markers on logs difficult. Similarly, lithologic variability in the predominantly dolomite reservoirs of the San Andres Formation is such that there is no common impermeable section of any great lateral extent. One may encounter oil and water at the same depth within close lateral proximity. Because of these impredictable porosity intervals, we have designated the formations of southern Lea County to have "localized" occurences of moderately saline water.

OCCURANCE OF DEEP FRESH WATER

The next step in the analysis was to perform an in-depth analysis of a part of Lea County where the deep fresh water is especially prevalent (Figure X). The purpose was to identify the geologic controls of the fresh-water, so as to delineate the zones which may require UIC protection.

aquifers, Hiss suggests that the effects of recharge are diminishing, reducing the hydraulic load and isolating fresher waters already in place. To determine the feasibility of protecting the groundwater a more detailed investigation was performed on these areas.

SUMMARY OF IN-DEPTH STUDY

Based on the detailed literature search, analysis of logs and interpretation of geology in the study area, it is apparant that the detailed evaluation of aquifers pursuant to UIC guidance does produce results which differ from the existing State regulatory program which is based on less detailed information. The differences can be summarized as follows.

	State Program	UIC Program
Basis:	General geohydrologic knowledge of area	Detailed geohydrological study
Result:	Aquifers protected to base of Triassic; deeper units classed as salt-water aquifers	Some Paleozoic units contain contain fresh water in variable locations and must be considered as aquifers into which injection cannot occur unless there is a basis for exempting the aquifers from protection

APPENDIX 1. Aquifer Maps based on Reconnaissance Studies

From the literature search a number of basic findings were reached regarding the geohydrology of the area.

General Geology. The principal source of water in Lea County is the Tertiary Ogallala Formation, a fine-grained, poorly consolidated, calcareous sand which crops out at or near the surface of all but the western edge of the county. In northern Lea County, where it covers most of the High Plains, the Ogalla Formation ranges in thickness from 100-250 feet; in general, the lower half of the unit is saturated. High Plains water wells yield up to 1700 gpm. The Ogallala in the High Plains is topographically isolated from the Ogallala in the rest of the county; because there are no permanent streams, all recharge in the High Plains is derived from local precipitation. Because the Ogallala dips very shallowly to the south and east, there is some groundwater movement in these directions.

The Ogallala Formation in southern Lea County thins to the west and locally is covered by 2 Quaternary alluvium which ranges from 0-400 feet thick. In many localities the Ogallala is not saturated, but along stream valleys and over the Eunice Plain, not only the Ogallala but also some of the overlying alluvium may be saturated. Water wells completed in the Ogallala Formation of southern Lea County yield from 30-700 gpm. Recharge in the southern part of the county is from both local precipitation and through-flowing streams.

The Ogallala Formation is underlain in scattered locations by unnamed Cretaceous shales and limestones. The Cretaceous sedimentary rocks are a major source of water only in the northern part of the county where the Ogallala is very thin. They yield water which is slightly more saline than that from the Ogallala, but the water is still of good quality.

Sandstones and shales of the Triassic Dockum Group underlie the Cretaceous sedimentary rocks. The Dockum Group underlies most of Lea County, but water is produced from it primarily in the southwestern and far northwestern parts of the county where overlying sediments are thin and/or unsaturated. Wells completed in the Dockum generally yield 10-15 gpm. Dockum waters average 500 mg/l sulfate, considerably higher than the 200 mg/l average of the overlying units. Recharge of the Dockum results from precipitation on up-dip outcrops of the formations along the western side of the county and from infiltration from overlying formations.

Most data dources on Lea County ground-water depict the base of useable fresh water as the bottom of the Rustler Formation (Nicholson and Clebech, 1961). W.L. Hiss (1975) presents evidence of groundwater containing less than 10,000 mg/l TDS within aquifers at depths greater than the Rustler, although none is now being used for human consumption. A study of these aquifers within Lea County was necessary to relate the feasibility and extent of possible designation of these aquifers as an underground drinking water source.

U.S. Dept. of Agricultural Economics (1943), Burnes, Ellis, et al. (1949), Yates and Galloway (1954), Minton (1956), Dinwiddie (1963), Chen and Long (1965), Long (1965), Havens (1966), Havens (1966), Cronin (1969), Theis (1969), Hudson (1971), Mourant (1971), Theis (1971), Brown and Signor (1972), Brown and Signor (1973), Buchnan (1973), Signor (1973), Galloway (1975), Jacobs (1975), N.M. I.S.C. and N.M. S.E. (1975), Sorensen (1977), Brown and Wood (1978), Akin and Jones (1979).

3. A few articles provided information on the history of brine contamination incidents. All such incidents involved contamination of the Ogallala Formation, with brine ponds being the principal source of the problem. These references were useful as background information for UIC program, but did not bear directly on the evaluation of aquifers. The references included: Rice (1958), Parker (1971), Bigbee and Taylor (1972), Wright (1979), Bigbee (1972).

4. A few references which provide important information on Permian aquifers. These include regional studies which focus on the oil-related brine aquifers of the Permian Basin: Nicholson (1954), Borton (1960-67), Hood (1962), McNeal (1965), Hiss (1969), Chavez (1968-1979), Hiss (1970), Hiss (1973), George (1974), Hiss (1975a; 1975b), Lambert (1978). Also included are very localized studies of the geohydrology of an area in which the analysis of aquifers is carried well into the Paleozoic: Borton (1948), Galloway (1959), West (1961), Cooper (1962), Mercer (1977). As will be discussed below, these references indicated that some fresh water (TDS less than 10,000 mg/l) does occur in a few of the Permian rock units. Therefore, it is necessary to determine if these rock units are to be classified as protected aquifers, or

The first step in the in-depth study of south-central Lea County was to perform a comprehensive literature search which included dozens of published and unpublished references on the geology and hydrology of the area. This also included review of existing water-quality records for wells which obtain water from Paleozoic rocks. The purpose of the in-depth literature search was to provide a comprehensive basis for the understanding of the geohydrology of a typical part of Lea County, and to produce specific maps and cross-sections appropriate to a UIC program, such as: geologic maps and sections; water-table maps; maps and sections showing water quality; and a stratigraphic column. This level of detail is commensurate with that suggested in the EPA guidance previously cited. A bibliographic form was completed for each reference (see Figure 6). Then, those references which appeared to have the best information were reviewed in detail. Based on the bibliographic forms, the references were categorized as follows.

1. Reports or articles which discuss water resources at a regional level. These are the same references reviewed during the initial study, and were cited previously.

2. References which discuss the known aquifers of Triassic age or younger (especially the Ogallala Fm.), or which discuss in general the water supplies of the area. Such aquifers would be protected by UIC without question, and thus while these references could be of value in site-specific UIC permitting, they are of no value in the overall aquifer evaluation process. Examples of such references include: Nye (1930), Theis (1937), Conover and Akin (1942),

viewed included: Garza and Wesselman (1959), Ash (1961a; 1961b), Nicholson and Clebsch (1961), Ash (1961), Ash (1962), West and Broadhurst (1975), U.S. Bureau of Reclamation (1972¢). Figure 3 is a stratigraphic column for the study area which summarizes the results of the literature study.

The conclusion reached from the literature is that most drinking water in Lea County is obtained from shallow rock units (dominantly the Tertiary Ogallala Formation), and that there is no significant amount of fresh water in rocks older than Triassic. This concept is the basis for State regulations which permit oil field brines to be injected into rocks of Permian age or older. Figure 4 is a map showing the base of the Triassic (also the top of the Permian Rustler Formation). According to the general literature and the State regulations, aquifers below this elevation do not require protection pursuant to the UIC program.

IN-DEPTH LITERATURE SEARCH

A detailed aquifer evaluation study was performed in a 144-square mile in the south-central portion of the County (Figure 5), in order to determine if if the reconnaissance study provided an accurate evaluation of geohydrologic conditions. The initial methods used were those developed in the Artesia study: review of technical reports; analysis of well logs; and analysis of borehole geophysics data.

three categories. Salt-water aquifers are rock units which contain water having a total dissolved solids content (TDS) in excess of 10,000 mg/l. Non-aquifers are rock units which are not able to yield significant amounts of water to a well or spring. An exempted aquifer is a rock unit which is not a source of drinking water for reason of economics, technology, gross contamination, or relationship to subsidence or collapse zones.

EPA guidance regarding aquifer evaluation indicates that it should be should be relatively thorough and detailed (Ground Water Program Guidance No. 4.2). The agency specifically suggests the use of techniques such as: maps and cross-sections showing TDS isocons; maps showing depth to base of fresh water; maps of aquifer thickness, elevation, and saturated thickness; maps of water levels in different aquifers at different dates; and many others.

In 1979 the New Mexico Oil Conservation Division (OCD) performed a prototype study to develop and assess procedures for the evaluation of aquifers. The study involved geohydrological mapping in a geologically complex 144 square-mile area near Artesia, Eddy County, New Mexico. Procedures used and maps produced followed EPA guidance. The results indicated that rock units can be mapped and evaluated as required by the UIC program. However, studies of the scope suggested by the EPA guidance were estimated to cost at least $10 per square mile, which would impose a considerable cost on the statewide implementation of the UIC program.

Interestingly, the in-depth analysis undertaken in the Artesia area produced a result which was effectively the same as the principals of injection control which had long been enforced by the State OCD. The results of aquifer classification from the State program and the in-depth (UIC) analysis can be summarized as follows.

	State Program	UIC Program
Basis:	General geohydrologic knowledge of area	Detailed geohydrological study
Result:	Aquifers protected to base of existing drinking water aquifer; deeper units classed as salt-water aquifers	Same as State program except that some of the deeper units contain fresh water in isolated low porosity zones and are better classified as non-aquifers

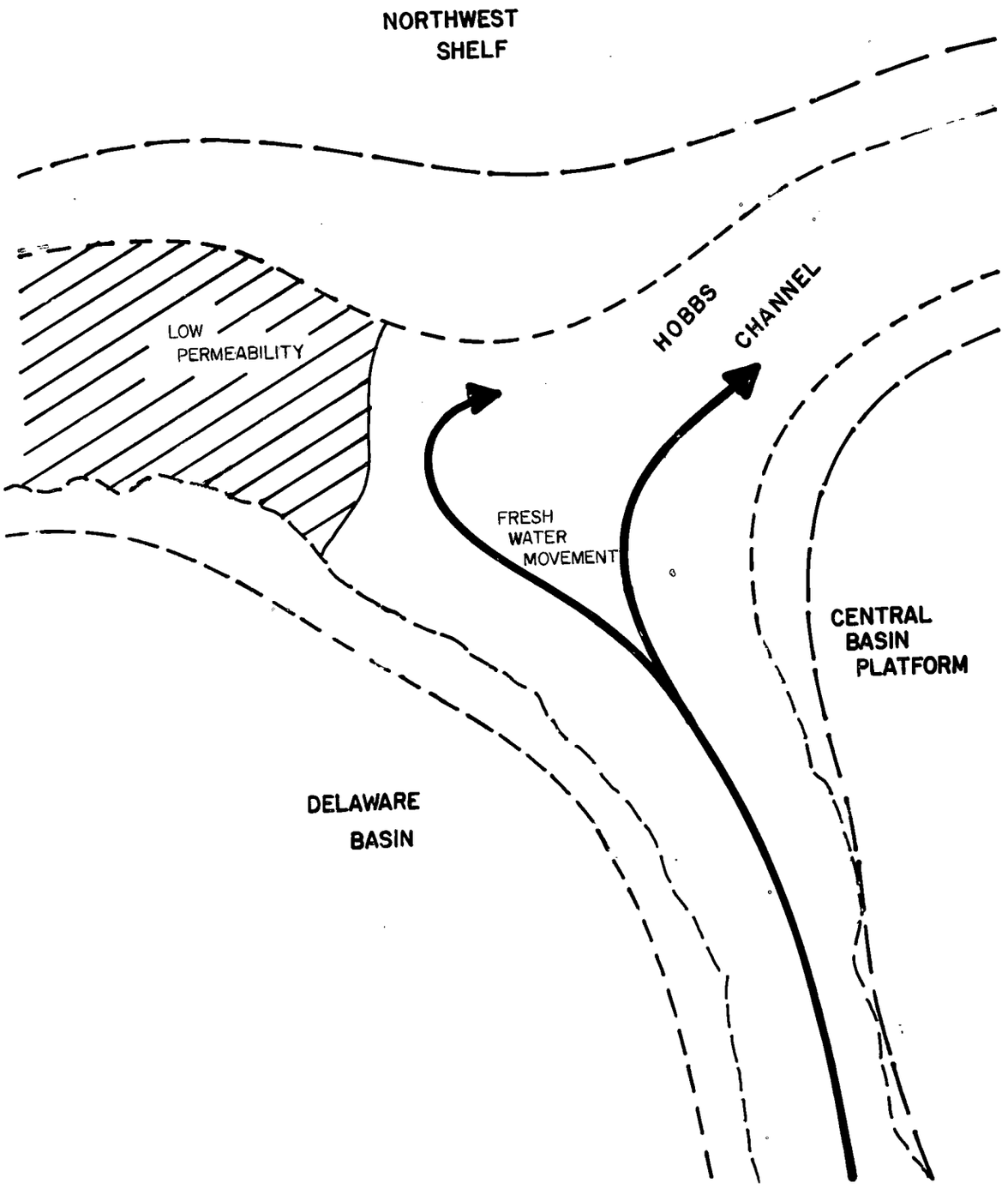
In Artesia the major benefit of a detailed geohydrologic study was to show that some rock units deemed by the State to be salt-water aquifers are in fact non-aquifers which contain fresh water. The rules for injection control are not changed by such a distinction, and consequently State regulations are correct in allowing injection below the base of the deepest existing underground source of drinking water. Resources invested in the more detailed UIC study provided no additional protection of the fresh-water resource.

On the basis of this initial prototype study, it was hypothesized that an in-depth analysis may not be required to ensure the accurate evaluation of aquifers. Rather, evaluations might be performed satisfactorily at a reconnaissance level, using procedures similar to those already applied by the State. Such an approach would reduce costs of implementing the UIC program, without endangering water supplies. In 1980 OCD performed a second study aimed at testing this hypothesis. The study began by applying Figure 1 to an injection area using basic data and existing State regulatory concepts. Next, an in-depth study according to the original UIC guidance was performed to determine if the simple approach would result in the potential for contamination of potential drinking-water aquifers. Finally, the study followed a prototype UIC permit application through the prospective regulatory mill, to see if there was a need to have applicants provide a site-specific aquifer evaluation as part of the permitting requirements.

The area chosen for study was Lea County, which is the leading oil producing County in New Mexico, and an area where there is considerable injection for both secondary recovery and brine disposal (Figure 2).

INITIAL CLASSIFICATION

The initial classification of aquifers in Lea County was based on studies of regional geohydrology published in readily available reports, and supplemented by a review of the existing State regulatory program. References re-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