

A Study of the Economic Impact of Interstate Highway 10 On Chambers County, Texas

by

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Economic Impact of the Interstate System
on Selected Areas in Texas

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Other members of the Economics Department of the Texas Transportation Institute have made valuable contributions to the completion of this study. Special tribute is due Mr. H. G. Meuth, who conducted much of the field work, and Dr. C. V. Wootan, who reviewed this final report. Mr. James W. McFarland, a student assistant, performed many of the calculations necessary for this report.

The opinions, findings, and conclusions expressed in this publication are those of the author and not necessarily those of the Bureau of Public Roads.

Foreword

In November of 1957, the U. S. Bureau of Public Roads and the Texas Highway Department authorized the Texas Transportation Institute to conduct an economic impact study along sections of the Interstate Highway System in Texas. This authorization called for joint financial support by the Bureau of Public Roads and the Texas Highway Department.

The study was to include an analysis of the economic impact of the Interstate Highway System on local areas. With the advice of the Project Advisory Committee, nine such sites were selected for study in or near the following Texas cities: Austin, Temple, Rockwall, Waxahachie, Merkel, Houston, Huntsville, Conroe, and Anahuac. At a later date, the Committee authorized a restudy of the Austin and Temple areas.

At the time the study was authorized, it was requested that a preliminary report of findings be submitted to the Bureau of Public Roads by July 1, 1958. These findings were to be used by the Department of Commerce in its report to Congress on nonvehicular benefits as required under Section 210 of the Highway Revenue Act of 1956. A report on three areas was submitted to the Bureau of Public Roads at that time. Since then, final reports have been published on the Austin, Temple, Waxahachie, Rockwall and Merkel areas. Also, final reports have been prepared on all the other areas.

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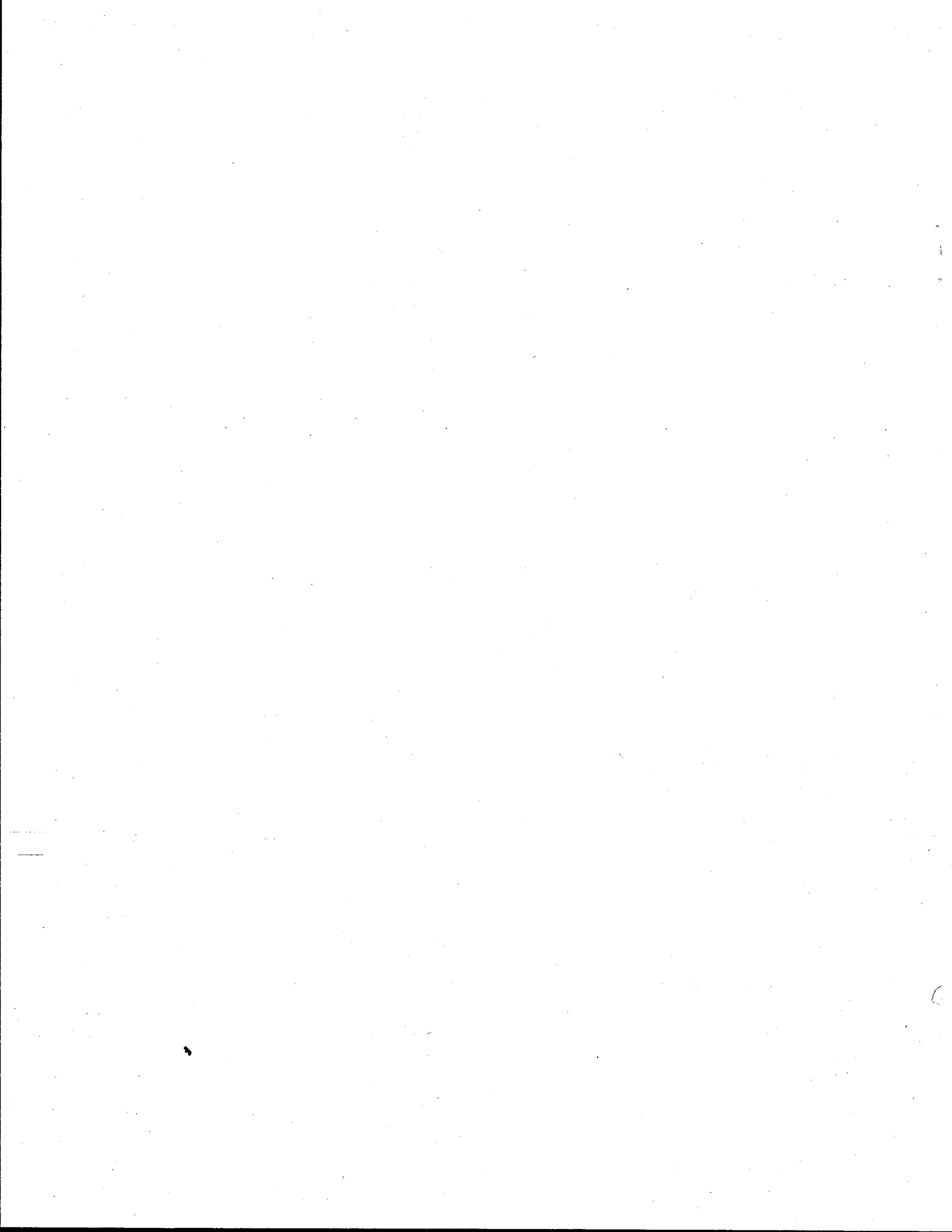
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Summary of Findings

The analysis of the Chambers County study area land value, land use, and business activity data is summarized below:

1. In a predominantly agricultural area considerably removed from an urban area, properties abutting IH 10 received significant positive land value influences from the highway improvement.

2. Practically all of the tracts of land which changed to higher uses (rural residential and commercial) were abutting IH 10.

3. Six of the seven commercial businesses in the study area are abutting IH 10. They are heavily concentrated at interchanges. The location of these businesses indicates IH 10 was considered the most desirable place for commercial establishments.

4. The performance of selected economic indicators suggests that the economic base of Chambers County has been modestly stimulated by the construction of IH 10.

Introduction

IH 10

IH 10 connects Houston with Beaumont and Port Arthur. (See Figure 1.) The old connecting route, US 90, is mostly a two-lane facility and passes through eight small towns. The new route, passing through only one town, is a more direct route and has substantially reduced the travel time between these major cities. Prior to the construction of IH 10, the area south of US 90 was not adequately served by a major east-west highway route. The need for a new highway was evident before World War II when the people of Harris, Chambers, and Jefferson Counties first began negotiating with the Texas Highway Department.

Purchase of a 150-foot right of way was begun in 1944 and completed in 1948. Before construction began on this route, then called SH 73, plans for the proposed Interstate Highway System were formulated to the extent that it became evident that such a route would be included as a part of the new system. Additional right of way was purchased in order to meet Interstate System standards. By 1956 most of the additional right of way was purchased and construction of the facility at its higher design began. Previous preliminary construction was incorporated into the new program.

Although some sections of the Chambers County portion of this route were completed in 1960, it was not

completed throughout the county until mid-1961. By the latter part of 1965, IH 10 had been completed between the downtown areas of Houston and Beaumont.

Study and Control Areas

At the time the study of the economic impact of the Interstate Highway System on local areas in Texas was initiated, one of the objectives was to study an area that had little commercial activity in existence. Since this area was largely devoted to rice farming with no substantial population centers and was well removed from both Houston and Beaumont, it was selected. The intent was to see how the Interstate System would affect a basically rural area.

A rectangular strip of land lying between Turtle's Bayou and Winnie was designated as the Chambers County study area. (See Figure 2.) It is approximately three miles wide and 14 miles long. This area was selected because of its agricultural use and because there was no other route in the vicinity prior to the construction of IH 10.

The control area lies just north and south of the study area and is highly similar to the latter in land use and road service.

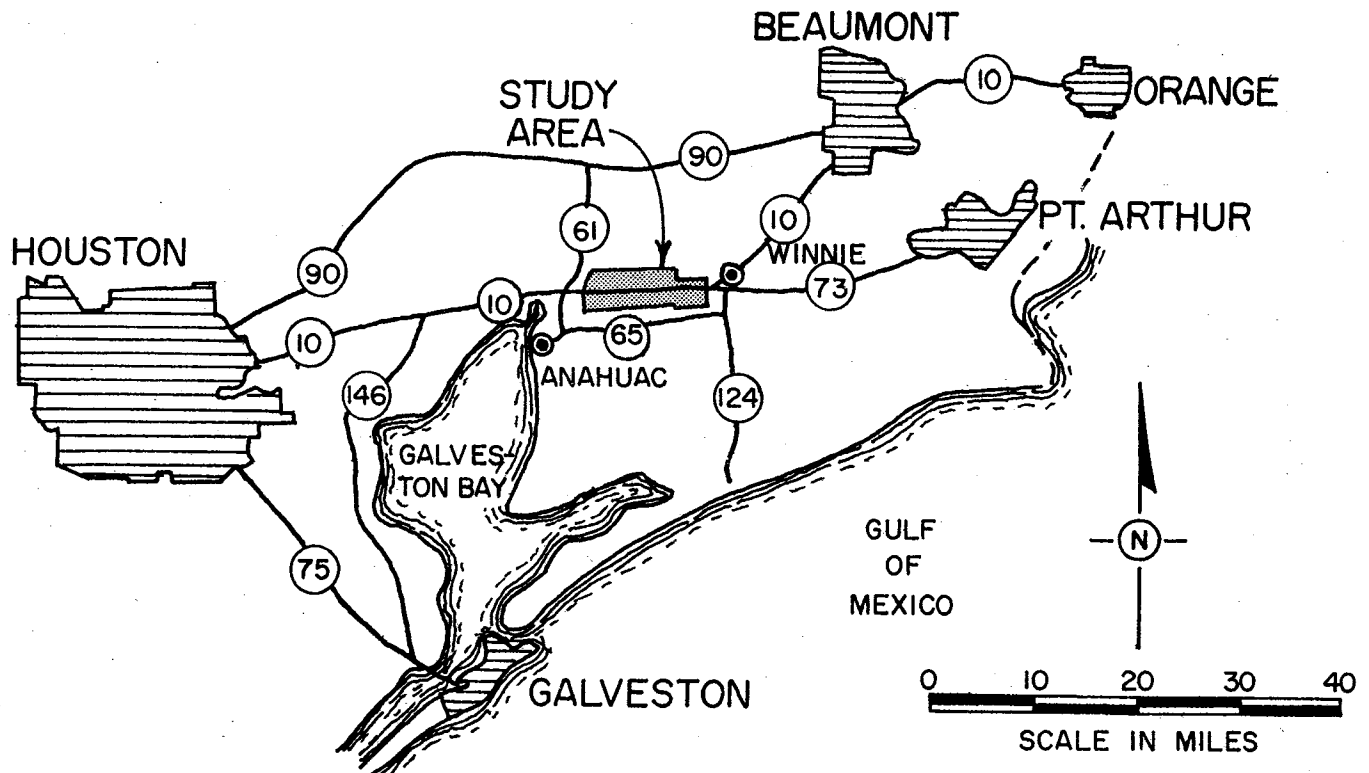
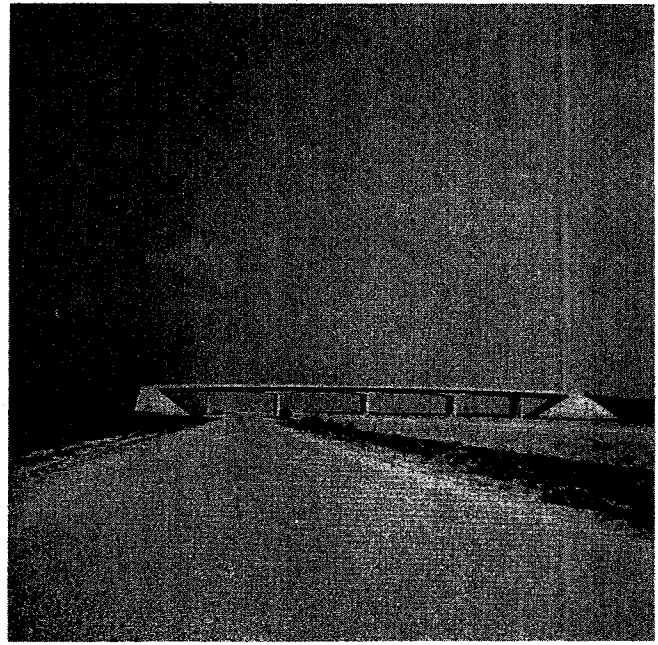


Figure 1. Location of study area with respect to surrounding cities and IH 10.



FM 1663



IH 10

Type of road service in the Chambers County study area, before and after construction of IH, respectively.

Purpose of Study

The over-all purpose of this study is to determine the economic impact of IH 10 on the selected local area in Chambers County. The results of this study may be used in anticipating the economic effects of the Interstate Highway System upon comparable agricultural areas.

The principal objectives were to determine the effects of the Interstate System upon:

1. Land values
2. Land uses
3. Business activity
4. Travel habits, and
5. General community development.

Method of Study

The general method of studying the economic effects of the Interstate System on local areas is the "before" and "after" comparative approach. Before and after periods were established by the dates of right of way purchase, highway construction, and official opening of the facility. In this area, the first date of right of way purchase was disregarded because it would have required the before period to include the World War II years.

For purposes of this study, the before period was begun in 1947. At that time the right of way for State 73 had been obtained, but the majority of the right of way for IH 10 had not yet been purchased. For a study of land values in the study and control areas, the before period was established as the years 1947-55; the construction period was determined as 1956-59; and the after period was designated as 1960-65. For land use analysis in the study area, the last year prior to the beginning of construction of IH 10 was designated as

the before period year (1955), and the last year of study was designated as the after period year (1965).

The land value analysis is based only on bonafide sale prices of properties in the study and control areas. Public and private records in Chambers County were searched for all land sales occurring in both areas. When the amount of the consideration was not stated in the deed, Federal Revenue Stamps were used as a close approximation of the sale price. Each \$.55 worth of stamps represents a maximum of \$500 of consideration. To minimize estimating error in computing the total consideration, the last \$.55 was divided in half; that is, it was estimated at \$250 of value. Tracts with improvements that were valued high enough to influence the price significantly were classified as improved property.

The sale prices used in the land value analysis were adjusted to common dollars by using the Consumer Price Index (see explanation and schedule in the Appendix). These data were appropriately tested to determine significant before and after period differences. The results of such tests appear in the footnotes under the appropriate tables.

Land use in the study area was determined for each tract in the before and after years of study. This was done by personal inspection, interpretation of aerial photographs and interviews with people living in the area.

Definitions

The land in the study area received the following use designations before and after construction of IH 10.

1. Timberland—Tract covered with heavy timber suitable for lumber production.
2. Agricultural land—Tract used for agricultural purposes.
3. Land held for future use—Tract generally con-

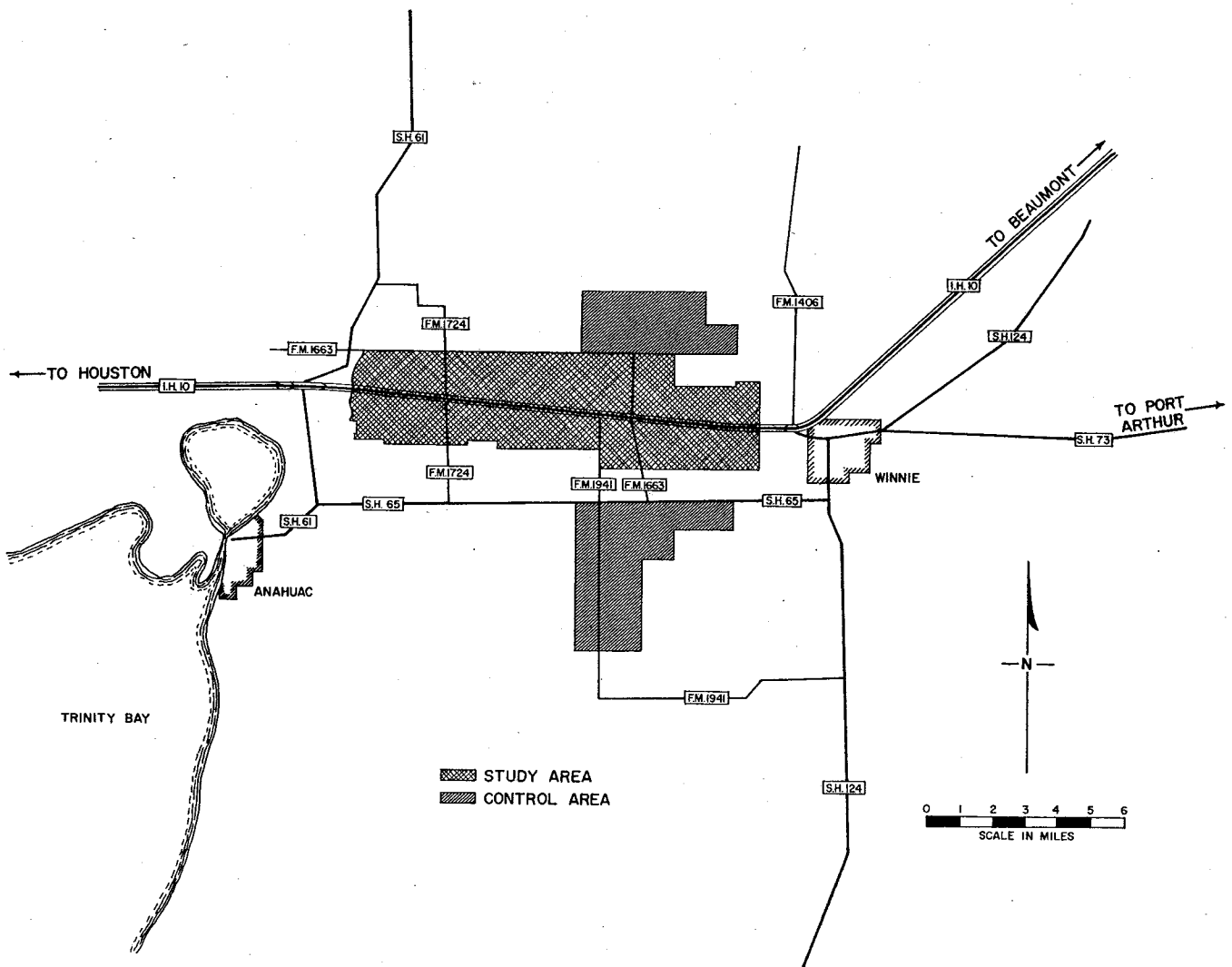


Figure 2. Location of study with respect to control area and roads.

sidered to be held for future use rather than its present utility, but may be farmed or grazed or used for other agricultural purposes during the interim period.

4. Rural residential land—Tract used primarily for a rural residence.

5. Commercial traffic serving land—Tract used for commercial purposes and heavily dependent upon highway customers.

6. Commercial nontraffic serving land—Tract used for commercial purposes and not heavily dependent upon highway customers.

7. Industrial land—Tract used for manufacturing, processing, or storage of some product.

8. Institutional - municipal land—Tract used as school, park, cemetery, hospital, etc., in a nonprofit-making capacity.

Land Value Influences of IH 10

The collection of the 19 years (1947-65) of property sale prices is used to furnish an indication of the influence of IH 10 on land values in the study area. Table 1 shows the number of sale transactions used in the study. Because there were few improved properties selling, the analysis is limited to unimproved properties, two of which were deleted from the tables because they sold for extremely high prices. The price per acre of similar tracts was so much lower than that paid for these tracts. Also, the prices of all other abutting tracts were considerably lower than the prices of these two tracts. Both of these are now improved with traffic serving businesses abutting IH 10.

Study Versus Control Areas

Table 2 shows selected comparative characteristics of unimproved acreage tract sales, by period, in the study and control areas. As can be seen, the tract size and frontage on a road of study area sales declined sharply between periods, while the size and frontage on a road of control area sales increased. These changes were caused, in part, by several small properties which sold abutting IH 10. In the case of the control area, the size of tract increased because farmers may have desired

larger and larger operating units. The highest and best use for control area land is still agricultural, whereas, the new highway has changed the highest and best use of some of the abutting properties to commercial or industrial. Regardless of the period, the differences between the sales year of both areas are not significant enough to suggest that most of the value differences is due to variations in time.

Table 3 presents the analysis of land values of unimproved properties in the study area versus that of the control area. The mean values are very dependable, as suggested by their corresponding standard deviations. This indicates that there were no extreme values which determine these means. The variations in the sale prices were low for both areas, which is highly desirable when an attempt is being made to measure highway influence.

Even for an agricultural area considerably removed from an urban area, the data suggest a probable highway influence of \$15 per acre, which is 25 percent of the study area's before period price. If the two sales with extremely high prices had been included in the table, the probable highway influence would have been \$1,028 per acre or 1,773 percent.

Proximity to IH 10 in Study Area

Study area land value changes attributable to proximity to IH 10 are presented in Table 4. The land sales abutting IH 10 were analyzed separately from the non-abutting sales, and price changes in both groups were compared to changes in control area.

This analysis revealed that abutting land values received a probable highway influence of \$81 per acre. Nonabutting values failed to increase as much as control area values. If the two extreme prices of abutting tracts had been included in the table, the probable highway influence would have been \$3,706 per acre or 5,070 percent.

Thus, for an area such as the one in Chambers County, it appears that abutting properties are the only properties which received a significant positive land value influence from the highway improvement. Non-abutting properties have not shared in this highway influence to any appreciable extent because of the abun-

Table 1
NUMBER OF LAND SALES TRANSACTIONS USED
IN THE ANALYSIS OF LAND VALUES, CHAMBERS
COUNTY, TEXAS, 1947-65

Period	Number of Transactions		
	Unimproved	Improved	Total
Study Area			
Before Period (1947-55)	22	1	23
During Period (1956-59)	7	0	7
After Period (1960-65)	19	3	22
Subtotal	48	4	52
Control Area			
Before Period (1947-55)	19	0	19
During Period (1956-59)	1	1	2
After Period (1960-65)	4	0	4
Subtotal	23	1	24
Grand Total	71	5	76

Table 2
COMPARATIVE CHARACTERISTICS OF UNIMPROVED ACREAGE TRACT SALES IN THE STUDY AND CONTROL AREAS BY PERIOD*

Characteristic	Before Period		After Period	
	Study Area	Control Area	Study Area	Control Area
Price of Tract (In Dollars)	10,645(22)	20,839(19)	23,086(17)	60,775(4)
Size of Tract (In Acres)	211(22)	366(19)	86(17)	480(4)
Frontage on Road (In Feet)	2,089(18)	3,182(17)	761(13)	4,460(4)
Depth of Tract (In Feet)	2,976(18)	3,821(17)	1,827(13)	3,090(4)
Time of Sale (In Years)	51(22)	50(19)	63(17)	62(4)

*The data in this table are arithmetic means based on the number of observations in parentheses.

Table 3
PRICES OF UNIMPROVED ACREAGE TRACTS LOCATED IN THE STUDY AND CONTROL AREAS CHAMBERS COUNTY, TEXAS, IN CONSTANT DOLLARS (1947-49 = 100)

Period	Study Area		Control Area		Difference Between Areas	Percent of Study Area Before Period Price
	Price Per Acre ¹	Standard Deviation	Price Per Acre ¹	Standard Deviation		
Before Period (1947-55)	\$ 58(22)	\$ 26	\$ 54(19)	\$ 31	4 ²	
During Period (1956-59)	131 (7)	64				
After Period (1960-65)	210(17)	107	187 (4)	113	23 ³	
Change Between Periods						
Before and During						
Dollars	\$ 73					
Percent	126%					
During and After						
Dollars	\$ 79					
Percent	60%					
Before and After						
Dollars	\$152		\$133		\$19	33% ⁴
Percent	262%		246%		16% ⁵	
Probable Highway Influence						
Percent	25% ⁶					
Dollars	\$ 15 ⁷					

¹The number of transactions is shown in parentheses.

²The standard error (SE) is \$1.95. This value is significant beyond the 96 percent level; t is equal to 2.05.

³The S.E. is \$20. This value is significant beyond the 79 percent level; t is equal to 1.15.

⁴Assuming that the property prices in the study and control areas would have increased in value by the same dollar value in the absence of a new road improvement, the between period dollar difference between areas would have been zero. But the study area prices changed by a greater amount, with the net difference shown above stated as a percent of the study area's before period price.

⁵Same assumption as Footnote 4, except based on percent changes.

⁶Average of Footnotes 4 and 5 percentages, based on before and after period changes.

⁷Footnote 6 percentage multiplied by the study area's before period price.

Table 4
PRICES OF UNIMPROVED ACREAGE TRACTS ABUTTING AND NONABUTTING IH 10 IN THE STUDY AREA COMPARED TO THE CONTROL AREA, CHAMBERS COUNTY, TEXAS IN CONSTANT DOLLARS (1947-49 = 100)

Period	Price Per Acre ¹			Difference Between Areas			Percent of Respective Parts of Study Area's Before Period Price	
	Study Area Abutting	Study Area Nonabutting	Control Area	Abutting Vs Non-abutting	Abutting Vs Non-abutting		Abutting	Non-abutting
					Control	Control		
Before Period (1947-55) ²	\$ 66(5)	\$ 56(17)	\$ 54(19)	\$ 10	\$ 12	\$ 2		
During Period (1956-59)	201(2)	103 (5)		98				
After Period (1960-65) ³	295(4)	184(13)	187 (4)	111	108	3		
Change Between Periods								
Before and During								
Dollars	\$135	\$ 47						
Percent	205%	84%						
During and After								
Dollars	\$ 94	\$ 81						
Percent	47%	79%						
Before and After								
Dollars	\$229	\$128	\$133	\$101	\$ 96	\$ - 5	145%	-9%
Percent	347%	229%	246%	118%	101%	-17%		
Probable Highway Influence⁴								
Percent	123%	-13%						
Dollars	\$ 81	\$ - 7						

¹The number of transactions is shown in parentheses.

²For abutting versus nonabutting, the S.E. is \$.5. This value is significant beyond the 95 percent level; t is equal to 2.00. For abutting versus control, the S.E. is \$5.10. This value is significant beyond the 97 percent level; t is equal to 2.35. For nonabutting versus control, the S.E. is \$2.10. This value is significant beyond the 93 percent level; t is equal to 1.82.

³For abutting versus nonabutting, the S.E. is \$26. This value is significant beyond the 99 percent level; t is equal to 4.30. For abutting versus control, the S.E. is \$16.50. This value is significant beyond the 99 percent level; t is equal to 6.55. For nonabutting versus control, the S.E. is \$19.90. This value is significant beyond the 11 percent level; t is equal to .15.

⁴Footnotes 4, 5, 6, and 7 under Table 3 give explanations.

dant supply of future commercial and industrial sites abutting IH 10. Their values are still largely production based and will likely continue to be so for several more years because of their considerable distance from a large town or city. Another reason, is that nonabut-

ting properties are generally a considerable distance from the new highway due to the considerable size of the abutting tracts. Few nonabutting tracts are within one-fourth mile of the facility and a much greater distance from an interchange by road.

Land Use Influences of IH 10

Land use influences of IH 10 in the study area are analyzed here with Figures 3A and 3B showing the 1955 and 1965 land uses and land use changes, respectively. First, land use changes in the whole study area, and secondly, land use changes of properties abutting IH 10 are discussed.

Figure 4 is a 1963 aerial photograph of the study area showing the land uses as of that time.

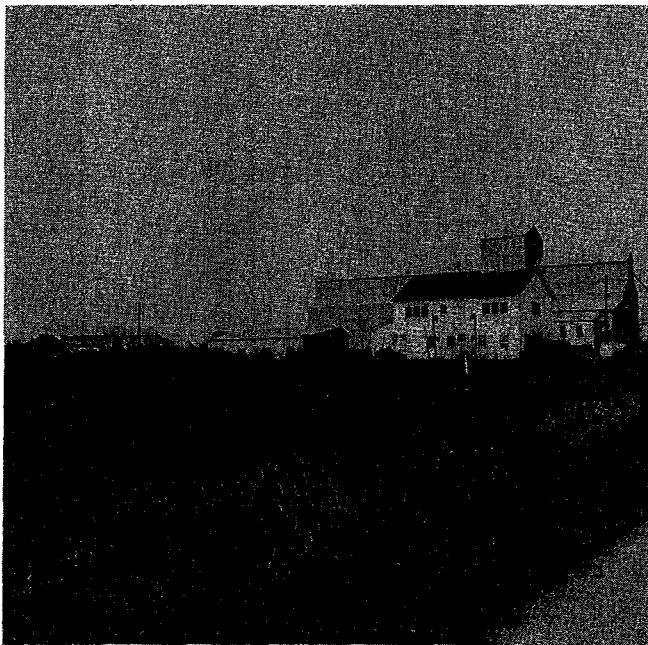
Study Area

A study of Figure 3A reveals that almost all the study area land was in agricultural use during 1955.

Table 5
QUANTITY OF STUDY AREA LAND IN VARIOUS USES IN 1955 AND 1965

Land Use	Number of Acres ¹		Changes Between 1955 and 1962	
	1955	1965	Acres	Percent
Timberland	1,320	1,208	-112	- 8%
Agricultural	22,620	22,513	-107	- .5
Institutional-				
Municipal	2	55	+ 53	+2650
Held for Future Use	535	544	+ 9	+ 2
Rural Residential	130	216	+ 86	+ 66
Industrial	55	55	0	0
Commercial				
Traffic Serving	0	8	+ 8	NA
Commercial Non-				
traffic Serving	2	43	+ 41	+2050
Other (Roads, Canals, etc.)	1,136	1,158	+ 22	+ 2
Total Area	25,800	25,800		

¹Approximate figures.



Rice Drier

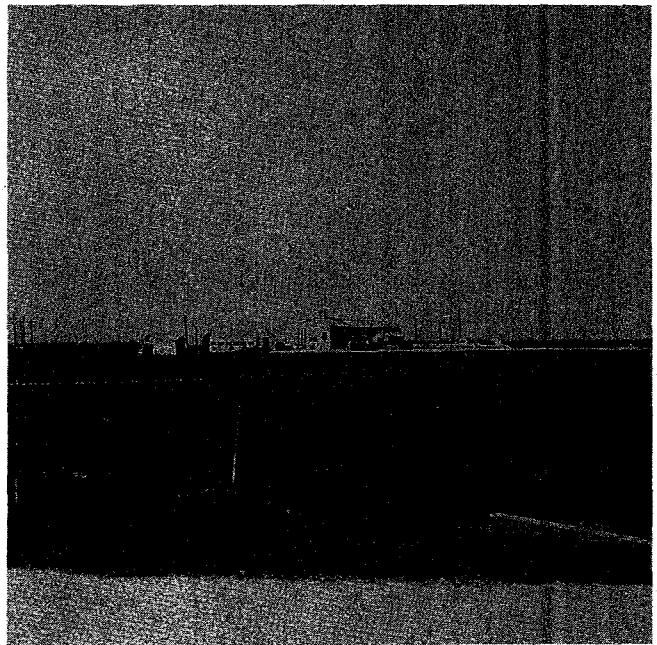
Figure 3B, an overlay map to Figure 3A, indicates that very few changes in land use have occurred during the 10 year period since 1955. Table 5 shows the approximate quantity of land in various uses at the beginning (1955) and the ending (1965) of this period. Also shown in this table is the net quantity of land changing to or from specific uses.

Since most of the IH 10 right of way was purchased before 1955, several tracts had already changed to land held for future use before construction began. Later, a few additional tracts, one abutting the new facility, changed to land held for future use.

As shown in Table 5, there has been a net reduction in the quantity of agricultural and timberland during the period. Most of this land changed to rural residential, institutional, and commercial uses. Also, some additional right of way was purchased for the IH 10 interchanges. It is interesting to note, however, that no

Table 6
NUMBER OF STUDY AREA ABUTTING TRACTS IN VARIOUS USES BY PERIOD

Land Use	Before Period	After Period
Timberland	5	4
Agricultural	43	43
Institutional	1	2
Held for Future Use	21	22
Rural Residential	0	4
Industrial	0	0
Commercial Traffic Serving	0	5
Commercial Nontraffic Serving	0	1
Total Number of Tracts	70	81



Pipeline Pump Station

The only two industrial tracts in the Chambers County study area existed prior to construction of IH 10.

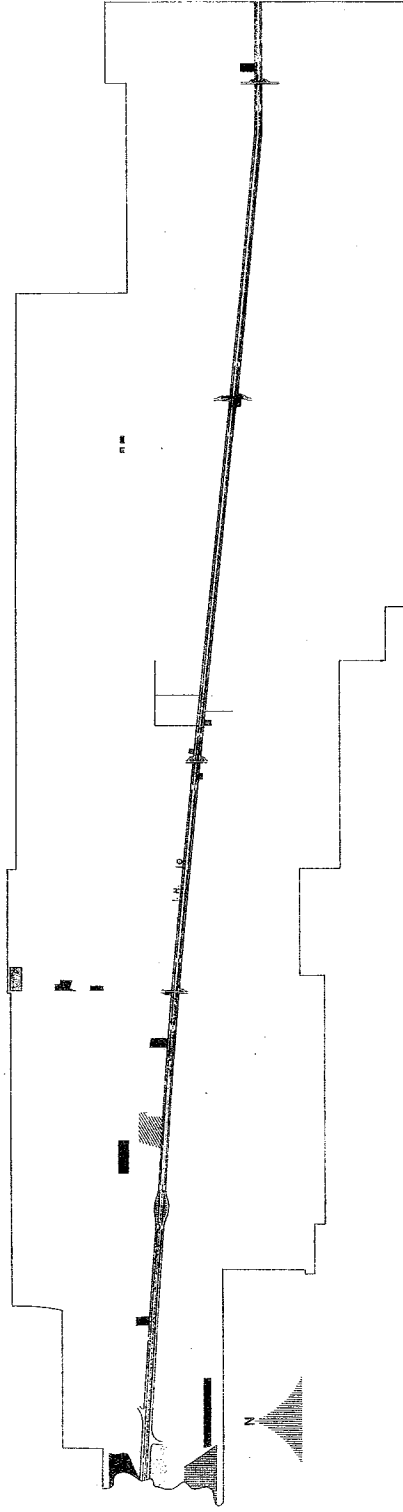
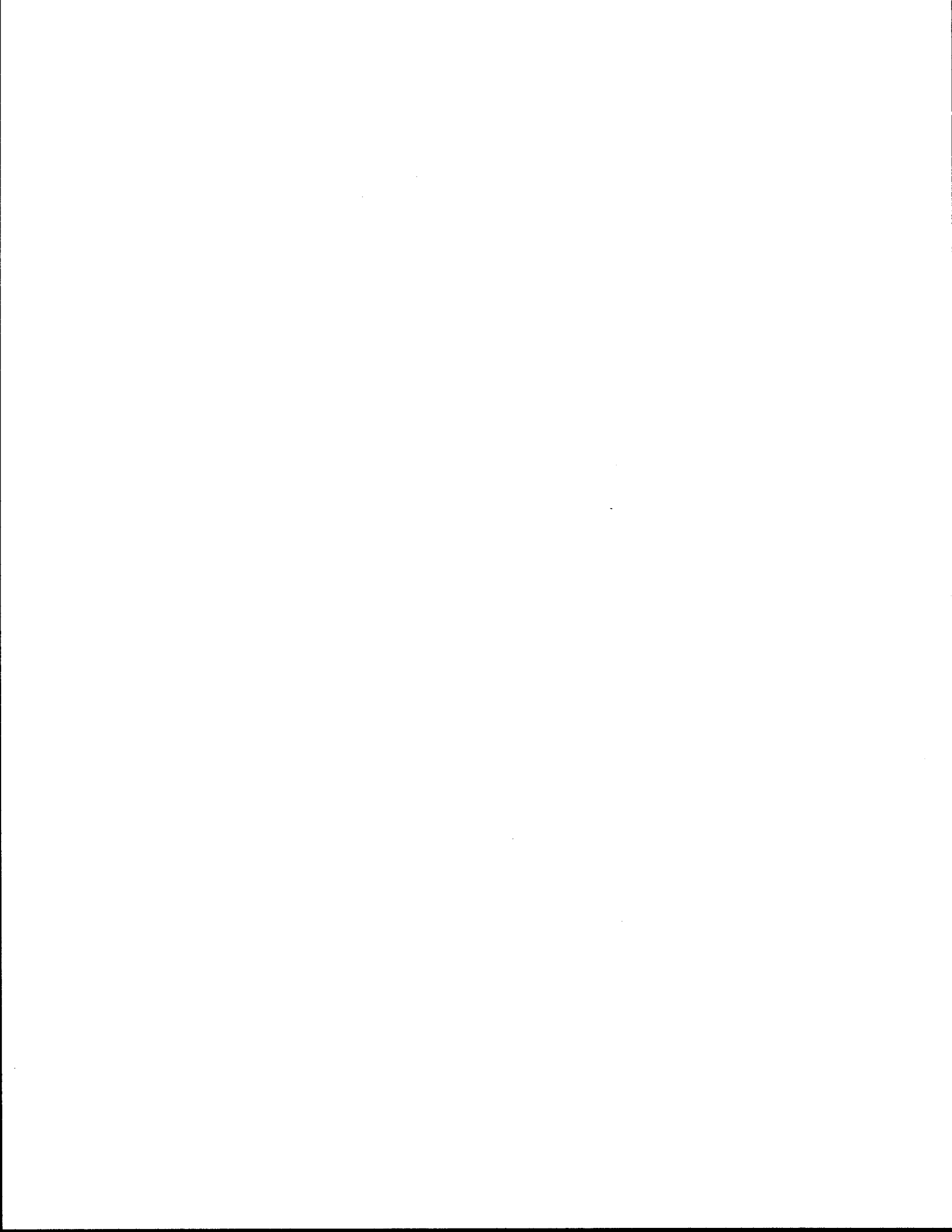


Figure 3B. Overlay map of the Chambers County study area showing land use changes between 1955-65, during and after construction of IH 10.



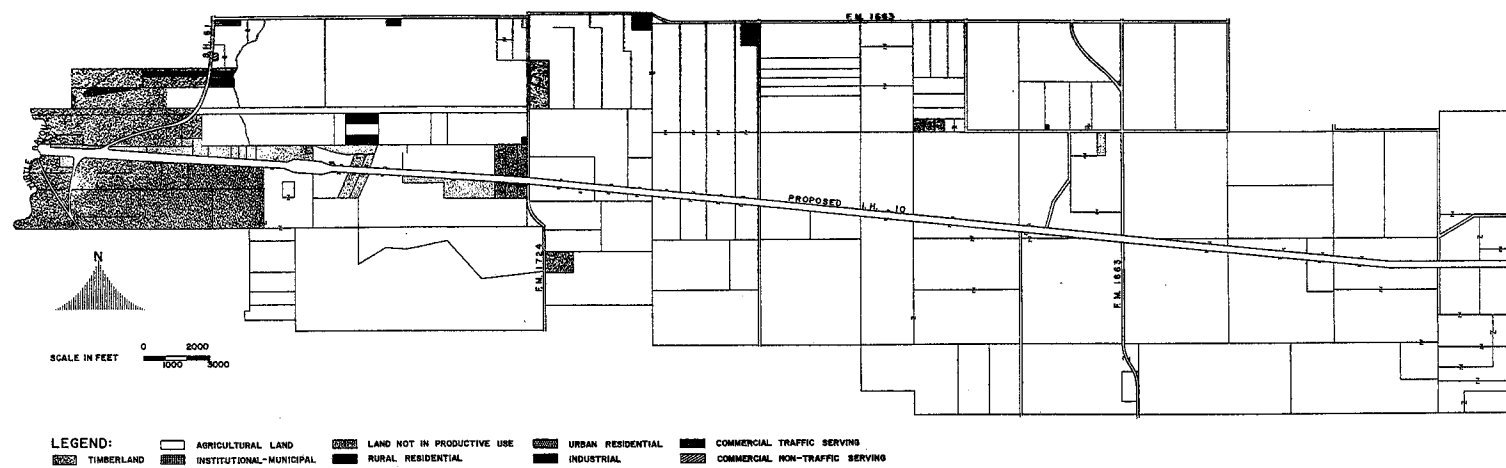
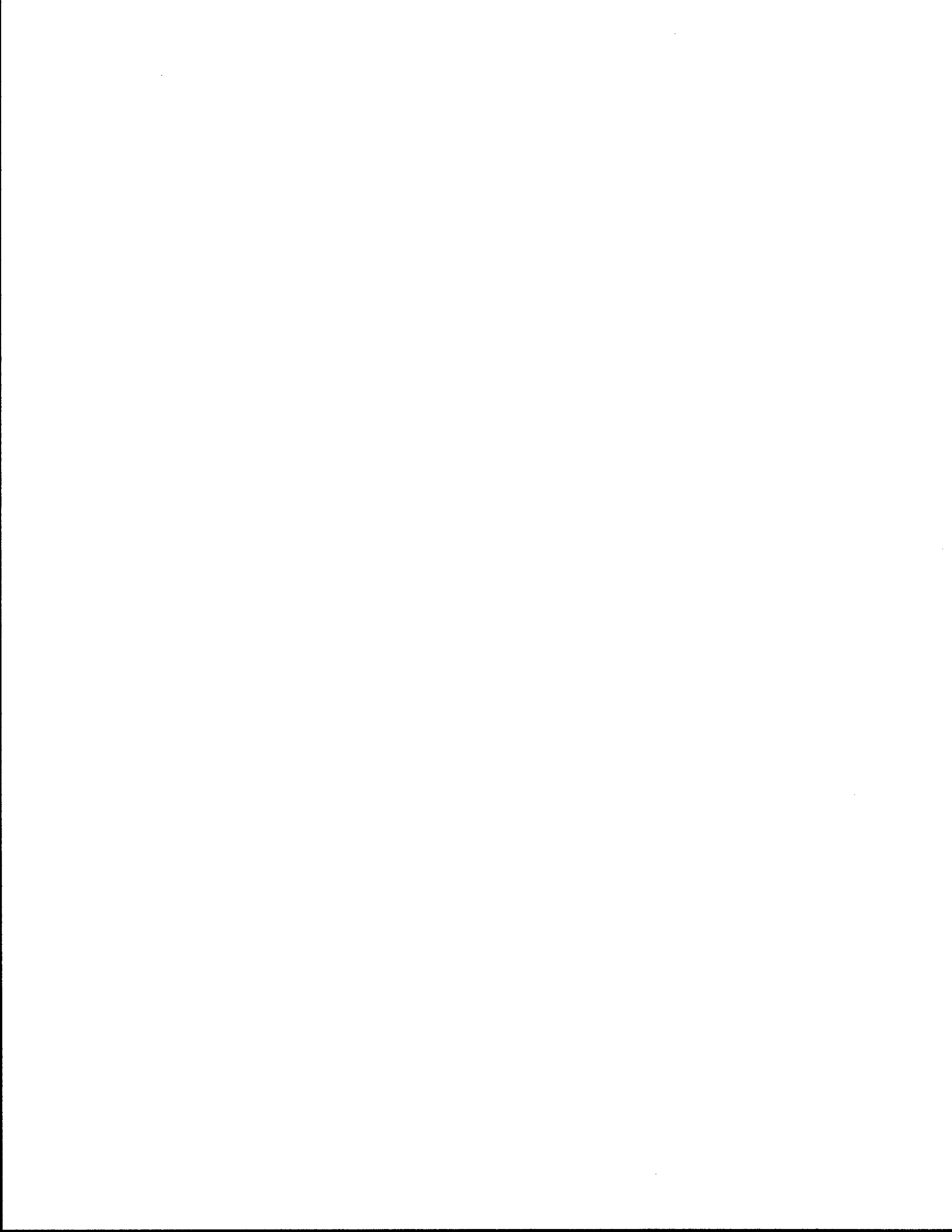


Figure 3A. Base map of the Chambers County study area showing land use as of 1955, before construction of IH 10.



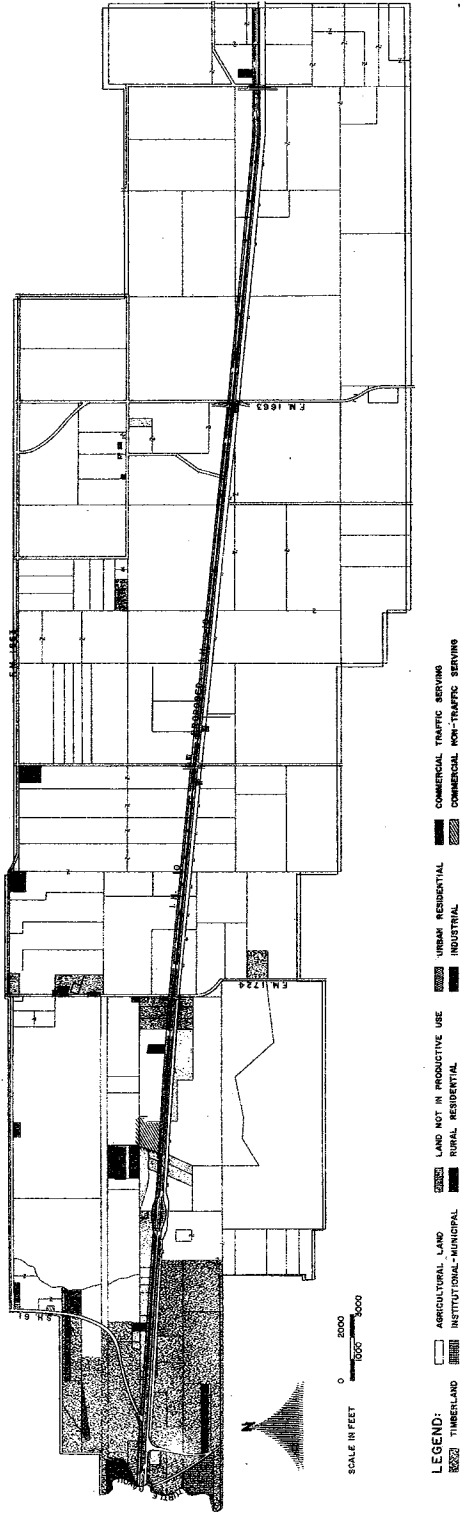


Figure 2A. General map of the Charlotte County study area showing land uses as they are before construction of I-10 and after construction of I-10.



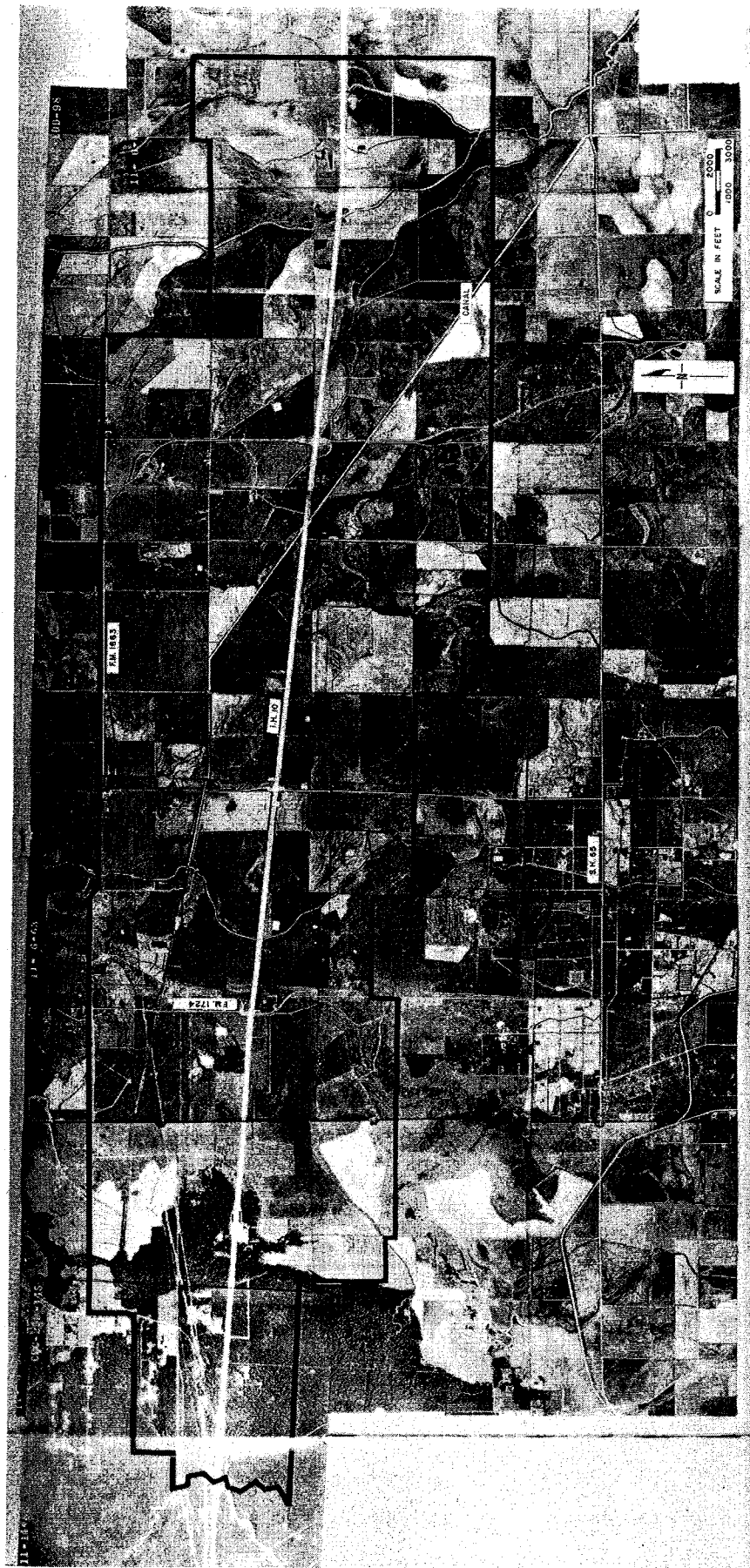


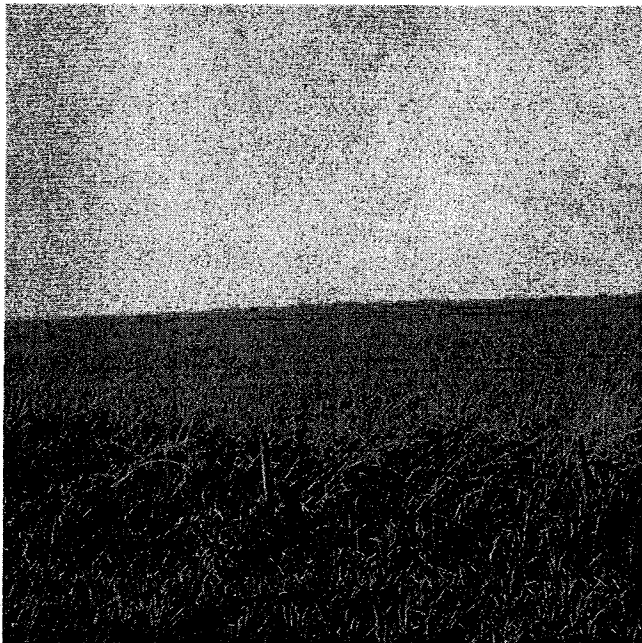
Figure 4. A 1963 aerial photograph of the Chambers County study area.



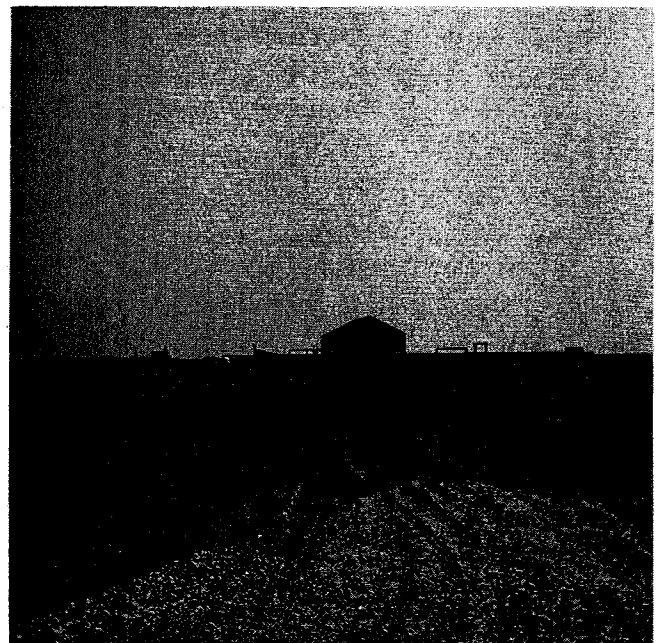
Timberland



Timberland Held for Sale



Rice Farm



Livestock Farm

Tracts of land abutting IH 10 are in various uses.

additional industrial land has been developed after highway construction. All told, only about one percent of the land has changed in use.

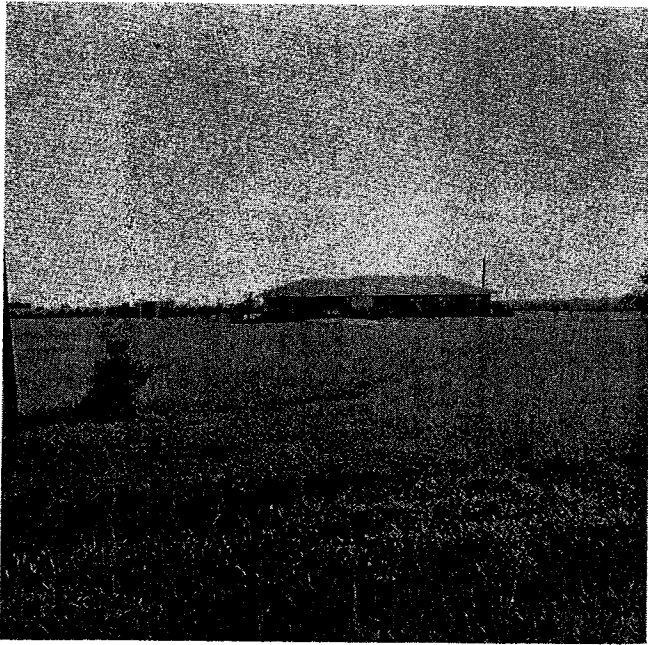
Proximity to IH 10

Table 6 shows the number of tracts abutting IH 10 in the study area during the before and after period. The most significant change between periods is the location of six commercial firms on these abutting properties. There is only one other commercial tract in the

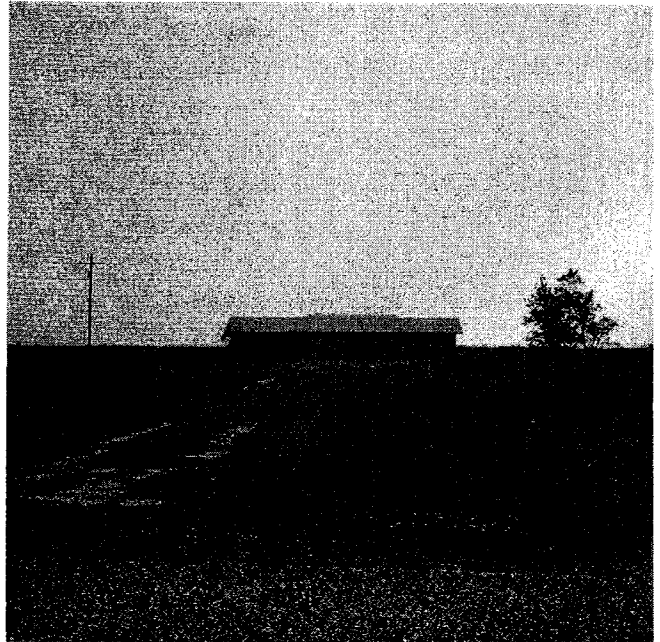
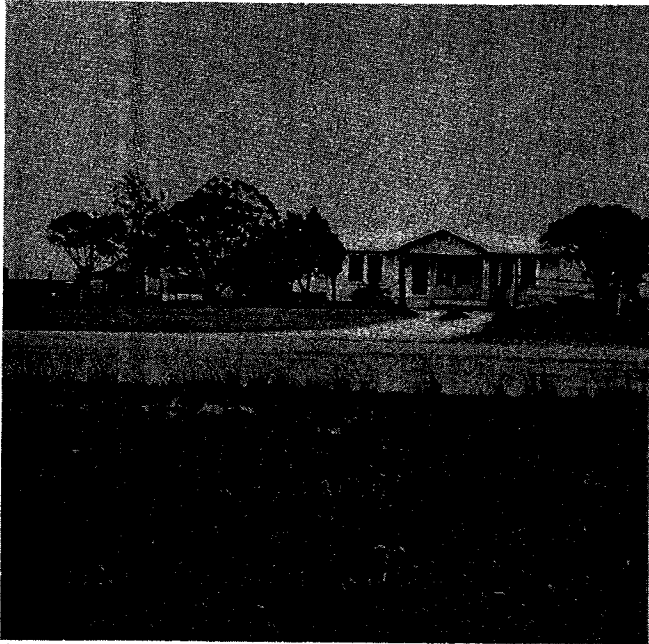
study area, and it existed prior to 1955. Four of the six commercial sites are at interchanges. All of these are improved with commercial, traffic serving businesses.

The next most significant change is the location of four rural residential tracts along IH 10.

Thus, for a section of abutting land in an agricultural area, IH 10 has caused some commercial and rural residential development. Development to date, however, has been highly selective with less than one percent of the study area land being involved in a land use change.



Two new rural residences located along IH 10 in the study area.



An old and new rural residence, respectively, located along farm roads in the study area.

Business Activity Influences of IH 10

As mentioned earlier, six commercial businesses have been located along IH 10 during the study period. Table 7 specifies these businesses by type; five of which are traffic serving, and one of which is nontraffic serving. Although classified as nontraffic serving, this particular business depends on the new facility to a considerable extent.

These commercial businesses provide some stimulation to the economy of this area. They have provided employment for several people and have created more county and school tax revenues. With more persons and firms having local bank accounts, the increased lend-

ing capacity of these institutions will aid in the further development of this area.

Two of the traffic serving businesses on IH 10 are owned by a national firm. Of all such retail outlets owned by the firm, these two (one facing the other) rank near the top in gross sales.

Outside of agricultural production, IH 10 appears to be the other principal motivator of economic activity in the study area. Oil and gas production, in addition to agricultural production, support the economy of other parts of Chambers County and to a lesser extent in the study area.

Since construction of IH 10, the only petroleum refinery in Chambers County (located near the new facility at the town of Winnie) has helped the economy of the county by expanding its productive capacity.

Table 8 shows the performance of selected economic indicators in Chambers County. Most of these indicators show significant percentage gains between the before and after completion of IH 10, which occurred in 1961.

The prospect is that the presence of IH 10 will encourage further commercial and industrial development, not only in the study area, but also in other parts of the county. It has made Anahuac, the countyseat, more accessible and should encourage that town's economic growth.

Table 7
COMMERCIAL BUSINESSES LOCATED IN THE
CHAMBERS COUNTY STUDY AREA

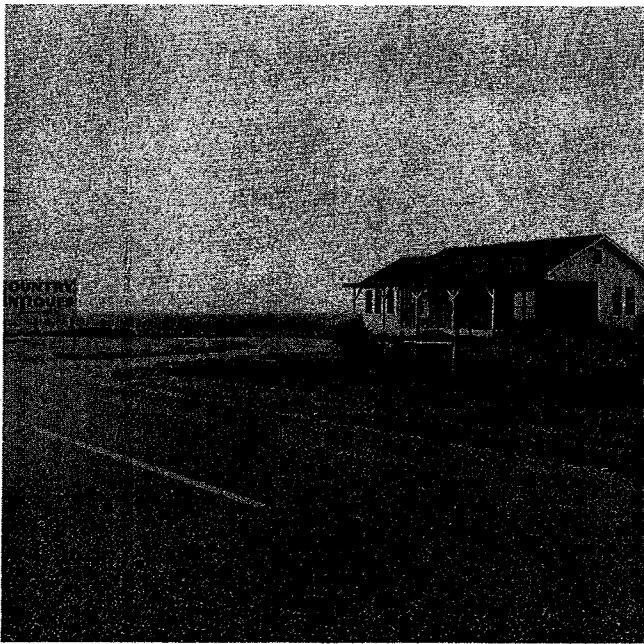
Type of Business	Number of Businesses	
	Abutting IH 10	Elsewhere in Study Area
Farm Implement Dealer	0	1
Fish Production and Sales	1	0
Antique Sales	1	0
Service Station	1	0
Gas, Snack Bar, and Candy	2	0
Drive-In Restaurant	1	0
Total Number of Businesses	6	1

Table 8
PERFORMANCE OF SELECTED ECONOMIC INDICATORS IN CHAMBERS COUNTY

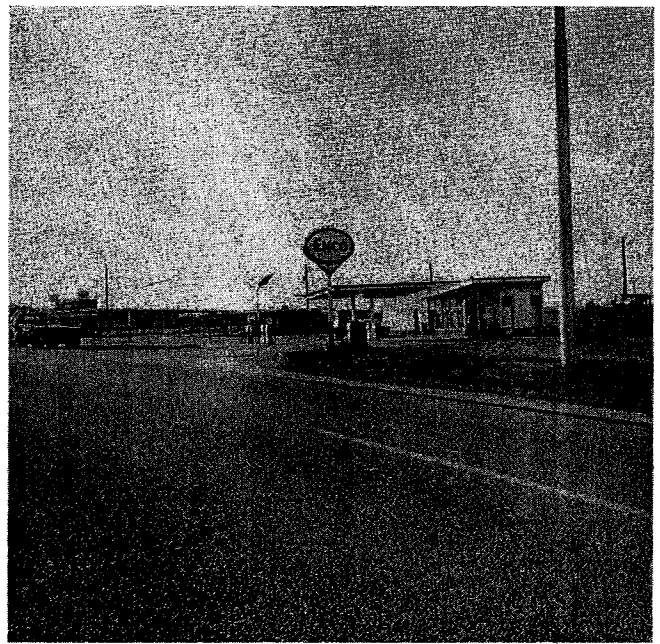
Indicator ¹	Quantity		Change Between Years	
	1958	1963	Quantity	Percent
Retail Trade²				
Sales (Dollars)	8,157,000	11,117,000	+ 2,960,000	+36%
Payroll Entire Year (Dollars)	606,000	917,000	+ 311,000	+51
Selected Services²				
Receipts (Dollars)	517,000	752,000	+ 235,000	+45
Payroll Entire Year (Dollars)	86,000	166,000	+ 80,000	+93
Minerals Produced (Dollars)	61,695,821	60,635,766	- 1,060,055	- 2
Motor Vehicles (Number)	6,612	8,732	+ 2,120	+32
Labor Force				
	1959	1964		
Total Force (Number)	4,250	4,100	-	150
Unemployed (Number)	150	140	-	10
Nonfarm (Number)	2,250	3,240	+	990
Manufacturing (Number)	150	155	+	5
Farming (Number)	1,850	565	-	1,285
Bank Deposits (Dollars)	5,567,000	8,675,000	+ 3,108,000	+56
Tax Valuations (Dollars)	40,343,460	61,872,805	+21,529,345	+53
	1960	1965		
Population (Number)	10,379	11,100	+	721

¹All data, except that of retail trade and selected services, are from the 1961-62 and 1966-67 editions of the Texas Almanac.

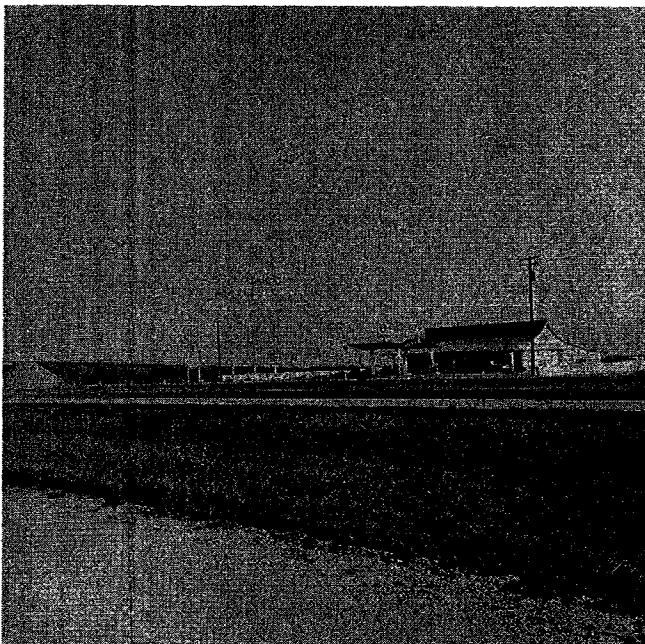
²Data from the 1958 and 1963 editions of the U. S. Census of Business.



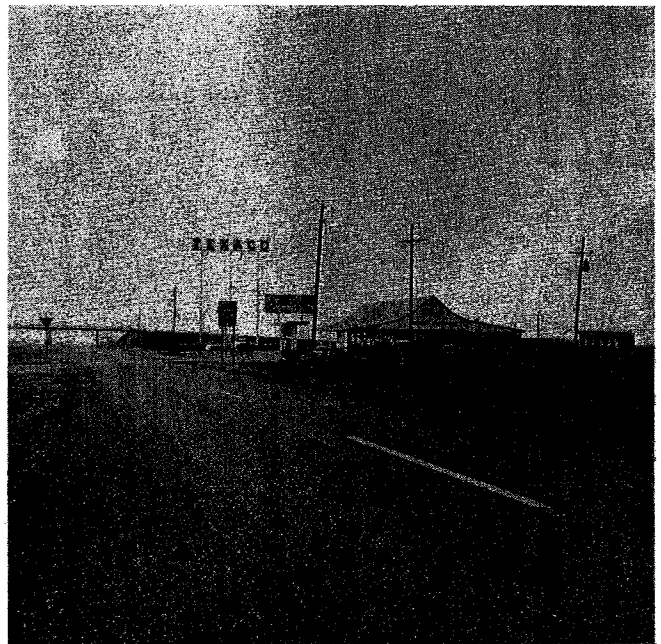
Antique Shop



Service Station & Drive-In Restaurant



Gas, Snack Bar, and Candy



Gas, Snack Bar, and Candy

Several commercial businesses are located along IH 10 in the study area.

Appendix

CONSUMER PRICE INDEX

Below is a listing of the consumer price index and its reciprocal for each year involved. The base was 1947-49 = 100. The reciprocals were used to deflate the land prices to constant dollars.

Year	Index	Reciprocal
1944	75.2	1.330
1945	76.9	1.300
1946	83.4	1.200
1947	95.5	1.047
1948	102.8	0.973
1949	101.8	0.982
1950	102.8	0.973
1951	111.0	0.901
1952	113.5	0.881
1953	114.4	0.874
1954	114.8	0.871
1955	114.5	0.873
1956	116.2	0.861
1957	120.2	0.832
1958	123.5	0.810
1959	124.6	0.803
1960	126.5	0.791
1961	127.9	0.782
1962	129.3	0.773
1963	131.0	0.764
1964	132.6	0.754
1965	134.4	0.744

Formulas and Statistical Terms Used in Land Value Analysis

In the footnotes of the land value tables, certain statistical data are presented to aid the reader in further evaluating the land value information given in the tables. By using the appropriate small sample formulas, the standard errors of the difference between various pairs of means (study versus control areas) were computed and shown in the footnotes under each table. These standard errors were used in formulas deriving Student's t values. The Student's t, is the deviation of the

difference between two sample means from the mean of the population, expressed in units of the standard error of the difference between the means. These Student's t values are also shown. Finally, the approximate confidence level in which these t values are significant is shown. The larger the value of t, the less the chance that its value is due to chance only. For example, if the value of t is 2.05 (based on sample means with each having 15 observations) at a 95 percent probability level, the interpretation is that a value of t this large would occur only five times out of a 100 and can not be due to chance alone.

An explanation of the formulas used in determining the standard error of difference between two means and the t values is presented below.

For a pair of samples consisting of less than 30 observations, the standard error of the difference between the means of these two samples is given by

$$S_d = \sqrt{\frac{\sigma_1^2 + \sigma_2^2}{N_1 + N_2 - 2}}$$

where σ_1 and σ_2 are the standard deviations of the populations of means from which sample means 1 and 2 come respectively. With the two σ 's not known, we substituted for them the σ 's of the corresponding samples. N_1 and N_2 are the number of observations that make up samples 1 and 2 respectively. In determining whether the difference between the means of samples 1 and 2 deviates significantly at a certain confidence level, a T value is computed by using Student's t and is given by

$$t = S_d \frac{D}{\sqrt{\frac{N_1 + N_2}{N_1 \times N_2}}}$$

where D is the difference between the means of samples 1 and 2, and S_d is the standard error given above. It is assumed that samples 1 and 2 come from normal populations with the means.