94-483-026

DICKINSON BAYOU WATERSHED
REGIONAL DRAINAGE PLAN
PHASE III

COMBINATION ALTERNATIVE
SUPPLEMENT TO PHASE II
PRELIMINARY ALTERNATIVE DESIGN REPORT

PREPARED FOR:

GALVESTON COUNTY, TEXAS
AND
THE TEXAS WATER DEVELOPMENT BOARD

PREPARED BY:

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PRELIMINARY DRAFT FOR REVIEW
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Study Requirements

Due to a rapid increase in population in recent years and growing concern over flood abatement issues, the County of Galveston entered into a contractual agreement with the Texas Water Development Board to develop a flood protection plan for the Dickinson Bayou Watershed in Galveston County. The overall study has been divided into three main phases.

- **Phase I** (January through August 1992) involved the establishment of baseline hydraulic data for Dickinson Bayou and a number of major tributaries, the development of a preliminary institutional framework for cooperation among local entities in implementing flood control measures, and the preparation of a drainage criteria manual for the watershed.
- **Phase II** (January through October 1993) involved the development of baseline hydraulic data for additional streams in the watershed, preparation of a supplement to the Phase I institutional framework report, the development of baseline environmental data, and completion of a preliminary analysis of four alternatives for reducing flooding potential within the watershed.
- **Phase III** (February through November 1994) involves the development of a Combination Alternative which incorporates the best features of alternative flood plain management approaches evaluated in Phase II. A phasing and implementation plan will be developed in conjunction with an environmental assessment of the Combination Alternative as part of the Master Drainage Plan for the Dickinson Bayou Watershed.

Scope of Work

The major tasks of the combination alternative analysis described in this report are as follows:

1) Develop a combination alternative that provides a reduction in the flood hazard while minimizing cost and impacts.
2) Evaluate the effects of alternatives on flooding potential along Dickinson Bayou and its tributaries;
3) Prepare estimates of the costs associated with each element of the combination alternative;
4) Identify the hydraulic, socioeconomic, and environmental impacts of the combination alternative;
5) Prepare a report which summarizes the results of the combination alternatives analysis.

Description of Possible Elements In Combination Alternative

As possible elements of the Combination Alternative, the four alternatives analyzed in Phase II of this study reflect very different approaches to watershed management.

For the ***No-Action Alternative***, it is assumed that there will basically be no active watershed management by local regulatory agencies. With this alternative, development of the watershed would proceed with no requirements concerning mitigation of impacts on flooding conditions.

For the ***Non-Structural Alternative***, it is assumed that flood damages will be reduced or eliminated by purchasing the flood plain and removing all habitable structures. This non-intrusive approach is very desirable from an environmental standpoint.

The ***Channelization/Diversion Alternative*** represents an approach involving the construction of improved channels which efficiently convey flood waters to Dickinson Bayou with a minimum of overbank flooding. This includes improvements to existing channels as well as the construction of interceptor and/or diversion channels.

Finally, the ***Detention Alternative*** calls for the abatement of flooding problems through temporary storage of flood waters in reservoirs located at strategic points throughout the watershed. On-site detention for all new development is an integral part of this alternative.

Each of these alternatives are described in more detail in the Phase II "*Preliminary Alternative Design Report*," dated October 1993.

OVERVIEW OF THE DICKINSON BAYOU WATERSHED

Description of the Watershed

The Dickinson Bayou watershed is located to the southeast of Houston, Texas, and west of Galveston Bay. Adjoining watersheds include those of Clear Creek, Mustang Bayou, Halls Bayou, Highland Bayou, and Moses Bayou. Dickinson Bayou empties into Dickinson Bay approximately 1.5 miles downstream of State Highway 146. Dickinson Bay lies along the western edge of Galveston Bay. Exhibit 1 illustrates the location of the Dickinson Bayou watershed.

The Dickinson Bayou watershed currently covers a total of approximately 63,830 acres, or 99.7 square miles, upstream of State Highway 146, the downstream terminus of this study. The watershed is elongated in shape, with a length of 22 miles from west to east. The maximum width of the watershed is approximately 7 miles.

The topography of the watershed may best be described as gently sloping. Ground elevations vary from 50 feet in the west to mean sea level at the mouth of the Bayou. Ground slope in the watershed varies from about 3 feet per mile to about 13 feet per mile. Areas of consistent ponding or marsh are located near the mouth of the Bayou where the channel begins to meander. No unusual changes in topography occur in the watershed except where canal and irrigation levees are built.

Soils in the watershed are typically clayey or loamy in nature. All of the soils are characterized by slow permeability and poor drainage which results in high runoff potential.

Land use in the watershed varies from open farm and rangeland to concentrated development with "subdivision" lots. The areas with the highest percent urban development include the areas in the vicinity of the cities of Dickinson and League City.

Several major roads, railroads and canals cross the watershed. The major roads include Interstate Highway 45, State Highway 146, State Highway 3, State Highway 35, and FM 528. These highways generally run in a north-south direction. Major east-west highways include FM 517, FM 646, and State Highway 6. Three railroads cross the watershed, with two of the three crossing the channel of Dickinson Bayou. Two major irrigation canals, the American Canal and the Gulf Coast Water Authority "Galveston Channel", also cross the watershed.

Description of Streams Included in this Study

Dickinson Bayou

Dickinson Bayou is the main branch in the watershed. The bayou begins in Brazoria County as an intermittent stream and flows easterly for approximately 24 miles to Dickinson Bay. At stream mile 18.8, the bayou merges into the Dickinson Bayou Bypass Channel. Approximately 0.5 mile downstream of this merge, low flows are diverted from the Bypass Channel back into Dickinson Bayou. The bayou north of the Bypass Channel is not in a natural state.

Dickinson Bayou Bypass Channel

The Dickinson Bayou Bypass Channel begins in Brazoria County as a diversion from Chigger Creek and flows from west to east. The lower 1.3 miles of the Bypass Channel are comprised of the channel of Cedar Creek, which turns southward and flows into Dickinson Bayou. The major portion of Cedar Creek remains in its natural state, whereas the Bypass Channel is completely man-made.

Major Tributaries

Dickinson Bayou receives runoff from a number of major tributaries. The tributaries included in the study which drain into the bayou from the north are Bordens Gully, Magnolia Bayou, Bensons Bayou, Gum Bayou, and the West Tributary to Gum Bayou. These streams drain a large area which includes the City of Dickinson.

Studied tributaries draining to Dickinson Bayou from the south include Ditch #4, Ditch #5, Ditch #6 (LaFlores Bayou), Ditch #7 (Johnson Draw), Ditch #8 (Francis Bayou), Ditch #9 (Runge

Bayou), Ditch #9c and #9d, Ditch #12 (Thaman Draw), Ditch #10, Ditch #11 (Metzler Gully), Cottonwood Ditch, and the Ditch #5, 5a, and 5b system. The southern tributaries drain areas along State Highway 6, Interstate Highway 45, and State Highway 3. Flows in the upper reaches of each of these streams are intermittent. Significant improvements have been made in the lower reaches of Runge Bayou, where a new outfall channel to Dickinson Bayou begins south of Second Avenue. Other improvements consisting of straightening, cleaning out, and maintaining channels have been completed on the majority of the northern and southern tributaries. Exhibit 2 identifies the location of each stream in the study.

Existing Land Use

The Dickinson Bayou watershed currently covers a total of approximately 63,850 acres. The City of League City plans to provide drainage for about 2,390 acres of this area to outfalls along Clear Creek. This leaves approximately 61,460 acres of land in the future watershed of Dickinson Bayou. Of the remaining 61,460 acres, only about 18 percent (10,960 acres) are currently developed. The majority of the existing development is within the corporate limits of the cities of Dickinson and League City and along the Interstate Highway 45 corridor. Except for the land along the freeway corridor, the developed land is predominantly single family residential. It is worth noting that throughout the developed areas within the watershed there are many mixed use areas. These areas are both large and small in scale.

Development along the IH 45 corridor is predominantly commercial, but includes some light industrial and multi-family uses. However, even along the freeway corridor, the majority of land continues to be vacant.

Along State Highway 146 there are a significant number of industrial and light industrial land uses, including a Houston Lighting & Power generating plant, several commercial fishing operations, and other noxious uses. A deterrent to development of non-industrial uses along SH 146 is the existence of large electrical transmission lines and towers adjacent to the west side of the right-of-way.

Areas west of IH 45 are predominantly agricultural.

The watershed has much potential for growth since vacant, undeveloped land makes up 82 percent (50,504 acres) of the watershed's approximate 61,460 acres. The Grand Parkway, a planned major highway, will help facilitate and accelerate the development of the watershed west of IH 45.

Developed land uses at the upper reaches of the watershed, especially along State Highway 35, are mixed with a high percentage of commercial, office warehouse, and light industrial.

SUMMARY OF DATA SOURCES

Existing conditions data collected for the purposes of this study vary from previous studies of the region to field surveys and observations to soils information. The data have been collected from a variety of sources, including governmental agencies (FEMA, the US Soil Conservation Service, the US Army Corps of Engineers), state agencies (the Texas Water Development Board, the Harris-Galveston Coastal Subsidence District), private engineering firms (Lichliter/Jameson & Associates, Inc., VanSickle-Mickelson & Klein, Inc., Dannenbaum Engineering Corporation), and local political entities (drainage districts, participating cities and counties).

Right-of-Way

An effort to obtain information on existing right-of-way along all the streams involved in the study was made as part of Phase I data collection. A preliminary investigation was completed by contacting the Texas Department of Transportation and the US Army Corps of Engineers. No right-of-way specifically dedicated to Dickinson Bayou or the tributaries involved in the study was found by these sources. A further investigation was made by requesting each local political entity to research available records to determine whether any right-of-way exists. The results of the investigation revealed that existing right-of-way is very limited and that the right-of-way which has been dedicated is generally connected with developed areas.

Previous Regional Drainage Studies

All known previous studies of the region were collected to determine what information concerning existing regional drainage programs could be applied to this study. These include the following:

1) *Master Drainage Plan for the City of League City*: Lichliter/Jameson & Associates, Inc. (June 1990).

2) *Brazoria County Conservation and Reclamation District No. 3 Master Drainage Plan*: Snowden Engineering, Inc., vol. 1-3, (November 1989).

3) *Bay Colony Master Drainage Plan*: VanSickle-Mickelson & Klein, Inc. (January 1987).

4) *Letter of Map Amendment and Conditional Statement of Belief for Bordens Gully and Magnolia Bayou*: VanSickle-Mickelson & Klein, Inc. (July 1988).

5) *Clear Creek Regional Flood Control Plan, Hydraulic Baseline Report*: Dannenbaum Engineering Corporation (July 1990; Revised September 1991).

6) *Dickinson Bayou Watershed, Texas: Flood Damage Prevention Reconnaissance Report*: US Army Corps of Engineers, Galveston District (Not Dated).

7) *Drainage Study for Galveston County*: Gerry E. Pate, Consulting Engineer, Inc. (Not Dated).

8) *Tropical Storm Claudette*: US Army Corps of Engineers, Galveston District (September 1980).

9) *An Analysis of Houston Area Floods*: Rice Center (June 1980).

10) *Flood Insurance Study, Galveston County, Texas, Unincorporated Areas*: Federal Emergency Management Agency (November 1990).

11) *Flood Insurance Study, City of Texas City, Texas*: Federal Emergency Management Agency (November 1982).

12) *Flood Insurance Study, City of League City, Texas*: Federal Emergency Management Agency (September 1990).

13) *Flood Insurance Study, City of Friendswood, Texas*: Federal Emergency Management Agency (June 1988).

14) *Flood Insurance Study, City of Dickinson, Texas*: Federal Emergency Management Agency (March 1991).

Technical Publications

1) *Soil Survey of Galveston County, Texas*: US Department of Agriculture, Soil Conservation Service (February 1988).

2) *Soil Survey of Brazoria County, Texas*: US Department of Agriculture, Soil Conservation Service (June 1981).

3) *HEC-1 Flood Hydrograph Package Users Manual*: US Army Corps of Engineers, Hydrologic Engineering Center (September 1990).

4) *HEC-2 Water Surface Profiles Package Users Manual*: US Army Corps of Engineers, Hydrologic Engineering Center (September 1990; Revised February 1991).

5) *Hands-On HEC-1*: Dodson & Associates, Inc. (February 1992).

6) *Hands-On HEC-2*: Dodson & Associates, Inc. (January 1992).

7) *Incorporation of Environmental Features into Flood Control Channel Designs*: US Army Corps of Engineers.

CHAPTER 2: DISCUSSION OF ANALYTICAL METHODS

This chapter of the report briefly describes the methods used to determine or estimate peak flow rates, channel cross-section requirements, and detention storage volume requirements in conjunction with analysis of the combination alternative. This chapter also describes the methods used in socioeconomic analysis of the combination alternative.

SOURCES OF DATA

The majority of the base data utilized in this study were obtained from baseline hydraulic data developed in Phase I and Phase II of the Dickinson Bayou Regional Drainage Study. These data are presented in reports entitled "*Dickinson Bayou Regional Drainage Plan: Hydraulic Baseline Report*" (August 1992), "*Dickinson Bayou Regional Drainage Plan: Supplement to Phase I Hydraulic Baseline Report*" (October 1993), and "*Dickinson Bayou Regional Drainage Plan: Preliminary Alternative Design Report*" (October 1993).

METHODS USED FOR HYDROLOGIC ANALYSES

HEC-1 Computer Program

The HEC-1 computer program was developed by the Hydrologic Engineering Center of the US Army Corps of Engineers. The HEC-1 program is a widely-accepted tool for watershed analysis. The hydrologic processes which may be simulated using the HEC-1 program include rainfall, infiltration, and runoff.

The use of the HEC-1 program allows the division of large watersheds, such as that of Dickinson Bayou, into a number of sub-watersheds. A runoff hydrograph from each individual sub-watershed may then be computed, routed downstream, and combined with runoff hydrographs from other sub-watersheds. This feature of the HEC-1 program, along with capabilities which facilitate the modeling of flow diversions and other special hydrologic conditions, allows large, complex watersheds to be divided into smaller, more homogeneous units which may be more easily handled. This in turn increases the level of detail associated with the analysis of the watershed.

The HEC-1 program computes hydrographs, or relationships between flow rate and time, at user-specified locations in a watershed. The program performs computations at even intervals of time throughout the duration of the storm event being analyzed. At each interval, HEC-1 determines how much rainfall occurs over the watershed or sub-watershed and computes the infiltration loss and runoff rate. The interval of time used by the program is specified by the user and is termed the "computation interval." This same computation interval is used in routing or combining runoff hydrographs.

In this study, HEC-1 modeling data developed for the "*Dickinson Bayou Regional Drainage Plan: Supplement to Phase I Hydraulic Baseline Report*" are modified and utilized to provide estimates of future conditions peak flow rates at strategic locations within the Dickinson Bayou watershed. Future urban development is reflected by increasing the appropriate parameters for each sub-watershed within the overall Dickinson Bayou watershed. For the watershed as a whole, it is assumed that an average of 75% of all undeveloped areas outside the existing floodway will be developed in the future. For this study, it is anticipated that development density and intensity will be greater in areas east of Interstate Highway 45 than those west of that highway. In order to reflect this, estimates of the percentage of undeveloped areas to be developed in the future are set at either 65%, 75%, or 85% for individual sub-areas within the watershed. Exhibit 3 provides a summary of the values applied to the various sub-watersheds.

Future development will include a wide range of land uses and development densities, but for this study single-family development at a density of 3.2 units per acre is assumed to be the average. All areas within the watershed not involved in existing or future development are assumed to remain vacant or to be used as agricultural or park land.

Drainage Area vs. Peak Discharge Curves

Drainage area versus peak discharge curves are utilized in this study to estimate peak discharge rates at key locations along Dickinson Bayou and its tributaries. These relationships are developed from results obtained using the HEC-1 computer program and modeling data developed for the Dickinson Bayou watershed. Drainage area versus peak discharge curves provide a quick and simple method for estimating flow rates which, if applied properly, will yield results similar to those obtained using more complex methods such as the HEC-1 computer program.

Triangular Hydrograph Detention Sizing

The determination of required detention storage volumes for sub-regional basins located on tributaries to Dickinson Bayou or the Bypass Channel is made using a triangular hydrograph approach. The peak inflow rate and total basin inflow volume are estimated and used to construct a triangular inflow hydrograph. A minimum detention storage requirement is estimated by determining the area below the inflow hydrograph and above a horizontal line which intersects both the rising and falling limbs of the hydrograph at the allowable peak discharge from the basin. A maximum storage is then estimated by determining the area below the inflow hydrograph and above a line which connects the origin of the hydrograph (coordinate 0,0) with the point on the falling limb of the hydrograph at the point where the flow rate equals the allowable peak discharge. The average of the minimum and maximum storage volumes is taken as the volume requirement for the basin.

Runoff hydrographs generated using the HEC-1 computer program could have been used to establish detention volume requirements for sub-regional basins. However, this would have necessitated the sub-division of a number of sub-watersheds in the HEC-1 model and the development of additional hydrologic data in order to compute runoff hydrographs at the appropriate locations. Because the triangular hydrograph method described in the preceding paragraph has been found through past experience to provide detention storage estimates consistent with those obtained through the use of the HEC-1 program, it was decided not to use HEC-1 methods for the purposes of this planning-level study.

METHODS USED FOR HYDRAULIC ANALYSES

The HEC-2 water surface profiles computer program of the U. S. Army Corps of Engineers Hydrologic Engineering Center is used to compute the 10-year, 50-year, 100-year, and 500-year water surface profiles for Dickinson Bayou and for the major tributaries of Dickinson Bayou analyzed in this study. The HEC-2 program is a very widely accepted tool for the computation of flood plain and floodway data.

The existing conditions HEC-2 model of Dickinson Bayou developed in Phase I of this study is used to establish the boundaries of the residual flood plain along the bayou for the Combination Alternative. The Channel Improvement option of the HEC-2 program is also used to estimate channel excavation volumes where appropriate.

METHODS USED FOR SOCIOECONOMIC ANALYSIS

Population

The current 1990 census tract population statistics were analyzed for all census tracts within the watershed boundaries. There are four census tracts that are totally within the watershed. There are thirteen other tracts that are partially within the watershed.

For the partial tracts, the watershed population and socioeconomic characteristics are estimated based on the proportion of the total of the census tract that was within the watershed boundary. As indicated in Table 1, the total population in the watershed is estimated to be 44,051. Boundaries of the various census tracts and the estimated percentages of each tract are shown on Exhibit 4.

Table 1: Population Estimates for Dickinson Bayou Watershed

Census Tract	1990 Census Tract Total Population	Share in Watershed	1990 Watershed Estimates
Galveston County			
1202	8,166	10%	817
1203	13,196	75%	9,897
1204	3,424	50%	1,712
1207	9,221	35%	3,228
1208	5,582	100%	5,582
1210	4,787	25%	1,197
1212.01	3,522	100%	3,522
1212.02	5,344	100%	5,344
1213	1,977	100%	1,977
1214	5,363	95%	5,095
1215	3,518	30%	1,056
1216.10	1,238	50%	619
1223	7,467	5%	374
Galveston County Sub-Total			**40,420**
Brazoria County			
602.32	3,891	2%	78
603.10	4,610	40%	1,844
603.20	1,601	98%	1,569
605.20	6,964	2%	140
Brazoria County Sub-Total			**3,631**
Watershed Total			**44,051**

Age Distribution

From available census data, it is possible to compute the actual number and percentage of persons for each age group for the census tracts that are wholly and partially within the watershed boundary. The largest percentage of people are between 30 and 39 years of age. The age distributions, shown on the following bar graphs in five year increments, are illustrated for the portions of the watershed that are in Galveston County and Brazoria County and also for the total watershed.

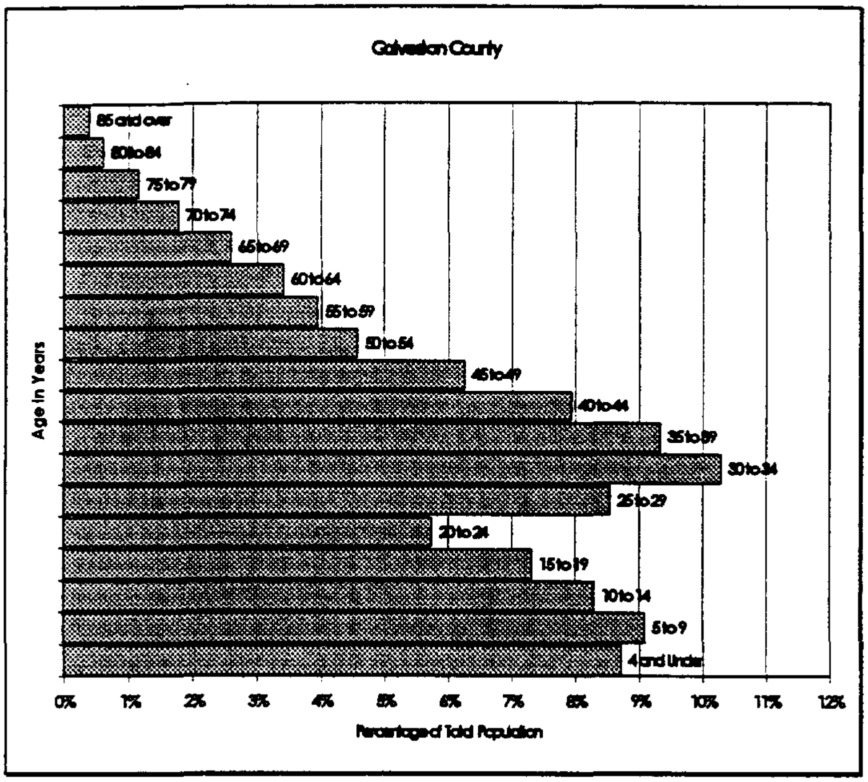


Figure 1: Age Distribution for Dickinson Bayou Watershed in Galveston County

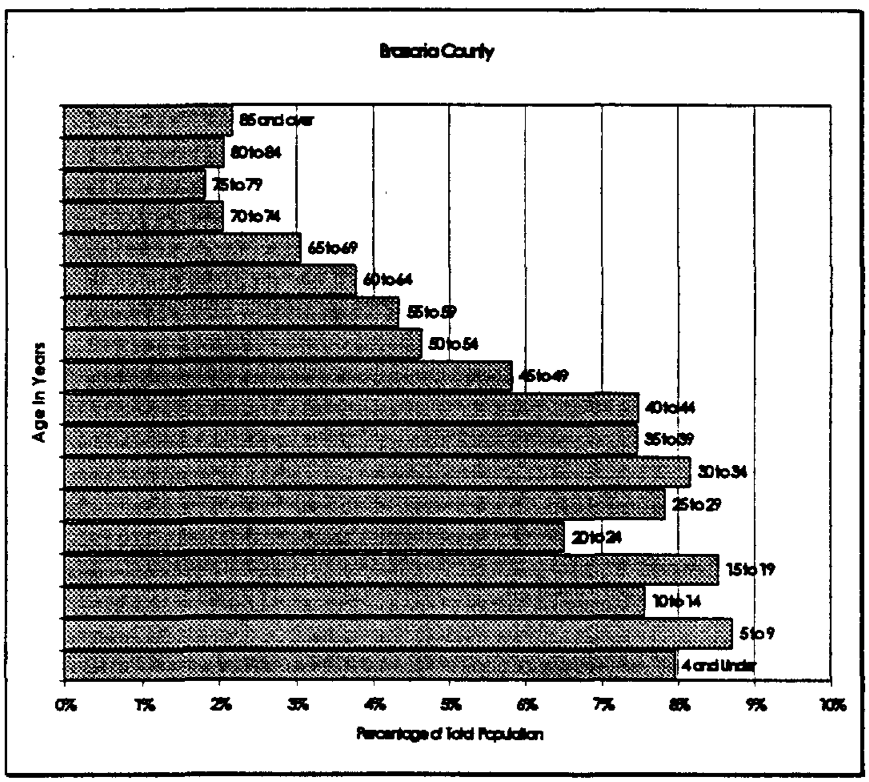
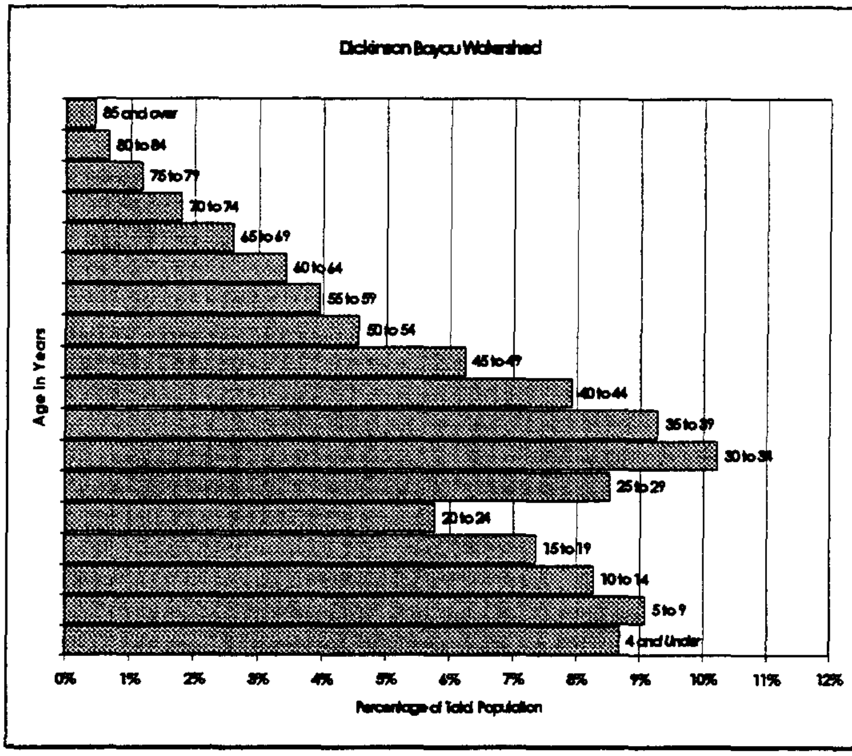


Figure 2: Age Distribution for Dickinson Bayou Watershed in Brazoria County

Figure 3: Age Distribution for Total Dickinson Bayou Watershed



Housing

The 1990 census is analyzed to obtain housing statistics. As indicated in Table 2, it is estimated that the aggregate (accumulated) value of housing in the watershed is between 600 and 700 million dollars.

Table 2: Aggregate Housing Values

1990 Census Tract	Total Aggregate Value	Share in Watershed	1990 Value Estimates
Galveston County			
1207	$208,768,000	35%	$73,068,800
1208	$42,791,000	100%	$42,791,000
1213	$37,538,500	100%	$37,538,500
1216.10	$27,787,500	50%	$13,893,750
1215	$58,294,000	30%	$17,488,200
1214	$67,941,000	95%	$64,543,950
1203	$232,492,000	75%	$174,369,000
1204	$45,899,000	50%	$22,949,500
1210	$41,231,500	25%	$10,307,875
1202	$257,464,000	10%	$25,746,400
1223	$87,779,500	5%	$4,388,975
1212.01	$59,009,500	100%	$59,009,500
1212.02	$61,615,500	100%	$61,615,500
Galveston County Sub-Total			**$607,710,950**
Brazoria County			
602.32	$32,622,500	2%	$652,450
603.10	$46,962,500	40%	$18,785,000
603.20	$9,405,000	98%	$9,216,900
605.20	$75,478,500	2%	$1,509,570
Brazoria County Sub-Total			**$30,163,920**
Watershed Total			**$637,874,870**

Housing Characteristics

Approximately 67 percent of housing units within the watershed are owner occupied, and about 10 percent of the housing units in the watershed are vacant.

The average median value for housing in the portions of Galveston County that are in the watershed boundary is approximately $68,000. The average median value for housing in the portions of Brazoria County that are in the watershed boundary is approximately $63,500. The average median value for housing in the total watershed boundary is approximately $67,000. The following bar graphs illustrate these results.

Nearly three-fourths of the housing units in Galveston County are single family units whereas less than half of the homes in Brazoria County are single family units. Overall, about 71 percent of the housing units in the watershed are single family. There is an average 2.9 persons per occupied housing unit.

Tables 3 and 4 summarize the results of the housing characteristics analysis for the Dickinson Bayou watershed.

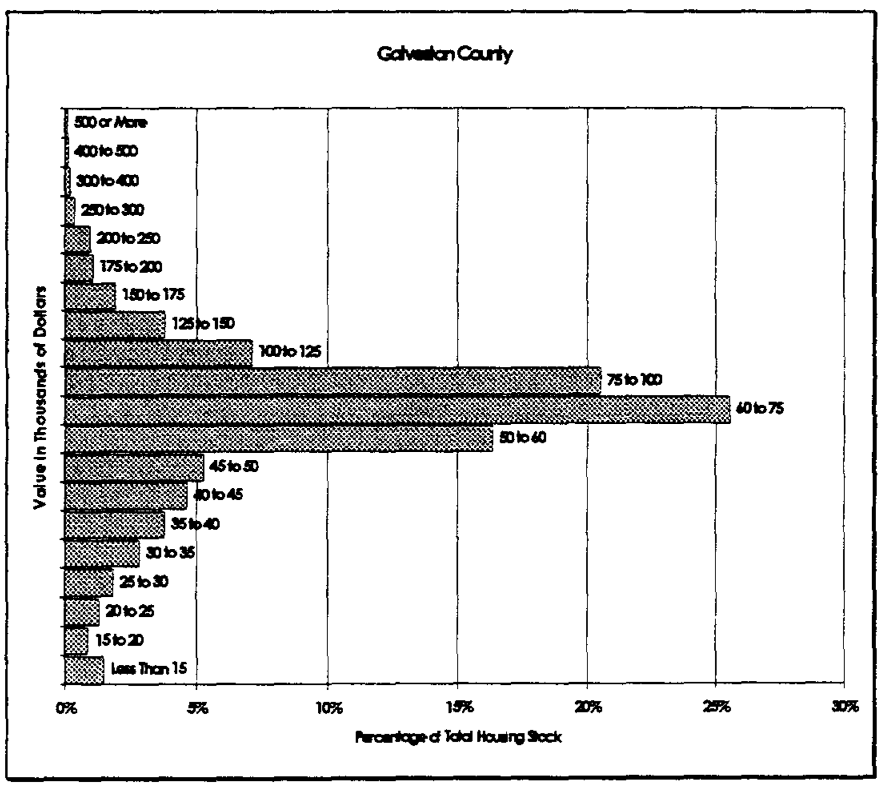
Table 3: Housing Characteristics by Census Tract

Census Tract	% Owned	% Vacant	Persons per Occupied Unit	Median Value
Galveston County				
1207	72%	5%	2.93	$79,000
1208	57%	9%	2.96	$53,800
1213	74%	10%	2.75	$66,700
1216.10	68%	9%	2.41	$87,100
1215	78%	5%	2.78	$71,800
1214	76%	6%	2.98	$65,400
1203	75%	4%	3.02	$67,800
1204	56%	6%	2.63	$67,000
1210	54%	20%	2.77	$40,700
1202	87%	4%	3.16	$97,200
1223	78%	8%	2.91	$59,900
1212.01	65%	11%	2.80	$67,100
1212.02	46%	12%	2.80	$65,900
County Average	**68%**	**8%**	**2.84**	**$68,415**
Brazoria County				
602.32	67%	18%	3.03	$63,400
603.10	77%	9%	3.11	$66,900
603.20	59%	24%	2.92	$61,200
605.20	53%	11%	2.88	$63,200
County Average	**64%**	**16%**	**2.99**	**$63,675**
Watershed Average	**67%**	**10%**	**2.87**	**$67,300**

Table 4: Housing Type by Census Tract

	Percentage of Units by Housing Type			
Census Tract	Single Family	Duplex/ Fourplex	Multi Family	Mobile Home
Galveston County				
1207	78%	2%	14%	6%
1208	59%	4%	7%	30%
1213	86%	1%	0%	11%
1216.10	64%	7%	2%	5%
1215	73%	3%	1%	22%
1214	68%	2%	4%	25%
1203	87%	2%	5%	5%
1204	73%	15%	12%	7%
1210	68%	2%	1%	28%
1202	95%	1%	2%	2%
1223	66%	1%	0%	29%
1212.01	80%	1%	13%	5%
1212.02	58%	4%	30%	8%
County	**73%**	**3%**	**7%**	**14%**
Brazoria County				
602.32	42%	0%	0%	49%
603.10	60%	0%	0%	38%
603.20	39%	1%	2%	42%
605.20	54%	2%	27%	16%
County	**49%**	**1%**	**7%**	**36%**
Watershed	**71%**	**3%**	**7%**	**19%**

Figure 4: Owner-Occupied Housing Distribution for Dickinson Bayou Watershed in Galveston County



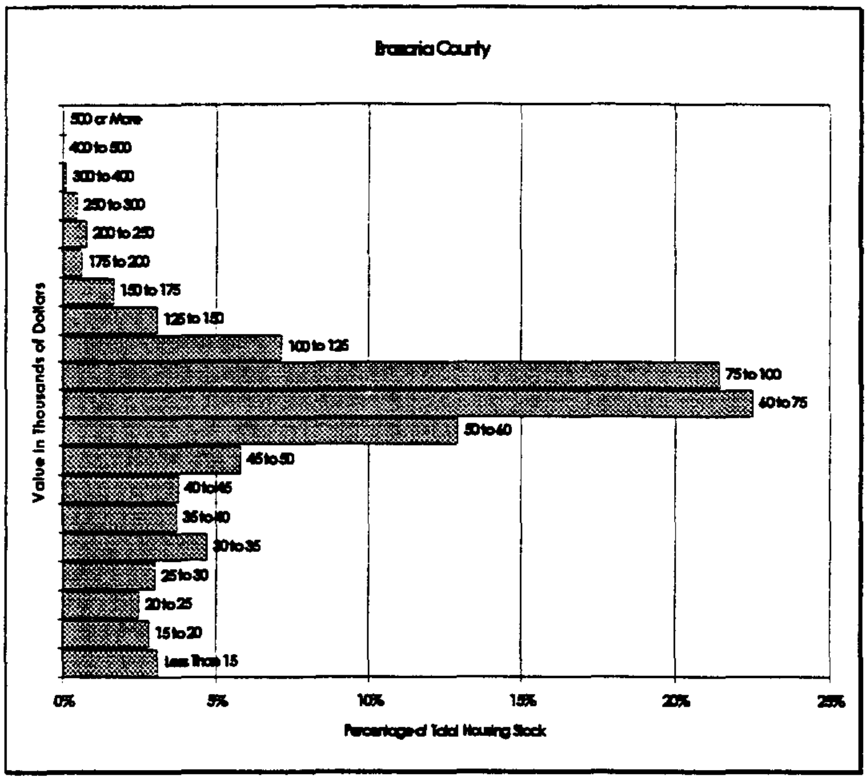


Figure 5: Owner-Occupied Housing Distribution for Dickinson Bayou Watershed in Brazoria County

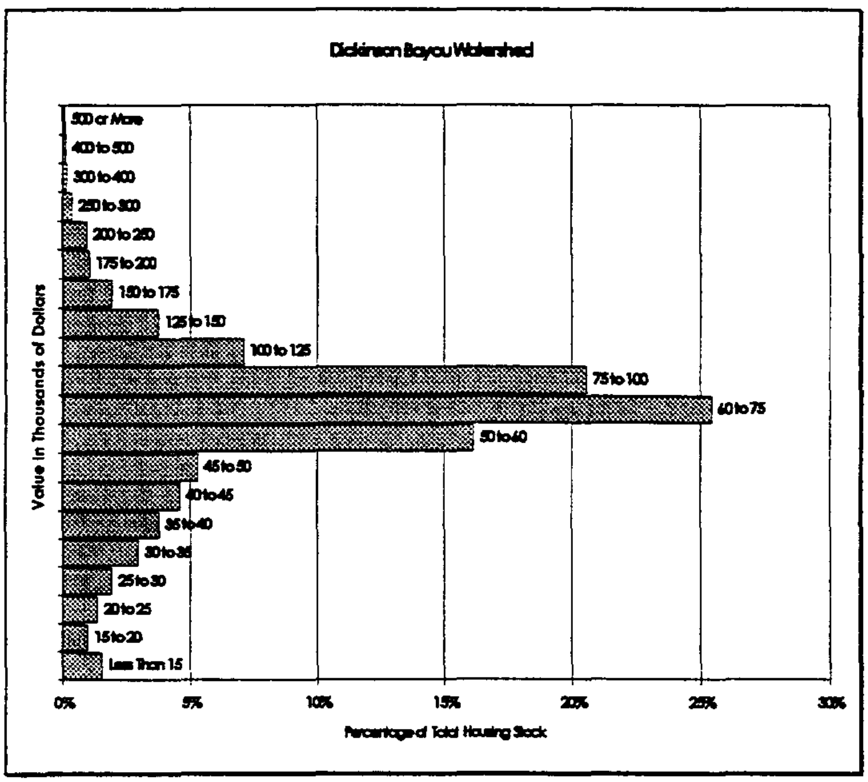


Figure 6: Owner-Occupied Housing Distribution for Total Dickinson Bayou Watershed

Estimated Housing Units

As indicated in Table 5, there are an estimated 16,500 dwelling units in the watershed. The current average housing density for developed areas in the watershed is 1.5 units per acre. Only 18 percent of the total 61,460 acres in the watershed are currently developed.

Table 5: Number of Housing Units

Census Tract	Total Units	Percent Share	Watershed Estimates
Galveston County			
1207	3,278	35%	1,148
1208	2,055	100%	2,055
1213	8,02	100%	802
1216.10	566	50%	283
1215	1,332	30%	400
1214	1,911	95%	1,816
1203	4,558	75%	3,419
1204	1,385	50%	693
1210	2,150	25%	538
1202	2,682	10%	269
1223	2,776	5%	139
1212.01	1,419	100%	1,419
1212.02	2,159	100%	2,155
County Sub-Total			**15,136**
Brazoria County			
602.32	1,560	2%	32
603.10	1,624	40%	650
603.20	610	98%	598
605.20	2,730	2%	55
County Sub-Total			**1,335**
Watershed Total			**16,471**

Land Cost Evaluation Method

An essential component of the cost of the various elements of the combination alternatives is the cost of land. Because of the large number of land parcels involved in the alternative, it was decided to use an average land cost for this stage of the study (more detailed cost information will be developed for the final plan).

Table 6 shows the estimated land cost per acre for each subdrainage area within the watershed. These costs are also illustrated on Exhibit 3.

To establish the average costs, the assessed values for property throughout the watershed were collected and analyzed. Assessed property value information was obtained directly from the Galveston County Appraisal District, and from Baca Land Data services. For Brazoria County, the information was obtained from Baca Land Data services, whose records are identical to those of the Brazoria County Appraisal District but more easily accessible. A sample number of tracts were selected in each abstract in the watershed. The sample included both developed and undeveloped tracts. Values were collected and averaged. The assessed values were adjusted upward approximately 10 percent to more accurately reflect the fair market value of the property (the actual difference between assessed and fair market value will vary from tract to tract, and may be greater than 10%). The average for each abstract was then assigned to each corresponding sub-drainage area. To verify the values obtained from the two appraisal districts, the asking prices for a number of tracts currently listed "for sale" were checked and compared to the average values established as described above. The comparison showed a reasonable level of correlation.

Table 6: Land Costs for Individual Sub-Watersheds

Sub-Watershed	Land Cost for Undeveloped Acreage	Land Cost for Developed Acreage
1	$3,000	$17,000
2	$3,000	$17,000
3	$3,000	$17,000
4	$4,000	$22,500
5	$3,000	$17,000
6	$3,000	$17,000
7	$4,000	$22,500
8	$3,500	$20,000
9	$3,500	$20,000
10	$4,000	$22,500
11	$5,000	$30,000
12	$5,000	$30,000
13	$5,000	$30,000
14	$8,000	$45,000
15	$8,000	$45,000
16	$3,500	$20,000
17	$3,000	$17,000
18	$4,500	$25,000
19	$4,500	$25,000
20	$4,500	$25,000
21	$4,500	$25,000
22	$4,500	$25,000
23	$7,500	$42,000
24	$5,000	$30,000
25	$5,000	$30,000
26	$15,500	$85,000
27	$4,000	$25,000
28	$13,500	$75,000
29	$20,000	$110,000
30	$11,500	$65,000
31	$18,500	$105,000
32	$11,500	$65,000
33	$8,000	$45,000
34	$5,000	$30,000
35	$5,000	$30,000
36	$5,000	$30,000
37	$5,000	$30,000
38	$5,000	$30,000
39	$5,000	$30,000
40	$4,500	$25,000
41	$4,000	$22,500
42	$4,500	$25,000
43	$8,000	$45,000

To the cost of the land actually taken in condemnation actions must be added the cost of damages to the remainder of the tracts which are only partially acquired. For the Channelization/Diversion alternative, a cost of 15 percent for damages to the remainder is assumed. For the Detention and Non-Structural alternatives, the cost of damages to the remainder is assumed to be 5 percent. This lower percentage is used because these facilities will involve the purchase of many whole tracts of land whereas the land acquisition for channel right-of-way will likely sever many partial tracts, resulting in higher damages to the remainder tracts.

For most areas of the watershed, the cost of acquisition is the (average) cost of the raw land plus the cost for damages to the remainder because the flood management alternatives were designed to avoid developed property wherever possible. However, in some areas it was not possible to avoid the developed areas. An average cost of improvements was established for those areas, using the same methodology described above for raw land. These average improvement costs are added to the total of land plus damages as appropriate.

Flood Damage Evaluation Method

A flood damage estimate for the combination alternative is presented in this report for the purpose of comparing the possible benefits of this alternative with the four alternatives developed in Phase II. The damage estimates correspond to a 100-year storm event. The following procedure is utilized in preparing the flood damage estimate:

1) the total area within the flood plain is determined;
2) the total area of existing development within the flood plain is determined with respect to three development densities: low, medium, and high;
3) the total future development within the flood plain is estimated by assuming that 75% of currently undeveloped land outside the existing floodway will be developed;
4) the number of housing units within the flood plain is estimated using density ratios of 0.4 unit per acre, 1.6 units per acre, and 3.2 units per acre for low-density, medium-density, and high-density development. All future development is assumed to be high-density;
5) the number of housing units is multiplied by an estimated average claim per unit.

The product of the number of housing units and the average claim is the estimated total flood damage. According to the "*Clear Creek Regional Flood Control Plan, Preliminary Alternative Design Report*" the average claim for flood damages in Harris County averages $15,400 per claim (1991 dollars), and 66.5% of the homes that are within the flooded area actually sustain flood damage. This translates into an average claim of $10,250 per unit located within the flood plain ($15,400 × 0.665). Thus, the estimated total flood damage is equal to the number of housing units located in areas within the flood plain times an average flood damage claim of $10,250 per unit.

CHAPTER 3: EXISTING FLOODING POTENTIAL IN THE DICKINSON BAYOU WATERSHED

This chapter of the report describes the flooding history of the Dickinson Bayou Watershed, in particular the effects of Tropical Storm Claudette. The existing flood potential, based on the results of the hydrologic and hydraulic study of the watershed, will also be discussed.

FLOODING HISTORY

The average yearly rainfall total for the Galveston area is approximately 48 inches. This annual total is more or less evenly distributed throughout the year. However, monthly rainfall totals generally fall below the overall average of four inches per month during the late fall, winter, and spring. Monthly totals for the summer and early fall generally exceed the overall average for the winter months.

In addition to normal rainfall, the region is subject to intense thunderstorms in the spring and summer months, to hurricanes during late summer and fall, and to extended periods of wet weather during the winter months. Therefore, the potential for floods due to heavy rain or from a combination of rain and tidal surge is always present. While this flooding potential remains fairly constant, the amount of damage resulting from severe storm events increases as development in the area continues. As an example, during Hurricane Carla in September 1961, 15 inches of rain fell over most of the region, high tides at Galveston measured 9 feet above mean sea level (MSL), and 216 square miles of Galveston County were flooded. Total damages were estimated at $84 million. Later, in July 1979, Tropical Storm Claudette dropped 10-20 inches of rain over the area, while tides at Galveston were about 5 feet above MSL. The estimated cost of damage was $227.5 million, almost 3 times the cost of damage from Hurricane Carla.

Flooding is a principal problem in Dickinson Bayou Watershed. Throughout the watershed streams meander and, in general, have small channel capacities relative to the areas drained. Consequently, overbank flows frequently occur. Damaging floods have occurred in the watershed in the past. One of the earliest recorded hurricanes occurred in the year 1900. Flooding can result from storm surge from the high winds of a hurricane, a large amount of rain from intense thunderstorms or frontal systems, or a combination of these events. A 100-year storm surge elevation of approximately 11 feet (the surge level determined for the Galveston County Flood Insurance Study) floods the watershed up to Highway 3. Rain from intense thunderstorms or tropical storms can cause extensive flooding over a larger area of the watershed.

Tropical Storm Claudette

Tropical Storm Claudette was a major storm in the history of the region. The center of the storm crossed the Texas Gulf Coast near Beaumont while moving in a northerly direction. Instead of continuing in this direction, the storm center became erratic and settled over the Houston area for about 30 hours. Rainfall was extremely intense during this time. A record 42 inches of rain fell in less than 24 hours at one location north of Alvin, Texas. Recorded rainfall totals from a number of rainfall gauges in the vicinity of the Dickinson Bayou watershed are presented in Table 7.

Table 7: Recorded Rainfall Data for Tropical Storm Claudette

County and Gage	Latitude	Longitude	Rainfall 7/25/79	Rainfall 7/26/79	Rainfall 7/27/79	Total Rainfall
Galveston County						
Clear Lake Shores	29° 32.7'	95° 02'	-	-	-	15.00+
Dickinson Village	29° 28'	95° 03'	-	-	-	24.50
Friendswood	29° 32'	95° 11'	14.00	12.00	-	26.00+
La Marque	29° 23'	95° 02'	0.24	9.11	-	9.35
League City	29° 29'	95° 08'	9.60	15.30	-	24.90
San Leon	29° 29'	94° 55'	-	-	-	7.80
Texas City	29° 26'	94° 58.1'	0.42	8.60	0.22	9.24
Alta Loma	29° 22.1'	95° 05.9'	12.00	5.00	-	17.00
Alta Loma	29° 22.1'	95° 06'	-	-	-	13.80
Brazoria County						
Alvin 3.2 NW	29° 26.5'	95° 17.8'	19.00	24.00	2.00	45.00
Alvin	29° 25'	95° 14'	13.00	16.20	1.50	30.70

Flooding in the Dickinson Bayou watershed was widespread, with an estimated 1,757 structures sustaining damage. Because tides in Galveston Bay were only slightly above normal, the flooding was caused mainly by the extremely intense rainfall. Many of the channels within the Dickinson Bayou watershed were not sufficiently improved or maintained to contain the runoff generated from the heavy rainfall. An analysis of the rainfall from the storm was performed in Phase I of the study. The results from the HEC-1 analysis using the rain gage data produced a peak flow rate of 38,000 cfs (at State Highway 146) as compared to a flow rate of 27,000 cfs predicted for a 24-hour, 100-year storm. This indicates that the overall rainfall totals for the Dickinson Bayou watershed were well above levels associated with a 100-year frequency storm event.

RESULTS OF HYDRAULIC BASELINE STUDIES

A study of the existing conditions in the watershed and in Dickinson Bayou and its tributaries was completed to update the 100-year flood plain boundary and identify the current potential for flooding damage. The complete study is presented in two reports: "*Dickinson Bayou Regional Drainage Plan: Hydraulic Baseline Report*" (August 1992) and "*Dickinson Bayou Regional Drainage Plan: Supplement to Phase I Hydraulic Baseline Report*" (October 1993). A brief summary of the results of the study are presented here.

A 100-year storm, a rainfall event that has a 1% chance of occurring in any given year, would produce a total of approximately 13 inches of rain over a 24-hour period. If this storm occurred over the Dickinson Bayou watershed, the results as shown in

Exhibit 5 are predicted to occur. Approximately 35,000 acres, or 55 % of the watershed area, would be in the flood plain. The depth of water would vary from inches at the fringes of the flood plain to almost 18 feet deep along Dickinson Bayou upstream of Cemetery Road. Most minor road crossings would be overtopped and major roadways such FM 517 at Dickinson Bayou and Gum Bayou, Cemetery Road at Ditch 9D, State Highway 3 at Benson Bayou, FM 646 at Benson Bayou and Gum Bayou, and FM 1266 at West Gum Bayou would also be overtopped. The main bridges of Interstate Highway 45 and State Highway 6 would remain passable for all traffic from the area and also from Galveston Island if an evacuation was ordered. The cost of flood damages as a result of a 100-year storm occurring in 1993 is estimated to be $97,051,100. A breakdown of this estimated cost is presented in Table 8.

Table 8: Estimated Cost of 100-Year Flood Occurring in 1993

Item	Galveston County	Brazoria County	Combined Totals
Total Area in Existing Flood Plain (ac)	31,350	3,652	35,002
Existing Development In Flood Plain			
High Density (acres)	1,830	107	1,937
Medium Density (acres)	1,213	49	1,262
Low Density (acres)	2,858	269	3,127
Totals (acres)	5,901	425	6,326
Estimated Number of Structures in Flood Plain			
Existing High Density (3.2 Units/Acre)	5,856	342	6,198
Existing Medium Density (1.6 Units/Acre)	1,941	78	2,019
Existing Low Density (0.4 Unit/Acre)	1,143	108	1,251
Sub-Totals	8,940	528	9,468
Average Cost Per Flood-Damaged Structure	$10,250	$10,250	$10,250
Total Flood Damages for 100-Year Storm	**$91,635,000**	**$5,416,100**	**$97,051,100**

The number of structures located within the flood plain in Galveston and Brazoria Counties is estimated to be 9,468. This number represents approximately two-thirds of the existing structures within the watershed. This ratio is so high because many of the more urbanized areas within the watershed, including areas in Dickinson and Santa Fe, are largely within the 100-year flood plain.

CHAPTER 4: DESIGN ALTERNATIVES FOR REGIONAL DRAINAGE PLAN

OBJECTIVES OF THE REGIONAL DRAINAGE PLAN

The major objective of the Dickinson Bayou Watershed Regional Drainage Plan is to develop a plan for controlling flooding within the watershed as development occurs. Some of the desired characteristics of this plan are described below:

1) make the plan cost-effective in terms of the degree of flood protection achieved for the money spent;
2) minimize or mitigate environmental and socioeconomic impacts to the greatest degree practicable;
3) develop a plan which may be implemented in affordable stages.

In Phase II of the Dickinson Bayou study, four flood protection alternatives, or approaches to watershed management, were examined. These alternatives are briefly described in the following section. In Phase III of this study, a combination of the alternatives is developed into one watershed drainage plan.

BRIEF DESCRIPTIONS OF ALTERNATIVES TO BE CONSIDERED

No-Action Alternative

The No-Action Alternative assumes that full watershed development will take place and that no channelization on the major tributaries (those analyzed in detail for this study) will be completed. Small tributaries (those not analyzed in detail for this study) are assumed to be fully channelized for purposes of hydrologic analysis. No flood mitigation measures are considered in this alternative. Flood plain management is assumed for purposes of analysis to include few restrictions on development, with the exception that National Flood Insurance Program regulations concerning development within the existing floodway would be observed. See Exhibit 5.

Channelization/Diversion Alternative

For the Channelization/Diversion Alternative, channel are assumed to be straightened, deepened, and widened in order to increase flood conveyance capacity. A diversion channel designed to reduce flows in the main stem of Dickinson Bayou is incorporated into the channelization plan in order to eliminate the need for channel improvements within environmentally sensitive areas along the bayou. It is assumed that on-site detention will not be required in the watershed. See Exhibit 6.

Detention Alternative

For the Detention Alternative, on-site detention is assumed to hold peak runoff rates from new developments at existing levels. Regional and sub-regional detention facilities are assumed to be constructed for the purpose of reducing flows below existing conditions levels, thus reducing the extent of the existing flood plain along Dickinson Bayou. Where possible, regional and sub-regional detention facilities will reduce 100-year peak flow rates to bank-full channel capacity, thereby eliminating much of the existing flood plain. Existing channels are assumed to be deepened in order to provide adequate detention outfall depth. See Exhibit 7.

Non-Structural Alternative

The Non-Structural Alternative involves the purchase of the existing 100-year flood plain plus areas added to the flood plain as a result of future development in non-flood prone areas. Channel improvements are assumed to be minimal or non-existent. Flood damage reduction is achieved by removing habitable structures from flood-prone areas.

Preliminary Combination Alternatives

The results of the previous alternatives provide a basis for formulating several preliminary combination alternatives for further analysis. In formulating the preliminary combination alternatives, a systematic process is used to identify the combination alternative. The process includes the following steps:

1. **Analysis of Revised Full Channelization Alternative**: Another drainage alternative can be developed by assuming that existing and future flood plain problems are addressed by channelization, but that all new development will be constructed using on-site detention. The purpose of this alternative is to identify the cost-effectiveness of on-site detention as a component of an overall program of watershed-level drainage improvements. This alternative is developed using approximate methods, and is not as detailed as the "pure" alternatives developed in Phase II of this study, and described earlier in this chapter.

2. **Identify Planning Units**: The Dickinson Bayou Watershed is divided into numerous "Planning Units" which provide a sufficient level of detail for planning the appropriate drainage approach for each portion of the watershed. However, these Planning Units are more aggregated than the watershed sub-basins identified in Phase I and Phase II of this study. The selection of watershed sub-basins was made primarily for accuracy and convenience in hydrologic modeling; the selection of Planning Units is made primarily for accuracy and convenience in planning and economic analysis. In general, planning units will consist of individual tributaries. Tributaries will not generally be sub-divided into smaller units in order to determine the best alternative to use for each portion of a particular tributary. In fact, in some cases, the planning units actually consist of a group of tributaries, especially when they share a single regional detention basin or are interconnected or interdependent in some other way.

3. **Economic Analysis of Planning Units**: For each Planning Unit, a cost effectiveness (expressed as cost per net acre) is calculated. "Cost" is defined as the cost attributed to the planning unit for each of the five drainage alternatives. Net acreage is defined as the area within the planning unit that is

outside of the flood plain, and not contained in a regional or on-site detention facility or channel easement.

4. **Preliminary Combination Alternative Number 1**: Using the results of the tabulation process, a preliminary combination alternative will be assembled which consists of the most cost-effective alternative for each planning unit. "Cost Effectiveness" will be determined on the basis of Public Cost, that is, the estimated cost of construction borne by public agencies responsible for drainage services within the watershed. Minor adjustments are made as necessary in order to provide a coherent overall watershed drainage plan.

5. **Preliminary Combination Alternative Number 2**: After inspection of the Preliminary Combination Alternative Number 1, Preliminary Combination Alternative Number 2 is formulated to address any potential problems with Preliminary Combination Alternative Number 1. Development of this alternative involves some adjustments to the results indicated by the tabulations of individual planning units. In addition, such factors as downstream effects and environmental damage are considered so that the Preliminary Combination Alternative Number 2 is as realistic as possible. At the time that adjustments are made to Preliminary Combination Alternative Number 1, the relative priorities of existing flooding problems within the watershed should also be considered, so that the Preliminary Combination Alternative Number 2 begins to reflect improvements which meet short-term priorities, as well as being economical for long-term development.

6. **Preliminary Combination Alternative Number 3**: Preliminary Combination Alternative Number 2 is again adjusted to reflect the recommendations of previous master drainage studies within the Dickinson Bayou Watershed.

7. **Hydrologic Analysis**: Preliminary Combination Alternatives 1, 2, and 3 are analyzed using appropriate HEC-1 hydrologic models of the Dickinson Bayou watershed.

8. **Combination Alternative**: Based on the results of the Hydrologic Analysis, the Combination Alternative is finalized.

9. **Socioeconomic Analysis**: The flood damages expected from the adjusted combination alternative are quantified in the same manner as was done for the "pure" alternatives considered in Phase II. Additional adjustments may be made in the combination alternative as a result of this analysis. This analysis is described in Chapter 5 of this report.

10. **Cost Estimates**: Cost estimates are prepared for the combination alternative. These cost estimates are presented in Chapter 5 of this report.

11. **Environmental Assessment**: The environmental consequences of the proposed combination alternative is assessed, and additional adjustments may be made in the combination alternative to reduce the environmental consequences of the

project. This assessment is described in Chapter 5 of this report.

Preliminary Combination Alternative Number 1

This alternative was developed on the basis of lowest public cost for providing ultimate drainage system capacity throughout the Dickinson Bayou watershed. The analysis of planning units throughout the watershed indicated that the option of full detention (regional detention plus on-site detention) provided the lowest public cost for most of the watershed, except for the following planning units:

- The Upper Dickinson Bayou watershed
- The Lower Dickinson Bayou bypass channel
- The Bordens Gully watershed
- The Magnolia Creek watershed
- The Bensons Bayou watershed
- The Gum Bayou watershed
- The West Gum Bayou watershed
- Ditch 7 (Drainage District 1)
- Ditch 11 (Drainage District 1)

For these planning units, the option of channelization with on-site detention provided the lowest public costs. Because Ditch 7 and Ditch 11, if channelized, are assumed to require the construction of the Dickinson Bayou Diversion Channel, and since the construction of this facility is not justified on the basis of serving other planning units within the watershed, these planning units are assumed to be served by a full detention system.

The HEC-1 hydrologic analysis of this alternative indicates that the channelization of the Upper Dickinson Bayou watershed and the Lower Dickinson Bayou bypass channel result in increases in the existing 100-year peak flow rates in the reach of Dickinson Bayou upstream of Interstate Highway 45. These increases disappear below the confluence of Bordens Gully.

Preliminary Combination Alternative Number 2

As a result of the increases observed in 100-year peak flow rates in the middle portion of the Dickinson Bayou watershed for Combination Alternative Number 1, Combination Alternative Number 2 includes full detention for the Upper Dickinson Bayou and Lower Bypass Channel planning units. Other aspects of this alternative are identical to Combination Alternative Number 1.

The HEC-1 hydrologic analysis of this alternative indicates that the peak flow rates in Dickinson Bayou are below existing levels at all locations.

Preliminary Combination Alternative Number 3

The City of League City Master Drainage Plan included regional detention facilities in the Bensons Bayou and Gum Bayou watersheds. In order to provide coordination with the League City plan, Combination Alternative Number 3 includes full detention for these two tributaries. Other aspects of this alternative are identical to Combination Alternative Number 2.

The HEC-1 hydrologic analysis of this alternative indicates that, because of timing effects, regional detention in the Bensons Bayou watershed actually increases 100-year peak flow rates in Dickinson Bayou. Therefore, regional detention is not recommended for this tributary. For Gum Bayou, the regional detention facility provides a decrease in 100-year peak flow rates in Dickinson Bayou. However, these peak flow rates are already well below existing levels because of the presence of other regional detention basins throughout the Dickinson Bayou watershed. In addition, the reach of Dickinson Bayou below the Gum Bayou confluence is subject to inundation by the 100-year storm surge from Galveston Bay. Therefore, the incremental cost of regional detention in the Gum Bayou watershed does not provide any significant incremental benefit in the form of flood plain reduction.

Comparison of Preliminary Combination Alternatives

Table 9 summarizes the effects of Combination Alternative Number 1, 2, and 3 on peak flow rates in Dickinson Bayou.

Table 9: Computed 100-Year Peak Flow Rates in Dickinson Bayou

Location Along Dickinson Bayou	Existing Conditions	Preliminary Combination Alternative Number 1	Preliminary Combination Alternative Number 2	Preliminary Combination Alternative Number 3
Above Bordens Gully	11,338	12,676	8,407	8,407
Below Bordens Gully	12,024	12,982	9,153	9,153
Below Magnolia Bayou	14,815	14,048	11,191	11,191
Below Bensons Bayou	17,533	15,558	13,279	13,626
Below Gum Bayou	24,050	20,348	18,318	18,072

The HEC-1 hydrologic analysis indicates that Combination Alternative Number 2 provides a plan which is feasible from a technical standpoint, is consistent with the goal of maintaining or reducing existing flood levels in Dickinson Bayou, and provides the lowest possible public cost of implementation.

CHAPTER 5: THE COMBINATION ALTERNATIVE

The main objective of the Combination Alternative is to develop a conceptual drainage and flood protection plan for the purpose of substantially eliminating the existing 100-year flood plain on Dickinson Bayou tributaries and significantly reducing the extent of the existing flood plain along the bayou itself. Assumptions made in connection with the Combination Alternative are as follows:

1) The watershed will be fully developed with on-site detention provided for all future development;

2. Full channelization of tributaries will be considered as necessary to contain future 100-year flood flows within channel banks;

3. Flood plain widths along Dickinson Bayou will be reduced as much as is technically, physically, and economically feasible;

4) Regional and sub-regional detention basins will be provided on most tributaries to achieve reductions in existing 100-year peak flow rates and corresponding reductions in flood plain widths to approximate the residual flood plain defined for the channelization/diversion alternative;

5. Tributary channels will be assumed to be improved sufficiently to provide flow capacity for delivering runoff to regional detention facilities or outfall channels, and to provide adequate outfall depth for both on-site and regional detention basins.

DETAILED DESCRIPTION OF COMBINATION ALTERNATIVE

Exhibit 8 illustrates the major components of the Combination Alternative, including the locations of all proposed regional and sub-regional detention basins and the extents of improved stream reaches.

Improved stream channels are assumed to have side slopes of 3 horizontal to 1 vertical (3:1) and a minimum bottom width of 6 feet. No concrete-lined sections are considered for this analysis. Longitudinal slopes range from 0.05% to 0.12%. A Manning roughness coefficient of 0.04 is assumed for improved channels.

All detention basins are assumed to be excavated earthen structures with side slopes no steeper than 3:1.

IMPACTS OF THE COMBINATION ALTERNATIVE

The impacts of the Combination Alternative are evaluated in several areas, including:

- Hydrology and Hydraulics
- Socioeconomic Factors
- Environmental Values

The following sections describe the impacts of the Combination Alternative in each of these areas.

Hydraulic Impacts of Combination Alternative

The effects of the Combination Alternative on 100-year flood plain boundaries are illustrated on Exhibit 8. As indicated, the 100-year flood plain is limited to the banks of all tributary streams. The residual flood plain along Dickinson Bayou is reduced to approximately 8,087 acres, about 1,097 acres of which consists of developed property. These impacts are identical to the impacts of the Detention Alternative.

Socioeconomic Impacts of Combination Alternative

For the purpose of estimating the possible benefit of the Combination Alternative as compared to the No-Action Alternative, the damages resulting from a single 100-year flood event are compared. A single 100-year storm event would cause $166,919,200 in flood damages for the Combination Alternative. This is $731,091,500 less than the damages caused assuming no action. It is expected that the Combination Alternative will stimulate land development in the watershed.

In addition to providing benefits in flood management, it is anticipated that regional detention ponds will provide recreational opportunities, as well as esthetic and environmental benefits. Recreational opportunities include the possibility of providing park land and open space that can be used for passive and active recreational uses. Exhibit 9 illustrates a conceptual layout of a multi-purpose detention facility which combines flood control, recreational, and environmental features.

Regional detention ponds would also help to preserve the esthetic and environmental qualities of the existing Dickinson Bayou channel by eliminating the need for channelization along the bayou itself.

Environmental Impacts of Combination Alternative

Deepening and Widening of Existing Channels

Construction-Related Effects of Channelization

The construction of deeper and wider tributary channels within the Dickinson Bayou watershed may result in several environmental effects:

1. **Sediment**: Channelization of tributary channels, as with any construction activity within a stream channel, would result in a temporary degradation of water quality due to increases in turbidity and sediment.
2. **Riparian Habitat**: Further channelization of Dickinson Bayou tributaries would essentially destroy all the riparian forest and wetland areas adjacent to those streams. However, riparian areas along many of these tributaries are now dominated by Chinese Tallow, an introduced invader of little ecological value.

3. **Other Habitat**: Besides adjacent wetlands, channelization would most likely cause destruction of isolated wetlands within the watershed as well.
4. **Dredged Material**: Increased channelization means more dredged material disposal, which could result in the filling of isolated wetlands.
5. **Fresh-Water Inflows**: Channelization may increase flow into Dickinson Bay thus affecting shallow water aquatic nursery habitat. The potential for erosion would be increased, and water quality may also decline due to increases in sediment load and turbidity.

Long Term Effects of Channelization

In addition to effects discussed previously on channelization, the long term results of widening tributary channels could reduce the aesthetic value, limit diversity of biotic communities within the watershed, may require costly mitigation efforts, and destroy valuable shallow water habitat important as nursery for fish and other aquatic animals. Since it is unlikely that any endangered or threatened species exist within the watershed, their habitat would not be affected. However, species such as the peregrine falcon that migrate through the area may be affected by loss of forested riparian habitat. Loss of these large trees would eliminate roosting areas that the falcon and other endangered or threatened birds might use during migration.

Development within the watershed will generally result in increased runoff and greater pollution potential. Elimination of existing flood plain areas, some of which may act as a pollution filter, could also result in increased pollution potential. Elimination of existing flood plain areas may also result in the elimination of wetlands located within the flood plain.

Impact of Regional Detention Facilities

Construction-Related Effects of Detention

There is some leeway in placement and configuration of regional and sub-regional detention facilities. Therefore, damage to wetland areas, riparian forest, and other valuable biotic communities can be minimized through avoidance. However, construction of regional detention ponds, due to their size, will inevitably cause some destruction of riparian habitat and wetland areas. Placement of the excavated material could also detrimentally impact these habitats. However, as with pond placement, valuable wetlands, riparian forest and other habitat could be at least partially avoided.

Table 10 summarizes the loss in habitat resulting from the construction of the proposed regional detention facilities on the most important habitat types (wetlands and riparian woodlands) in the study area. Impacts on wetlands and riparian woodlands habitat may require mitigation.

Table 10: Impacts of Regional Detention on Habitat

Notes: Wetland acreage at least partially meets prior converted cropland criteria. Wetland, Farmland, Tallow, and Woodland acreages may overlap in some cases.

Pond Number	Pond Area (ac)	Wetlands (ac)	Farmland (ac)	Tallows (ac)	Woodland (ac)
1, 3, 5, 6	952	105	847	47	0
2	44	4	40	4	0
4	39	4	0	39	0
7	319	62	319	8	0
8	26	4	26	3	0
9	46	4	42	0	0
10	43	6	6	37	0
11	131	2	131	2	0
12	133	3	133	0	0
13	65	30	49	20	16
14	103	10	0	70	10
15	42	4	0	12	5
16	67	7	0	0	67
17	71	10	53	18	0
18	23	2	21	2	0
TOTALS	**2,104**	**257**	**1,667**	**262**	**98**

Construction of the regional and sub-regional detention facilities will create an increased potential for erosion. Increases in erosion would be accompanied by greater sediment loads and higher turbidity levels in downstream areas along Dickinson Bayou.

Long-Term Effects of Detention

Detention basins would aid in controlling the increased runoff due to watershed development. Detention areas will become polluted from the runoff, but would act as a filter, reducing the amount of pollutants actually reaching the main channel. Construction of regional and sub-regional detention facilities will be accompanied by the elimination of existing flood plain areas, some of which may act as a pollution filter. This could result in increased pollution potential in some areas. Elimination of existing flood plain areas may also result in the elimination of wetlands located within the flood plain.

Mitigation of Environmental Consequences

Due to the large size of regional detention sites, avoidance of habitat would be difficult at best. Therefore, mitigation of habitat loss is necessary. However, these large detention basins would also provide ideal locations for creations of compensatory wetlands and/or riparian woodlands habitats.

Along channelized tributaries, extensive mitigation measures would be required. Mitigation of some of the habitats that would be lost may be extremely costly and difficult. Therefore Best-Management Practices should be employed. The following section describes a number of such practices for channelized streams as well as regional detention basins.

Best Management Practices

In the design of channel improvements to existing tributary streams, impacting wetland and wooded habitats as well as cultural resources should be avoided as much as practical. Coordination with regulatory agencies will be important in achieving these goals. Since avoidance would be difficult, however, other construction designs may be useful in limiting impacts. For example, impacts could be reduced by using one-sided construction. Construction of a benched floodway above the existing stream bed would limit disturbance of aquatic habitats. Channel banks and other disturbed areas should be revegetated with native plants that provide wildlife with food and cover. Mature trees should be avoided or additional trees should be reestablished at a frequency of at least one tree planted for every tree lost.

Regional and sub-regional detention sites should be placed so that valuable biotic communities and cultural resources are avoided if possible. Coordination with regulatory agencies will be important in achieving these goals. Additionally, detention ponds should be designed to blend in with the landscape. For instance, curved shapes may be used rather than a basic rectangle, in order to improve the aesthetic qualities of the facility.

Mitigation Action

Wetland areas can be created within the basin of on-site detention ponds depending on construction design. Thus, habitat for small amphibians, reptiles, small mammals and birds could be created. Regional detention basins could also be designed to create wetland habitat. Additionally, these larger basins could also provide open water habitat for waterfowl, fish, larger amphibians, and larger reptiles.

COST ESTIMATE FOR COMBINATION ALTERNATIVE

The total estimated cost of the Combination Alternative equals the total of the following costs:

- Channelization Right-of-Way Cost
- Channelization Construction Cost
- Regional Detention Land Cost
- Regional Detention Excavation Cost
- On-Site Detention Land Cost
- On-Site Detention Excavation Cost

In addition, there will be some residual flood damage costs which will not be completely eliminated by the Combination Alternative. In a formal study, these costs would have to be evaluated for a wide range of flood frequencies and converted to average annual flood damages. For the purpose of this study, however, the expected residual flood damages from a 100-year storm event are computed and used as an indicator of the remaining costs of flood damages not eliminated by the Combination Alternative.

Channelization Construction Costs

The cost associated with tributary channel improvements is a total of the construction costs and land costs for right-of-way. The construction costs are based on current unit prices. The following assumptions and criteria were used to calculate the cost of construction:

1) **Clearing and Grubbing**: The area of clearing and grubbing is equal to the total area of ROW required. This value is also used for the area of seeding and mulching.

2) **Road Crossings**: Bridge installation is assumed at existing road crossings where the proposed right-of-way width is greater than equal to 150 feet. Culverts are assumed at minor road crossings with a proposed right-of-way width less than 150 feet. At crossings where culverts are indicated, the total assumed cost is $30,000 for a right-of-way width of 120 feet or less, $45,000 for a right-of-way width of 130 feet, and $60,000 for a right-of-way width of 140 feet.

3) **Slope Protection**: Slope protection is not included in the channel design. All channels are assumed to be earthen-lined. Concrete paving under bridges is included in the unit cost of bridge installation.

4) **Backslope Drains**: The number of backslope drains is calculated based on a 1,000-foot spacing on both sides of the channel.

5) **Relocations**: A lump sum value of $300,000 is used for each pipeline relocation. A lump sum value of $50,000 is used for each powerline relocation.

6) **Drop Structures**: A lump sum value of $25,000 is assumed for sloping drop structures. For straight drops, a lump sum of $50,000 is assumed.

7) **Land Costs**: The land costs are determined as described in Chapter 2 of this report. Total land costs are based on the total right-of-way acreage required. Although some ditches have limited existing right-of-way, this area was not excluded in the cost estimate. This assumption makes the cost estimate slightly more conservative. In addition, a 15 percent premium is added to the land acquisition cost to compensate land owners for damages to the remainder of tracts which are only partially acquired.

8) **Flood Damages**: Flood damages are estimated only for the residual flood plain along Dickinson Bayou downstream of the Bypass Channel. The 100-year flood plain in other areas is restricted to the banks of the various tributary channels.

Table 11 summarizes the total construction and land costs for each channelized ditch.

Table 11: Channelization Cost for the Combination Alternative

Studied Stream	Length of Stream Reach (ft)	Range of Estimated Widths (ft)	Excavation Volume (cu yd)	Total ROW (ac)	Total Cost ($)
Bordens Gully	11,450	10-50	161,400	43.5	$6,189,575
Magnolia Bayou	15,100	35-50	414,960	76.1	$8,467,478
Bensons Bayou	22,080	8-80	456,600	66.4	$6,846,915
West Gum Bayou	10,815	10-40	100,100	38.8	$2,212,158
Gum Bayou	21,500	60-175	848,900	123.1	$6,076,450
TOTALS			**1,981,960**	**347.9**	**$29,792,576**

Due to uncertainties regarding habitat and wetlands area mitigation ratios and other mitigation requirements, which are established through negotiation with the US Army Corps of Engineers and other agencies, this figure does not include costs associated with environmental mitigation. Other costs not included in the estimate are:

1) Costs associated with channelization of small tributaries and of stream segments not represented in HEC-2 computer models of major tributaries.
2) Potential costs associated with the disposal of excavated material.

Although these items are not included in the cost estimates due to the reconnaissance level of this study, evaluation of these costs will be an important consideration in determining the economic feasibility of this and other structural alternatives.

Regional Detention Costs

The total cost associated with the detention alternative is a total of the costs for the regional detention plus the costs for selective channelization of the ditches to convey flows to the detention sites. The cost of on-site detention is also determined. This cost is included in the total cost of the detention alternative even though the need for the on-site detention will not be required until the undeveloped land is developed. By including on-site detention in the cost estimate, a "total cost" approach is maintained, wherein the total cost to be borne by residents of the watershed, whether for on-site or regional detention, is represented. Use of this total cost approach reveals all potential costs to the taxpayer and makes comparisons of the costs associated with each alternative more valid.

The cost of regional detention is a total of the construction cost plus land cost. Construction costs are based on a unit price of $4.00 per cubic yard of excavation. This unit price includes all aspects of detention pond construction including hauling, grading and outfall structures; therefore, the unit price is greater than the unit price for excavation in the channelization alternative. Land costs per acre are determined as described in Chapter 2. The estimated per acre cost of undeveloped land and developed land is multiplied by the respective surface areas required. In addition to the cost of the land, total acquisition cost includes a 5 percent premium to compensate land owners for damages to the remainder of tracts which are only partially acquired. The need for maintenance berms around the perimeter of each basin is accounted for (approximately) in the total area requirement for each basin.

For hydraulic purposes, the streams are minimally channelized to allow flows to reach the detention ponds and to provide outfall depth for on-site as well as regional facilities. Construction and land costs are determined using the same assumptions and criteria as the Channelization/Diversion Alternative. These costs include bridge replacements and pipeline adjustments.

The area of on-site detention is determined for each sub-area of the watershed based on the area of undeveloped land that would be developed in the future. Construction costs are based on a unit price of $4.70/cy of excavation. This unit price is greater than the unit price of excavation for the regional detention ponds because the on-site detention construction is assumed to be constructed in smaller quantities, thus raising the unit prices. Land costs per acre are determined as described in Chapter 2. The total surface area of on-site detention for each sub-area is used as the area of land required.

Tables 12 through 16 summarize the construction costs and land costs for the regional detention, the selective channelization, and the on-site detention.

Due to uncertainties regarding habitat and wetlands area mitigation ratios and other mitigation requirements, which are established through negotiation with the US Army Corps of Engineers and other agencies, this figure does not include costs associated with environmental mitigation. Other costs not included in the estimate are:

1) Costs associated with channelization of small tributaries and of stream segments not represented in HEC-2 computer models of major tributaries.

2) Potential costs associated with the disposal of excavated material.

Table 12: Tributary Channel Improvement Cost for the Combination Alternative

Studied Stream	Length of Stream Reach (ft)	Range of Estimated Widths (ft)	Excavation Volume (cu yd)	Total ROW (cy)	Total Cost ($)
Upper Dickinson	16,404	6	138,000	41.7	$1,576,400
Bypass Channel	36,400	6	627,800	102.8	$4,694,800
DD #1 Ditch #4	19,112	6	215,800	60.9	$2,894,731
DD #1 Ditch #5	10,452	6	157,500	36.0	$2,005,449
DD #1 Ditch #6	10,744	6	151,600	37.0	$1,465,797
DD #1 Ditch #7	13,548	6	83,000	33.8	$1,153,289
DD #1 Ditch #8	13,556	6	145,100	39.2	$2,412,581
DD #1 Ditch #9	18,050	6	124,000	55.9	$2,052,875
DD #1 Ditch #9C	10,800	6	101,400	38.9	$2,363,950
DD #1 Ditch #9D	9,385	6	81,200	21.8	$1,258,493
DD #1 Ditch #10	4,742	6	39,600	12.9	$1,013,434
DD #1 Ditch #11	11,444	6	99,000	28.5	$1,522,380
DD #1 Ditch #12	19,000	6	88,000	56.7	$2,246,095
Old Runge Bayou	5,826	6	18,100	16.6	$435,788
DD #2 Ditch #2	5,251	6	36,900	14.2	$805,376
DD #2 Ditch #5	4,600	6	2,500	12.7	$170,923
DD #2 Ditch #5A	10,450	6	37,200	25.8	$1,016,940
DD #2 Ditch #5B	10,270	6	38,900	28.5	$1,701,323
TOTALS			**2,185,600**	**663.9**	**$30,790,624**

Table 13: Estimated Land Costs for Regional Detention for Combination Alternative

Basin No.	Sub-Area	Total Basin Area (ac)	Land Unit Cost ($/ac)	Total Land Cost ($)
1, 3, 5, 6	6, 7, 10, 11	952	4,000	$3,998,400
2	7	44	4,000	$184,800
4	8	39	3,500	$143,325
7	13, 14	319	6,500	$2,177,175
8	16	26	3,500	$95,550
9	17	46	3,000	$144,900
10	17	43	3,000	$135,450
11	19	131	4,500	$618,975
12	20	133	4,500	$628,425
13	22	65	4,500	$307,125
14	25	103	5,000	$540,750
15	27	42	4,000	$176,400
16	27	67	4,000	$281,400
17	30	71	11,500	$857,325
18	32	23	11,500	$277,725
TOTALS		**2,104**		**$10,567,725**

Table 14: Estimated Excavation Costs for Regional Detention for Combination Alternative

Basin No.	Sub-Area	Total Excavation (cy)	Unit Cost of Excavation ($/cy)	Total Excavation Cost ($)
1, 3, 5, 6	6, 7, 10, 11	12,025,500	$4.00	$48,102,000
2	7	559,500	$4.00	$2,238,000
4	8	426,200	$4.00	$1,704,800
7	13,14	4,611,600	$4.00	$18,446,400
8	16	487,700	$4.00	$1,950,800
9	17	557,000	$4.00	$2,228,000
10	17	520,000	$4.00	$2,080,000
11	19	1,492,800	$4.00	$5,971,200
12	20	687,300	$4.00	$2,749,200
13	22	790,900	$4.00	$3,163,600
14	25	1,461,100	$4.00	$5,844,400
15	27	333,400	$4.00	$1,333,600
16	27	706,300	$4.00	$2,825,200
17	30	549,300	$4.00	$2,197,200
18	32	238,800	$4.00	$955,200
TOTALS		**25,447,400**		**$101,789,600**

Costs Associated with On-Site Detention

Table 15: Estimated Land Costs Associated with On-Site Detention for Combination Alternative

Notes: Area Ratio = 0.0822 ac/developed ac

Sub-Area	Future Urban Development (ac)	Detention Storage Volume (ac-ft)	Area (ac)	Land Unit Cost ($/ac)	Land Total Cost
1	686	377.3	56.4	$3,000	$169,168
2	622	342.1	51.1	$3,000	$153,385
3	289	159.0	23.8	$3,000	$71,267
4	463	254.7	38.1	$4,000	$152,234
5	489	269.0	40.2	$3,000	$120,587
6	161	88.6	13.2	$3,000	$39,703
7	1160	638.0	95.4	$4,000	$381,408
8	504	277.2	41.4	$3,500	$145,001
9	494	271.7	40.6	$3,500	$142,124
10	827	454.9	68.0	$4,000	$271,918
11	938	515.9	77.1	$5,000	$385,518
12a	387	212.9	31.8	$5,000	$159,057
12b	257	141.4	21.1	$5,000	$105,627
12d	363	199.7	29.8	$5,000	$149,193
13	275	151.3	22.6	$5,000	$113,025
14	1201	660.6	98.7	$8,000	$789,778
15	167	91.9	13.7	$8,000	$109,819
16	898	493.9	73.8	$3,500	$258,355
17	1320	726.0	108.5	$3,000	$325,512
18	203	111.7	16.7	$4,500	$75,090
19	1608	884.4	132.2	$4,500	$594,799
20	599	329.5	49.2	$4,500	$221,570
21	484	266.2	39.8	$4,500	$179,032
22	1218	669.9	100.1	$4,500	$450,538
23	256	140.8	21.0	$7,500	$157,824
24	620	341.0	51.0	$5,000	$254,820
25	987	542.9	81.1	$5,000	$405,657
26	175	96.3	14.4	$15,500	$222,968
27	844	464.2	69.4	$4,000	$277,507
28	548	301.4	45.0	$13,500	$608,116
29	1117	614.4	91.8	$20,000	$1,836,348
30	894	491.7	73.5	$11,500	$845,098
31	2481	1364.6	203.9	$18,500	$3,772,857
32	635	349.3	52.2	$11,500	$600,266
33	1391	765.1	114.3	$8,000	$914,722
34	957	526.4	78.7	$5,000	$393,327
35	81	44.6	6.7	$5,000	$33,291
36	118	64.9	9.7	$5,000	$48,498
37	401	220.6	33.0	$5,000	$164,811
38	3674	2020.7	302.0	$5,000	$1,510,014
39	706	388.3	58.0	$5,000	$290,166
40	257	141.4	21.1	$4,500	$95,064
41	1767	971.9	145.2	$4,000	$580,990
42	1837	1010.4	151.0	$4,500	$679,506
43	244	134.2	20.1	$8,000	$160,454
TOTALS			2,926.6		$19,416,010

Table 16: Estimated Excavation Costs Associated with On-Site Detention for Combination Alternative

Notes:
Volume Ratio = 0.55 ac-ft/ac;
Excavation Ratio = 1.1258 cy/cy;
Excavation Cost = $470/cy

Sub-Area	Future Urban Development (ac)	Detention Storage Volume (ac-ft)	Excavation Volume (cy)	Excavation Cost
1	686	377.30	685,286	$3,220,846
2	622	342.10	621,353	$2,920,359
3	289	158.95	288,699	$1,356,887
4	463	254.65	462,518	$2,173,837
5	489	268.95	488,491	$2,295,909
6	161	88.55	160,833	$755,913
7	1,160	638.00	1,158,793	$5,446,329
8	504	277.20	503,476	$2,366,336
9	494	271.70	493,486	$2,319,385
10	827	454.85	826,140	$3,882,857
11	938	515.90	937,024	$4,404,014
12a	387	212.85	386,597	$1,817,008
12b	257	141.35	256,733	$1,206,644
12d	363	199.65	362,622	$1,704,325
13	275	151.25	274,714	$1,291,156
14	1,201	660.55	1,199,751	$5,638,829
15	167	91.85	166,826	$784,084
16	898	493.90	897,066	$4,216,210
17	1,320	726.00	1,318,627	$6,197,547
18	203	111.65	202,789	$953,108
19	1,608	884.40	1,606,327	$7,549,739
20	599	329.45	598,377	$2,812,372
21	484	266.20	483,497	$2,272,434
22	1,218	669.90	1,216,733	$5,718,646
23	256	140.80	255,734	$1,201,949
24	620	341.00	619,355	$2,910,969
25	987	542.85	985,973	$4,634,075
26	175	96.25	174,818	$821,644
27	844	464.20	843,122	$3,962,674
28	548	301.40	547,430	$2,572,921
29	1,117	614.35	1,115,838	$5,244,439
30	894	491.70	893,070	$4,197,430
31	2,481	1,364.55	2,478,419	$11,648,571
32	635	349.25	634,340	$2,981,396
33	1,391	765.05	1,389,553	$6,530,900
34	957	526.35	956,005	$4,493,222
35	81	44.55	80,916	$380,304
36	118	64.90	117,877	$554,023
37	401	220.55	400,583	$1,882,740
38	3,674	2,020.70	3,670,179	$17,249,839
39	706	388.30	705,266	$3,314,749
40	257	141.35	256,733	$1,206,644
41	1,767	971.85	1,765,162	$8,296,262
42	1,837	1,010.35	1,835,089	$8,624,920
43	244	134.20	243,746	$1,145,607
TOTALS	**35,603**	**19,581.65**	**35,565,968**	**$167,160,050**

Flood Damages for Combination Alternative

Table 17 presents an estimate of the total flood damages which would occur in a future 100-year storm event, assuming that the watershed is fully developed, and that the Combination Alternative is fully implemented.

Table 17: Flood Damages for Combination Alternative

Note: Floodway not defined on latest Brazoria County Flood Insurance Rate Maps. Brazoria County flood plain acreage assumed to equal existing value.

Item	Galveston County	Brazoria County	Combined Totals
Total Area in Residual Flood Plain (ac)	8,087	0	8,087
Existing Development In Flood Plain			
High Density (ac)	375	0	375
Medium Density (ac)	430	0	430
Low Density (ac)	292	0	292
Totals (acres)	**1,097**	**0**	**1,097**
Total Undeveloped Area in Floodway (ac)	1,040	(See Note)	1,040
Future Development in Flood Plain (ac)	4,463	0	4,463
Estimated Number of Structures in Flood Plain			
Exist. High Density (3.2 Units/ac)	1,200	0	1,200
Future High Density (3.2 Units/ac)	14,280	0	14,280
Exist. Med. Density (1.6 Units/ac)	688	0	688
Exist. Low Density (0.4 Unit/ac)	117	0	117
Sub-Totals	**16,285**	**0**	**16,285**
Average Cost Per Flood-Damaged Structure	$10,250	$10,250	$10,250
Total Flood Damages for 100-Year Storm	**$166,919,200**	**$0**	**$166,919,200**

Total Cost Estimate for Combination Alternative

Table 18 presents the total cost estimate for the Combination Alternative. As indicated, the combined total cost of the alternative is over $526 million. Of this total, about $173 million is required for channel improvements and the construction of regional detention facilities.

Table 18: Combined Cost Estimate for the Combination Alternative

Item	Estimated Cost	Reference
Channelization Costs	$29,792,576	Table 11
Tributary Channel Improvements	$30,790,624	Table 12
Land Costs for Regional and Sub-Regional Detention Facilities	$10,567,725	Table 13
Excavation Cost for Regional and Sub-Regional Detention Facilities	$101,789,600	Table 14
Construction & Land Cost Sub-Total for Major Infrastructure	**$172,940,525**	-
Land Cost for On-Site Detention	$19,416,010	Table 15
Excavation Cost for On-Site Detention	$167,160,050	Table 16
Total Cost of On-Site Detention	**$186,576,060**	-
Flood Damages from Future 100-Year Storm	$166,919,200	Table 17
Overall Total Cost of Alternative	**$526,435,785**	-

CHAPTER 6: SUMMARY AND COMPARISON OF ALTERNATIVES

This chapter provides a brief comparison of the results of this preliminary analysis of alternatives. Hydraulic, socioeconomic, and environmental impacts are discussed, and a summary of the total cost associated with each of the four alternatives is presented.

This chapter provides a brief comparison of the results of this preliminary analysis of alternatives. Hydraulic, socioeconomic, and environmental impacts are discussed, and a summary of the total cost associated with each of the alternatives is presented.

DESCRIPTION OF ALTERNATIVES

No-Action Alternative

The No-Action Alternative assumes that there will basically be no active watershed management by local regulatory agencies. With this alternative, development of the watershed would proceed with no requirements concerning mitigation of impacts on flooding conditions.

Although full development of the Dickinson Bayou Watershed is assumed, it is also assumed that entities responsible for drainage activities will comply with the National Flood Insurance Act. Since FEMA regulations, 44 CFR Ch. 1, Part 60, prohibits adverse effects on existing development, the likelihood for implementation of the no-action alternative is slim and has no chance of active public support.

The existing 100-year flood plain increases from 35,002 acres to 43,084 acres. The total cost of this alternate is approximately $898,010,700.

Non-Structural Alternative

The Non-Structural Alternative assumes that flood damages will be reduced or eliminated by purchasing the flood plain and removing all habitable structures. This non-intrusive approach is very desirable from an environmental standpoint.

The Non-Structural Alternative is the same as the No-Action Alternative except that it evaluates the feasibility of purchasing the future 100-year flood plain. The total cost of this alternative is approximately $620,818,050, which includes lateral channel cost and future 100-year flood plain buy out. Land in the 100-year flood plain increases from 35,002 acres (existing conditions) to 39,043 acres.

Channelization Alternative

The Channelization Alternative represents an approach involving the construction of improved channels which efficiently convey flood waters to Dickinson Bayou with a minimum of overbank flooding. This includes improvements to existing channels as well as the construction of an interceptor and a diversion channel.

The land in the 100-year flood plain decreases from 35,002 acres (existing conditions) to 9,106 acres, The total cost of this alternative is approximately $394,428,322. This estimate includes land and construction cost for all lateral channels and diversion channel.

Detention Alternative

The Detention Alternative calls for the abatement of flooding problems through temporary storage of flood waters in reservoirs located at strategic points throughout the watershed. On-site detention for all new development is an integral part of this alternative.

Regional detention facilities are constructed to reduce the existing flows to the point where the resultant water surface elevation in the main channel and tributary channels closely approximate the water surface elevation obtained in the Channelization Alternative. This alternative requires approximately 23 regional detention sites covering 2,539 acres of land. On-site detention covers approximately 2,900 acres. The existing flood plain decreases from 35,002 acres to 8,087 acres. Channel improvements are included only to the extent of providing outfall depth for detention ponds. Total cost for this alternative is approximately $541,551,612, including the cost of regional and on-site detention ponds and channel improvements.

Combination Alternative

The Combination Alternative represents an approach involving the on-site detention requirement for new development, construction of regional detention facilities for the watershed except the northeastern portion of the Dickinson Bayou drainage area, and channelization of Gum, West Gum, Bensons, Magnolia and Bordens Bayous. In addition, it involves channel improvements to convey flood water into the regional detention facilities.

The Combination Alternative is very similar to the Detention Alternative throughout most of the watershed. In fact, the 100-year flood plain is the same for both of these two alternatives. (The 100-year flood plain decreases from 35,002 acres to 8,087 acres.) Total cost for this alternative is $526,435,785.

COMPARISON OF IMPACTS ASSOCIATED WITH EACH ALTERNATIVE

Hydraulic Impacts

Of the five alternatives analyzed, the No-Action Alternative results in the greatest extent of 100-year flood plain and the highest potential for flood damage. The Non-Structural Alternative has the second highest total flood plain area, but would have the lower potential for flood damage.

The Channelization/Diversion, Detention, and Combination Alternatives results in major reductions in the 100-year flood plain. Each of these three alternatives would greatly reduce flooding potential within the watershed. Table 19 presents a summary of the impacts of the various alternatives with respect to cost and residual flood plain acreage.

Table 19: Computed Costs and Results for Each Alternative

Note: All Costs are in $Millions

Item	No-Action Alternative	Channel-ization/ Diversion Alternative	Detention Alternative	Non-Structural Alternative	Combin-ation Alternative
Construct-ion Cost	$0	$202	$188	$0	$173
On-Site Detention	$0	$0	$187	$0	$187
100-Year Flood Cost	$898	$192	$167	$0	$167
Flood Plain Buy-Out	$0	$0	$0	$508	$0
Total Cost	**$ 898**	**$ 394**	**$ 542**	**$ 508**	**$ 527**
Residual Flood Plain	43,084 ac	9,106 ac	8,087 ac	39,043 ac	8,087 ac
Non-Inundated Area	18,376 ac	52,354 ac	53,373 ac	22,417 ac	53,373 ac

Environmental Impacts

The regional flood control plan considers a variety of alternatives: No-Action, Channelization/Diversion, Detention, Non-Structural and a Combination Alternative. The short-term and long-term impacts associated with the plan vary considerably among alternatives. The No-Action and Non-Structural Alternatives have the least impact on the riparian environment. Assuming further development within the watershed, the impacts typically consist of additional runoff resulting in increased flooding. However, the No-Action Alternative does assume some channelization of minor tributaries. Channelization causes more loss of ecosystems than any of the other alternatives. Both the short term and long term effects are detrimental to the biotic communities due to the disturbance of and permanent change to different habitats. Detention and Channelization/Diversion are similar, when comparing impacts, in that both alternatives will destroy habitats during construction and result in a conversion of terrestrial ecosystems to semi-aquatic ecosystems. The impacts of the Combination Alternative are similar to those of the Detention Alternative, although it results in a higher loss of habitats due to channelization of tributaries.

Each of the proposed alternatives has benefits and disadvantages of its own. No alternative alone will facilitate the desired result of maintaining biodiversity while providing the necessary flood protection within the Dickinson Bayou Watershed,

Socio-Economic Impacts

Table 19 summarizes the costs for each of the five alternatives, as well as the total flood plain area and the total area of non-inundated land. Components included in the total cost for each alternative include the construction cost, the on-site detention cost, and the flood plain buy-out cost. In addition, the flood damages resulting from a 100-year magnitude event are also included. Flood damages from other storm events are not included.

As the table shows, the No-Action Alternative has the highest total cost, followed by the Detention Alternative and the Non-Structural Alternative. The Channelization/Diversion Alternative has the lowest total cost of the four options.

The cost estimates developed for this study do not include environmental mitigation costs. These costs may affect the choice of alternatives and will be estimated on the basis of average cost per acre of habitat loss.

Comparison of Alternatives

The Detention and Non-Structural Alternatives are comparable in terms of cost, but the Detention Alternative creates the greater amount of environmental damage.

The Channelization/Diversion, Detention and Combination Alternatives leave far smaller amounts of residual flood plain than the No-Action and Non-Structural Alternatives, thus providing the greatest potential for future development and economic growth.

The Non-Structural Alternative will result in major losses in taxable property by rendering the flood plain undevelopable and under public ownership. The amount of developable acreage left in the watershed under this alternative may not be adequate to support the cost of the plan.

The Combination Alternative is the most effective in terms of meeting the goals of reducing the total cost, lowering the residual flood plain and potential flood damages, increasing the potential for economic development and the capacity to fund a regional drainage plan, and providing environmental safeguards.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

The Dickinson Bayou Watershed currently covers a total of approximately 63,830 acres, or 99.7 square miles, upstream of State Highway 146, the downstream terminus of this study. The watershed is elongated in shape, with a length of 22 miles from west to east. The maximum width of the watershed is approximately 7 miles.

Five alternative flood control concepts were analyzed for the Dickinson Bayou watershed, including the following alternatives:

1. No-Action
2. Non-Structural
3. Channelization
4. Detention
5. Combination

An extensive analysis is presented, including the hydrology, hydraulics, cost, socio-economic effects, and environmental impacts of each alternative. Cost and flood damages summaries are listed in Table 20. Major findings for each alternative are presented below.

Table 20: Computed Costs and Results for Each Alternative

Note: All Costs are in $Millions

Item	No-Action Alternative	Channel-ization/ Diversion Alternative	Detention Alternative	Non-Structural Alternative	Combin-ation Alternative
Construct-ion Cost	$0	$202	$188	$0	$173
On-Site Detention	$0	$0	$187	$0	$187
100-Year Flood Cost	$898	$192	$167	$0	$167
Flood Plain Buy-Out	$0	$0	$0	$508	$0
Total Cost	**$ 898**	**$ 394**	**$ 542**	**$ 508**	**$ 527**
Residual Flood Plain	43,084 ac	9,106 ac	8,087 ac	39,043 ac	8,087 ac
Non-Inundated Area	18,376 ac	52,354 ac	53,373 ac	22,417 ac	53,373 ac

CONCLUSIONS OF ANALYSIS

The following conclusions may be drawn from the results of the alternatives analysis.

1) The Channelization/Diversion Alternative has the lowest cost, but will involve the greatest environmental damage and thus the highest environmental mitigation cost.

2) The No-Action Alternative clearly involves the highest total cost and the greatest flooding potential of the five alternatives.

3) The Non-Structural, Detention, and Combination Alternatives are comparable in terms of cost, but the Non-Structural Alternative will create the least amount of environmental damage.

4) The Channelization/Diversion, Detention, and Combination Alternatives leave far smaller amounts of residual flood plain than the No-Action and Non-Structural Alternatives, thus providing the greatest potential for future development and economic growth.

5) The Non-Structural Alternative will result in major losses in taxable property by rendering the flood plain undevelopable and under public ownership. The amount of developable acreage left in the watershed under this alternative may not be adequate to support the cost of the plan.

6) The Combination Alternative will probably be the most effective in terms of meeting the goals of lowering the total cost, reducing the residual flood plain and potential flood damages, increasing the potential for economic development and the capacity to fund a regional drainage plan, and providing environmental safeguards.

Several permits will be be required from state and federal regulatory agencies in connection with this project. These include the following:

- A permit from the US Army Corps of Engineers under Section 10 the Rivers and Harbors Act of 1899.
- A permit from the US Army Corps of Engineers under Section 404 of the Clean Water Act.
- A National Pollutant Discharge Elimination System (NPDES) permit from the US Environmental Protection Agency under Section 402 of the Clean Water Act. (This permit is required for storm water discharges from construction activities disturbing more than 5 acres of surface area.)
- A Water Quality Certification from the Texas Natural Resources Conservation Commission (TNRCC) under Section 401 of the Clean Water Act.
- A certification from the Texas General Land Office according to the Coastal Zone Management Plan (CZMP) for the State of Texas (assuming that Texas has a federally-authorized CZMP in place by the time that the project is initiated.)

Careful coordination with these regulatory agencies and others such as the Texas Parks and Wildlife Department, and the Texas Historical Commission will be required in order to successfully implement the selected Combination Alternative. Through this type of coordination, the identification of potential impacts to cultural and natural resources, including wetlands and archaeological sites, will be made more precise and complete. Such coordination would become especially important as specific projects are proposed and more detailed environmental and cultural data are collected.

RECOMMENDATION

As expected, the No-Action, Non-Structural, and Detention Alternatives have a very high cost per net acre when compared to the Channelization and Combination Alternatives. In addition, the implementation of these alternatives is unlikely due to unacceptable socioeconomic and environmental concerns.

The Channelization/Diversion Alternative is approximately 25% cheaper than the Combination Plan. However, the Channelization/Diversion Alternative is not likely to be implemented, for the following reasons:

- Extremely wide right-of-way for channel expansion will be required;
- Residential property and business will have to be displaced to make room for channel improvements;
- A large initial cost is involved which is difficult to divided into phases;
- The environmental impact to sensitive areas may be significant enough to be unacceptable to regulatory entities;
- The plan may not have public support.

Therefore, the Combination Alternative is recommended as the preliminary design of the final drainage plan for the Dickinson Bayou watershed. The final plan will be developed in detail upon review and comment of this report by the Texas Water Development Board, Galveston County and all other entities participating in this study. The final plan is likely to be divided into a series of several short-range and long-term plans, based on location and timing of drainage facilities that are normally associated with development trends.

The following definitions are intended to provide the reader with an understanding of several terms used throughout this report.

100-Year Storm Event: A flooding event which has a 1% chance of being equaled or exceeded in any given year. Over an extended period of time, such a flood is expected to occur once every 100 years.

1978 Adjustment Of Vertical Datum: A set of surveyed elevation data obtained by the US Geological Survey (USGS) in 1978. In order to account for the effects of ground surface subsidence in the Houston-Galveston area, which is due primarily to the withdrawal of groundwater from local aquifers over a period of many years, the USGS periodically updates the elevations of survey benchmarks in the area. The last general update, or re-leveling, for the Houston-Galveston area was completed in 1978.

Bottomland Hardwoods: a forest cover type consisting of species of trees, other than pine, spruce, or other conifers, which are found on low lying land rich in alluvial soil bordering a stream.

Channelization: The widening, deepening, and/or lining of existing streams and channels for the purpose of increasing flood flow capacity and reducing overbank flooding

Confluence: a point at which two streams come together, or at which one stream empties into another.

Detention Basin: an excavated or dammed area in which flood waters are temporarily stored in order to reduce peak rates of flood flow in downstream areas.

Diversion Channel: a channel which conveys flood waters along a route outside the natural valley of a stream.

Flood Plain: The area covered by flood waters as a result of overbank flooding during a given storm event. For example, the 100-year flood plain for the Dickinson Bayou watershed is defined as the area covered by flood waters in response to a design rainfall event of 13.0 inches within a period of 24 hours).

Floodway: A zone along a stream or channel within which flood flows from a 100-year storm event can be conveyed at an elevation 1.0 foot above the normal 100-year flood elevation in the stream. The floodway is a portion of the 100-year flood plain.

Full Watershed Development: For this study, an average of 75% of all acreage currently undeveloped and lying outside the existing floodway will be developed. The intensity of development will vary, with the highest intensities associated with land lying east of IH-45. The percentage of developed land covered by impervious materials (asphalt, concrete, etc.) will average 35%. On average 25% of all acreage currently undeveloped and outside the existing floodway is assumed to remain undeveloped. Land uses in undeveloped areas will include parks, open space, agricultural land, and vacant land.

Hydrograph: A relationship between rate of flow and time for discharges of storm water from a watershed.

Impervious Cover: Areas within a watershed which are covered by materials through which rainfall cannot infiltrate. These materials would include concrete, asphalt, etc.

Infiltration: The process by which rainfall passes into the soil.

Manning's "n" Value: A coefficient (the "n" value) which is utilized in Manning's Equation, a widely-accepted formula which may be applied to the solution of open-channel hydraulics problems. The "n" value, which is also called the "roughness coefficient," is used in Manning's Equation to represent the roughness of a stream. As the "n" value increases, the flow-carrying capacity of the stream decreases.

Multiple-Use Facility: a detention basin or other structure which is designed to provide recreational and/or environmental benefits in addition to flood protection.

Overbank Flooding: The presence of flood waters outside the banks of the stream or channel.

Peak Flow Rate or Peak Discharge of a Hydrograph: The maximum rate of flow in the hydrograph, or the maximum rate (volume of water per unit of time) at which storm water passes the outlet point of the watershed for which the hydrograph is computed.

Riparian Habitat: the ecosystem (the natural environment and the interrelated plant and animal populations) located along the banks of flowing bodies of water.

Runoff: That portion of total rainfall which does not infiltrate into the soil.

Waters of the United States: Waters which are under the jurisdiction of the Federal Government. Under the Clean Water Act of 1972, a permit is required to discharge pollutants (including fill or dredged material) into these waters. According to Section 122.2 of Title 40 of the Code of Federal Regulations, the Waters of the United States are defined as follows:

"a) All waters which are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide;

b) All interstate waters, including interstate "wetlands";

c) All other waters such as intrastate[1] lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wet-

[1] Note the use of the word "intrastate." The waters described in this paragraph are wholly contained within one state, but are

lands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds the use, degradation, or destruction of which would affect or could affect interstate or foreign commerce including any such waters:

1) Which are or could be used by interstate or foreign travelers for recreational or other purposes;

2) From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or

3) Which are used or could be used for industrial purposes by industries in interstate commerce;

d) All impoundments of waters otherwise defined as waters of the United States under this definition;

e) Tributaries of waters identified in paragraphs a) through d) of this definition;

f) The territorial sea; and

g) Wetlands adjacent to waters (other than waters that are themselves wetlands) identified in paragraphs a) through f) of this definition.

Waste treatment systems, including treatment ponds or lagoons designed to meet the requirements of CWA are not waters of the United States."

Wetlands: those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support and that under normal circumstances do support a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands are considered "Waters of the United States" and are thus protected from filling or other disturbances without a permit from the US Army Corps of Engineers. Note: this definition is taken from Section 122.2 of Title 40 of the Code of Federal Regulations.

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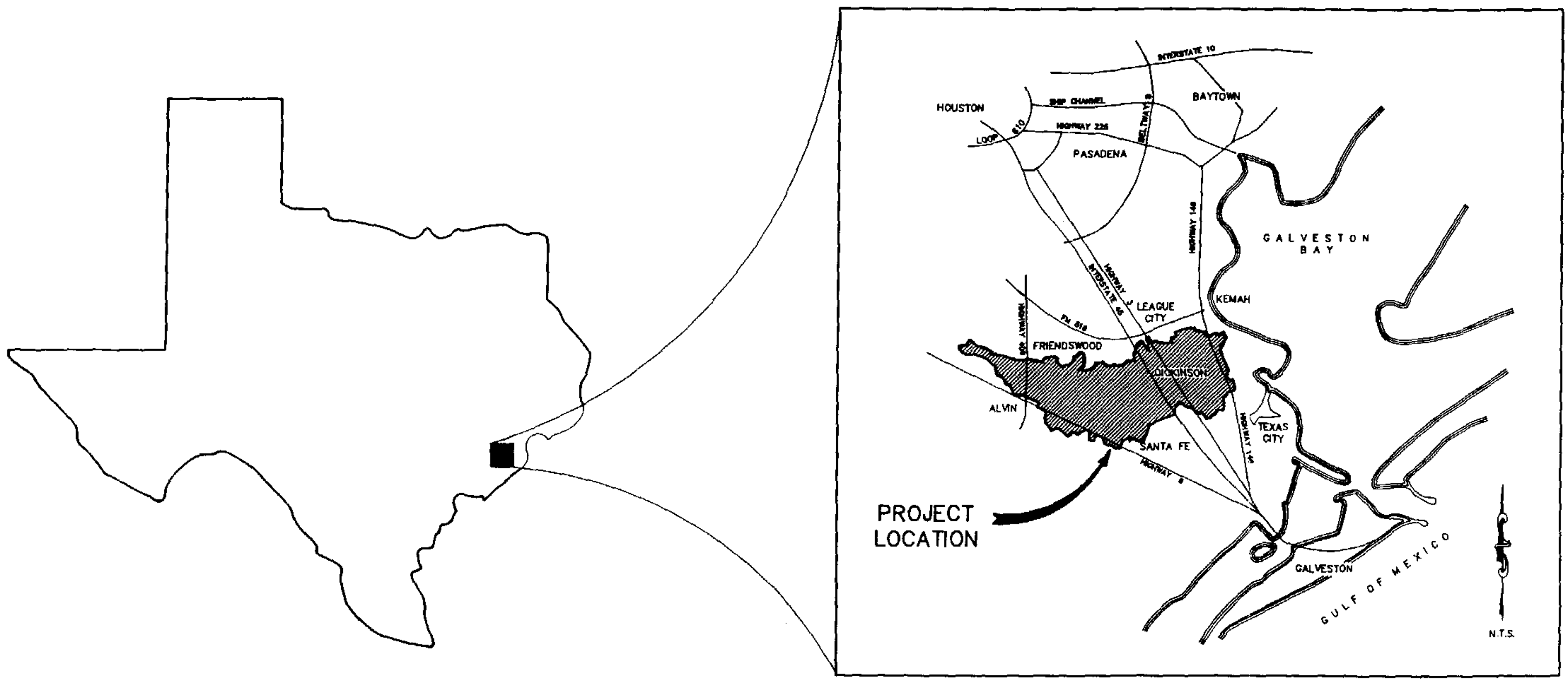
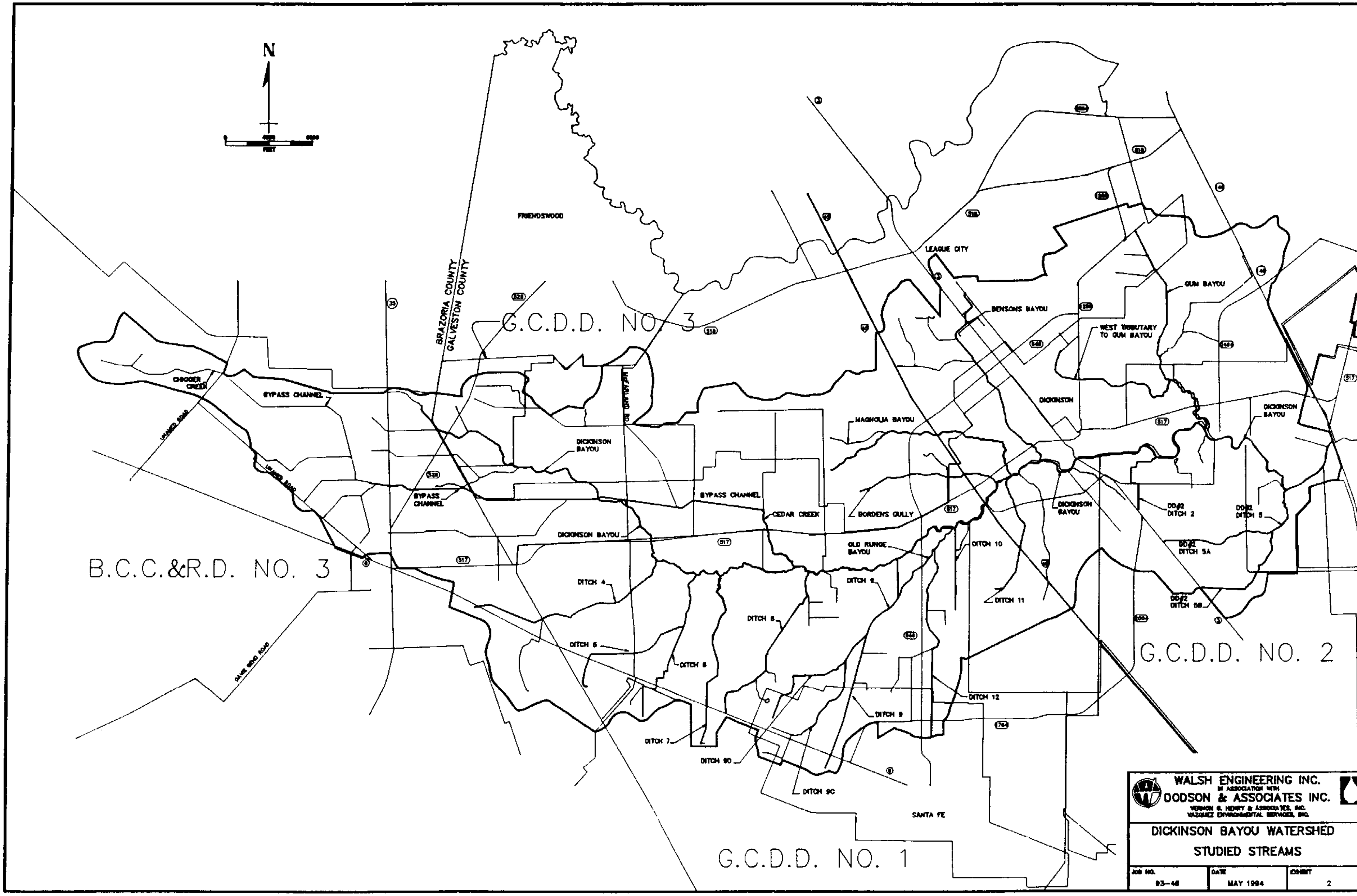
still considered waters of the United States because of their actual or potential use in interstate or international commerce.

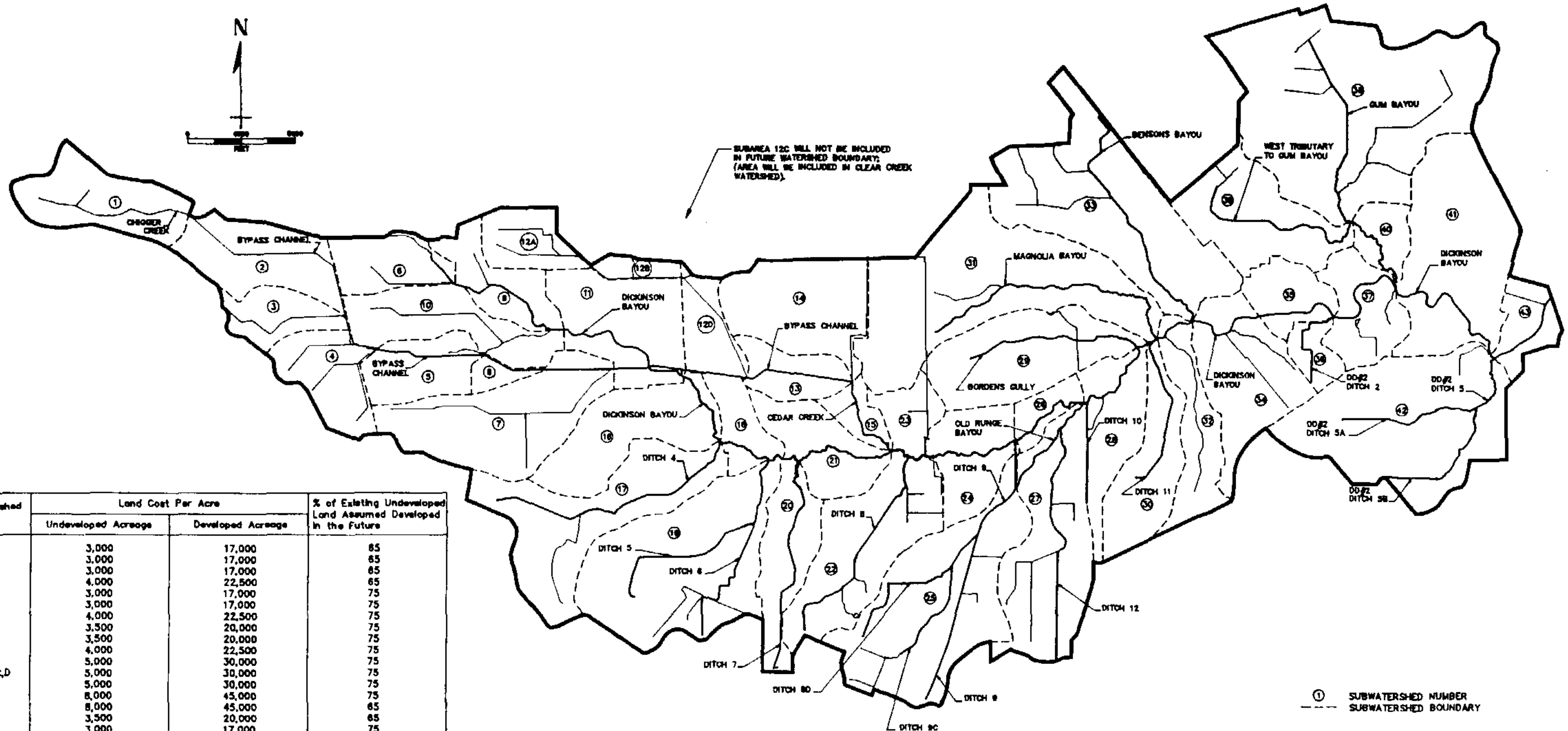


WALSH ENGINEERING INC.
IN ASSOCIATION WITH
DODSON & ASSOCIATES INC.

DICKINSON BAYOU WATERSHED
LOCATION MAP

JOB NO.	DATE	EXHIBIT
93-46	MAY 1994	1


N
FRIENDSWOOD
BRAZORIA COUNTY
GALVESTON COUNTY
G.C.D.D. NO. 3
LEAGUE CITY
BENSONS BAYOU
GUM BAYOU
WEST TRIBUTARY TO GUM BAYOU
DICKINSON
DICKINSON BAYOU
CHIGGER CREEK
BYPASS CHANNEL
MAGNOLIA BAYOU
CEDAR CREEK
BORDENS GULLY
OLD RUNGE BAYOU
DD#2 DITCH 2
DD#2 DITCH 5
DD#2 DITCH 5A
DD#2 DITCH 5B
B.C.C.&R.D. NO. 3
DITCH 4
DITCH 5
DITCH 6
DITCH 7
DITCH 8
DITCH 9
DITCH 10
DITCH 11
DITCH 12
DITCH 9B
DITCH 9C
SANTA FE
G.C.D.D. NO. 2
G.C.D.D. NO. 1
WALSH ENGINEERING INC.
IN ASSOCIATION WITH
DODSON & ASSOCIATES INC.
DICKINSON BAYOU WATERSHED
STUDIED STREAMS
JOB NO. 93-46
DATE MAY 1994
EXHIBIT 2



Subwatershed Number	Land Cost Per Acre		% of Existing Undeveloped Land Assumed Developed in the Future
	Undeveloped Acreage	Developed Acreage	
1	3,000	17,000	65
2	3,000	17,000	65
3	3,000	17,000	65
4	4,000	22,500	65
5	3,000	17,000	75
6	3,000	17,000	75
7	4,000	22,500	75
8	3,500	20,000	75
9	3,500	20,000	75
10	4,000	22,500	75
11	5,000	30,000	75
12 A,B,C,D	5,000	30,000	75
13	5,000	30,000	75
14	8,000	45,000	75
14	8,000	45,000	65
16	3,500	20,000	65
17	3,000	17,000	75
18	4,500	25,000	65
19	4,500	25,000	75
20	4,500	25,000	65
21	4,500	25,000	65
22	4,500	25,000	75
23	7,500	42,000	65
24	5,000	30,000	75
25	5,000	30,000	75
26	15,500	85,000	85
27	4,000	25,000	75
28	13,500	75,000	85
29	20,000	110,000	85
30	11,500	65,000	85
31	18,500	105,000	85
32	11,500	65,000	85
33	8,000	45,000	85
34	5,000	30,000	85
35	5,000	30,000	85
36	5,000	30,000	85
37	5,000	30,000	75
38	5,000	30,000	85
39	5,000	30,000	85
40	4,500	25,000	75
41	4,000	22,500	75
42	4,500	25,000	85
43	8,000	45,000	65
Average	$8,300/Acre	$35,000/Acre	75%

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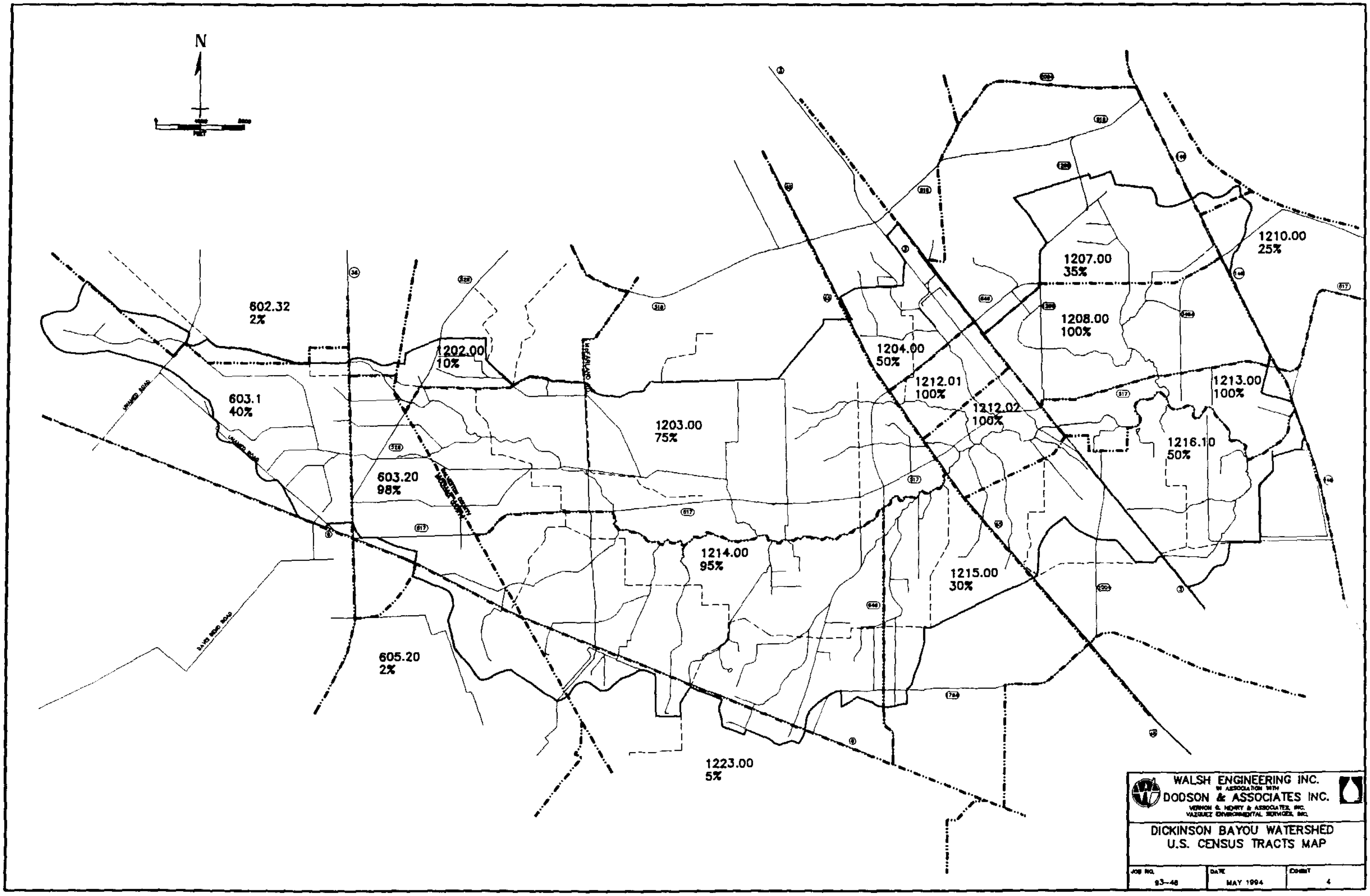
DICKINSON BAYOU WATERSHED AVERAGE ESTIMATED PER ACRE LAND COST MAP

JOB NO.	DATE	EXHIBIT
83-46	MAY 1994	3


N
602.32
2%
603.1
40%
603.20
98%
605.20
2%
1202.00
10%
1203.00
75%
1204.00
50%
1212.01
100%
1212.02
100%
1207.00
35%
1208.00
100%
1210.00
25%
1213.00
100%
1216.10
50%
1214.00
95%
1215.00
30%
1223.00
5%
WALSH ENGINEERING INC.
DODSON & ASSOCIATES INC.
DICKINSON BAYOU WATERSHED
U.S. CENSUS TRACTS MAP
93-46
MAY 1994
4

Dickinson Bayou Watershed
Regional Drainage Plan
Phase III
Galveston County, Texas
And
The Texas Water Development Board
#94-483-026

The following maps are not attached to this report. Due to their size, they could not be copied. They are located in the official file and may be copied upon request.

Dickinson Bayou Watershed
Regional Drainage Plan Proposed Flood Plain For Existing And No Action Conditions
Exhibit 5
Job No. 205.60
May 93

Dickinson Bayou Watershed Regional Drainage Plan Proposed Flood Plain For Channelization Alternative
Exhibit 6
Job No. 205.60
May 93

Proposed Flood Plain For Dentention Alternative
Exhibit 7
Job No. 205.60
May 93

Proposed Flood Plain For Combined Alternative
Exhibit 8
Job No. 270
May 94

Conceptual Layout Multi-Use Detention Facility
Exhibit 9
Job No. 205.60
May 93

Please contact Research and Planning Fund Grants Management Division at (512) 463-7926 for copies.