REGIONAL DRAINAGE STUDY
MARYS, COWARTS, AND CHIGGERS WATERSHEDS
CITY OF FRIENDSWOOD, TEXAS

Submitted to:

Clear Creek Drainage District

City of Friendswood

Texas Water Development Board

8-31-01

Alejandro Flores V.

Prepared by:

Dannenbaum Engineering Corporation

August, 2001

REGIONAL DRAINAGE STUDY
MARYS, COWARTS, AND CHIGGERS WATERSHEDS

TABLE OF CONTENTS

TABLES

TABLE OF CONTENTS (Cont'd)

EXHIBITS

APPENDICES (Under Separate Cover)

REGIONAL DRAINAGE STUDY
MARYS, COWARTS, AND CHIGGERS WATERSHEDS

EXECUTIVE SUMMARY

The purpose of this drainage study is to develop and analyze means of reducing existing flooding problems and providing orderly watershed development in the Clear Creek Drainage District and City of Friendswood planning area. The planning area encompasses the downstream portions of Marys, Cowarts, and Chiggers Creeks located in the City of Friendswood City Limits. Clear Creek, the receiving stream, is not included in this study. Within the planning area there are a significant number of National Flood Insurance Repetitive Flood Loss locations which demonstrates the need to provide flood protection planning. Additionally, there are a large number of small detention ponds associated with small, developed tracts that require significant maintenance. In order to reduce the number of small ponds required, especially for 5 ac. or less tracts of land, regional detention basins are needed.

Public meetings were held at three times during the study. The first public meeting was held at the beginning of the study period to present the goals and objectives of the study. The second public meeting was held at the 50% completion stage. In this meeting the preliminary results were presented and comments were received from residents regarding the study. The third and final public meeting was held just prior to the completion of the study and the final results were presented. Final comments from the public were incorporated into this report.

Alternatives to reduce flooding that were evaluated in this study include regional detention, non-structural alternatives, and channelization. Currently the Clear Creek Drainage District is excavating two regional detention sites. A 40-ac. tract of land on Cowarts Creek will provide 239 ac-ft. of volume. A 33-ac. tract of land on Chiggers Creek will provide 137 ac-ft. of volume. These locations were analyzed and the average reduction in flow and water surface elevation was determined. For the recommended design, benefits such as the average drop in flow and average drop in water surface elevation were determined. The average decrease is computed using the value at the pond location as well as the mouth of the tributary. The average

drop in flow (water surface elevation) is 297 cfs (0.36 ft.) for the 10-year and 122 cfs (0.14 ft.) for the 100-year on Cowarts Creek and 111 cfs (0.17 ft.) for the 10-year frequency on Chiggers Creek. A negligible increase is seen for the 100-year frequency on Chiggers Creek. Additionally, capacity could be provided in the streams to allow up to 200 ac. of development on Cowarts Creek. It is not recommended that this full amount of development be allowed because of the significant reduction in benefits of the regional detention to the tributaries. Some percentage of this development, determined by the needs of the CCDD and COF, could be allowed. The overall reduction in flood plain area for both tributaries is 9.20 ac. for the 10-year and 3.21 ac. for the 100-year frequency, without the additional development.

Future regional detention sites would allow for increased benefits on each of the streams, including Marys Creek. For Mary's Creek, the average benefits up to the County Line are a reduction in flow (water surface elevation) of 168 cfs (0.23 ft.) and 240 cfs (0.41 ft.) for the 10-year and 100-year frequencies respectively. For Cowarts Creek the average drop in flow (water surface elevation) is 494 cfs (0.74 ft.) for the 10-year and 655 cfs (0.71 ft.) for the 100-year frequency. On Chiggers Creek the average decrease in flow (water surface elevation), including the benefits of the pond on Eagle Creek are 174 cfs (0.24 ft.) and 239 cfs (0.26 ft.) for the 10-year and 100-year frequencies respectively. The total decrease in the riverine flood plain area, if improvements are provided on the main tributaries, is 23.79 ac. for the 10-year (10%) and 55.51 ac. for the 100-year frequency (10%).

The locations that would benefit from non-structural alternatives are for the most part influenced by the flood stages on Clear Creek. Since it is not possible to reduce the stages on Clear Creek with alternatives presented in this study, it is recommended that structures deep within the Clear Creek flood plain be considered for property acquisition by the Clear Creek Drainage District or City of Friendswood. Finally, it was determined that the implementation of any channelization alternatives would be difficult since the Clear Creek Drainage District does not have continuous right-of-way along the channels and there are a large number of property owners from which right-of-way would need to be acquired. It is recommended that the Clear Creek Drainage District continue its practice of acquiring right-of-way as it becomes available so that in the future, channelization alternatives might become more feasible.

The cost associated with regional detention was determined based on land cost, excavation amount and the cost of building a diversion structure. The cost to fully implement the existing regional detention sites would be $6,761,000 or $17,000 per ac-ft. of volume. Future regional detention sites are considerably more expensive at a total cost of $19,591,000, or between $16,000 and $25,000 per ac-ft. of volume, depending on the location.

Implementation of this project will require participation from several entities. Benefits will be provided to both the Clear Creek Drainage District and the City of Friendswood for the existing ponds. Future ponds are partially located in Brazoria County, providing that area with benefits, thus Brazoria County Drainage District No. 4 and the City of Pearland would also be potential participants. Based on the mutual benefits realized from the proposed improvements, cost sharing between the participants, including funding and in-kind services, could be pursued. Additionally, since the proposed improvements allow for some additional acreage to develop without detention, some capacity in the regional detention basins could be sold to small developments.

I. PROJECT SCOPE AND BACKGROUND

The City of Friendswood (COF) and the Clear Creek Drainage District (CCDD) are located in the Clear Creek Watershed and specifically the Marys, Cowarts, and Chiggers Creek sub-watersheds. (See Exhibit 1.) The focus of this study is Marys Creek, Cowarts Creek, Chiggers Creek and Eagle Creek, a tributary to Chiggers Creek. Portions of the study area are affected by Clear Creek, but improvements to Clear Creek are outside the scope of work. Modeling has been performed on these tributaries in the past so existing models are available. Flood protection planning has also been performed on these tributaries; however, that planning was based upon the assumption that the U S Army Corps of Engineers (USACE) would improve conveyance on Clear Creek, increasing its capacity. This improvement has not occurred. Thus it has become necessary to modify the existing flood protection plan to reflect more accurate assumptions. The large number of repetitive losses in the planning area indicate that there is a need to revise the recommended flood protection planning for existing conditions. Alternatives to accomplish this include detention, non-structural methods, channelization, and any combination of these alternatives.

The goal of the planning is to recommend means to reduce the flood plain area and alleviate flooding at as many repetitive loss properties as possible as well as reduce flood stages in the main tributaries and facilitate secondary system drainage. Additionally, planning should provide for orderly watershed development especially in regards to the development of small tracts (up to 5 ac.). As development occurs, mitigation for future conditions will need to be based on improved channel conveyance along major tributaries and Clear Creek or controlled through on-site detention or regional detention with costs borne by developers. Major developments should use on-site detention to control developed runoff.

Therefore, the purpose of this study is to use existing condition models to determine alternatives for alleviating flooding in the planning area for existing conditions and to allow for orderly watershed development of small tracts. Additionally, an implementation plan including construction costs will be studied and recommendations made regarding cooperation and inter-

local agreements between entities. Public meetings will be held to present results of the study and to receive comments from the residents.

II. DATA COLLECTION

1. Modeling Information

Prior to the analysis phase of the study, a data collection phase was performed. The following information was collected.

a. Existing conditions HEC-1 models – The HEC-1 models for Cowarts, Chiggers (including Eagle Creek) and Clear Creeks were taken from the "Hydraulic Baseline Report" prepared for the Clear Creek Watershed by Dannenbaum Engineering Corporation (DEC) in 1991. The HEC-1 model for Marys Creek was taken from the "Mary's Creek Modeling Update" prepared by DEC in 1997.

b. Existing conditions HEC-2 models – The three main tributaries were modeled using HEC-2 in the "Hydraulic Baseline Report" funded 50% by the Texas Water Development Board (TWDB) and 50% by Harris County Flood Control District (HCFCD) and completed by Dannenbaum Engineering Corporation in 1991. The Eagle Creek model has only recently been modeled using HEC-RAS in an independent project sponsored by the Clear Creek Watershed Steering Committee. Also included in the Steering Committee project was an update of the main tributaries with improvements that have occurred since the original modeling update. The updates include channel improvements, bridge construction and superior topographic survey performed after the original models were created. The updated models, created by Dannenbaum Engineering Corporation, were used as a base for this study. The HEC-2 model elevations are based on the 1978 Datum Adjustment. The HEC-RAS model is based on the 1987 Adjustment. The conversion from the 1987 to 1978 Adjustment is +0.43 ft.

c. Future pond locations – A meeting was held with the Clear Creek Drainage District and the District's Engineer to identify land that was available for purchase in the City of Friendswood, as well as just across the Brazoria/Galveston County Line. From the verbal information received in this meeting, the use of aerial photos and information from the Brazoria County Appraisal District, future detention locations to be analyzed were identified.

d. Available channel right-of-way – The availability of channel right-of-way and the feasibility of channel improvement issues were also discussed at the above-mentioned meeting. The amount and location of channel right-of-way was taken from the Clear Creek Master Drainage Plan dated December, 1992. For the most part, channel right-of-way is not available and the feasibility of channel improvement is limited by a sand layer below the existing channel flow line along most of the study area.

e. Survey - Survey information was acquired on selected house slab elevations and is discussed in more detail in Section IV of this report.

2. Public Meeting Information

Three public meetings were held for this project, corresponding to the beginning of the project, the 50% completion stage, and just prior to the final report submittal. The public, elected officials and interested parties were invited to attend the meetings and give input regarding the project. The first public meeting was held on February 22, 2001 to present the goals and objectives of the project. The second public meeting was held on May 31, 2001 to present the preliminary results developed in the study. The final public meeting was held on July 12, 2001 to present the final results and receive any final comments to be incorporated into the report.

Comments were not given at the first public meeting. At the second public meeting verbal comments were received from four residents. The majority of the comments pointed out that the recommendations outlined in this study would not correct the major problem in the area which is flooding on Clear Creek. The residents who pointed this out said that the money required to implement this plan would be better spent in trying to convince the USACE to fully implement improvements on Clear Creek. One resident disagreed with this view however, and mentioned that while the recommendations presented in this study would not correct all of the problems, at least it is a step in the right direction.

The third public meeting had the best attendance of the three meetings since, in the time between the second and third public meetings, a tropical storm caused widespread flooding in the

Friendswood area. As with previous meetings, the majority of the comments were not related to the Drainage Study presentation. A large portion of the comments focused on questions regarding the jurisdiction and maintenance of drainage systems and flooding problems outside the flood plain. These issues were addressed by the CCDD Board Members. A few comments were once again directed towards problems on Clear Creek. This was expected since the actual flooding experienced during the tropical storm was due to high elevations on Clear Creek. Comments related to the study included questions about when the existing regional detention site excavation would be completed and if the money for the construction of the ponds had already been authorized. One resident questioned what type of channel improvements were ultimately planned in conjunction with the detention locations. The majority of the comments regarding the study requested clarification of how the regional detention sites would help each individual resident. It was explained that these ponds would not necessarily benefit those residents who flooded due to localized problems.

III. CALIBRATED EXISTING CONDITIONS

HEC-1 and HEC-2/HEC-RAS modeling are used in this study to determine the impacts of the studied alternatives. In order to allow a direct comparison between existing conditions and the revised conditions that reflect the improvements, it is necessary to calibrate the existing condition models. For the HEC-1 modeling, all information is acquired at node locations, therefore it is necessary to place nodes at each location where information will be required, or in other words, where the alternative information will be input into the model. In the calibrated model, nodes are placed at future improvement locations, without adding the improvements. In this way, a direct comparison between calibrated existing conditions and revised conditions can be made. Similarly, for the HEC-2 model any additional cross section locations or change in flow values that will be required in the alternative analysis need to be input into the calibrated model without the improvements to facilitate the comparison.

For Marys and Cowarts Creeks, the existing HEC-1 and HEC-2 models contained all of the information necessary for adding alternative improvements, so that a separate calibrated conditions model did not need to be created. For Chiggers Creek, two calibrated models were created. For the existing pond analysis, a node (CH100#2A) was input at the 33-ac. pond diversion location and the existing channel routing reach divided into two segments. The routing reach from CH100#2 to A100#10 was divided into reaches from CH100#2 to CH100#2A and from CH100#2A to A100#10. Exhibit 2 shows the location of the additional node. For the future pond analysis, it was necessary to subdivide the Chiggers Creek sub-watershed containing Eagle Creek so that the effects of a future pond on Eagle Creek could be determined. The existing sub-area was divided into five smaller sub-areas, with three covering Eagle Creek and two on Chiggers Creek. An additional node was added along the Eagle Creek reach (CH100#3A) and at the confluence of Eagle Creek with Chiggers Creek (CH100#3). Exhibit 2 shows the calibrated sub-area breakdown and node locations.

IV. TARGET ELEVATIONS

1. Repetitive Loss Survey

A selective number of house slab elevations were acquired through in-house survey and information requested from the U.S. Army Corps of Engineers (USACE) as a means of determining target elevations for each tributary. The purpose of the target elevations is to determine the level of flood protection required for each tributary, which aids in the selection of the alternative for implementation. The determination of which house slab elevations to survey was based on National Flood Insurance Program (NFIP) repetitive loss information. A list of the homes that have filed flood insurance claims as of November 1997 was acquired and consists of approximately 320 locations. (See Exhibit 3.) Since it was cost prohibitive to survey each of these houses, an assumption was made that houses with the most claims have the worst flooding problems and that those homes with 4 or more claims would provide a representative sample of homes with flooding problems. Thus a list of 69 homes, or 22-percent of the repetitive loss claims, was compiled and the survey information acquired for these locations.

Repetitive loss information from 1979 to 1997 was used to determine the average claim value during that period of time. The total property loss was $27,900,000 from 680 claims or $41,000 per claim. An estimate was made of the average claim per acre of flood plain by saying that three losses per acre were paid. The resultant claim per acre is $123,000 per acre.

All survey information was tied to benchmarks set up in conjunction with the USACE General Re-Evaluation Report for Clear Creek which will be completed in 2003, and are based on NAVD88 (2000 Epoch). A physical tie was made between these benchmarks and FEMA benchmarks (1978 Datum) located on each tributary to provide an adjustment factor. All house slab elevations were converted to the 1978 adjustment so that a direct comparison could be made with the hydraulic model flood stages for the tributaries.

Table 1 presents the house slab elevation information. The elevations for each location are presented as well as the tributary on which they are located, the 100-year water surface elevation taken from the hydraulic models, and observations regarding the surveyed location. It can be seen that of the 69 houses surveyed, 39 of them are affected by the Clear Creek 100-year water

elevation. These homes are primarily located at the confluence of each tributary with Clear Creek. Of these locations, 28 are located between the 10-year and 50-year flood levels, 5 are located between the 5-year and 10-year flood levels, and 5 are located below the 5-year level. This information is useful in determining the effectiveness of non-structural alternatives.

Of the 69 houses surveyed, 30 were located outside the influence of Clear Creek. When compared with the 100-year water surface elevation taken from the hydraulic model, only 3 of these homes are lower than this elevation. This is an unexpected result since the assumption was made that those houses with 4 or more repetitive loss claims would be the deepest in the flood plain. A more detailed investigation was performed to determine if there was a valid reason for these results. This investigation included looking at the hydraulic models in the vicinity of the locations, researching high water marks in the area, and performing a field visit. The explanations for discrepancies at each location are listed under "Observations" in Table 1.

Subsequent to the field visit in which explanations for flooding were determined, tropical storm Allison caused widespread flooding in the Friendswood area. After this flooding event, the project team was able to visit the sites once again and see first hand the causes of flooding at the surveyed locations.

2. Tropical Storm Allison

Tropical storm Allison caused widespread flooding in the Friendswood area. On Tuesday, June 5, 2001, the storm entered the area dropping at least 8 inches of rain in 24-hours. The system stalled as it moved inland resulting in an additional 11 in. – 17 in. of rainfall through Saturday, June 9, 2001. The 5-day storm total at one location showed that 28 inches of rain had fallen.

Subsequent to this flooding event, high water marks were measured in several locations including the Imperial Valley subdivision, which is adjacent to Clear Creek. From the water depths measured in this location, flood stages on Clear Creek were verified to be in excess of the 100-year frequency. Additional high water marks in other locations showed the flood stages to be in excess of the 500-year frequency. High water marks measured along the tributaries showed that the elevated stages on these creeks was due to the backwater effect of Clear Creek.

Flooding reports were received from areas outside the influence of Clear Creek; however, in these cases the flooding was due to localized problems or the house slab elevations were significantly lower than surrounding houses.

Based on the survey information, in conjunction with the results from recent flooding, definite target elevations on the tributaries could not be set to provide guidance in determining the level of protection required on each tributary. The majority of the flooding appears to be caused by high water elevations on Clear Creek or localized drainage problems. The improvements that are recommended in this study would not affect the elevations on Clear Creek, which is the main cause of flooding. Therefore, relative benefits of the drainage study improvements are presented, since any drop in water surface elevation on the tributaries will provide some benefit to the area. An example of a relative benefit analysis would be to determine the existing levels in the tributaries and compare these elevations with the reduced stages resulting from drainage improvements. The relative difference between the elevations in these models is the benefit seen.

V. ALTERNATIVE ANALYSIS

1. Existing Regional Detention Locations

The Clear Creek Drainage District has acquired acreage for use in regional detention on both Cowarts and Chiggers Creeks. A 40-ac. tract of land is located on Cowarts Creek, upstream of the Baker Road bridge, on the southeast side of the channel and can provide approximately 266 ac-ft. of volume. A gravel access road that crosses a portion of the detention pond will need to be maintained, therefore an equalizer culvert under this road was designed. The small amount of off-site sheet flow to the area is re-routed around the pond in an interceptor ditch. A 33-ac. tract of land is located on Chiggers Creek, downstream of Windsong and south of the creek and is split into two separate areas by a Phillips pipeline easement. Ultimately this pond will provide 155 ac-ft. of detention volume. This pond has an area of off-site sheet flow that drains to the pond, which cannot be re-routed around the pond. Also, due to the high tailwater conditions on Chiggers Creek, the off-site flow cannot simply be conveyed through the pond and some volume must be stored. Therefore, a portion of the detention volume will be utilized for this off-site area. Excavation has occurred on both ponds as means of disposing of the dirt have become available.

Originally, the analysis for these ponds was performed for two scenarios so that a determination of the most effective use of the ponds could be made. The first scenario was to mitigate for the 10-year frequency only, utilizing the entire pond volume to lower the flows for this frequency. The second scenario was to reserve some volume in the pond to mitigate for the 100-year frequency. In this way, while a somewhat smaller reduction would result for the 10-year frequency, a reduction in the 100-year flow could be provided as well. However, comments received from the review of the draft report pointed out that it would not be feasible to mitigate for both the 10-year and 100-year frequencies. The ponds are designed to provide benefits for the 10-year frequency.

Since the previously mentioned sites have already been purchased, a detailed analysis of the detention design was performed using the Advanced Interconnected Pond Routing (AdICPR) model to support the preparation of construction plans. A time-stage relationship was developed based on the HEC-1 and HEC-2 models to simulate the flow in each creek at the detention pond

diversion location. A stage-area relationship was developed for each of the detention ponds based on preliminary sizing information provided by the Clear Creek Drainage District. For the "10-Year Only" design, the 10-year time-stage relationship was used at the inflow point to the pond. Using an iterative process, a structure was designed to divert flow from the creek to the detention pond. The goal was to design a structure that would provide the most efficient use of the pond volume to decrease stages on the tributaries. The AdICPR analysis provided a time-discharge relationship for the final structure but could not be used to determine the amount of mitigation provided on the stream. For this, HEC-1 modeling was used.

As described previously, a calibrated condition HEC-1 model was developed to provide a creek hydrograph at each pond location. Using this hydrograph and the time-discharge relationship developed in AdICPR, the impact of the detention improvements was determined in one of two ways. For the Cowarts Creek pond an inflow-outflow (DI-DQ) relationship was created. In a DI-DQ relationship, for every flow in the creek hydrograph, a corresponding diversion amount is provided. As the flow in the creek hydrograph, and thus the corresponding water surface elevation, increases, the amount of flow diverted to the detention pond increases until the pond is filled to its maximum volume. The resultant hydrograph is comprised of the flow that was not diverted and, when compared with the creek hydrograph, shows the mitigation amount or decrease in creek flow. For the Chiggers Creek pond a supplied hydrograph (QI) was added to the model to simulate flow from the creek to the pond. A final step in the analysis was to convert the decrease in flow to a corresponding decrease in water surface elevation from the pond location downstream to the confluence with Clear Creek by utilizing the HEC-2 model for each creek.

Cowarts Creek

In the "10-Year Only" analysis for the 40-ac. pond on Cowarts Creek, a single weir structure was designed. For this pond, the maximum 10-year water surface elevation in Cowarts Creek is greater than the lowest top of bank of the pond. Therefore, it was necessary to ensure that the amount of flow diverted to the pond was large enough to decrease water elevations to below top of bank downstream of the inflow structure. The structure consists of a 160 ft. weir at elevation 28.9 ft. The maximum water surface elevation in the pond is 28.79 ft. which is 0.21 ft. lower

than top of bank and corresponds to 239 ac-ft. of volume. This diversion amount decreases the flow in Cowarts Creek by 382 cfs at the pond location and 212 cfs at the mouth of the tributary. (See Table 2.) The corresponding decrease in water surface elevation averages 0.36 ft from the confluence with Clear Creek to the Brazoria/Galveston County Line. (See Table 3.) The reduction in the 10-year flood plain area is 3.68 ac. The pond was designed for the 10-year frequency only, however, due to the shape of the inflow hydrograph, a residual decrease in flow of 243 cfs is seen for the 100-year frequency at the mouth of the tributary. This decrease in flow results in a average drop in water surface elevation of 0.14 ft.; however, this drop only occurs along a short reach of channel, so that the 100-year flood plain area reduction is only 3.21 ac. The proposed pond layout is shown in Exhibit 6.

Chiggers Creek

In the "10-Year Only" analysis for the 33-ac. pond on Chiggers Creek, a weir structure was also designed. The weir consists of a 50 ft. weir at elevation 25.0 ft The maximum water surface elevation in the pond is 26.0 ft. which is 1.5 ft. lower than the lowest top of bank, and corresponds to 137 ac-ft. of volume. This diversion amount decreases the flow in Chiggers Creek by 64 cfs at the pond location and 157 cfs at the mouth of the tributary. (See Table 2.) The corresponding decrease in water surface elevation averages 0.17 ft. from the confluence with Clear Creek to the Brazoria/Galveston County Line. The reduction in the 10-year flood plain area is 5.52 ac. (See Table 3.) Since the pond was designed for the 10-year frequency only, a drop in flow and water surface elevation is not seen for the 100-year frequency. From Table 3 it can be seen that there is a slight impact due to the 33-ac. pond for the 100-year frequency, which is at most a 0.05 ft. increase. This impact is due to the fact that a portion of the 33-ac. pond receives runoff from the off-site area, mentioned previously. Also, the proposed weir allows flow to communicate between the creek and the pond at an elevation where flow previously would not occur. The runoff fills the pond before the stages on Chiggers Creek rise and thus reverse flow occurs through the weir. Also, after the peak flow occurs on Chiggers Creek, the weir allows some detained flow to drain out which increases the creek flow by no more than 12 cfs. Although this slight impact is seen at the pond location, residual benefits are provided at the mouth of the creek so the impact is considered negligible. The proposed pond layout is shown in Exhibit 7.

One goal outlined in the scope of work is to provide for orderly watershed development. One of the current needs in the COF is to limit the number of detention ponds on small tracts (5 ac.). While the existing ponds are designed for the 10-year frequency only, with the residual 100-year benefits it might be possible to allow these small tracts to purchase capacity in the regional detention ponds and then drain directly to the creeks, without causing an impact. An analysis was performed where the amount of development was increased by 200 ac. on both Cowarts and Chiggers Creeks. The results are presented in Table 9. The results show that the increased development can be mitigated on Cowarts Creek; however, the benefit of the regional detention to the creek is significantly reduced. On Chiggers Creek the increased development causes an impact at the pond and there is a slight increase in flow at Clear Lake. On Chiggers Creek it is recommended that the full detention capacity be used to correct existing flooding problems. It is recommended that only a portion of the regional detention capacity on Cowarts Creek be sold for additional development. This will limit the amount of allowable development to less than the 200 ac. mentioned above. The exact amount will need to be determined based on the needs of the CCDD and COF. Only those tracts that can drain directly to Cowarts Creek will be able to purchase capacity in the regional detention basins.

2. Future Regional Detention Locations

The future regional detention locations identified in the data collection phase of the study were analyzed using a less detailed method than that used for the existing regional detention locations which still allowed for the overall effectiveness of the detention to be determined. Whereas in the existing detention analysis, the inflow-outflow relationship was taken from an AdICPR analysis, for the future ponds, the inflow-outflow relationship was determined graphically, based on the pond volume available for each frequency. The creek hydrograph was plotted and then a flow diversion amount was chosen so that all of the flow greater than this amount was diverted to the pond. Using an iterative process, the flow diversion amount was varied until the amount of volume being diverted (area under the curve and above the diversion amount) equaled the available detention site volume.

In order to determine the most realistic amount of future detention for the analysis, tracts of undeveloped land that might become available for purchase were chosen for the calculations.

For each tract, the maximum available volume was determined based on the available acreage, depth of the pond, and assuming 4:1 side slopes were used. For all ponds, a 150-ft. tree buffer was left adjacent to the creek. To determine the depth, natural ground and flow line elevations were taken from available topography and the HEC-2 cross section information, and 1-ft. of freeboard was assumed.

While specific tracts were utilized as a guide for the analysis, it should be noted that future detention considerations do not need to be limited to the locations chosen in this analysis. For that reason, the approximate location of the detention pond is shown on Exhibit 4 with a dashed oval. Any available land in the area around the detention ponds could be used for future detention volume. The locations that were studied as future regional detention sites are as follows:

- 55 ac. on Marys Creek, located at the confluence of Marys Creek and Marys Creek Bypass in Brazoria County
- 98 ac. on Cowarts Creek located adjacent to the existing 40 ac. pond location and along the Cowart Creek tributary CW102-00-00 near the confluence with Cowarts Creek
- 28 ac. on Chiggers Creek upstream of Windsong Drive
- 20 ac. on a small tributary of Eagle Creek

The Marys Creek detention pond was assumed to provide 418 ac-ft. of volume and was designed for the 10-year and 100-year frequencies. Using the inflow-outflow diversion, the amount of flow on Marys Creek was reduced by 235 cfs and 240 cfs at the pond location and 101 cfs and 239 cfs at the confluence with Clear Creek for the 10-year and 100-year frequencies, respectively. (See Table 4.) In order to determine the resulting decrease in water surface elevation, the split flow analysis between the Marys main channel and bypass was recomputed, and the model was run. While a decrease in water surface elevation is seen throughout the entire reach from the pond location to the confluence, the CCDD and COF jurisdiction is only to the Brazoria/Galveston County Line. The average drop in water surface elevation from the County Line to the confluence is 0.23 ft. for the 10-year and 0.41 ft. for the 100-year frequency. The reduction of flood plain area within the COF City Limits is 0.59 ac. for the 10-year and 1.83 ac.

for the 100-year. (See Table 5.) This slight reduction is expected since the flood plain is mostly within banks through the COF.

The Cowarts Creek detention volume was divided into two pond locations. With two ponds, the upstream pond had to be designed first because the reduction in flow provided by this pond would change the shape of the inflow hydrograph to the downstream detention pond. The upstream detention pond mitigates flows on the tributary CW102-00-00, reducing the amount of flow to Cowarts Creek. The downstream pond models an expansion of the 40 ac. pond located at the County Line that would be possible if adjacent land is acquired. The combination of these two ponds decreases the flow in Cowarts Creek by 592 cfs and 653 cfs at the downstream pond location and 395 cfs and 586 cfs at the confluence with Clear Creek for the 10-year and 100-year frequencies, respectively. (See Table 4.) The average drop in water surface elevation within the COF is 0.74 ft. for the 10-year and 0.71 ft. for the 100-year. The 10-year flood plain area is reduced by 12.0 ac. and the 100-year flood plain area is reduced by 33.63 ac. (See Table 5.)

The Marys Creek and Cowarts Creek ponds were designed to provide mitigation for both the 10-year and the 100-year frequency in one pond. Similarly, the future pond on Chiggers Creek at Windsong is designed for both frequencies; however, the existing pond design will remain effective for the 10-year frequency. The existing pond designed for the "10-Year Only" conditions is combined with a "10-Year and 100-Year" design for the future pond location just upstream so the combination of the two ponds provides an efficient mitigation for both the 10-year and 100-year frequencies on Chiggers Creek. An additional 86 ac-ft. of volume is available in the future detention pond. The combined pond system decreases the flow in Chiggers Creek by 189 cfs and 187 cfs upstream of the confluence with Eagle Creek for the 10-year and 100-year frequencies, respectively. (See Table 4.)

One future regional detention site is located on Eagle Creek. Flow from the Mission Estates and Carmel Village subdivisions, located at the upstream end of Eagle Creek is diverted to the 77 ac-ft. future detention pond located on a small tributary to Eagle Creek. (See Exhibit 4.) A diversion channel will need to be constructed to convey the flow to the pond and the pond will drain through a small restrictor pipe into the tributary of Eagle Creek so that the flow to this

tributary is limited and does not negatively impact downstream reaches. This detention pond decreases the flow downstream of Mission Estates and Carmel Village by approximately 200 cfs for both the 10-year and 100-year frequencies. This flow decrease could be utilized to reduce water surface elevations along the entirety of Eagle Creek by a small amount; however, it appears that the most effective use of the benefits provided by detention would be to correct localized flooding problems as possible.

The City of Friendswood Master Drainage Plan, Phase I (1993) identifies two localized problem areas north of the proposed diversion. Recommendations to eliminate the flooding presented in the Master Drainage Plan include increasing the capacity of existing culverts. Under existing conditions these improvements cannot be performed since they would cause an increase in flow downstream. The most effective use of the detention on Eagle Creek would be to allow the culvert capacity to be added. A HEC-1 model was run with an increased conveyance value to model the culvert improvements. The flows from this model were input into the improved Eagle Creek HEC-RAS model, which contains the improvements outlined in the Master Drainage Plan and the resulting change in water surface elevation was computed. The increased flow from the improvements is fully mitigated in the detention pond. The average drop in water surface upstream of the detention diversion is 0.75 ft. for the 10-year frequency and 1.36 ft. for the 100-year frequency.

The combination of the future ponds on Chiggers and Eagle Creeks gives a reduction of flow at the mouth of Chiggers Creek of 226 cfs for the 10-year and 355 cfs for the 100-year. This decrease provides an average reduction in elevation along Chiggers Creek of 0.24 ft. for the 10-year and 0.26 ft. for the 100-year frequency. The reduction in the 10-year flood plain area is 11.22 ac. and the 100-year reduction is 20.05 ac. (See Tables 4 and 5.)

3. Non-Structural Alternatives

As defined in the scope of work, the non-structural alternative involves studying the purchase of the 100-year flood plain as a means of eliminating future losses. On the major tributaries Marys, Cowarts, and Chiggers, the 100-year flood plain is affected by two conditions. One condition includes the backwater effects from Clear Creek main channel and the other is related to the

flood plain generated by riverine conditions on the tributary itself. For this report only the 100-year flood plain purchase associated with the riverine conditions on the tributaries will be considered since the scope of work does not extend to Clear Creek. As an alternative, flood plain purchase represents the worst case scenario, since it assumes that all the property in the flood plain is subject to flooding and neglects those structures raised above the 100-year elevation. From existing models, approximately 415 acres (not including channel top width) are in the combined tributary 100-year flood plain (riverine only) and it was assumed that approximately 52% of the area is developed. Using 1998 real estate data, the approximate median home value for Friendswood is $130,000, or $390,000 per acre if three houses are developed in one acre. Undeveloped land can be priced at $30,000 per acre on average. Acquisition of the developed and undeveloped land within the 100-year riverine flood plain on Marys, Cowarts and Chiggers Creeks would cost approximately $152,660,000. (See Table 6.)

As seen from the above calculation, acquisition of the entire flood plain is not cost effective, and generally does not have public support. Instead selective acquisition has proven effective. For instance, acquisition is targeted towards those houses that are deep in the flood plain and are least likely to see benefits from structural improvements such as detention and channelization. In general, those properties below the 5-year flood stages are potential candidates for acquisition. In addition to acquisition, in some locations it may be possible to relocate the structure to higher ground or raise the floor elevation. Also, flood proofing of existing structures can be effective. Several techniques have been used in the past including placing berms and flood walls around buildings and dry/wet flood proofing. While these two final options provide protection for the structure, FEMA does not recognize these practices as removing the structure from the flood plain for residential structures.

While selective property acquisition is presented as an alternative to reduce flood damage, in this study location specific recommendations are not made. The slab survey information presented in Table 1 shows that along the tributaries the structures are not low enough to meet the general criteria for property acquisition. There may be some locations that are candidates since the values presented in Table 1 are a small sample of repetitive loss locations and does not include those structures without flood insurance. A survey of flooding by local entities would be

required to locate these structures. As mentioned previously, the study does not include Clear Creek; however, from Table 1, it can be seen that several locations along the creek meet the general criteria for property acquisition. These and similar locations may be helped by the USACE General Re-evaluation Report on Clear Creek, but in the interim are potential acquisition locations.

4. Channel Improvements

Channel improvements are included as an alternative to analyze in the scope of work; however, due to several issues, channel improvements may not be feasible at this time. First, the major tributaries in the COF have sandy soils close to their existing flow line, making it difficult for channel deepening. Second, there is not a continuous channel right-of-way (ROW) or easement available for the tributaries. Due to the large number of property owners along the channels, acquisition of the amount of ROW necessary for significant channel improvements will most likely not be feasible. Based on the previous facts, a regional channelization alternative was not evaluated in the study. Since the effectiveness of channel improvements in reducing flood stages is well known, it is advisable to promote right-of-way/easement acquisition for future improvements as well as being able to perform routine maintenance. The regional detention future conditions presented in this study would allow for future channel improvements if the necessary R.O.W. is eventually acquired. One final issue is that some reaches of the major tributaries are considered jurisdictional by the USACE either by Section 10 or Section 404 when wetlands may be involved. The CCDD exercises care when improving channels that may require a USACE permit.

VI. COST ESTIMATES

Probable construction costs for drainage improvements were computed for all detention sites and grouped under existing or future conditions (see Tables 7 and 8). The construction cost covers all work associated with the detention basin construction. Right-of-way costs for detention facilities and associated appurtenances were also included in this estimate. The latest unit prices from Clear Creek Drainage District (CCDD), Harris County Flood Control District (HCFCD), and private developers on similar projects form the basis for the costs utilized for this report. For the culvert improvements on Eagle Creek, the actual cost (less contingencies and engineering) was taken from the City of Friendswood Master Drainage Plan. A 15% contingency value is included in the cost as well as 10% engineering fees. The total probable construction cost for all drainage improvements is approximately $6,761,000 and $19,591,000 for existing and future conditions, respectively. A portion of the existing regional detention cost has already been expended by the Clear Creek Drainage District through the purchase of land and partial excavation of the sites. The construction cost presented assumes that a public bid will be taken for drainage improvements, however cost savings can be made if the CCDD performs construction work with its own forces.

VII. IMPLEMENTATION PLAN AND SCHEDULE

In order for a Regional Drainage Plan to be effective, it must be able to be implemented. The results presented in this analysis are such that the improvements can be effectively performed in phases. The existing detention sites can be excavated in stages as disposal locations for the dirt become available. The control structure can be constructed as funding becomes available at any time prior to full excavation of the detention pond. Future regional detention sites, which are conceptual and not tied to a specific location, can be acquired as land becomes available in the general vicinity and as funding is secured. Excavation in these future sites can be performed in stages just as with the existing ponds. Channel ROW can be acquired when possible. An implementation plan can be developed as follow:

1. Continue with the construction of existing detention sites.
2. Acquire right-of-way for future detention sites and channel easements for maintenance and channel improvements.
3. Address localized flooding issues based on benefits provided by detention sites such as on Eagle Creek.
4. Start construction of future detention sites.

A more detailed schedule for the implementation can be prepared, as funding sources become available.

As shown in this study, some of the future regional sites would be located in Brazoria County, outside of the project area, since Friendswood is fairly developed and available sites are limited. In these cases, inter-local entity agreements will be required when a project of mutual benefit is found. Most likely the CCDD and the COF would coordinate with Brazoria County Drainage District #4 (BCDD#4) and the City of Pearland regarding implementation of detention sites outside the service area.

Once a phasing plan of mutual benefit to the various entities is identified and agreed upon, each entity will collect funds through whatever method they wish. Funds can be available from ad

valorem taxes levied on taxable property, the sale of bonds, Federal Grants, TWDB low-interest loans and Texas Parks and Wildlife Department grants. A CIP program could be scheduled over a period of 10 years to allocate funds for construction and predict cost sharing by each entity. An additional element could be the selling of regional basin capacity to small developments. The CCDD would take the lead in approaching other entities for the phasing of the improvements recommended in this Regional Drainage Study. One advantage of cost sharing could be in-kind services. For instance, BCDD#4 could use its own forces to excavate detention sites in Brazoria County. More input from the entities will be sought to establish an implementation plan as sites and funding sources become available.

VIII. RESULTS AND RECOMMENDATIONS

This Regional Drainage Study has provided an analysis of several flood protection alternatives. In general it has been determined that there are means to reduce the flood levels in the tributaries and provide relief from flood stages by a small amount. It was also determined that the most severe flooding problems are a result of stages on Clear Creek. A more detailed discussion of results and recommendations is provided below.

It has been shown that the existing regional detention sites are able to provide effective benefit through a drop in flow and water surface elevation for a single frequency with residual benefits for multiple frequencies. The 40-ac. detention on Cowarts Creek is designed to mitigate for the 10-year frequency, since the control structure will fully reduce the peak flow by 212 cfs. For the 100-year frequency, the pond banks will be overtopped so complete reduction of the peak is not possible. A residual reduction of 243 cfs is provided at the mouth of the creek but the benefits are not seen along the entire reach. The 33-ac. pond on Chiggers Creek receives some direct runoff from off-site areas, but still provides benefit by reducing the 10-year peak flow by 64 cfs. For the 100-year frequency, due to the timing of the off-site runoff, a slight impact in flow and stages is seen on Chiggers Creek but can be considered negligible. The estimated cost for the existing regional drainage site development is $6,761,000. While some amount of development could be allowed to drain to Cowarts Creek without detention, it is recommended that only a portion of the detention capacity be used for this purpose. Therefore, the amount of allowable development will be less than the 200 ac. mentioned previously and should be determined based on the needs of the CCDD and COF.

In the future detention analysis, it is recommended that a detention design provide mitigation for both the 10-year and the 100-year frequencies for a few reasons. First, the target elevation information gathered in this study does not provide a clear picture of the level of flood protection that should be provided. Secondly, while channel improvements do not seem feasible at this time, it is possible that in the future, acquisition of ROW will allow channel improvements to occur. If the pond is designed to mitigate for both frequencies, then the impact of these channel improvements can most likely be mitigated. Also, it will be possible to sell capacity in the ponds

and allow for small tracts to drain directly to the creeks without providing detention. The large cost of land acquisition and detention excavation associated with the future regional detention sites ($19,591,000) will mean that the future benefits will not be provided for several years. It is recommended that the regional detention site on Eagle Creek be partially used to solve localized flooding problems.

In regards to the non-structural alternative, the cost of acquiring the entire flood plain, which is $153 million, prohibits implementation of this alternative. The most likely candidates for acquisition are located in areas influenced by the water elevations on Clear Creek. While, in the future, the USACE may perform improvements to reduce the flood stages on Clear Creek, it is unlikely that full protection will be provided for those structures located below the 5-year levels. Further, it will be several years before any improvements are in place. Thus, acquisition of the structures below the 5-year flood levels appears to be an effective non-structural option. An additional criterion could be to acquire any structures that are substantially damaged after a storm event. Substantially damaged means that the cost to repair the damage to the structure is more than 50% of the value of the home. In Tropical Storm Allison, mentioned previously, approximately 200 homes in the City of Friendswood met this criterion.

In general, channel improvements provide the best benefit-cost ratio, and the fact that this alternative may not be implementable limits the benefits that can be realized in the City of Friendswood. It is strongly recommended that the Clear Creek Drainage District continue its practice of acquiring channel right-of-way as it becomes available so that in the future, channelization becomes a more viable option.

A rough benefit-cost analysis can be performed for the future regional detention alternative. Previously in this report the flood plain reduction for this alternative was given as 56 ac. Thus, based on the claim value of $123,000 per acre determined previously, $6,888,000 in future damages could be avoided. The cost for the future regional detention alternative is estimated at $19,591,000 giving a benefit-cost ratio of 0.35. These numbers show that the cost of the future detention is not necessarily justified by the monetary benefits provided, but the drop in flow and water surface elevation would still be of use in correcting flooding problems.

As mentioned in Section VII inter-local agreements between entities will be required once projects of mutual benefit are recognized. In addition to this agreement a cost-sharing and phasing plan will need to be developed.

Therefore, the recommendations of this study are as follows:

1. Continue with construction of existing detention sites.

2. Once the existing detention pond is fully excavated on Cowarts Creek, facilitate small tract (5 acres or less) development by allowing some amount of development to purchase regional detention capacity and drain directly to the creek without on-site detention. The amount of capacity to be sold will need to be determined.

3. Pursue acquisition and excavation of future detention sites.

4. As possible, acquire right-of-way for channel maintenance and possible future channel improvements.

5. Pursue flood plain acquisition for those structures that are located below the 5-year frequency elevation on Clear Creek or have been substantially damaged in storm events. Federal matching grants are available to local entities to aid in the acquisition of structures.

IX. LIST OF REFERENCES

Claunch & Miller, Inc. and Albert H. Halff Associates, Inc. Master Drainage Plan - Phase I. Houston: Claunch & Miller, Inc., 1993.

Dannenbaum Engineering Corporation. Clear Creek Regional Flood Control Plan Hydraulic Baseline Report. Houston: Dannenbaum Engineering Corporation, 1991.

Dannenbaum Engineering Corporation. Clear Creek Regional Flood Control Plan Master Drainage Plan. Houston: Dannenbaum Engineering Corporation, 1992.

Dannenbaum Engineering Corporation. Mary's Creek Hydraulic Modeling Update. Houston: Dannenbaum Engineering Corporation, 1997.

Federal Emergency Management Agency. Repetitive Loss for Galveston County. Washington D.C.: FEMA, 2000.

John Chance Land Surveys, Inc. GPS Survey Report Mapping Control for Clear Creek, TX Watershed. Lafayette: John Chance Land Surveys, Inc., 2000.

Nguyen, Cuong A. ProHEC1 Plus. Vers. 4.0.1PH. Computer Software. Dodson & Associates, Inc., 1999.

Nguyen, Cuong A. ProHEC2 Plus. Vers. 4.6.2PH. Computer Software. Dodson & Associates, Inc., 1997.

Streamline Technologies, Inc. AdICPR. Vers. 2.11. Computer Software. Streamline Technologies, Inc., 1995.

U.S. Army Corps of Engineers Hydrologic Engineering Center. HEC-RAS River Analysis System. Vers. 3.0.1. Computer Software. Dodson & Associates, Inc., 2001.

Table 1
Slab Elevations

DEC Identifier	Location	# of NFIP Claims	Slab Elevation COE Datum	Slab Elevation FEMA 1978 Datum	Creek	Channel Station	100-Year Model Water Surface 1978 Datum	Difference	Observations
			(ft)	(ft)			(ft)	(ft)	
1	CLOVER RIDGE	4	31.01	31.55	Cowarts	15126	28.14	3.41	Located on tributary - may have localized problems.
2	COWARDS CREEK	3	27.33	27.87	Cowarts	15126	28.14	-0.27	
3	COWARDS CREEK CT	4	26.19	26.73	Cowarts	12326	24.63	2.1	Inaccurate cross section topography.
4	COWARDS CREEK CT	6	25.62	26.16	Cowarts	12326	24.63	1.53	Inaccurate cross section topography.
5	COWARDS CREEK CT	5	25.6	26.14	Cowarts	12326	24.63	1.51	Inaccurate cross section topography.
6	COWARDS CREEK CT	3	26.51	27.05	Cowarts	12326	24.63	2.42	Inaccurate cross section topography.
7	DEEPWOOD	3	22.2	22.74	Cowarts	CCk BW	20.51	2.23	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
8	DEEPWOOD	7	22.5	23.04	Cowarts	CCk BW	20.51	2.53	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
10	DEEPWOOD	7	17.5	18.04	Cowarts	CCk BW	20.51	-2.47	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
11	MERRIWOOD DR	6	23.55	24.09	Cowarts	CCk BW	20.51	3.58	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
12	WOODVINE ST	8	14.6	15.14	Cowarts	CCk BW	20.51	-5.37	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
13	WOODVINE ST	4	15.9	16.44	Cowarts	CCk BW	20.51	-4.07	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
15	DIAMOND LN	4	20.82	21.48	Marys	CCk BW	20.51	0.97	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
16	IMPERIAL DR	4	21.5	22.16	Marys	CCk BW	20.51	1.65	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
17	IMPERIAL DR	5	20.7	21.36	Marys	CCk BW	20.51	0.85	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
18	IMPERIAL DR	5	20.8	21.46	Marys	CCk BW	20.51	0.95	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
19	IMPERIAL DR	5	20.4	21.06	Marys	CCk BW	20.51	0.55	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
20	IMPERIAL DR	4	21.1	21.76	Marys	CCk BW	20.51	1.25	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
21	IMPERIAL DR	4	21.2	21.86	Marys	CCk BW	20.51	1.35	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
22	IMPERIAL DR	5	20.3	20.96	Marys	CCk BW	20.51	0.45	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
23	IMPERIAL DR	6	20.2	20.86	Marys	CCk BW	20.51	0.35	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
24	IMPERIAL DR	6	20.6	21.26	Marys	CCk BW	20.51	0.75	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
25	IMPERIAL DR	6	19.6	20.26	Marys	CCk BW	20.51	-0.25	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
26	IMPERIAL DR	4	21.1	21.76	Marys	CCk BW	20.51	1.25	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
27	IMPERIAL DR	6	20.6	21.26	Marys	CCk BW	20.51	0.75	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
28	IMPERIAL DR	5	20.4	21.06	Marys	CCk BW	20.51	0.55	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
29	IMPERIAL DR	4	21.1	21.76	Marys	CCk BW	20.51	1.25	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
30	IMPERIAL DR	5	20.9	21.56	Marys	CCk BW	20.51	1.05	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
31	IMPERIAL DR	4	21	21.66	Marys	CCk BW	20.51	1.15	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
32	IMPERIAL DR	5	21.8	22.46	Marys	CCk BW	20.51	1.95	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
33	IMPERIAL DR	5	21.5	22.16	Marys	CCk BW	20.51	1.65	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
34	IMPERIAL DR	5	21.3	21.96	Marys	CCk BW	20.51	1.45	Storms in excess of 100-year - Clear Creek flows may be underpredicted.
35	IMPERIAL DR	4	21.8	22.46	Marys	CCk BW	20.51	1.95	Storms in excess of 100-year - Clear Creek flows may be underpredicted.

Notes:
- NFIP - National Flood Insurance Program
- COE - US Army Corps of Engineers
- Adjustments from COE Datum to FEMA 1978 Datum
  - Mary's Adjustment +0.66
  - Cowart's Adjustment +0.54
  - Chigger's Adjustment +0.99
- Adjustments from 1973 to 1978 Datum
  - Clear Creek Adjustment -0.6
- * Problem area in City of Friendswood Master Drainage Plan Phase I
- (CW) - Cowart's Creek Adjustment used to get 1978 Elevation
- (CH) - Chigger's Creek Adjustment used to get 1978 Elevation
- (MA) - Mary's Creek Adjustment used to get 1978 Elevation
- CCk BW - Clear Creek adjustment used to get 1978 Elevation

Table 1 (Cont.)
Slab Elevations

DEC Identifier	Location	# of NFIP Claims	Slab Elevation COE Datum	Slab Elevation FEMA 1978 Datum	Creek	Channel Station	100-Year Model Water Surface 1978 Datum	Difference	Observations
			(ft)	(ft)			(ft)	(ft)	
36	MARY'S CT	4	30.09	30.75	Marys	10350	27.86	2.89	Storms in excess of 100-year/Flows may be underpredicted/Problem with debris
37	MARY'S CT	4	29.98	30.64	Marys	10350	27.86	2.78	Storms in excess of 100-year/Flows may be underpredicted/Problem with debris
38	MARY'S CT	4	30.13	30.79	Marys	10350	27.86	2.93	Storms in excess of 100-year/Flows may be underpredicted/Problem with debris
39	QUAKER DR	5	17.19	17.85	Marys	CCk BW	[illegible]	[illegible]	[illegible] 50-Year Flood Level
40	ROYAL CT	4	21.79	22.45	Marys	CCk BW	[illegible]	[illegible]	[illegible] 50-Year Flood Level
41	VIRGINIA LN *	4	29.67	30.33	Marys	CCk BW	23.93	6.4	Documented localized flooding problems
42	VIRGINIA LN *	5	29.46	30.12	Marys	CCk BW	23.93	6.19	Documented localized flooding problems
43	WINDING RD	5	30.82	31.48	Marys	10285	25.96	5.52	Storms in excess of 100-year/Flows may be underpredicted/Problem with debris
44	WINDING RD	4	30.28	30.94	Marys	10285	25.96	4.98	Storms in excess of 100-year/Flows may be underpredicted/Problem with debris
45	WINDING RD	4	30.04	30.7	Marys	10285	25.96	4.74	Storms in excess of 100-year/Flows may be underpredicted/Problem with debris
46	WINDING RD	4	29.78	30.44	Marys	10285	25.96	4.48	Storms in excess of 100-year/Flows may be underpredicted/Problem with debris
47	WINDING RD	5	28.98	29.64	Marys	10285	25.96	3.68	Storms in excess of 100-year/Flows may be underpredicted/Problem with debris
48	WINDING RD	5	29.53	30.19	Marys	10285	25.96	4.23	Storms in excess of 100-year/Flows may be underpredicted/Problem with debris
49	SAINT ANDREWS	4	34.26	35.25	Chiggers	27590	33.4	1.85	Located adjacent to creek, garage flush with natural ground
50	WILDERNESS	7	26.72	27.71	Chiggers	17310	25.31	2.4	Inaccurate cross section topography.
51A	WINDSONG	3	31.3	32.29	Chiggers	22630	30.39	1.9	Structure flush with natural ground and lower than top of road
52	CLEAR CREEK DR	4	17	17.54	Clear Creek (CW)	88898	[illegible]	[illegible]	[illegible]
53	CLEAR CREEK DR	7	13.3	13.84	Clear Creek (CW)	88898	[illegible]	[illegible]	[illegible]
54	CLEAR CREEK DR	5	14.4	14.94	Clear Creek (CW)	88898	[illegible]	[illegible]	[illegible]
55	N CLEAR CREEK DR	4	25.7	26.24	Clear Creek (CW)	88898	19.3	6.94	Survey elevation may not be correct.
56	CLEARVIEW AV	4	18.1	18.76	Clear Creek (CH)	101260	[illegible]	[illegible]	[illegible]
57	CLEARVIEW AV	4	21.3	21.96	Clear Creek (CH)	101260	[illegible]	[illegible]	[illegible]
58	CLEARVIEW AV	4	20.1	20.76	Clear Creek (CH)	101260	[illegible]	[illegible]	[illegible]
59	HAVERFORD	5	19.9	20.56	Clear Creek (CH)	99042	[illegible]	[illegible]	[illegible]
61	LEISURE LANE	4	22.5	23.04	Clear Creek (CW)	86892	18.2	4.84	Storms in excess of 100-year - flows may be underpredicted.
62	MINGLEWOOD	4	19	19.54	Clear Creek (CW)	94120	[illegible]	[illegible]	[illegible]
63	MINGLEWOOD	8	13	13.54	Clear Creek (CW)	94120	[illegible]	[illegible]	[illegible]
64	MINGLEWOOD	9	13.7	14.24	Clear Creek (CW)	94120	[illegible]	[illegible]	[illegible]
65	TIMBER LN	4	16.4	16.94	Clear Creek (CW)	94120	[illegible]	[illegible]	[illegible]
71	SUN CT *	5	32.1	33.09	Chiggers	22401	30.34	2.75	Documented localized flooding problems
72	SUN CT *	4	32.39	33.38	Chiggers	22401	30.34	3.04	Documented localized flooding problems
	WANDERING TRAIL	3	21.6	22.26	Clear Creek (MA)	101260	[illegible]	[illegible]	[illegible]
	WANDERING TRAIL	2	22.3	22.96	Clear Creek (MA)	101260	22.9	0.06	Flow/WSEL on tributary or Clear Creek may be underpredicted
	WHITTIER OAKS	2	23.3	23.96	Clear Creek (MA)	101260	22.9	1.06	Flow/WSEL on tributary or Clear Creek may be underpredicted
	WHITTIER OAKS	2	23.8	24.46	Clear Creek (MA)	101260	22.9	1.56	Flow/WSEL on tributary or Clear Creek may be underpredicted
	WHITTIER OAKS	3	26.3	26.96	Clear Creek (MA)	101260	22.9	4.06	House significantly higher than others - no explaination for flooding from Creek

Notes:
- NFIP - National Flood Insurance Program
- COE - US Army Corps of Engineers
- Adjustments from COE Datum to FEMA 1978 Datum
  - Mary's Adjustment +0.66
  - Cowart's Adjustment +0.54
  - Chigger's Adjustment +0.99
- Adjustments from 1973 to 1978 Datum
  - Clear Creek Adjustment -0.6
- * Problem area in City of Friendswood Master Drainage Plan Phase I
- (CW) - Cowart's Creek Adjustment used to get 1978 Elevation
- (CH) - Chigger's Creek Adjustment used to get 1978 Elevation
- (MA) - Mary's Creek Adjustment used to get 1978 Elevation
- CCk BW - Clear Creek adjustment used to get 1978 Elevation

Table 2
Flow Comparison at Nodes
Existing Regional Detetention Sites

Node	Location	100-Yr Flow				10-Yr Flow			
		Calibrated (cfs) (1)	Revised (cfs) (2)	Difference (cfs) (3)	% Reduction (4)	Calibrated (cfs) (5)	Revised (cfs) (6)	Difference (cfs) (7)	% Reduction (8)
		A100CAL.IH1	A100REV.IH1	(2)-(1)	(3)/(1)	A10CAL.IH1	A10REV.IH1	(6)-(5)	(7)/(5)
CW100#3	*Downstream CW103 Confluence (40 Ac. Pond)*	*3604*	*3604*	*0*	*0.0%*	*2147*	*1765*	*-382*	*17.8%*
A100#9 U/S	*Upstream Confluence with Clear Creek*	*4774*	*4531*	*-243*	*5.1%*	*2851*	*2639*	*-212*	*7.4%*
A100#9	Conf. Cowart Creek (Near FM 528)	18380	18380	0	*0.0%*	10929	10595	-334	*3.1%*
CH100#2A	*Downstream Windsong Rd. (33 Ac. Pond)*	*2089*	*2101*	*12*	*-0.6%*	*1257*	*1193*	*-64*	*5.1%*
A100#10 U/S	*Upstream Confluence with Clear Creek*	*3730*	*3690*	*-40*	*1.1%*	*2115*	*1958*	*-157*	*7.4%*
A100#10	Conf. Chiggers Creek	22146	22119	-27	*0.1%*	13227	12878	-349	*2.6%*
A100#11	Conf. Magnolia	22627	22598	-29	*0.1%*	13507	13163	-344	*2.5%*
A100#12	Conf. Landing	23632	23588	-44	*0.2%*	14194	13861	-333	*2.3%*
A100#13	Conf. A111-00-00 (IH-45)	24022	23956	-66	*0.3%*	14464	14140	-324	*2.2%*
A100#14	Conf. Cow Bayou (Egret Bay Blvd)	24913	24815	-98	*0.4%*	15160	14837	-323	*2.1%*
A100#15A	Conf. Robinson Bayou	25435	25316	-119	*0.5%*	15543	15219	-324	*2.1%*
A100#15B	Armand Bayou	39245	38870	-375	*1.0%*	23046	22881	-165	*0.7%*
A100#15C	Taylor's Bayou	44232	43877	-355	*0.8%*	26260	26176	-84	*0.3%*
A100#15	Galveston Bay	44613	44265	-348	*0.8%*	26328	26258	-70	*0.3%*

Note: Shaded value indicates taken from HEC-1 graphical results.

Table 3
Water Elevation Comparison
Existing Regional Detention Sites

10-Year Frequency

Location	Cross Section	Calibrated Flow (cfs)	Calibrated Elevation (ft)	Calibrated Top Width Area (ac)	Mitigated Flow (cfs)	Mitigated Elevation (ft)	Mitigated Top Width Area (ac)	Elevation Difference (ft)	Top Width Area Difference (ac)
Cowart's Creek									
Confluence with Clear Creek	0	2851	8.97	0	2639	8.67	0	-0.26	0
F.M. 518	3150	2851	10.83	18.55	2639	10.54	18.06	-0.25	-0.49
Winding Way	4180	2851	11.14	25.63	2639	10.87	24.95	-0.23	-0.68
West Castlewood	5800	2600	13.79	31.7	2320	13.47	30.73	-0.28	-0.97
Sunset Dr.	9826	2600	18.15	42.41	2320	17.73	40.86	-0.37	-1.55
Baker Rd.	17056	2300	29.88	64.52	1995	29.45	62.23	-0.52	-2.29
Detention Pond Location / County Line	17694	2147	30.5	71.41	1765	30.06	67.73	-0.51	-3.68
F.M. 2351	21501	1275	33.07	100.86	1275	32.95	93.29	-0.14	-7.57
Chigger's Creek									
Confluence with Clear Creek	150	2115	2.02	0	1958	1.68	0	-0.34	0
Oak Dr.	5581	1925	10.19	23	1790	9.95	21.89	-0.24	-1.11
F.M. 518	6990	1925	11.9	27.17	1790	11.68	25.96	-0.22	-1.21
Manison Rd.	8938	1925	14.28	43.66	1790	14.05	42.07	-0.23	-1.59
F.M. 528	11181	1524	17.1	48.97	1425	16.82	47.21	-0.28	-1.76
Greenbriar Ave.	12696	1524	17.72	54.1	1425	17.44	51.92	-0.28	-2.18
Detention Pond	19707	1400	26.39	75.4	1300	26.2	71.96	-0.19	-3.44
CH100#2A	20515	1257	27.33	78.98	1183	27.14	74.83	-0.19	-4.15
Windsong Dr.	22630	1272	29.71	90.44	1272	29.69	85.29	-0.02	-5.15
Confluence with Chigger's Bypass	25590	505	30.91	127.67	505	30.91	122.16	0	-5.51
St. Cloud Drive	28050	505	34.94	132.49	505	34.94	126.98	0	-5.51
County Line	31530	440	36.43	221.04	440	36.43	215.52	0	-5.52

100-Year Frequency

Location	Cross Section	Calibrated Flow (cfs)	Calibrated Elevation (ft)	Calibrated Top Width Area (ac)	Mitigated Flow (cfs)	Mitigated Elevation (ft)	Mitigated Top Width Area (ac)	Elevation Difference (ft)	Top Width Area Difference (ac)
Cowart's Creek									
Confluence with Clear Creek	0	4774	11.56	0	4531	11.28	0	-0.28	0
F.M. 518	3150	4774	13.2	22.77	4531	12.94	22.3	-0.26	-0.47
Winding Way	4180	4774	13.33	31.4	4531	13.08	30.76	-0.25	-0.64
West Castlewood	5800	4350	15.83	39.51	4200	15.61	38.65	-0.22	-0.86
Sunset Dr.	9826	4350	20.35	54.69	4200	20.18	53.4	-0.17	-1.29
Baker Rd.	17056	3850	31.56	133.32	3840	31.56	130.14	0	-3.18
Detention Pond Location / County Line	17694	3604	31.98	149.41	3604	31.98	146.2	0	-3.21
F.M. 2351	21501	1925	34.32	199.93	1925	34.31	196.65	-0.01	-3.28
Chigger's Creek									
Confluence with Clear Creek	150	3730	4.45	0	3692	4.41	0	-0.04	0
Oak Dr.	5581	3350	12.16	33.34	3300	12.11	33.05	-0.05	-0.29
F.M. 518	6990	3350	13.9	38.62	3300	13.84	38.28	-0.06	-0.34
Manison Rd.	8938	3350	16.36	57.41	3300	16.3	57.02	-0.06	-0.39
F.M. 528	11181	2688	19.68	64.46	2588	19.58	63.98	-0.1	-0.48
Greenbriar Ave.	12696	2688	20.31	75.29	2588	20.2	74.4	-0.11	-0.89
Detention Pond	19707	2300	27.7	116.67	2340	27.75	115.78	0.05	-0.89
CH100#2A	20515	2089	28.48	124.65	2101	28.52	123.89	0.04	-0.76
Windsong Dr.	22630	2126	30.12	147.82	2126	30.13	147.42	0.01	-0.4
Confluence with Chigger's Bypass	25590	1077	32.06	205.85	1077	32.06	205.65	0	-0.2
St. Cloud Drive	28050	1077	35.25	213.05	1077	35.25	212.85	0	-0.2
County Line	31530	930	36.75	347.68	930	36.75	347.48	0	-0.2

Note:
All Elevations Based on 1978 Datum Adjustment

Table 4
Flow Comparison at Nodes
Future Regional Detention Sites

Node	Location	100-Yr Flow				10-Yr Flow			
		Calibrated (cfs) (1)	Revised (cfs) (2)	Difference (cfs) (3)	% Reduction (4)	Calibrated (cfs) (5)	Revised (cfs) (6)	Difference (cfs) (7)	% Reduction (8)
		A100CALE.IH1	A100FTE2.IH1	(2)-(1)	(3)/(1)	A10CALE.IH1	A10FTE2.IH1	(6)-(5)	(7)/(5)
MA100#3	*Downstream Future Detention Pond*	*2320*	*2080*	*-240*	*10.3%*	*1290*	*1055*	*-235*	*18.2%*
A100#7 U/S	*Upstream Confluence with Clear Creek*	*2965*	*2726*	*-239*	*8.1%*	*1825*	*1724*	*-101*	*5.5%*
A100#7	Conf. Marys Creek	14183	13953	-230	1.6%	8192	8177	-15	0.2%
A100#8	Conf. Cedar Gully	14400	14170	-230	1.6%	8346	8332	-14	0.2%
CW100#3 TRIB D/S	*Downstream Future Detention Pond on Tributary*	*1830*	*1405*	*-425*	*23.2%*	*776*	*428*	*-348*	*44.8%*
CW100#3 D/S	*Downstream Future Detention Pond (40Ac Expand.)*	*3604*	*2951*	*-653*	*18.1%*	*2147*	*1555*	*-592*	*27.6%*
A100#9 U/S	*Upstream Confluence with Clear Creek*	*4774*	*4188*	*-586*	*12.3%*	*2851*	*2456*	*-395*	*13.9%*
A100#9	Conf. Cowart Creek (Near FM 528)	18380	17594	-786	4.3%	10929	10522	-407	3.7%
CH100#2	Downstream Future Detention Pond	2126	2004	-122	5.7%	1272	1151	-121	9.5%
CH100#2A	Downstream Windsong Rd. (33 Ac. Pond)	2089	1967	-122	5.8%	1257	1194	-63	5.0%
CH100#3 U/S	Upstream Confluence with Eagle Creek	3159	2972	-187	5.9%	1983	1794	-189	9.5%
CH100D2	*Future Detention Pond Diversion Location*	*616*	*566*	*-50*	*8.1%*	*411*	*323*	*-88*	*21.4%*
CH100#3A	*Downstream Confluence with Minor Trib*	*1009*	*937*	*-72*	*7.1%*	*559*	*453*	*-106*	*19.0%*
CH100#3 TRIB U/S	*Upstream Confluence with Chiggers Creek*	*1387*	*1314*	*-73*	*5.3%*	*789*	*688*	*-101*	*12.8%*
CH100#3	Eagle Creek Confluence	4313	3952	-361	8.4%	2628	2407	-221	8.4%
A100#10 U/S	Upstream Confluence with Clear Creek	5121	4766	-355	6.9%	3028	2802	-226	7.5%
A100#10	Conf. Chiggers Creek	22220	21256	-964	4.3%	13559	13097	-462	3.4%
A100#11	Conf. Magnolia	22717	21740	-977	4.3%	13882	13386	-496	3.6%
A100#12	Conf. Landing	23773	22783	-990	4.2%	14578	14092	-486	3.3%
A100#13	Conf. A111-00-00 (IH-45)	24191	23225	-966	4.0%	14849	14370	-479	3.2%
A100#14	Conf. Cow Bayou (Egret Bay Blvd)	25139	24226	-913	3.6%	15569	15090	-479	3.1%
A100#15A	Conf. Robinson Bayou	25695	24815	-880	3.4%	15965	15488	-477	3.0%
A100#15B	Armand Bayou	40236	39690	-546	1.4%	23798	23448	-350	1.5%
A100#15C	Taylor's Bayou	45218	44680	-538	1.2%	27167	26833	-334	1.2%
A100#15	Galveston Bay	45605	45094	-511	1.1%	27227	26918	-309	1.1%

Table 5
Water Elevation Comparison
Future Regional Detention Sites

10-Year Frequency

Location	Cross Section	Calibrated Flow (cfs)	Calibrated Elevation (ft)	Calibrated Top Width Area (ac)	Mitigated Flow (cfs)	Mitigated Elevation (ft)	Mitigated Top Width Area (ac)	Elevation Difference (ft)	Top Width Area Difference (ac)
Mary's Creek									
Confluence with Clear Creek	0	1825	11.03	0	1724	10.85	0	-0.18	0
Mary's Crossing	745	1825	11.71	2.54	1724	11.51	2.49	-0.2	-0.05
F.M. 2351	4400	1825	16.93	11	1724	16.69	10.74	-0.24	-0.26
Dunbar Estates Dr.	9010	1825	22.27	21.49	1724	22.04	20.98	-0.23	-0.51
Winding Rd.	10285	1825	23.48	24.12	1724	23.16	23.57	-0.32	-0.55
Downstream Confluence with Mary's Bypass / Brazoria-Galveston County Line	10775	757	25.68	25.14	708	25.38	24.55	-0.3	-0.59
Dixie Farm Rd.	15426	757	35.22	46.49	708	35.04	43.6	-0.18	-2.89
F.M. 518	19873	757	39.14	70.13	708	38.98	65.92	-0.16	-4.21
Upstream Confluence with Mary's Bypass	23183	1290	41.23	93.01	1055	41.06	87.19	-0.17	-5.82
Detention Pond Location	24233	1290	41.74	104.26	1290	41.51	97.11	-0.23	-7.15
Cowart's Creek									
Confluence with Clear Creek	0	2851	8.97	0	2456	8.36	0	-0.61	0
F.M. 518	3150	2851	10.83	18.55	2456	10.28	17.57	-0.55	-0.98
Winding Way	4180	2851	11.14	25.63	2456	10.63	24.29	-0.51	-1.34
West Castlewood	5800	2600	13.79	31.7	2120	13.2	29.82	-0.59	-1.88
Sunset Dr.	9826	2600	18.15	42.41	2120	17.39	39.51	-0.76	-2.9
Baker Rd.	17056	2300	29.88	64.52	1750	28.88	55.39	-1	-9.13
Detention Pond Location / County Line	17694	2147	30.5	71.41	1555	29.56	59.41	-0.94	-12
F.M. 2351	21501	1275	33.07	100.86	1275	32.84	81.18	-0.23	-19.68
Chigger's Creek									
Confluence with Clear Creek	150	3034	3.55	0	2802	3.21	0	-0.34	0
Oak Dr.	5581	2820	11.51	28.99	2620	11.24	27.68	-0.27	-1.31
F.M. 518	6990	2820	13.21	33.81	2620	12.93	32.37	-0.28	-1.44
Manison Rd.	8938	2820	15.65	51.96	2620	15.37	50.26	-0.28	-1.7
F.M. 528	11181	1983	18.62	58.24	1794	18.2	56.33	-0.42	-1.91
Greenbriar Ave.	12696	1983	19.17	65.67	1794	18.74	63.01	-0.43	-2.66
Detention Pond	19707	1550	26.66	90.53	1440	26.46	85.56	-0.2	-4.97
CH100#2A	20515	1257	27.59	95.5	1194	27.41	89.61	-0.18	-5.89
Windsong Dr.	22630	1272	29.72	107.91	1194	29.6	100.75	-0.12	-7.16
Confluence with Chigger's Bypass	25590	505	30.92	145.46	505	30.8	134.33	-0.12	-11.13
St. Cloud Drive	28050	505	34.94	150.28	505	34.94	139.1	0	-11.18
County Line	31530	440	36.43	238.83	440	36.43	227.63	0	-11.2
Eagle Creek									
Confluence with Chiggers Creek	0	789	13.64	0.00	688	13.64	0.00	0.00	0.00
Pond Outfall	339	789	15.91	1.57	688	15.82	1.57	-0.09	-0.01
Culvert Crossing	1506	702	18.39	6.44	597	18.13	6.40	-0.26	-0.04
Culvert Crossing	2482	702	19.63	8.09	597	19.2	7.98	-0.43	-0.10
Detention Structure Outfall	3474	603	23.97	9.47	497	23.74	9.30	-0.23	-0.17
Confluence with Tributary	4405	603	24.16	12.10	497	23.9	11.86	-0.26	-0.24
Diversion	8570	428	28.6	25.71	338	27.68	25.05	-0.92	-0.67
San Joaquin Parkway	10861	179	32.66	35.12	221	31.69	32.84	-0.97	-2.28
End of Creek	12728	179	32.84	53.13	221	32.47	35.39	-0.37	-17.75

Note:
Mary's, Cowart's & Chigger's Creek - Elevations Based on 1978 Datum Adjustment
Eagle Creek - Elevations Based on 1987 Datum Adjustment

Table 5 (Cont.)
Water Elevation Comparison
Future Regional Detention Sites

100-Year Frequency

Location	Cross Section	Calibrated Flow (cfs)	Calibrated Elevation (ft)	Calibrated Top Width Area (ac)	Mitigated Flow (cfs)	Mitigated Elevation (ft)	Mitigated Top Width Area (ac)	Elevation Difference (ft)	Top Width Area Difference (ac)
Mary's Creek									
Confluence with Clear Creek	0	2965	13.08	0	2726	12.72	0	-0.36	0
Mary's Crossing	745	2965	13.86	3.02	2726	13.47	2.94	-0.39	-0.08
F.M. 2351	4400	2965	18.99	13.52	2726	18.62	13.06	-0.37	-0.46
Dunbar Estates Dr.	9010	2965	24.47	26.26	2726	24.06	25.36	-0.41	-0.9
Winding Rd.	10285	2965	25.96	29.33	2726	25.56	28.32	-0.4	-1.01
Downstream Confluence with Mary's Bypass / Brazoria-Galveston County Line	10775	1541	28.55	31.55	1344	28.01	29.72	-0.54	-1.83
Dixie Farm Rd.	15426	1541	36.92	98.17	1344	36.72	82.67	-0.2	-15.5
F.M. 518	19873	1541	40.42	160.47	1344	40.31	137.69	-0.11	-22.78
Upstream Confluence with Mary's Bypass	23183	2320	42.93	219.73	2080	42.61	179.83	-0.32	-39.9
Detention Pond Location	24233	2320	43.45	254.27	2320	43.17	209.16	-0.28	-45.11
Cowart's Creek									
Confluence with Clear Creek	0	4774	11.56	0	4118	10.75	0	-0.81	0
F.M. 518	3150	4774	13.2	22.77	4118	12.45	21.43	-0.75	-1.34
Winding Way	4180	4774	13.33	31.4	4118	12.63	29.57	-0.7	-1.83
West Castlewood	5800	4350	15.83	39.51	3700	15.18	37.03	-0.65	-2.48
Sunset Dr.	9826	4350	20.35	54.69	3700	19.62	50.8	-0.73	-3.89
Baker Rd.	17056	3850	31.56	133.32	3200	31.09	103.43	-0.47	-29.89
Detention Pond Location / County Line	17694	3604	31.98	149.41	2951	31.53	115.78	-0.45	-33.63
F.M. 2351	21501	1925	34.32	199.93	1925	34.25	160.03	-0.07	-39.9
Chigger's Creek									
Confluence with Clear Creek	150	5134	5.96	0	4766	5.6	0	-0.36	0
Oak Dr.	5581	4700	13.55	40.68	4300	13.16	38.82	-0.39	-1.86
F.M. 518	6990	4700	15.39	47.44	4300	14.97	45.16	-0.42	-2.28
Manison Rd.	8938	4700	17.94	67.62	4300	17.5	64.95	-0.44	-2.67
F.M. 528	11181	3159	21.09	77.59	2972	20.67	73.02	-0.42	-4.57
Greenbriar Ave.	12696	3159	21.68	93.94	2972	21.25	87.4	-0.43	-6.54
Detention Pond	19707	2520	27.97	149.84	2400	27.83	136.72	-0.14	-13.12
CH100#2A	20515	2089	28.73	158.6	1967	28.6	145.08	-0.13	-13.52
Windsong Dr.	22630	2126	30.18	183.77	2004	30.04	167.49	-0.14	-16.28
Confluence with Chigger's Bypass	25590	1077	32.07	242.83	1077	31.97	222.91	-0.1	-19.92
St. Cloud Drive	28050	1077	35.25	250.05	1077	35.25	230.01	0	-20.04
County Line	31530	930	36.75	384.68	930	36.75	364.63	0	-20.05
Eagle Creek									
Confluence with Chiggers Creek	0	1387	15.75	0.00	1314	15.75	0.00	0.00	0.00
Pond Outfall	339	1387	16.49	2.05	1314	16.43	2.05	-0.06	0.00
Culvert Crossing	1506	1246	19.41	7.10	1172	19.29	7.08	-0.12	-0.02
Culvert Crossing	2482	1246	21.51	8.99	1172	21.28	8.94	-0.23	-0.05
Detention Structure Outfall	3474	1083	24.86	10.78	1010	24.73	10.59	-0.13	-0.20
Confluence with Tributary	4405	1083	25.21	13.77	1010	25.06	13.53	-0.15	-0.25
Diversion	8570	657	29.49	28.73	604	28.92	28.29	-0.57	-0.44
San Joaquin Parkway	10861	254	34.96	62.53	307	33.1	49.60	-1.86	-12.93
End of Creek	12728	254	34.97	115.27	307	33.31	76.51	-1.66	-38.77

Note:
Mary's, Cowart's & Chigger's Creek - Elevations Based on 1978 Datum Adjustment
Eagle Creek - Elevations Based on 1987 Datum Adjustment

Table 6
Estimated Cost
Non-Structural Alternative

MARYS CREEK

Item No.	Description	Quantity	Unit	Unit Price	Cost
1	DEVELOPED ACREAGE ACQUISITION	4	AC	$390,000	$1,560,000
2	UNDEVELOPED ACREAGE ACQUISITION	4	AC	$30,000	$120,000
3	ADMINISTRATIVE COSTS	1	LS	$1,300,000	$1,300,000
	SUB-TOTAL				$2,980,000

COWARTS CREEK

Item No.	Description	Quantity	Unit	Unit Price	Cost
1	DEVELOPED ACREAGE ACQUISITION	42	AC	$390,000	$16,380,000
2	UNDEVELOPED ACREAGE ACQUISITION	42	AC	$30,000	$1,260,000
3	ADMINISTRATIVE COSTS	1	LS	$13,000,000	$13,000,000
	SUB-TOTAL				$30,640,000

CHIGGERS CREEK

Item No.	Description	Quantity	Unit	Unit Price	Cost
1	DEVELOPED ACREAGE ACQUISITION	162	AC	$390,000	$63,180,000
2	UNDEVELOPED ACREAGE ACQUISITION	162	AC	$30,000	$4,860,000
3	ADMINISTRATIVE COSTS	1	LS	$51,000,000	$51,000,000
	SUB-TOTAL				$119,040,000
	TOTAL				$152,660,000

Table 7
Preliminary Drainage Improvements Cost
Existing Regional Detention Sites

COWARTS CREEK

Item No.	Description	Quantity	Unit	Unit Price	Cost
1	LAND ACQUISITION	40	AC	$10,000.00	$400,000
2	EXCAVATION	429,147	CY	$6.50	$2,789,456
3	STRUCTURE	1	LS	$100,000.00	$100,000
	SUB-TOTAL				$3,289,456
	CONTINGENCIES (15%)				$493,418
	TOTAL CONSTRUCTION COSTS				$3,782,874
	ENGINEERING AND ADMINISTRATION (10%)				$378,287
	SUB-TOTAL				$4,161,161

CHIGGERS CREEK

Item No.	Description	Quantity	Unit	Unit Price	Cost
1	LAND ACQUISITION	33	AC	$10,000.00	$330,000
2	EXCAVATION	250,067	CY	$6.50	$1,625,436
3	STRUCTURE	1	LS	$100,000.00	$100,000
	SUB-TOTAL				$2,055,436
	CONTINGENCIES (15%)				$308,315
	TOTAL CONSTRUCTION COSTS				$2,363,751
	ENGINEERING AND ADMINISTRATION (10%)				$236,375
	SUB-TOTAL				$2,600,126
	TOTAL				$6,761,287

Table 8
Preliminary Drainage Improvements Cost
Future Regional Detention Sites

MARYS CREEK

Item No.	Description	Quantity	Unit	Unit Price	Cost
1	LAND ACQUISITION	55	AC	$25,000.00	$1,375,000
2	EXCAVATION	674,373	CY	$6.50	$4,383,425
3	STRUCTURE	1	LS	$100,000.00	$100,000
	SUB-TOTAL				$5,858,425
	CONTINGENCIES (15%)				$878,764
	TOTAL CONSTRUCTION COSTS				$6,737,188
	ENGINEERING AND ADMINISTRATION (10%)				$673,719
	SUB-TOTAL				$7,410,907

COWARTS CREEK

Item No.	Description	Quantity	Unit	Unit Price	Cost
1	LAND ACQUISITION	98	AC	$10,000.00	$980,000
2	EXCAVATION	819,573	CY	$6.50	$5,327,225
3	STRUCTURE	1	LS	$100,000.00	$100,000
	SUB-TOTAL				$6,407,225
	CONTINGENCIES (15%)				$961,084
	TOTAL CONSTRUCTION COSTS				$7,368,308
	ENGINEERING AND ADMINISTRATION (10%)				$736,831
	SUB-TOTAL				$8,105,139

CHIGGERS CREEK

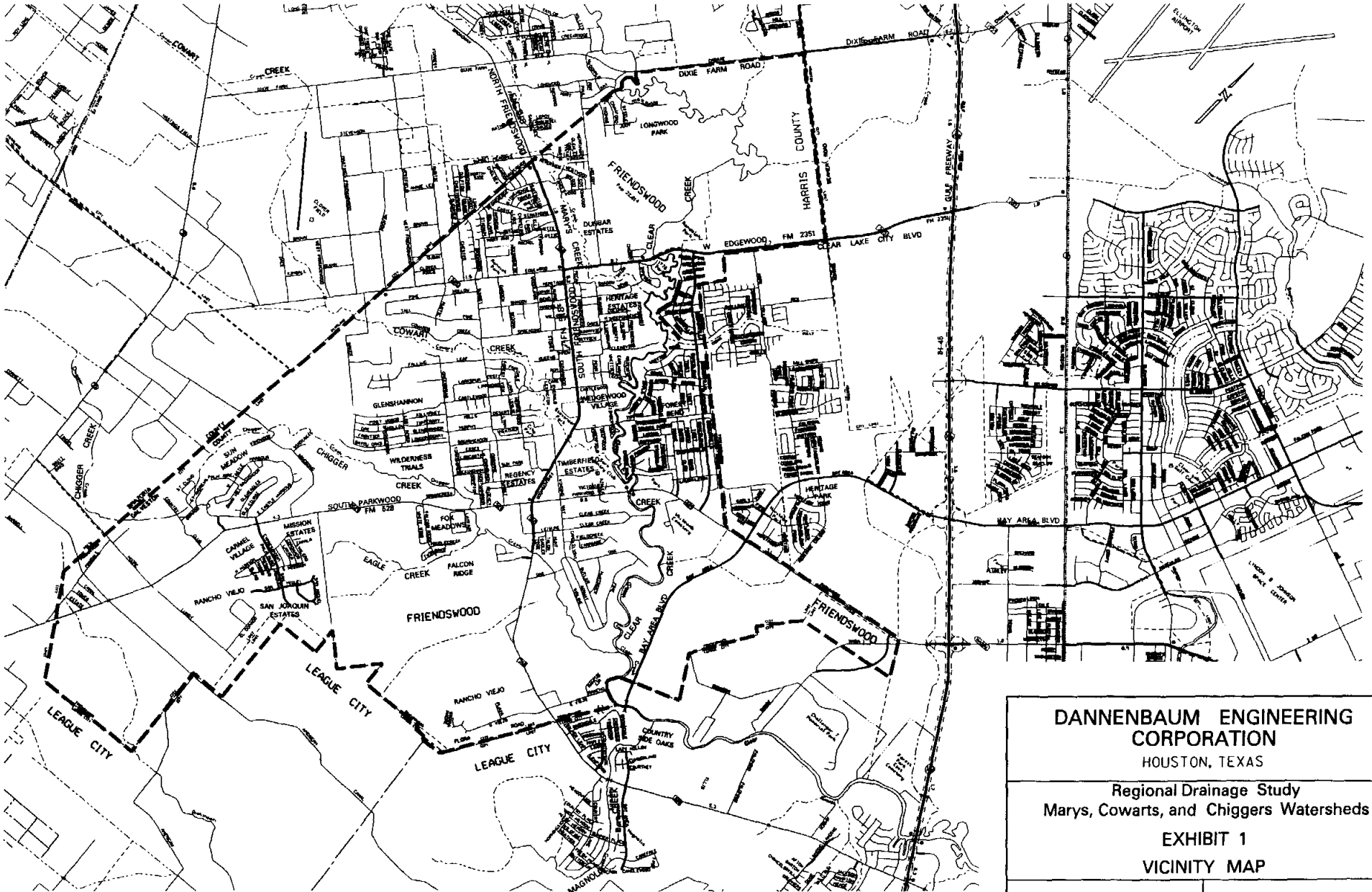
Item No.	Description	Quantity	Unit	Unit Price	Cost
1	LAND ACQUISITION	28	AC	$25,000.00	$700,000
2	EXCAVATION	138,747	CY	$6.50	$901,856
3	STRUCTURE	1	LS	$100,000.00	$100,000
	SUB-TOTAL				$1,701,856
	CONTINGENCIES (15%)				$255,278
	TOTAL CONSTRUCTION COSTS				$1,957,134
	ENGINEERING AND ADMINISTRATION (10%)				$195,713
	SUB-TOTAL				$2,152,847

EAGLE CREEK

Item No.	Description	Quantity	Unit	Unit Price	Cost
1	LAND ACQUISITION	20	AC	$25,000.00	$500,000
2	EXCAVATION	124,227	CY	$6.50	$807,476
3	STRUCTURE	1	LS	$100,000.00	$100,000
4	ADDITIONAL CULVERT CONSTRUCTION	1	LS	$111,930.00	$111,930
	SUB-TOTAL				$1,519,406
	CONTINGENCIES (15%)				$227,911
	TOTAL CONSTRUCTION COSTS				$1,747,316
	ENGINEERING AND ADMINISTRATION (10%)				$174,732
	SUB-TOTAL				$1,922,048
	TOTAL				$19,590,941

Table 9
Flow Comparison at Nodes
Existing Regional Detetention Sites with 200 Ac Additional Development

Node	Location	100-Yr Flow				10-Yr Flow			
		Calibrated (cfs) (1)	Dev. w/ Det (cfs) (2)	Difference (cfs) (3)	% Reduction (4)	Calibrated (cfs) (5)	Dev. w/ Det (cfs) (6)	Difference (cfs) (7)	% Reduction (8)
		A100CAL.IH1	A100DEV2.IH1	(2)-(1)	(3)/(1)	A10CAL.IH1	A10DEV2.IH1	(6)-(5)	(7)/(5)
CW100#3	*Downstream CW103 Confluence (40 Ac. Pond)*	*3604*	*3604*	*0*	*0.0%*	*2147*	*1765*	*-382*	*17.8%*
A100#9 U/S	*Upstream Confluence with Clear Creek*	*4774*	*4603*	*-171*	*3.6%*	*2851*	*2788*	*-63*	*2.2%*
A100#9	Conf. Cowart Creek (Near FM 528)	18380	18332	-48	0.3%	10929	10591	-338	3.1%
CH100#2A	*Downstream Windsong Rd. (33 Ac. Pond)*	*2089*	*2089*	*0*	*0.0%*	*1257*	*1261*	*4*	*-0.3%*
A100#10 U/S	*Upstream Confluence with Clear Creek*	*3730*	*3689*	*-41*	*1.1%*	*2115*	*2075*	*-40*	*1.9%*
A100#10	Conf. Chiggers Creek	22146	22086	-60	0.3%	13227	*12909*	-318	2.4%
A100#11	Conf. Magnolia	22627	22567	-60	0.3%	13507	13198	-309	2.3%
A100#12	Conf. Landing	23632	23568	-64	0.3%	14194	13906	-288	2.0%
A100#13	Conf. A111-00-00 (IH-45)	24022	23942	-80	0.3%	14464	14186	-278	1.9%
A100#14	Conf. Cow Bayou (Egret Bay Blvd)	24913	24811	-102	0.4%	15160	14900	-260	1.7%
A100#15A	Conf. Robinson Bayou	25435	25321	-114	0.4%	15543	15290	-253	1.6%
A100#15B	Armand Bayou	39245	39049	-196	0.5%	23046	23000	-46	0.2%
A100#15C	Taylor's Bayou	44232	44057	-175	0.4%	26260	26268	8	0.0%
A100#15	Galveston Bay	44613	44449	-164	0.4%	26328	26350	22	-0.1%



DANNENBAUM ENGINEERING CORPORATION HOUSTON, TEXAS	
Regional Drainage Study Marys, Cowarts, and Chiggers Watersheds EXHIBIT 1 VICINITY MAP	
AUGUST, 2001	SCALE: 1" = 4000'

REGIONAL DRAINAGE STUDY MARYS, COWARTS, AND CHIGGERS WATERSHEDS CITY OF FRIENDSWOOD, TEXS

2000-483-355

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

Exhibit 2 HEC-1 Node Information Scale 1:2000 August, 2001

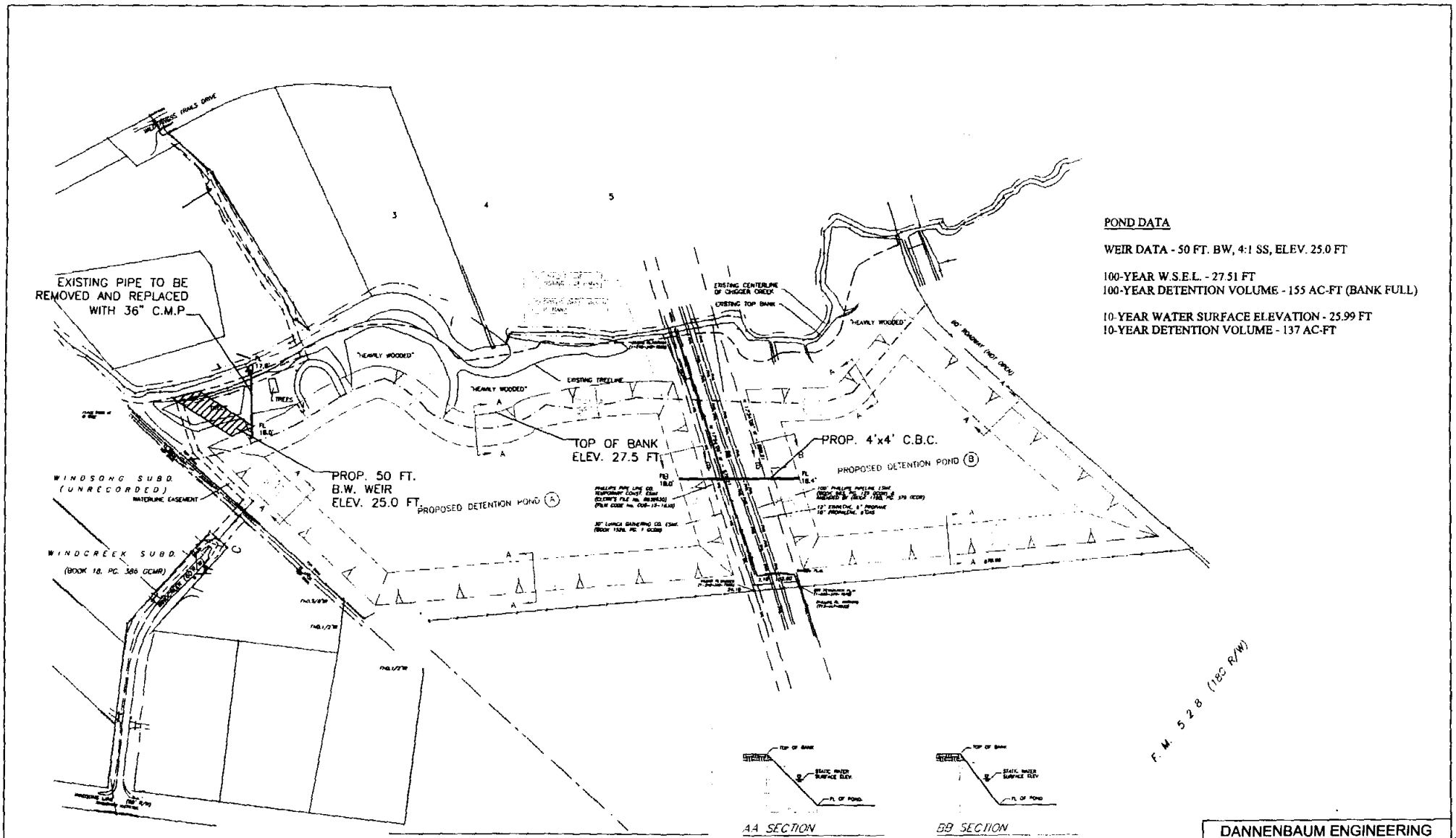
Exhibit 3 Repetitive losses

Exhibit 4 regional Detention Locations Scale 1:2000 August, 2001

Firm Flood Insurance- community Panel Number 485468 0005 E

The complete report has been kept because of the large maps.

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



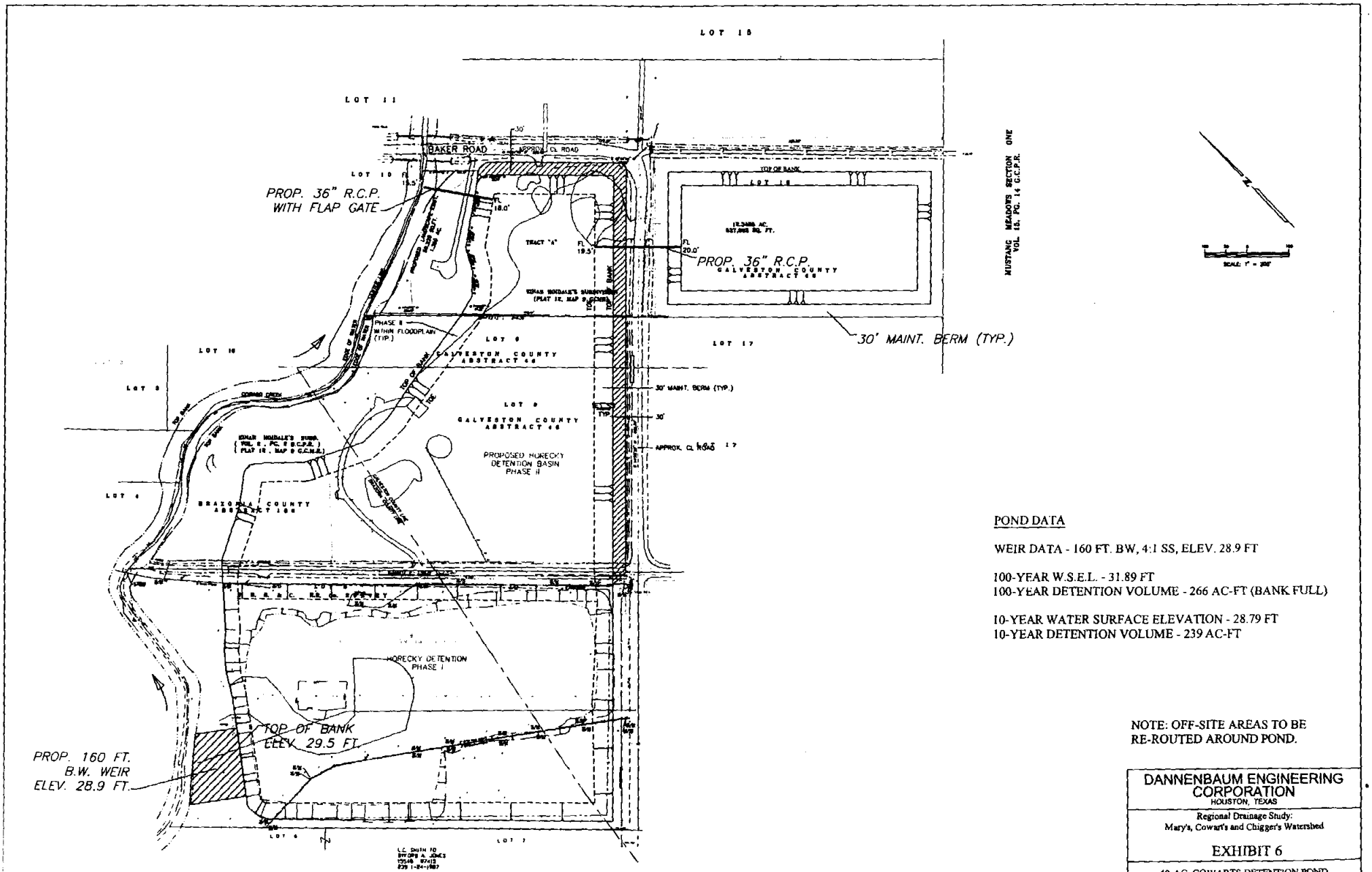
POND DATA

WEIR DATA - 50 FT. BW, 4:1 SS, ELEV. 25.0 FT

100-YEAR W.S.E.L. - 27.51 FT
100-YEAR DETENTION VOLUME - 155 AC-FT (BANK FULL)

10-YEAR WATER SURFACE ELEVATION - 25.99 FT
10-YEAR DETENTION VOLUME - 137 AC-FT

DANNENBAUM ENGINEERING CORPORATION HOUSTON, TEXAS	
Regional Drainage Study: Mary's, Cowart's and Chigger's Watershed	
EXHIBIT 7	
33-AC. CHIGGERS DETENTION POND	
SCALE: 1" = 200'	AUGUST, 2001



POND DATA

WEIR DATA - 160 FT. BW, 4:1 SS, ELEV. 28.9 FT

100-YEAR W.S.E.L. - 31.89 FT
100-YEAR DETENTION VOLUME - 266 AC-FT (BANK FULL)

10-YEAR WATER SURFACE ELEVATION - 28.79 FT
10-YEAR DETENTION VOLUME - 239 AC-FT

NOTE: OFF-SITE AREAS TO BE
RE-ROUTED AROUND POND.

DANNENBAUM ENGINEERING CORPORATION
HOUSTON, TEXAS

Regional Drainage Study:
Mary's, Cowart's and Chigger's Watershed

EXHIBIT 6

40-AC. COWARTS DETENTION POND

SCALE: 1" = 200'

ATTACHMENT 1
TEXAS WATER DEVELOPMENT BOARD
Review of the Draft Final Report: Contract No. 2000-483-355
"Regional Drainage Study for Marys, Cowarts, and Chiggers Watersheds, City of Friendswood, Texas

1. An Application for Approval of Reclamation Project need not be filed with the Texas Natural Resource Conservation Commission for the referenced proposal. It was determined from our review that the proposed project, since it is in the City of Friendswood, needs to be permitted by the City. The City of Friendswood by virtue of its participation in the National Flood Insurance Program, and in accordance with Section 16.236 (h) (4) of the Texas Water Code, has approval authority for the project. If the City has not already done so, they should insure that the proposed construction is documented and permitted in accordance with their Flood Hazard Prevention Ordinance. This documentation should also be submitted by the City to the Federal Emergency Management Agency to obtain a Letter of Map Revision (LOMR) of the City of Friendswood's Flood Insurance Rate Map.

2. The technical content of the referenced report is based on acceptable hydrological and hydraulic methods and is complete. Therefore, the merits of the proposed project can be evaluated from the report.

3. Task 3.0 of the Scope of Work (SOW) was to determine target elevations for various tributaries based on slab elevations. Pg 9 of the report stated that it wasn't possible to set target elevations and that the analysis instead was based on relative benefits. It appears that the contractor did an adequate effort in comparing slab elevations to HEC-2 surface water elevations, and the analysis provided in Table 1 is useful information. However the report should explain more clearly how an analysis based on "relative benefits" was conducted.

4. Exhibits depicting an overall plan and profile view of the drainage improvement plan were not included in the draft report per Task 6.0 of the SOW.

5. The draft report contains several citations. The citations should be complete enough that an interested individual can obtain a copy and should be shown in a List of References.

6. It appears that current, acceptable methodologies have been employed in the accumulation and presentation of data in this report. Construction of detention basins for flood control purposes is eligible for Board financing. Estimations of project costs appear to be based on reasonable assumptions. The report would be appropriate for use in support of an application to the Board for financing the proposed improvements. All additional information required by Board rules, 31 TAC 363.401-404, and required to make legal findings required by Texas Water Code Chapter 17.771-776 would be required at the time of application.

7. Although channel improvements and non-structural alternatives are not recommended in this study, those activities are eligible for TWDB financing. The purchase of floodplain property for use as public open space, removal of buildings from the floodplain, relocation of floodplain residents and installation of flood warning systems are examples of eligible non-structural activities.

EXHIBIT 8

REGIONAL DRAINAGE STUDY MARYS, COWARTS, AND CHIGGERS WATERSHEDS CITY OF FRIENDSWOOD, TEXS

2000-483-355

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

Exhibit 2 HEC-1 Node Information Scale 1:2000 August, 2001

Exhibit 3 Repetitive losses

Exhibit 4 regional Detention Locations Scale 1:2000 August, 2001

Firm Flood Insurance- community Panel Number 485468 0005 E

The complete report has been kept because of the large maps.

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