CACHE LA POUDRE RIVER NEAR FORT COLLINS, COLORADO

FLOOD MANAGEMENT ALTERNATIVES — RELOCATIONS AND LEVEES

by

Robert E. Koirtyohann, Ronald L. Miller,
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Preface

This report was prepared by a study team from Colorado State University as a part of the requirements for the Master of Science degree. It was written as a follow up report to Flood Plain Management of the Cache la Poudre River near Fort Collins, Colorado (5), a report prepared last year by a similar study team at Colorado State University.

The purpose of this report is to investigate two flood management alternatives, relocations and levees, which were suggested in the report prepared last year. It should be noted that the two plans studied provide different degrees of protection and were made using different assumptions and are therefore not directly comparable. We did not recommend the implementation of either plan. This is due to the fact that the selection of any plan is dependent upon many considerations such as degree of protection desired, political and environmental constraints, and type of financing available. It should also be noted that we do not necessarily consider either of the two plans studied the "optimal" solution to flood management in Fort Collins. In fact the City of Fort Collins has already started to implement another of the alternatives suggested in last year's report, the National Flood Insurance Program.

Acknowledgements

The authors gratefully acknowledge the advice and guidance of our graduate committee in the preparation of this report. The committee, all members of which are associated with Colorado State University, consists of Norman Evans, Director, Environmental Resources Center, Chairman of the committee; Henry Caulfield, Professor of Political Science; R. Burnell Held, Professor of Outdoor Recreation; Kenneth Nobe, Chairman of the Department of Economics; and Everett Richardson, Professor of Civil Engineering.

The Study Area

The study area adopted for this report consists of about 15.4 miles of the flood plain of the Cache La Poudre River near Fort Collins, Colorado. This area corresponds to the areas investigated in the Corps of Engineers Flood Plain Information Report for Fort Collins (15) and in *Flood Plain Management of the Cache la Poudre River near Fort Collins, Colorado* (5). This study reach extends from the upstream limit near the mouth of Cache La Poudre Canyon to the downstream limit below Fort Collins at the mouth of Spring Creek. A map showing the study area is included as Figure 1. The flood plain is roughly triangular in shape through the study reach, varying in width from approximately 450 feet at the upstream limit to about 4,840 feet at the downstream limit. Channel slopes through the study reach are generally steeper at the upstream limits, averaging about 28 feet per mile near Poudre Canyon. Slopes near the downstream limits of the study reach average about 16 feet per mile. The channel of the Cache La Poudre River through the study reach averages about 160 feet wide and 7.0 feet deep. Channel capacity is reached at a discharge of about 5,000 c.f.s. (cubic feet per second) (15). On the average, there is about a 17% chance that the 5,000 c.f.s. discharge will be equaled or exceeded in any given year (5, p. 10).

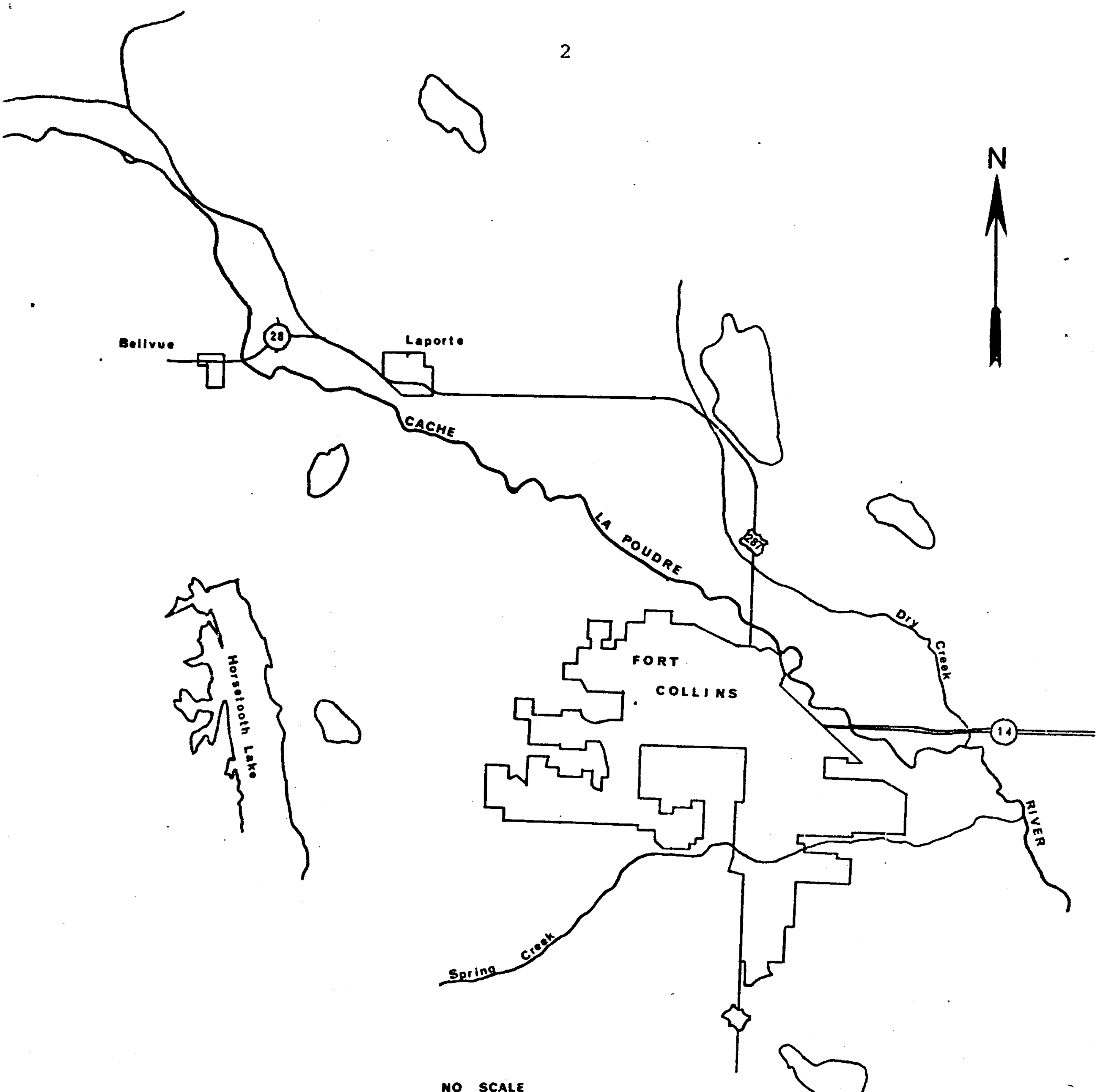


Figure 1.
CACHE LA POUDRE RIVER
FORT COLLINS, COLORADO

Annual peak flows for the Cache La Poudre near Fort Collins since 1882 to the present are available from the U. S. Geological Survey. Records indicate that there have been 16 discharges since 1882 that have exceeded bank-full capacity of the river, with two of these floods (1891 and 1904) exceeding 20,000 c.f.s. Narratives of many of these floods are also available from the U. S. Geological Survey (16). The last significant flood occurred in 1930 and had an estimated discharge of 10,200 c.f.s. Should the reader desire, a more complete description of flood flows, physiographic features of the basin, and other related information, can be found in the Corps of Engineers flood plain information report mentioned previously.

Existing Flood Plain

In view of the fact that no flood with a discharge exceeding 6,200 c.f.s. (approximately the 10-year flood) (5, p. 10) has occurred in the study reach since 1930, development in the flood plain is very limited. The existing flood plain contains about 500 households with an estimated population of about 1,500 residents. In addition, there is a correspondingly limited number of small businesess, farm, and other commercial structures. Based on a reconnaissance of the flood plain by the study team, none of the existing structures appear to be protected against flood hazards by flood proofing or other structural measures.

Plans Selected for Investigation

Flood Plain Management of the Cache la Poudre River Near Fort Collins, Colorado presents a wide variety of possible alternatives for management of the flood plain of the study area.(5) Possible alternatives either individually or in combination include greenbelts, National Flood Insurance Program, flood plain ordinances, flood proofing, flood forecasting and warning, relocation of flood plain residents, structural improvements, and flood management using existing irrigation structures. Each of these plans offer varying degrees of flood protection and flood damage reduction. Additionally, each also has both positive and negative effects, which vary in scope and intensity, on the existing environment. No "best plan" can be determined from this group except from the individual's personal point of view. It should be recognized, however, that the successful implementation of any plan will require a viable coalition of the political and social communities who can generally be counted on to give support to the plan.

The two plans presented in this report, the levee plan and the relocations plan, were selected since they were believed by the study team to be viable structural and non-structural alternatives based on an overall viewpoint. Interest in maintaining the river channel in as nearly its present state as possible is apparently high in the community, as evidenced by the Environmental Impact Study for the proposed Central Fort Collins Expressway. Letters contained in this study from the Poudre Valley Greenbelt Association, Trout Unlimited, Neighbor to Neighbor, Inc., and numerous other organizations support this contention (9, pp. 149-195). As a result, the plans investigated were also selected in order to lessen adverse environmental effects.

Relocations Plan

One of the two plans examined in this report is described in the following paragraphs. This plan, referred to hereinafter as the relocations plan, has as its major components relocation of residential structures located within the boundary of the 100-year frequency floodway as designated by the Omaha District Corps of Engineers Flood Plain Information report (1973), combined with zoning ordinances and other measures designed to prevent future encroachment in the flood plain.

As stated, the regulatory flood frequency adopted for this plan is the 100-year frequency flood, or that flood which on the average can be expected to be equaled or exceeded once every 100 years. Another way of stating this frequency is to say that flood which has a one-percent chance of occurrence in any given year. This definition is often preferred, since some people tend to believe that once a flood with a frequency in the 100-year range has occurred, it will be about 100 years before another flood of that magnitude can be expected. Needless to say, this is not the case. Just as in rolling a die two sixes may occur successively, two floods of large magnitude may also occur within successive years.

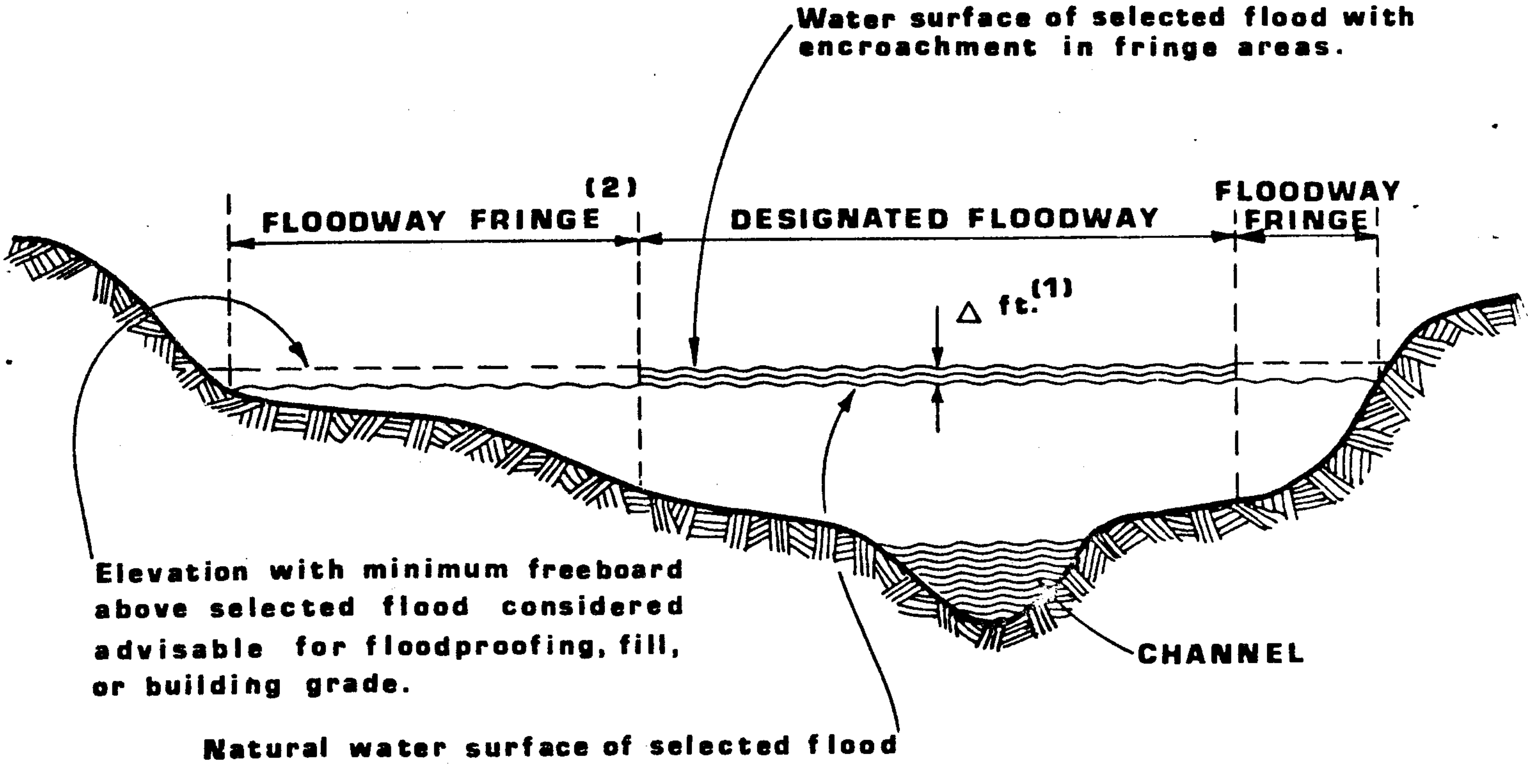
There were two primary considerations which governed the selection of the 100-year frequency flood as the regulatory flood for investigation of this alternative. First, 100-year flood protection is commonly the minimum level desired by most Federal, State, and local governmental agencies for developed residential areas. Secondly, it also corresponds to the regulatory flood level adopted for the National Flood Insurance Program.

The flood plain of the 100-year flood consists of the total area which would be inundated by a flood of this magnitude. The flood plain is subdivided into two regions, the flood fringe and the floodway. By definition, the floodway is that portion of the flood plain which carries the major portion of the flood discharge. The floodway is characterized by deeper and faster moving flows than are normally found in the flood fringe. In contrast, depths and flows in the flood fringe are shallower and slower moving, carrying only a relatively small percentage of the total flows.

Although the majority of flow is carried by the floodway, removal of the flood fringe area from the flood plain by fill or other encroachment will of necessity raise the level of the regulatory flood, since some storage area for the flood waters has been lost and also since the floodway must now carry that portion of the flood previously carried by the flood fringe. If we assume that this encroachment or fill progresses from the outer limits of the flood plain toward the floodway in a uniform manner, the induced rise in the water surface elevation for a given flood can be calculated. In practice, this method is often used to delineate the floodway and flood fringe. By selecting a permissible induced rise in the water surface elevation (usually 0.5 to 1.0 feet), filling is assumed to occur in the flood fringe areas, proceeding from the outer limits of the flood plain toward the main channel of the stream. The limits of the fill are then incremented until the induced rise in the water surface elevation is equal to the maximum permissible rise. At this point, the area which remains to carry the flood flow is designated as the floodway, while that portion of the flood plain assumed to have been filled is designated as the flood fringe. These features are shown graphically in the following diagram, Figure 2.

Features of the Plan

This plan consists of relocation or removal of residential structures located within the 100-year frequency floodway combined with adoption of zoning ordinances, building codes, and other measures deemed appropriate to prevent future encroachment in the flood plain which could result in



(1) Maximum of 1 foot or less if so established by State or local regulations.

(2) The floodway fringe should normally be considered as the area between the designated floodway limit and the limit of the natural selected flood as long as the encroachment results in only an insignificant increase (less than 1 foot) in the water surface of the selected flood.

Figure 2. Typical Flood Plain Cross Section.

economic loss and threat to loss of life. Although economic loss could be expected to occur to structures located anywhere within the flood plain should a flood of major proportions occur, preliminary investigations do not indicate economic justification for relocation of all structures in the flood plain. It is, however, the opinion of the study team that a significant threat to loss of life does exist due to the location of residential structures in the floodway. The combination of increased depths and velocities which would be experienced in the floodway in the event a major flood should occur could be sufficient to sweep buildings from their foundations. Although depths and velocities could be expected to vary widely depending upon the existant physical characteristics of the location, it is often accepted that depths exceeding two feet combined with velocities greater than three feet per second can be considered as dangerous (15, p. 22). Such depths and velocities could generally be expected to be equaled or exceeded throughout the floodway.

Locations of structures in the floodway were identified using U.S.G.S. quadrangle maps, scale 1:24,000, supplemented through the more populated areas of Fort Collins and Laporte by maps obtained from the Larimer County Planning Office, scale 1:2,400 with four-feet contour intervals. Once the structure was identified as being located in the floodway, on-site investigations were made to determine if the structure was a residential structure, the type of construction, and the approximate value. Investigations were also made to determine whether new structures had been constructed subsequent to publication of the maps. Values of these residences were determined in some cases by contact with local realtors advertising the property for sale. In other cases, the value of similar property was obtained from realtors and from newspaper advertisements in order to more accurately estimate the value of properties.

The 100-year floodway through the study reach contains about 27 single family residences which range in value from a low of about $5,000 for a farm home just upstream of Martinez Park near the intersection of the Cache La Poudre River and North College Avenue to a high of about $58,000 for a four-bedroom tri-level home located on the Cache La Poudre River near Cotton Willows Estates just west of Laporte. Total value of residential dwellings located in the floodway through the study reach is estimated to be about $580,000. A breakdown of estimated values of individual residential structures located in the floodway is presented in Table 1.

The costs of relocating these residential structures to a flood-free location were estimated using average costs of moving similar structures approximately the same distances as would be required for these relocations. Individual costs vary depending upon the type and size of structure and with the distance to be moved. Of the 27 residential structures

TABLE 1

Estimated Value of Residential Structures in Floodway

Location	Estimated Value	Number of Residences and Other Comments
Mouth of Poudre Canyon	$10,000	1 single story frame
Approx. 1 mile upstream of Watson Lake	35,000	1 two-story stucco sided
Approx. 3/4 mile upstream of Watson Lake	6,000	3 ea. cabin-type units at $2,000 each
Poudre at Taft Hill	20,000	1 two-story brick house
Poudre at Shields	85,000	4 houses, one is brick veneer
Watson Lake	60,000	2 brick veneer houses
Below Hatchery	65,000	2 single story frame houses
Poudre at Cotton Willow Estates	174,000	3 brick veneer tri-level houses
Buckingham	42,000	3 single story frame houses
Buckingham	15,000	1 single story frame house
Buckingham	33,000	3 single story frame houses
Poudre at N. College	30,000	2 frame houses, one stucco sided
Approx. 1/2 mile upstream of intersection of Poudre and N. College	5,000	1 two-story frame farmhouse
Totals	$580,000	27

Note: All structures are single family residences.

determined to be in the 100-year floodway, all but three would require relocation. The remaining three are motel-type units which have apparently fallen into disrepair, and it is believed that the cost of relocation would exceed the market value of the units. In this case, the structures would be condemned and removed with the owner reimbursed the fair market value, estimated to be about $6,000. Estimated costs of relocating the remaining 24 residences is about $120,000. An estimated cost of $5,000 for relocation of each house was arrived at after conversations with a professional house moving service (6). The above cost figures do not reflect any purchase of land.

Preventing Future Encroachment in the Flood Plain

After relocation of dwellings has been accomplished, it would be advisable for the city and county to enact ordinances prohibiting future encroachment in the flood plain. The ordinances may possibly differentiate between the floodway and the floodway fringe. As previously explained, the floodway conveys the majority of water during the designated flood, while the fringe primarily acts to store water and commonly has little or no flow velocity. In the floodway fringe, the flood is less severe and ordinances could be less restrictive for this area and allow the construction of structures that are probhibited in the floodway.

These ordinances would prevent the reoccurrence of problems similar to the one rectified under the relocation plan. If the community is primarily concerned with the risk to life, the ordinances may just prohibit the construction of dwellings. If property damage and possible ramifications of floodway encroachment are of concern to the city, ordinances may be expanded beyond dwellings to prohibit structures of any type.

The ordinances may also establish open space usage of the floodway. Trails and interpretative plans are being developed for the Poudre River corridor. This is an excellent open space usage to allow local residents to become more aware of local plant and wildlife and several unique historical sites that exist near the river. Other open space uses could include parks, golf courses, and parking lots.

It has been established that local communities have the legal right to tailor uses of the flood plain. Application of the police power to land uses is no different than its application to crimes against property and persons (10). The community, operating under enabling legislation of the State, can prohibit individual actions that would constitute a nuisance or threaten the public safety. Flood plain structures may cause higher flood stages by impeding the normal flow pattern of the flood. He may also constitute a nuisance when structures are removed from their foundations and float downstream, inflicting property damage on other landowners. Courts generally give support to flood plain regulations designed to prevent nuisances and threats to the public health and safety.

Properly designed flood plain ordinances are more likely to encounter problems in the political rather than the judicial atmosphere. However, with the public's increasing awareness of environmental aspects and increasing yearly flood damages in this country, the ordinances should become more politically acceptable. It should be noted that the City of Ft. Collins is presently holding hearings on the proposed enactment of flood plain ordinances, consistent with the guidelines established by HUD for the National Flood Insurance Program. The first reading of these flood plain ordinances was held and approved in the city council meeting of July 15, 1975. There was no public opinion either pro or con expressed at this meeting on the proposed flood plain ordinances. The second reading will be held, and the ordinances will be voted on in the August 5, 1975 meeting of the city council. If the ordinances are approved in this meeting, they will become law after 10 days (4). See Appendix C for the proposed flood plain ordinances for Fort Collins.

Protective Measures for Structures Remaining in Flood Plain

Under the proposed relocations plan, only dwellings situated in the floodway are to be relocated. Dwellings located in the floodway fringe are not included in the relocations plan, for flood severity and flow velocities are considerably less here and the danger to loss of life is minimal. Nevertheless, commercial structures remaining in the floodway, and commercial and dwelling structures remaining in the floodway fringe will be subject to flood damages. Owners of these structures may protect their interests by taking advantage of the provisions of the National Flood Insurance Program.

The National Flood Insurance Program was initiated in 1968 (Title XIII of the Housing and Urban Development Act, P.L. 90-448). This was an action subsequent to the realization that people are to be controlled rather than the water, if a long-range solution to increasing yearly flood damages is to be formulated. Managing the flood plains to discourage development and allowing them to serve their natural function of storing overbank flow and recharging groundwater is a desirable alternative to spending large sums to confine the river flow.

The Federal Insurance Administration adopted the 100-year flood level as determining the flood plain. The 1968 Act made available to owners of structures in the flood plain insurance through private companies.

To achieve the desired purposes in land use regulations, the Flood Insurance Act requires that policies can only be sold in participating communities--those that pass and enforce land use control. Participants are then eligible for subsidized insurance rates.

There are two types of requirements for community participation in the insurance program. Under the first phase, the emergency program, the local government seeking eligibility must certify that it will enforce the following standards in the flood prone areas:

1) a building permit system that includes reviewing permits to assure that any known flood hazard is considered, 2) requirements for anchoring and flood proofing structures to be built in the known flood prone area, 3) review of subdivision proposals to assure that they will minimize flood damage, and 4) requirements that new water and sewage systems and utility lines be constructed to avoid impairment of them during flooding. Once FIA is informed of such certification, subsidized insurance will then be available for both old and new construction. The above flood prone designation will be dependent upon the Flood Hazard Boundary Map, showing the extent of the 100-year flood plain.

In the second phase, the regular program, the FIA provides the community with a Flood Insurance Rate Map. This map contours the 100-year flood plain to indicate the floodway and other zones of damage risk. With this information, the community must require that:

1) On the flood plain

a) new residential construction of substantial improvement of existing homes must have the lowest level above the elevation of the 100-year flood

b) non-residential construction must meet the same standard or be floodproofed to that level

2) In the floodway, ordinances must prohibit

a) expansion of existing structures

b) fill or encroachments unless offset by stream improvements compensating for reductions in the carrying capacity.

After the Flood Insurance Rate Map is available, new construction is permitted within the flood plain (dependent upon local ordinances), but such structures will not be eligible for subsidized insurance.

Congress adopted the Flood Disaster Protection Act of 1973, amending the 1968 Act. This Act makes flood insurance mandatory as a condition for any federally related financial assistance to communities or individuals wishing to acquire or refinance property or build within the flood hazard area. Under this act, federally related financial assistance includes not only loans and grants from federal agencies, but also money through federally regulated or insured institutions. The 1973 legislation also provides the limits on coverage at $70,000 and $20,000 for private homes on the structure and contents, respectively (7).

Thus while relocation of dwellings may be necessary in the floodway to reduce the risk to loss of life, the burden of large property damage caused by a flood may be eased by taking advantage of the provisions of the National Flood Insurance Program.

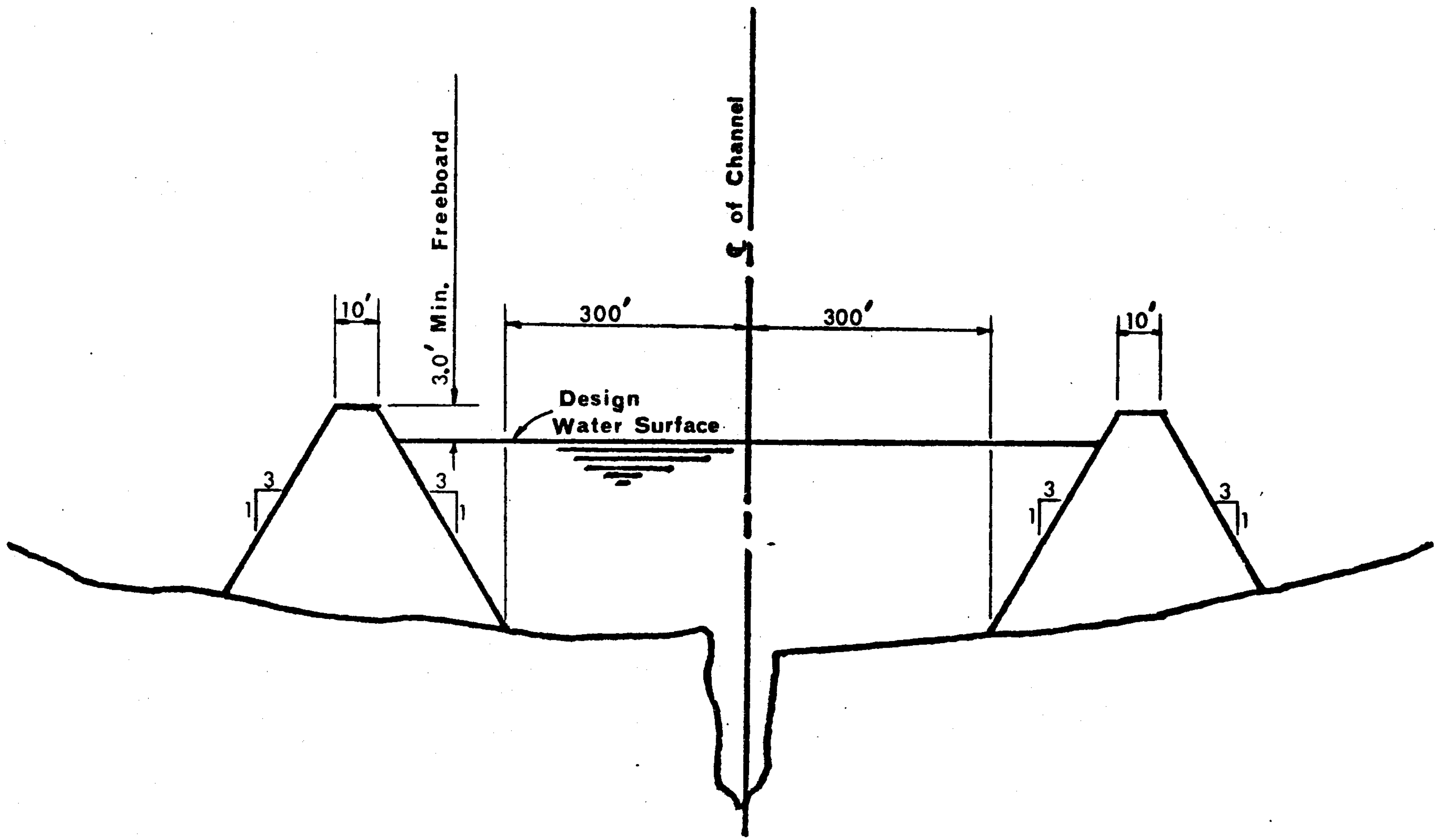
Fort Collins is presently under the initial phase, the emergency phase, of the National Flood Insurance Program. And, as was stated earlier, flood plain ordinances that will qualify Fort Collins for the second phase of the program will be voted on in the city council meeting on August 5, 1975.

The Poudre School District Board of Education voted June 23, 1975 to purchase flood insurance for five schools identified as being in flood-prone areas. These schools are Eyestone, Cache La Poudre elementary and junior high, Boxelder, and Wellington junior high. Total cost for flood insurance for the five schools is $4,559 (11).

Levee Plan

Two levee plans were studied in this report, one for 100-year flood protection and the other for standard project flood protection. The 100-year flood has been defined earlier in this report. The standard project flood is defined as "the flood that may be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations" (15, p. 26). The proposed levees have 1:3 sideslopes (1 vertical to 3 horizontal), 10 feet top widths, and 3 feet freeboard. These design parameters were chosen to yield the smallest levee that is structurally desirable. Levee bank slopes are usually very flat due to relatively poor construction materials, with recommended side slopes ranging from 1:3 to 1:5. A minimum top width of about 10 feet is required to permit movement of maintenance equipment. Recommended freeboard ranges from 2 to 5 feet (8, p. 587). The levees were placed with their riverward toes 300 feet from the centerline of the river. The distance of 300 feet that was chosen appeared to be reasonable after an initial review of available maps. See Figure 3 for a typical levee cross section. The levees would be placed on both sides of the river and would extend a distance of about 10.2 miles, from approximately 3 miles downstream of Mulberry Street, to approximately one mile upstream of Laporte. These limits corresponde to sections 79 and 39, respectively, in the Corps of Engineers flood plain study of Fort Collins. The levees were terminated into high ground a mile upstream of Laporte, because areas subject to flooding above Laporte are largely underdeveloped, and used for cropland or pasture.

It should be noted that the levee plans that were studied are not complete designs of a levee system, nor are they meant to be. The purpose of this section of the report was to approximately determine the costs of a levee system for Fort Collins subject to the constraints of the study team of time and money. Also as stated earlier, the levee plans studied are not considered by the study team to be the "optimal" solution to the Fort Collins' flood "problem."



Typical Levee Section
(no scale)

Figure 3

Design Procedure

General

Water surface profiles (backwater curves) were computed in the proposed leveed reach by the standard step method for both the 100-year and standard project floods. The water surface elevations obtained from these computations were compared to the water surface elevations for natural conditions computed by the Corps of Engineers in their flood plain study of Fort Collins. Since the profiles the study team obtained closely resembled those obtained by the Corps of Engineers, they were considered satisfactory. Therefore, to obtain the water surface elevations in the leveed floodway, the study team used the Corps elevations with additional depth added on rather than using their own elevations interpolated between sections. The Corps profiles were used since they were calculated on a computer, using more data and more precise methods and assumptions. To these elevations, the study team added 3 feet of freeboard to obtain the top of levee elevations. Using these elevations the volume of earthwork required for the levees was computed.

Standard Step Method

Gradually varied flow is steady flow whose depth varies gradually along the length of a channel. Two conditions are signified by this definition: (a) that the flow is steady - the hydraulic characteristics of flow remain constant for the time interval under consideration, and (b) that the streamlines are practically parallel - that hydrostatic distribution of pressure prevails over the channel section. Most theories that have been developed for gradually varied flow have depended on the following assumption - the head loss at a section is the same as for a uniform flow having the velocity and hydraulic radius of the section. This means that uniform-flow formulas may be used to evaluate the energy slope of gradually varied flow at a given channel section, and the corresponding coefficient of roughness developed primarily for uniform flow is applicable to the varied flow (3, p. 217). The standard step method is a method to compute gradually varied flow profiles. In general, step methods are characterized by dividing the channel into short reaches and carrying the computation step by step from one end of the reach to the other. The standard step method can be applied to nonprismatic channels where the hydraulic elements are dependent on the distance along the channel and is the method best suited to computations for natural channels (3, pp. 262-268).

The standard step method assumes that the total energy head at an upstream section is equal to the total energy head at a downstream section plus energy losses, friction losses and eddy losses. The friction losses are equal to the distance between sections times the average friction slope at the two sections. When the Manning formula is used, the friction slope is expressed by

$$S_f = \frac{n^2 V^2}{2.208\ R^{4/3}}$$

where

S_f = friction slope

n = Manning roughness coefficient

V = velocity

R = hydraulic radius.

The standard step method is a trial and error procedure as follows. Starting with a known depth of flow at the first section, the depth of flow at the next section upstream is assumed; and the total energy head equal to elevation head plus depth of flow plus velocity head is computed. This total energy head is compared to the energy head equal to the original energy head plus the friction losses.

Data Used

The study team used cross sections 5-5, 6-6, 7-7, 8-8, 9-9, and 10-10, shown in the Corps of Engineers flood plain study of Fort Collins to obtain the hydraulic data required for the standard step backwater procedure. The discharges used in the computations were also given in the flood plain study and are shown below. The mouth of Dry Creek is located approximately 1/3 of the way between sections 10-10 and 9-9 near Mulberry Street.

Location	100-year Flood Peak Discharge (c.f.s.)	Standard Project Flood Peak Discharge (c.f.s.)
Above mouth of Dry Creek	16,200	40,000
Below mouth of Dry Creek	19,700	60,000

The study team assumed a composite Manning roughness coefficient, n, for the channel and flood plain to be 0.045. This assumption assigned equal weight to resistance in the channel, n = 0.04, and in the overbank, n = 0.05.

The energy coefficient, alpha, was assigned a value of one by the study team. The eddy losses, h_e, were assumed to be zero.

In the backwater calculations performed by the study team no bridge sections were used to compute swellhead through the bridges that cross the Poudre. It was assumed that since the backwater profiles were of the M-1 type, and the channel slope was fairly steep (approximately 0.0035 feet per foot); that the effects of swellhead through the bridges would be diminished upstream as the water surface approached normal depth.

Tables 2 and 3 display the results of the backwater computations performed by the study team.

TABLE 2

Standard Project Flood Backwater Computation Summary

Station	Change in Distance (feet)	Channel Bottom Elevation (feet,M.S.L.)	Depth of Flow (feet)	Velocity Head (feet)	Total Energy (feet, M.S.L.)
Q = 60,000 CFS					
10-10	0	4902.0	16	2.50	4920.50
10-10(A)	100	4902.3	17	1.97	4921.27
10-10(B)	100	4902.6	17.5	1.75	4921.85
10-10(C)	100	4902.9	17.7	1.70	4922.30
10-10(D)	1400	4905.0	21.5	0.87	4927.37
At Mouth of Dry Creek, Discharge Changes					
Q = 40,000 CFS					
9-9	5400	2921.0	15.1	0.66	4936.76
8-8	5600	4935.5	13.6	0.90	4950.00
7-7	8500	4964.0	12.8	0.92	4977.72
6-6	9400	5004.0	13.2	1.23	5018.43
5-5	9600	5045.0	15.6	1.06	5061.66

TABLE 3

100-Year Flood Backwater Computation Summary

Station	Change in Distance (feet)	Channel Bottom Elevation (feet, M.S.L.)	Depth of Flow (feet)	Velocity Head (feet)	Total Energy (feet, M.S.L.)
Q = 19,700 CFS					
10-10	0	4902.0	10.4	1.51	4913.91
10-10(A)	100	4902.3	11.3	1.10	4914.70
10-10(B)	100	4902.6	11.7	0.97	4915.27
10-10(C)	100	4902.9	11.9	0.91	4915.71
At Mouth of Dry Creek, Discharge Changes					
Q = 16,200 CFS					
9-9	6800	4921.0	12.4	0.23	4933.63
8-8	5600	4935.5	9.7	0.48	4945.68
7-7	8500	4964.0	9.3	0.43	4973.73
6-6	9400	5004.0	9.8	0.66	5014.45
5-5	9600	5045.0	11.9	0.58	5057.48

Comparison with Corps of Engineers Profiles

The water surface elevations computed by the study team for the leveed floodway are compared with the water surface elevations of the Corps for natural conditions in Tables 4 and 5. Considering the lack of data and the assumptions made (roughness coefficient, composite cross sections, no bridges, etc.), the study team feels that the computed water surface elevations are satisfactory since they closely parallel the water surface elevations of the Corps. The computed profiles for the standard project flood and the 100-year flood contained within the leveed floodway were about 4 feet higher and 2 feet higher, respectively, than the profiles computed by the Corps of Engineers for natural conditions. See Appendix A for the flood profiles of the Corps of Engineers.

Top of Levee Elevations

The study team decided to use the Corps water surface elevations for natural conditions plus additional depth to determine the top of levee elevations rather than use the computed water surface elevations for the leveed floodway interpolated between sections. This was done in the realization that the Corps of Engineers water surface elevations were more accurate. Therefore, the elevations of the tops of the levees along the Cache La Poudre River were determined as follows:

TABLE 4

Standard Project Flood Comparison
of Water Surface Elevations

Section	Study Team Water Surface Elevation (feet, M.S.L.)	Corps Water Surface Elevation (feet, M.S.L.)	Difference (feet)
10-10	4920.6	4914.6	6.0
9-9	4936.1	4932.3	3.8
8-8	4949.1	4945.1	4.0
6-6	5017.2	5014.2	3.0
5-5	5060.6	5056.6	4.0
		Average Difference	= 4.16 feet

TABLE 5

100-Year Flood Comparison
of Water Surface Elevations

Section	Study Team Water Surface Elevation (feet, M.S.L.)	Corps Water Surface Elevation (feet, M.S.L.)	Difference (feet)
10-10	4914.8	4912.1	2.7
9-9	4933.4	4930.4	3.0
8-8	4945.2	4944.3	0.9
6-6	5013.8	5012.1	1.7
5-5	5056.9	5054.5	2.4
		Average Difference	= 2.14 feet

Note: Study team water surface elevations are for the 600 feet leveed floodway.
Corps water surface elevations are for natural conditions.

for the standard project flood,

top of levee =	Corps water surface elevation for natural conditions (SPF)	+ 4 feet (due to constriction of channel by levees)	+ 3 feet (freeboard);

and for the 100-year flood,

top of levee =	Corps water surface elevation for natural conditions (100-year)	+ 2 feet (due to constriction of channel by levees)	+ 3 feet (freeboard).

See Appendix B for the Corps of Engineers water surface elevations used to compute the top of levee elevations.

Volume of Earthwork

Using the top of levee elevations computed by the method previously described, sectional areas for the levees were computed at various sections along the river. Adjacent sectional areas were averaged and then multiplied by the distance between the sections to obtain the volume of earthwork required for the levees between sections. The total volumes of earthwork required for the levee systems are as follows:

standard project flood - 2,000,000 cubic yards

100-year flood - 850,000 cubic yards.

Using an estimated value of $1.50 per cubic yard of earthwork in place (1), the total cost for the construction of the levees is as follows:

standard project flood - $3,500,000

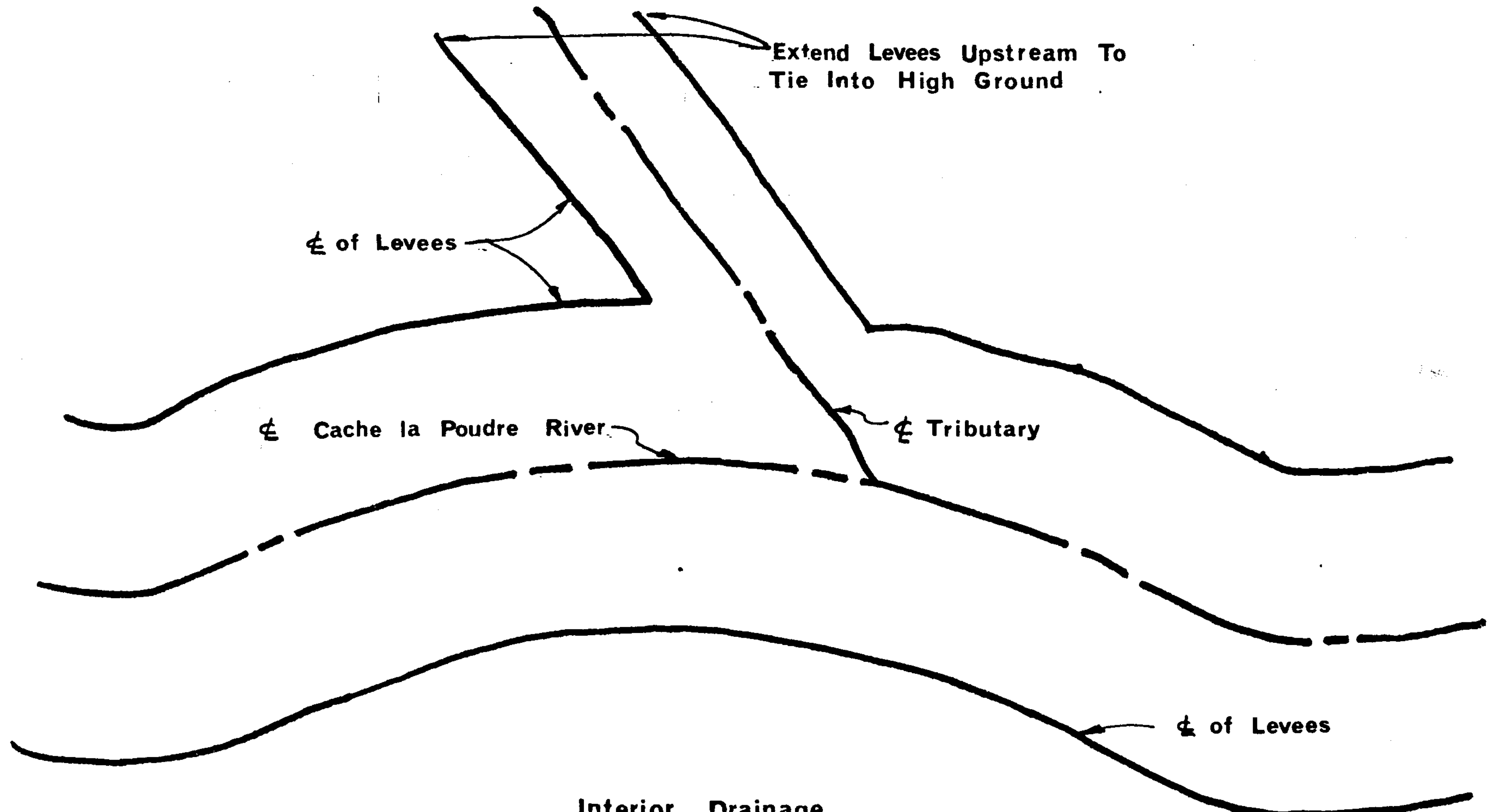
100-year flood - $1,275,000.

Interior Drainage

As the levees must be continuous if they are to provide the desired protection, local runoff from behind these levees becomes a problem. The design of the interior drainage network is quite complicated and is beyond the scope of this study. The study team will suggest several possible means of handling the interior drainage and will estimate the cost as a percentage of the total project cost.

One method of providing for the interior drainage is to run the levees upstream along the tributary drainage paths to high ground as is shown on Figure 4. When it is necessary for the levees to cross the natural drainage paths, provisions must be made to provide for alternative means of drainage. These alternative methods of providing for the interior drainage include flood gates, pumping plants, lateral collector ditches, and pressure conduits. Examples of these various methods of providing for the interior drainage are shown on Figures 5 through 8. The selection of the proper alternative is basically an economic decision.

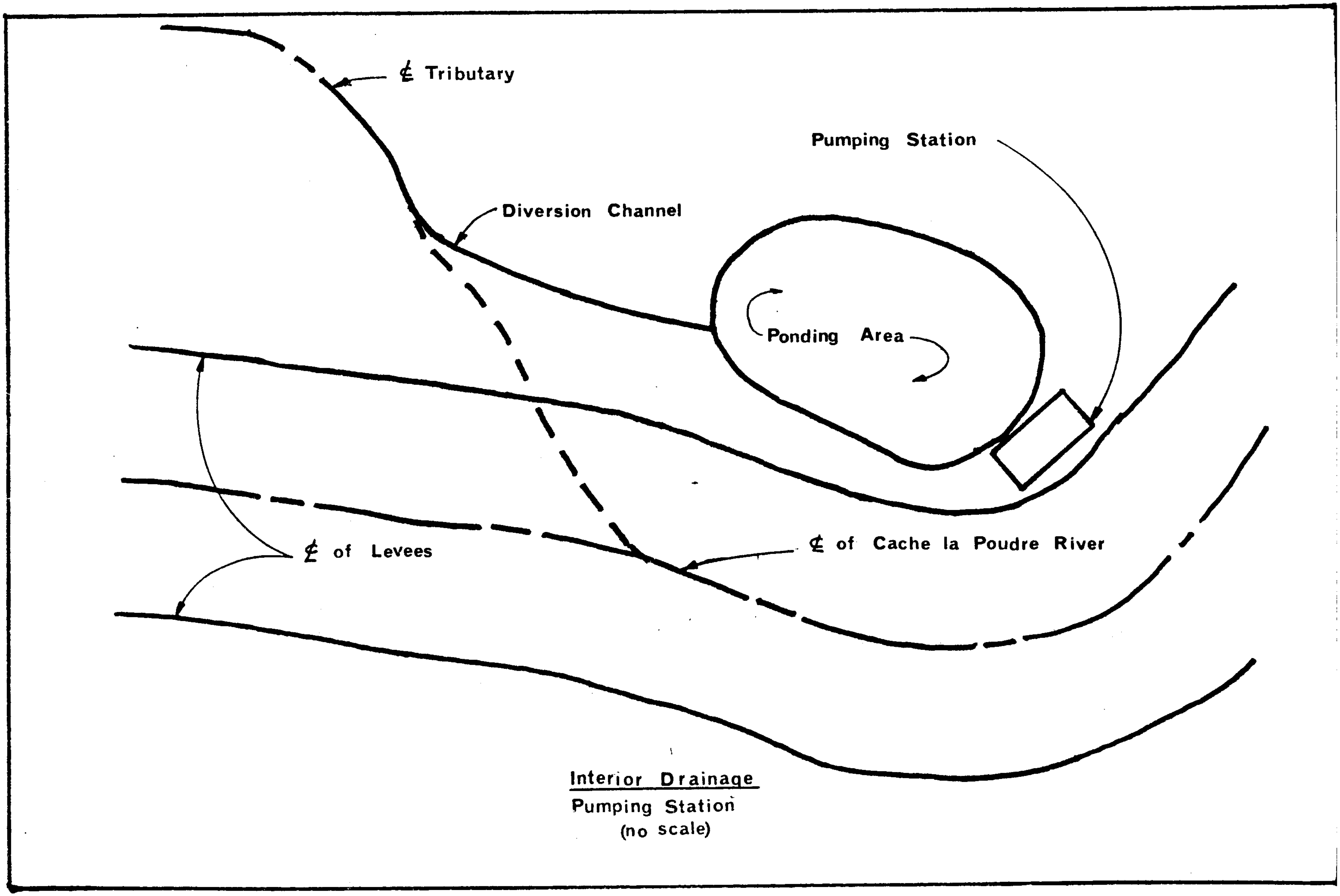
The size of the drainage path and steepness of the valley cross section will be of considerable importance in determining which of these alternatives is least costly. For a more thorough discussion of the alternative means of providing for



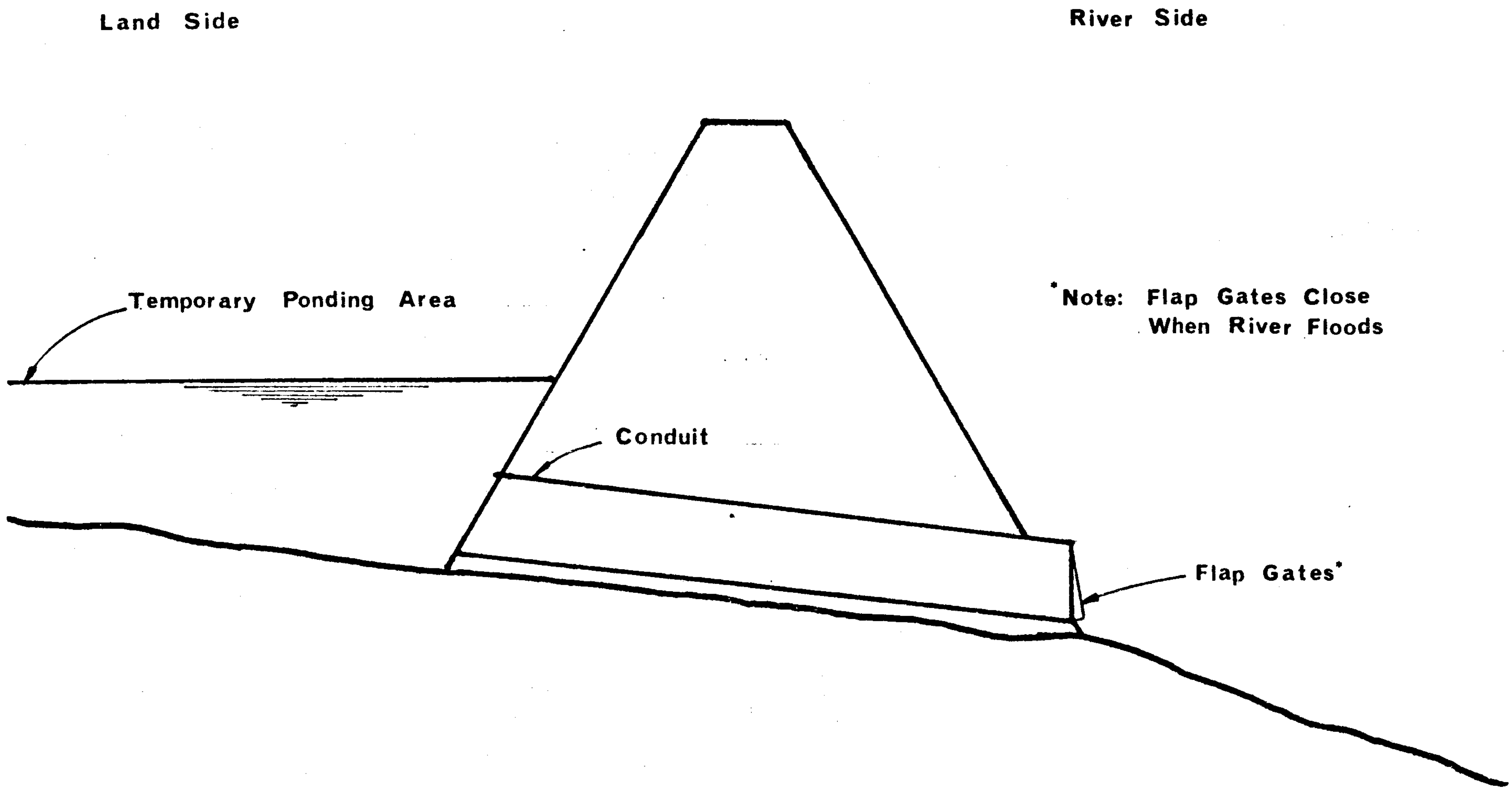
Interior Drainage
Levee Treatment At Tributary
(no scale)

Figure 4

Figure 5

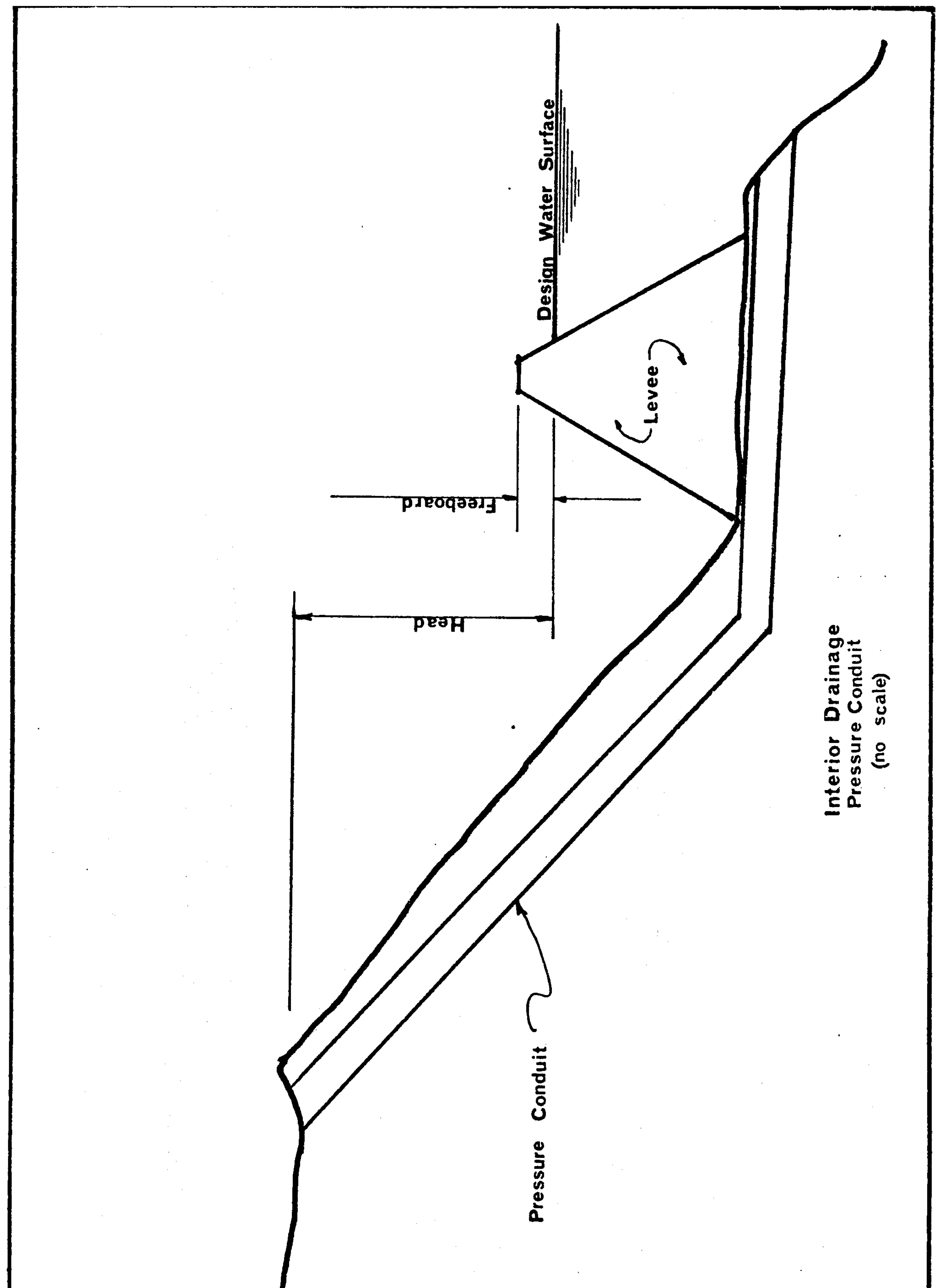


Interior Drainage
Pumping Station
(no scale)



Interior Drainage
Flood Gates
(no scale)

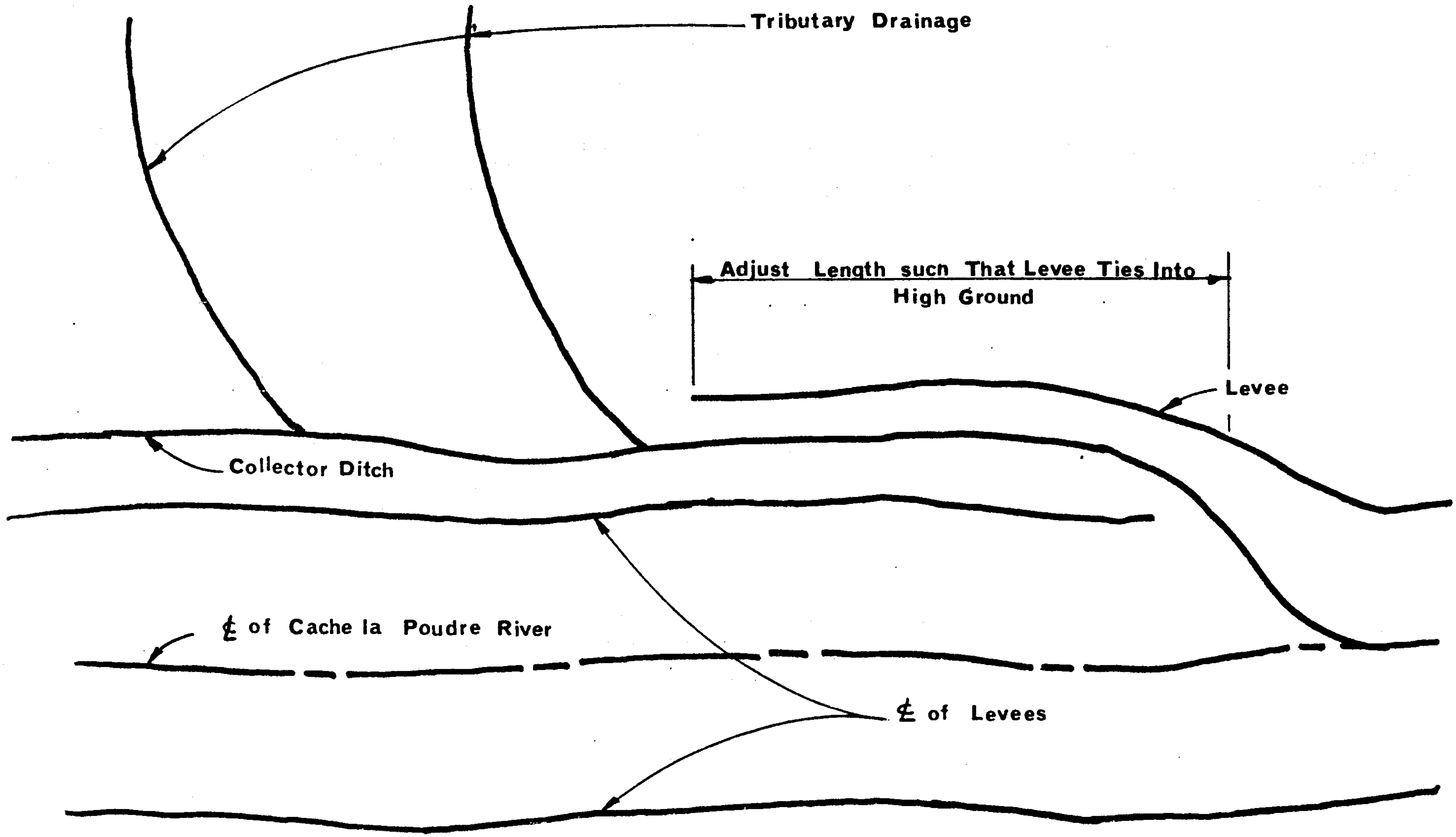
Figure 6



Interior Drainage
Pressure Conduit
(no scale)

Figure 7

Figure 8



Interior Drainage
Lateral Collector Ditch
(no scale)

the interior drainage see Linsley and Franzini (8, pp. 590-591). Also see Corps of Engineers Engineering Manual 1110-2-1410 (14) for a complete list of the steps required in the design of an interior drainage network.

One of the more important decisions that must be made before the design can be made is to determine the frequency for the design. One of the main factors governing this decision is how long is the leveed stream in flooding conditions. As the Poudre is a mountain stream with short duration floods it is recommended that the interior drainage system be designed for a fairly low frequency runoff (5-10 year exceedence frequency). By keeping this design frequency relatively low the cost of the interior drainage system will also be kept relatively low. Keeping this in mind it was estimated that the interior drainage network would represent 20 percent of the earthwork costs of the levee system. This means that the interior drainage costs would be as follows:

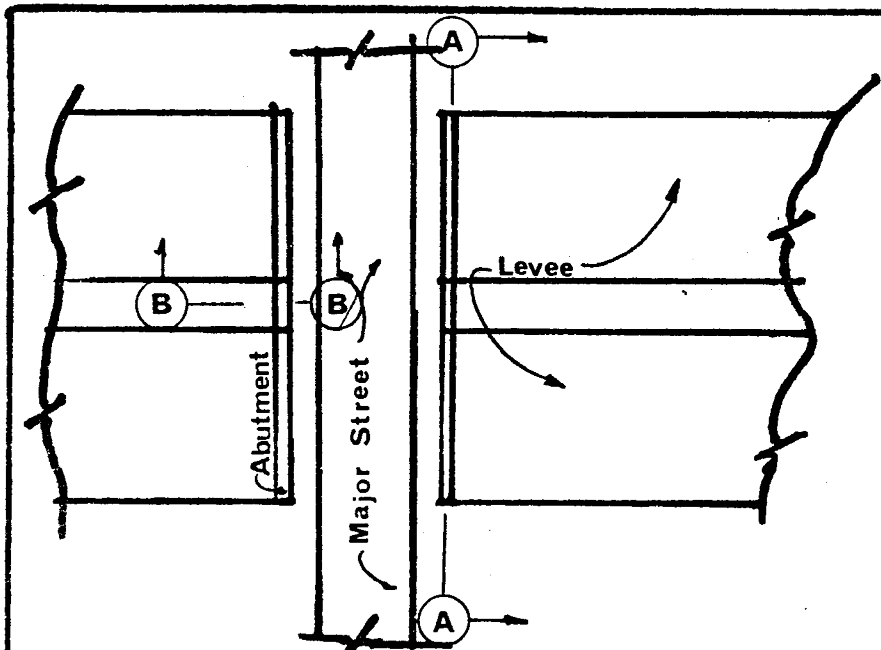
standard project flood	- $700,000
100-year flood	- $255,000

Design at Bridges

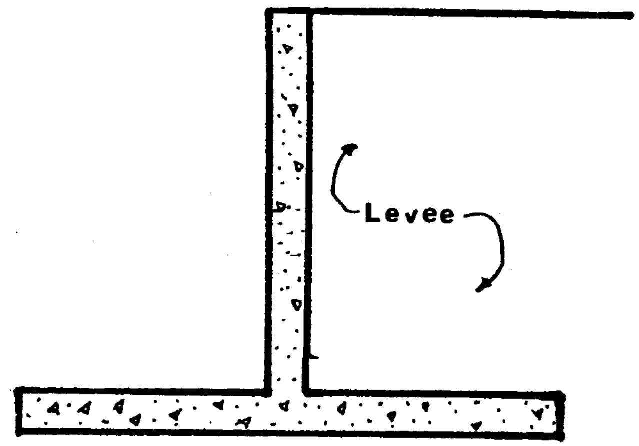
Special care must be taken where major streets and highways cross the leveed floodway to insure that floodwaters are contained within the levees. These crossings require individual designs with much detail. However due to the level of this report, only two solutions were proposed for which approximate costs were estimated.

One solution is a ramp type crossing. For the 100-year levee plan, the levees range in height from 0 up to about 14.2 feet, with the majority of levee sections in the 6 feet range. For the standard project flood levee plan, the levee height ranges from 2.5 to 18.5 feet. Using 6 feet for the levee height, a ramped road over the levees would require a ramp approximately 200 feet long if 6 percent grades are utilized. Therefore for large levee sections, the use of a ramp type crossing may be impractical due to the length of ramp required. These ramps would require that the sideslope of the levees be warped to fit them.

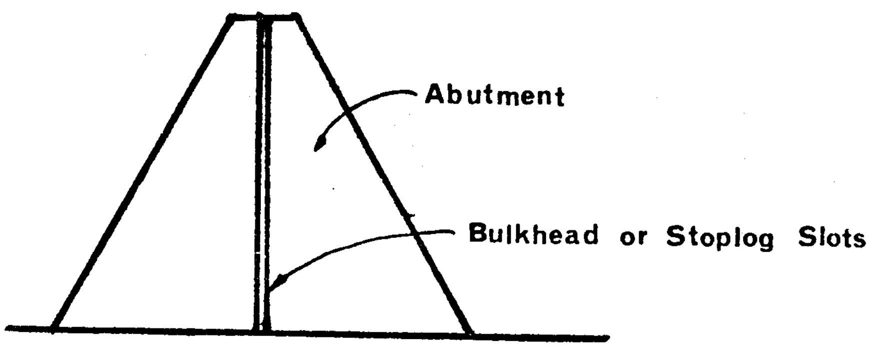
As the ramp type crossing may be undesirable due to safety reasons, a second type of crossing was investigated. This second type of crossing would consist of a concrete abutment with stoplog or bulkhead slots. As the hydraulic head against these stoplogs or bulkheads would be generally about 3 feet for the 100-year flood and about 9 feet for the standard project flood, their design would not be too complicated. Should the stoplogs become too cumbersome, consideration should be given to the use of sand bags. Care should be taken to insure that materials are available (stoplogs, bulkheads, or sandbags) to make the closure regardless of the method chosen. One factor to consider in this type of closure is whether or not adequate time is available to make the necessary closure. For an example of this method of road crossing see Figure 9.



PLAN



SECTIONAL ELEVATION
SECTION B–B



ABUTMENT ELEVATION
SECTION A–A

Levee Treatment At Roads
(no scale)

Figure 9

Another factor that should be considered in making the determination of the type of crossing to be used is whether or not it is desirable that the road be closed. It would be necessary to close the road to vehicular traffic under both types of crossings discussed above. Should it be necessary that the street or highway not be closed during highwater, then the only solution would be to raise the road above the water surface elevation. This approach would be quite costly and was not given serious consideration in this study.

For the purpose of a cost estimate, the study team used the abutment-stoplog method of crossing. It was estimated that each of the roads crossing the leveed section would cost $15,000 for the 100-year levee plan and $40,000 for the standard project flood levee plan. These calculations assumed the cost of in place concrete to be $100 per cubic yard. Since the levee is crossed in 9 places by bridges, the total estimated costs of the levee crossings are $135,000 for the 100-year flood plan and $360,000 for the standard project flood plan.

Land Acquisition in Leveed Floodway

The construction of the proposed levees would require the acquisition of land and the relocation of or reimbursement for the existing structures located along the leveed 10.2 miles of river. The total land required to be taken on each side of the river would be 300 feet plus the width of the levee. Since the width of levee is a function of the levee height which varies along the river, the study team assumed that all the land located within 400 feet of either side of the river would be acquired.

Approximately 100 structures of various kinds--residences, businesses, and outbuildings--are located within 400 feet of either side of the Poudre River in the proposed leveed reach. Average values for both land and improvements were used to estimate the cost of land and structural acquisitions. The real estate values used were based on the assessed values of the land and improvements as determined from the county tax records (9, p. 27).

The estimated value of the land and structures located within 400 feet of either side of the Cache La Poudre River in the 10.2 mile proposed leveed reach is approximately $4,850,000. Please see Table 6 for a breakdown of this figure.

Greenbelt Aspects

The completion of the levee system, including land acquisition and the relocation or destruction of existing structures within the levees, would in effect create a 300 feet wide greenbelt on each side of the center line of the river. Care would be taken in the construction of the levees and the relocation or destruction of the existing structures to not disturb the existing vegetation. In most places along the river vegetation is present in bands 100-200 feet

TABLE 6

Land and Improvement Values Along Cache La Poudre River in the Proposed Leveed Reach (9, p. 27)

Assessed Valuation	Left Bank: Miles Along River	Left Bank: Value	Right Bank: Miles Along River	Right Bank: Value
Less than $10,000 per acre (estimate $2,000 average value)	9.5	$920,000	9.25	$895,000
$10,000-$40,000 per acre (estimate $25,000 average value)	0.5	$610,000	0.3	$365,000
More than $40,000 per acre (estimate $50,000 average value)	0.2	$485,000	0.65	$1,575,000
	10.2	$2,015,000	10.2	$2,835,000
		$2,835,000		
	Total	$4,850,000		

Note: For 400 feet width, the conversion factor is 48.5 acres per mile distance along the river.

wide. Care would also be taken to preserve the historic sites that exist within the leveed area. These sites include the second Camp Collins, which became Fort Collins during the Civil War; Mason Farm, one of the original homesteads situated on the stage road; the original site of Camp Collins, which was established in 1863; and three sites at Laporte Station--county bridge over the Poudre River at the exact location of the original trail crossing into Laporte, Overland Stage Station near Lion's Park; and the old courthouse site (9, pp. 36-37). For a more detailed discussion of a greenbelt along the Poudre River see Combs et al. (5, pp. 12-18).

Summary

Proposed levee (100-year flood and standard project flood)

Sideslope	1:3 (1 vertical to 3 horizontal)
Top width	10 feet
Freeboard	3 feet
Distance from river centerline	300 feet to river side toe
Total distance along river	10.2 miles

Levee costs

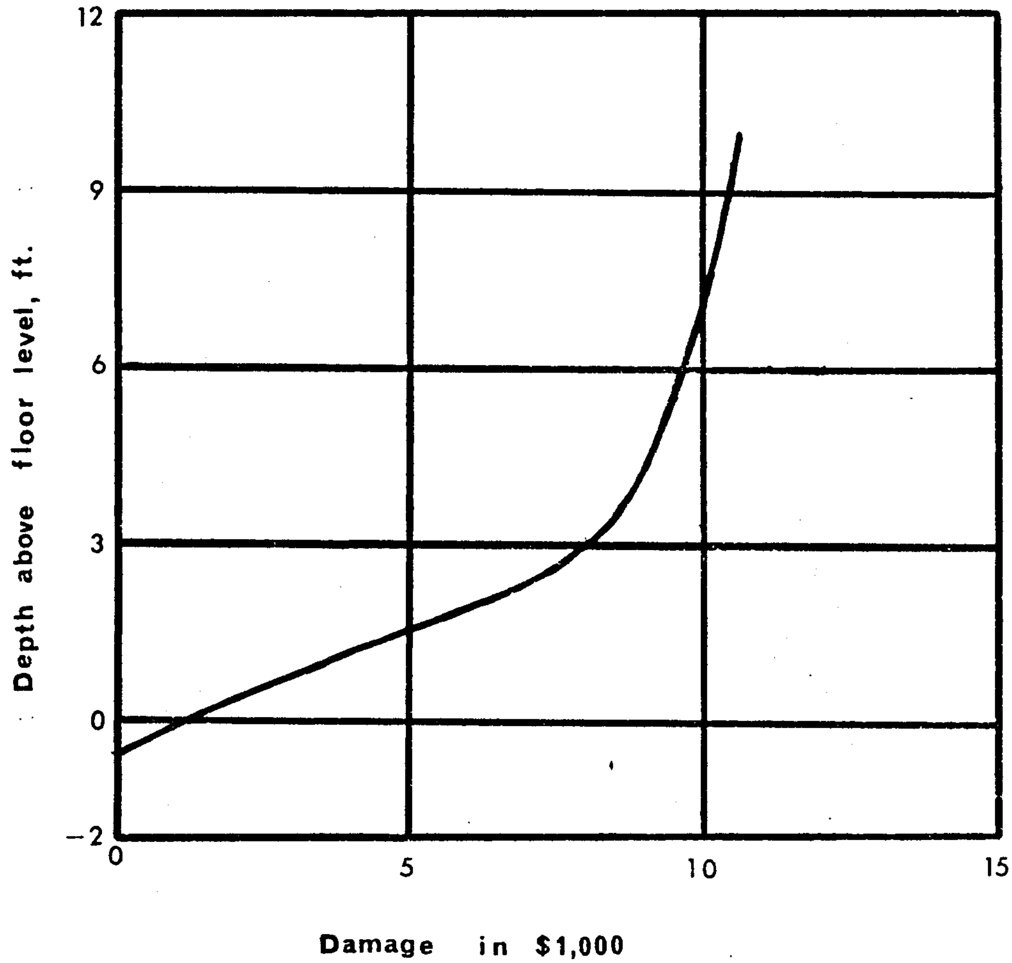
	100-year Flood	Standard Project Flood
Earthwork	$1,275,000	$3,500,000
Interior drainage	$ 255,000	$ 700,000
Bridges	$ 135,000	$ 360,000
Land acquisition	$4,850,000	$4,850,000
Total costs	$6,515,000	$9,410,000

Levee benefits

100-year flood - the levees designed for this flood would provide protection from the 100-year flood.

standard project flood - the levees designed for this flood would provide protection from the standard project flood

To have estimated dollar values of benefits would have required a detailed field reconnaissance of all areas to be protected by the levee system. An estimate of expected damages v. depth of flooding for a $15,000 house is shown in Figure 10. Damage estimates of this type along with flood frequency analyses could be used to compute flood protection benefits.



Flood Depth v. Damage Curve for a Typical One-Story House Valued at $15,000 [12, p. 3].

Discussion of Relocations and Levee Plans

In the previous sections of this report, two basic plans have been presented as possible measures to curtail flood damages and the threat to loss of life. A possible relocations plan and levee plan have been studied in detail so that comparisons may be drawn on the aspects of the two approaches. It should be understood that while the detail presented in this report is greater than any other known to exist by the study team on these two alternatives, a more in depth investigation would be required prior to the implementation of either plan. This is primarily due to the cost figures used in the report and the reconnaissance of the study area. In some cases, exact costs were not available, so what was considered to be reasonable estimates had to be substituted. All cost data is sure to become out-dated with the passage of time. While some recently created county maps were used in the investigation, the study team in some cases had to utilize USGS topographic maps that were somewhat obsolete and had large contour intervals. Although, the floodway was inspected in as great a detail as time allowed, it would be very likely that not all dwellings were canvassed in the relocations plan. These restrictions, while presenting no significant hinderance to the study team in accomplishing its goal of examining in general terms the two plans, should be kept in mind in employing further any data presented in this report.

From a political viewpoint, it would appear that the relocations plan is more feasible than the levee plan. This is substantiated by the fact that the City of Fort Collins has implemented an open space plan and is in the process of enacting flood plain ordinances to curtail development in the floodway. The increasing concern for the environment would also decrease the political viability of the levee plan, or any other structural measure.

In environmental terms, many would hasten to favor the relocations plan. Levees have been contended to be unsightly and very disruptive to the existing plant and wildlife. Life cycles in the riverbottom would be interfered with by changes in topography and habitat associated with levee construction. However, one should consider that levees could provide protection to the nesting areas of terrestrial animals. Additionally, with the levee system there would be an approximately 300 feet wide greenbelt on each side of the river. This would be composed of the area between the levee and the river and would contain no development.

The relocations plan would not disrupt the natural drainage patterns along the river. A levee system however would affect overland flow, but it would be improper to speculate on the ramifications. A more detailed study would be required to determine the nature and effect of these alterations.

The levee plan would provide flood protection to the area confined by the system. Naturally, the 100-year levee design would provide protection against the 100-year flood, while the standard project levee design should provide protection against any foreseeable flood under the most detrimental climatic and hydrologic conditions. The relocations plan, however, would not provide this degree of flood protection. The relocations plan is primarily addressed to dwellings in the floodway of the 100-year flood. Subsequently, there would be property damage under the relocations plan to commercial establishments in the floodway and to all structures in the floodway fringe, although the risk to life would be minimal. Under the levee plan, there would be no property damage or risk to loss of life for floods not exceeding the design frequency.

Another aspect that deserves consideration is that levee construction may induce greater development within the protected area. If greater residential construction occurs landward of the levee system, the threat to loss of life may be much greater if levees are overtopped by a flood, than that which existed prior to levee construction. For the same reason, the false sense of absolute security implied by local residents in a levee system sometimes causes increased property damage due to flooding.

The cost of the 100-year levee plan is $6,515,000 and the corresponding figure for the relocations plan is $126,000. The cost of the standard project flood levee plan is $9,410,000. It must be realized that these are not firm figures but only broad estimates based on the information available. It is not for the study team to speculate on a preferable plan, but rather it would be for the local residents to decide whether the difference in cost is reasonable for the added flood protection against property losses.

The relocations plan itself may be met with different sentiments among the various people located in the floodway along the river. For example, the residents of Buckingham might look favorably upon the prospect of being relocated while the residents near Cotton Willow Estates, perceiving themselves as having much more to lose, may be opposed to a relocations plan for residents of the floodway.

The method of financing may influence the desirability of one plan over the other. The levee construction plan may entail large expenditures of capital over a short period of time--capital that may not necessarily be readily available to the city. However, the relocations plan could be pursued at a pace commensurable with the financial capabilities of the city. There may be a possibility of obtaining federal assistance under either of the plans, thereby easing the local financial burden.

There is no maintenance costs associated with a relocations plan after the program has been accomplished and proper ordinances have been enacted and are enforced. A levee system would be subject to deterioration over time. Subsequently, to keep the levee in proper condition, considerable sums of money may have to be expended on general maintenance. Even if the levee could be constructed largely at Federal expense, it is normally the requirement of local interests to operate and maintain the system. Thus the financial considerations associated with a levee system extend beyond the immediate time of project completion to encompass the expected project life.

Since the levee plan also involves the relocation of clusters of dwellings, it as well as the relocations plan will include disruption of some existing neighborhoods. In other areas, each plan involves the relocation of isolated dwellings. Nevertheless, on this particular social aspect, the two plans are similar in their effects.

A relocations plan does not to any degree foreclose possible future alternatives. A relocations plan may be implemented, but if at some future date it should become apparent that this was not the proper course of action, another alternative may be pursued. Any structural plan generally limits flexibility and forecloses some future alternatives.

Thus, in summary, it would seem that the relocations plan is more feasible and compatible with ongoing city actions, but by no means should this preclude consideration of the levee plan. It would be desirable to make more detailed investigations of these two plans before their possible implementation. Further studies may also be broadened to include other flood management alternatives.

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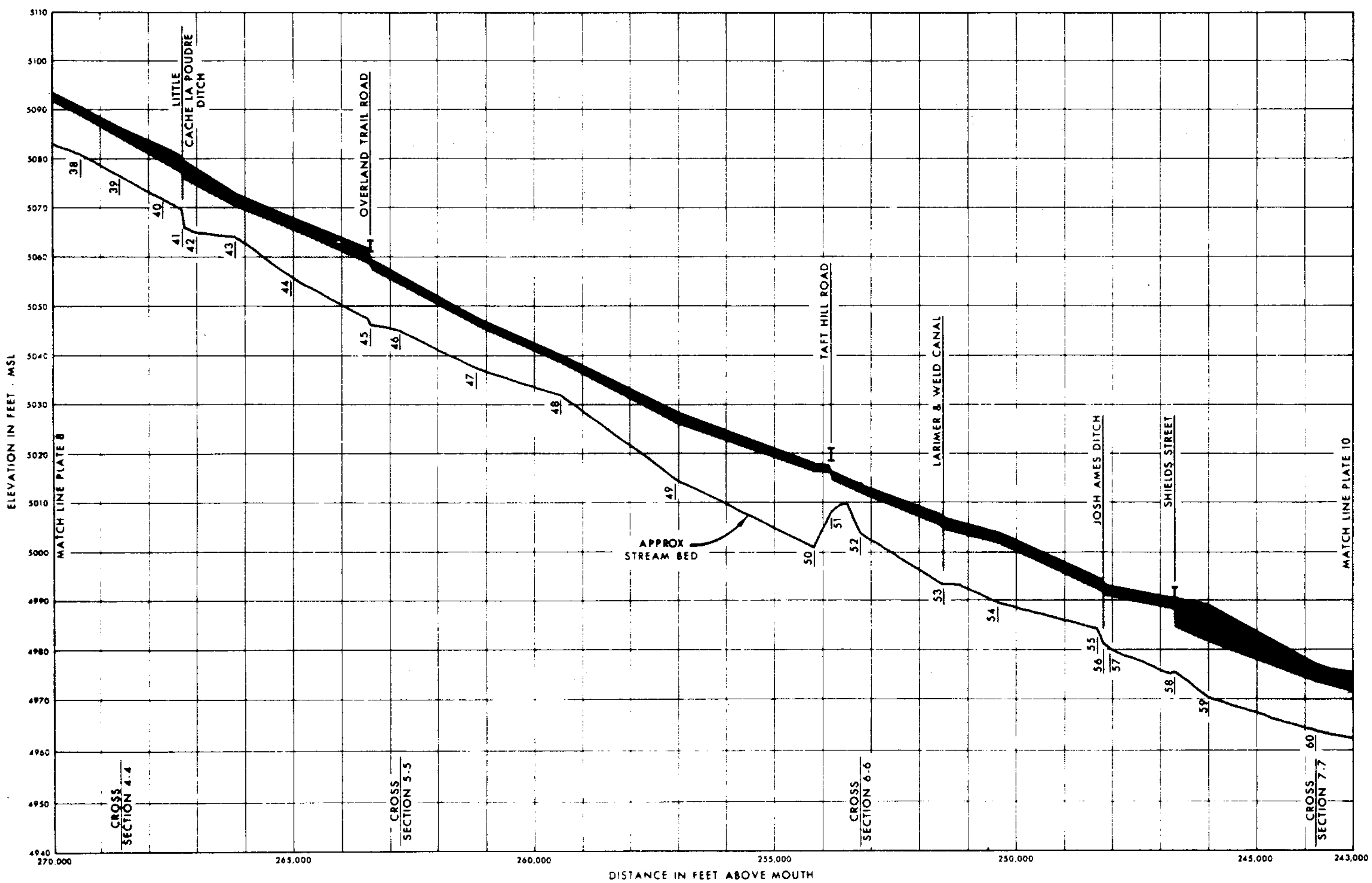
Appendices



LEGEND:

INTERMEDIATE REGIONAL FLOOD
STANDARD PROJECT FLOOD

Bridge: Deck; Top of Waterway

2 — Reference Point

NOTES:

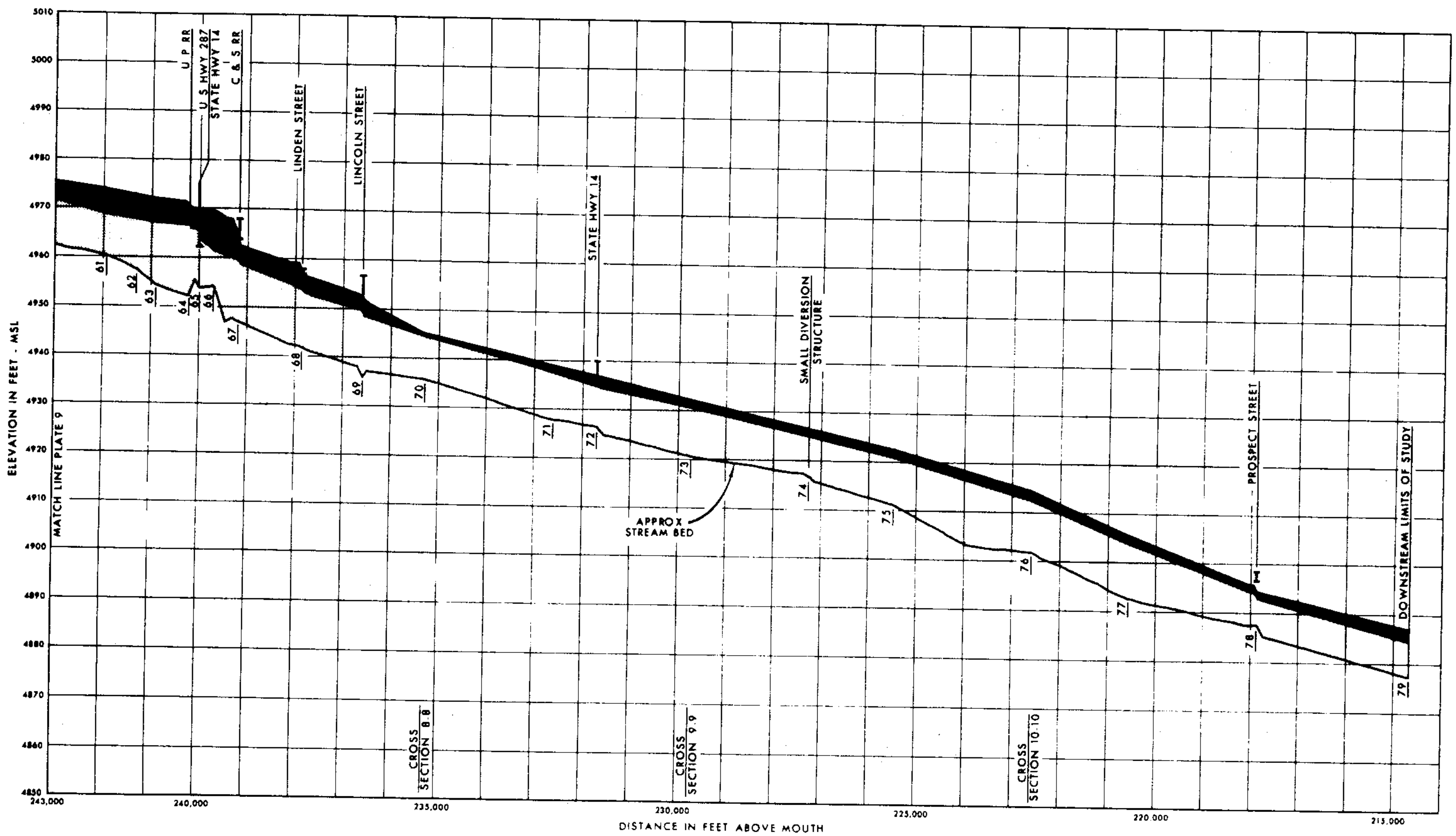
1. For location of Cross Sections, see Plates 4, 5, & 6.
2. For Illustrated Cross Sections, see Plates 12 & 13.
3. For flood elevations at the reference points, see Table 5.

SOUTH PLATTE RIVER BASIN
FT. COLLINS, COLORADO

CACHE LA POUDRE RIVER

PROFILE

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
OCTOBER 1973



NOTES:
1. For location of Cross Sections, see Plates 6 & 7.
2. For Illustrated Cross Sections, see Plates 14 & 15.
3. For flood elevations at the reference points, see Table 5.

SOUTH PLATTE RIVER BASIN
FT. COLLINS, COLORADO
CACHE LA POUDRE RIVER
PROFILE
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
OCTOBER 1973

APPENDIX B

Table 5
FLOOD PLAIN REFERENCE DATA
CACHE LA POUDRE RIVER

Identification	Reference Point Number	Distance in Feet	Stream Bed Elevation Ft. M.S.L.	Intermediate Regional Flood Elevation Ft. M.S.L.	Standard Project Flood Elevation Ft. M.S.L.	Bearing
	35	272,030	5089.4	5098.0	5100.8	N 17° E
	36	271,610	5086.2	5096.9	5099.6	N 24° E
	37	270,410	5084.5	5093.3	5095.6	N 10° E
	38	269,400	5080.9	5088.7	5090.8	N 10° E
	39	268,590	5076.5	5084.3	5086.5	N 11° E
	40	267,700	-	5079.2	5082.7	N 18° E
Little Cache la Poudre Diversion Structure	41	267,310	5069.9	U/S 5077.3	U/S 5080.9	--
				D/S 5076.7	D/S 5080.3	
	42	267,000	5064.9	5074.7	5078.4	N 14° E
	43	266,200	5064.2	5070.4	5073.3	N 34° E
	44	265,050	5056.1	5065.8	5068.5	N 23° E
Overland Trail Rd (Bridge)	45	263,410	5046.4	U/S 5058.8	U/S 5062.1	--
				D/S 5057.7	D/S 5059.9	
	46	262,780	5045.2	5054.5	5056.6	N 28° E
	47	261,200	5037.6	5046.2	5048.1	N 30° E
	48	259,460	5032.2	5038.8	5040.7	N 34° E

Table 5
FLOOD PLAIN REFERENCE DATA
CACHE LA POUDRE RIVER

Identification	Reference Point Number	Distance in Feet	Stream Bed Elevation Ft. M.S.L.	Intermediate Regional Flood Elevation Ft. M.S.L.	Standard Project Flood Elevation Ft. M.S.L.	Bearing
	49	257,060	5015.0	5026.4	5029.1	N 28° E
	50	254, 170	4998.9	5016.5	5018.4	--
Taft Hill Road (Bridge)	51	253,830	5008.2	U/S 5016.3	U/S 5018.1	--
				D/S 5014.7	D/S 5016.8	
	52	253,220	5004.1	5012.1	5014.2	N 23° E
Larimer & Weld	53	251,480	4993.2	U/S 5005.3	U/S 5007.9	--
(Diversion Struct.)				D/S 5004.6	D/S 5007.6	
	54	250,360	4989.9	5001.7	5004.2	N 32° E
	55	248,300	4984.4	4992.4	4995.0	N 35° E
Josh Ames Ditch	56	248,180	4981.2	U/S 4992.0	U/S 4994.4	--
(Diversion Struct.)				D/S 4991.3	D/S 4994.0	
	57	248,050	4980.2	4991.1	4993.6	N 35° E
Shields Street (Bridge)	58	246,700	4975.6	U/S 4988.4	U/S 4990.9	--
				D/S 4984.7	D/S 4986.7	
	59	246,000	4970.4	4981.7	4983.9	N 37° E
	60	243,780	4963.8	4973.5	4976.8	N 35° E
	61	241,930	4960.3	4968.8	4974.1	N 35° E
Lake Canal	62	241,290	4957.7	U/S 4967.8	U/S 4973.0	--
(Diversion Struct.)				D/S 4967.8	D/S 4973.0	

Table 5
FLOOD PLAIN REFERENCE DATA
CACHE LA POUDRE RIVER

Identification	Reference Point Number	Distance in Feet	Stream Bed Elevation Ft. M.S.L.	Intermediate Regional Flood Elevation Ft. M.S.L.	Standard Project Flood Elevation Ft. M.S.L.	Bearing
	63	240,910	4954.5	4967.2	4972.2	N 38° E
Union Pacific RR (Bridge)	64	240,210	4952.2	U/S 4966.7	U/S 4971.6	--
				D/S 4966.1	D/S 4971.0	
U.S. Hwy 287 (Bridge)	65	240,000	4953.9	U/S 4965.5	U/S 4969.7	--
				D/S 4963.9	D/S 4967.4	
	66	239,710	4954.3	4961.5	4964.8	N 22° E
Colo. & Southern RR (Bridge)	67	239,180	4046.9	U/S 4959.4	U/S 4965.2	--
				D/S 4958.7	D/S 4962.8	
Linden Street (Bridge)	68	237,860	4941.9	U/S 4953.5	U/S 4959.3	--
				D/S 4953.3	D/S 4957.2	
Lincoln Street (Bridge)	69	236,600	4936.0	U/S 4949.5	U/S 4953.0	--
				D/S 4948.2	D/S 4952.2	
	70	235,290	4935.6	4944.3	4945.1	N 46° E
	71	232,600	4927.7	4937.4	4939.1	N 39° E
State Hwy 14	72	231,680	4926.2	U/S 4934.5	U/S 4937.1	--
				D/S 4934.4	D/S 4937.0	
	73	229,710	4920.5	4930.4	4932.3	N 37° E
Diversion Structure	74	227,230	4916.7	U/S 4924.7	U/S 4926.7	--
				D/S 4924.6	D/S 4926.5	

Table 5
FLOOD PLAIN REFERENCE DATA
CACHE LA POUDRE RIVER

Identification	Reference Point Number	Distance In Feet	Stream Bed Elevation Ft. M.S.L.	Intermediate Regional Flood Elevation Ft. M.S.L.	Standard Project Flood Elevation Ft. M.S.L.	Bearing
	75	225,480	4911.1	4920.8	4922.9	N 34° E
	76	222,590	4901.8	4912.1	4914.6	N 50° E
	77	220,540	4892.4	4903.4	4905.7	N 53° E
Prospect Street (Bridge)	78	217,880	4887.7	U/S 4894.0	U/S 4895.8	--
				D/S 4892.7	D/S 4894.5	
	79	214,700	--	4884.4	4887.5	N 39° E

APPENDIX C

PROPOSED FORT COLLINS FLOOD PLAIN ORDNANCES

ORDINANCE NO. ____, 1975
BEING AN ORDINANCE PROVIDING FLOOD
HAZARD AREA REGULATIONS

Section 1: Statement of Purpose.

It is the purpose of this ordinance to promote public health, safety and general welfare and to minimize flood losses by provisions designed to:

A. Protect human life and health;

B. Minimize public and private property damage;

C. Lessen public expenditures for flood relief and flood control projects;

D. Control flood plain uses which acting alone or in combination with other uses will cause damaging flood heights and velocities or obstruct flows;

E. Control development which will, when acting alone or in combination with similar development, cause flood losses if public streets, sewer, water and other utilities must be extended below the flood level to serve the development;

F. Protect the natural areas required to convey flood flows and retain slow flow characteristics.

This ordinance is a remedial ordinance and its provisions shall be liberally construed to effectuate the foregoing purposes.

Section 2: Definitions.

For the purposes of this ordinance the following words or phrases shall have the meanings and be defined as hereinafter set forth:

A. CHANNEL. A natural or artificial water course or drainway with perceptibly defined beds and banks to confine and conduct, continuously or periodically, a flow of water.

B. CHANNEL FLOW. That water which is flowing within the limits of a defined channel.

C. DRAINWAY or DRAINAGEWAY. A natural or artificial land surface depression with or without perceptibly defined beds and banks to which surface run-off gravitates and collectively forms a flow of water continuously or intermittently in a definite direction.

D. FILL. A deposit of materials of any kind placed by artificial means.

E. FLOOD FRINGE. That portion of the flood plain between the floodway district boundary and the upper limits of the intermediate regional flood. The flood fringe is the low hazard portion of a drainway channel or water course outside of the floodway portion.

F. FLOODWAY. The unobstructed portion of the flood plain consisting of the stream channel and overbank areas capable of conveying the flood discharge and keeping it within designated heights and velocities. The floodway is the high hazard portion of a drainway channel or water course which is reasonably required to carry and discharge the intermediate regional flood.

G. FLOOD. Temporary rise of water in a natural drainway or water course which results in inundation of adjoining lands not ordinarily covered by water.

H. FLOOD PROFILE. A graph or longitudinal profile showing the relationship of the water surface elevation of a flood event to location along a stream or river.

I. FLOODPROOFING. A combination of structural provisions, changes or adjustments to properties and structures subject to flooding, primarily for the reduction or elimination of flood damages to properties, water and sanitary facilities, structures and contents of buildings in a flood hazard area.

J. FLOOD HAZARD AREA. That area of a drainway channel or water course which will be inundated by flood flows as a result of an intermediate regional flood based upon conditions of complete development of the City and surrounding areas, taking into consideration the future land use plans of the City of Fort Collins and such surrounding areas and other relevant factors.

K. INTERMEDIATE REGIONAL FLOOD. A flood flow, the magnitude of which is expected to occur on the average of a 100-year frequency or has a 1% chance of being equalled or exceeded during any one year.

L. OBSTRUCTION. Any dam, wall, wharf, embankment, levy, dike, pile, abutment, projection, excavation, channel rectification, bridge, conduit, culvert, building, wire, fence, rock, gravel, refuse, fill, structure or matter in, along, across or projecting into a drainway, channel or water course which may impede, retard or change the direction of the flow of water either in itself or by catching or collecting debris carried by such water or that is placed where the flow of water might carry the same downstream to the damage of life and property.

M. OFFICIAL FLOOD PLAIN MAP. The map adopted by this ordinance which indicates flood hazard areas within the City of Fort Collins and as amended.

N. REGULATORY FLOOD PROTECTION ELEVATION. An elevation of not less than one foot-six inches above the water surface elevation associated with the intermediate regional flood.

Section 3: Official Flood Plain Map.

A. Establishment of Official Flood Plain Map. The official flood plain map, together with all explanatory matter thereon, which is attached hereto, is hereby adopted by reference and declared to be a part of this ordinance. A copy of the official flood plain map, as amended from time to time, shall be on file in the office of the City Clerk of the City of Fort Collins.

B. Lands to Which Ordinance Applies. The official flood plain map delineates areas designated as the floodway district and the flood fringe district. The floodway district is that area which constitutes the floodway of a drainway, channel or water course. The flood fringe district is that area which constitutes the flood fringe of a drainway channel or water course. This ordinance sets forth regulations governing the use of areas within the designated floodway district and flood fringe district.

C. Uses Within District Boundaries. In addition to any restrictions placed upon any lands within the City by virtue of the zoning ordinance of the City, all lands within the floodway district or the flood fringe district, as defined by this ordinance, shall conform to and meet all requirements for such districts as hereinafter set forth.

D. Amendment of Official Flood Plain Map. The City Council may from time to time amend the official flood plain map established by this ordinance upon petition of the owner of any property within a floodway district or flood fringe district or upon the initiative of the City Council. Before making any amendments to the official flood plain map, the City Council shall review all pertinent engineering data submitted to it relating to flood hazards in the area affected and amendments shall be made consistent with the purposes of this ordinance.

E. Warning and Disclaimer of Liability. The degree of flood protection required by this ordinance is considered reasonable for regulatory purposes and is based upon engineering and scientific methods of study. Floods of greater magnitude than the intermediate regional flood may occur on rare occasions or flood heights may be increased by man-made or natural causes such as ice jams and bridge openings restricted by debris.

This ordinance does not imply that areas outside of the flood plain districts, or land uses permitted within such districts, will be free from flooding or flood damages. This ordinance shall not create liability on the part of the City of Fort Collins or any officer or employee thereof for any flood damages that result from reliance on this ordinance or any administrative decision lawfully made thereunder.

Section 4. Floodway District.

changed

No land located within the floodway district as designated herein shall be used for any purpose, provided they are permitted uses under the zoning ordinances of the City of Fort Collins and are not prohibited by any other ordinance of the City. Except as permitted under Part B hereof, no structure, fill or storage of materials or equipment shall occur on any land within the floodway district in connection with any permitted use.

A. Uses Not Requiring Special Review. Subject to the limitations of the zoning ordinance or other ordinances of the City, the following uses shall be permitted.

1. Private and public recreational uses such as golf courses, driving ranges, archery ranges, picnic grounds, swimming areas, parks, wildlife and nature preserves, game farms, fish hatcheries, shooting preserves, target ranges, trap and skeet ranges, hunting and fishing areas, hiking and horseback riding trails.

2. Agricultural uses.

3. Uses which are accessory to residential uses, such as lawns, gardens, parking areas and play areas.

B. Special Revise Uses. The following uses which involve structures (temporary or permanent) or storage of materials or equipment may be permitted after special review and approval by the City Council and upon compliance with all of the requirements of Section 6 of this ordinance.

1. Uses permitted under Part A of this section but utilizing structures, fill or storage of materials or equipment.

2. Temporary roadside stands, signs for identification.

3. Extraction of sand, gravel and other materials.

4. Railroads, streets, bridges, utility transmission lines and pipelines.

5. Other uses similar in nature to the uses above set forth.

C. Standards for Floodway Special Review Uses. In determining whether to grant a permit for any special review use the City Council and any administrative officer of the City making recommendations to the City Council on a proposed use shall be governed by the following:

1. All Uses. No structure (temporary or permanent), deposit, obstruction, storage or materials or equipment, or any

other use shall be allowed as a special permit use which acting alone or in combination with existing or future uses unduly affects the capacity of the floodway or unduly increases flood heights. Consideration of any request for a special review use shall be based upon the cumulative effects from an equal degree of encroachment extending for a significant reach on both sides of the stream.

2. Structures.

a. No structure in this district shall be utilized for human habitation.

b. All structures in this district shall have a low flood-damage potential.

c. Any structure permitted in this district shall be constructed and placed on the building site so as to offer the minimum obstruction to the flow of flood waters.

d. All structures constructed in this district shall be firmly anchored to prevent flotation which may result in damage to other structures, restrictions of bridge openings and restrictions of other narrow sections of the stream or river.

e. All service facilities to structures in this district, such as electrical and heating equipment, shall be constructed at or above the regulatory flood protection elevation for that area or shall be floodproofed.

3. Storage of Material and Equipment.

a. Within this district the storage or processing of materials or equipment that are buoyant, flammable, explosive or for other reasons could be injurious to human, animal or plant life, shall be prohibited.

b. Within this district the only materials or equipment which shall be stored shall be those which are not subject to major damage by floods and all such materials or equipment shall be firmly anchored to prevent flotation.

4. Water Supply and Sanitary Sewer Systems. Within this district water supply systems and sanitary sewage systems shall be designed in such way as to minimize or eliminate infiltration of flood waters into the systems and discharges from the systems into the flood waters. On-site waste disposal systems shall be located so as to avoid impairment of the same or contamination from them during flooding.

Section 5: Flood Fringe District.

A. Permitted Uses. Any use permitted by the zoning ordinance of the City and not prohibited by any other ordinance of the City shall be permitted within this district, subject to the restrictions hereinafter set forth.

B. Structures. Any structure erected within this district shall be placed on fill so that the lowest floor of the structure is above the regulatory flood protection elevation. The fill shall be a point no lower than the regulatory flood protection elevation for the particular area and shall extend at such elevation at least fifteen feet beyond the limits of any structure or building erected thereon.

C. Public Improvements. Notwithstanding any other provision contained in this ordinance, within this district streets, bridges and utility lines may be constructed and installed below the regulatory flood protection elevation provided that the same are reviewed and approved by the City Manager or his designated representative. In the event the City Manager refuses a permit for any such installation, the person requesting the same may apply to the City Council for a permit to install the proposed improvement as a special review use.

D. Special Review Uses. In cases where existing streets or utilities are at elevations which make compliance with the requirements of Section 4B above impractical, or in any other case where because of the particular conditions of any site, a hardship would be imposed on the property owner to require compliance with the provisions of Part B above, the owner of property within this district may apply to the City Council for permission to erect the structure below the regulatory flood protection elevation. Such application shall be made and processed in accordance with the provisions of Section 6 of this ordinance.

Section 6. Special Review

No special review permit shall be granted by the City Council except in accordance with and upon compliance with the requirements of this section.

A. Application for a special review permit shall be made to the Director of Engineering Services upon a form supplied by such office. The Director of Engineering Services may require such information regarding the application as he deems necessary to process the same. Such information may include, but is not limited to, the following:

1. Up to five (5) copies of the plans for the proposed project drawn to scale showing the nature, location, dimensions and elevation of the lot, existing or proposed structures, existing or proposed fill, information regarding storage of materials, information regarding any proposed flood-proofing measures, and the relationship of the above to location of the channel, floodway and flood protection elevation.

2. A typical valley cross-section showing the channel of the stream, the elevation of land areas adjoining each side of the channel, cross-sectional areas to be occupied by the proposed development, and high water information.

3. Plans (surface view) showing two foot contours of the ground; pertinent structure, fill or storage elevations; size, location and spatial arrangement of all proposed and existing structures on the site; location and elevation of streets, water supplies, sanitary facilities, photographs showing existing land uses and vegetation upstream and downstream, soil types and other pertinent information.

4. A profile showing the slope of the bottom of the channel or flowline of the stream.

5. Specifications for building, construction

and materials, floodproofing, filling, dredging, grading, channel improvement, storage of materials, water supply and sanitary facilities.

C. The Director of Engineering Services shall review the application and shall forward the same to the City Council, together with a report setting forth his recommendation on the application, including the reasons for such recommendation and any conditions which he recommends be imposed in approving the application.

D. Upon receipt of the application and the report of the Director of Engineering Services, the City Council shall schedule a hearing on the application and shall give the applicant written notice of the date and time of such hearing at least two days before the date of the same.

E. After the hearing the City Council shall act upon the application and shall either grant the same, grant the same with additional conditions, or deny the same.

F. The Director of Engineering Services in making recommendations on applications, and the City Council in passing on such applications, shall consider all relevant factors set forth in this ordinance and all other pertinent matters bearing on the application, including, but not limited to, the following:

1. The danger to life and property due to increased flood heights or velocities caused by encroachments.

2. The danger that materials may be swept on to

other lands or downstream to the injury to others.

3. The proposed water supply and sanitation systems and the ability of these systems to prevent the spread of disease, contamination and unsanitary conditions.

4. The susceptibility of the proposed facility and its contents to flood damage and the effect of such damage on the owners of such facility.

5. The requirements of the facility for a location in the area applied for.

6. The availability of alternate locations for the proposed use, not subject to flood hazards or subject to lesser flood hazards.

7. The capatibility of the proposed use with existing development and development anticipated in the foreseeable future in compliance with the ordinances and plans of the City.

8. The relationship of the proposed use to the comprehensive plan of the City and to the Flood Plain Management Program for the area.

9. The safety of access to the property in times of flood by ordinary and emergency vehicles.

10. The expected heights, velocity, duration, rate of rise and sediment transport of flood waters expected at the site.

G. In acting upon an application, the City Engineer may recommend conditions to the approval of the application and the City Council may adopt such conditions. Such conditions, by way of illustration but not limitation, may include the following:

1. Modification of waste disposal and water supply facilities.

2. Limitations on periods of use and operation.

3. Imposition of operational controls.

4. Requirements for construction of channel modifications, dikes, levies and other protective measures.

5. Protection from erosion in areas that have been filled.

6. Special design and construction of bridges so as to allow the passage of flood waters over the structure or so as to give way and disintegrate in the path of the flood.

7. Flood proofing measures designed consistent with the flood protection elevation for the particular area and consistent with anticipated flood velocities, durations, rate of rise, hydrostatic and hydronamic forces and other factors anticipated with the regulatory flood. Such flood-proofing measures, by way of illustration but not limitation, may include the following:

a. Anchorage to resist flotation and lateral movement.

b. Installation of water-tight doors, bulk heads and shutters or similar methods of construction.

c. Reinforcement of walls to resist water pressures.

d. Use of paints, membranes or mortars to reduce seepage of water through walls.

e. Addition of mass or weight to structures to resist flotation.

f. Installation of pumps to lower water level in structures.

g. Construction of water supply and waste treatment systems so as to prevent the entrance of flood waters.

h. Installation of pumping facilities or comparable practices for subsurface drainage systems for buildings to relieve external foundation, wall and basement flood pressures.

i. Construction to resist rupture or collapse caused by water pressure or floating debris.

j. Installation of valves or controls on sanitary and storm drains which will permit the drains to be closed to prevent back up of sewage and storm waters into the buildings or structures. Gravity draining of basements may be eliminated by mechanical devices.

k. Location of all electrical equipment, circuits and installed electrical appliances in a manner which will assure that are not subject to flooding and so as to provide protection from inundation by the regulatory flood.

1. Location of any structural storage facilities for chemicals, explosives, buoyant materials, flammable liquids, or other toxic materials which could be hazardous to public health, safety and welfare in a manner which will assure that the facilities are situated at elevations above the heights associated with the regulatory flood protection elevation or are adequately flood-proofed to prevent flotation of storage containers which could result in the escape of toxic materials into flood waters.

The Director of Engineering Services in receiving applications for special review uses contemplating such flood-proofing measures may require that the applicant submit a plan or document certified by a registered professional engineer that the floodproofing measures contemplated are consistent with the regulatory flood protection elevation and associated flood factors for the particular area.

Section 7. Building Inspector

The Building Inspector shall issue no permit for the construction of any improvements on any land located in the flood-fringe district or the floodway district not permitted by this ordinance. In the case of any use requiring a special review permit, he shall issue no building permit until the special review permit has been issued by the City Council. In addition, no certificate of occupancy shall be issued for any structure constructed in the floodway district or the flood-fringe district pursuant to a special review permit until the applicant has submitted a certificate by a registered professional engineer that the improvements have been completed in accordance with the approved plan and that all conditions of the special review permit have been met.

Section 8. Nonconforming Uses

A structure or the use of a structure or premises which existed and was lawful before the passage of this ordinance but which is not in conformity with the requirements of this ordinance may be continued notwithstanding the provisions of this ordinance, subject to the following conditions:

A. No such use shall be expanded, enlarged, changed or altered in a way which increases its nonconformity with the requirements of this ordinance.

B. If such use is continued for twenty-four (24) consecutive months, any future use shall conform to the requirements of this ordinance.

C. If any nonconforming structure is destroyed by any means, including floods, to an extent of fifty percent (50%) or more of its assessed value as shown on the latest records of the County Assessor, such structure shall not be reconstructed except in conformity with the provisions of this ordinance.

D. Any alteration, addition or repair to a nonconforming structure involving a cost of in excess of fifty percent (50%) (25%) of the assessed value of the structure shall be made only in conformity with the provisions of this ordinance.

Section 9. Safety Clause

The City Council hereby declares that should any section, paragraph, sentence, word or other portion of this ordinance be declared invalid for any reason, such invalidity shall not affect any other portion of the ordinance and the City Council hereby declares that it would have passed all other portions of this ordinance, independent of the elimination herefrom of any such portion which may be declared invalid.

Introduced, considered favorably upon first reading and ordered published this _____ day of _____________, A.D. 1975, and to be presented for final passage on the _____ day of _______________, A.D. 1975.

ATTEST: ______________________ Mayor

____
City Clerk

Passed and adopted on final reading this _____ day of _______________, A.D. 1975.

ATTEST: ______________________ Mayor

____
City Clerk