FLOOD PLAIN MANAGEMENT OF THE CACHE la POUDRE RIVER NEAR FORT COLLINS, COLORADO

by
Glendol M. Combs
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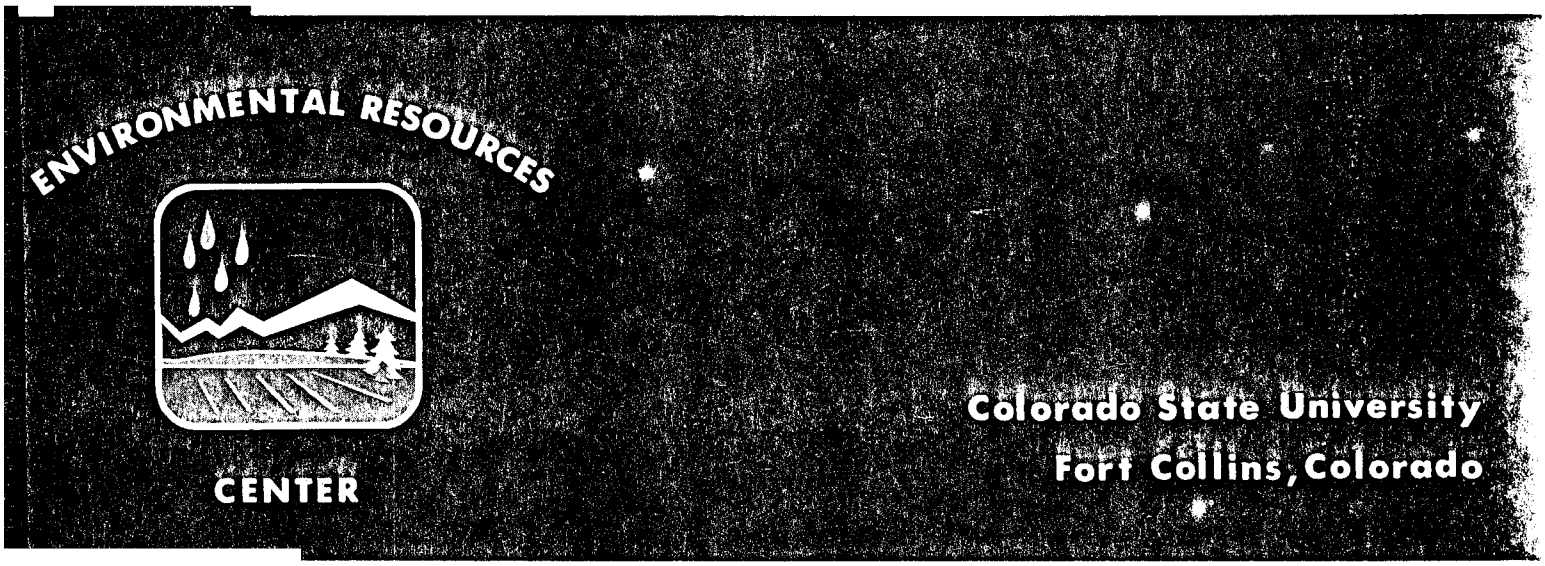
Marvin R. Martens
Garry M. Rowe

August 1974



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requirements of the Degree
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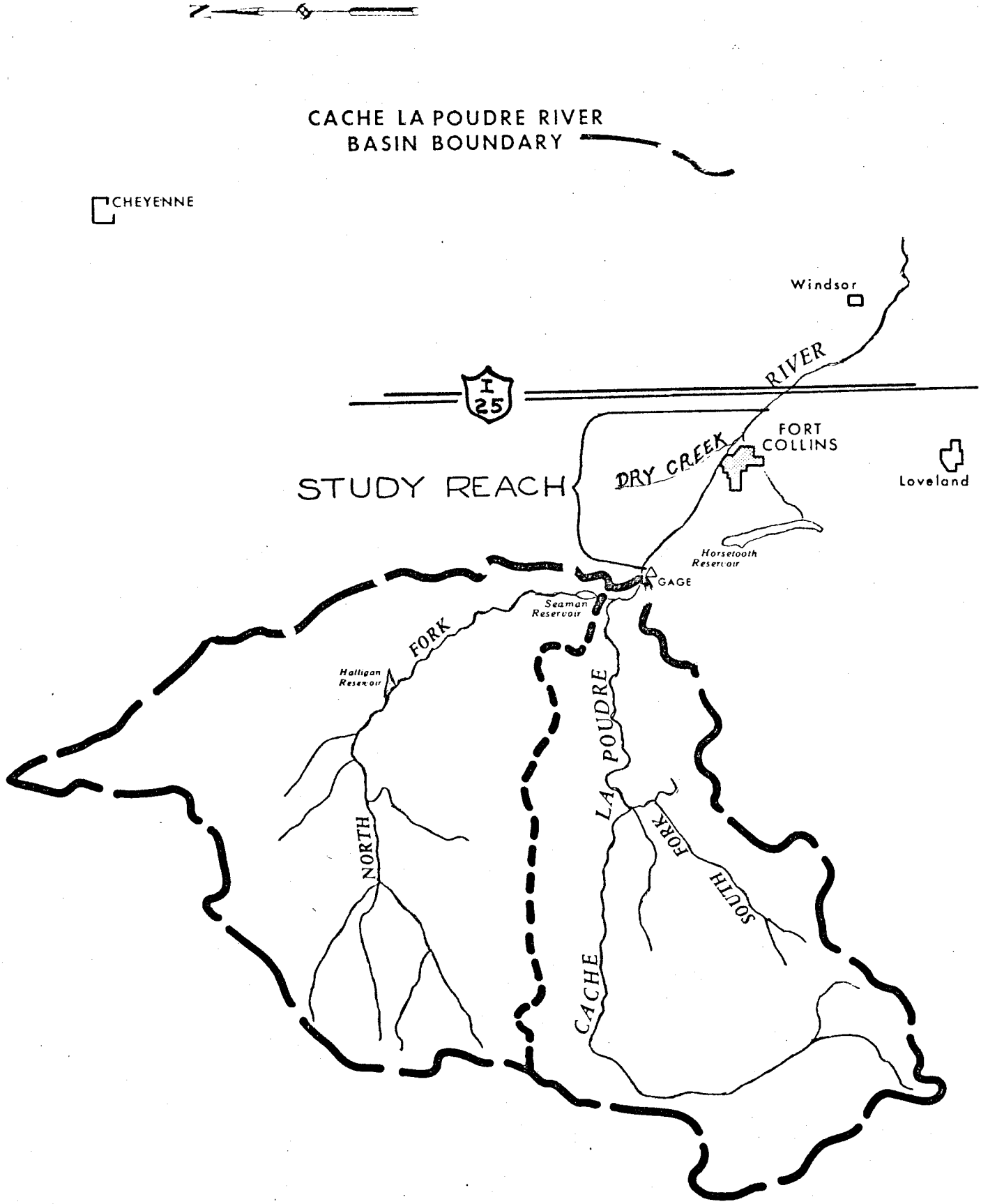
PREFACE

This report was prepared by a study team from Colorado State University as a part of the requirements for the Master of Science degree. The topic was suggested by Freeman Rader, Senior Planner for the City of Fort Collins in March 1974. The city and county are aware of the flood threat from the Cache la Poudre River (Poudre River) shown in Figure 1 and are currently investigating ways of meeting that threat. They are seeking answers to the following questions:

1. Should the City's efforts be geared towards "learning to live with" the problem or geared towards "eliminating" the problem?
2. Can the flood threat be prevented altogether?
3. If so, what are the costs and what are the alternatives?
4. If not, what alternatives exist?
5. Should ordinances be devised which "prevent" development along the river or "promote" desired development?
6. Should the river be left as a somewhat secluded nature area or developed as a major urban amenity? What are the comparative benefits to the public?

We have addressed these questions from a general rather than technical standpoint in the hope of providing an appropriate direction for planning efforts.

Time and data requirements have precluded detailed benefit and cost analyses of alternatives that are necessary to select a specific plan. The scenario approach is presented, not as a prediction, but as a possible result of inaction. Rapid City, South Dakota has already suffered the fate that could happen to Fort Collins.



BASIN MAP

NO SCALE

FIGURE 1

SCENARIO: NO ACTION HYPOTHESIS

On June 2, 1990, at about 10:00 p.m., a large thunderstorm was moving across western Colorado. The radar unit at Limon, Colorado had monitored the storm but it appeared to pose no real threat as it moved across the mountains. Near the Continental Divide its character changed suddenly to produce a virtual cloudburst which dumped about six inches of rain in less than three hours. Unusual weather is characteristic of mountain areas but no one expected this much. The area involved was the Poudre River drainage basin which consists of 1,055 square miles above the Canyon Gage near the mouth of Poudre Canyon. By midnight a flood of unprecedented magnitude was spilling down the canyon, carrying with it tons of debris which included the homes of residents along the Poudre River. Below lay the city of Fort Collins, a thriving city of 125,000 people.* As the flood burst out of the canyon, frantic warnings were transmitted to the Fort Collins Police Department by canyon residents who were high enough to escape the torrent. Warning sirens were activated and emergency crews did their best to warn residents of low-lying areas but their efforts were too late. The velocity of the flood water was much less after spreading onto the valley floor but it was laden with debris and carried enough force to sweep houses from their foundations. Virtually everything flooded to three feet above the natural ground surface was destroyed.

A few of the residents were awakened by the sirens and managed to escape but the others either did not hear them or did not understand their meaning. The toll was 287 dead, 1200 were homeless, and millions

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*Estimate by City of Fort Collins.

of dollars damage was incurred on residences, roads, bridges, and commercial establishments.

City leaders were aghast at what had happened. After all, there hadn't been a flood of major consequence since 1904. There was a flurry of interest back in 1973 when the Corps of Engineers published its Flood Plain Information report. City and county planners recognized the flood threat and initial interest in finding a solution was high. Regulations were hastily prepared to comply with minimum requirements of the National Flood Insurance Act of 1968. A "Green Belt" plan was studied and more restrictive ordinances were discussed but after awhile, apathy set in agair as other issues became more urgent. Variances were granted to the ordinances thus allowing residential development in the flood fringe with minimum flood proofing measures. As the city continued to grow rapidly, the pressure became intense to develop the areas near the river which is near the downtown area. This land could be developed by elevating the structures about two feet to satisfy minimum flood insurance requirements. With skyrocketing land values, the land was too valuable to lie idle and city planners could not resist the political pressure for development.

The above described flood can happen next year, in 1990, or year 2300, but it is virtually certain to happen at some future date. The questions city leaders are faced with are, can we, in good conscience, take the risk? Should we ignore the flood threat and hope it never comes? Should we spend taxpayers' money to build levees or other control structures from which the benefits may be years in the future? Should we forbid any development in the flood plain and forego present day benefits of using this land? Is there a low cost method of protection that will permit use of the flood plain? These questions need answers!

RAPID CITY ANALOGY

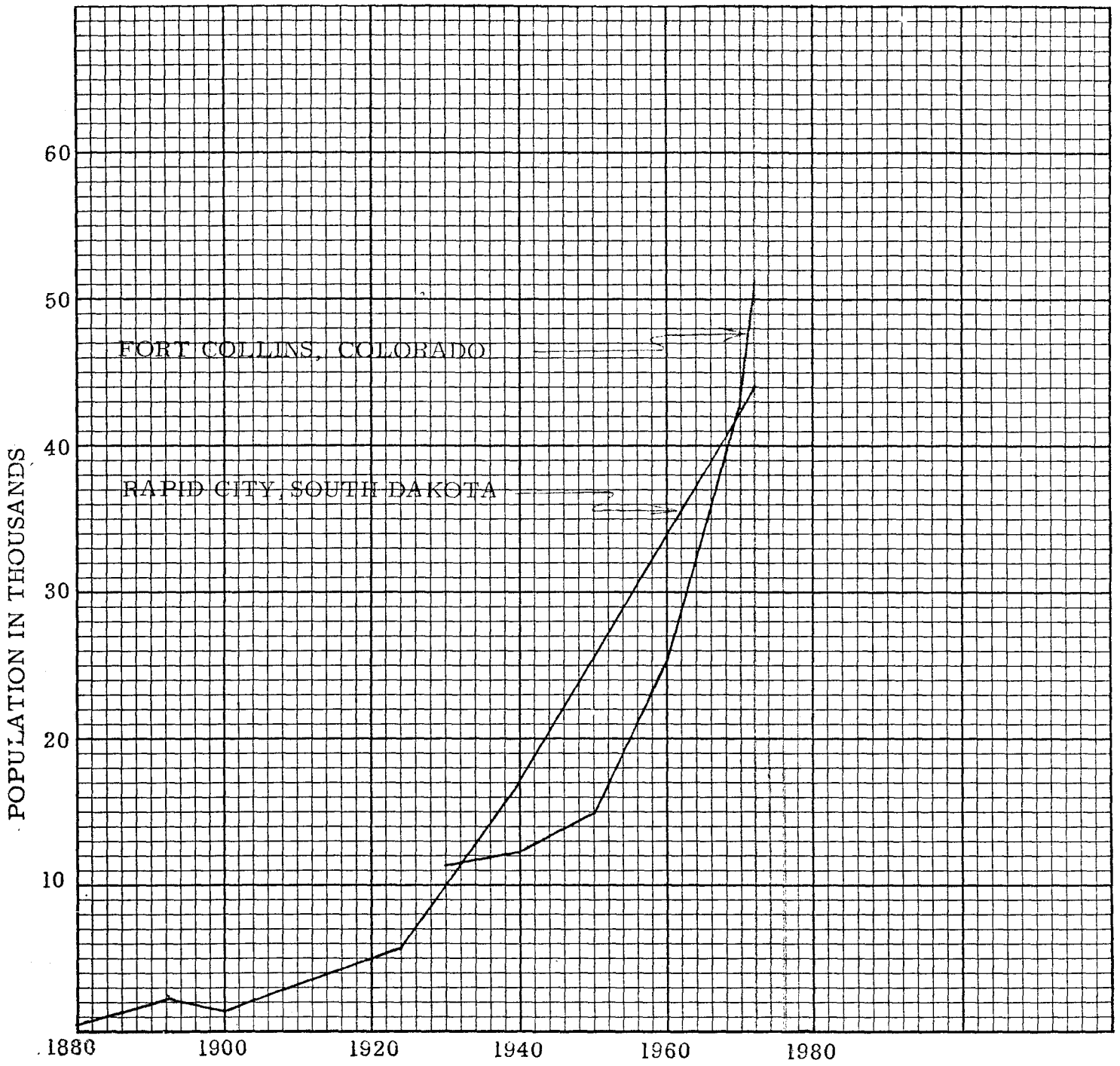
There is a striking similarity between the conditions at Rapid City, South Dakota [21] and those at Fort Collins, Colorado. The cities are approximately the same size as shown on Figure 2 and are situated at the downstream edge of a mountainous drainage basin. Both cities are located on the eastern edge of the mountains where the peak discharge is greatest from storms moving from west to east.

In Rapid City, the last major flood to occur prior to the June 9, 1972 tragedy occurred May 14, 1920 while Fort Collins' last major flood occurred in 1904. The May, 1904 flood exceeded 21,000 c.f.s. discharge which destroyed all bridges but one in Fort Collins and swept 140 houses from their foundations. A less serious flood occurred in 1930 when a discharge of 10,200 c.f.s. was recorded.

The 1972 Rapid City flood resulted from a 12-inch rain over 99 square miles of Rapid Creek drainage which produced a peak discharge of 50,600 c.f.s. The Poudre River has 1,055 square miles of drainage area above the Canyon Gage which is more than adequate to duplicate the Rapid City disaster. A discharge of 40,000 c.f.s. on the Poudre River is considered a Standard Project Flood (SPF) by the Army Corps of Engineers.

The 1972 Rapid City flood killed 231 persons and property damage estimates ranged from $82 million to over $100 million. The Corps of Engineers estimated that nearly 1,000 buildings and mobile homes were destroyed. Fort Collins has not yet experienced a SPF flood.

Rapid City leaders had been interested in flood plain management for several years. A 30-year Open-Space program was started in 1968 and a request was made to the Corps of Engineers on December 9, 1970 to prepare a Flood Plain information report but the study was not begun until



Source: U.S. Department of Commerce, Bureau of Census.

FIGURE 2
COMPARISON OF HISTORICAL POPULATION
FORT COLLINS, COLORADO, &
RAPID CITY, SOUTH DAKOTA

January, 1972. Rapid City applied for flood insurance protection on March 3, 1971 [5]. The enactment of ordinances to comply with flood insurance requirements was scheduled for April, 1972 but was postponed. After the flood on June 9, 1972, the city imposed encroachment lines that prohibit development in the most hazardous areas. In addition, many properties were selected for acquisition.

Similarly, Fort Collins city leaders are aware of the flood threat although the general public seems apathetic. This is evidenced by recent development along the river bank although the city is fortunate that the flood plain is relatively undeveloped at present. The Army Corps of Engineers completed a Flood Plain Information report in October, 1973 [20] at the request of the Larimer-Weld Regional Planning Commission. The city is currently drafting ordinances to qualify for flood insurance coverage and is exploring methods of preventing a disastrous flood in Fort Collins.

This study is a reconnaissance level investigation of the range of alternatives available to city and county planners with the objective of identifying the most promising areas for detailed planning.

There are many alternatives, both structural and non-structural, that could be used to alleviate the flood hazard. Their feasibility of use depends upon economic and social conditions. Since a catastrophic flood in the Fort Collins area has a very low frequency of occurrence, the present worth of future benefits would probably be very small, but could be large if the flood occurs in the near future. One area that should be explored is that of discounting costs for the risk factor which is implicit in insurance purchases.

The city estimates the 1990 population to be around 125,000 persons or a growth of about 70,000. An increase of this magnitude will place

heavy development pressure on flood plain lands. Once development has occurred, the less costly alternatives may have vanished leaving only expensive structural measures that would be repulsive to an environmentally conscious Fort Collins. If action is not taken now, the city may be forced in the future to consider alternatives such as:

1. Levees on both sides of river.
2. Constructing a by-pass channel to handle SPF flows.
3. Building a dry-dam across Poudre Canyon or perhaps an inflatable Fabri Dam.
4. Constructing a diversion dam and canal or tunnel to divert flood waters to Horsetooth Reservoir.
5. Purchase of floodway (at future prices) and relocation of residents.
6. Channelization and perhaps concrete lining of Poudre River throughout the relevant reach.
7. Weather modifications to neutralize potential storms.

Obviously, the city has a more attractive list of alternatives from which to choose today and should take advantage of this opportunity.

HYDROLOGY

The major controls of the Poudre River above Fort Collins are its position with respect to the storm tracks and the basin topography. The storm tracks lie well to the north of Fort Collins during the summer. These storms migrate southward during fall and early winter providing a significant portion of the annual precipitation. However, the major amount of precipitation falls during the spring when the storm track migrates northward passing over the area again.

The topography of the basin above Fort Collins consists of high mountains which act to increase precipitation. During the winter and early

spring the mountain areas provide storage for large amounts of potential surface runoff. It is the spring runoff potential combined with the spring rain activity that provides the flood potential of the Poudre River.

The basic hydrologic considerations in regard to floods are the magnitude of the flood peak, how often a given peak can occur, and the area that will be inundated by the flood. The Corps flood plain report [20] was the principal source of hydrologic and hydraulic properties. Several other sources indicating flood potential in the vicinity of Fort Collins were also investigated. These included informal work done as a graduate class assignment using regional analysis and the environmental study of the proposed Fort Collins Bypass done by Meheen Environmental Consultants [12].

Fort Collins has not had a large flood for over 70 years which has resulted in complacency by the public toward potential flooding. Due to complacent attitudes and the seeming conflict of the several sources as to flood potential, we felt it necessary to develop a peak discharge frequency curve [1] and to spot check the flood plain delineations. From this frequency curve shown as Figure 3, it is seen that the 100-year peak discharge is about 16,200 c.f.s. The frequency curve shows the approximate recurrence period for a flow of 40,000 c.f.s. which is the peak discharge for the Corps standard project flood for the Poudre River above Dry Creek. The values presented in the Corps report were proven consistently accurate. Other sources based their analysis on selected data or used less sophisticated methods of analysis.

THE PLANNING PROCESS

The planning process can take many forms and an analysis of each is beyond the scope of this paper. The city and county are fortunate to

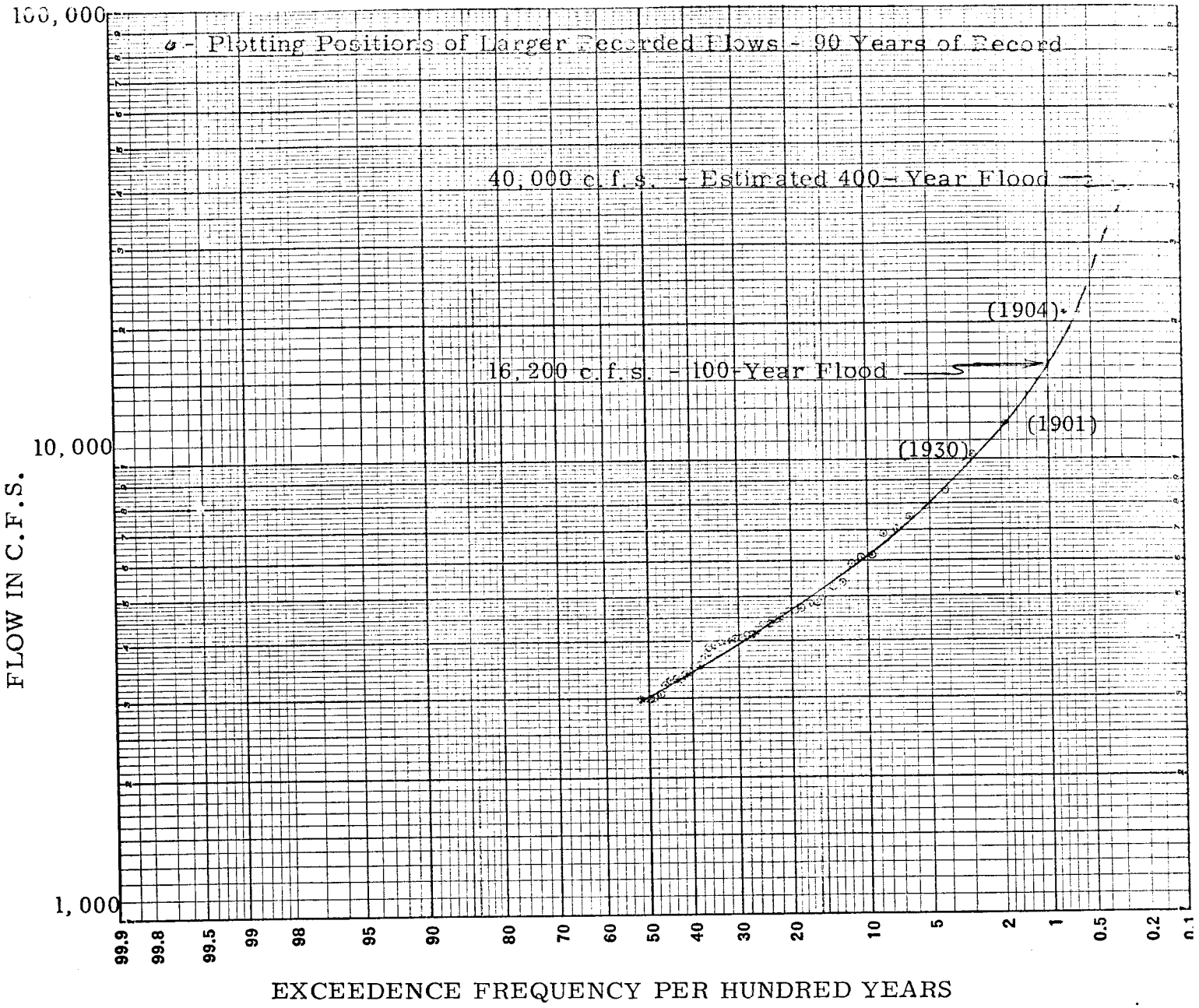


FIGURE 3
CACHE LA POUDRE RIVER
PEAK DISCHARGE FREQUENCY CURVE
STUDY REACH ABOVE
DRY CREEK

have a staff of professionally trained planners to focus on this and other problems. The city council and Larimer County Commissioners are ultimately responsible to the citizens; therefore, the plan selected must be politically viable within the affected communities.

A form of planning that merits special consideration is called "Mixed Scanning" [6]. It is basically a synthesis of the Rational Comprehensive approach and the Disjointed Incrementalist approach. Each method is summarized below to show the pros and cons of each.

The Rational Comprehensive (RC) approach is useful when one can focus on a narrow system that has few externalities. It assumes a closed system that can agree on goals which is never quite the case. It is impossible to completely map a social system, thus data requirements are prohibitive. The RC planner is committed to his initial clients and will lose them if the goals are changed. He is accused of having vested interests by those suffering negative externalities if he doesn't change. Polarization rather than compromise occurs and a balanced assessment cannot be achieved at the beginning of the planning process. The RC approach makes an unrealistic requirement for social consensus on goals and alternatives. The RC approach is not responsive to change because it creates new alternatives which provide new goals which means the process of achieving agreement must begin again. Most planners try to be comprehensive which makes the plan both expensive and hard to sell.

The Disjointed Incremental (DI) planner [11] operates on the existing margin and moves in small increments with constant reevaluation. Since a consensus on goals cannot be achieved, the DI planner seeks out the "evils" in a system. Groups will mobilize to reshape an evil (such

as flooding) even if they have a gross disagreement on goals. This approach assumes that negotiation is possible and that groups are roughly equal in power and influence which is not the case in Fort Collins. Also, the small moves from the margin are not always sufficient to mobilize affected parties.

The Mixed Scanning (MS) approach has synthesized the RC and DI approaches into two levels of decision-making. The variety of choice is scanned in low detail at the beginning of the planning process. Alternatives are evaluated within existing technical capacity and those options are eliminated that violate the norms of the planner and the norms of the people essential to plan implementation. After the alternatives are narrowed down, the one that seems to be the best is selected and acted upon. The next level of decision-making, the "bit" level, calls for action with automatic reevaluation of the planning alternatives after more data is obtained. The MS planner is constantly alert for changes in the "big picture" for the future as well as during the action stage.

We believe the mixed scanning approach is applicable to this problem. This study has scanned the alternatives, narrowed the list, and recommended a starting point for action. It is up to the city and county political leaders to take action and for the planners to rescan the choices as new data becomes available, and as goals change.

ALTERNATIVES

Greenbelt

The need for areas of continuous open space including a greenbelt through the city along the Poudre River has been recognized as early as 1962. Subsequently in 1970 the Poudre Valley Greenbelt Association requested that Fort Collins and Larimer County develop a greenbelt system

including the Poudre River. In 1971 the Association's request for an open space system including the Poudre River was reiterated in the Designing Tomorrow Today (DT^2) program. In 1973, a capital improvement program was approved by the voters. Part of the capital improvement program consisted on an Open Space Plan for land acquisition and an expanded park program. The program was to be initiated in 1973 with a completion date of 1980. Funds allocated for the Open Space Plan consisted of $2,350,000 ($300,000/year) for the land acquisition and $1,355,000 ($193,000/year) for the park program [16]. It is evident by the approval of the capital improvement program and by the efforts of the various citizen groups that the community established a high priority and has a sincere desire for establishment of a greenbelt.

The reasons why the community has attached such high importance to the greenbelt are shown in the following paragraphs which generally describe the unique natural and historic characteristics of the Poudre River and its flood plain.

The Poudre River flood plain has several historical sites and structures of local and national significance. One site, the second Camp Collins, is owned by the city and was officially designated as a Historic Landmark in November 1969 [12]. This became Fort Collins during the Civil War and an army cavalry company was stationed there primarily to protect the Overland Stage Line from highwaymen. Other important sites located in the flood plain include: (1) Mason farm which was one of the original homesteads located on the Overland Stage Line; (2) Laporte Station which includes five sites: county bridge over the Poudre River which is at the exact location of the original trail crossing into Laporte; Overland Stage Station near Lion's Park; old Courthouse site;

General Store; the only log cabin still standing and the site of the blacksmith shop; and (3) the original site of Camp Collins which was established in 1863. In addition, the Cherokee and Overland Trail routes are partially located in the flood plain. The importance of these sites should be evaluated when considering a flood control or management plan.

Vegetation is present in narrow bands on each side of the Poudre River which are usually no wider than 100-200 feet with the exception of a few places where the bands are 800-1,000 feet on one side of the river. Cottonwood trees are the dominant and outstanding vegetation in the immediate flood plain. In addition, other species associated with the cottonwood communities consists of a mixture of Russian olive, box elder and Chinese elm. The shrub understory is abundant and consists of willow, snowberry and wild rose.

Herbaceous vegetation in the flood plain is very diverse and consists of grasses (blue grama, sand dropseed, foxtail), sedges, rushes, and forbs (sunflowers, gumweed and clover) [7].

All of the cottonwood communities along the Poudre River have been classed as a high value area. The cottonwood stands are not dense or unique but are important because of their aesthetic value, wildlife habitat and recreational value.

Recent surveys have shown that the Poudre River flood plain area supports a diverse variety of fauna. For example, 29 to 133 bird species were found at five sampling sites along the proposed foothills trail. In addition, 44 mammal species consisting of shrews, squirrels, gophers, rabbits and deer were also found. Within the study area, there are also

several small gravel pits and several species of ducks and Canada geese use the small water areas in large numbers [7].

Therefore, the narrow band of trees, shrubs and forbs along the Poudre River and irrigation canals, and the small lakes are of high value to wildlife. The importance of this limited habitat to wildlife is very great because intensive farming and residential development has seriously climinated the riparian habitat. Any additional removal of habitat will reduce the wildlife value of the Poudre River. Although the Poudre River has no real value for any significant hunting (primarily due to the large extent of land under private ownership and to the high degree of development and dense population), it does offer significant value for passive recreational experiences such as photographing wildlife or the aesthetic enjoyment in observing wildlife. Such values are becoming more important to society, especially where the areas of habitat are in close proximity to the city and where the visitation or usage can be quite high.

The Poudre River within the limits of the study area is presently classified as a warm-water fishery and is subject to several constraints or problems which are limiting the fishery management potential of the stream. One of the main problems is the lack of water in the river during certain periods when the water is either being diverted into irrigation systems or held for storage. In addition, limited access to the river is interfering with recreational fishing. Therefore, these limitations have severely damaged the area for recreational fishing.

Watson Lake, located near Bellvue, offers a substantial amount of recreation and sport fishing enjoyment to residents of Fort Collins and other visitors. The Colorado Division of Wildlife stocks trout

and manages the lake. The numerous gravel pits located in the flood plain offer excellent potential fishing but are presently under private ownership and they have not been stocked with fish.

Within the flood plain area there are four areas where active recreational facilities exist or where programmed recreation occurs (Lions Park, Buckingham Park, Laporte Community Park and Cache La Poudre School athletic field). In addition, there are four other areas which have either been designated or have high potential for active recreation. The main features which favor recreation activities are the Poudre River and adjacent flood plain and numerous gravel pits. The recreational opportunities for the entire stretch are potentially of high value. The river in high water lends itself to canoeing, running rapids and other related activities [12]. Many of the gravel pits provide excellent ponds for fishing and ice-skating; however, only one of these is presently open to the public and is owned by the City of Fort Collins.

The preliminary plans for the greenbelt along the Poudre River indicate that it will be approximately 50 feet wide on each side of the river and run from Watson Lake near Bellvue to the Colorado State University Nature Center near the intersection of Drake Road and the Poudre River. It is also anticipated that future park development such as the Martinez Park will be incorporated into the greenbelt. Initial plans call for trails for walking, cycling, and horseback-riding. The city is presently in the initial stages of negotiation for land acquisition [15].

The establishment of a greenbelt along the Poudre River has many advantages. One of the main advantages is that this action would preserve a strip of riparian vegetation and wildlife habitat along the

Poudre River flood plain. Because there is only a limited amount of vegetation left in the flood plain, the remaining vegetation becomes very important. The preservation of open space and vegetation would not only preserve the natural beauty of the area but would also preserve the historical sites located in or near the greenbelt. The greenbelt would in turn provide a tremendous source for passive recreational activities such as hiking, biking, fishing, horseback-riding, nature studying and picnicking. The provision of public recreational areas becomes very important, especially in the future when the Fort Collins population is expected to reach 125,000 by 1990. Not only would the greenbelt preserve the riparian vegetation and natural areas from residential and agricultural encroachment, but it would also provide some limited flood damage reduction. The reduction in flood damage would be due to the prevention of development near the river. The greenbelt as presently proposed would not be sufficient to prevent damages for a 100-year or SPF flood because of its narrow width. However, when the greenbelt is combined with flood plain zoning ordinances, and flood proofing measures, it is conceivable that the combination would be very effective in reducing flood damages.

A possible disadvantage of establishment of the greenbelt would be associated with the social effects of transferring private land to public ownership. Although the city passed the capital improvements program, it is conceivable that individuals whose land would be incorporated into the plan would experience some degree of social anxiety and forfeit plans for future development of their land. However, the individuals would be reimbursed by the city for the fair market value of the land. (The magnitude of the losses would be minimal.) The transfer of the private land to public ownership would result in removal of approximately 140 acres

from city and county tax rolls. In general, most of the land which would be acquired is either river bottom land or agricultural land, the assessed value would be low compared to higher value land uses. Therefore, the tax revenue lost due to transfer to public ownership would not be significant. Although the greenbelt would improve access between residential, business and recreational areas, it would also provide an opportunity for many urbanites to experience a unique recreational experience. However, the influx of visitors or users to the greenbelt would also interfere with the privacy of existing residents adjacent to the greenbelt. While some would not object to influx of people, others would and problems dealing with allegations of trespass may develop. The boundaries of the greenbelt would need to be well defined to ameliorate problems.

National Flood Insurance Program

The National Flood Insurance Program offers another tool for public management to promote sound and economic development of the flood plain. The principles incorporated in the National Flood Insurance Act of 1968 were set forth in the report A Unified National Program for Management of Flood Losses [32]. The basic principles are that full cost of flood plain occupance would be put on the prospective occupants themselves through a mandatory risk-related occupancy charge. Also, the program encourages only investment in the flood plain that clearly is warranted by the net benefits gained and discourages flood plain development that detracts from the total social income.

The Act makes a distinction between those already occupying the flood plain by providing for them a subsidized insurance rate. Owners

of property built or developed after the eligibility date for flood insurance are charged full-risk rates. Thus, the program provides owners of existing property with flood insurance rates they can afford to pay without subsidizing new developments on flood hazard areas [4].

Regulations of the National Flood Insurance Act prescribe:

> . . . the minimum requirements for adequate land use and control measures for flood-prone . . . areas that a community must adopt based upon the amount of relevant technical data available to it in order to obtain or to retain flood insurance.

The requirements for Larimer County and the City of Fort Collins for eligibility are summarized below [28]:

1. Require new construction or substantial improvement of residential structures within the area of special flood hazards to have the lowest floor (including basement) elevation to or above the level of the 100-year flood.

2. Require new construction or substantial improvements of non-residential structures within the area of special flood hazards to have the lowest floor (including basement) elevated to or above the level of the 100-year flood or together with attendant utilities and sanitary facilities to be floodproofed up to the level of the 100-year flood.

3. Designate a floodway for passage of the water of the 100-year flood. The floodway must be designed to carry the waters of the 100-year flood, without increasing the water surface elevation of that flood more than 1 foot at any point.

4. Provide that existing nonconforming uses in the floodway shall not be expanded but may be modified, altered, or repaired to incorporate flood proofing measures without raising the level of the 100-year flood.

5. Prohibit fill or encroachments within the designated floodway that would impair its ability to carry and discharge the waters resulting from the 100-year flood, except where the effects on flood heights is fully offset by stream improvements.

These regulations thus require both the city and county to pass land use ordinances and building regulations to meet these requirements.

Although the flood insurance program is an excellent alternative, there is a tendency for the public and in some cases the planners to view the requirements as a maximum level of regulation rather than the minimum standards. Local lending institutions currently exercise some control of flood plain construction by refusing to loan money on property not covered by insurance. This control will be lost if flood insurance is obtained. Therefore, minimum standards could actually increase the risk.

Can the city and county afford to require minimum flood plain regulations which allow protection against only the 100-year flood when a SPF flood could result in increased damage and claim many lives?

Flood Plain Ordinances

Local administrative agencies most directly responsible for planning in the area considered in the study are the Larimer County planning office and the city planning office in Fort Collins. At this time these two bodies are working closely together in order to develop consistent flood plain regulations. The individual's legal relationship to the community raises many issues. Of upmost importance is the concern that individual rights will be unnecessarily eroded by community actions. The absence of regulations invites individual actions that could have an adverse effect on the entire community. A resident of the flood plain may increase the flooding hazard directly by exercising various private options. The individual's right to land should not include the right to harm others.

The community then has the authority to direct development through enactment of ordinances or other measures which specify uses of the

flood plain [16]. It can prohibit individual actions that would constitute a nuisance or threaten the public safety. The community gets this authority from State enabling legislation.

Legal history has shown that the courts invariably give support to flood plain ordinances designed to prevent threats to the public health and safety. Flood plain ordinances are presumed to be constitutional but the courts must determine whether the goals and objectives are justified when weighed against the loss of individual rights [16]. It then boils down to a determination of constitutionality by individual judges as to whether the restrictions placed on an individual are balanced by the public good.

Care should be taken to see that these ordinances are tailored to the needs of Fort Collins and not simply borrowed from another community and adopted to meet minimum requirements for flood insurance. Many planners tend to regard the program guidelines as the maximum criteria they are forced to comply with and a great deal of the "spirit" of the program is lost.

There are several potential problems associated with flood plain ordinances. It is misleading to think that an area is ever completely protected or that damage potential and the benefits from protection remain unchanged. Partial protection can lead to a false sense of security with increased development in the flood plain. This can actually increase damages when a low frequency flood occurs. Flood plain development can also increase the damages from a low level (high frequency) flood.

Use of flood plains involving periodic damage from floods is not in itself a sign of unwarranted or inefficient development. It may well be

that the advantages of flood plain location outweigh the intermittent cost of damage from floods. Flood plain occupation in which benefits do not exceed the total costs, including opportunity cost, is undesirable. From a national efficiency standpoint it causes an eventual net loss to society. Any public policy which encourages submarginal development adds to these losses.

Some cities have experienced difficulty in enforcing stringent ordinances that regulate the SPF flood plain. Political expedience may require flexibility. The range of options can be expanded if development is allowed in the flood plain provided that all costs are internalized and the structures (if residences) are flood proofed against the maximum flood (SPF). As an extreme example, a high rise apartment building could be located in the floodway by placing it on pilings with the first floor at a level that would pass the SPF flood. Suitable protection from debris could be provided and channel capacity could be increased to prevent these structures from imposing costs on other persons. If the locational advantage of flood plain land exceeds total costs (including social and environmental) then it is a viable alternative (opportunity) that should not be legislated away. However, it is imperative that lives be safeguarded and costs internalized.

Ordinances should be based on a large flood with the 100-year or Intermediate Regional Flood most commonly used. If too large a flood is used the regulation may be judged unreasonable. However, a much larger flood is suggested by responsible planners when designing flood control works in urban areas.

The regulatory goals of flood plain ordinances can be summarized as the promotion of public welfare and protection of private rights by:

1. preventing fraud and victimization, nuisances, and threats to public safety.

2. promoting social and economic well being, efficient use of community lands, and environmental quality.

3. avoiding discrimination, unreasonable regulation, and the taking of lands without compensation.

4. insuring participation by affected individuals, due process of law and reasonable certainty in use of lands [16].

Flood Proofing

Flood proofing consists principally of structural modifications to new or existing structures within the flood hazard area which would reduce or eliminate flood damage to the structure or its contents. It can be entirely an individual effort or might be partly controlled or supported by public agencies. The City of Fort Collins, for example, might encourage flood proofing by disseminating related technical information, by requiring its use in new structures through regulations or building permits, or by making it economically attractive through tax allowances or deductions.

The National Flood Insurance Program requires that the first floor or basement if constructed for any residential building be above the elevation of the 100-year flood. First floors of commercial buildings need not be above the 100-year flood elevation if adequate flood proofing measures are adopted. Hence flood proofing is a viable alternative for all new commercial construction and also for new residential construction in areas inundated by the standard project flood but not by the 100-year flood.

When incorporated in the original design visible indications of flood proofing are minimal and costs might be expected to be about 5 percent

of the cost of the structure. In older buildings flood proofing might range from 5 to 100 percent of the value of the structure. Indications are that in general the flood proofing of private residences tends to have relatively high costs and low economic returns. Since the price of a new home, for example, might be increased by two thousand dollars, the particular location in the flood plain would have to be considered desirable enough to justify the additional expenditure to build there. Flood proofing requirements for new construction built by a developer might also serve as a warning indication to prospective buyers that the property is in a flood hazard area. Due to the increased costs of construction and the implied warning to prospective buyers, administration of strict flood proofing regulations in the flood fringe may be politically infeasible.

However, flood proofing has special promise in areas subject only to short duration flooding with a low stage and low velocity. Much of the flood fringe in the area considered by this study is such an area of special promise. In particular the existing homes in parts of Buckingham and in the Andersonville area of Fort Collins and the new Cotton Willows development above Laporte might be economically flood proofed against at least the intermediate regional flood. Security and peace of mind, though intangible, would be very real benefits to these home owners.

Flood proofing is a very flexible alternative which is often employed when flood control works such as dams and levees are not feasible. It can provide a very high degree of protection. Flood proofing can be used in combination with an effective warning system. Contingent or emergency flood proofing measures such as sandbagging might be provided for but not employed except when an actual flood warning is in effect. These measures

might prove more economically feasible or convenient as compared to permanent flood proofing adjustments as shown in Figure 4 [22].

Flood Forecasting and Warning Systems

Flood forecasting and warning systems are used as a major adjustment in varying degrees throughout the United States to cope with flooding. Reliable, accurate and timely forecasts of flood stages can be coupled with temporary evacuation to save lives and reduce property losses.

The success of a flood warning service hinges upon the immediate detection of impending weather events and the observation of hydrometeorlogical factors associated with floods. As in any warning service, time is at least as important as accuracy. A reliable communications system is essential to the timely and widespread dissemination of forecasts and warnings. Groups and individuals must be able to quickly relate the flood forecasts to their individual flood problems.

The National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA) is responsible for preparing official forecasts and issuing public warning for floods. At the present time the National Weather Service Forecast Office at Denver provides a general alert to the danger of flash flooding on the Poudre River. In addition to routine four times daily forecasts for the area, the National Weather Forecast Office makes special forecasts of severe storms and issues flood warnings when required.

Forecasts and warnings are transmitted over the NOAA National Weather Wire Service and the NOAA VHF/FM Radio Transmission Service to organizations with receiving equipment [14]. Organizations without receiving equipment are notified by telephone and telegraph. The City of Fort Collins

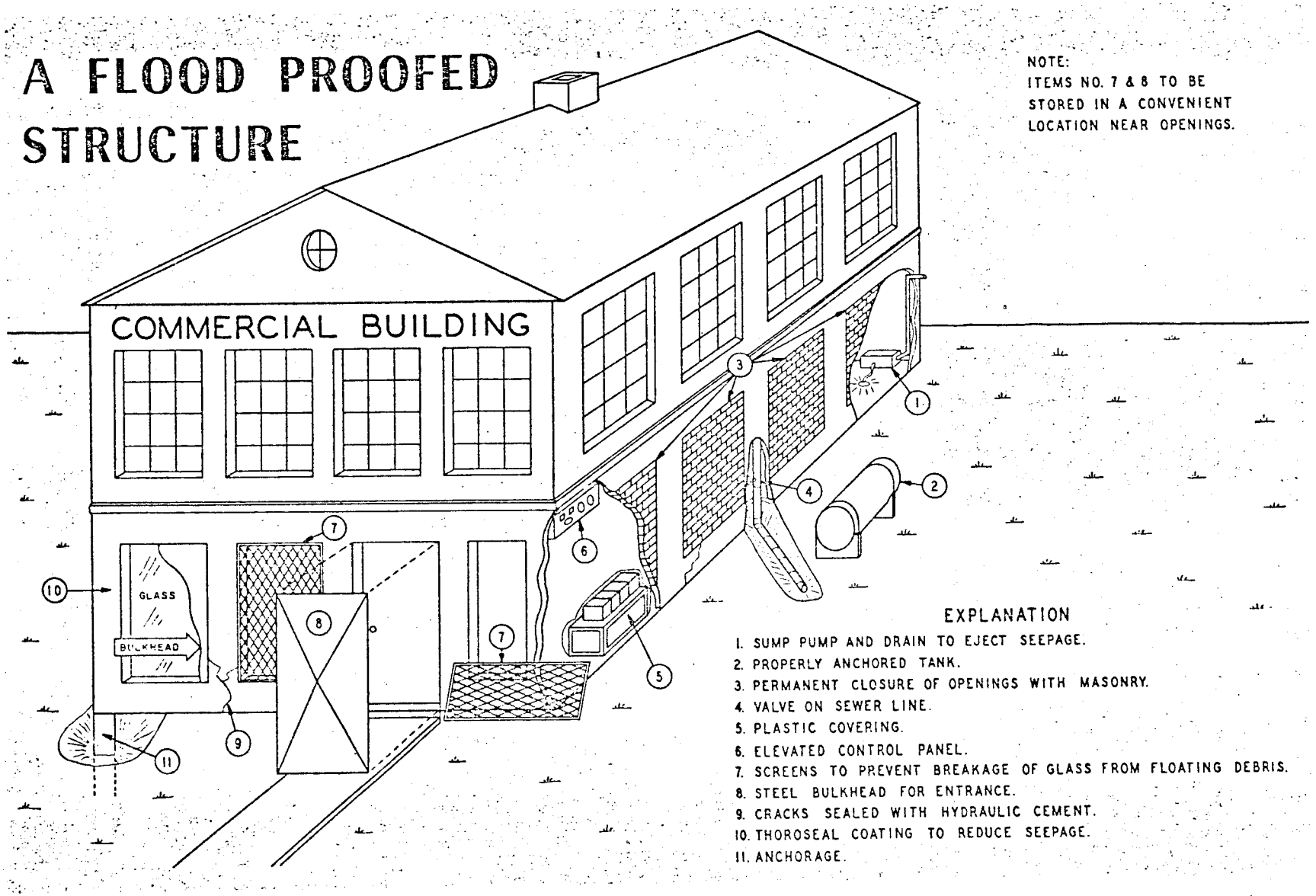

A FLOOD PROOFED STRUCTURE
NOTE:
ITEMS NO. 7 & 8 TO BE STORED IN A CONVENIENT LOCATION NEAR OPENINGS.
COMMERCIAL BUILDING
GLASS
BULKHEAD
EXPLANATION
1. SUMP PUMP AND DRAIN TO EJECT SEEPAGE.
2. PROPERLY ANCHORED TANK.
3. PERMANENT CLOSURE OF OPENINGS WITH MASONRY.
4. VALVE ON SEWER LINE.
5. PLASTIC COVERING.
6. ELEVATED CONTROL PANEL.
7. SCREENS TO PREVENT BREAKAGE OF GLASS FROM FLOATING DEBRIS.
8. STEEL BULKHEAD FOR ENTRANCE.
9. CRACKS SEALED WITH HYDRAULIC CEMENT.
10. THOROSEAL COATING TO REDUCE SEEPAGE.
11. ANCHORAGE.

FIGURE 4

does not have access to the National Weather Wire Service. However, the Office of Emergency Services does have communication contact with the National Warning System (NAWAS).* NAWAS is a communications system of the Office of Civil Defense (OCD) and consists of full-period, private-line voice circuits leased from the telephone companies. NAWAS is a hot line, in operation 24 hours per day, and is designed specifically for simultaneous issuance of attack warnings on a nationwide basis to all stations connected to the System. The National Weather Service does have access to NAWAS and would notify Fort Collins of an impending flood. Following receipt of the warning, city officials would activate the air raid warning sirens which is a signal for residents to tune their radio to KCOL radio station for additional directions.

Both the National Weather Wire Service and the NAWAS systems have various criticisms or shortcomings. Some of the shortcomings are: (1) many smaller towns or broadcasting stations either cannot or do not pay for the $100 per month for the special service; (2) dissemination of warnings via telephone or telegraph is time-consuming and slow; and (3) unfortunately none of the warnings reach the public directly and consequently the press, radio and TV must relay the message. This consequently tends to reduce the urgency of the threat and many people may conclude that the warning does not depict a serious situation. In addition, public broadcasts seldom give explicit instructions on appropriate action to be taken.

The flood forecasting system is felt to be unsuitable for flash floods in smaller drainage areas. There are three basic approaches to

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*Information received from the Office of Emergency Services.

prediction and warning of flash floods that are being used in the United States. The first approach which is used by LaFollette, Tennessee, is a community Flash Flood Warning System. With this system, a local official collects precipitation and streamflow reports and prepares on his own initiative a local forecast using procedures furnished by NWS and equipment at local cost. The community is then alerted through a prearranged system. The 1964 cost of this service is $9,500 for installation and $3,500 for operation [34].

The second approach is the Automatic Flash Flood Alarm which is designed to trigger an alarm to the community when a flash flood is impending. This new flash flood warning system was first installed at Wheeling, W. Va., and subsequently 9 others have been installed [36]. The system has three elements linked by electric circuitry: a robot water-level sensor at an upstream point on the river; an intermediate station several miles or more downstream to provide electric power to the sensor; and a community-alarm station from which warnings can be quickly spread to the public.

The third approach is the conventional Weather Warning system which depends on the expertise of the local weather forecaster, who issues a generalized warning of possible flood conditions.

At the present time, the City of Fort Collins does not have a flash flood warning system, or a city flood disaster plan. The Office of Emergency Services coordinates planned disaster activities of a general nature. This recently established office recognizes the importance of an improved warning system for both floods and flash floods and is in the process of studying the situation.

An efficient flood warning system for floods and flash floods can be very valuable for reducing loss of life and damages. It has been estimated by some that an efficient warning system could provide benefits roughly five times their costs.

Major emphasis needs to be placed on a reevaluation program of the city's existing warning system. The problem of dissemination of the warnings directly to the public, concurrent with specific instructions for action, needs to be studied and a solution derived which would inform the public of the severity of an impending flood. The transient nature of a large percentage of the population makes communication of flood threats a major problem because the people don't understand the meaning of warning sirens. In addition, the city needs to develop a flood warning system for a flash flood. The community Flash Flood Warning System and the Automatic Flash Flood Alarm should be given serious consideration by the city and county officials. More importantly, the city should develop a specific flood disaster plan. This emergency preparedness plan should be established and kept in readiness.

The effectiveness of the city's present warning system for floods and flash floods is very doubtful. Only with an improved warning system and a flood disaster plan will this type of adjustment make a significant difference in reducing loss of life, damage to structures and contents, and social disruption in the Poudre River flood plain.

Relocation of Floodway Residents

The possibility of evacuating homes and businesses located in the Poudre River floodway to reduce potential flood damages is a viable alternative which should be given consideration.

This alternative has been selected as the most practicable and only economically feasible plan of improvement for flood protection at Prairie du Chien, Wisconsin. Prairie du Chien, located on the Mississippi River, has been subject to 13 severe floods since the 1820's. Several alternatives were considered but evacuation with future wise management of the flood plain was chosen. The evacuation-management plan selected includes relocation of 157 homes and small businesses, purchasing and demolishing of approximately 48 structures, raising of 33 homes above design flood levels, and flood proofing 7 business and industrial buildings. All inhabitable developments located more than 100 feet riverward from the edge of the design flood outline and/or subject to more than two feet of flooding over the natural ground surface would be evacuated. This criterion would limit residential flood plain development to the fringe areas only where access during flood periods could safely be maintained and where public service such as power and police and fire protection could remain uninterrupted. The 1970 estimated cost of the project is $1,640,000 [23].

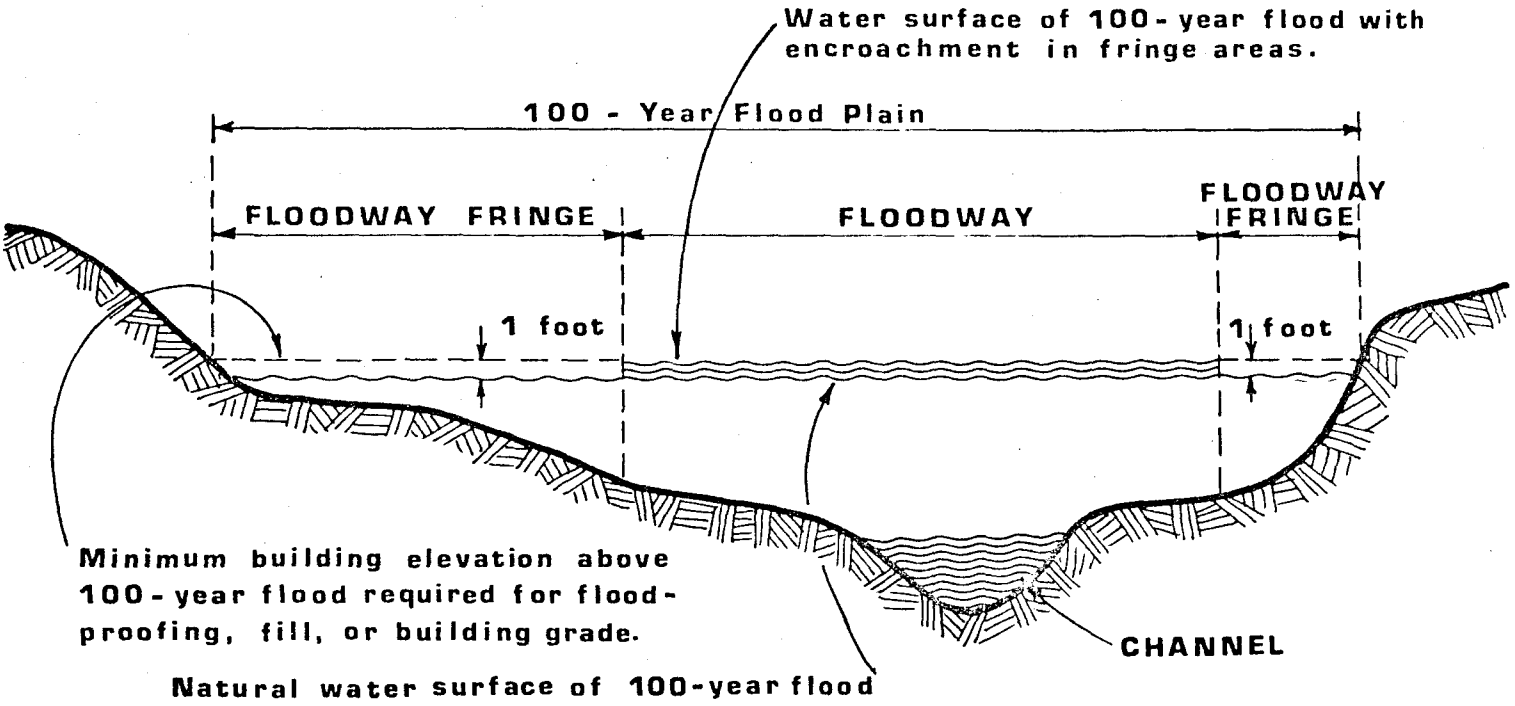
Although the Poudre River flood damages historically have not been as great as those associated with Prairie du Chien, the removal of structures in conjunction with strong zoning ordinances would reduce flood losses and alleviate human suffering. However, there are two major considerations which would determine whether or not this alternative could be feasible.

The first would be that of delineation of the limits of the floodway and flood fringe located within the flood plain. The determination of the floodway would be very important because all structures located within the floodway would be subject to removal.

The floodway is the channel or watercourse and adjacent lands required to carry and discharge a flood flow of a given magnitude, generally the 100-year peak discharge or greater. The criterion for determining the floodway encroachment lines or floodway limits is to determine the area required to pass the selected flood discharge assuming complete obstruction by the encroachment and allowing a selected maximum rise in water surface elevation at any point. The required floodway would thus require more land adjacent to the water course for the smaller allowable water elevation rise. A one-half foot selected rise would thus involve more area within the floodway limits than would a maximum rise of one foot.

If the one-half foot encroachment height is selected for the Poudre River, the floodway would range from 300 to 1000 feet wide. However, if the one foot height is selected the floodway would be quite small and be approximately 300 feet wide. The one foot level would allow more development to encroach upon the flood plain but may increase the number of structures necessary to relocate. See Figure 5.

The second major consideration is that of economic justification. Estimated costs for moving an average house would be around $8,000. Undoubtedly some of the buildings not suitable for relocation would be acquired. In addition, it might be necessary to include in the purchase price an additional $5,000 relocation payment similar to provisions of the Uniform Relocation Assistance and Land Acquisition Act of 1969. The provision would help mitigate the adverse effects associated with relocation and provide a fair and equitable treatment for displaced persons towards the purchase of a decent and safe dwelling to accommodate the displaced owner. Therefore, tangible costs associated with



FLOOD FRINGE

Suggested Uses

Uses permitted in the floodway area
Residential, Commerical, Industrial,
Public & other development with
floodwater entry points at or above
design elevation for encroachment.

Uses Not Appropriate

Hospitals & Nursing Homes
Boarding Schools & Orphanages
Sanitariums
Detention Facilities
Refuge Center

FLOODWAY AREA

Suggested Uses

Farms, Truck Gardens & Nurseries
Livestock & Other Agriculture
Non-obstructive Structures
Parking Lots, Playgrounds & Parks
Golf Courses & Open Recreation
Preserves & Reservations

Uses Not Appropriate

Land Fills & Obstructive Structures
Floatable Storage
Feeding or Disposal of Garbage, Rubbish,
Trash or Offal
All uses precluded from floodway fringe
area.

FIGURE 5
FLOODWAY DESIGNATION

the alternative would be quite high. For example, if 100 structures were relocated and 25 houses acquired, the estimated costs would be in the neighborhood of $1,050,000. Detailed studies will be required to determine the feasibility of relocation.

From an environmental standpoint, evacuation of the floodway would be quite beneficial and preserve valuable riparian habitat and historical sites. There would be many sociological problems associated with evacuation and relocation of people in the floodway. There are approximately 12-14 identifiable social neighborhoods consisting of 501 households approximating some 1500 individuals. Not all of these households would be relocated. However, the social structure represented by the numerous social neighborhoods is very diverse and ranges from the traditional Chicano neighborhoods of Buckingham and Andersonville to the more affluent neighborhood of Cotton Willows Estates located west of Laporte. With the exception of residents in Cotton Willows Estates, the majority of residents active in the labor force are skilled or semi-skilled blue collar workers. The neighborhoods are characterized by the absence of middle aged families leaving elderly couples and families with young children. Therefore, many of the flood plain residents might oppose a relocation plan due to the anxieties associated with social disruption.

Structural

It is misleading to think that the era of flood plain management involves only the use of flood insurance programs, flood zone land use regulations, flood proofing and warning systems. There is a great

danger and tendency that once ordinances are written and flood insurance obtained, all the traditional means of flood damage reductions are forgotten. There may well be a need for beneficial and desirable conventional engineering works. The program of flood plain management requires flexibility and must sometimes be used in conjunction with structural measures.

Structural alternatives to flood damage reduction includes the following possibilities either singly or in some combination: dams, levees, and channelization. The capital investment required by these alternatives is generally substantial and represents an immediate sunk cost. After the project is begun it is essentially an irreversible decision. Structural alternatives have the advantage of immediately reducing the potential losses due to flooding. However over time the potential losses to flooding will begin to increase, reaching a level perhaps nearly equal to that before the structural measures were adopted. This is of course due to increased development in the flood plain encouraged by the false security assumed by individuals to be provided by the flood control structures. This does not mean that structural alternatives should not be considered. For this study area structural measures may be very beneficial; however, other controls over development in the flood plain must also be incorporated in any efforts to reduce flood losses.

The high relief in the catchment area upstream of the study reach provides several potential dam sites. One of the most promising sites was included in a study of the Cache la Poudre Unit by the Bureau of Reclamation and described in their report of June 1963 [29]. The site location is approximately one mile upstream of the canyon gage. A reservoir

at this location, designated the Grey Mountain Dam site, could provide recreational, agricultural, power, municipal and industrial, and flood control benefits. The benefits due to flood control provided by this structure were studied by the Omaha District U.S. Army Corps of Engineers at the request of the Bureau of Reclamation. The conclusions reached in 1963 are generally that benefits would be $100,000 annually for a firm flood control storage of 50,000 acre feet and releases limited to 2,500 c.f.s. However, after allocating costs the Bureau found that the cost of this storage was more than the benefits and only incidental flood control was included in the project. It was finally concluded by the Bureau at that time that the Grey Mountain Dam and Reservoir could not be justified and in fact the entire Cache la Poudre Unit was set aside for further study. Emphasis on environmental quality may make the Grey Mountain site an attractive hydro-power alternative to transmountain power lines. Reevaluation of this site for multiple purpose use using new criteria for determining benefits and costs should be considered.

The modification of the Poudre River to increase the existing channel capacity from 5,000 c.f.s. to approximately 40,000 c.f.s. (projected for SPF flood) would require extensive channelization. An extensive channelization plan would result in complete modification of the existing stream habitat and would also severely reduce the riparian vegetation and wildlife habitat. The degradation of the Poudre River and the adjacent habitat would seriously degrade the aesthetic and natural value of the proposed Greenbelt and Open Space program for the Poudre River flood plain. In view of the fact that the community has expressed a strong desire for the open space program and greenbelt, it is conceivable that there would be no public support for an extensive channelization plan for the Poudre River.

However, additional hydrologic studies may indicate that minor channelization in short stretches of the river could greatly increase the channel capacity and reduce damages. If this is the case, then mitigative measures would have to be incorporated into the design to reduce the adverse environmental effects associated with channelization. Various mitigative measures such as partial channelization or channelization on one side of the river and construction of high flow channels would be incorporated into the project design. These measures would reduce the amount of habitat disturbed and if aesthetically designed with various vegetation planting could also blend in with the existing landscape in order to be compatible with the green belt. In addition, it would also be possible to restore some of the nearby gravel pits and various vegetation planting and a fish management stocking program. Although short stretches of the river would be altered, the various mitigative measures reduce the impact of the alterations.

The use of levees by government and quasi-government agencies for flood protection has been practiced throughout the United States for several years. A levee could be constructed adjacent to both sides of the Poudre River in order to provide protection to areas susceptible to flooding. The levee would no doubt be located near the river channel and would require removal of large amounts of riparian vegetation. The levee alignment could be moved to avoid some trees but it still would reduce the limited amount of vegetation in the flood plain. In addition, the levee could also degrade the historical sites located near the river. There would also be annual maintenance and operation costs for the levee which would have to be paid by the taxpayers. At a time when the community

is extremely conscious of the environment, it appears that this alternative, like channelization, would not be politically feasible.

Additional studies in the flood plain may indicate certain selected areas such as Buckingham, Andersonville, and Cotton Willows where small levees could be built to provide limited protection to valuable commercial or residential areas. With proper landscaping and design, these short stretches could be incorporated into the greenbelt as part of either a bike trail or a horse trail.

Flood Management with Existing Irrigation Structures

The existing irrigation system offers a possibility of reducing the flood peak by about 2,500 c.f.s. A reduction of this magnitude would require that all existing diversion canals be utilized to their full capacity. The major questions related to this alternative are: (1) Can a management program be worked out in conjunction with the canal owners; (2) Does sufficient capacity exist in the storage reservoirs to receive the flood waters; (3) What areas will be endangered by such a plan in case capacities are exceeded; and (4) Can the existing system be improved to accommodate a larger portion of the flood peak? Note that the 100-year flood peak could be reduced to a residual 50-year flood by diversion of about 4,000 c.f.s. at the time of the flood peak.

CONCLUSIONS AND RECOMMENDATIONS

This report has generally addressed and answered some of the specific questions which were initially asked by the City of Fort Collins pertaining to the flood threat from the Cache la Poudre River. In particular, it must be noted that the flood threat cannot be prevented

altogether, but an efficient and effective flood plain management program would reduce the flood damages and loss of life.

It must also be noted that there can be no single solution to the potential flooding problem of the Poudre River. It is apparent from the results of this reconnaissance study that an integrated approach involving a combination of non-structural and some limited structural measures must be implemented. An approach of this type would ultimately result in the most acceptable use and regulation of the flood plain. A combination of the measures would not only reduce flood losses but if properly planned would allow for continuation of regional development and economic efficiency, preserve environmental quality and maintain social stability.

Implementation is the most crucial phase of any of the alternatives discussed. Without the necessary approvals, political support and funding, all of the planning and evaluation will be in vain. Therefore, in order to provide for an effective flood plain management program, financing plans must be developed which meet with the general approval of the public and satisfy legal arguments [8]. Timely formulation of financing plans will be most important in developing a flood plain management plan for the Poudre River. Public support for these plans could be solicited through Designing Tomorrow Today (DT^2). DT^2 efforts have been quite effective in coalescing public support for various public programs.

Therefore, in order to develop an effective flood plain management program for the Poudre River, the study team makes the following recommendations:

1. Land acquisition for the Open Space Plan and Green Belt should be initiated as soon as possible in order to meet the completion date of 1980.

2. The city and county should continue their efforts to formulate flood plain ordinances, which are specifically designed for the Poudre River and the needs of Fort Collins.

3. Following enactment of flood plain ordinances, the city should immediately apply to the Federal Insurance Administrator in the U.S. Department of Housing and Urban Development for participation in the National Flood Insurance Program.

4. Immediate efforts should be undertaken by city and county officials to improve the flash flood warning system. In addition, emergency disaster plans should be prepared and efforts be made to inform and educate flood plain residents of the seriousness of the problem.

5. Some limited structural measures such as a ring levee around Buckingham to provide for 100-year flood protection should receive additional investigation and evaluation.

6. City and county officials should develop a debris removal and maintenance program for the Poudre River in order to increase and maintain channel capacity.

7. Any public development in the flood plain should be flood proofed or planned and designed to help contain flooding.

8. Detailed studies on any of the alternatives or mix of alternatives discussed in this report should be completed using the procedures, objectives and accounts as described in the Principles and Standards for Planning Water and Related Land Resources [31].

9. Copies of this report should be made available by the city to all interested citizens and interest groups.

10. The use of optimization techniques is recommended to determine a more precise mix of the alternatives discussed in this report. Optimization requires sophisticated environmental, engineering, social and economic analyses. We recommend these studies be done in cooperation with Colorado State University because of the University's expertise in these areas.

Although the City of Fort Collins has not experienced a major flood since 1904, it is imperative that action be taken now to reduce the damages and loss of life associated with either a 100-year or Standard Project Flood.

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