

THE USE OF RIPARIAN OPEN SPACE
AS AN ALTERNATIVE TO
STRUCTURAL FLOOD CONTROL MEASURES IN THE UNITED STATES

by

THOMAS OLSON

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Dr. Keith W. Muckleston

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THE USE OF RIPARIAN OPEN SPACE
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ABSTRACT. Annual flood damages continue to rise in the United States in spite of massive investments in flood control structures since 1936. These increased losses can be attributed, in part, to the inherent limitations in scope and nature of traditional "structural" approaches to flood control. Acquisition of floodplain lands is a "nonstructural" approach which reduces flood damage while preserving natural floodplain values and providing recreation potential. Selected case studies (Charles River, MA., Prarie du Chien, WI., Littleton, CO., Rapid City, SD., Baltimore County, MD., Indian Bend Wash, AZ., and the Snohomish River Basin, WA.) are presented as examples of the use of open space for flood damage reduction as an alternative to structural flood control. Open space can be viewed as a viable but underutilized approach to flood damage reduction. The Federal government has been slow to abandon traditional structural control measures. Implementation of Federal policy supporting the use of open space for flood damage has lagged behind legislative intent.

THE PROBLEM OF FLOODING*

Flooding is a natural process which has always occurred. Before man there were floods but no flood problems. Flooding and flood damage is a problem to man only because of intrusion into natural floodplains.** Our forerunners often accepted the inevitable losses with floodplain occupancy out of their need for proximity to water and its many uses. With the rapid advance of technology, however, modern man has been free, in most cases from an absolute dependence on riparian settlement. Needed water can now be pumped cheaply and efficiently to the user at a location removed from the risk of flooding. And the utilization of most other water-related goods and services does not depend on direct occupancy of the flood-prone land. Yet ignorance, inertia, the pressures of population and urban growth, and the ease of floodplain development have combined to increase, not lessen, demands for the development and occupancy of the floodplain.

According to Goddard, about seven percent (541,310 Km² or 209,000 miles²) of the conterminous United States is subject to inundation by the 100-year flood. Yet, more importantly, an estimated 16% of the nation's urban areas were located in the natural 100-year floodplain in 1970.

* The current (1980) value of dollar amounts given in this paper vary widely because of the range of years over which the projects were formulated and developed. Since dollar values have not been converted to a base year, in most cases, caution should be used in comparing figures from year-to-year and project-to-project. Unless a date is specifically stated cost figures are assumed to correspond to the year the source document was written.

** The "100-year floodplain" (ie., the land area inundated by a flood with a 1% change of occurrence in any year) is the floodplain level referred to in this paper unless otherwise specified.

Over 20,000 communities with flood-prone areas exist in the United States. As of 1973, 53% of the nation's floodplains in urban areas were developed and subject to flood damage.¹ During the early 1970's the rate of expansion into floodplain areas was estimated to be between 1.5-2.5% annually.²

Human occupancy of the floodplain is not without risks and costs. Development in the nation's floodplains has been estimated recently at \$250 billion.³ Annual flood losses were calculated to be a staggering \$3.8 billion as of 1975 with a potential damage predicted for the year 2000 of \$6 billion annually.⁴ In addition to property damage, human suffering and loss of life during floods is considerable and priceless. An average of as many as 89 deaths are attributed to flooding each year with individual disasters such as the Rapid City flood of 1972 claiming 238 lives.

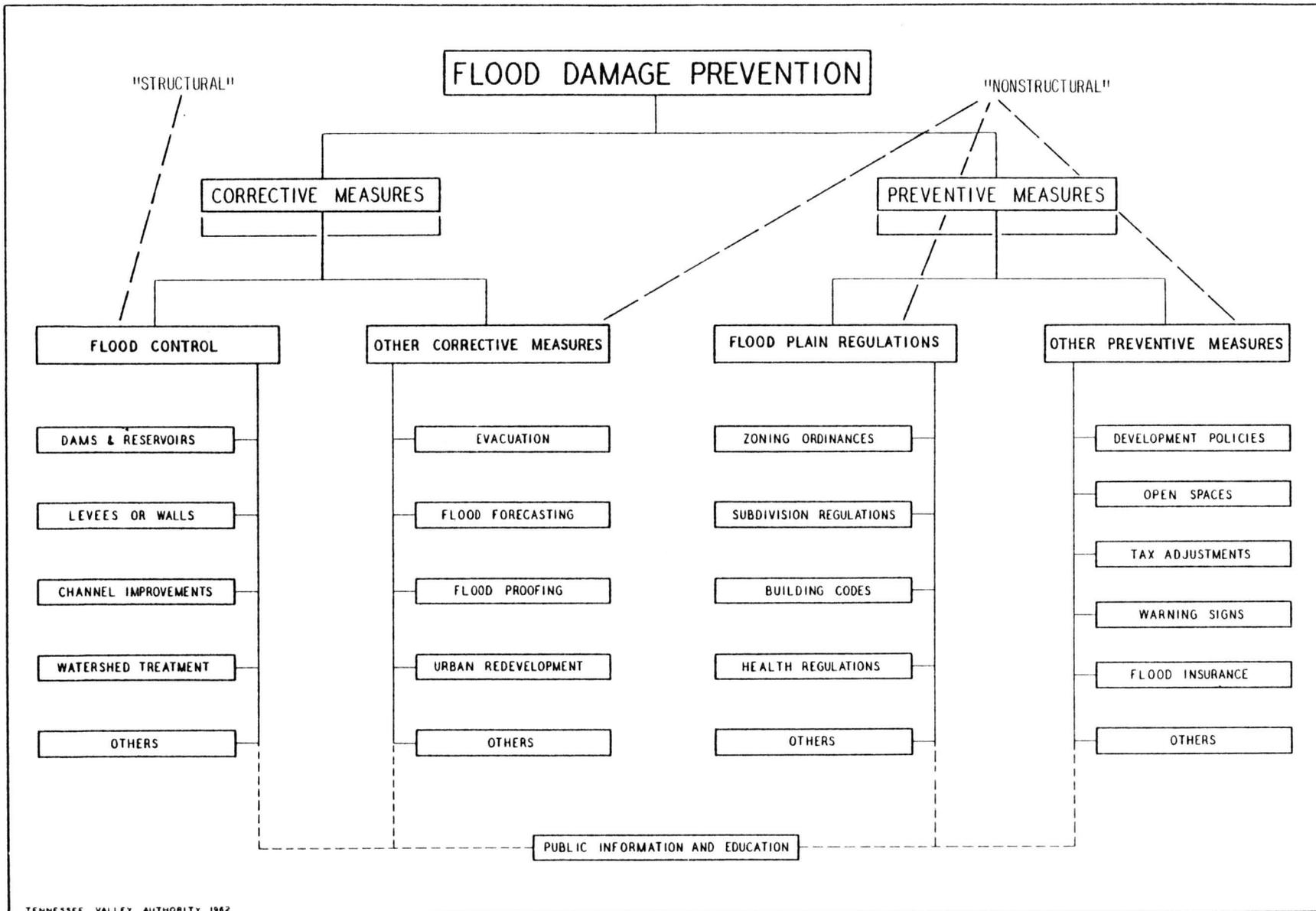
APPROACHES TO FLOOD CONTROL

Flooding has always been a human concern, prompting efforts throughout history to prevent or reduce flood damages. These efforts can be divided into two distinct approaches: "structural" (modify flood flows or 'keep floods away from man') and "nonstructural" (modify man's actions or 'keep man away from floods'). (See Figure 1)

Structural Approaches

Structural approaches rely on dams, detention reservoirs, levees, dikes, floodwalls or channel improvement individually or in combination to "control" floodwaters. While historically a private and local responsibility, structural flood control gradually became an almost

FIGURE 1



exclusively Federal program following the Flood Control Acts of 1936 and 1938. Projects were erected throughout the country in the next thirty years originally with the single purpose of flood control and in later years with multiple purposes including flood control, navigation, irrigation, hydropower, water supply, and recreation.

Structural flood control projects costing an estimated \$13 billion have been constructed.⁵ As long ago as 1968 the Water Resources Council estimated additional projects worth \$6.1 billion were under construction and projects with an estimated cost of \$3.4 billion were planned but not begun.⁶

The United States Army Corps of Engineers estimated its' flood control structures alone prevented \$14.6 billion in flood losses between 1936 and 1966. Current flood damage reduction benefits from flood control works are estimated at more than \$1 billion per year.⁷

In spite of massive investment in and the large savings ascribed to flood control structures, flood damages in the United States have continued to rise due to the limited scope and nature of the structural approach.

Flood control structures are designed to provide protection from a specified hydrologic event (ie., the design flood). However, floods exceeding the design level can and do occur causing massive damages in "protected" areas. Holmes, for instance, estimated that 33% of flood losses between 1903-1958 occurred from the overtopping or failure of flood control works.⁸ At least 40% of losses from Tropical Storm Agnes in 1972 were due to the overtopping of flood protection levees.⁹ Furthermore, floodplain encroachment is "encouraged" by the false sense

of security given by structural protection upstream resulting in an increase in flood damage potential greater than that in existence prior to the flood control project. Some flood control projects also flood large amounts of upstream land to protect smaller amounts of urban land downstream. Numerous adverse environmental and ecological problems have also been associated with structural flood control projects.

Nonstructural Approaches

"Nonstructural" approaches to flood control have only attained any prominence in recent years as a delayed reaction to the often adverse environmental effects of structural flood control projects and their inability to stem the rise in flood damages. Nonstructural flood control measures include all approaches seeking to modify man's susceptibility to flooding rather than modifying flood waters. Nonstructural approaches can be subdivided into "corrective" and "preventive" measures (Figure 1).

Nonstructural measures based on "corrective" action include evacuation, urban redevelopment, flood forecasting and warning, and floodproofing. Corrective measures are aimed at reducing flood damage through the temporary or permanent rectification of past "mistakes," that is, settlement in the natural floodplain.

Nonstructural flood control measures based on "preventive" action include flood insurance, floodplain regulation, warning signs, and open space. Preventive actions differ from corrective actions in that they seek to reduce flood damage before it occurs by limiting development in flood-prone areas.

Nonstructural measures are categorized in Table 1 based on their ability to meet the floodplain management objectives of 1) maintaining natural flood storage, 2) reducing existing damage potential, and 3) preventing increasing damage potential. Acquisition of floodplain land for open space use is the only technique which meets all management objectives.

OPEN SPACE AS A NONSTRUCTURAL FLOOD DAMAGE REDUCTION TECHNIQUE

Dedication of floodplain lands to open space*** uses limits flood damage by preventing intensive development of damage-prone structures in dedicated floodplain areas. Open space uses for natural areas, parks, recreation, ball fields, parking lots, wildlife habitat, agriculture, golf courses, sand and gravel mining, and bicycle, equestrian, and footpaths are generally compatible with occasional flooding. Facilities and structures are few and designated to provide minimal resistance to floodwaters. Open space uses provide temporary natural storage of floodwaters while permitting natural recharge of groundwater. By allowing the river to spread onto an unobstructed floodplain dedicated to open space uses, property damage from flooding is minimized, casualties potentially eliminated, the role of flood control structures reduced in importance, and valuable recreation and wildlife habitat provided. (See Figure 2 for a diagram representing definable flood levels and land uses appropriate for those flood levels).

*** "Open space" may be defined to include both open and natural areas that have characteristics suitable for permanent preservation in a natural state or for various open space purposes.

TABLE 1

NONSTRUCTURAL MEASURES CORRESPONDING TO
FLOOD PLAIN MANAGEMENT OBJECTIVES

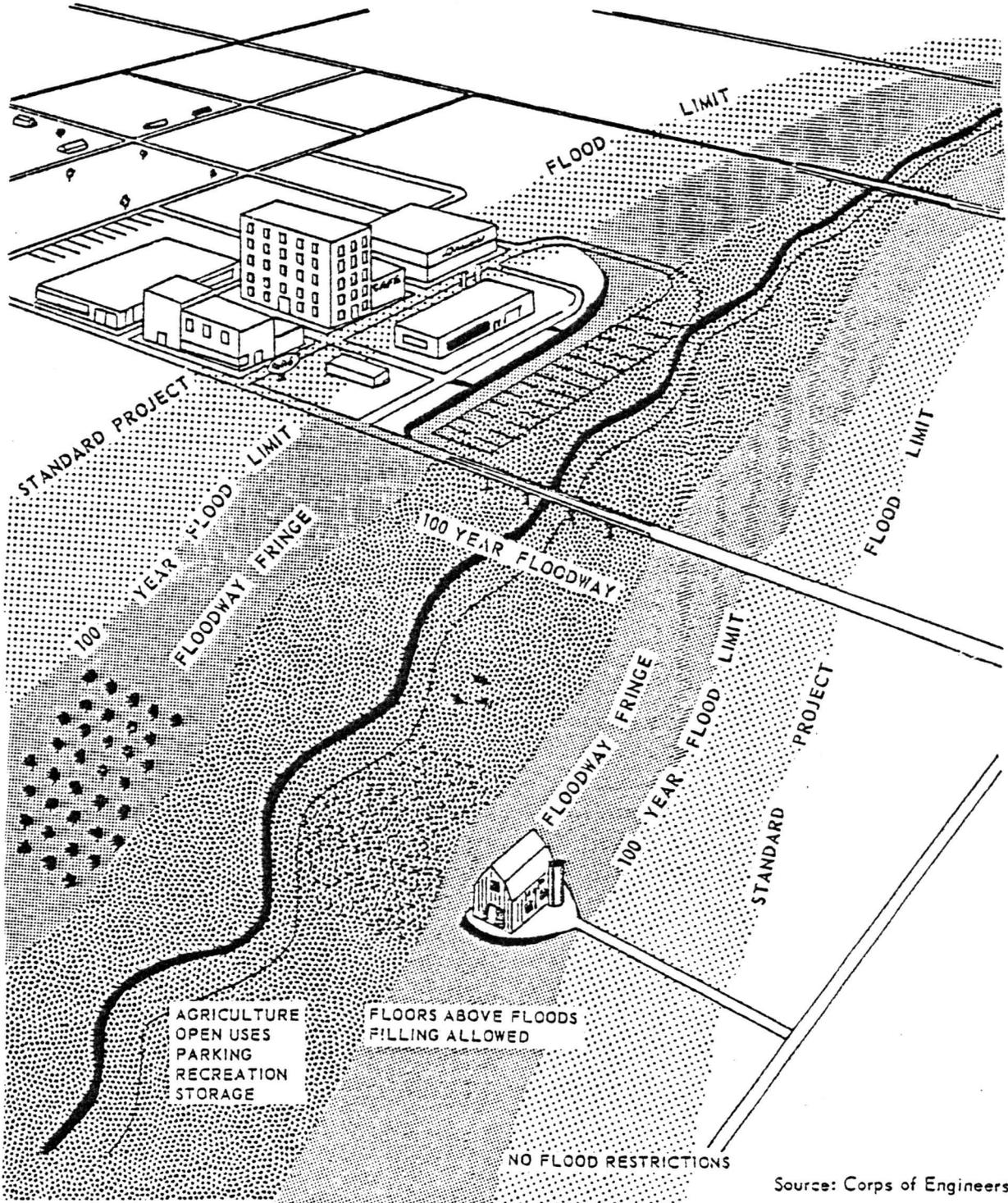
	Maintain Natural Storage	Reduce Existing Damage Potential	Prevent Increasing Damage Potential
Subsidized Insurance		X	
Compulsory Insurance	X		X
Emergency Relief		X	
Flood Warning and Forecasting		X	
Emergency Evacuation		X	
Floodplain Acquisition	X	X	X
Floodplain Zoning			X
Cluster Zoning	X		X
Wetland Laws	X		
Building Codes			X
Subdivision Regulations	X		X
Encroachment Regulations	X		X
Urban Renewal		X	X
Control of Utilities	X		X
Flood Proofing		X	X

Source: CME Associates Supplemental Study Phase I Report

FIGURE 2

FLOOD PLAIN REGULATIONS

TO ENCOURAGE WISE USE AND AVOID FLOOD DAMAGE



Currently, the dedication of floodplain lands to open space is an approach to flood damage reduction in a formative stage. Local and state government participation may serve to lessen future flood damage through tax incentives or development easements to private individuals for the maintenance of their floodplain land as open space. Local, state, and Federal governments may also acquire and convert developed or semi-developed floodplain areas to open space using public funds.

SELECTED CASE STUDIES

The following case studies provide examples of the use of open space for flood damage reduction as an alternative to structural flood control. Acquisition of open space in the floodplain is linked with various combinations of other nonstructural approaches while structural components are reduced or eliminated. The examples selected represent geographically diverse areas of the United States subject to differing flood regimes and various levels of floodplain development. The cases selected range from completed projects to conceptualizations waiting for authorization or funding.

Charles River, Massachusetts

The Charles River and its tributaries, located in eastern Massachusetts, has a total drainage area of 795 Km^2 (307 miles^2) including Boston and its suburbs. The Charles River rises in the town of Hopkinton about 40 Km (25 miles) southwest of Boston and meanders for 129 Km (80 miles) before emptying into Boston Harbor. The Charles has a gentle gradient with extensive swampy areas (8,097 hectares or 20,000 acres) which tend to reinforce the generally sluggish nature of the

river. Flooding can occur at any time of the year in the Charles Basin from a variety of causes including spring rain-on-snow floods, cyclonic storms or intense summer rainstorms.

Flood damage occurs primarily in the heavily urbanized lower watershed areas. Boston, Cambridge, and other lower Charles communities have developed the floodplain with increasing rapidity resulting in large flood losses. Moreover, accelerated urbanization of middle and upper Charles' towns has magnified flood losses in areas formerly unaffected by flooding. Flood damages from the 1955 flood-of-record are estimated at \$5.5 million for the entire watershed. Damages of \$12.4 million were estimated for a comparable flood in 1976 for the lower watershed alone.¹⁰

Corps of Engineers' studies have shown that the swampy areas mentioned above have historically provided a natural means of flood control ("natural valley storage") for the Charles River watershed. Natural valley storage reduced the peak flow from the 1955 flood-of-record at South Natick by 65%, for instance. Flood peaks were also desynchronized causing a lag in maximum outflows by about three days. This "damping effect" is so powerful that the river as a whole does not return to normal flows for 3-4 weeks after a major flood-producing storm.¹¹

Based on local conditions, the Corps planned two distinct approaches to flood control for the Charles basin. A new flood control dam was needed at the mouth of the Charles to prevent the tidal flooding of Boston. Yet it was realized that a major upstream flood control dam or extensive levee and dike systems would be prohibitively expensive, impractical, and environmentally disruptive, while providing no greater flood protection than that afforded by existing natural valley storage.

(Channelization of a 10-mile stretch of river was estimated to cost \$30 million, exclusive of social and environmental costs¹²). In a reversal of its traditional pattern, the 1972 Corps of Engineers' study of the Charles basin recommended the purchase of 17 natural valley storage areas totalling 3,441 hectares (8,500 acres) rather than the construction of upstream dams, dikes, levees or channelization. (See Map I).

In 1971 the purchase of the 3,441 hectares of natural valley storage was expected to cost \$7.5 million and provide natural storage for approximately 68 million m³ (55,000 acre-feet) of water--the size of an average Corps of Engineers reservoir in New England.¹³ Administrative and financial realities restricted the wetlands acquisition to 3,441 "key" hectares out of the 4,049 hectares (10,000 acres) considered to be important for flood control. While geographically separated, the natural valley storage areas act as a hydraulically integrated system of flood control.¹⁴ These areas are being acquired in order of importance to flood storage and flood damage mitigation either through outright purchase or through the purchase of floodway easements.

Project benefits for flood control are based on the difference in annual losses under present land use conditions and those associated with the projected loss of 30% of valley storage by 1990 if development on crucial wetlands is allowed to continue. Annual benefits so derived average \$647,000. An annual project benefit of \$124,800 is also assigned to the preservation of wetlands based on the enhancement of fish and wildlife habitat and recreation.¹⁵ This benefit is a minimum value and does not reflect potential inclusion of the Charles River wetlands in the National Wildlife Refuge system which is currently being considered.

Due to its environmental characteristics and proximity to metropolitan Boston, the Charles wetlands are an ideal site for migratory waterfowl habitat, hunting, fishing, natural history education, hiking, skiing, and canoeing. A benefit-cost ratio of 1.6/1 is attributed to the total project.¹⁶

Although the Charles River project is several years behind the original schedule, acquisition of 426 hectares (1,053 acres) through outright purchase and 266 hectares (657 acres) through restrictive easements had been accomplished by Spring, 1979.¹⁷ An additional four years are expected to be necessary to complete the acquisition of the designated natural valley storage areas.

Prairie duChien, Wisconsin

Prairie duChien, Wisconsin's second oldest settlement, is located in southwestern Crawford County near the confluence of the Mississippi and Wisconsin rivers. Prairie duChien is a town of 5,769 people (1973) situated between the Mississippi and its steep river bluffs and is subject to almost annual spring snow-melt floods. Six hundred people occupy 242 homes and 34 businesses in the 100-year floodplain at Prairie du Chien including all of St. Friol Island in the Mississippi and the east bank to 625 feet above mean sea level. The flood-of-record occurred in 1965 and caused damages estimated at \$2,469,000.¹⁸ Flooding also occurred in 1967, 1969, 1971, 1973, and 1975. Average annual flood damages are estimated at \$178,000.¹⁹

Prairie duChien's history of flooding led to a study of the problem by the Corps of Engineers in 1971. All of the structural and nonstructural approaches outlined in Figure 1 were considered for their potential in

reducing flood damages. A "combined approach" of nonstructural means was selected as the most desirable approach to flood damage reduction at Prairie du Chien. This approach includes:

- Evacuation of 130 houses, 2 businesses, and 285 people from the 10% floodplain^{****} over a four year period.
- Partial floodproofing of 110 residences (at the owner's option and expense) up to the level of the 0.8% flood (ie., the 1965 flood).
- Continuation of existing regulation of floodplain development.
- Participation in the National Flood Insurance Program will be continued.
- Evacuated areas on St. Friol Island will be maintained as a combination park, recreation, and historical area. The Villa Louis Historical Museum (built in 1843), along with several other historic buildings, is the showcase of a revitalized local recreation and tourist attraction planned for St. Friol Island. The 28 hectare (70 acre) evacuated area is planned for development as a "quiet" open space recreation area with a trail system and public beach. An existing 2 hectare (5 acre) municipal park will be expanded for general and recreational purposes.²⁰ These uses are compatible with occasional flooding. (See Maps II and III).

Annual benefits of the combined nonstructural approach are \$167,000 while annual costs are \$152,000 for a total benefit-cost ratio of 1.1/1. The total first cost of this plan is \$3,950,000.²¹ Average annual flood damages will be reduced by 52%.²²

The Prairie du Chien project was authorized in Section 2 of the Water Resources Development Act of 1974 with \$1,840,000 authorized as the

**** The "10% floodplain" is the land inundated by a flood with a 10% chance of occurrence in any year.

Federal share. In spite of the promise of this project, progress in implementing the Prairie du Chien project is considerably behind schedule and will not be completed until 1982.

Littleton, Colorado

Chatfield Dam and channel improvements below the dam were authorized to protect metropolitan Denver from the flooding of the South Platte River by the Flood Control Act of 1950. The flood of June 16, 1965 which caused damages in excess of \$300 million in the Denver area was the inducement necessary for funding of the project and the beginning of construction in 1967.²³

Existing channel capacity below Chatfield Dam ranged from 57 to 170 cms (2,000 to 6,000 cfs). This capacity was inadequate to contain flooding from the uncontrolled drainage below Chatfield Dam or the maximum operational discharge from the dam (142 cms or 5,000 cfs) during a flood event. For these reasons the Corps prepared a design memorandum for channel improvements between Chatfield Dam and West Oxford Avenue on the edge of Denver in 1968. The design memorandum proposed a combination of channel improvement, revetted channel banks, and nine foot high levees for the entire six miles between Chatfield Dam and West Oxford Avenue.²⁴ In 1971, however, local interests in the Littleton area expressed opposition to the Corp's proposal for the South Platte for environmental reasons and suggested land acquisition in lieu of channelization.

The "Littleton Plan," prepared by the City of Littleton proposed the use of Federal channel construction funds by the City of Littleton for the purpose of acquiring floodplain lands between Chatfield Dam and the neighboring city of Columbine Valley. Two hundred and sixty-three

hectares (650 acres) of floodplain land in the first two miles below the dam were proposed for purchase at a total cost of \$1,499,567.²⁵ According to the plan, the land would be turned into a riparian park and recreation area capable of passing releases from Chatfield Dam of 142 cms (5,000 cfs) with minimal "flood" damage. The riparian park proposed by Littleton is primarily "wilderness" in character. Bicycle, horse, and foot trails will be emphasized along with enhanced fishing opportunities and picnic facilities.²⁶

In response to the Littleton Plan, Corps planners reassessed the entire range of structural and nonstructural alternatives available for use. For a combination of topographic or economic reasons all potential alternatives were eliminated except for two. While a plan consisting strictly of channel improvements produced higher national economic development benefits, the Littleton Plan (riparian park from Chatfield Dam to Littleton with a traditional flood control channel from Littleton to Denver) had both higher environmental quality benefits and a higher degree of public preference. The combined benefit-cost ratio for the recreational development and the selected incremental flood control plan is 1.3/1.²⁷ (See Maps IV, V, and VI).

Authorization for Federal participation in the Littleton Plan was given by Section 88 of the Water Resources Development Act of 1974. This legislation authorized Corps financial participation in the land acquisition/recreational development aspects of the Littleton Plan to the amount saved by this alternative to channelization of this reach of the South Platte. This amount is estimated at \$756,000.²⁸ Significant delays have occurred in the completion of land acquisition to fulfill the

Littleton Plan due to uncertainty over the location of the 100-year floodplain boundary caused by mapping errors. Only 84 hectares (207 acres) of the 263 hectare (650 acres) floodplain marked for acquisition had been purchased by March 1980.²⁹

Rapid City, South Dakota

The most devastating flood in terms of lives lost in United States history struck Rapid City (1970 population--44,000) on the night of June 9, 1972. The normally placid Rapid Creek, which bisects the city, "flashed" into a destructive torrent with only a few hours of warning. The Pactola flood control reservoir upstream from Rapid City (10 air miles, 18 creek miles) was unable to prevent the disaster since a localized thunderstorm dumped up to 381 mm (15 inches) of precipitation in the "unprotected" 171 Km² (66 miles²) drainage between the dam and the city. The dam at Canyon Lake, a small recreational reservoir on the edge of Rapid City, was breached and a "wall of water" estimated at 1,416 cms (50,000 cfs) (previous peak discharge was 93 cms or 3,300 cfs in 1962) crashed through Rapid City killing 238 people, destroying 473 homes or businesses, and damaging an additional 351 structures. Direct property damage from the flood reached \$165 million in Rapid City and its surrounding area with secondary economic losses totalling an additional \$36 million.³⁰ Previous flooding had occurred in 1890, 1920, 1942, 1952, and 1962. Congressional authorization for flood control structures had been given in 1964, but no action was taken because of a combination of economic, engineering, and environmental difficulties with the proposed projects.

Post-flood planning indicated a program of floodplain management to be more effective and less costly than a series of dams and/or channels for flood damage reduction in most of Rapid City. Rapid City received approval for a \$64 million urban renewal project jointly funded by the Department of Housing and Urban Development (\$48 million) and Rapid City (\$16 million) in November, 1972.³¹ Total Federal aid amounted to \$116 million.³² The objective of the urban renewal project was to purchase and clear the approximately 1,400 parcels of land (405 hectares or 1,000 acres) in the 100-year floodway. An estimated 5,950 of the 9,000 occupants in the floodplain were affected by the land acquisition program.³³ The net cost of the acquisition and relocation program totalled \$42.4 million for the 1,364 parcels purchased by 1977.³⁴ (See Maps VII and VIII).

Once this clearance activity was completed in the floodway, development of recreational activities was begun. A floodplain ordinance was approved delineating boundaries and uses for the area. All development in the 100-year floodplain was prohibited except preflood structures damaged less than 50% and located outside of the floodway.³⁵ Authorized floodplain uses which have been developed include ball-fields, golf courses, tennis courts, soccer fields, manicured park lands, natural areas, parking lots, tree nurseries, garden plots, and a pedestrian/bicycle path running the five mile length of the floodplain in Rapid City. \$1.8 million in Bureau of Outdoor Recreation funds was matched by Rapid City to fund the recreational development of this linear park.³⁶ Acquisition and redevelopment of the floodplain is expected to be completed on schedule by November, 1980.³⁷

While the majority of the Rapid Creek floodplain was being converted to open space uses, a combination levee/channel alteration plan was determined to be necessary for the Baken Park area of Rapid City. The location of a major shopping center, hospital, water treatment plant, and fifty houses along this reach made acquisition and clearance economically and socially infeasible. This structural program is estimated to cost \$1,390,000 with a benefit-cost ratio of 1.3/1.³⁸

Baltimore County, Maryland

Baltimore County, Maryland, containing the City of Baltimore, suburban, and rural areas, began the "Baltimore County Flood Control Program" in 1975. The intent of the program was to mitigate flood damages from the 65 Km² (25 miles²) Dead Run watershed in Baltimore County without increasing flood flows downstream in the City of Baltimore. Dead Run watershed was developed to the extent that 60% of the watershed surface was impervious. The primary cause of flooding was an undersized bridge that constricted flood flows. The county task force studying the situation found that the construction of a new bridge to allow unimpeded flood flows would cost an estimated \$1.9 million while the acquisition and relocation of the seventeen homes in the 100-year floodplain would cost only \$900,000.³⁹ Since flood damages could be reduced for half the cost through a program of floodplain acquisition and conversion to open space than by structural improvements, Baltimore County proceeded to acquire and demolish or move the homes in the floodplain. The acquired land was then transferred to the Department of Parks and Recreation for development as a linear park with twin purposes of recreation and flood damage reduction. Significantly, planning was accomplished in only 22

months and acquisition carried out entirely with local government funds from the Baltimore County Departments of Public Works and Parks and Recreation.⁴⁰

The Baltimore County Flood Control Task Force also made similar recommendations for a comprehensive program for seven other county watersheds. The six year program ("Program Open Space") called for the purchase of 246 homes and the construction or development of four retention ponds, parks, and open space areas for natural flood storage in the county's floodplains at a total cost of \$27 million (\$4.5 million/year). Annual costs for the open space acquisition program were comparable to the county's traditional "structural" program of spot corrections to culverts, sewers, bridges, roads, and utilities.⁴¹ This basically nonstructural approach emphasized the natural function of the floodplain to accommodate flood flows while providing additional passive recreation opportunities in floodplain open space areas. Baltimore County had completed over 50% of the Program Open Space project by 1979.⁴²

Indian Bend Wash, Arizona

Indian Bend Wash is an ephemeral stream which bisects Scottsdale, Arizona, and extends into Tempe, Arizona, about 11 Km (7 miles) downstream. In the past fifty years, thunderstorms and frontal storms have sent floods over the banks of Indian Bend Wash fifteen times. Only after Scottsdale "boomed" in the 1950's and 1960's did the occasional flooding do serious damage. The combination of residential floodplain development and the increased probability of floods from growing areas of impervious surfaces within the basin drastically increased damages during floods. The June, 1972, flood, for instance, cut the city in

half for several days, damaged 1,500 homes, and caused \$1,459,000 in damages.⁴³

The Corps of Engineers was given Congressional authorization in 1965 to remedy the situation by means of channelization. Indian Bend Wash was scheduled to be lined with concrete along its 7½ mile length to "speed" flood flows through Scottsdale before they could build up and escape channel banks. Cost of the project was estimated at \$7,250,000.⁴⁴ A county-wide bond issue to raise \$23 million for 29 projects (including \$2 million for the local share of the Indian Bend Wash project) was badly defeated, however, and local planners sought a new approach to flood control.

Instead of a concrete channel which might form a socio-economic barrier to movement between the two halves of Scottsdale, city officials endorsed the concept of an open space greenbelt along 8 Km (5 miles) of Indian Bend Wash.⁴⁵ A feasibility study in 1967 proved the greenbelt concept to be practicable provided peak flood discharges into Indian Bend Wash could be reduced. The construction of two upstream flood control dams was rejected in favor of flood detention dikes erected by the Bureau of Reclamation as part of the Central Arizona Project.⁴⁶ Indian Bend Wash, itself, was widened and deepened in spots to contain the 100-year flood estimated at 849 cms (30,000 cfs). At the same time, Scottsdale passed a floodplain ordinance limiting development within the floodplain. In exchange for free floodway easements from private floodplain owners, the city gave developers denser zoning privileges on adjoining lands.

Scottsdale voters approved a \$10 million city-wide flood control

bond issue by a 7-1 margin in 1973 to fund the city's portion of the Indian Bend Wash project. City funds were used for street drains, bridges, and land easements. The Corps allocated \$17.6 million to the total project for flood control (1979 dollars). The Corps and the Bureau of Outdoor Recreation provided \$5.5 million to construct recreation features related to flood control. Non-federal entities contributed \$8.8 million for flood control and \$5.8 million for recreation.⁴⁷ Total cost of the greenbelt and associated projects is \$37.7 million (1979 dollars) which is only slightly more than original estimates for the concrete channel at 1979 prices.⁴⁸ An estimated \$1,565,000 (1973 dollars) in damages are expected to be prevented during a serious flood.⁴⁹ (See Maps IX and X).

Since more than 80% of Scottsdale's residents live within walking distance of the greenbelt, recreation benefits from the Indian Bend Wash project are considerable. Five parks and six golf courses dot the greenbelt and vary in width with the floodway from 183-335 m (600-1,100 feet). A series of ponds and lakes provide flood control and multi-purpose recreation. Bicycle and equestrian paths, ball fields, wildlife habitat areas, picnic facilities and active and passive recreation areas are also present in the wash. A community center, exhibit plaza, swimming pool, and other structures are floodproofed and designed to provide minimal resistance to flood passage.⁵⁰

The Indian Bend Wash project has proceeded smoothly and is nearing completion in 1980.

Snohomish River Basin, Washington

The Snohomish River of western Washington and its principal tributaries, the Snoqualmie, Skykomish, and Tolt, drain an area of 4,921 Km² (1,900 miles²) between the steep, forested Cascade mountains and the urbanized Puget Sound coastal zone. Of 23,887 hectares (59,000 acres) in the floodplains of these rivers, approximately 60% are used for agriculture, 32% is forest or marshland and 7% is urbanized.⁵¹ The basin's population is almost 138,000 people (1975). Average annual flood losses (1976 prices) approach \$4.7 million and are expected to rise due to continued floodplain development, rising land values due to regional population growth, and reduced retention time of surface water runoff due to urban development.⁵²

A serious flood in 1959 prompted an attempt to solve the basin's flood problems. The Seattle District Corps of Engineers completed their report on the Snohomish basin in 1969. The Corps' report recommended the following:

- Construction of a 148 million m³ (120,000 acre-foot) dam and reservoir at river mile 10.0 on the Middle Fork of the Snoqualmie (42% reduction in flood damages predicted).
- Acquisition of 931 hectares (2,300 acres) of recreational land surrounding the reservoir.
- Low flow augmentation for fishery enhancement.
- Retention of floodplain open space and greenbelts.⁵³

This plan was not acceptable to Governor Evans or local elements, however, and the controversy over flood management in the Snohomish basin continued. In 1974 the Governor obtained the agreement of all

parties that the controversy should be mediated by an impartial arbiter.

The "Snohomish River Basin Mediated Agreement" was completed in 1974 and brought fifteen years of open conflict to an end. Of the seventeen state, county, local, and tribal governments participating, no group is completely satisfied with the Mediated Agreement. However, all parties are theoretically committed to its total implementation. (The City of Seattle was not a party to the Mediated Agreement because it is located outside of the Snohomish basin. Moreover, the importance of water supply from the Snohomish basin to Seattle was not fully recognized at the time).

Snoqualmie River--Middle Fork

--The upper valley will be dedicated exclusively to forestry uses. A combined program of land acquisition and development of floodway easements will be used to mitigate flood damage in unprotected areas of the Middle Fork.

--"Three Forks Park" is to be established at the confluence of the Middle Fork with the North and South Forks for the dual purpose of providing natural valley storage and recreation.

--Levees are to be built to protect major developed areas (Snoqualmie, North Bend) while attempting to maintain maximum valley storage in the existing floodplain.

--The Lower Valley (below Snoqualmie Falls) will be maintained as an "agricultural greenbelt" based on the 100-year floodplain. Development rights and/or floodway easements will be acquired to maintain exclusive agricultural usage of the floodplain.

Snoqualmie River--North Fork

--The construction of a single multi-purpose dam at Big Creek is proposed.

--Forestry, recreation, and flood control uses are projected for the upper valley. Development rights for all other uses are to be acquired.

--The lower valley is to be retained for agriculture and single family residences with a four hectare (10 acre) minimum lot size.

Tolt River

--The spillway of the Tolt River Dam will be raised for maximum flood control.

Skykomish River

--Development rights for the "Braided Channels" area between the communities of Goldbar and Sultan will be acquired to preserve natural valley storage and steelhead spawning habitat.

Snohomish River

--The "Delta Lobes" area will be purchased for non-intensive recreation, open space, and to preserve the estuarine ecosystem.⁵⁴ (See Map XI).

Total cost projected for implementation of the Mediated Agreement (May 1976) is \$168,594,000 with an overall benefit-cost ratio of 1.6/1.⁵⁵ Corps participation is valued at \$75,081,000 while other Federal, state, and local government agencies would be responsible for the remaining \$93,513,000. Some \$62,730,000 and 48% of project benefits are assigned to the supply of municipal water to Seattle. Yet Seattle was not a party to the Mediated Agreement and is a questionable participant in the future, thus jeopardizing the economic feasibility of the entire project.⁵⁶

While the Mediated Agreement is a mixture of structural and nonstructural approaches to flood management, nonstructural techniques such as open space acquisition and floodway easements are prominent features intended to minimize environmental disruption. Implementation of the Mediated Agreement in the period 1974-1979 has been minimal.⁵⁷ In addition to the question regarding water supply for Seattle, a primary source of controversy has been the position of the Corps that the purchase of development rights (\$6,300,000) and the acquisition of the Three Forks, Braided Channel, and Delta Lobes areas as open space/parks/natural valley storage (\$5,400,000) is a local, not Federal, responsibility.⁵⁸ For this reason the Corps did not link these areas to the flood damage benefits calculated for the total project. The Corps maintains it needs specific congressional authorization for the use of Federal funds to acquire areas for natural valley storage in the Snohomish basin similar to the project in the Charles River basin. The ultimate implementation of the Mediated Agreement or other flood control measures in the Snohomish basin is unknown at this time.

SUMMARY AND CONCLUSIONS

The dedication of floodplain areas to open space uses would appear to be a viable, but underutilized, means of reducing potential flood damages in many cases, especially when used in conjunction with other structural and nonstructural techniques appropriate to the specific site.

A geographically diverse group of communities in the United States have employed or are planning to employ this technique to reduce flood

damages or flood damage potential.⁵⁹ In several cases the dedication of floodplain areas to open space uses has negated or reduced the need for traditional structural flood control projects (eg., Indian Bend Wash). Adverse environmental impacts from the flood control projects have been reduced while providing equivalent flood protection at the same or lower cost (eg., Charles River basin, Littleton).

Scattered and often unilateral actions, primarily on the local level, characterize the implementation of flood damage reduction efforts through open space uses of the floodplain at this time. While a few individual cities and counties have shown the ability to mobilize their efforts to reduce flood damage potential using this approach (eg., Baltimore County, Rapid City), most local governments and Federal agencies have been slow to abandon their reliance on traditional structural flood control measures. Despite the specific authorization of funds for a few selected projects and a series of Federal documents from the Executive branch (eg., Executive Order 11988--"Floodplain Management," A Unified National Program for Flood Plain Management) and congressional action (Section 73 of the Water Resources Development Act of 1974) focusing positive attention on the subject, implementation of Federal policy has lagged far behind intent. The use of open space as a tool for flood damage reduction has not been fully integrated into the bureaucratic apparatus of the Federal government. Institutional inertia has reduced the ability of planners to look beyond time-honored structural flood control measures. Federal financial support and cost-sharing policies have also favored structural measures. Funding of projects under Section 73 has not been approved by the Office of Management and Budget

over six years after passage of the necessary legislation.

The dedication of floodplain lands for open space uses has great potential for reducing flood damages, but must be given equal legislative and administrative status and funding with other flood damage reduction techniques before this potential can be realized. In the meantime, traditional flood control measures, primarily structural in nature, will almost surely continue to dominate flood control efforts.

FOOTNOTES

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- 3 L. Douglas James, "Information Needs to Facilitate Implementation of Nonstructural Alternatives," in Waldon R. Kerns, ed. Implementation of Non Structural Alternatives in Flood Damage Abatement. (Blacksburg VA: Virginia Water Resource Research Institute, 1976), 26.
- 4 Goddard, op. cit., footnote 1, 49.
- 5 Rutherford Platt, Options To Improve Federal Nonstructural Response To Floods, (Washington D.C.: U.S. Water Resources Council, 1979), 9.
- 6 U.S. Water Resources Council, The Nation's Water Resources: The First National Assessment of the Water Resources Council, (Washington D.C.: U.S. Water Resources Council, 1968), 5-2-3.
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- 9 White, op. cit., footnote 2, 9-10.
- 10 Rutherford H. Platt and George M. McMullen, Fragmentation of Public Authority Over Floodplains: The Charles River Response, (Amherst, MA: Water Resources Research Center, 1979), 59.

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- 21 Ibid., 36-37.
- 22 Ibid., 94.
- 23 Omaha District, U.S. Army Corps of Engineers, Supplement 1 Design Memorandum No. PC-20. Phase I Report. Downstream Channel Improvements. South Platte River, Colorado. Chatfield Dam and Lake. Volume 1. Summary and Appendix I, (Omaha, NB: U.S. Army Corps of Engineers, 1976), A-1.

- 24 Ibid., A-7.
- 25 Ibid., A-7.
- 26 Ibid., D-5 and Personal Communication with Nancy Usnick, Planner, City of Littleton, CO., March 10, 1980.
- 27 Ibid., G-6.
- 28 Ibid., F-5.
- 29 Usnick, op. cit., footnote 26, March 10, 1980.
- 30 Omaha District, U.S. Army Corps of Engineers, Flood Report, Cheyenne River Basin, South Dakota Black Hills Area, Flood of 9-10 June, 1972, (Omaha, NB: U.S. Army Corps of Engineers, 1972), 82.
- 31 Personal Communication from Bonnie J. Hughes, Community Development Assistant/Relocation Director, Rapid City SD, January 14 and February 5, 1980.
- 32 Omaha District, Corps of Engineers, op. cit., footnote 30, III-2.
- 33 Hughes, op. cit., footnote 31, February 5, 1980
- 34 Ibid., January 14, 1980.
- 35 Ibid., January 14, 1980.
- 36 Ibid., January 14, 1980.
- 37 Ibid., January 14, 1980.
- 38 Omaha District, U.S. Army Corps of Engineers, Flood Protection for Rapid City. Detailed Project Report, (Omaha, NB: U.S. Army Corps of Engineers, 1975), 46.
- 39 John D. Seyffert, "Baltimore County: A Local Government Expedites Floodplain Management," Environmental Comment (June, 1977), 14.
- 40 Ibid., 15.
- 41 Ibid., 15.

- 42 Personal Communication with John Butler, Department of Parks and Recreation, Baltimore County, Towson, MD, March 10, 1980.
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- 44 Ibid., 2.
- 45 Rae Pimley, "Interagency Cooperation Created Indian Bend Wash Project," News Release, Public Information Office, City of Scottsdale, AZ, January 10, 1980.
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- 53 Ibid., IV-27,28.
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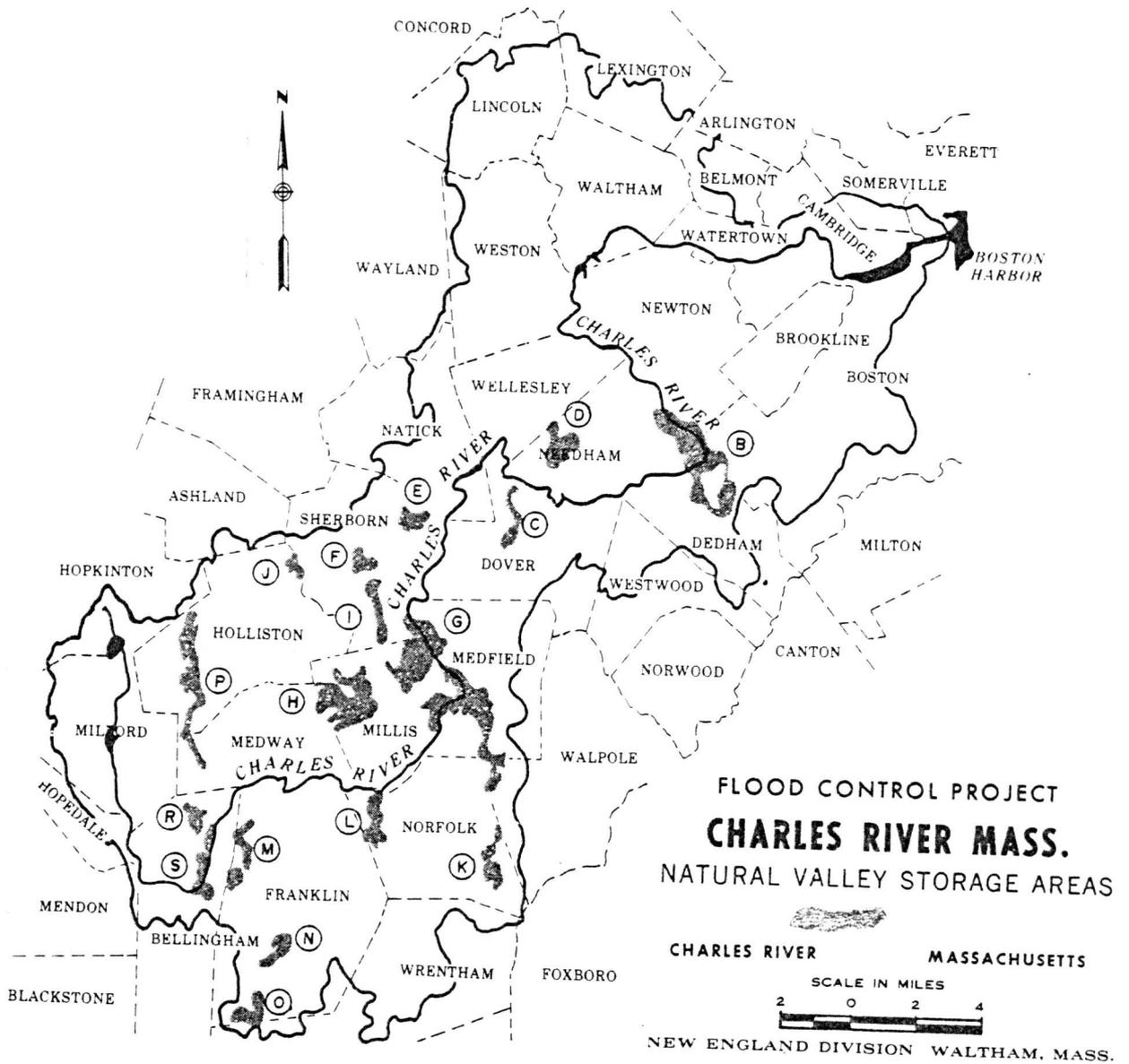
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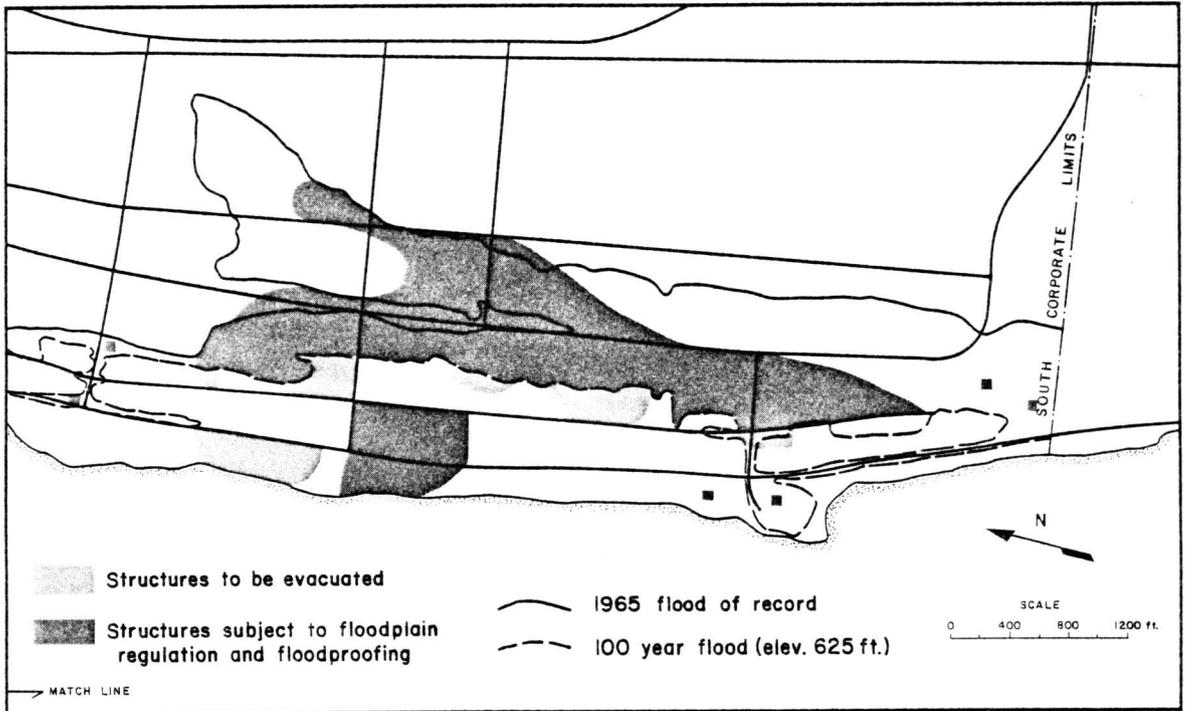
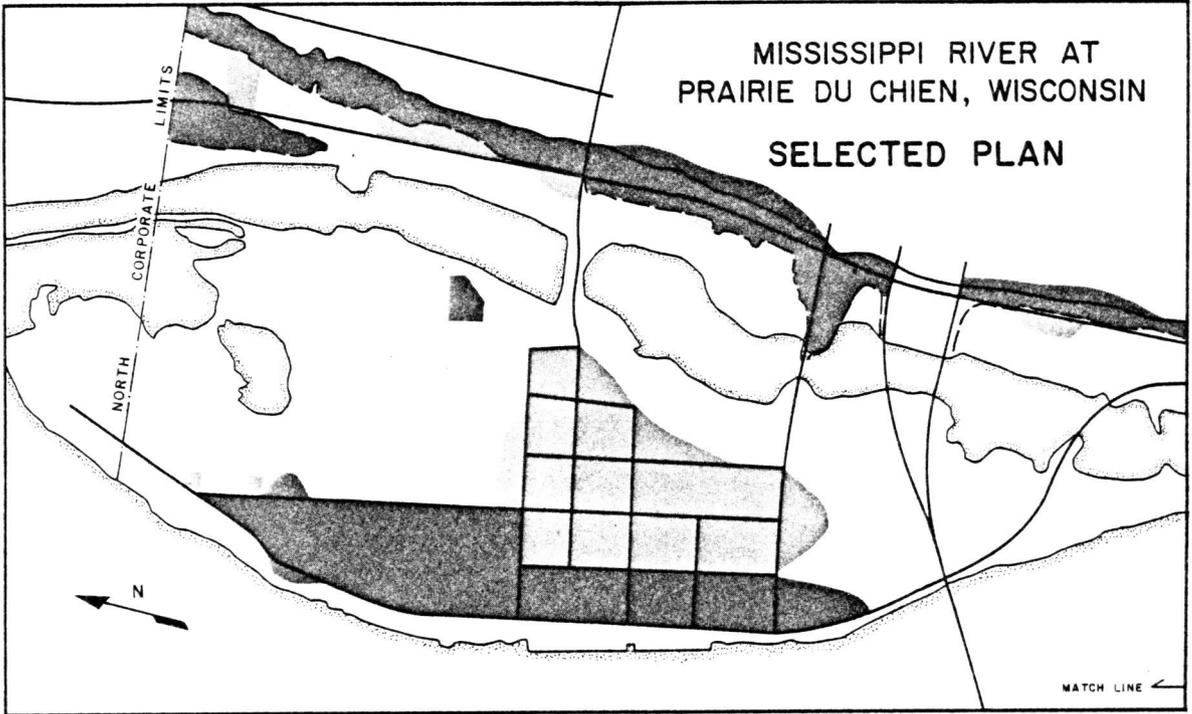
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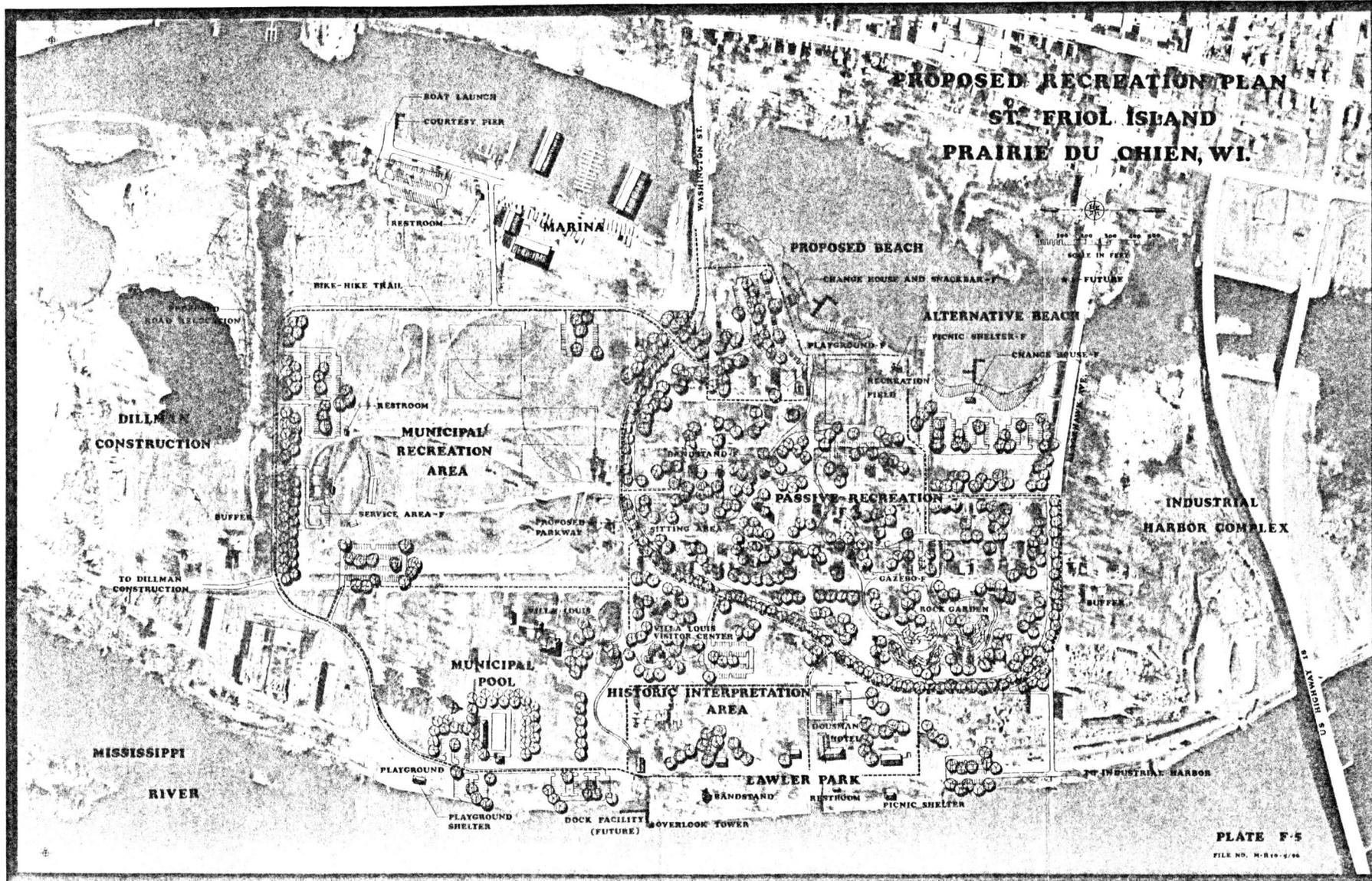
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MAPS

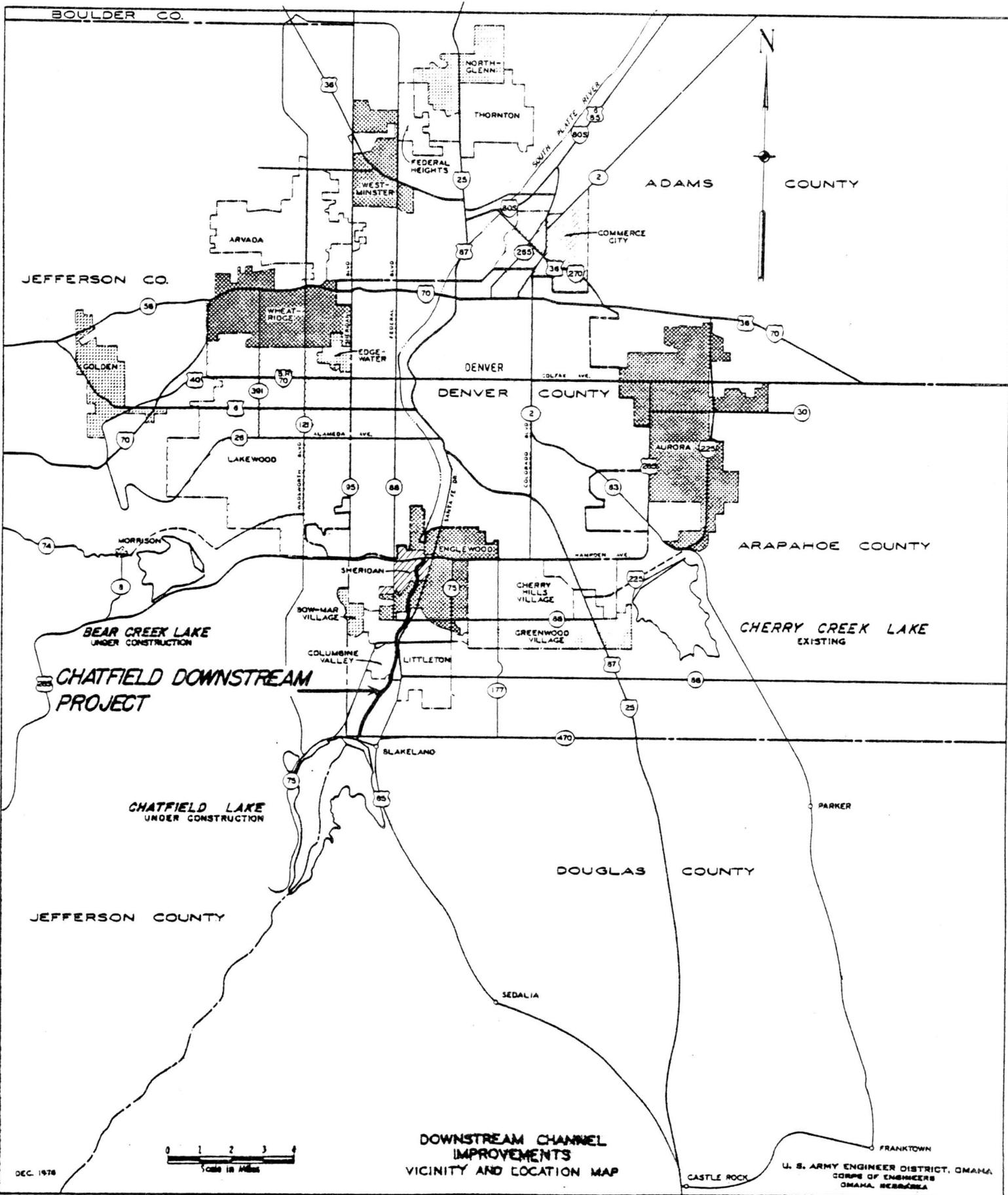
MAP I



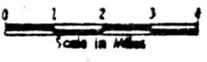




MAP IV

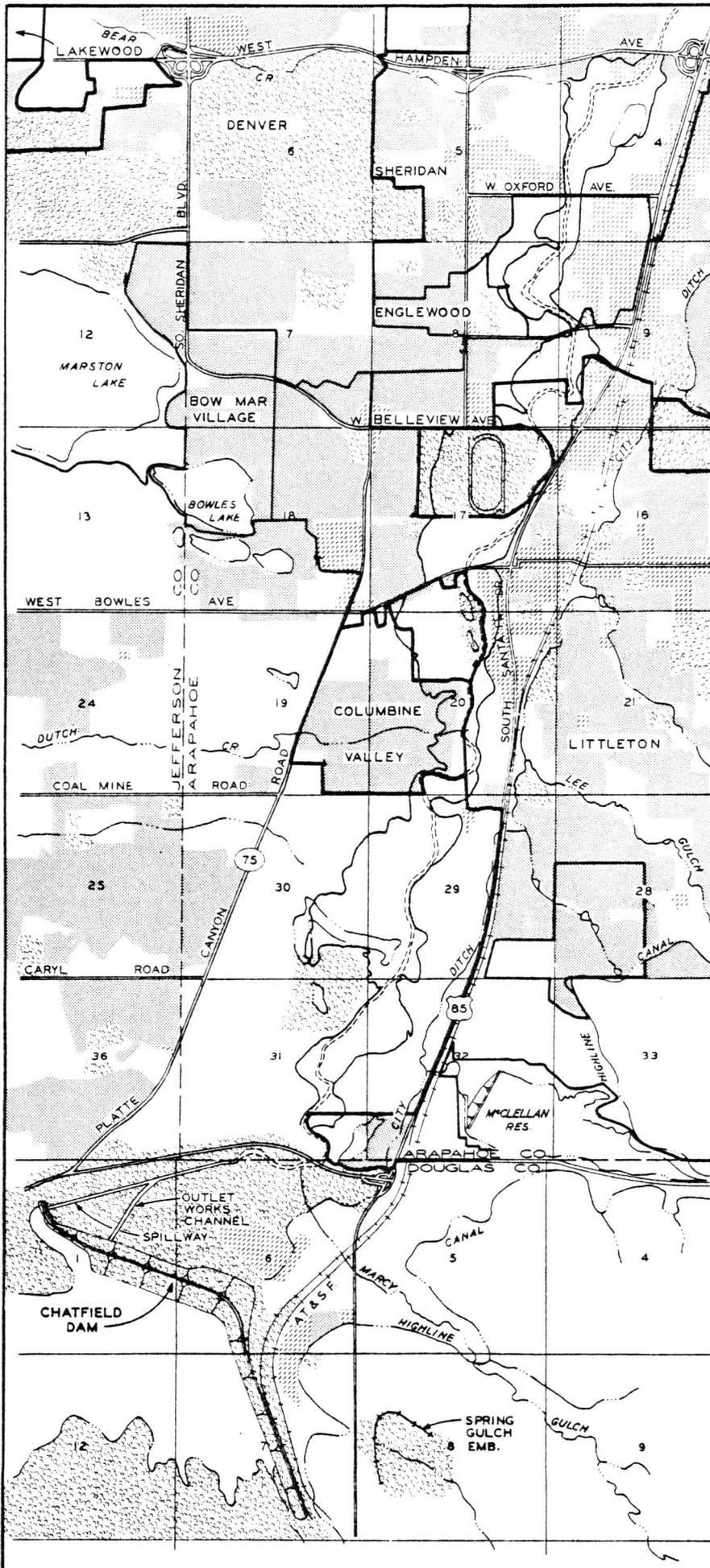


DEC. 1978



DOWNSTREAM CHANNEL IMPROVEMENTS VICINITY AND LOCATION MAP

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



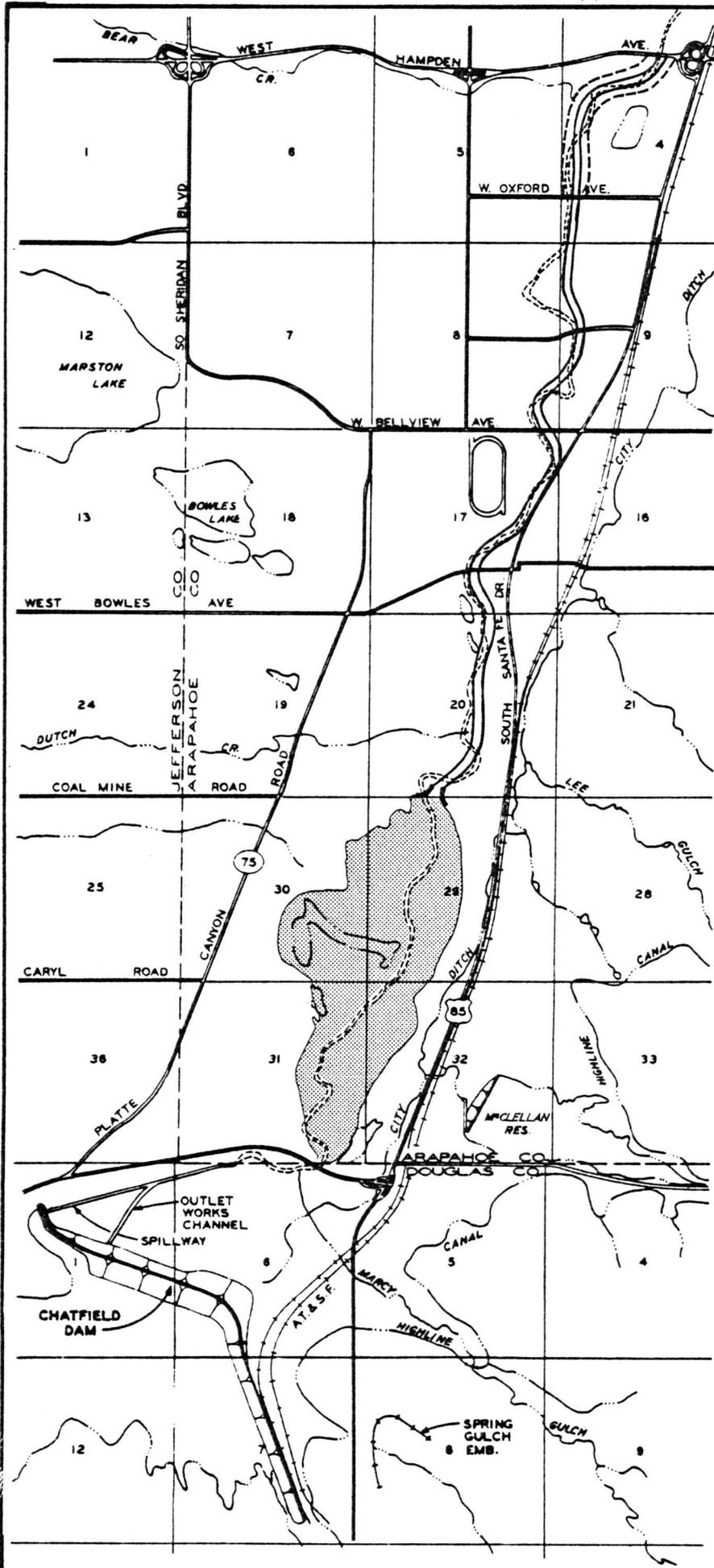
MAP V

LEGEND

- RESIDENTIAL
- COMMERCIAL AND INDUSTRIAL
- PUBLIC AND RECREATIONAL
- OPEN SPACE AND AGRICULTURAL
- ONE PERCENT FLOOD OUTLINE EXISTING CONDITIONS
- CITY LIMITS



SOUTH PLATTE RIVER; COLORADO
 CHATFIELD LAKE, COLORADO
 DOWNSTREAM CHANNEL
 IMPROVEMENTS
 LAND USE - EXISTING CONDITIONS
 U.S. ARMY ENGINEER DISTRICT, OMAHA
 CORPS OF ENGINEERS OMAHA, NEBRASKA
 DEC. 1976



MAP VI

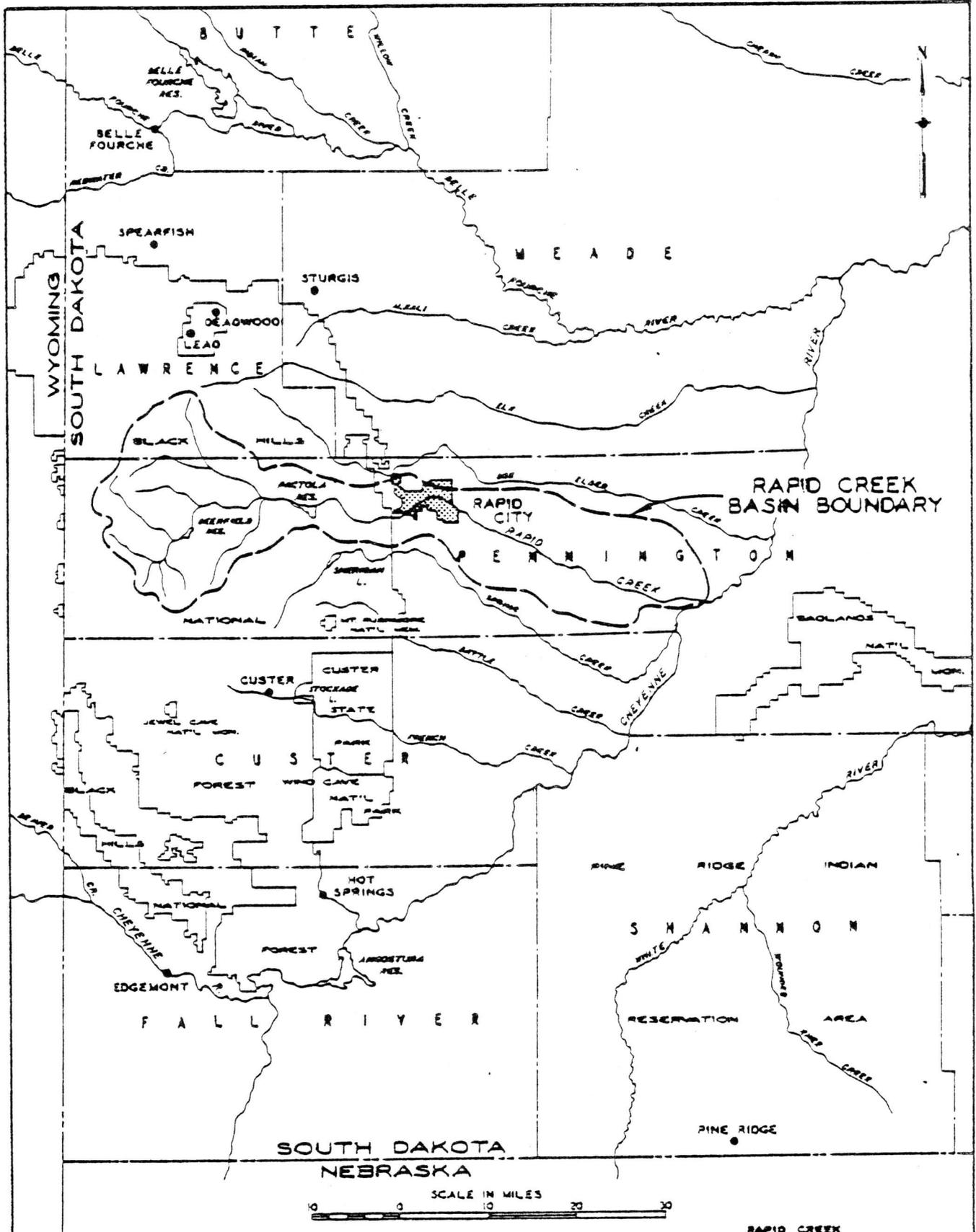
- ==== 1 PERCENT CHANNEL
- 1 PERCENT FLOODWAY
- MINIMUM 5000 C.F.S. CHANNEL
- ACQUISITION OF FLOODWAY



SOUTH PLATTE RIVER
 CHATFIELD LAKE, COLORADO
 DOWNSTREAM CHANNEL
 IMPROVEMENTS
 RECOMMENDED PLAN

U.S. ARMY ENGINEER DISTRICT, OMAHA
 CORPS OF ENGINEERS OMAHA, NEBRASKA
 DEC. 1976

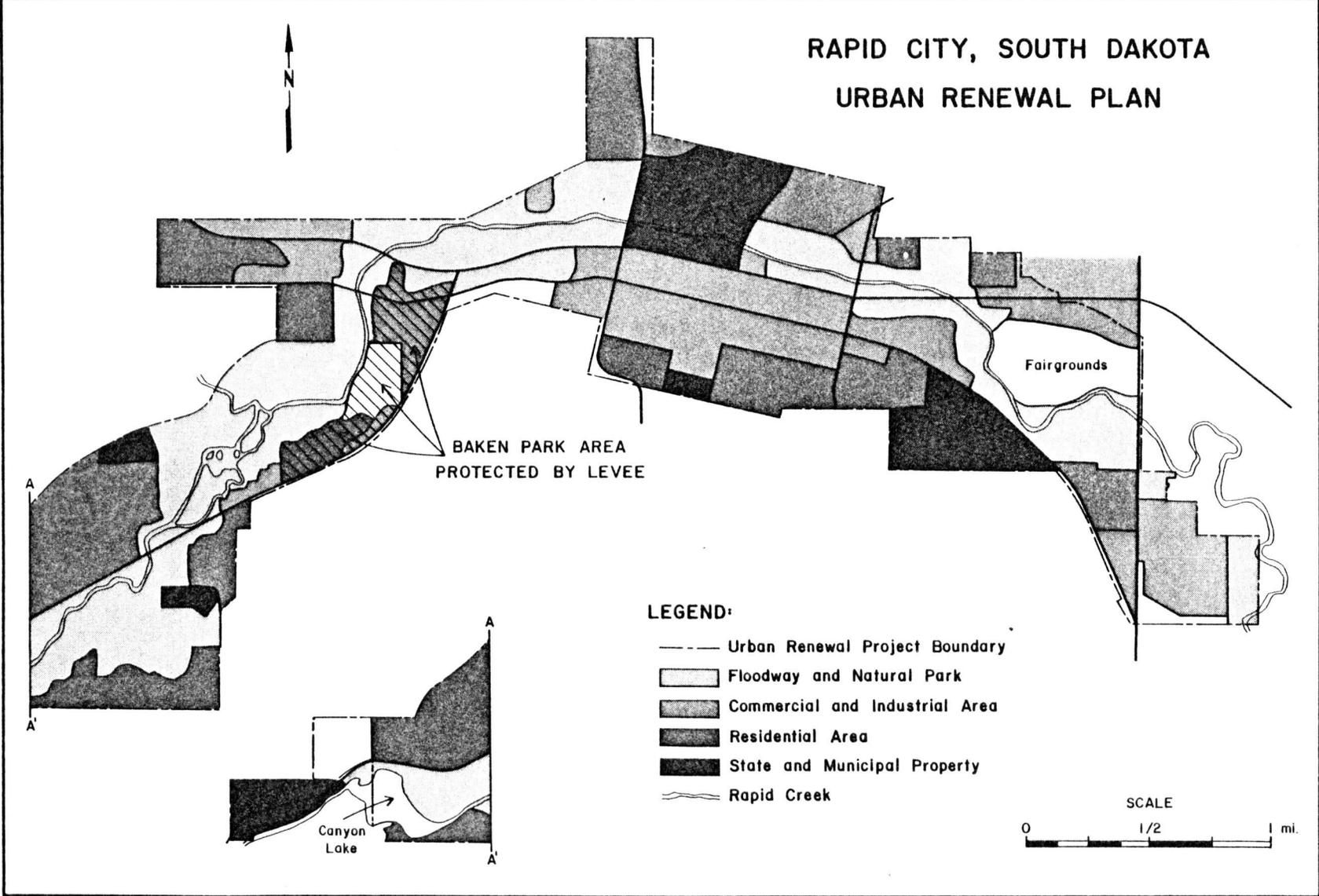
MAP VII



RAPID CREEK
 RAPID CITY, SOUTH DAKOTA
 FLOOD PROTECTION PROJECT
 BASIN MAP

U. S. ARMY ENGINEER DISTRICT, OMAHA
 CORPS OF ENGINEERS OMAHA, NEBRASKA
 OCT. 1975

RAPID CITY, SOUTH DAKOTA URBAN RENEWAL PLAN



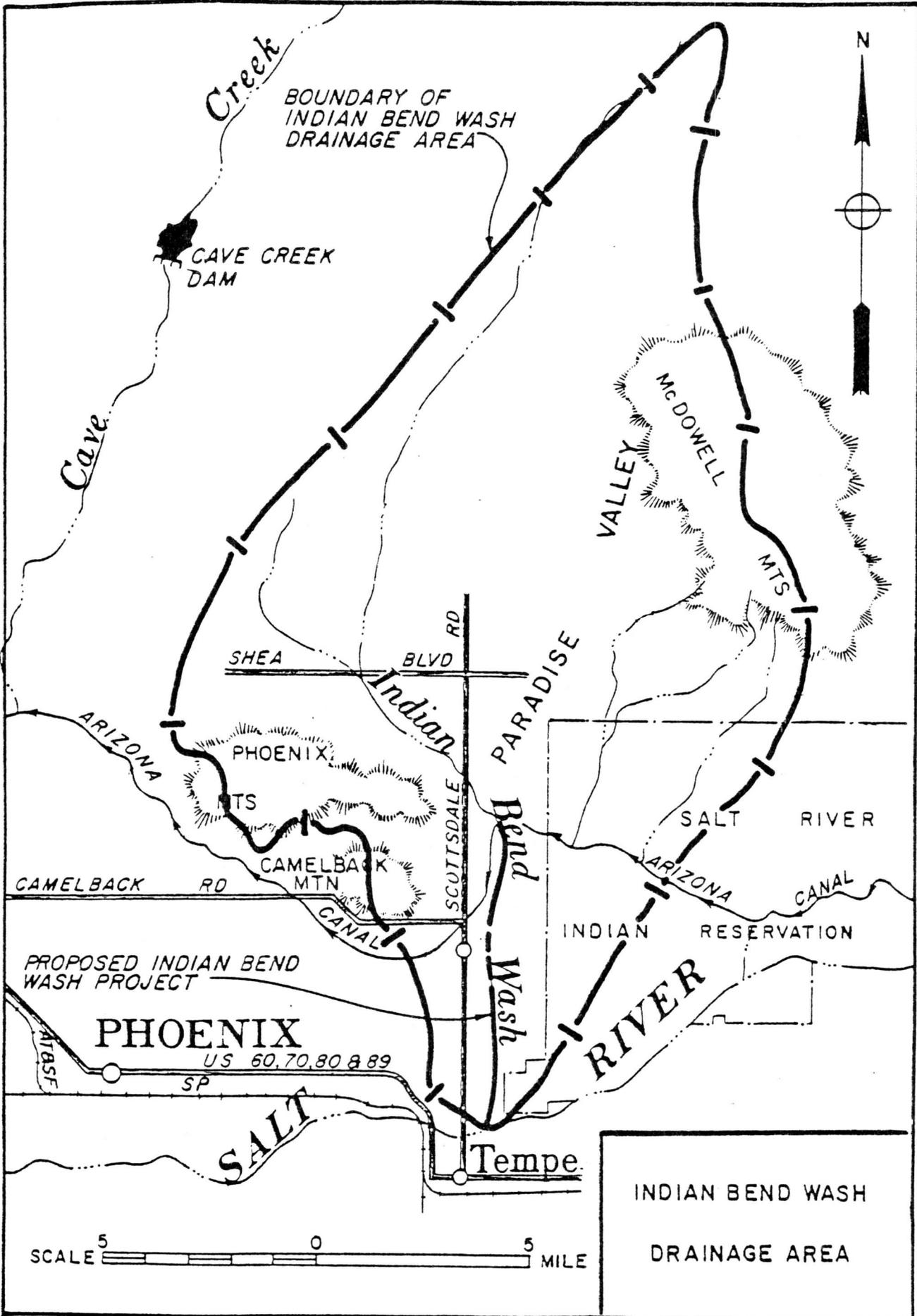
BAKEN PARK AREA
PROTECTED BY LEVEE

Fairgrounds

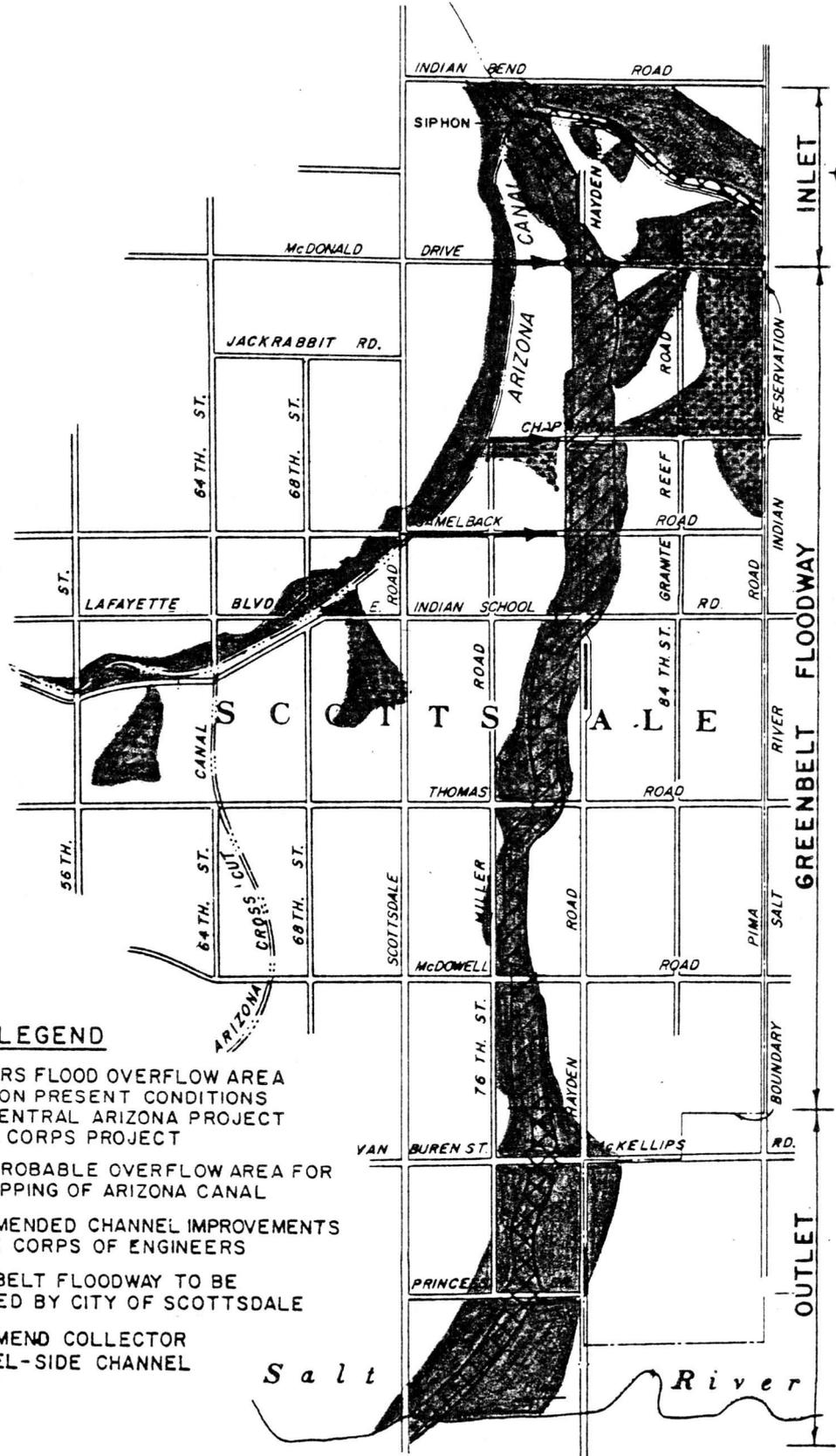
Canyon
Lake

- LEGEND:**
- Urban Renewal Project Boundary
 - Floodway and Natural Park
 - ▨ Commercial and Industrial Area
 - ▩ Residential Area
 - State and Municipal Property
 - ~ Rapid Creek

SCALE
0 1/2 1 mi.

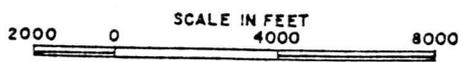


MAP X



LEGEND

-  100 YEARS FLOOD OVERFLOW AREA BASED ON PRESENT CONDITIONS WITH CENTRAL ARIZONA PROJECT AND NO CORPS PROJECT
-  MOST PROBABLE OVERFLOW AREA FOR OVERTOPPING OF ARIZONA CANAL
-  RECOMMENDED CHANNEL IMPROVEMENTS BY THE CORPS OF ENGINEERS
-  GREENBELT FLOODWAY TO BE MANAGED BY CITY OF SCOTTSDALE
-  RECOMMEND COLLECTOR CHANNEL-SIDE CHANNEL



INDIAN BEND WASH OVERFLOW AREAS

MAP XI

SNOHOMISH RIVER BASIN

