PROCEEDINGS

SYMPOSIUM

ON

FLOOD MONITORING
and
MANAGEMENT

AWRA

Arizona Section

AMERICAN WATER RESOURCES ASSOCIATION

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WATER RESOURCES RESEARCH CENTER

April 14, 1980

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PROCEEDINGS

SYMPOSIUM
ON
FLOOD MONITORING AND MANAGEMENT

ARIZONA SECTION
AMERICAN WATER RESOURCES ASSOCIATION

EDITED BY

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INTRODUCTION

This symposium was designed to discuss and disseminate information on the need for flood monitoring and management. Information was presented by representatives of Federal, State and local governments, the private sector, and the public at large. The symposium provided a forum to exchange information and news and to discuss the impact of management alternatives.

The symposium was organized by the Arizona Section of the American Water Resources Association. The principal objectives of the AWRA are the advancement of research planning, development, management, and education as well as the establishment of a common meeting ground for physical, biological, and social scientists, engineers, and other persons concerned with water resources.

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KEYNOTE ADDRESS

James E. Goddard
Consultant, Floodplain Management

James E. Goddard is a registered professional engineer and consultant in floodplain management and has pioneered and guided the concept of an integrated attack on flood losses. With the Tennessee Valley Authority he was responsible for developing the Local Flood Relations program, starting in 1953. He was a member of the Presidential Task Force on Federal flood control policy that prepared the report "A Unified National Program For Managing Flood Losses" (H.D.465) in 1966. During 1966-67 he served on the staff of the Chief of Engineers, Army Corps of Engineers in organizing and giving direction to the broadened activities of the Corps relating to flood plain information, flood plain regulations, and overall flood plain management.

Mr. Goddard addressed the group on the history of floodplain management legislation and the Federal government's attempts to implement such mandates; suggested a broad framework within which modern management operations might function; and supported the possibilities of non-structural measures for flood-hazard alleviation.

PRESENTATIONS

FLOOD CONTROL PROBLEM AREAS, STATE OF ARIZONA

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Phoenix, Arizona

FLOOD CONTROL PROBLEM AREAS

by William D. Mathews
Chief, Flood Control Branch
Arizona Water Commission

During and after each significant flood event in Arizona, the Corps of Engineers and Soil Conservation Service are called upon to perform emergency flood fighting, damage assessment and project studies. Although a number of problems have been found to have solutions which would economically justify federal participation, most do not qualify. Projects which, in the past, have been found to be economically justified, may no longer be possible due to the increase of federal discount rates over the last few years from 3 percent to 6-7/8 percent. Federal projects are usually built to provide at least 100-year level protection while satisfying certain economic and environmental requirements. All these considerations make a finding of feasibility difficult under federal laws and regulations. State and local governments, however, may not be bound by the same discount rates, levels of protection, and environmental requirements in implementing programs that do not involve federal participation so that state-local sponsored programs may be possible where federal projects aren't.

Listed below are areas of flood hazard which frequently are subjected to damage and a brief statement concerning possible flood problem solutions.

1. Clifton. The Corps of Engineers has been called upon to perform emergency work on several occasions during the 1960's and 1970's. All Corps' studies to date indicate that federal participation in a structural solution is not economically justified. A Corps' planning assistance study to identify applicable flood reduction measures is now complete and Clifton can utilize the study to determine its future course. Relocation of development from the floodplain appears to be the most cost-effective solution. However, lack of land on which to relocate is a serious problem.

2. Duncan. After the 1972 flood, the Corps studied the problem and determined that federal participation in a structural solution would not be economically justified. Replacement of damaged flood control structures has been justified in the past. These structures provide only limited protection and the most economical long-term solution is to relocate development outside the floodplain.

3. Safford. Construction of Camelsback Dam and clearing of the channel downstream were authorized in 1962 and would have provided flood protection for the Safford-Little Hollywood area. Environmental opposition stopped the clearing and local assurances necessary to advance the project were withdrawn in 1973; however, local support has surged anew in recent years. Camelsback Dam alone can no longer be

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Presented at the Flood Monitoring and Management Symposium of the American Water Resources Association, Arizona Section, October 26, 1979, Tucson, Arizona.

justified on economic terms as a federal project. The project was declared inactive by the Corps in 1977. Meaningful floodplain regulation and some relocation appears to be the solution here.

4. Tucson. A feasible Rillito project was developed and offered to the city and county by the Corps in the late 1960's. Local assurances were not available at that time. Later, support was expressed but it was dependent upon the project being used as a recreation area. The project as originally proposed probably can't be justified under today's regulations. Flood problems throughout the metropolitan area are now being addressed in the Corps' Tucson Urban Study as well as studies requested of the Water Commission by the Pima County Flood Control District under the program authorized by the Legislature in 1978. A coordination of these efforts will result in a comprehensive flood control program proposal within the next two or three years.

5. Globe. A federal project was found feasible on Pinal Creek in 1964. Local government failed to make the necessary commitments and the proposal was placed in inactive status. Under present federal regulations and criteria the project would probably not be economically justified. A flood control or flood proofing project appears to be the answer.

6. Nogales. Corps' studies indicated in the early 1960's that a project on Ephriam Wash was economically justified. Local support was not forthcoming and the project went inactive. Studies of the project were reactivated last year. Economic justification now appears marginal. A structural measure will be required here since extensive development exists along the water course. Aggressive floodplain regulation in other areas of Nogales would help reduce future damages and appears the most likely solution.

7. Bullhead City. Corps' studies have indicated that there is no economically justified structural solution to most flood hazards here. Due to the nature of the threat many watersheds would require some control and the present development will not warrant apparent expenditure requirements. Aggressive floodplain management will prevent worsening of the problem and relocation of much of the existing development would appear necessary.

8. Phoenix Metro. Presently authorized projects along with those which will be found desirable in the Phoenix Urban Study should provide adequate protection to the metropolitan area, except for the Salt-Gila floodplain. In this latter area the solution must come in the form of the earliest possible construction of upstream control plus the implementation of aggressive floodplain management including some form of channel improvement and utilization of flood proofing techniques. Without upstream control, extensive relocation of development will be imperative.

9. Holbrook. The Corps has completed a draft report on the proposal to increase the protection to Holbrook now provided by dikes built in

1948. Further study on such a project is underway and the project appears to be economically justified. The Commission has also been requested to study this problem to seek an economical solution. We will hold off on our study efforts until the Corps' determinations are complete.

10. Winslow. Studies after the 1972 flood indicated that protecting Bushman Acres and Ames Acres would not be economically justified under federal criteria. Navajo County Flood Control District requested assistance from the Commission on January 31, 1979, in resolving flooding problems associated with the Little Colorado River in the vicinity of Winslow. As a result of this request, the Commission has prepared a reconnaissance level report which evaluates four basic concepts designed to provide varying degrees of relief to the flooding problem. The evaluated concepts which consist of levee improvements, channelization, floodplain clearance, and flood proofing, produce several alternative plans which seem to be economically feasible.

    As a result of this preliminary study, the Commission concludes that a flood control project, consisting of improvements to an existing levee system, could be implemented for approximately 1.5 to 2.0 million dollars. Installation of this project would provide three major subdivisions and several hundred acres of agricultural land with protection against the 100-year flood and produce a project benefit/cost ratio of approximately 2:1. Final planning studies are scheduled to begin in early 1980 with project construction commencement possible in the summer or fall of 1980.

11. Quartzsite. The Corps has studied possible solutions to problems related to Tyson Wash and determined that federal participation in a structural solution was not economically justified. The Water Commission prepared a reconnaissance level study to determine if there was an economically viable solution on a State and locally sponsored basis. Based on our work to date no economical solution can be found.

12. Prescott. The Corps studied Granite Creek in the 1960's and found no economical structural solution. A structural solution appears to be essential due to the degree of development in the floodplain. No request has been made to the Water Commission for studying this area.

13. Sedona. The Corps' consideration of Oak Creek and tributaries in 1977 failed to develop a structural solution that is economically justified under federal criteria. Floodplain regulation in this area would help to minimize the problems and appears the most likely approach.

14. Cottonwood-Clarkdale-Camp Verde. Cursory studies by the Corps of Engineers have not been encouraging with regard to the feasibility of a structural solution. Floodplain management and relocation appear most feasible.

15. St. Johns. Corps' consideration divulged no feasible structural measures. Floodplain regulation appears to be the best alternative.

16. Flagstaff. Corps' studies on Rio de Flag indicate that federal participation in structural solutions probably would not be economically justified. A nonfederally funded projected appears to be the most viable solution since existing development would be very difficult to relocate.

17. Wickenburg. Corps' studies on the Hassayampa River have consistently indicated that structural solutions are not economically justified. Floodplain management should minimize problems in this area and should be encouraged.

Status of State Flood Control Programs

Flood Control Assistance Program

This program provides up to 50 percent reimbursement of expenditures by local sponsors for federally constructed flood control projects. Local responsibilities include the acquisition of all necessary land rights and the relocation of utilities such as bridges, water lines, sewers, etc. Since 1973, when this program was created, considerable progress has been made in solving flood problems in portions of the Phoenix metropolitan area. Without the State's contribution, local jurisdictions could not have fulfilled the local obligations required to implement badly needed projects.

In the period 1973 to the present a total of $21,121,000 has been appropriated to the Water Commission for this program. In most of the years, appropriations were not sufficient to match the expenditures of local governments. The $8,000,000 appropriation in 1978 allowed the program to catch up with previously unpaid claims and to provide adequate funds through Fiscal Year 1978-79. The appropriation of $4,000,000 will provide all funds required to carry the program through Fiscal Year 1979-80.

To date, projects which have been expedited through financial assistance by the State's program include:

Indian Bend Wash -- Scottsdale-Tempe
Spook Hill Dam -- East Mesa-Gilbert
RWCD Floodway -- Mesa-Gilbert-Chandler
Arizona Canal Diversion Channel -- Phoenix-Glendale
Cave Buttes Dam -- Phoenix
Adobe Dam -- Phoenix-Glendale-Maryvale
New River Dam -- Sun City-Peoria-Avondale
Foote Wash Project -- Safford
Wickenburg Watershed -- Wickenburg
Harquahala Valley Watershed -- West Maricopa County

The funding level required for this program is based on 50 percent reimbursement of local costs for federal projects and is governed by the rate at which local jurisdictions can raise funds for flood control projects. The $4,000,000 requested for Fiscal Year 1980-81 appears adequate to match funds available to local jurisdictions for federal flood control projects.

Alternative Flood Control Assistance Program

Although it is generally less costly to the local jurisdictions to obtain federal assistance on flood control projects, it also takes many years to go through the required planning, authorization and funding steps necessary for such assistance. Frequently those steps take 10, 12 or more years to go from initial study to construction. The alternative assistance program, created by the Legislature in 1978, provides for engineering, planning and financial assistance to county flood control districts seeking to solve flood problems in a more timely manner without federal funding assistance.

Since most counties throughout the State had not formed flood control districts, it was deemed advisable by the Legislature in 1978 to do so for them. This was carried out by Section 45-2301A ARS which states: "There shall be in each county a county flood control district which shall include the entire county." The Board of Supervisors in each county is designated to be the board of directors of the district. The directors receive no compensation for these responsibilities. The board of directors are given the necessary powers to operate a jurisdiction of this type which is a subdivision of the State.

Section 45-2309A provided: "Upon the application of any district organized pursuant to this article and subject to available appropriations, the Arizona Water Commission shall conduct a study and if deemed justified by the Commission develop a flood control plan to address any flood control problem within the district." The Commission was authorized, in fulfilling its duties assigned by this statute, to utilize either its own engineers and resources or to contract for outside consulting engineers and resources.

Section 45-2309D also provided: "Any plan developed by the Commission pursuant to this section shall to the extent practicable resolve the particular flood control problem. The practicality of any solution to a flood control problem shall be determined jointly by the Commission and the flood control district based upon cost effectiveness and design criteria developed by the Commission."

In order to provide for financial assistance to the county flood control districts in efforts to construct projects planned by the Arizona Water Commission, Section 45-2721A provided: "Any flood control district organized pursuant to Chapter 10, Article 1, of this title may subject to available appropriations qualify for assistance from this State for any flood control project if such project is being developed pursuant to a plan developed pursuant to Section 45-2309." Assistance funds appropriated by the Legislature for this purpose were appropriated to the Arizona Water Commission for administration. Limits on the State's involvement were placed at not more than 50 percent of the total cost of a flood control project or $5 million, whichever amount is less.

Subsequent authority was provided to the Arizona Water Commission in the 1979 legislative session in the form of Section 45-2731 which provided for flood control loans. Section 45-2731A reads: "The Arizona Water Commission may grant loans from the flood control loan fund established by Section 45-2732 to defray the cost of a county flood control district organized pursuant to Chapter 10, Article 1 of this title or a special flood control district organized pursuant to

Chapter 10, Article 5 of this title for flood control projects eligible for alternative flood control assistance under Article 2 of this chapter. Loans may be granted subject to the provisions of this article in such a manner and upon such terms and conditions as may be prescribed by the Commission." Certain review requirements were made of the Commission in order to determine that the proposed projects for which loan funds were requested would provide meaningful flood control and were in the best interest of this State. Loans to be granted by the Commission were limited to not more than 25 percent of the cost of the project or $2.5 million whichever might be less and the term of such loans was limited to not more than 20 years. Loans to any given flood control district at any given time were limited to 30 percent of the funds then available in the loan fund.

The loans which were available to the flood control district have varying interest rates ranging from 3 percent per annum for a 5-year payback, 5 percent per annum for a 10-year payback, and 6 percent per annum for a term of more than 10 years payback. The statutes provide that each loan to a flood control district must be evidenced by contract between that district and the Arizona Water Commission acting on behalf of the State. The contract must provide for the loan payment of a stated sum on equal annual increments including principal and interest for the term of the loan. It provides that the Attorney General may commence whatever actions necessary to enforce this contract and to achieve repayment of the loans provided by the Commission pursuant to this statute.

To the present time under the alternative flood control assistance program, the Water Commission has received requests to study 17 projects. Of the 17 projects requested one is near completion, that being Tyson Wash in the vicinity of Quartzsite. Unfortunately, this first planning effort resulted in our not finding any economically feasible solution to the flood problem.

Studies are nearly completed for Rillito Creek in Tucson. The reach of channel under study is that area lying between Oracle Road and Flowing Wells Road. We are also studying the Little Colorado River in the vicinity of Winslow and have completed the reconnaissance level study which is written in more detail in another part of this paper. We are also preparing a reconnaissance level study for Julian Wash in South Tucson. Completion of this reconnaissance level study is anticipated before the end of 1979. The Commission has awarded a contract to a private engineering firm to study the Gila River flood problem through the Wellton-Mohawk Irrigation District in Yuma County. This contract which has a four-month term provides that the consulting firm will prepare a reconnaissance level study for this reach of the Gila River making use of all available information stemming from previous Corps of Engineers studies and determining which reaches of the river will provide for the most cost-effective flood control projects.

Twelve more flood control projects have been requested for study by the Arizona Water Commission. These projects will be started approximately in the order of the following list.

Gila River -- Duncan, Greenlee County
Orangewood Estates -- Tucson, Pima County
Little Colorado -- Holbrook, Navajo County
Agua Caliente -- Tucson, Pima County
Cottonwood Wash -- Snowflake, Navajo County

Los Reales Cardinal -- Tucson, Pima County
Silver Creek -- Taylor, Navajo County
Finger Rock Canyon -- Tucson, Pima County
Silvercroft -- Tucson, Pima County
Black Wash -- Tucson, Pima County
Santa Cruz -- Tucson, Pima County
Canada del Oro -- Pima County

As can be seen from the preceding, only four counties have actively come to the Water Commission requesting studies for solutions to flood control problems. Although we have had dialogue with other counties, no other county flood control district has come forward with an official request for study. It is anticipated that over the next year several other counties will determine that existing flood control problems are of such paramount priority that funds must be made available to solve those problems. It is assumed that at that time these counties will come to the Water Commission seeking the planning and funding assistance which the Legislature has so wisely made available to them.

The Legislature has now appropriated to the Water Commission six million dollars to be disbursed for assistance funding. The loan fund has been appropriated five million dollars as a starting level. A sum of $500,000 has been appropriated to the Water Commission for study costs which are borne entirely by the State.

PRESENT PRACTICES AND FUTURE GOALS FOR FLOODPLAIN MANAGEMENT WITHIN PIMA COUNTY, ARIZONA

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Tucson, Arizona

PRESENT PRACTICES AND FUTURE GOALS FOR FLOOD PLAIN MANAGEMENT WITHIN PIMA COUNTY, ARIZONA

BY

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I. Present Practices - Flood Plain Management

Background

During the latter part of the 1960's and early 1970's, Pima County Government began to recognize the importance of analyzing not only the impact of urbanization upon major drainage systems alone, but upon both local and minor drainage systems as well.

Initially, regulations pertaining to provisions for the control of flood waters were incorporated into the Pima County Zoning Ordinance and associated subdivision/development standards. These regulations were generally applicable only to lands that were being subdivided or developed in a manner that required local government approvals prior to the initiation of construction. Most other lands were exempted from these regulations.

However, in December of 1974, Pima County adopted an ordinance entitled "Pima County Flood Plain Management Ordinance #1974-86", which provided for the regulation and control of flood waters over a much broader range of circumstances. It included control of development of private parcels of land within flood-prone areas which would not normally be subject to local zoning and/or other governmental regulations.

Through 1978, the Flood Plain Management Ordinance was administered principally by the Pima County Highway Department, under the direction of the County Engineer. Near the latter part of 1978, however, the Pima County Flood Control District was established and the administration of the Flood Plain Management Ordinance was included under its jurisdiction, along with all other flood-related matters. Recently, the two (2) agencies were combined to form the Pima County Department of Transportation and Flood Control District.

The Approach to Proposed Development

The Department's flood plain management policy regarding proposed development is to encourage non-structural or "passive" solutions rather than structural or "active" solutions to flood-related problems. Whenever and wherever possible, high-density urban land uses are discouraged from developing within the regulatory (100-year) flood plains of Pima County. This can most easily be accomplished in advance by denying rezonings which would otherwise allow such land uses to develop within known flood hazard areas. However, in some instances, existing zoning of land makes a totally "passive" solution economically infeasible, and other alternatives must be sought.

In most cases, the Pima County Department of Transportation and Flood Control District requires that a complete hydrologic and hydraulic analysis be prepared by a Registered Professional Civil Engineer for parcels of land within Pima County, prior to their development. This analysis must delineate each and every flood-prone area which traverses the parcel under investigation. The Pima County Department of Transportation and Flood Control District defines an area as being "flood-prone" if its associated watercourse carries a volume of flow equal to or greater than fifty (50) cubic feet per second (c.f.s.) during a regulatory (100-year) flood. Therefore, most parcels of land large enough to be of interest to subdividers may be expected to contain at least one (1) flood-prone area. This fact alone could lead to monumental problems, with attendant costs, if a structural solution were sought for each and every flood-prone area within Pima County. From the Department's viewpoint, the preferred practice for dealing with a flood-prone area would be to merely avoid any type of structural encroachment. In this regard, it is encouraging to note that most of the more recent development which has occurred within Pima County has been planned with just this approach in mind. That is, the flood-prone areas are clearly delineated upon all subdivision plats and/or development plans, so that improvements may only be constructed <u>outside</u> of flood areas. When this approach is not economically feasible, or physically practicable, due say to the existing zoning of land which allows for high-density uses, then structural measures must be undertaken to guarantee the safety of all improvements not only within the developing parcel, but upon parcels which may consequently be influenced by these measures as well.

<u>Assistance to Developers and Engineers</u>

Since the development of lands partially or wholly contained within flood hazard areas may influence flood conditions on adjacent lands, a decision as to whether the "passive" or "active" approach should be taken toward flood plain development can become one of critical importance to a land developer and his engineer. In this regard, one of the most important functions of the Pima County Department of Transportation and Flood Control District relating to flood plain management is that of working with the developer and engineer by providing information concerning flood hazard areas not only to them, but to all interested parties, whether public or private. This information may in turn be used to make advanced planning decisions that could ultimately result in the saving of many millions of dollars which might have later been spent in unsuccessful attempts to control "Mother Nature".

Assistance to Private Individuals

However, the flood plain information provided by the Pima County Department of Transportation and Flood Control District may also be extremely useful to individual homeowners who may merely wish verification that their home is not within a designated flood hazard area. Presently, this information is needed before lending institutions will provide mortgage monies without first requiring flood plain insurance as a condition of granting such a loan.

Another benefit derived from dissemination of flood plain information is that of obtaining valuable knowledge prior to the purchase or sale of property which might enable the buyer and/or seller to make a more realistic appraisal of the property's true economic worth. Real estate agents have found such information to be invaluable to them in their day-to-day work.

The Approach to Present Development

Present flood plain management practices and/or policies of the Pima County Department of Transportation and Flood Control District with respect to existing development within flood hazard areas, including on-going operations such as the extraction of sand and gravel from river bottoms, also emphasize, whenever possible, the "passive" approach to the solution of flood-related problems. However, existing conditions normally dictate that "active" solutions be sought to mitigate potential flood damages. In such instances, it must be clearly demonstrated that all measures employed to alleviate flooding conditions upon existing development, or to allow on-going operations to continue within flood-prone areas, will in no way influence flood hazard conditions upon surrounding lands; that is, unless prior agreements have been reached with all affected landowners, or said measures can be shown to benefit adjacent properties as well.

II. Future Goals - Flood Control Planning

Future goals of the Pima County Department of Transportation and Flood Control District for flood plain management include the development of a master drainage plan for Pima County, as well as formulation of sound flood control programs which will provide for an orderly development of presently rural areas to urbanized areas in a hydrologically compatible manner. These goals come under the more general heading of "Flood Control Planning", to which a separate section of personnel devote their entire attention at the present time.

Upslope Urbanization

"Flood Control Planning" differs for upstream and downstream problems. The latter refers to stabilizing river banks and to zoning land use along major valleys so that residential and business developments are separated from the path of floods, generated upstream, as they traverse the downstream reaches.

On the other hand, planning against floods on the far more numerous upstream areas must consider other natural processes, their impact upon man's intensive settlement of the land, and vice versa. The implications of these hydrologic processes associated with wide sheet flows which disgourge onto the bajadas of Pima County from steeper rocky mountains will be discussed here. As Tucson continues to grow, urbanization spreads across such areas of ill-defined drainage. Developments built across sheet outwashes are exposed to special problems of drainage and sediment, not experienced in locations where easily recognized natural drainageways had mainly kept urban investments out of trouble. Typical problems are discussed, together with possible solutions, for an example area southwest of Tucson, shown in Figure 1, page 15.

Surprises in Store for High Density Development

Rugged individualists who have lived in one home per 4 acres or more accept the surprise of sheetflow flooding and mud on road dips which occur randomly throughout these normal dry areas. This fan shaped watershed totals 86 square miles of relatively flat land through wide swaths of sheetflows in constantly meandering braided shallow streams. Small headwater catchments of 3.5, 2, 1.5, 3, 5.2, 0.4, 7, 15, 8.6, and 14 square miles of steep, bare hills produce intense flash floods in response to unpredictable summer storms. Under native conditions, the bajadas attenuate the fury of a flood wave by spreading it into a wide shallow flow across the course outwash material, into which they readily infiltrate. Downstream urban investments within the path of flood wave will be struck by mud and sand-laden flows that will cost maintenance to streets and private property alike. Increased impervious areas will transform the natural flood-absorbing terrain into one which itself augments the onrush of more frequent summer flood waters. Uncoordinated attempts at local channelization will increase velocities and sediment transport that will aggravate problems immediately downstream. Approximately thirty square miles in the neighborhood of Valencia Road, San Joaquin Road, and the Ajo-Tucson Highway, presently delineated on federal maps as subject to sheet flooding, could be transformed into prime developments by implementing the following upstream flood control plan. The zig-zag traces on Figure 1, page 15, symbolize the uncertain path of sheet flows which plague the flatter heartland of possible dense development. When many citizens are using the streets, and when large acreages of desert have been bared for housing projects, serious flood damages will occur.

There Is A Rainbow On The Horizon

An economical solution to the above problems is available, which has other community benefits. Each of the rectangles labeled 1 through 10, in Figure 1, page 15, suggests a detention basin which could double for groundwater recharge and dry-weather

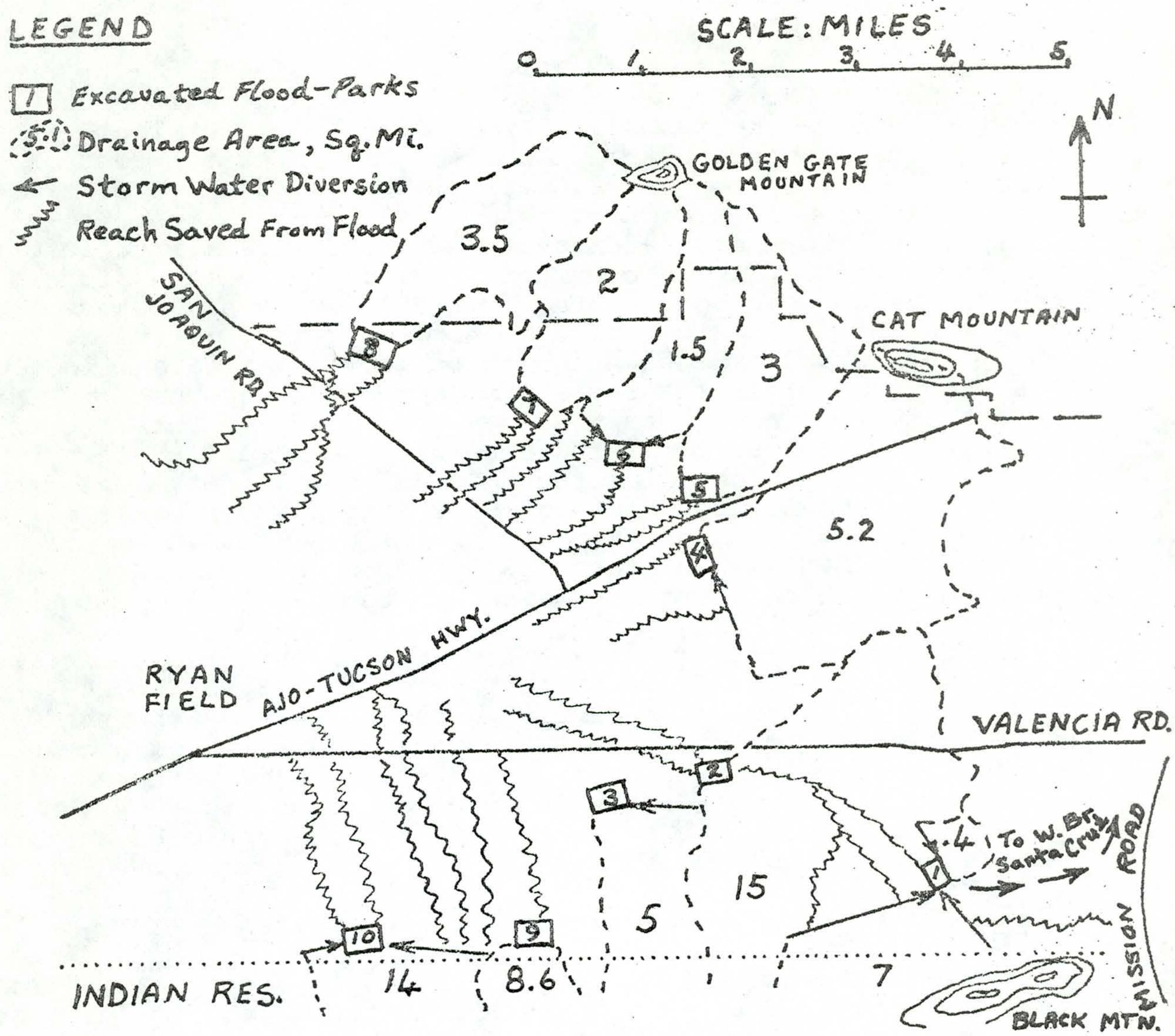

Figure 1. Scheme of Detention Basins That Could Eliminate Sheet Flooding and Provide Open Space Throughout Area Southwest of Tucson.

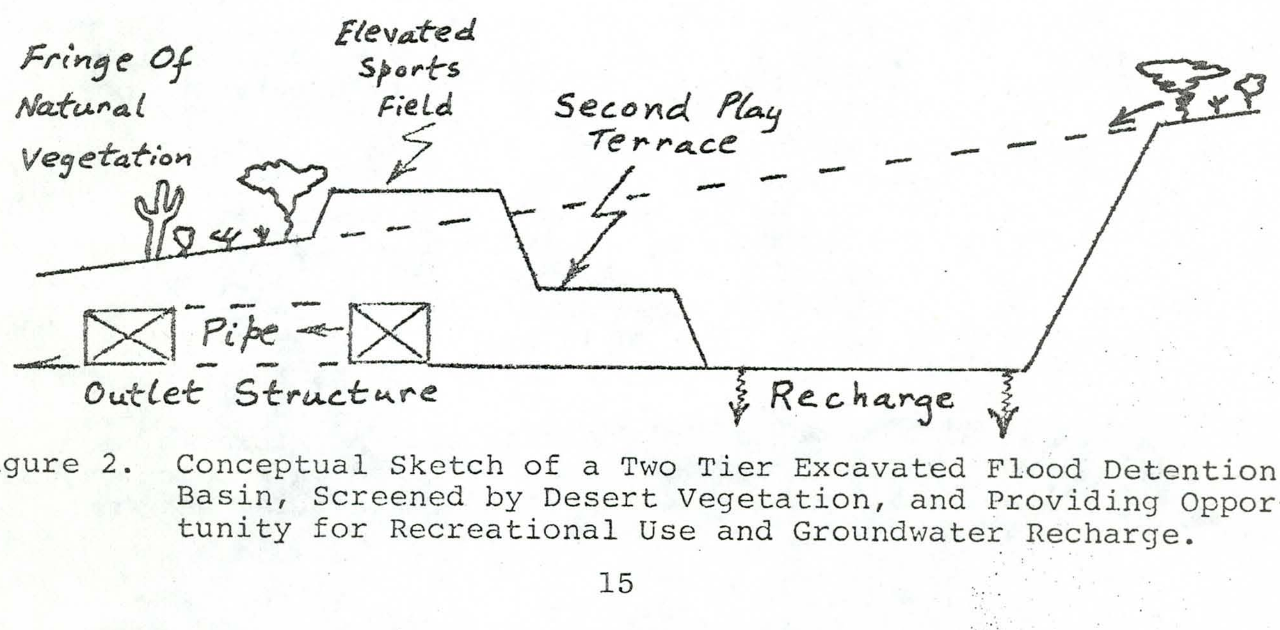

Figure 2. Conceptual Sketch of a Two Tier Excavated Flood Detention Basin, Screened by Desert Vegetation, and Providing Opportunity for Recreational Use and Groundwater Recharge.

recreation space. Figure 2, page 7, is a schematic cross-section through one such facility. Overland flows would enter such a detention basin, which will be excavated ten feet or more below original ground level, possibly by way of diversion ditches that would cut off stormflow from neighboring washes, as in example 10. Some of the excavated dirt will be formed into a shallow wide downstream berm which would provide the highest sports field. A second terrace could add play area above the level to which flood water would normally rise. It will, however, be low and extensive enough to provide additional detention space for exceptionally large floods whose peaks must be reduced before passing through to the downstream developments. Outflows from the flood detention structure will be throttled down by pipes of about 6 foot diameter. Recharge wells may be arranged to enhance groundwater recharge of the detained storm runoff. Between storms, the lowest parts of the basin would be available for rougher recreational use. Ramps of 6 to 1 or flatter would provide easy egress from the area, in the eventuality of a flood.

Approximate flood peaks that could be expected to strike these sites are listed in Table 1, page 17. Even the 10-year peaks are too high to be carried without scouring the sandy drainageways which conventionally would be put through developments immediately downstream. However, a flood-park described above could be designed to throttle down storm outflows to about 10% of its inflow rate. These reduced flows could be carried harmlessly through downstream developments in manicured channels.

Who Could Afford Such A Planned Drainage System?

The drainage system can be designed to accept flows from the new urban areas, as well as street drainage. In fact, acres presently subject to sheet flooding could be retrieved for beneficial development. Those who develop this land will clearly gain from implementing such a co-ordinated improvement scheme. Future residents of these areas will be freed from harassment by future floods. The recreational space located throughout the neighborhood will enhance the value of their properties. Maintenance of county roads or drainageways will be saved from frequent washouts or cleanup needed after mudflows. The community at large will gain by recharging the groundwater with increased surface runoff generated more frequently by urban developments.

A tentative balance sheet of costs and benefits is presented in Table 2, page 17. Additional amenities, difficult to quantify, will be provided to the gasoline-deprived residents of the future. Natural vegetation encircling each detention basin will provide islands for the birdlife and the preservation of other fauna. Removal of sediment from these dams will provide fill material for future home sites. Who would doubt that our developers would be delighted by this opportunity to contribute to a better-built community? A new method of financing such area-wide facilities must be devised. The classical provision of local drainageways on each quarter section of land on a piecemeal basis will not suit this sheet-flow situation. That is, each mosaic

Table 1. Approximate Flood Peaks That Must Be Reduced, And Runoff Volumes That Are Available For Groundwater Recharge.

DRAINAGE AREA		100-YEAR	10-YEAR		Average Annual
#	Square Miles	Peak, c.f.s.	Peak, c.f.s.	Volume Ac. Ft.	Runoff Ac. Ft.
1	7.4	8,000	2,400	280	200
2	15	12,000	5,000	640	300
3	5	6,500	2,000	190	100
4	5.2	9,000	4,500	300	160
5	3	5,800	2,800	180	140
6	1.5	3,500	1,700	100	80
7	2	4,400	2,000	110	90
8	3.5	6,000	2,600	170	100
9	8.6	8,600	2,600	180	200
10	14	10,000	3,000	220	300
TOTALS	65.2			2,370	1,670

Table 2. Approximate Costs And Benefits For A Communal Flood Detention, Groundwater Recharge And Open Space Scheme For Suburban Development Of 20 Square Miles Southwest Of Tucson.

IMPLEMENTATION COSTS	MILLION $
10 Detention Parks, 500 Acres............	2.0
41 Mile Channel R/W 100' to 200'..........	2.3
Inlet & Outlet Works......................	1.5
Fencing..................................	1.0
Excavate Ten 300 Acre-Feet Basins.........	5.0
Outlet Pipes..............................	0.5
Engineering...............................	1.5
Exigencies................................	0.2
	14.0

BENEFITS	
Release 6,000 Acres From Floods	18.0
Reduce Number & Size of Culverts	12.0
Eliminate Dip Maintenance Provide Neighborhood Parks Future Sale of Sand & Gravel From Clearing Basins	Annual Savings

can only be placed in the outwash areas following the implementation of upstream flood storage and development of a regionally planned drainage system. Surely a scheme can be devised for equitably dividing the costs among those who will benefit from development, and the Pima County Department of Transportation and Flood Control District is presently working toward this goal.

TWO FLASH FLOOD MANAGEMENT PROBLEMS: KASSANDRA[1] AND THE SIRENS[2]

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1/ A Greek mythological figure given the gift of prophecy by the God, Apollo; she was also cursed in that no one ever believed her forecasts.

2/ Bird-like creatures of mythology whose enchanting song drew mariners who sailed near their island to destruction and death on the surrounding rocks.

TWO FLASH FLOOD MANAGEMENT PROBLEMS: KASSANDRA AND THE SIRENS

The two Greek mythological figures symbolic of grim but unheeded prophecy, and a constant call to danger continue to plague us long after the fall of Troy, and completion of Odysseus' epic journey. The National Weather Service (NWS) whose task it is to forecast and warn of flood events often plays the role of Kassandra to a public drawn to danger by the beauty and spaciousness of its environment. Unwary of flash floods hazards, thousands of Americans visit and camp in canyons and mountain parks; homebuyers are drawn to picturesque residential developments near streams, or at the base of mountains. Cities are entwined by ribbons of concrete. Broad avenues, shopping malls, parking lots for city and urban life are also unknown traps for death. When confronted with a flood hazard, many Americans do not know how to respond to save themselves, or their property. Lulled by a false sense of security when structural flood protection is provided, or by the subconscious feeling that "it can't happen to me", the reaction to devastation and loss of life is anger at what could have been, and resignation over what was.

The complexities of citizen response to flood forecasts are compounded by the characteristics of the flash flood and individual behavior. Sometimes referred to as a fast flood or "short-fused" flood, a flash flood occurs quickly, usually within 6 hours of the causative event (heavy rainfall, dam failure, or ice jam breakup). Therefore, the time taken to collect, analyze, forecast, broadcast and react to the warning is extremely short, forecast accuracy notwithstanding. So, in addition to the believability of the potential for danger, the credibility of the forecast is in question, and under circumstances in which doubt or hesitancy can quickly lead to death which is the ultimate price usually paid by the very young and old. Organizations charged with responsibility for issuing forecasts, and warnings (NWS), and providing for public safety such as local police and fire departments, Civil Defenses and Red Cross, must devise management strategies to cope with these problems in order to fulfill their missions. One strategy used by the National Weather Service is to place a great deal of emphasis on interagency coordination at the local, regional and federal levels, as described below.

Background

The National Weather Service's job is to provide, among other weather services, river and flood stage forecasts for the country. Its National flash flood program was born out of the devastation caused by Hurricane Camille in 1969. The storm dumped up to 27 inches of rain in a 24-hour period over the Appalachian Mountains of Virginia, and more than 100 lives were lost in the resulting flash floods. The followup disaster report to the Administrator of the National Oceanic and Atmospheric Administration (NOAA) cited the lack of community flash flood preparedness programs in the James River Basin, and it called for development of radar systems, automated networks, and flash flood warning systems -- all needed to improve forecast accuracy, shorten the time to forecast, release, and lengthen the time needed to respond.

Since Camille, much progress has been made despite the lengthy procedures involved in systems procurement and a recent history of fiscal austerity in Government. NOAA Weather Radio, a VHF-FM radio transmitter provides continuous weather/river information, now reaches more than 200 cities, and there are ongoing programs toward implementation of a new RADAR computerized data processing system, and a high-speed internal computer controlled communications system. Techniques for meteorological analysis and prediction of flash flood producing storms are being developed through research, and through new man-machine arrangements. Finally, there are a growing number of local flash flood warning systems. In 1978, there were more than 650 such programs in the country.

The local warning systems are backed by solid plans for reaction during emergencies, and continuing contact between public safety, rescue and disaster aid groups at the local, regional and National levels.

Local Coordination

The Local Flash Flood Warning System (LFFWS) concept is based on organization of the community into a unified response unit. The National Weather Service provides this unit with a hydrologic assessment of its area, design of a data network and guidance of rainfall-runoff relation to make a preliminary flash flood forecast. The community therefore gains time needed for reaction and response to the emergency. By using these procedures, the community becomes a part of forecast and warning process in partnership with the NWS.

The "Kassandra Syndrome" is alleviated in a number of ways. First, formulation of the plan is an educational process. The community becomes aware of its surroundings and the specific reasons for its vulnerability to flooding. The community may want to, in addition to the LFFWS, seek other flood prevention measures. In turn, the NWS becomes more aware of its users and their special needs. Changes in NWS programs can reflect these needs. Finally, a local plan should include instructions to individual residents on flood hazard areas and how to respond in case flooding occurs. Information should be given to businesses and homeowners in the flood plain, and posted prominently in tourist spots.

During flood emergencies an action plan reduces the hesitancy response time because the community unit is aware of what to do. Alternative plans have already been evaluated, and a procedure is ready to operate. Time is saved and more time to carry out the response is allowed. In addition, efficiency of response improves when the plan is carried out by people with whom individual residents can identify as members of the community. Members of the action group have as much impact in the outcome of the event as the rest of the community. And the citizens asked to respond by the action group are reacting to a request from their neighbors -- not from an office located several, sometimes hundreds of miles away.

Finally, the forecast accuracy and believability are enhanced since a community observation network provides a tremendous data base for use by the servicing NWS offices. While the amount and timeliness of the data received may not improve immediate response in the affected community, the observations help the NWS issue forecasts for downstream and nearby basin areas.

Maintenance of a local flash flood warning system is as important as the initial planning. Contacts with the NWS are initiated as planning begins and continued through periodic drills, and by updating the information pertaining to the hydrologic environment. Community response units are thus ready for flooding at anytime, but not left completely alone to deal with emergencies. Community response to significant flash flood events becomes more complex the longer the rainfall continues, and the flash flood procedures supplied by the community become less effective. Observed rainfall data must be supplied for use in the complex hydrologic models used by NWS River Forecast Centers as the situation evolves into more generalized stream flooding. Also, in such cases, it is more likely that the community will need outside help in coping with evacuations, disaster relief, and cleanup.

Regional Interagency Coordination

The NWS is now pursuing development of regional interagency plans for handling flash flood problems. The approach requires designation of state coordinators and design of multicounty warning systems, grouped within specified regions of the country with similar flash flood problems.

This new strategy is yet to be tested for its operational effectiveness since the program is just getting started. The

States will share the costs of equipment and will provide personnel to assist their counties. The Weather Service will provide expertise from servicing NWS Forecast Offices and regional River Forecast Centers. It is envisioned that data collection and computing centers be established by each State involved with direct high-speed links to NWS Forecast Offices.

The benefits of the multicounty or regional approach are several. First, initiatives and incentives in the form of legislation and funding will be provided by States for their counties to participate. Such is the case now in Arizona. Second, regional warning plans will cover unincorporated towns and rural areas which do not have the resources to seek help individually from the Weather Service. Third, there will be less pressure on Weather Service personnel since major contact will be with a single coordinator from each State instead of individuals from each town. Therefore, no additional NWS people should be needed to run the program.

Operationally, the regional plans will promote coordination between NWS offices which have responsibility over the weather affected areas, and will provide continuity for assessment of meteorological conditions from State to State.

As in the local warning schemes, the improved coordination and preparedness will dispel doubts and hesitancy when flash flooding occurs. Residents of the areas become aware of their vulnerability to these meteorological events and take the necessary steps to save themselves and their property.

The first regional model is being developed in the Appalachian States with help from the Appalachian Regional Commission. A prototype system is expected to be operational in 1984.

National Interagency Coordination

National Weather Service headquarters personnel follow a daily procedure by which they and officials of other major disaster agencies stay alert to the potential for flash flooding. It is a "National Preparedness Plan."

Quantitative Precipitation Forecasts (QPF) are received via facsimile circuit at NWS headquarters from the National Meteorological Center (NMC) located in Suitland, Maryland. One "fax" product, the 24 and 48 hour QPF, is a U.S. map over which are superimposed isohyets of potential rainfall for the period ending at 1200 GMT, 24 to 48 hours after the product is issued. Another QPF, the Excessive Rainfall Potential Outlook, also a U.S. map, depicts areas where rainfall potential exceeds threshold values needed to cause flooding. The threshold values or flash flood guidance, are provided by NWS River Forecast Centers, and are based on soil moisture conditions in headwater and small basin areas. This product also shows critical areas where the maximum rainfall potential exceeds 5 inches.

The QPF's are given a qualitative assessment and the information is telephoned to the National Red Cross and the Federal Emergency Management Agency (FEMA). The Red Cross uses the material to plan for flash flood emergencies to move personnel and resources into areas where the potential for flooding exists. The information is used by FEMA to be ready and pave the way for disaster aid should it be requested. The link with FEMA is an official one. The NWS must verify weather related disasters before the President officially declares an area a disaster thereby making the residents eligible for Federal relief.

The "preparedness" plan described above is also an operational procedure if flooding is reported. QPF information is supplemented with observed rainfall and river stage data, and weather statements, forecasts, and bulletins received from local NWS offices. Briefings take place by phone whenever new information becomes available. Conversely, local Red Cross workers send reports on conditions in the flooded areas to their district and National offices which in turn are relayed to the NWS. These can be forwarded to NWS regional offices and given to local NWS offices as feedback on their forecasts and observed data. So, an information loop exists between local communities and emergency aid agencies, the NWS at all levels, and National disaster relief sources.

In addition to preparatory and operational liaison with FEMA and the Red Cross, the Weather Service routinely reports on current flooding to the Federal Insurance Agency (FIA), a subset of FEMA. FIA uses NWS verification of flooding to validate claims. These daily briefings allow FIA officials to evaluate the number and kind of claims they will be receiving since the report includes a qualitative assessment of the type of flooding which is occurring. In the long run, FIA can identify the particularly vulnerable areas and sell insurance to residents, and also initiate development of local warning systems.

Summary

The twin problems of forecast believability and constant potential for danger are two major barriers to effective citizen response to flash flooding. The National Weather Service as the responsible forecasting agency, and public safety groups in affected communities must develop management and flood monitoring strategies in order to fulfill their respective missions. In the 10 years of NWS management of a National flash flood program, interagency coordination and preparedness planning have proven to be very effective in alleviating these problems. Interagency coordination and preparedness planning are being carried out at the local level through development of community local flash flood warning systems; at the regional level through statewide data collection and computing programs developed by the States and the NWS in areas which share like flash flood problems; and at the National level by the NWS through its daily and operational information exchange with the Red Cross, the Federal Emergency Management Agency. These relationships provide an information loop which allows all participants to share data; to feedback observations and information of conditions to the NWS and to aid in its forecasting; and to give disaster and emergency groups as much time and information as possible to save lives and property. Preparedness plans eliminate doubt or hesistancy as to the mode of response when flash flooding occurs. Finally, preparedness planning educates participating groups to areas of flash flood danger, and particular community needs in dealing with such emergency situations.

SALT RIVER PROJECT EMERGENCY STORM OPERATIONS
SYSTEM FOR SALT RIVER AND VERDE RIVER WATERSHEDS

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Salt River Project
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SALT RIVER PROJECT

EMERGENCY STORM OPERATIONS SYSTEM

FOR SALT RIVER AND VERDE RIVER WATERSHEDS

The Salt River Project was the first project constructed by the U.S. Reclamation Service (now U.S.B.R.) under the Reclamation Act of 1902.

This Project consists of six dams - four on the Salt River and two on the Verde River constructed for the purpose of conserving water for use within the Project area encompassing approximately 254,000 acres.

The Salt River dams beginning upstream are Roosevelt, Horse Mesa, Mormon Flat and Stewart Mountain. On the Verde are Horseshoe and Bartlett.

The Salt River dams impound 1,754,000 acre-feet from a watershed covering 6,211 square miles. This is a storage to area ratio of 282 AF/Sq. mile, whereas the mean annual runoff is only 126 AF/Sq. mile. The ratio of storage to average runoff is 2.24.

The Verde River dams impound 309,000 AF from a watershed encompassing 6,185 square miles or 50 AF/Sq. mile. The average annual runoff is 60 AF/Sq. mile, and the ratio of storage to average runoff is 0.83.

In addition to storage factors, analysis of runoff from 1913 to the present provides some interesting proportions.

In the Salt River system, the maximum historic runoff is 3.75 times the mean annual runoff and 1.5 times the combined reservoir capacity.

These large but infrequent peak flows make adequate conservation storage to capture them unjustifiable, while on the other hand, the Salt River Project presently does not have legal responsibility for flood control and cannot construct facilities to contain these peak flows.

The Salt River Project does have the authority and responsibility, however, to mitigate damages caused by these peak flows, and in the last several years has made significant strides in this endeavor.

In an effort to accomplish this task, the Project has organized emergency operating procedures for storms emanating on the watershed and additional procedures for storms directly affecting the Salt River Valley. I will direct my remarks primarily to procedures relating to watershed storms.

The objective of these procedures is to provide timely identification of conditions with potential for destructive flooding and to provide information required for effective mitigating decisions.

In order to meet this objective, an extensive data collection system has been developed. These data are classified into the following elements: storm movement, precipitation, temperature, runoff, lake levels and reservoir releases. I will discuss in detail the facilities and procedures related to the collection of each data classification.

Storm Movement

In order to effectively utilize storm movement data, real time information is required. The Project has installed a United Press International Unifax II satellite image receiving unit connected to the National Weather Service network which provides a picture of the global weather systems affecting Arizona every 30 minutes. These images greatly assist our staff meteorologist in determining and predicting strategic movement of major storm systems.

Tactical storm movement information is provided by a weather radar system. The Salt River Project has installed a remote radar monitoring system in the Operations Control Center, which operates as a slave unit to the National Weather Service radar system. This radar unit has range selections of 100 KM and 500 KM radius from Phoenix and has the capability of selection and display of enlarged quadrants. It also has the capability of selection and indication of precipitation intensity.

Storms within the range of this radar system are displayed on a color TV monitor in 6 different colors representing varying intensities of precipitation within the storm. The screen has a geographic overlay indicating the location of the Salt and Verde rivers and the reservoir system. The monitor presents an updated picture every 2 minutes as the antenna rotates.

In addition to real time observation of storm movements on the radar screen, we have installed a video recorder used for lapse time recordings of storm movement. The recorder is normally set to record 5 seconds of every minute in sequence. The video tape can then be played back, thus condensing 1 hour into 5 minutes of viewing time.

In addition to the satellite pictures and weather radar, we have an extensive program of weather observers covering the Salt and Verde watersheds. We have established procedures with the Sheriff's departments in Gila, Yavapai and Coconino counties providing them with standard storm data forms for use by their Deputies in the field. While a storm is in progress, the dispatching centers of these Sheriff's offices periodically contact their field Deputies for specific information on precipitation amounts, either snow or rain, wind velocities and directions and temperature.

The Project Watershed Division contacts the Sheriff's office dispatchers at prescribed times to collect this information.

In addition to the Sheriff's observers, we also have interested citizens residing at various locations on the watershed who have volunteered to report similar information on request.

The Project Watershed Division staff conduct field surveys during storms over prescribed routes and periodically report the similar information requested from the Sheriff's departments and citizen observers.

Other Salt River Project operating personnel report storm movement and precipitation amounts from the reservoir sites.

Precipitation

The second class of information is precipitation which can come in the form of rain or snow. During the past year, the Project has received permission from the National Weather Service to interrogate the Weather Service DARDC stations. This is an acronym meaning "Device for Automatic Rain Data Collection".

These stations are interrogated by telephone through a computer in Medford, Oregon and provide information on precipitation amounts accumulated during the past 6, 12, 18 and 24 hours.

The Project has also installed a receiving terminal which is connected to the Soil Conservation Service SNOTEL system. There are 15 SNOTEL stations on or adjacent to the Salt and Verde watersheds. These stations provide information on snow water content, temperature and accumulated precipitation.

The Salt River Project has participated with the National Aeronautic and Space Administration (NASA) for 4 years in a satellite snow mapping program. During the winter season, NASA processes images received from the GOES satellite and overlays the snow covered area on the Salt and Verde River watersheds on a map and determines the percent coverage of the total watershed area. A picture taken by the satellite camera this afternoon would be processed and transmitted to the Project facsimile receiver and delivered to our Watershed Division tomorrow morning.

Satellite snow maps are received daily during the snow accumulation season when no cloud cover is present. If the watershed area is partially cloud covered, the picture will be sent; however, the percent of aerial coverage is not computed.

This information is utilized in determining the potential volume of runoff as the pack recedes and also in determining the lowest elevation of the snow pack which helps in judging how much runoff can be expected from a warming trend over the watershed.

Precipitation data is also collected from the human weather observers mentioned previously under storm movement.

Temperature

Temperature information is collected from the standard weather stations on the watershed and from the SNOTEL stations. Mean daily temperatures are calculated and used to determine melt rates in the snow pack. Temperature is also important during a storm to determine if precipitation is falling as rain or snow because rain will result in immediate runoff, whereas snow will not.

Runoff

The Salt River Project has a cooperative stream gaging program with the U.S. Geological Survey. This program supports 18 stream gages on the Salt and Verde Rivers and tributaries. The Project operates an automatic stream gage reporting system from 7 stream gaging stations which provide real time water stage data to our Operations Center. This system is known as METS, or Motorola Environmental Telemetry System.

Several of these stations are located higher in the watershed to provide advanced warning of runoff into reservoirs.

Examples are: Chrysotile Station at the Highway 60 crossing of the Salt River which records flows 12 to 16 hours before reaching Roosevelt Reservoir.

On the Verde River, METS stations are located at Camp Verde, in the Verde River below the confluence of the East Verde, and Verde below Tangle Creek upstream from Horseshoe Reservoir. These stations provide information on major tributary inflows and also provide 12 hours' warning before flows reach Bartlett Reservoir.

The Project also has a communications terminal capable of interrogating the NOAA-NESS computer in Suitland, Maryland for information received from the GOES satellite for tributary flows from the Black River, the White River and from Cherry Creek, all tributaries to the Salt River.

Lake Levels

The Project has recently installed an automatic lake level recording system which transmits water levels from the 6 reservoirs to our Hydrology Office on a continuous basis. This equipment allows the computation of differential reservoir gains which are then used in a computer program to compute reservoir adjacent inflow and other vital reservoir operating information.

All of the data described is received by the Operating Divisions in the Water Group and is provided to the Project Reservoir Operating Committee, called the P.R.O.P. Committee. This Committee consists of personnel from all departments in the company whose activities and functions are affected by storms or excessive runoff. Emergency storm operations are classified at 3 levels:

A. Flood Advisory - Conditions having a potential of requiring releases from the reservoirs in excess of the water order but less than 10,000 cfs.

B. Flood Warning - Conditions requiring releases from the reservoirs in excess of the water order but less than 10,000 cfs.

C. Flood Emergency - Conditions expected or requiring releases from the reservoirs in excess of 10,000 cfs.

When weather conditions indicate that a flood advisory condition should be established, the Chairman of the P.R.O.P. Committee issues a flood advisory notice to all Division Managers and supervisors affected.

A situation briefing is immediately called, at which the weather forecasts are presented by a staff meteorologist.

The Project's Watershed Specialists report on watershed conditions and the potential for runoff resulting from the forecasted storm.

The Hydrology Department reports on the reservoir status and the recent river flow record. Runoff hydrographs are projected for a range of precipitation flows and watershed yields. A detailed assessment is made of the potential of the anticipated storm and mitigating plans are drafted accordingly.

Recommendations for action are made by the P.R.O.P. Committee and approved by Project Management, and action proceeds in an expeditious manner.

In 1978, the Project cooperated with the National Weather Service River Forecast Center located in Salt Lake City in developing a computer model of the Verde River Basin for rainfall runoff. This model was utilized in the storm of December 17-20, 1978 and in subsequent storms in January through March of 1979.

During these storm events, the Project P.R.O.P. Committee called the River Forecast Center for assistance, and within one hour, a projected hydrograph for the Verde River was received.

Notifications

When flood warning and/or flood emergency conditions are declared, the Salt River Project begins to make notifications to municipal and public agencies and private enterprises that will be affected by storm water releases into the Salt River channel.

The Project Water Customer Service Office maintains a current listing of 98 agencies and private businesses that must be called in the initial notification, and nearly all of these are notified each time a significant change is made in storm water releases.

The Project also operates an information desk at the Maricopa County Disaster Defense Center to coordinate Project activities with the County, State and local emergency forces. Detailed procedures for the notifications and for the Disaster Defense Center activities are maintained.

EARLY-FLOOD WARNING SYSTEM FOR TUCSON BASIN

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EARLY-FLOOD WARNING SYSTEM FOR TUCSON BASIN

by

Dan Chudnoff and Robert Reynolds[1]

The U.S. Army Corps of Engineers has been directed by Congress, at the request of local governments, to investigate alternative solutions to a wide range of water resources problems in eastern Pima County.

Starting in December 1977, the first job of the Tucson Urban Study (TUS) was to identify water resource problems and to develop a Plan of Study that would direct the Corps activities in solving these problems. The TUS Plan of Study, approved by local governments in October 1978, identified two major study elements to address the problems. The problems are:

1. The depletion of the area's natural water supply (addressed in the Eastern Pima County Regional Water Resources Element); and

2. Flooding and the degradation of the area's watercourses (addressed in the Regional Flood Control Element).

In the Regional Water Resources Element, the Corps has developed a technical base on water supply and demand and wastewater supply and potential reuse. This data base will be used by the area's major water users to allocate a limited water supply among users and to help facilitate out-of-court settlements of numerous lawsuits.

The Regional Flood Control Element concentrates on the role of watercourses within the region. Stage 1 of this study element, completed in 1978, identified flood-prone sites in the metropolitan area and identified eight watercourses that will be studied by the Corps. These water courses are:

--Canada del Oro Wash
--Airport Wash
--Rillito River
--Tanque Verde Creek
--Santa Cruz River (at Tucson, Marana and Green Valley)
--Rodeo Wash
--Pantano Wash
--Agua Caliente Wash.

Within the flood control element of the study, the Corps has identified three possible alternatives to reduce flood damages: no action, non-structural flood plain management techniques, and channel modification. The range of non-structural alter-

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natives includes an early-flood warning system as a viable tool for coping with the flood hazard.

This paper presents the Corps' preliminary findings and recommendations with respect to the feasibility of developing an early flood warning system for the Tucson Basin.

Flooding in the Tucson Basin is caused by long duration rainfall, in possible combination with snowmelt, or by intense short-lived thunderstorms. Severe flooding or high flows in the area's watercourses have resulted in considerable damages. Utilities, roads and bridges have been washed out. Residential, commercial and industrial buildings and lots have been damaged or destroyed. The loss of human life is documented yearly.

Those who live in flood-prone areas, and workers and visitors in the flood plain form the aggregate population-at-risk (Downing, 1977). The total number of people varies according to season, day of the week and time of day. In a recent survey, the Corps identified more than 4,000 structures within the area's major flood plains. More than 16,000 persons reside in the same area. The number of visitors and workers is much larger.

Canyons in the Santa Catalina, Rincon and Santa Rita Mountains are important recreation areas around the basin. At a given time on a normal spring weekend more than 2000 persons can be found hiking or picnicking within the Sabino and Bear Creek Canyon recreation area. "Flash floods are most likely to occur in the late afternoon or early evening from late spring to early fall; at those times more tourists and visitors are in the flood plain" (Downing, 1977). On September 5th of 1970, 23 lives were lost to flash floods in northern Arizona. Fourteen died attempting to flee their campgrounds. Sabino Canyon and other recreation areas are settings for a similar disaster. Future development of the flood plain for recreational and residential purposes will expose a growing number of people to the risk of flooding.

The benefits of an early-flood warning system are obvious. With minimal lead times flood plain evacuation plans can be implemented. Access to canyons can be sealed, those inside can be directed to high ground. Lives can be saved. Utilities can be shut off. With sufficient warning, contents of homes and businesses can be elevated or removed for protection. With longer lead times, low areas and important buildings can be protected with dikes and by sandbagging. At present, the Tucson Basin receives no such protection.

In August of 1979 the TUS began to study the feasibility of an early-flood warning system for the Tucson Basin. Our initial investigation was limited to interviews of local, state and Federal agencies with an interest in flood warning, and a review of technical literature. The remainder of this paper will review our findings and conclusions. One conclusion that we quickly arrived at was that there is no flood warning system at present.

Radar, spotter networks, self-reporting raingages, flash flood alarm gages, as well as an adequate preparedness program are essential requirements for an effective warning system.

Because of the sparse population in areas where flash floods originate, radar is the best potential tool for monitoring weather systems and predicting floods once a storm system develops (Williams et. al., 1978). The nearest radar station to Tucson is located 100 miles away at Sky Harbor Airport in Phoenix. With a maximum range of 250 miles, it was believed that the station in Phoenix would be able to provide adequate coverage for all of southeastern Arizona. The Official in Charge at the Tucson Weather Service Office believes, however, that the mountains surrounding Tucson greatly handicap the radar's transmission. On August 12, 1979 a thunderstorm was accompanied by a funnel that would have been a tornado had it touched ground. Had there been radar detection, advance warning could have been issued. The local Weather Service Office can cite other occasions when thunderstorms have developed without detection by the Phoenix radar.

While radar is an important tool for observing systems, a ground-level spotter network is needed to provide information on what is happening within the storm.

The Tucson metropolitan area is fortunate in having what is perhaps the most comprehensive spotter network in the nation. The Tucson Weather Service Office and the Pima County Transportation and Flood Control District have issued over 250 raingages to residents in the area. Observers are requested to regularly submit reports of precipitation, and to immediately report unusually large amounts of rainfall. In addition to the volunteer spotters, a number of agencies maintain their own network of recording raingages. None of them are self-reporting.

Flood and flash-flood alarm gages can also be effective in providing warning. This equipment is set to trigger an alarm whenever flow within a channel rises to a predetermined level. The alarm can be triggered locally, such as sirens or flashing lights at road-dip crossings, or it can be automatically relayed by radio or telephone to an appropriate office with 24-hour duty personnel. The U.S. Geological Survey maintains the largest number of stream gages in the basin. The University of Arizona, the Soil Conservation Service and a number of other organizations have gages for research and data gathering purposes. None of them are self-reporting. The USGS fields personnel to monitor their stream gages during flow events.

However, the agency does not have a clear-cut policy to evaluate field observations and to transmit warning to local emergency response organizations.

The last ingredient of a flood warning is a preparedness program. Within Pima County, the Department of Emergency Services is charged with developing and maintaining emergency response programs. The department has developed a flood and flash flood response program, but in the words of the Director, "Getting information as a warning tool is almost impossible." A second problem limiting the county's response effectiveness is communication.

With the exception of a tie-in with the National Warning System (NAWAS), the department receives all of its information secondhand. During a given severe storm event, either the local Weather Service Office or a regional center will issue flood watches or warnings. This is then relayed via NAWAS to the Department of Emergency Services and to Pima County Communications. When rainfall commences and washes begin to run, concerned citizens often call in to Communications, the Weather Service Office or the Flood Control District. Patrolling deputy sheriffs will also notify Communications of any unusual developments. Communications will then request all officers in the area to be on the alert. If roads have been cut by flowing washes, deputies will be dispatched to set up barricades. During all storm events, the Director of Communications, who is not a trained meteorologist or hydrologist, must evaluate all information, decide what action must be taken, and whether Emergency Services should be alerted. Once alerted, Emergency Services takes control of all activities and implements its disaster preparedness program.

The whole system is dependent on visual observation, voluntary reports by citizens, and follow-up checking by deputies. Valuable time is lost in the communication process.

Realizing the need for early-flood warning systems, the Corps of Engineers and the Arizona Water Commission (AWC) have begun initiatives to evaluate the present state of the art as it is practiced in Arizona, and to address themselves to the problem, both state wide and within eastern Pima County.

In January of 1979, the Corps of Engineers Phoenix Urban Study called together a meeting of organizations with an interest or mandate in flood warning, to discuss the Corps' proposed study of flood problems on the Salt and Gila Rivers. During this and subsequent meetings, it became evident that there was a need for coordination of the efforts of the many agencies present. As a consequence, the Central Arizona Hydro-met Data Management Association (CAHDMA) was established to facilitate the exchange of information and to provide a forum for agency programs to be evaluated through peer review.

As a result of these meetings, the AWC applied for and received funding from the state for flood warning. The AWC was allocated $150,000 in FY80 to hire two hydrologists to develop and implement flood warning programs. The National Weather Service also would provide one hydrologist and the office space necessary to coordinate the state's work. The USGS has also agreed to match the state's $150,000 and to provide an additional $150,000 in matching funds to Maricopa County for their flood warning program. Presently the AWC, in conjunction with the Arizona Division of Emergency Services, is evaluating flooding problems and warning needs in the state's 14 counties as a preliminary step in determining how to allocate their funds.

Locally, the TUS and the Pima County Flood Control District have also begun to address the problems of poor instrumentation and lack of planning efforts. In August of 1979 the TUS began meeting with various local and Federal agencies to discuss the flood warning needs of the Tucson Basin. The Corps found a consensus among all agencies that there was a lack of instrumentation, and there was a need for coordinated efforts by all agencies.

Based on our evaluation of the present state of flood warning, and our discussions with other agencies, the TUS proposes the following with respect to the development of an adequate early flood warning system for the Tucson Basin:

> An organization similar to CAHDMA should be established to facilitate intercommuncation and coordination of agency efforts. The success of CAHDMA in opening lines of communication and cooperation has resulted in a bonanza of Federal and local funding for Arizona, and for Maricopa County in particular. While the flooding problems of central Arizona are unique to that area, the CAHDMA concept is adaptable to the Tucson Basin. The majority of agencies that would be involved are already members of the TUS Multi-purpose Technical Committee (MPTC) which is our peer review group. This organization can serve as a forum through which members are kept informed of each others' programs. There are a number of Federal agencies and programs with the capability of providing significant funding for local efforts. The Corps, either through the TUS or other programs, the USGS, the Soil Conservation Service and the National Weather Service have programs to provide funding and technical assistance for flood warning.
>
> This organization can be a vehicle for getting these funds. Because a flood warning system encompasses a river basin and should not be limited by political jurisdictions, this organization can coordinate with similar efforts upstream in Santa Cruz County and downstream with the central Arizona counties and CAHDMA.

Secondly, the Corps proposes that a full range of hydro-met instrumentation for the basin, including radar, should be evaluated. The Pima County Flood Control District has expressed an urgent need for hardware in the upper watersheds of the basin. At the request of the AWC, the District has prepared a preliminary proposal to establish a network of self-reporting raingages tied into a mini-computer with the software capabilities to interpret the data and route the predicted runoff. The estimated cost for this system would be $25,000. The TUS will be looking into the feasibility of cost sharing in this or similar programs.

Program emphasis must be placed upon areas in which people and removable property can be protected by such a service. Put another way, from a Federal standpoint, flood warning hardware must be economically justified through benefit-cost analysis. To this end, the TUS has prepared land use projection maps for the major flood plains in the basin; and we are presently in the process of developing flood damage frequency curves.

Our third proposal is that an institutional study be undertaken to fully evaluate current flood warning planning and data dissemination procedures. If an early warning system is determined to be feasible, an agency with the capability to monitor the system, evaluate the data and transmit evaluations to an appropriate emergency response agency, would have to be established.

At present no agency within Pima County, including the Corps of Engineers, has the fiscal or personnel capabilities to pursue these proposals. I would like to reiterate however, that through concerted action, maximum benefit can be derived from our limited resources. Finally, the TUS would like to take the opportunity afforded by this forum to invite all organizations with an interest in flood warning to respond to the proposals presented. Follow-up meetings with you and members of our MPTC, and the obtaining of feedback from an already well-organized public involvement structure under the TUS, may be an acceptable and effective way of formulating an early flood warning system for the Tucson Basin.

Thank you for your time and interest in this matter.

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STORM FLOWS MANAGEMENT IN RELATION TO INDUSTRIAL DEVELOPMENT

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STORM FLOWS MANAGEMENT IN RELATION TO INDUSTRIAL DEVELOPMENT

This paper will discuss the effects of urbanization in a watershed on hydraulic and hydrologic parameters and discuss briefly one method of estimating runoff volume and peak rates of discharge. Obtaining reliable data on runoff volume and peak rates of discharge is difficult because conditions are constantly changing during the transition from rural to urban land use. At this time only general empirical relationships between the parameters that affect runoff and peak rates of discharge have been developed.

As population density and land values increase, the effects of uncontrolled runoff become an economic burden and a serious threat to the health and well-being of a community and its citizens. Emphasis must be placed on providing solutions to the runoff problems caused by radical changes in land use. Estimating the magnitude and frequency of future flood events makes possible systematic planning and installation of structural and nonstructural measures to reduce hazards to acceptable levels.

Management of runoff from even minor storms is rapidly becoming an engineering requirement of local and state governments to help reduce flooding and stream erosion. Rapid deterioration of stream channels caused by increased storm runoff has had a detrimental impact on communities. Counties and states are adopting policies which limit the effects that changes in land use may have on any stream within a development or watershed. These policies cover such areas as (1) assisting in the planned management of water resources, including storm drainage, throughout any watershed; (2) promoting and encouraging the inclusion of flood storage in all planned reservoirs; and (3) encouraging and assisting in planning for onsite retention of runoff through the use of temporary storage structures and infiltration devices.

There is a need for thorough understanding of the problems associated with the rapid conversion of land use and for adequate technical procedures to assist local communities, municipalities, and planning groups in assessing the effects of changed land use on streamflow.

An urban or urbanizing watershed can be defined as an area in which all or part of the watershed will be covered by impervious structures, such as roads, sidewalks, parking lots, and houses. Urban stream channels may also be supplemented by some form of artificial drainage system, such as paved gutters and storm sewers.

The effect of urbanization on the water regime has long been recognized. Investigations to evaluate the factors involved have been going on for some 40 years. Ideally, hydrologic studies to determine volume and rates of runoff should be based on long-term stationary streamflow records for the area being investigated. Such records are seldom available for small drainage areas, and because of the time involved in converting a water-shed from rural to urban conditions, available records normally are not adequate. It becomes necessary to estimate the magnitude and frequency of peak rates of runoff through modeling of measurable watershed characteristics. An understanding of these characteristics is required for judging how to alter parameters to reflect changing watershed conditions.

Urbanization of a watershed changes its response to precipitation. The most common effects are reduced infiltration and decreased travel time, which result in significantly higher peak rates of runoff. The volume of runoff is determined primarily by the amount of precipitation and by infiltration characteristics related to soil type, antecedent rainfall, type of vegetal cover, impervious surfaces, and surface retention. Travel time is determined primarily by slope, flow length, depth of flow, and roughness of flow surfaces. Peak rates of discharge are based on the relationship of the above parameters as well as the total drainage area of the watershed, the location of the development in relation to the total drainage area, and the effect of any flood control works or other manmade storage. Peak rates of discharge are also influenced by the distribution of rainfall within a given storm event. The Soil Conservation Service uses three standard rainfall distributions--types I, IA, and II. Type II-distribution applies to all areas of the United States except for parts of the Pacific Coast states, and was used in this example.

Since urban areas are seldom completely covered by impervious structures soil properties are an important factor in estimating the total volume of direct runoff. The infiltration and percolation rates of soils indicate their potential to absorb rainfall and thereby reduce the amount of direct runoff. Soils having a high infiltration rate (sands and gravels) have a low runoff potential, and soils having a low infiltration rate (clays) have a high runoff potential. Urbanization on soils with a high infiltration rate increases the volume of runoff and peak discharge more than urbanization on soils with a low infiltration rate.

The type of cover and its hydrologic condition affects runoff volume through its influence on the infiltration rate of the soil. Fallow land yields more runoff than forested land for a given soil type. Covering areas with impervious material reduces surface storage and infiltration and increases the volume of runoff.

Some rainfall is retained on the surface and by vegetation before runoff begins. Interception is rainfall that is caught by foliage, twigs, branches, leaves, etc. This rainfall is lost to evaporation and thus never reaches the ground surface. Increasing the vegetal cover increases the amount of interception.

Surface depression storage begins when precipitation exceeds infiltration. Overland flow starts when the surface depressions are full. The water in depression storage is not available as direct runoff.

Initial abstraction is the sum of interception, depression storage, and infiltration before runoff begins. It occurs on all types of cover, from pasture in good condition to concrete pavement. Obviously, the amount of initial abstraction is less on concrete pavement than on pasture.

Urbanization can change the effective length of a watershed if flow paths are altered by channelization and by terracing areas for building lots, parking lots, roads, and diversion ditches. The slopes of storm sewers, street gutters, roads, and overland flow areas as well as stream channels are significant in determining travel times through urban watersheds.

Flow length may be reduced if natural meandering streams are changed to straight channels. It may be increased if overland flows are diverted through diversions, storm sewers, or street gutters to larger collection systems.

Flow velocity normally increases significantly when the flow path is changed from flow over rough surfaces of woodland, grassland, and natural channels to sheet flow over smooth surfaces of parking lots, diversions,storm sewers, gutters, and lined channels.

All of the foregoing have an effect on the peak flow and time of peak for any storm producing runoff. The specific industrial development which I will discuss, was the first installation of International Business Machines at their industrial site located east of Tucson along Interstate 10. The property extends from Kolb Road on the West to a point East of Rita Road on the east. It also ranges from I-10 on the southwest to the Southern Pacific Railroad on the northeast. Traversing the site from east to west is Julian Wash. The total watershed at a point approximately one quarter mile east of Kolb Road comprises in excess of 7000 acres or 11 square miles. The length of the watershed is about 54,000 feet. It is approximately 6000 feet wide and is fairly typical of desert washes in the Tucson area. There was nothing remarkable about this drainage basin with the possible exception that very little development had occurred.

The primary objective of the early engineering studies was to develop concepts which would permit the client to utilize not only the upper channel of Julian Wash but also its associated flood plain. Very early in our discussions it became evident that any such undertaking would require sensitivity by the designer to the implications of urbanization as well as an understanding by the client of those implications. In addition, the client would have to agree to the additional engineering costs involved in such an investigation and analysis. Our client was agreeable, so the studies started.

Preliminary meetings with Pima County Flood Plain Management Staff resulted in an agreement for an estimate of the discharge to be expected if the entire basin was developed in accordance with approved area and neighborhood plans, as well as for the existing condition.

Now, while we had an estimate of the peak flows anticipated, we had very little useful information concerning the rates of flow preceding and following the peaks. In order to determine these values it was necessary to develop a water supply curve for each point of significance within the basin.

A water supply curve is an adequate and an efficient description of the dynamic process of runoff response and the resulting flood potential characteristics of small urban watersheds. This water supply curve is commonly referred to as a short duration unit hydrograph.

As a result of our studies, a scheme for on-site detention of the storm water occuring within the project boundaries was recommended by us and agreed to by the client. A channel was to be designed going around the site to carry the anticipated 100 year storm runoff from the upstream drainage area assuming industrial development without any on-site detention. The area above the channel was estimated to be 5000 acres. The site was approximately 2000 acres.

The contributory areas upstream have gentle slopes varying from 3 feet per thousand feet to 8 feet per thousand feet. They presently have sparse desert bush covering except in low lying areas where there are thickets of mesquite.

The generalized soils maps for Eastern Pima County indicated that the drainage basin consisted of approximately 20% Type D and 80% Type B soils. The basin consisted of four sub-basins contributing to the proposed channelized flow.

10-minute unit hydrographs were developed for each of the subareas for both the existing and improved conditions using the technique as discussed in "Nomographs for 10-Minute Unit

Hydrographs for Small Urban Watershed", ASCE Urban Water Resources Research Program, William H. Espey, Jr., Duke G. Altman, and Charles B. Graces, Jr., revised July 1977.

The unit hydrographs were based on the following assumptions:

1. The 1% probability precipitation for the area under consideration was 2.45 inches per hour.

2. The vegetative cover for the existing condition consists of 15% vegetative cover with 80% Type B soil and 20% Type D soil.

3. The curve number for Type B soil is 83 and for Type D is 92. This resulted in a weighted curve number of 85 for the natural condition.

4. The improved condition was assumed to consist of 55% curve number 98 and 45% of curve number 85. This resulted in a weighted curve number of 92 for the improved condition.

5. The impervious percentages were assumed to be 28 and 72 for the original and developed conditions respectively.

6. A conveyance factor of 1.1 was assumed for the natural state (Natural channel conditions with light channel vegetation). This factor was reduced to 0.7 assuming complete channel improvement with no vegetation, extensive use of curbs, pavement and storm drains for the fully developed condition.

7. An improved channel with a bottom width of 80 feet, side slopes of 3 to 1, depth as required, and a Mannings "n" factor of 0.025 was assumed to intercept all of the storm water entering the site.

Using these assumptions, a water supply curve was developed for each of the sub-basins and for the main site. These curves were computed for both the natural state and for the developed state.

The interceptor channel had slopes of 3 feet, 6 feet and 8 feet per thousand feet getting steeper as it went down stream. Stage discharge-velocity curves were constructed for each of the channel slopes.

Composite hydrographs were then developed for the entire basin; for the assumption that the site was completely developed with the upstream areas in a natural state intercepted by a channel; and finally for the assumption that the entire basin was improved.

The stage discharge velocity curves were used to determine the lag time in combining the several sub-basin water supply curves to determine the predicted run-off peaks and their related times. For the purpose of comparison, these are shown on Figure 1.

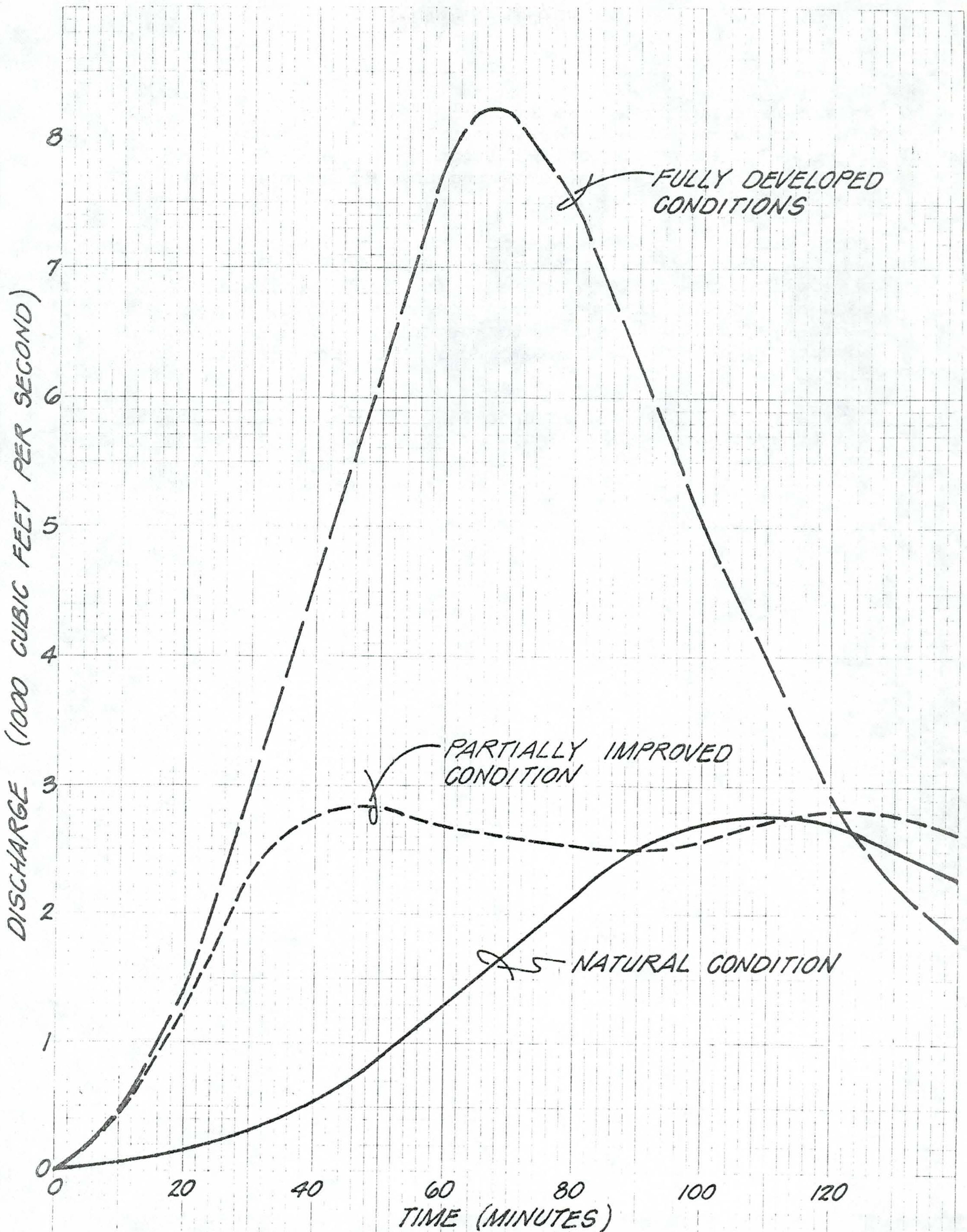
The predicted runoff for the 100 year storm in the natural state was 2800 cubic feet per second with the peak occurring one hour and 50 minutes after the start of the storm. When only the IBM site was assumed to be improved the water supply curve estimated two peaks of 2800 cubic feet per second with the first peak at 50 minutes and the second at 2 hours. For the complete developed basin the prediction was 8400 cubic feet per second peak flow occurring one hour and five minutes after the start of the storm.

The site was then investigated for additional opportunities of on-site detention. Rita Road was to be relocated and constructed approximately 3000 feet down stream from the interceptor channel, thus separating 420 acres from the actual plant site. This area consisted of two minor basins of 190 and 230 acres. The natural channels were broad and shallow. If the drainage structures were designed to pass the full 100 year flows, the discharges would be 190 and 230 cubic feet respectively with outlet velocities of 11 feet per second, would require multiple pipes and would have water depths of 7 to 8 feet on the inlets. In addition the full discharge would create problems with the drainage ditch systems within the site proper.

Therefore, it was decided to perform an inflow-outflow analysis of each inlet condition. This was done by the indicated storage process. It was found that approximately one acre of land in natural state would be flooded, that the depth of water would be approximately four feet, that the discharge of the pipe would be approximately 37 cubic feet per second at a velocity of 5 feet per second and that the cost of each installation would be reduced by $15,000. The dollar trade-off was about equal to the value of the land used for detention. The down stream benefit accrued to each of some thirty crossings of the ditches where the retarded flow did not have to be accommodated in the channels. The disadvantage was in the length of time required to fully discharge the storm water from the site. Our estimate was 8 hours for total runoff compared to approximately two hours with no on-site detention. This technique was wherever possible used throughout the site.

Clearly, the additional design effort on this project more than offset the client's cost of construction and utilization of the plant site. In addition, the bad effect on down stream property has been minimized.

Returning to Figure 1, it is easily seen that although this



COMPOSITE HYDROGRAGH FOR
JULIAN WASH, 1/4 MILE EAST OF KOLB ROAD

FIGURE 1

development by itself has minimal effect on the peak discharging into upper Julian Wash, as future development on the upper watershed occurs the peak will get higher and nigher until finally at some time the existing downstream channel will be overwhelmed.

Clearly something should be done to prevent such an occurrence on this or on any other watershed. As designers we should carefully explain to our clients the full implications, both good and bad, of on-site detention. As responsible professionals we must automatically look for detention possibilities. As educators, we must train tomorrow's engineers in these techniques.

Finally, each of us should urge Pima County to adopt appropriate criteria for industrial and commercial developments which mandate on-site detention and limit discharges after development to what they would have been before any development took place.

Obviously, we have no other choice. The alternative is a "planned" flood.

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THE SMALL WATERSHED PROGRAM (PL-566)

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THE SMALL WATERSHED PROGRAM, PL-566

by

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Since 1954, when the Watershed Protection and Flood Prevention Act (Public Law 566) was enacted, many rural and urban communities have shown that they can halt unchecked soil erosion and excessive water runoff, reduce destructive floods, improve drainage conditions on land in agricultural production, provide for more efficient irrigation, supply water for growing municipal needs, attract new industries, enhance fish and wildlife resources and provide developments for recreation.

Small watershed projects have come to mean protecting, managing, improving, and developing the water and related land resources of a watershed up to 250,000 acres in size through a project-type undertaking.

A project is planned and carried out jointly by local, state and federal agencies with the full understanding and support of a large majority of the landowners and citizens of the community.

It can include many purposes: Flood prevention; agricultural water management; ground-water recharge; water-quality management; control of agriculture-related pollution; municipal and industrial water supply, both for present and future use; recreation and fish and wildlife development.

It is based on (1) local initiative and responsibility, (2) federal technical, cost-sharing, and credit assistance, and (3) state review and approval of local proposals and opportunity for state financial and other assistance.

It is a land treatment or a combination of land treatment, nonstructural, and structural (dams, levees, grade-stabilization structures, etc.) measures to enhance environmental quality, maintain the resource base, and improve economic and social conditions in watershed areas.

It bridges the resource-development gap between the soil and water conservation work of individual landowners and large federal and state public-works projects for water resource

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development in major river valleys.

The Soil Conservation Service (SCS) of the U.S. Department of Agriculture has primary responsibility for carrying out the program with assistance from other federal, state, and local agencies.

GETTING STARTED

An application for federal help in developing and carrying out a watershed project can be submitted by any local organization having authority for such activities under state law. The law requires that the project be limited to a watershed area no larger than 250,000 acres.

State agencies and qualified local organizations can sponsor or cosponsor an application. They include soil and water conservation districts; municipalities, counties, watershed, flood-control, conservancy, drainage, irrigation, or other special-purpose districts, and irrigation and reservoir companies, water users' associations, or similar organizations not operated for profit. Other organizations can endorse project applications.

When SCS is able to furnish planning assistance, the state agency is requested to consider all unserviced applications in the state and to recommend those next in line for help. Each state agency has established criteria that must be met before an application is awarded a high priority rating. If an application meets the following conditions, it will satisfy the criteria of most states:

1. Sponsoring local organization have the legal authority and will use it to meet the commitments for carrying out and maintaining the project.

2. Help is desired to achieve full multiple-purpose development of the water and related land resources of the watershed.

3. Measurable progress has been or is being made in applying soil and water conservation measures on individual farms and ranches.

4. The proposed project will benefit a substantial number of people through improved resource use that will permit higher standards of living and a wider sharing of life's amenities in watershed areas and help bring about the redistribution of the nation's growing population.

5. Interest in and understanding and support of the project is prevalent throughout the watershed.

MAKING THE WATERSHED PLAN

An SCS watershed planning staff composed of engineers, hydrologists, geologists, economists, and other needed specialists is assigned to work with the local SCS representative to make environmental assessments and help the sponsoring organization develop a watershed plan. The Forest Service also assists. The Farmers Home Administration (FmHA) works with the local organization when it wishes to obtain a watershed loan. The Fish and Wildlife Service and the State Game and Fish Agency make studies relating to the impact of the proposed project on fish and wildlife resources. The Bureau of Outdoor Recreation may help in connection with recreation developments. Other federal and state agencies are notified by SCS of initiation of the studies and are invited to participate.

Findings are reviewed with the local organizations at progressive stages of planning. Then a draft plan is prepared that sets forth (1) the proposed land and water resource protection and development measures, (2) the cost of the proposed measures and cost-sharing arrangements, (3) the benefits, (4) the methods and schedule for installing and maintaining the measures, (5) a description of alternatives considered and why they were discarded, (6) the environmental impact of the project, (7) the provisions of land acquisition and displacement of any person, business or farm operation, and (8) comments from the designed clearinghouse.

WHAT THE PLAN CAN INCLUDE

Land Treatment

Land treatment measures are basic to any watershed project. Land treatment is coequal with nonstructural and structural measures. Watershed plans which contain only land treatment are acceptable. Structural measures cannot be fully effective unless these soil and water conservation measures are applied on individual farms and ranches, other rural land, the public lands, and critically eroding areas of the watershed.

For this reason, either the law or Department of Agriculture policy requires as a condition to providing assistance for structural measures that:

1. Owners of at least one-half of the land above floodwater retarding dams and retention reservoirs must be under basic conservation plans.

2. Not less than 50 percent of the area upstream from a floodwater retarding structure must be adequately protected prior to construction of the dam.

3. Installation is assured of on-farm practices needed to realize benefits from any structural measure for drainage or irrigation.

Flood Prevention

Flood prevention measures in watershed projects include land-stabilization measures to prevent the destruction of land and thereby to reduce the movement of damaging amounts of sediment to stream channels and lower land. Large gullies and severely eroding land may be brought under control with vegetation or structures. Road banks and fills may be protected. Waterways crossing two or more farms may be improved by shaping and planting. Trees and other vegetation needed to keep the soil tied down may be protected from fire.

Flood prevention also includes both nonstructural and structural measures for flood-plain management to reduce flood damage to groups of landowners, communities, and the general public.

Damages from surplus water can be reduced by dams to retard floodwater; channel improvement levees and dikes; desilting basins; floodways; floodwater diversions; and special water-holding or water-diverting terraces and dikes. Nonstructural measures include zoning or other regulatory actions, land acquisition, relocation, floodproofing, flood warning systems, etc.

AGRICULTURAL WATER MANAGEMENT

Agricultural water management measures that can be included in watershed projects are those for (1) irrigation, (2) drainage, and (3) supply and distribution of water for domestic and other agricultural uses.

The irrigation measures may include water-supply reservoirs, diversion dams, pumping plants, sluiceways, canal headworks, canal laterals, and main distribution pipelines to carry water to the farm boundary. They also may include lining canals and sealing storage reservoirs, and measures needed to conserve and use water supplies efficiently and to convey water with the least practical loss.

Drainage measures include all parts of a group drainage system, such as open ditch or tile, drops, checks, flumes, control gates, manholes, and pumping plants.

Help may be given to provide a more uniform supply and distribution of water for agricultural use to two or more landowners if the measures are part of the watershed plan. These measures will be designed to make annual streamflow more stable, to increase the recharge of ground-water reservoirs, and to distribute on a community-wide basis water for livestock and other agricultural purposes.

Public Recreation Development

Developments that create or improve facilities for the enjoyment of outdoor recreation based on the use of or proximity to water in reservoirs, lakes, natural streams, or along shorelines may be included in watershed projects. Such recreation uses include fishing, hunting, swimming, boating, water skiing, picnicking, camping, and related activities.

A watershed recreation development can include (1) a single reservoir, a single lake, a single reach of shoreline, or a well-defined reach of a single perennial stream (but not the entire stream system of the watershed); (2) land required for public access and public use; and (3) recreation facilities such as roads and trails, parking lots, public water supply, sanitary facilities, power facilities, beach development, boat docks and ramps, plantings and other shoreline or area improvments, and picnic tables and fireplaces.

Public Fish and Wildlife Development

Water-based developments to improve the fish and wildlife habitat can also be included in watershed projects. These may involve added storage capacity in reservoirs to regulate streamflow, modification of reservoir structures for releasing cold water, channel improvement, and marshes and pits to provide breeding and nesting areas for migratory waterfowl and aquatic mammals.

Municipal or Industrial Water Supply

To improve economic and social conditions in watershed areas, developments for supplying water for municipal or industrial use should be included wherever feasible. Storage capacity in reservoirs may be planned for present or future use. Pipelines conveying water from a reservoir or stream to a filter plant or distribution system may be included.

Carrying out the Project

There's a job for everyone in carrying out a watershed project--the sponsoring local organizations; individual landowners; citizens of the community; local, state and federal agencies; and community public and private organizations and groups.

FINANCING THE PROJECT

PL-566 PROGRAM

	COST SHARING (%)						
	PL-566			OTHER			
PURPOSE	CONST.	ENG. SERVICES	LAND RIGHTS	CONST.	ENG. SERVICES	LAND RIGHTS	WATER RIGHTS
WATERSHED PROTECTION	YES	YES		YES	YES	100	100
FLOOD PREVENTION							
NONSTRUCTURAL FLOOD PLAIN							
ACQUISITION	N/A	80 1/	80	N/A	20	20	N/A
WARNING SYSTEM	80	80 1/	80	20	20	20	N/A
PROOFING	80	80 1/	80	20	20	20	N/A
STRUCTURAL	100	100	-	-	-	100	100
AGR. WATER MANAGEMENT							
IRRIGATION	50	100	-	50	-	100	100
DRAINAGE	50	100	-	50	-	100	100
RECREATION, FISH AND WILDLIFE							
RESERVOIR	50	100	50	50	-	50	100
BASIC FACILITIES	50	50	50	50	50	50	-
FISH AND WILDLIFE ENHANCEMENT 2/	75	50	50	25	50	50	100
MUNICIPAL AND INDUSTRIAL WATER 2/	50	-	-	50	100	100	100
WATER QUALITY AND OTHER WATER MANAGEMENT 2/							
AGRICULTURAL	50	100	-	50	-	100	100
NONAGRICULTURAL	-	-	-	100	100	100	100

1/ This cost-share rate is used if the engineering is performed by an A&E contract. If SCS performs the engineering, the rate will be 100%, but the total cost-share rate will not exceed 80%.

2/ These features have been authorized by various acts and amendments, but have not been specifically approved for use by a policy statement of the Secretary of Agriculture.

Responsibilities of the Local Organizations

The major responsibilities are to:

1. Acquire land, easements, and right-of-way needed for structures or other improvements on private land. The local organization may acquire them by purcahse or gift. Included are removal, relocation, or replacement of bridges, roads, railroads, pipelines, buildings, fences, or wells, whether done by the local organization or by the owners.

2. Let contracts for construction or request the federal agency to administer contracts. The local organization and the SCS enter into an agreement covering each contract for construction (or for land rights for recreation or fish and wildlife development). This agreement is the basis for obligating federal funds.

3. Obtain agreements from land owners and operators to plan and apply soil and water conservation measures and provide assurance of the application of a high percentage of these land-treatment measures.

4. Comply with state laws governing watershed improvements, water rights, or specifications for structures.

5. Operation and maintenance of structural measures once they are installed to insure the proper function and life of the project.

Responsibilities of the individual landowners; citizens of the community; local, state and federal agencies; and community public and private organizations and groups.

The major responsibilities are to:

1. Assist local sponsors with acquisition of land easements, and right-of-way.

2. Provide input at public meetings to assure that all alternatives are considered and that the selected plan has the support of most individuals and groups.

3. Become knowledgeable on project features and impacts so that purposes of the project can be achieved and enjoyed.

TECHNICAL ASSISTANCE FOR LAND TREATMENT

The Soil Conservation Service gives technical assistance to landowners who plan and apply soil and water conservation measures on their farms and ranches or other rural land. Landowners receive this assistance through Natural Resource Conservation Districts. Additional technical assistance may be given from funds appropriated under Public Law 566 only as they are required to complete land treatment measures within the agreed upon period for project installation.

SCS technical assistance includes:

- Making a soil survey from which the land can be classified according to its capability for use and needs for treatment.

- Helping landowners to plan and apply soil and water conservation practices such as:

  - Terraces, dams, diversions, waterways, contour farming, stripcropping, and other vegetation needed to protect the soil from wind and water erosion and to restore, improve, and maintain soil productivity.

  - Seeding, sodding, or other vegetative land stabilization measures on critically eroding areas.

  - Irrigation, chiseling, subsoiling and pitting, contour furrowing, water spreading, drainage, wells, ponds, and other improvements to provide and conserve water for crops, livestock, fish and wildlife, and forage production.

  - Stocking rates, reseeding, erosion control, and other practices necessary to restore and improve range and permanent pastures not in national forests or managed in conjunction with national forests.

  - Woodland conservation practices that can be applied with general technical help.

SCS HELP WITH STRUCTURAL AND NON-STRUCTURAL ALTERNATIVES

The local organization has the option of using nonfederal, professional engineers or Soil Conservation Service engineers.

If the local organization requests, SCS can provide the engineering services for structural measures. These services include surveys, site investigations, layout, design, preparation of specifications, contract administration and supervision of construction of structures.

If the local organization uses nonfederal engineers satisfactory to SCS, it may be reimbursed by SCS for the cost allocated to flood prevention, agricultural water management, and recreation or fish and wildlife development. The local organization must provide or employ professional engineers for municipal or industrial water-supply development.

The SCS also provides analysis and investigations in the areas of biology, economics, geology, soils, hydrology, archeology, and landscaping. These disciplines make investigations to assure that structures are safe, that impacts on fish and wildlife habitat and archeology are adequately accounted for and actions taken to avoid or lessen impacts. Economists analyze projects to determine benefits to the region and nation that result from project actions. Landscape architects are hired to develop plans that can be used to make structural measures blend into the natural landscape. Input by these disciplines results in a project that is designed to address the real problems of the area and ensure that resulting impacts from project actions are known by all interested groups and individuals.

PUBLIC LAW 566 WATERSHED PROJECTS IN ARIZONA

COMPLETED

Florence Area	(IV)	Vanar Wash	(II)
Frye Creek-Stockton Wash	(IV)	Virgin Valley (AZ-NE)	(III)
Magma	(IV)	White Tanks (Pilot)	(III)

APPROVED FOR OPERATION

Apache Junction-Gilbert	(I) (IV)	Harquahala Valley	(III)
Buckeye*	(III)	Perilla Mountain	(II)
Buckhorn-Mesa	(I) (IV)	Wickenburg*	(III)
Fredonia*	(III)	Williams-Chandler	(I) (IV)
Guadalupe*	(I)		

AUTHORIZED FOR PLANNING ASSISTANCE

Cottonwood Wash	(IV)	Gila Floodway - Lower Queen Creek	(IV)
Dos Cabezas Peak	(II)	St. David	(II)
Eagle Tail Mountain	(III)		

APPLICATIONS WITHDRAWN

Black Bill-Doney Park	(III)	Wet Beaver Creek	(III)
Dry Beaver Creek	(III)	White Tail & Woods Canyon	(II)
Pinal Creek	(IV)		

APPLICATIONS ACCEPTED

Airport Wash	(II)	San Jose Canal	(IV)
Black Diamond	(II)	Tonopah	(III)
Granite Creek	(III)	Virden-Duncan Valley (AZ-NM)	(IV)
Harshaw Creek	(II)	Wenden-Salome	(III)
Picacho No. 1	(II)	West Branch-Santa Cruz	(II)

*Structural measures have been installed.

( ) Congressional District

RIVER BASIN AND
WATERSHED PROGRESS

CONSTRUCTION COMPLETED

1 Magma
3 Frye Creek-Stocton Wash
4 Florence Area
13 Vanar Wash
17 Buckeye
23 Fredonia
24 Guadalupe
27 Wickenburg
A Virgin Valley (Az.-Nev.)
P White Tanks (Pilot Project)

AUTHORIZED FOR CONSTRUCTION

10 Perilla Mountain
14 Buckhorn-Mesa (RWCD) 1/
18 Harquahala Valley

AUTHORIZED: PLAN BEING SUPPLEMENTED OR ENVIRONMENTAL IMPACT STATEMENT WRITTEN

15 Apache Junction-Gilbert (RWCD) 1/
16 Williams-Chandler (RWCD) 1/

AUTHORIZED FOR PLANNING

11 Dos Cabezas Peak
12 St. David
19 Eagle Tail
25 Cottonwood Wash
30 Gila Floodway-Lower Queen Creek

APPLICATION ACCEPTED

6 West Branch-Santa Cruz
7 Harshaw Creek
20 Tonopah
22 San Jose Canal
26 Black Diamond
28 Airport Wash
29 Granite Creek
31 Wenden-Salome
32 Picacho No. 1
B Virden-Duncan Valley (Az.-N.M.)

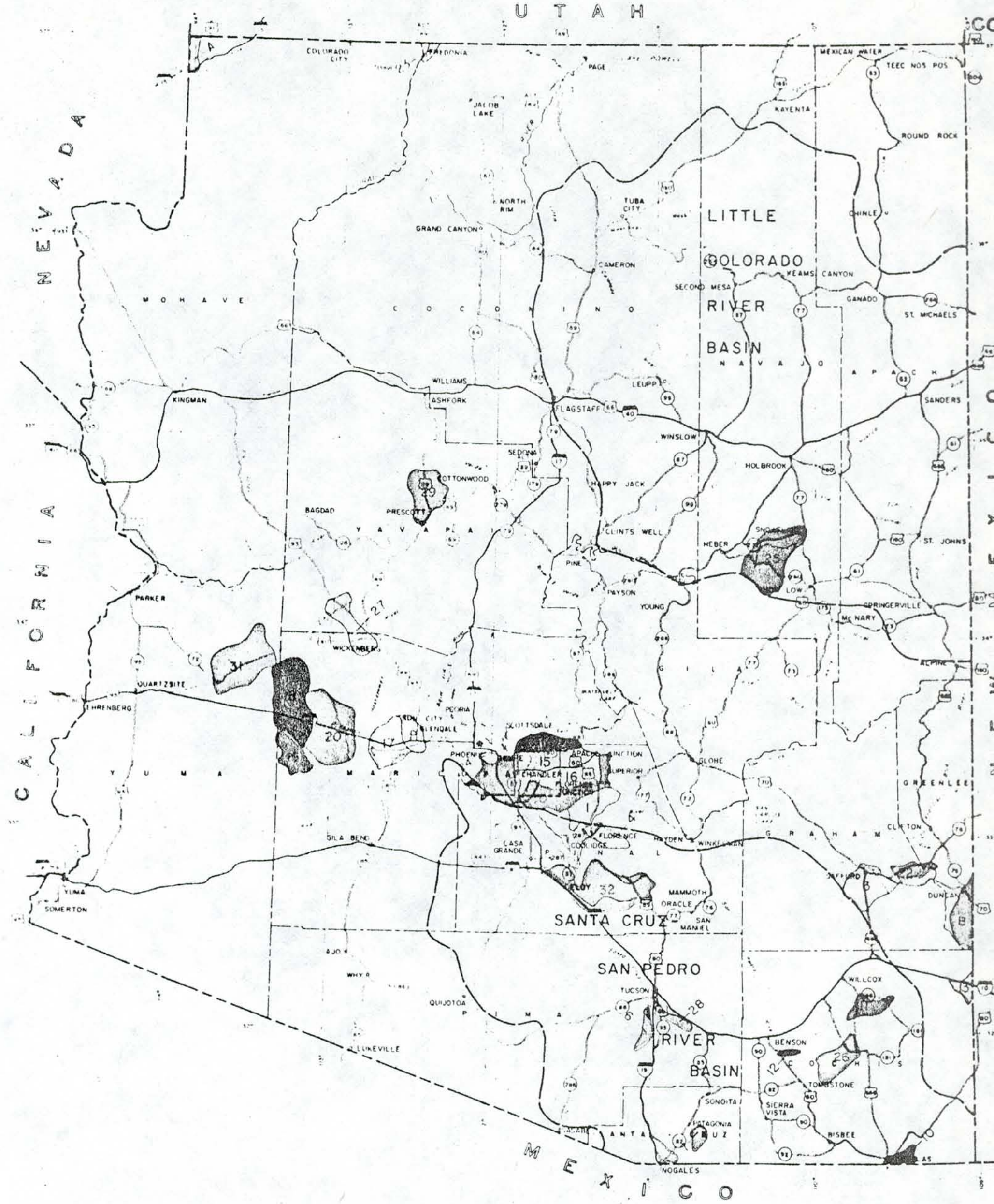
RIVER BASIN BOUNDARY

1/ Includes portion of Roosevelt Water Conservation District Floodway (RWCD)

STATUS OF RIVER BASIN SURVEYS

Little Colorado River Basin - Type IV Survey in Progress

Santa Cruz-San Pedro River Basin - Type IV Survey Completed



RIVER BASIN AND
WATERSHED PROGRESS
ARIZONA

JANUARY 1978

10 0 10 20 30 40 50 60 MILES

SCALE 1 : 3,400,000

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:1,000,000 Nat. Atlas.
Thematic detail compiled by state staff.
U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

M7-OL-22939-1

THE GOLDER DAM EXPERIENCE

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THE GOLDER DAM EXPERIENCE

Benson G. Scott[1]

INTRODUCTION

1978 was a wet year in Arizona. It started out with widespread flooding in late February and early March that was particularly severe in the Phoenix Metropolitan area as the Salt River reached a flood stage not experienced since before the Project was built. Incredibly in December of the same year, the State was again deluged with rain causing floods surpassing the records of just nine months earlier.

The Arizona Water Commission's Division of Dam Safety, responsible for the safety of some 170 nonfederal dams in the State, during a flood emergency would routinely prepare to respond to crises that usually would arise on some dam during periods of heavy runoff. On December 18, 1978, the staff had already been involved in emergency actions affecting the residents of Taylor and Snowflake from the heavily spilling Lone Pine Dam and the Community of Williams from the overtaxed Perrin Dam. Based upon reports of flooding in the Tucson area, the Commission's Flood Control and Dam Safety staffs were able on December 19th to obtain a National Guard helicopter for an aerial inspection of the flood damaged areas along Rillito Creek and also to check on operating conditions at Golder Dam on the Canada del Oro Wash, 25 miles north of Tucson.

The Commission had good reason to be concerned about the Golder Dam. Since its construction in 1964 by a private corporation, it was incapable of storing any significant water without severe and uncontrollable leakage. In a continuing battle with the owner, the Commission in 1973 had finally obtained a court order to prevent any permanent storage because such storage endangered the safety of the dam. During 1978 because of the owner's delay in effecting any kind of permanent repair, the State was preparing to bring suit to require him to either repair or remove the dam.

The dam reportedly did have some floodwater behind it on December 18th. Since 1971, floodwaters had been temporarily stored in the reservoir on a number of occasions to significant but not alarming levels.

The aerial reconnaissance on December 19th revealed a moderately full reservoir. Conditions were verified as to actual level by landing and measuring the high waterline. It was high enough, and rising, to warrant a field inspection within the

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[1]Chief, Division of Safety of Dams, Arizona Water Commission, Phoenix, Arizona. Presented at the Arizona Section, American Water Resources Association Symposium of "Flood Monitoring and Management" October 26, 1979 at Tucson, AZ.

next few days by engineers from the Commission. Fortunately conditions at this level, some 40 feet below spillway crest,were consistent with previous observations under similar storage conditions. At that time, inflow had decreased and the reservoir had started to drain,alleviating further concern.

The weather pattern over Arizona during January, 1979, continued to bring moisture into the State, with rain in the lower elevations and snow now accumulating at the high elevations, including the watershed for Golder Dam in the Catalina Mountains north of Tucson. By late January, the inflow to the Golder Reservoir was increased by more rainfall and runoff from snowmelt at low elevations. An inspection on January 28th confirmed that the reservoir was at the highest level observed by the Commission since 1971, elevation 3,362 feet. By January 31, 1979, a warm tropical-type storm, causing heavy rainfall in the Los Angeles area, was forecast to move into Southern Arizona.

Storage in the reservoir was at a high level and seepage below the dam had developed over an extensive area. The outlet was under full discharge conditions. Snow on the higher levels of the watershed was over three feet deep with a 25 percent water content, and the forecast was to expect a tropical-type storm to move into the area from its present location in Southern California. The watershed was already saturated and runoff would be heavy.

Thus the stage was set for the drama played out over the next several weeks, affecting many people in Pima County. The Commission was concerned about the threat for a major increase in the storage level and its effect upon the safety of the dam. The weaknesses in the dam were a matter of record from numerous experts and the engineers of the Commission. As storage level rose, seepage increased raising uplift pressures and creating greater potential for piping. The weather front that was forecast would produce more rain, more runoff, and raise the lake level, already higher than it had been in almost ten years. The outlet was discharging at its maximum rate and there was no other way to remove water from the reservoir. It was this very situation, a potential for full reservoir storage with its attendant risks, that had formed the basis for the Commission's current lawsuit to force repair or removal of the dam. Relying upon the probability of maintaining an empty reservoir did not provide sufficient margin of safety for all the people and property below the dam.

On January 31 because of concern for the safety of Golder Dam, the Commission staff implemented a continuous monitoring of the dam to observe rate of reservoir rise and rate of seepage buildup. They notified the State Division of Emergency Services and alerted the Pima County emergency organization with the warning that if conditions at the dam deteriorated to where the integrity of the dam was in question, an evacuation of people downstream would be necessary.

EMERGENCY ACTIONS

Although a dam such as Golder Dam may have a severe safety problem, the people who will probably be most affected will not be convinced that there is a problem until it is in the critical stages. By that time, it could well be too late for any emergency action except running for high ground. If the crisis passes without incident, people soon forget.

The State, through legislation enacted in 1929, has the responsibility to see that dam owners design, build, operate, and maintain their dams in a manner that will not jeopardize life or property. The State Water Engineer is specifically charged with this regulatory control and has ample statutory authority to see that the dams are safe. He does not have a source of funds with which to carry out emergency remedial action if the owner cannot or will not take such action. Without the money to effectuate emergency action as in the case of Golder Dam, the State Engineer has to rely upon help from other sources. This was the situation facing the State Engineer in January 1979.[2]

A potential source of help on dams during emergencies comes from the Army's Corps of Engineers. They can act in flood emergencies with immediate construction help through their authority under Public Law 99, but the threat of flooding has to be imminent. Commission Dam Safety engineers and engineers from the Corps conferred after their respective inspections of Golder Dam and agreed that this was not the case.

I believe many of you know the rest of the story about the emergency. Everyone and the dam survived. Fortunately, rain and warmer temperatures did not combine to produce more flooding and the reservoir eventually drained. The Commission monitored dam performance and, with Pima County, learned something about emergency planning. The dam is still there today as it was then and, unfortunately, in the same unsatisfactory condition.

DOWNSTREAM HAZARD POTENTIAL

This incident, and the longtime problems with Golder Dam, focused public attention on two aspects of dams that usually receive only passing attention:

1. The construction of a dam permanently alters the natural stream flow conditions and because it does offer protection from at least modest flooding, it fosters urban development.

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[2] House Bill 2457 passed by the 1979 Legislature, conferred authority on the State Engineer to perfect and foreclose a lien on a dam owner's property before taking remedial action. This now provides a means of funding for making required repairs.

2. The potential damage from dam failure is so severe that the dam must be conservatively designed, particularly its ability to safely pass severe floods.

I would like to discuss both of these points as they are illustrated by Golder Dam, both in the emergency episode we have just experienced and for future flood planning.

Golder Dam was conceived as the focal point for a major urban development. The concept was sound but unfortunately for all concerned, the dam was not. With a full reservoir, the lake would have had a surface area of 260 acres providing all the water-related recreational activities that are in such short supply in Arizona and particularly in this area. The lake would ideally have remained full all the time. Floods would have been passed through the uncontrolled spillway in the left abutment of the dam. There was no provision for flood control and downstream areas may have experienced severe flooding on a frequency not a great deal less than without the construction of the dam.

However, due to severe leakage and the regulatory control of the State, the dam remained empty most of the time after 1970. Also from the standpoint of safety, this period, except for 1973 and last year, was a period of modest precipitation. Thus, most of the time there was no significant flow in Canada del Oro below the dam. That which did flow from the Golder Dam watershed was limited to the capacity of the outlet - - a maximum of about 130 cubic feet per second. It stayed within the banks of the modest low flow channel of the Wash.

Benefitting from this incidental flood protection, it was not long before land development took place within the primary floodplain of the Wash. People are basically naive when they choose where to live. We only have to look at those perenially flooded locations around our State and in many other places to realize this. We have estimated that as many as 40 different improvements, primarily homes, have been located within a 3-mile stretch of the Wash below the dam. In 1964 when the dam was completed, there were no residences in this area.

During the emergency alert that was in effect last February, the people living in this area were upset, not so much that they could be severely flooded but rather because they were inconvenienced by the modest flow in the Canada del Oro Wash coming through the outlet pipe at Golder Dam. They still had no concept of where they lived relative to an upstream dam and its potential for either uncontrolled spill or a failure. These people have chosen to live in a river bottom. There was apparently no governmental control over this type of subdivision. Flood inundation studies by the federal government show that even the 100-year flood will completely cover this portion of the valley floor to depths of up to five feet.

The State is engaged in a major effort right now either to remove the dam or to have it restored to a safe, operable condition. In either case, there will be flooding on the Canada del Oro. As I mentioned earlier, downstream flooding would have occurred had the project been able to operate as originally conceived. Even if it were to be rebuilt and operated as a flood control project, a flood more serious than the 100-year storm would still result in uncontrolled spillway discharge and flooding in low-lying areas. If it were possible for flood control to be incorporated in this project, there has been no indication yet that a responsible government agency is willing or able to finance the necessary improvements and then operate it within the rigid regimen necessary to assure downstream protection.

A parallel to the Golder Dam problem might be drawn on a much grander scale with the Salt River Project and urban development in the Phoenix Metropolitan area. The Project, built under Reclamation Law, has one basic function, the conservation of water for irrigation. There was no flood control included and yet the Project over a 25-year span from 1941 to 1966 prevented all flow in the Salt River. Up until 1966 a large part of the population in Phoenix probably wondered why they had to have any bridges across the Salt River. Yet within a period of only six years, from 1973 to 1979, there have been three major floods. With the memory of these floods still fresh in their minds, people now clamor for flood protection and more bridges. They expect an irrigation project to offer flood control by gambling with the conservation of water. They don't realize that the so called "flood protection" was there only because there just wasn't much runoff then. The development of Phoenix as we see it today along the Salt River has been in part influenced by the measure of flood control offered by the Project - - primarily by just being there as is Golder Dam.

NATIONAL DAM SAFETY

People react to crisis and they make their feelings known through their Legislators or Congressmen. There were two major dam failures in the United States in 1972 causing heavy loss of life. Reacting to the resulting heavy public pressure, Congress, in 1972, enacted Public Law 92-367 which established a National Dam Safety Program. Unfortunately, it took two more dam failures before there was any money provided with which to inspect an estimated 9,000 potentially high hazard dams throughout the United States. In the interim period, the Corps of Engineers as the managers of the program had been able to develop a set of guidelines to be used in evaluating the safety of these dams. Extremely important among these guidelines were those for spillways.

The Corps developed a sliding scale for recommended minimum spillway design floods, ranging from the 100-year frequency event to the flood resulting from the probable maximum precipitation. The severity of the flood varied, dependent upon the dam height, reservoir storage and the potential downstream hazard.

Directed by the President in December, 1977 and with funds from Congress for the actual inspection program, the Corps moved rapidly into the investigation of high hazard dams in a cooperative program with the states. The guidelines were implemented and the first few reports were made public. Many dams were declared unsafe because they would not meet the minimum "guidelines" established by the Corps.

GUIDELINES

The Commission utilizing a similar concept in their evaluation of spillways has developed their own guidelines but still reserves the right to apply experience and judgment. Probable maximum precipitation, as established by the National Weather Service, is the generally accepted base from whence to derive the spillway design floods for high hazard dams. However, within the rather inexact science of hydrology, it cannot be said with absolute certainty that the answer derived by one method is the only correct solution and all others are wrong. Obviously the spillway designed to pass the greatest flood will give the dam the greater margin of safety but there does have to be a reasonable limit.

The guidelines were established to provide a means of evaluating spillway capacities. They were not meant to become inflexible standards as some engineers would want us to do. The federal dam building agencies have collectively contributed a great deal to the art and science of dams but have likewise developed standards which tend to become the "law". We have never advocated strict adherance to "guidelines" nor have we developed technical codes of standard requirements for design, construction or surveillance. Such codes cannot be applied uniformly to the widely varying conditions encountered at different damsites. Consequently, a large element of engineering judgment enters into the evaluation of required spillway capacities.

CASE HISTORIES

There are two dams in the southern part of the State that are scheduled for major modifications. The first is Golder Dam which we have been discussing. It is structurally deficient and is also deficient in spillway capacity. Its spillway inadequacy is typical of the problem faced by many dams today. It was designed in 1960-61 by an engineering firm applying principles and techniques that were recognized at the time as "state of the art" for Arizona. The design flood was based upon precipitation of five inches for six hours. In 1961, there were no habitations in the Canada del Oro Wash. Anyone that had lived around there was not foolish enough to live in a wash and the design report described the area downstream as uninhabited and the potential hazard was modest. Ten years later, when the Commission first looked at the dam, there were already people beginning to build homes in the wash, or further downstream, adjacent to the wash.

It appeared that the spillway was undersized in view of the increasing development occurring downstream. The Commission in a 1972 report recommended that the spillway be reanalyzed. They completed their own hydrologic study when the owner refused to do his own. The study, based upon the existing and future hazard potential for this dam, utilized the PMF concept. The spillway was significantly undersized and increased capacity would have to be included in any proposal to restore the dam to a safe operational structure.

Located northeast of Nogales on Sonoita Creek, Lake Patagonia, the second dam, is a 7,500 acre-foot recreational facility operated now by the Arizona State Parks Board. The project was conceived and built as a private lake in 1968. As with Golder Dam, at that time there was no development on the eight miles of Sonoita Creek to its confluence with the Santa Cruz River. The hazard potential at the time was low although, apparently, there had been some planning for the development, which we now see at the mouth of the Creek.

The Commission in 1974 was formally requested to evaluate the "safety" of Lake Patagonia Dam because the spillway was inadequate. By this time a number of independent studies all pointed to the need for a larger spillway and the Commission study confirmed this inadequacy. In 1976 the State Parks Board, the new owners, at Commission request completed their own spillway analysis based upon the probable maximum precipitation concept and it was accepted by the Commission. The new spillway design flood was three to four times the original design but was still not equal to the PMF derived by the Corps of Engineers. The Commission considered the new design adequate for present and future conditions and the owner is now preparing to make the modifications necessary to meet the new design.

The new designs for both Golder Dam and Lake Patagonia Dam will make the dams "safer" because the spillways can pass extremely severe floods without danger of overtopping the dam. However, the people downstream will not, in all probability, ever feel the effect of this added safety. They will not receive increased flood control benefits. In fact, at Lake Patagonia Dam for comparable floods, the spillway discharge will even be somewhat greater than under existing conditions. It will have absolutely no flood control benefit nor is there an obligation on the part of the owner or the State to provide such protection.

DAM BREACH

At both of these dams, the area downstream is going to experience flooding during major storms, attenuated but little from the pre-dam or natural conditions. There will not, though, be the fear of catastrophic failure because of spillway inadequacy. Using a technique developed by the National Weather Service, some indication of the effect of a sudden dam failure can be computed under a range of simulated conditions. Pima County had such a study made for the Golder Dam and the Canada del Oro Wash last March. The State Parks requested a similar study for Lake Patagonia Dam and Sonoita Creek.

In both cases it was quite clear that a dam failure could not be tolerated. The surge from a dam breach of a moderately high dam (Golder Dam, 125 feet, and Lake Patagonia Dam, 95 feet) creates such depth and velocity of flow that there is little attenuation even in the relatively broad floodplains existing at each site. Severe spillway design flows, that many will ridicule as being in the "never, never land" are still greatly exceeded by a dam failure flood for even modest sized dams.

OPERATIONS

For both Golder Dam and Lake Patagonia Dam, the people living downstream have to realize that the waterway will continue to experience floods. The small high frequency floods will be negligible because there is some small amount of incidental flood control through surcharge storage. A severe storm will result in runoff and flood discharge through the spillway. Under our present floodplain zoning laws, there is no protection beyond the 100-year storm for those people living downstream of a reservoir and adjacent to or in the floodplain.

The Salt River Project will experience the same type of problems but because of its size, with six storage dams, it does offer some flexibility in operation. Once the reservoirs are all full, even on this system, they will have to spill all new floodwater entering the system. We found that out the the last two winters. A single reservoir operated for conservation, or recreation, will spill water each time there is a modest flood.

Both the designers and regulators of dams, as well as community planners, need to recognize that spillways for dams in proximity to urban areas may have to operate. In cases where the dams were in place before any significant urban development had occurred, then a spillway flood easement should be maintained. There have been some instances where such spillways are aimed at unsuspecting and existing improvements. The theory is that such spillway operation would be infrequent but is it right to put people or property in the path of a spillway without acquiring the property?

CONCLUSION

I have been discussing a number of areas involving the interrelationship of dams and flood control. As urban development encroaches upon natural waterways, the means to protect the interests of both the upstream dam owners and the downstream urban interests become more complex and expensive. In the case of Golder Dam, the urban developers along the Canada del Oro look upon the dam as a threat to their endeavors because they receive no benefit even if the dam were repaired. They would prefer to see the dam removed. Yet based upon the engineer's original design report, the dam was there first.

The people living a little closer to Golder Dam in Pima County have a real flood problem of which the County is painfully aware. The County has made a study showing that the 50-square mile drainage area for Golder Dam would not contribute significantly to flooding, particularly on the lower reaches of the Canada del Oro Wash. However, we know from our own studies that a 100-year flood passed through the spillway or through the breached dam can discharge as much as 10,000 CFS down the Wash. As a result of last winter's experience, I believe there has been recognition of this flood problem and that positive action is underway.

The dam could be used for flood control if under the operation of a responsible governmental agency. A cost study might well show that modifications to the dam would be less expensive than frequent damages to the river bottom residents. However, the problem won't really go away until people refrain from living in the river bottom. In the meantime, an effective emergency warning system and evacuation plan could result in the saving of lives.

As for Golder Dam, repair or removal will be accomplished, probably not as soon as most people would like, and the selected solution will definitely not please everyone.

TRADITIONAL TECHNOLOGY FOR FLOODPLAIN MANAGEMENT IN SONORA, MEXICO

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TRADITIONAL TECHNOLOGY FOR FLOODPLAIN MANAGEMENT IN SONORA, MEXICO

Until the advent of the windmill and the pump-powered well, most permanent settlements in arid southwestern North America were restricted to the relatively few rivers which flowed or trickled through the region. The economy of these communities rested upon a foundation of floodplain irrigated agriculture supplemented by livestock raising. The two major environmental problems these communities faced were flood and drought. Today inhabitants of the Greater Southwest have freed themselves from these riverine oases by tapping deep reserves of groundwater or by damming and often destroying the rivers themselves. In the narrow and isolated river valleys of eastern Sonora, however, older patterns of land use and water control still persist. For centuries Sonoran farmers have met the challenges of flood and drought with little more than their own labor and the natural, renewable resources of their local environment. Some of their adaptations to these problems are remarkably ingenious in their simplicity. In this paper I will describe their most important system of floodplain management: the propagation of living fencerows of cottonwood and willow trees which not only protect their fields but trap floodwater sediment, thereby extending and fertilizing their fields as well.

The crucial geographical variable in traditional floodplain farming in the Greater Southwest is the proximity of arable land to available water. In areas like the Rio San Miguel watershed, where my colleague Gary Nabhan and I have conducted our research, both land and water are scarce resources. The San Miguel river, a tributary of the Rio Sonora, does not flow continuously except after heavy summer or winter rains. Instead, small springs or _nacimientos_ in the riverbed provide modest but reliable supplies of water which, if the floodplain in the vicinity is wide enough to support floodplain fields, is channeled into earthen canals by brush weirs which have to be replaced after every flood. Much of the San Miguel valley is too narrow to support floodplain agriculture. It therefore becomes essential to protect the relatively few pockets of arable floodplain land from erosion caused by floods.

San Miguel farmers have not constructed permanent dams along their river to control its flooding. They could not afford to do so if they wanted to, and besides, the localized nature of precipitation in the Sonoran Desert, especially during the summer, would reduce the effectiveness of a single major dam in the watershed anyway. Instead, these traditional agriculturalists have learned how to engage in a creative give-and-take with their river, to reduce the destructiveness of truly large floods and to make moderate flooding work for them. They do so by the conscious propagation and manipulation of riverine vegetation which hydrologists in the United States label as phreatophytic and often try to remove.

Between November and February, San Miguel farmers dig trenches approximately 1.5 meters deep in the riverbed parallel to their fields. They then prune the long branches of mature cottonwood and willow trees and plant these cuttings in the trenches. The cuttings root well and grow quickly, and by March they show new growth. Branch fill from riverine shrubs such as seep willow and burrobush is then woven between the cuttings. The construction of new fencerows is only carried out during the winter in order to give the cuttings sufficient time to establish themselves before the onslaught of late summer floods.

These fencerows perform three major functions, all of which are crucial to the stability of the San Miguel agroecosystem. Their most important purpose is to mitigate or prevent the erosion of floodplain fields. The extensive root systems of the cottonwoods and willows anchor the margins of the fields exposed to flooding, while the tree trunks and brush fill moderate the force of the floodwaters which spread across the fields. Downcutting does not seem to be an appreciable environmental danger in the San Miguel drainage since the floodplain of the watershed, at least in its upper portions, appears to rest upon bedrock rather than easily eroded alluvial deposits. Nevertheless, lateral cutting of the flood-swollen river does pose a serious threat to the agricultural economies of the San Miguel communities. Without the living fencerows their land bases would be severely degraded and continually rearranged by the floods which occur at least once a year. With the living fencerows farmers are able to stabilize their fields and exercise some control over the quality and configuration of the floodplains upon which they depend.

Protection against erosion is not the only purpose of the fencerows, however. Farmers along the San Miguel informed us that through the fencerows, they increase as well as maintain their arable land. In their words the woven fences of cottonwood and willow "give soil to the fields" by trapping the rich silt suspended in the floodwaters. As floods surge down the riverbed their waters flow into the space between the newly propagated fencerow, located in the riverbed itself, and the edge of the fields, which are usually protected by another, more mature line of trees. The force of the floodwaters is diminished by the trees and the brush fill between them, and so the floodwater sediment gradually settles out and is deposited behind the cuttings. One farmer described the process by saying that, "The trees and woven branches accept the floodwater and make it tame." Flood by flood enough fine alluvium is accumulated behind the new fencerow that cultivation eventually can be extended out to the fencerow itself. In this fashion, strips of arable land are added piece by piece to floodplain plots.

Remnants of older fencerows usually mark the former edges of fields. There are limits to this process of extension, however, and these limits are recognized by the San Miguel agriculturalists themselves. One farmer showed us portions of his field which had been formed by three successive and parallel fencerows. He told us that he could not extend his field much farther into the riverbed because, "The river needs its channel." The inhabitants of the San Miguel drainage realize that too narrow a riverbed results in more destructive flooding, and so they limit their encroachment upon the river just as they try to limit the river's encroachment upon them.

The third major function of the fencerows is the fertilization of floodplain fields. Most San Miguel agriculturalists cannot afford chemical fertilizers. They therefore rely on rich floodwater sediments, which they call "manure from the river", to replenish soil nutrients. After the force of the floodwaters is dissipated by the living fencerows, the waters spread across the floodplain fields and their nutrient-rich particulate load becomes part of these fields' topsoil. As long as the river renews the fertility of their plots, they are able to cultivate these fields without fallow several times a year. Since most farmers only control from one to ten hectares of arable floodplain land, annual multicropping of both food and forage plants is an economic necessity.

The origins and antiquity of this particular system of floodplain management are unknown. We have located living fencerows in narrow portions of the Sonora river drainage as well as in the San Miguel, and have talked to farmers who claim that their grandfathers were propagating them in the 1890s. The historical geographer Campbell Pennington (1963) notes that the Tarahumara Indians also plant rows of cottonwoods and willows to protect their fields from floods in the upper reaches of the Conchos river in Chihuahua. Unfortunately we have not encountered references to similar systems of floodplain management in the Spanish colonial documents, so we do not know whether living fencerows were an aboriginal practice of North American Indians or a European introduction. They may very well have been a part of the technological repertoire of Indian farmers since pre-Hispanic times.

Regardless of their origin, the fencerows clearly constitute an effective method of floodplain management that does not require large outlays of capital or a sophisticated technology to construct. The potential destructiveness of most floods along the San Miguel are avoided or considerably mitigated by this system. Nevertheless, the fencerows cannot completely contain major floods such as the ones which ravaged watersheds in Sonora and Arizona last winter. Flooding along the Magdalena river drainage to the west of the San Miguel caused an estimated 100 million pesos, or five million dollars, worth of damage, washing out a major bridge along Mexico's Highway 15, destroying crops and farm machinery, devastating approximately 145 hectares of fields, and killing several people (El Imparcial, January 15, 1979). San Miguel farmers claim that the floods of December, 1978, were as destructive as those which occurred in 1940, 1926 and 1914. In several locations below the pueblo of Cucurpe the fencerows had been breached and deep arroyos cut in the fields behind them. Other fields had been damaged by heavy deposition of sand and coarse gravels, or by the removal of fertile topsoils. Corners of some fields had been washed away. The living fencerows clearly are unable to completely tame floodwaters of such magnitude. As the farmers say, "The river is muy hombre. Sometimes it gives, and sometimes it carries away."

The fencerows did manage to avert a major disaster, however. Even though floodwaters covered the entire floodplain, few fields were totally devastated and many plots were not damaged at all. By June most of the fields had been restored and replanted. Earlier in the year a group of men from Cucurpe had journeyed to Hermosillo to petition the state governor for the use of bulldozers to reclaim the floodplain. The bulldozers were promised but never materialized. Instead, the Cucurpe farmers relied on each other rather than bureaucratic intervention to get the job done. Working with shovels, horses and a few local tractors, they removed the sand and gravel, filled in the gullies and dragged away the debris. The floods of 1978 will undoubtedly live in their memories, but thanks to the fencerows, none of the farmers permanently lost their land.

Hydrologists and geomorphologists have recognized the stabilizing effects of riparian vegetation on ephemeral stream channels in arid or semi-arid areas for a long time. During the 1930s, cottonwoods and willows were planted along stretches of the Gila river in the vicinity of Safford and in Canyon de Chelly on the Navajo Reservation by the Soil Conservation Service. Riparian trees and woody shrubs such as saltcedar significantly reduce bank erosion and lateral cutting of the floodplain by reducing the flow velocities of floodwaters along the sides of stream channels. Furthermore, studies in the southwestern United States indicate that woody riparian plants stabilize ephemeral stream channels as well. These plants enable the channel to achieve a state of equilibrium in which neither erosion nor aggradation takes place (Hadley and King 1977).

Removal of this vegetation on the other hand may have unforeseen and disastrous consequences. Cooke and Reeves (1976) argue that the cycle of arroyo-cutting that occurred in southern Arizona and other areas of the Greater Southwest in the late 19th and early 20th centuries was initiated by human impact on the floodplains of the drainages which became incised. One of the triggers of arroyo formation was the destruction of riparian plant communities by cattle, woodcutters and road and canal builders. Once this vegetation was removed, the resistance of valley floors to floods was reduced and more floodplain soil was exposed to the erosive forces of the floodwaters. Both downcutting and lateral cutting of southwestern drainages devastated the floodplain land bases of many agricultural communities including the Hopi village of Old Oraibi and the Hispanic settlements along the Rio Puerco in northwestern New Mexico (Hack 1942; Widdison 1959). Riverine oases and traditional riverine society along the Santa Cruz and San Pedro watersheds were also destroyed.

Riverine oases remain the loci of human settlement along the Rio San Miguel, however. Communities like Cucurpe do not have the resources to expand, but they still survive, providing a decent if modest life for their inhabitants. One of the most important keys to their survival is the system of living fencerows which protect, extend and fertilize their fields. Unlike many of their neighbors to the north, San Miguel farmers do not regard phreatophytes like cottonwoods and willows as pest species to be destroyed. Instead, they consciously and ingeniously continue to propagate them. The living fencerows may transpire precious water and contribute to the periodic diminished flow of riverine springs. Nevertheless, their value far outweighs their liability. They allow the people of the San Miguel to coexist with their river rather than destroying or being destroyed by it.

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CENTRAL ARIZONA WATER CONTROL STUDY

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CENTRAL ARIZONA WATER CONTROL STUDY

Presented at Symposium on Flood Monitoring and Management
Arizona Section, American Water Resources Association
Tucson, Arizona
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BACKGROUND

The Central Arizona Project was authorized by the U.S. Congress in 1968 with Orme Dam as one of its features. This dam would be built at the confluence of the Salt and Verde Rivers (Figure 1) and would provide both regulatory storage and flood control for the Phoenix area. In 1976 the U.S. Bureau of Reclamation published a Draft Environmental Statement for this project. The response caused considerable controversy. Environmental and recreation groups were concerned about the loss of riparian habitat, bald eagle nesting sites, and downstream tubing recreation. The Fort McDowell Indian Reservation voted against the project, which at high water would flood about two thirds of their reservation. An Inter-agency Task Force was established to review all the alternative ways of obtaining regulatory storage and flood control, including Orme Dam. But before the Task Force's recommendation was made, President Carter recommended that Orme Dam be eliminated from the CAP for environmental and social reasons.

Then came the floods of 1978 and 1979. Many people felt that Orme Dam could have prevented the flooding and should be built immediately. Others continued to feel that it was not necessarily justified, believing that the alternatives had been thoroughly studied.

The Central Arizona Water Control Study was born in an effort to provide consensus on what should be done to solve central Arizona's water problems. The study will examine all the reasonable alternatives, including Orme Dam, and will consider both regulatory storage and flood control. The overall study will be conducted by the U.S. Bureau of Reclamation. The U.S. Army Corps of Engineers will provide an analysis of the flood control alternatives.

The Central Arizona Water Control Study is a major feasibility study of all reasonable alternatives. At the end of the study an Environmental Impact Statement (EIS) will be prepared describing environmental, economic, and social impacts of all alternatives.

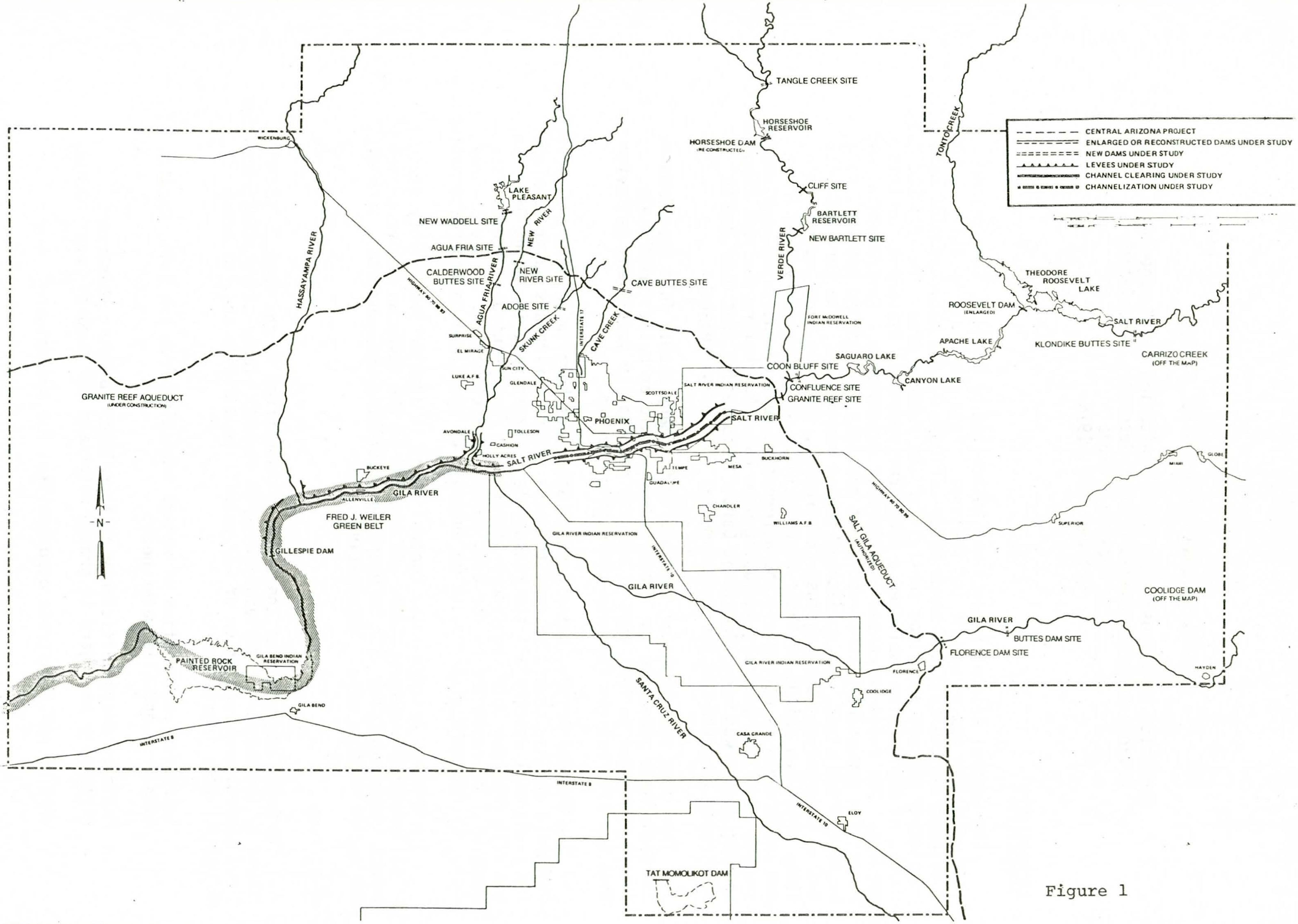
OBJECTIVES

The basic objective of the study as identified in the PLAN OF STUDY issued by the Bureau of Reclamation is to develop viable alternative plans for flood control and regulation of CAP water. In addition the following objectives were identified:

* Increased conservation of waters emanating from the Salt, Verde, Agua Fria and Gila watersheds.

* Maximize energy efficiency as it relates to water resources, especially in regard to ground water and CAP pumping requirements.

* Develop and illustrate opportunities for hydroelectric power


CENTRAL ARIZONA PROJECT
ENLARGED OR RECONSTRUCTED DAMS UNDER STUDY
NEW DAMS UNDER STUDY
LEVEES UNDER STUDY
CHANNEL CLEARING UNDER STUDY
CHANNELIZATION UNDER STUDY
TANGLE CREEK SITE
HORSESHOE RESERVOIR
HORSESHOE DAM
CLIFF SITE
BARTLETT RESERVOIR
NEW BARTLETT SITE
VERDE RIVER
TONTO CREEK
THEODORE ROOSEVELT LAKE
ROOSEVELT DAM
SALT RIVER
APACHE LAKE
KLONDIKE BUTTES SITE
CARRIZO CREEK (OFF THE MAP)
SAGUARO LAKE
CANYON LAKE
COON BLUFF SITE
CONFLUENCE SITE
GRANITE REEF SITE
LAKE PLEASANT
NEW WADDELL SITE
NEW RIVER
AGUA FRIA SITE
CALDERWOOD BUTTES SITE
AGUA FRIA RIVER
NEW RIVER SITE
CAVE BUTTES SITE
ADOBE SITE
SKUNK CREEK
CAVE CREEK
HASSAYAMPA RIVER
GRANITE REEF AQUEDUCT
PHOENIX
SALT RIVER
GILA RIVER
FRED J. WEILER GREEN BELT
GILLESPIE DAM
PAINTED ROCK RESERVOIR
SALT GILA AQUEDUCT
GILA RIVER
COOLIDGE DAM (OFF THE MAP)
GILA RIVER
BUTTES DAM SITE
FLORENCE DAM SITE
SANTA CRUZ RIVER
TAT MOMOLIKOT DAM
-N-
Figure 1

production associated with structural and nonstructural alternatives.

* Take advantage of opportunities to protect and/or improve the quality of certain natural or cultural resources or ecological systems.

* Take advantage of opportunities to enhance the social well-being of Indian communities.

* Develop plans for recreational facilities in urban areas (such as those proposed in the Rio Salado concept) as well as in rural/natural areas to provide opportunities for recreational enhancement at both upstream and downstream locations in the CAWCS area.

* Take advantage of opportunities to improve the management protection of open space and to increase its extent by maintaining existing wildlife areas and studying the potential for development of greenbelt floodways and multi-purpose projects such as Rio Salado.

* Improve management and preservation of the unique archaeological and historical resources in the CAWCS area.

* Conserve and enhance fish and wildlife resources by taking such measures as creating minimum pools for bass fisheries and developing cottonwood seeding programs.

STUDY ROLES

The responsibility for overseeing and funding the study has been given to the Bureau of Reclamation; however, the study is a joint effort of the Bureau and the Corps of Engineers. The primary responsibility of the Corps of Engineers is flood control and the Bureau is studying the regulatory storage of CAP water. In addition to the technical aspects, a vital element of the study is the public involvement program. Figure 2 graphically illustrates the relationship of public involvement to the primary aspects of the study.

Orme Dam was a unique solution to the problems of regulatory storage and flood control for central Arizona in that as a single structure it satisfied the needs in both areas. It is doubtful that any alternative solution will involve only a single element such as Orme Dam. Instead, the solution will be a system of elements which must be combined to meet the objectives of the study. Individual elements of the system may provide regulatory storage, flood control or both.

The chances of any project being built depends on people's willingness to use the study findings and work together toward a consensus on the most desirable action. For this reason there will be a major public involvement effort as part of the study. The adoption of any system will require that the public approve. In fact, it might be assumed that the public will make the decision on the final system to be adopted.

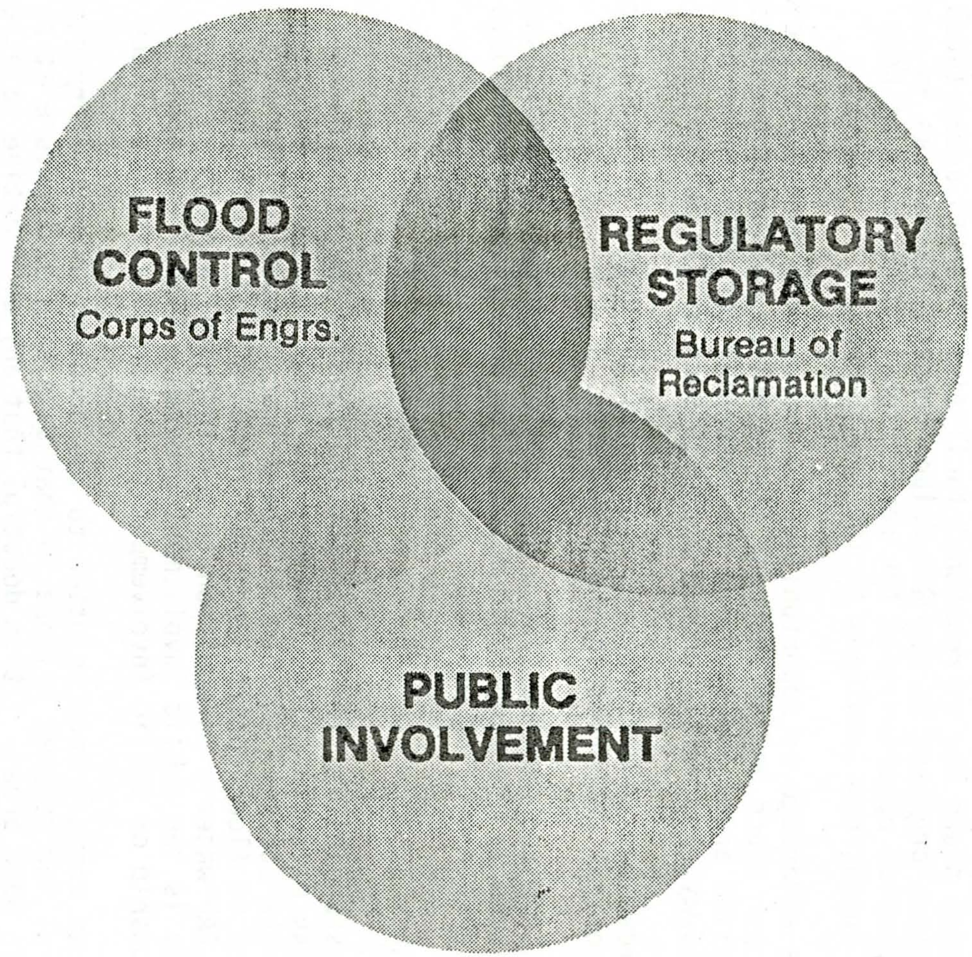

FLOOD
CONTROL
Corps of Engrs.
REGULATORY
STORAGE
Bureau of
Reclamation
PUBLIC
INVOLVEMENT

Figure 2

STUDY PROCESS

The study of alternatives to Orme Dam is an iterative process as illustrated on Figure 3. Various structural and nonstructural elements have been identified which have the potential to solve flood control or regulatory storage needs. These elements are studied individually (Phase IIA) and the most acceptable elements are then to be combined into systems. These systems (Phase IIB) are studied and the most acceptable systems are identified for further study. Plans (Phase III) are then developed to meet study objectives and the most technically feasible and environmentally compatible, and publicly acceptable plans are selected for CAP storage and flood control. Hopefully a single preferred plan will be identified for which an Environmental Impact Statement is prepared and forwarded for authorization. Thus, this study begins with many elements which are combined into many systems that are in turn analyzed and refined to a preferred plan.

The CAWCS is actually a planning study - not simply the preparation of an EIS for some predetermined plan. The study is guided by Principles and Standards for Planning Water and Related Land Resources, prepared in 1973 by the Water Resources Council.

As previously mentioned, study elements may satisfy the needs for flood control, regulatory storage or both. No attempt will be made in this paper to describe these elements in detail. They are identified on the Map (Figure 1). In general however, the elements involve dams on the Verde, Salt, Gila and Agua Fria Rivers; channels and levees on the Salt River; channel clearing in the lower Salt River; and water exchanges of CAP water under the jurisdiction of other agencies. A detailed description of the elements is contained in a bulletin published by the Central Arizona Water Control Study, Special Edition 1, Summary of Elements under Study.

ORGANIZATION

The CAWCS is one of the most complex studies of this type ever attempted. The Corps of Engineers and the Bureau of Reclamation have their own in-house study teams involved in the effort but, in addition, consulting firms have been retained by both organizations to handle various aspects of the study. If the reader reviews again the objectives of the study and recognizes the number of organizations involved, it will become clear that a strong well-organized management team is required for smooth operation. Also it is important to realize that the study is to be completed within a time frame shorter than normal for this type of investigation. The planning study and the EIS are scheduled for completion in May of 1982.

To illustrate the management structure involved the Study Organization Chart (Figure 4) and the Dames and Moore Organization Chart (Figure 5) will be reviewed. Dames and Moore is a contractor for the Bureau with responsibility for about 40% of the total project effort encompassing the environmental, social, economic and demographic aspects. Also, a major effort is involved in coordinating the public involvement program for the total project.

PROCESS FOR SELECTING PLANS FOR FLOOD CONTROL AND CAP STORAGE

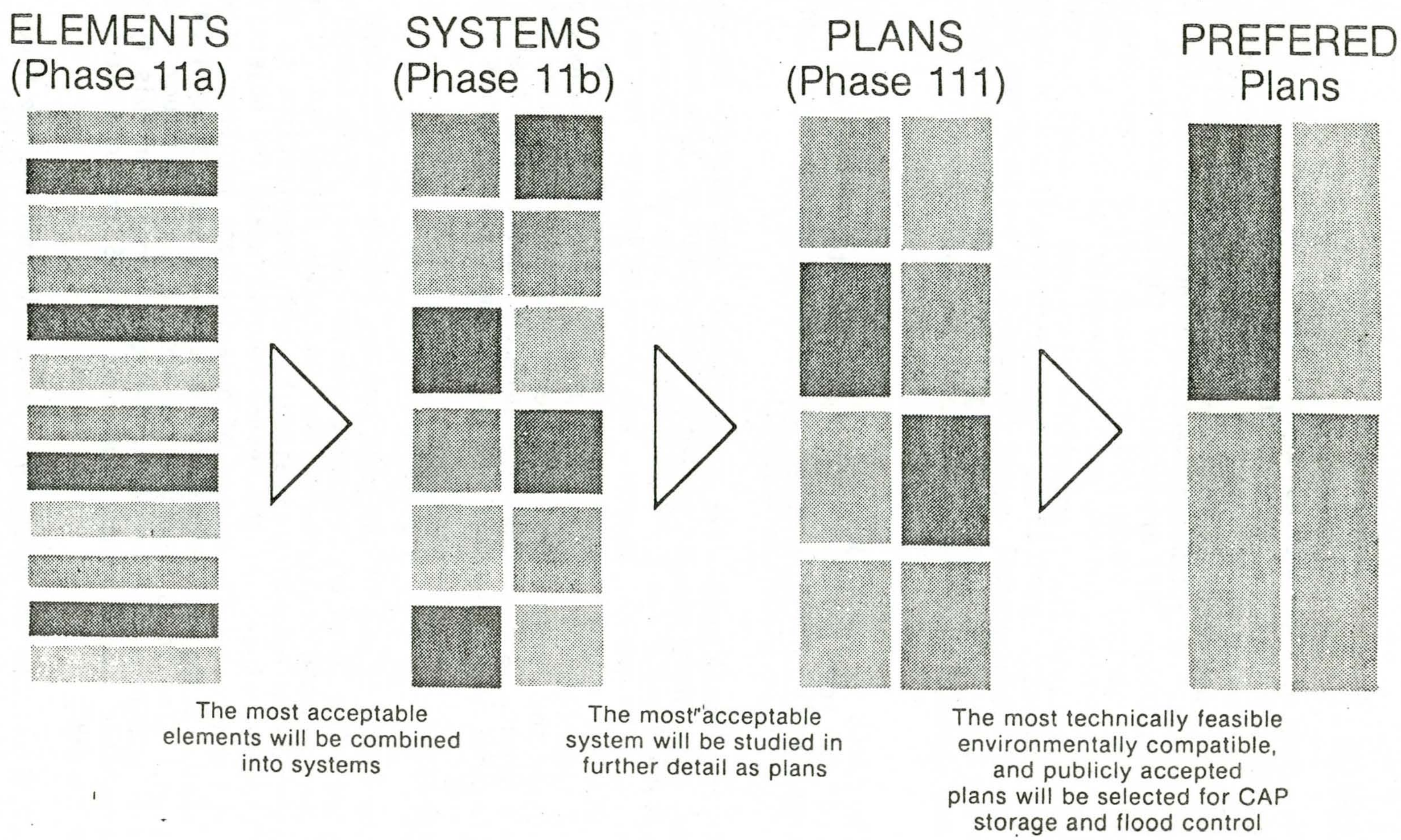


Figure 3

CENTRAL ARIZONA WATER CONTROL STUDY
STUDY ORGANIZATION CHART

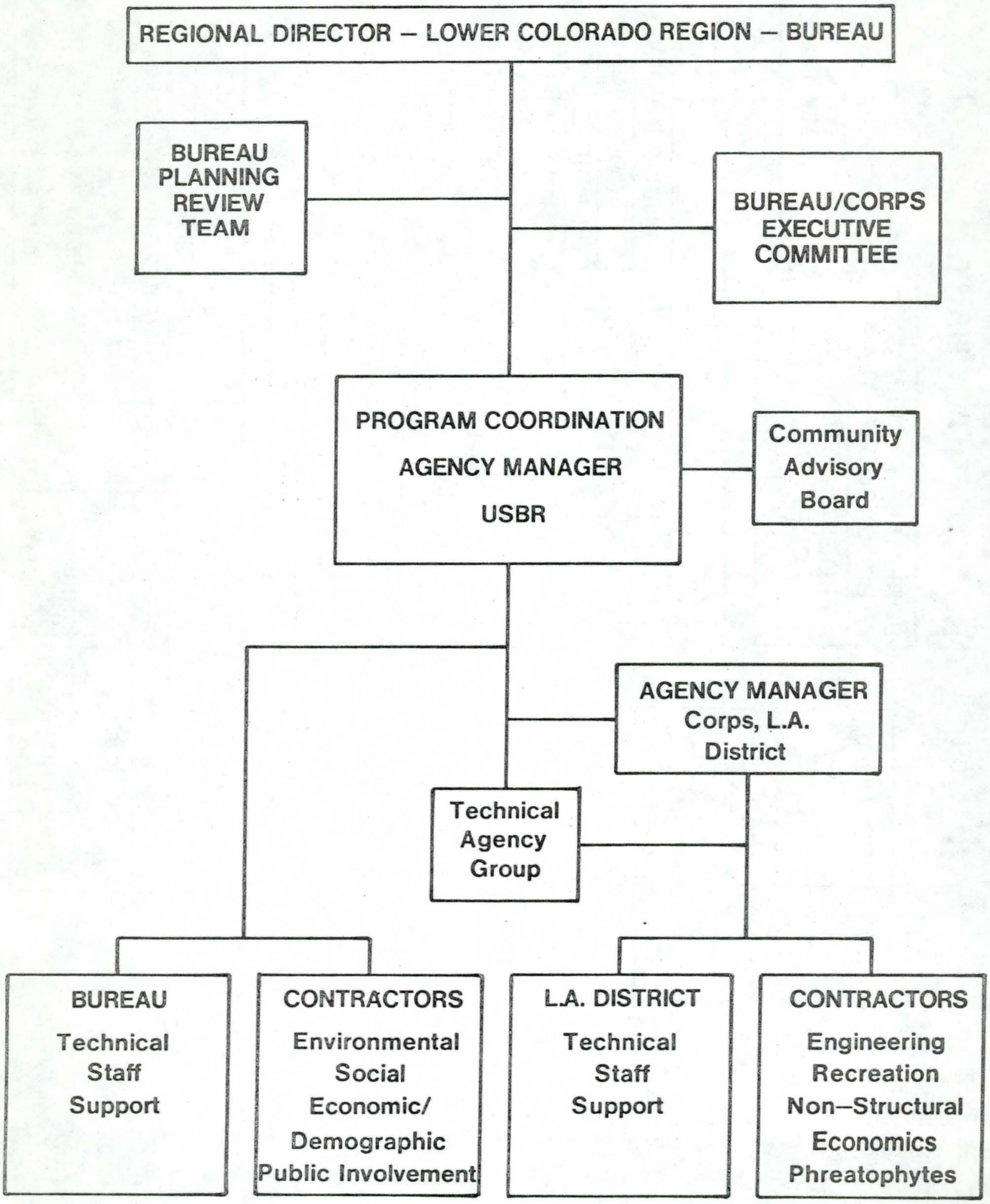


Figure 4

DAMES AND MOORE
CENTRAL ARIZONA WATER CONTROL STUDY
ORGANIZATION CHART

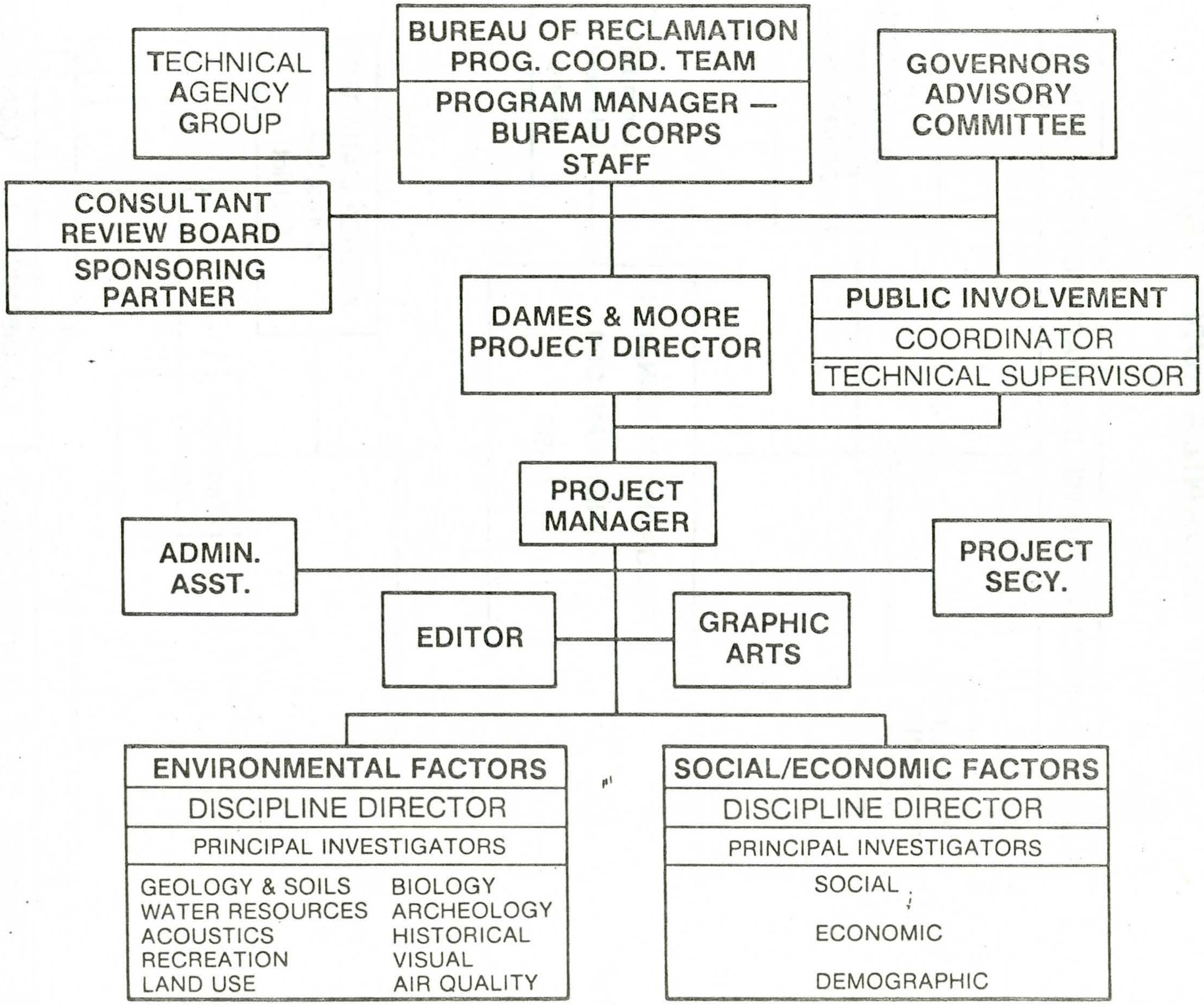


Figure 5

In addition to a full time public involvement coordinator, a consulting technical supervisor has been retained to develop and assist in the direction of this effort. A citizen's advisory committee was included in the original study plans. Fortunately the Governor appointed an Advisory Committee to keep his office posted on the progress of the study. This Governor's Committee fits the needs of the study perfectly. It is made up of representatives from government, industry, the Indian community and other social and political groups who are interested in the project. Consequently this group not only keeps the Governor informed of progress but also furnishes direct input to the study. It meets monthly with an agenda planned to provide the social, economic and political input at critical stages in the study.

Contacts with the public are accomplished through newsletters, bulletins and various meetings and workshops. These communication links are used to disseminate information but, equally important, they will supply input to public opinion to aid in decision making.

The technical input to the study comes in part from the Technical Agency Group, a group established by the Bureau and Corps which includes representatives from the Highway Department, Fish and Wildlife Service, Maricopa County Flood Control District, etc. This group meets every two months and furnishes the broad brush technical input required by a study such as this to make certain that all technical bases are covered.

The Dames and Moore technical function is coordinated by a Project Manager with discipline directors for the environmental and social-economic areas. Each particular discipline has a principal investigator leading the study. The Project Director is responsible for the Dames and Moore activities and is deeply involved in the public involvement program. He also has the responsibility of coordination with the Bureau and the Corps.

PROGRESS AND SCHEDULE

The planning study is scheduled for completion in mid-year of 1981 at which time the recommended alternative(s) will be chosen. The schedule calls for project completion including the EIS in May of 1982. The study is essentially on schedule at the present time. Most of the baseline information has been obtained and the "future without the project" has been established. Both the Governor's Advisory Committee and the Technical Agency Group were invaluable in the estimation of future conditions in central Arizona if the project were not constructed. This evaluation is a key step in the planning process because it furnished the base against which all proposed alternatives can be compared. Both the baseline information and "Future without" assumptions will be augmented and refined as the iterative process developes.

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