structural approaches to controlling floods, including, besides zoning, flood proofing and acquisition of land (Platt, 1980). Although this impressive policy has not been implemented to any great extent, it remains true that, with increasing difficulty in implementing reservoir flood control, floodplain management is getting further emphasis. The availability of flood insurance at reasonable rates helps obtain agreement on floodplain zoning.

This action was all constructive; it slowed, although it did not stop, the development in floodplains (Tucker, 1978). Meanwhile, four aspects combined to maintain or increase the flooding. First, the construction of levees and floodwalls automatically reduces the valley storage available (in the area protected) and correspondingly increases flooding elsewhere. Secondly, channel improvements speed the water downstream to increase flooding below. Thirdly, the construction of homes, businesses, and transportation facilities increases runoff because of the high proportion of impervious area. Even ordinary homes have considerable paved surfaces and roofs, and any small hollows, swamps, or meandering brooks are usually filled in or smoothed out in the grading process. The fourth aspect, while important, is not so obvious. If small detention basins are built to detain runoff from only a few acres of ground, they are designed to protect against the relatively frequent small storms with a concentration time of perhaps half an hour. Floods on even moderate-sized rivers may have a concentration time of perhaps 24 hours. The steady rain for 24 hours that produces a flood for the larger stream will be allowed to pass quickly through the outlets of conventionally designed small detention basins. Larger rivers may have concentration times of weeks or even months, and small detention basins covering even the entire drainage basin would have virtually no effect upon the flood flows of such a river. Accordingly, construction of conventional stormwater management detention dams has virtually no effect in reducing floods on the larger rivers. (Detention dams now being built with provisions for water quality are more effective.)

Levees, channel improvements, and floodways must be incorporated into the plan with great care, in view of their possible adverse side-effects. Although efforts have been made to decentralize-flood protection efforts, jurisdictional problems are bound to arise, since boundaries are more apt to follow streams and rivers than watershed limits.

## Special Districts

One of the best ways to plan and administer flood protection is the establishment of special districts for the purpose. The outstanding example is the Denver Urban Drainage and Flood Control District in Colorado. It combines functions of flood damage protection and drainage and also helps municipalities to develop requirements for quality of runoff. It is large enough to have a competent staff that is fully informed on all the complex issues involved. It does outstanding work in improving streams for flood control while building up environmental values and improving areas for recreation, especially walking and biking along the streams. However, special districts are exceptional.

## Benefit Evaluation

According to the "Principles and Guidelines" (U.S. Water Resources Council, 1983), flood control benefits are evaluated differently for agricultural flooding and for "urban flood damage." (These are economic benefits. Environmental benefits should be considered separately.) The instructions are very detailed, but the main points are as follows.

In principle, damage reduction benefits to agriculture are the increase in net income due to the flood control plan such as increased crop yields and decreased production costs. This seems appropriate.

As regards "urban flood damage," benefits are primarily the reduction in actual or potential damages associated with land use. However, if an activity is added to the floodplain because of a flood control plan, the benefit is different in aggregate net income with and without the plan. Flood damages include physical damages, income losses, and emergency costs. Prices used for evaluation should be those prevailing during the period of analysis. For water-based recreation the agency determines unit values.

Both agricultural and urban damage control benefits are evaluated as National Economic Benefit (NED). Presumably, the destruction of a fruit orchard in California would be excluded from damages if it were accompanied by increased marketing of the same fruit from Florida. However, this relationship is not specifically covered, and is difficult to establish.

Benefit/cost ratios are not the sole criterion used to determine the extent of federal investment in flood control. Intangible benefits, including prevention of loss of life, can also be considered. The unwritten (but very effective) policy has been to provide for control of at least a 100-year-frequency flood, for each project, even if economic analysis might show protection against the more numerous small floods to have a higher B/C ratio. Where there is as yet no flood control plan, the occurrence of any really disastrous flood has the effect of changing agency viewpoints very quickly, as was the case in both the Ohio River and the Columbia River.

## Flood Control Storage

For all but the small local areas, flood control storage must be carefully and deliberately planned. In addition to standard design, cost, and benefit studies, coordination may be required with other project purposes, such as water supply, as has customarily been done in traditional multiple-purpose studies. However, any major flood control study (and particularly the estimate of benefits) must also be accompanied by analysis of alternative non-structural methods, particularly land acquisition, flood proofing, and floodplain zoning. Also, possibilities of favorable environmental features should be considered.

It is usually desirable to plan protection of major flood hazard areas against all normal floods. The standard measure of protection is the 100-year flood. Occasionally, protection will be given for occurrence of the Standard Project Flood, which is larger. Of course, spillways for earth dams are designed to handle an even greater discharge, the Spillway Design Flood, since failure of the spillway would destroy the dam, with disastrous consequences downstream. (However, the very small dams are built with much reduced spillway design floods.) Figure 5-5 illustrates the dependence of the homes below a dam on the soundness of the dam/spillway construction.

The management of flood control storage during a flood may be a complex matter. Reservoirs are designed for a given amount of flood control storage that is only occasionally needed, but the shores of the reservoir are much used by wildlife and also for moorings for boats and other recreation facilities. Accordingly, once the storage is filled, there are demands to lower the level as fast as practicable. Moreover, there is

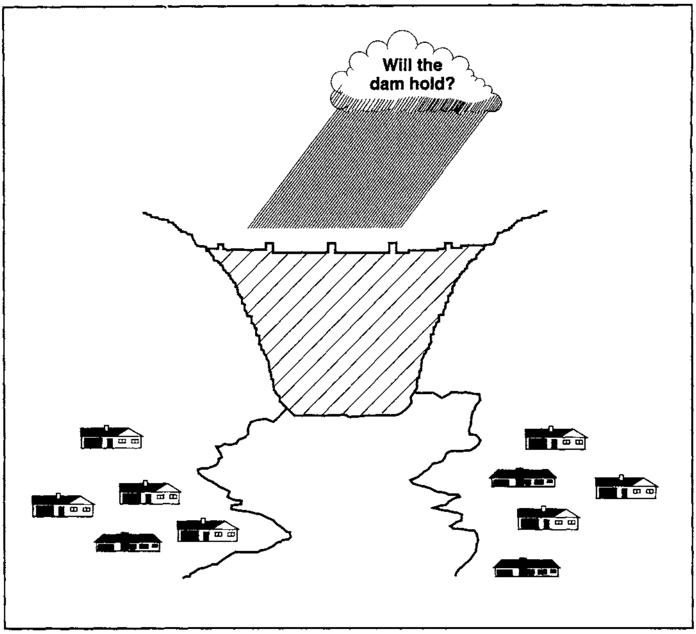


*Figure 5-5.* Necessity for a Spillway.

always the possibility of another storm occurring when the reservoir is already full and incapable of further storage. On the other hand, releasing the stored flood waters prolongs the inundation of floodplains downstream, which occupants may be anxious to get the use of. Altogether, the use of such storage requires good judgment and the reliable predictions of weather.

## Runoff Pollution

The handling of stormwater runoff was greatly complicated by the discovery (not long after the passage of the Clean Water Act) that the greater part of the pollution in streams generally comes not from the point wastes (towards which that act was primarily directed) but from "nonpoint sources." When this fact was revealed to an official of one state by a university researcher, instead of congratulating the university for innovation and successful research, he burst out, "My God! I hope this doesn't come to be known". (He was concerned with the fate of a state bond issue that had been publicized on the implicit assumption that the known point sources were all that had to be considered.) Since that time, great progress has been made, and the ways of dealing with pollution in run-off are now fairly well understood, as indicated in Chapters 8 and 9, although actual progress has been very irregular.

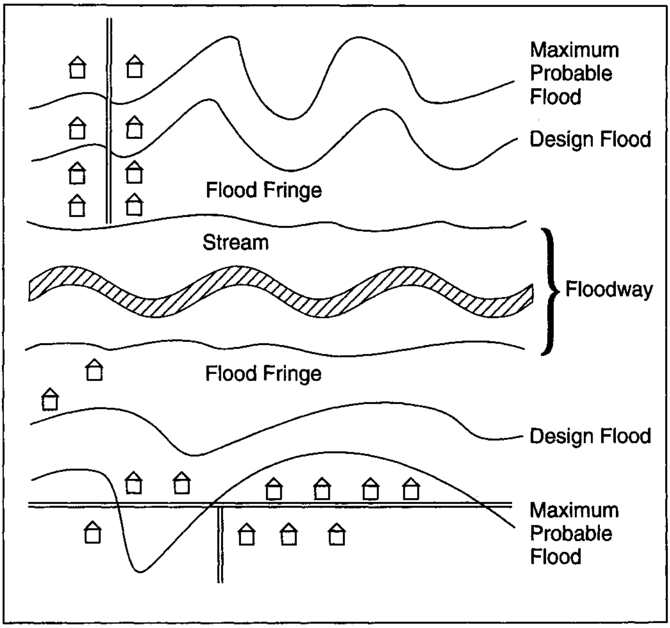


*Figure 5-6.* Diagram of Floodplain Zoning.

## Environmental Use of Floodplain Zoning

Historically, floodplain zoning has been established with the idea of preventing the building of homes and businesses in floodplains in order to reduce flood damage. See Figure 5-6.

Floodplain zoning, as shown in this figure, provides a frequently flooded floodway within which no construction is allowed except for indispensable structures, and a flood fringe area in which construction is limited. Any building permitted may have foundations raised out of reach of a 100-year flood or be otherwise flood-proofed. In some states such as New Jersey, the amount of fill that can be added by new construction in the flood fringe area is limited. The usual result, in other than urban areas, is that the floodway and most flood fringe areas remain naturally wooded or wetlands, and good refuges for birds, insect life, fish, and native plants. Although forestry and grazing lands can result in destroying a lot of woods, this does not have to be the case. With a few other restrictions, properly designed floodplain zoning can provide environmentally important strip corridors along most sizable streams. In partial recognition of this relationship, the Association of State Flood Plain Managers now encourages use of wetlands managers.

The Vicksburg District Corps of Engineers has found that numerous water control structures, confined disposal facilities, and borrow pits being built for flood control can be adapted to produce environmental benefits by impounding water. The intent is to compensate for habitat losses that would result from other features of the project (Fischenich, *et al.*, 1993).

## Summary

In summary, flood control on major streams should be developed by engineering analysis on a multiple-purpose watershed basis. To be complete, the flood control aspects must include floodplain management. If protection of the smaller rivers and streams is to be included, systems of small impoundments are needed. The plan for impoundments must be based upon systems of land use control, but should include provisions for controlling quality of runoff. (See Chapter 9.) It would be extremely difficult for all of this to be included in a single study or implemented through a single program. In later chapters, flood control is considered first as an aspect of standard multiple-purpose developments and secondly, it is used as part of a program including land use and nonpoint source control, aimed largely at water quality.

Moreover, there remains the major environmental benefit that may be gained from floodplain zoning and environmental use of flood control features. Altogether, flood control, originally considered to be a rather simple matter, now becomes very complex, with the inclusion of important environmental aspects.

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# Chapter 6

## Navigation, Hydroelectric Power, and Irrigation

### Navigation, General

Navigation was the first water use to attract national attention. It is hard for us to realize how essential water transportation was to our country before the development of our present systems of railroads and highways. In New Jersey, the 65-mile-long canal, the Delaware and Raritan Canal, links the Delaware River to the Raritan River, near New Brunswick. It is used for water supply and also as a strip corridor park. However, it was built entirely for navigation, to move coal barges drawn along a towpath by mules, from the coal-rich regions of Pennsylvania to the metropolitan New York area.

As our country spread to the West, explorers, trappers, and adventurers used the rivers as means of transportation, and many cargoes from the central part of the country were shipped down the Mississippi River to New Orleans for export. Consequently, much of the early thinking about our rivers envisaged them as means of transportation to be used together with ships at sea and in the Great Lakes. Even after full development of our railroad and highway systems, our rivers remained the most economical means of transportation for bulk cargoes. On the larger rivers this is done by large barges, assembled in tows of perhaps fifteen barges and pushed by a single tug boat.

Sometimes navigation is on the open river (such as the Missouri below Yankton, South Dakota, and the lower Mississippi). Other rivers have locks and dams, such as the Ohio, the upper Mississippi, and the Columbia above Bonneville Dam. The locks are preferably of a size to accommodate a tow of barges without the necessity of disassembling it and passing the separated barges. The depth of the navigation channel, including the locks, is a key factor governing the economy of river transport.

The locks on the Ohio, which, when built, were considered to be a tremendous engineering achievement, are now being painfully (and expensively) reconstructed, with locks 1,200 feet long and a great reduction in the number of locks and dams.

## Current Navigation Programs

Further major extensions of inland navigation in the United States are unlikely to be undertaken. More usual problems may involve proposals for deepening and improving channels in our ports and estuaries for seagoing traffic, reconstruction of obsolete locks, routine channel maintenance by dredging, and maintenance of river flows adequate for navigation. In times of drought, the maintenance of river flows adequate for navigation is competitive with other uses of water. On waterways with a high traffic in petroleum products, such as the Delaware Estuary and the lower Mississippi, water pollution due to spills and leakage is an important problem.

## Benefit Values of Navigation

The benefit of water transportation is evaluated as the difference between the costs of using the waterway and those of using alternative means of transportation (U.S. Water Resources Council, 1983). However, by law, comparison of prevailing rates may be used to represent costs for different modes of transportation. On an economic basis, the officially sanctioned comparison favors the waterways, as rail rates must include the cost of amortizing and maintaining the investment in rail infrastructure (with some reduction for land-grant rail lines), while water rates include no part of the construction or maintenance costs of the waterway. The waterways' benefits are usually computed on the basis of commercial cargo handling, but there is also a great deal of recreational boating on these waterways.

## Hydroelectric Power, General

Hydroelectric power is one of the more recent forms of government water resource development. As a means of generating energy, it is very clean, without the problems of waste heat and polluted exhaust that accompany thermal generation from coal, or the problems of dangerous waste and possible accidents from nuclear plants. Other alternative modes of generation are tidal, geothermal, and solar power, but they are exceptional.

## Hydroelectric Power Operations

In operation, hydroelectric power plants are very flexible. Whereas nuclear power plants must operate in a steady state, and large steam plants take some hours to start or to stop production, a hydroelectric turbine backed by a reservoir can readily be varied in operation in a matter of minutes, without much loss in efficiency. This is very important for system operation, as the demand for power characteristically fluctuates widely during the day and declines to very low levels at night. Also, there may be outages due to lightning or equipment failure.

To provide for flexibility in a large system, it is possible to have a special type of hydroelectric power plant, the pumped storage plant, strategically located near a major load center. This plant operates between a lower- and an upper-level water impoundment. Water drawn from the upper impoundment generates electricity as it is discharged into the lower impoundment (or river). Alternatively, the pumped storage plant can use surplus electricity to pump water back into the upper reservoir, in effect providing a reservoir for electric energy.

## Controversies Related to Hydroelectric Power

Although hydroelectric plants have great inherent advantages, they have major environmental disadvantages as regards fish. The rapid variation in the velocity of flow downstream of the dam to meet varying power requirements is harmful to certain fish. However, problems with anadromous fish are more important, particularly salmon. Power dams are usually located with deep impoundments of water (in order to gain high efficiency), and they usually form a barrier to passage of anadromous fish.

These problems with fish are raised in connection with about 1,600 nonfederal power dams. Environmentalists have been pressuring the