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THE WILLAMETTE RIVER, FLOOD CONTROL OR FLOOD MANAGEMENT*

DARYLL D. RAITT†

On December 21, 1964, the Willamette River overflowed and levied a 58 million dollar claim of destruction against society for use of the river's floodplain. This damage occurred despite man's attempt to contain the river with an investment of 275 million dollars in structural controls. The result of this disaster was renewed local interest in our traditional remedy for rampaging rivers—flood control structures.

The Willamette River, a tributary of the Columbia River, is located entirely within Oregon and drains 11,200 square miles. Oregon's three largest cities, as well as numerous smaller cities, border the river. About 1.17 million people, or 66 per cent of Oregon's population reside in the basin.

The first two major flood control dams on the Willamette River were completed in 1941 and 1942, respectively. Since 1945, five additional reservoirs have been built, three are under construction, and four others are authorized for construction. A comprehensive review study of the Willamette is currently underway and additional flood control reservoirs will undoubtedly be proposed.[1]

This article will: (1) evaluate the past effectiveness of the flood control program in alleviating flood damages in the Willamette Basin; (2) indicate the effectiveness of authorized projects in alleviating future damage if other flood management practices are not adopted; (3) outline the conditions necessary for an efficient flood management program; (4) review some alternative flood management practices available for alleviating damage; and (5) set forth some recommendations for action as a first step toward a flood management program.

The information used in this analysis was obtained from two reports issued by the Corps of Engineers. One was completed in 1950 and included data from historical floods of various magni-

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1. This review is being conducted by the Willamette Task Force composed of the Oregon State Water Resources Board, U.S. Department of Health, Education, and Welfare; U.S. Department of the Army; U.S. Department of Agriculture; U.S. Department of Labor; U.S. Department of Interior; and the Federal Power Commission.

tudes dating back to 1861.[2] Data on peak discharge rates at Salem, Oregon, estimated flood frequency, and acreage subject to inundation by these floods under conditions of no flood control are presented in Table 1. Damage rates are for the level of floodplain use and development in 1948. These damage values were adjusted to 1964 price levels so that 1948 damage values could be compared directly with 1964 damage values.

TABLE 1
EFFECTS OF VARIOUS MAGNITUDES OF FLOODS, FOR FLOODPLAIN CONDITIONS IN 1948 AND NO FLOOD CONTROL STRUCTURES

		Peak discharge in thousand cubic feet per second, representative floods, Salem station.[a]				
Item	Unit	248	262	301	456	530
Flood frequency[b]	Years	7	10	15	50	100
Acres inundated[c]	1000 acres	302	368	342	485	513
Damage[d]	1000 dollars	13,165	17,490	16,890	——	50,960

Source: Except as noted, the source of all data is the Corps of Engineers reports.[2,3]
a. Flood stage at Salem is 100,000 cfs.
b. Probable recurrence interval for this magnitude of flood.
c. Acres inundated on main stem of the river.
d. Values indexed by the Wholesale Price Index for All Commodities, U.S. Department of Labor to 1964 prices (1948 = 87.9, 1964 = 100.5).

Data used from the second report[3] included peak discharge rates at Salem, Oregon, and estimated damages by the 1964 flood under conditions of no flood control, existing control, and authorized control (Table 2).

The acreage subject to inundation by the 1964 flood under various levels of flood control was estimated from historical relationships between peak discharge rates at Salem and acreage inundated on the main stem of the Willamette River (Figure 1). The Salem gauging station was used because data are more complete for this station than for others farther downstream. Perfect correlation does not exist between peak discharge at Salem and acreage inundated by historical floods because of differences in storms, watershed conditions, and runoff patterns; however, the relationship as indicated by the curve in Figure 1 is close enough for the purpose of this analysis.

2. U.S. Dep't of the Army, Columbia River and Tributaries, Northwestern United States, Willamette River Basin, H.R. Doc. No. 531, 81st Cong. (1951).
3. U.S. Army Engineer District, Portland, Oregon, Flood of December 1964, Project Effects (1965).

TABLE 2
EFFECTIVENESS OF STRUCTURAL CONTROLS, 1964 FLOOD
WILLAMETTE RIVER

Item	Unit	Level of structural control No control	 Existing control	 Authorized control
Number of reservoirs	Number	0	7	14
Flood control capacity	1000 acre feet	0	1,187	1,962
Total cost of reservoirs[a]	Million dollars	0	275	500
1964 flood:				
Peak discharge at Salem	1000 CFS	471	308	210
Acres inundated[b]	1000 acres	490	380	260
Damage, 1964 conditions	1000 dollars	629,920	57,520	33,520

Source: Except as noted, the source of all data is the Corps of Engineers reports.[2,3]
a. This is the total cost of the reservoirs. Since the stored water is also used for other purposes, the cost allocated to flood control is somewhat less.
b. Estimated from curve in Figure 1.

I
EFFECTIVENESS OF FLOOD CONTROL

A. Past Effectiveness

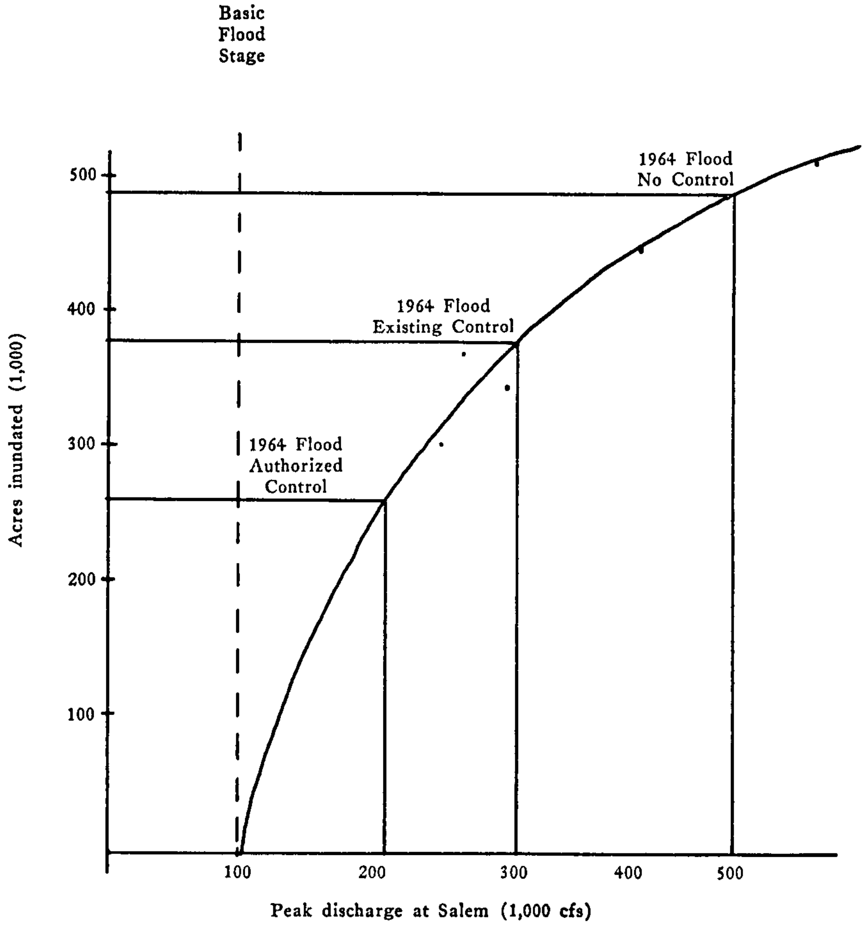
The past effectiveness of flood control structures in alleviating flood damages are illustrated by the two curves in Figure 2. Curve D represents the inundation-damage function for conditions in the floodplain in 1948 and Curve D_1 represents the same relationship for conditions in the floodplain in 1964.[4] The difference in these two curves indicates the change in potential damage due to increased use and development of the floodplain from 1948 to 1964.

The 1964 flood served as a benchmark for making several interesting comparisons. Lines C and C_1 indicate the acreage subject to inundation by the 1964 flood under conditions of no control and existing control, respectively.

The point of intersection of line C and curve D represents the damage that might have resulted from an unregulated flood of 1964 magnitude for floodplain land use and level of development in 1948. The estimated 630 million dollars[5] of damage that might have

4. The damage values for 1948 were indexed to 1964 prices so that the curves would be on the same price base.
5. This amounts to about 8 percent of the value of taxable property in the nine major counties in the basin.

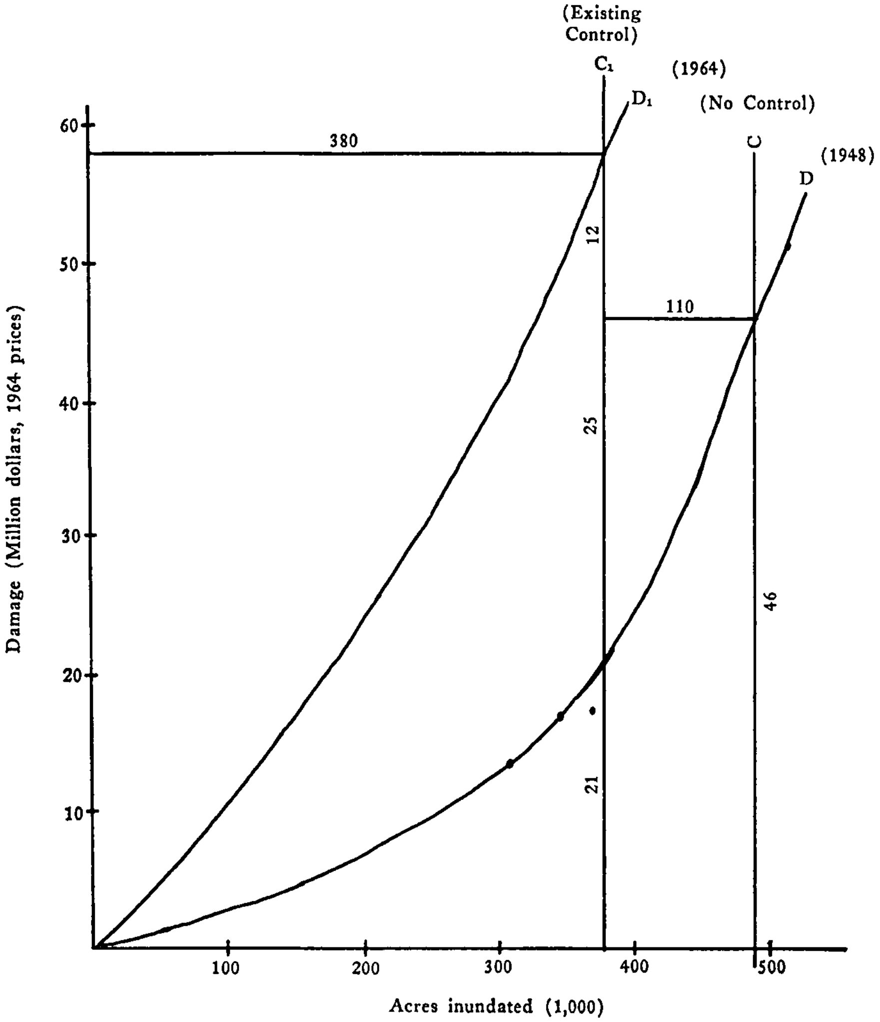
FIGURE 1
RELATIONSHIP BETWEEN PEAK DISCHARGE AT SALEM, AND ACREAGE INUNDATED, WILLAMETTE RIVER



occurred if flood levels from the 1964 storm had not been reduced by existing structures is not shown in Figure 2. Graphically, this point could be shown by extending curve D_1 and line C to their point of intersection. Although this damage figure is the one most often cited[6] by proponents of flood control structures, it has little relevance as a measure of the value of structures because it is based on the assumption that development in the flood plain would have progressed at the same rate in the absence of control structures.

6. The Corps states: "It is interesting to note that damages prevented in the Willamette River Basin in this one (1964) flood greatly exceed the total investment to date in flood-control and multi-purpose projects in that basin." *See* note 3 *supra*.

FIGURE 2
INUNDATION DAMAGE RELATIONSHIPS FOR CONDITIONS IN THE FLOOD PLAIN IN 1948 AND 1964, WILLAMETTE RIVER, OREGON



Since the purpose of the structures is to provide complete flood protection to some areas, thereby permitting more intensive land use, little value could be attributed to the structures if more intensive use did not occur in the protected areas. The benefit from structures is not the total loss prevented by flood control-induced changes in land use, but the difference between providing goods and services from the protected areas and providing them from alternative sources.

The estimated damage that occurred from the 1964 flood was

58 million dollars. Figure 2 indicates that although the seven reservoirs reduced the acreage inundated by 110,000 acres, the damage was 12 million dollars greater than a flood of this magnitude would have caused without any flood control if development in the floodplain had remained at the 1948 level.

Perhaps of more importance is the comparison of damage caused by the 1964 flood with existing control and that which would have occurred for the same level of protection under floodplain development conditions in 1948. Damage by the 1964 flood would have been 37 million dollars less, or about 21 million dollars for the existing level of control if development in the floodplain had remained the same as it was in 1948. In other words, development on the floodplain increased at a more rapid pace than the degree of flood protection provided by reservoirs. Consequently, flood damage increased in spite of the construction of seven reservoirs at a cost of some 275 million dollars.

B. Future Effectiveness

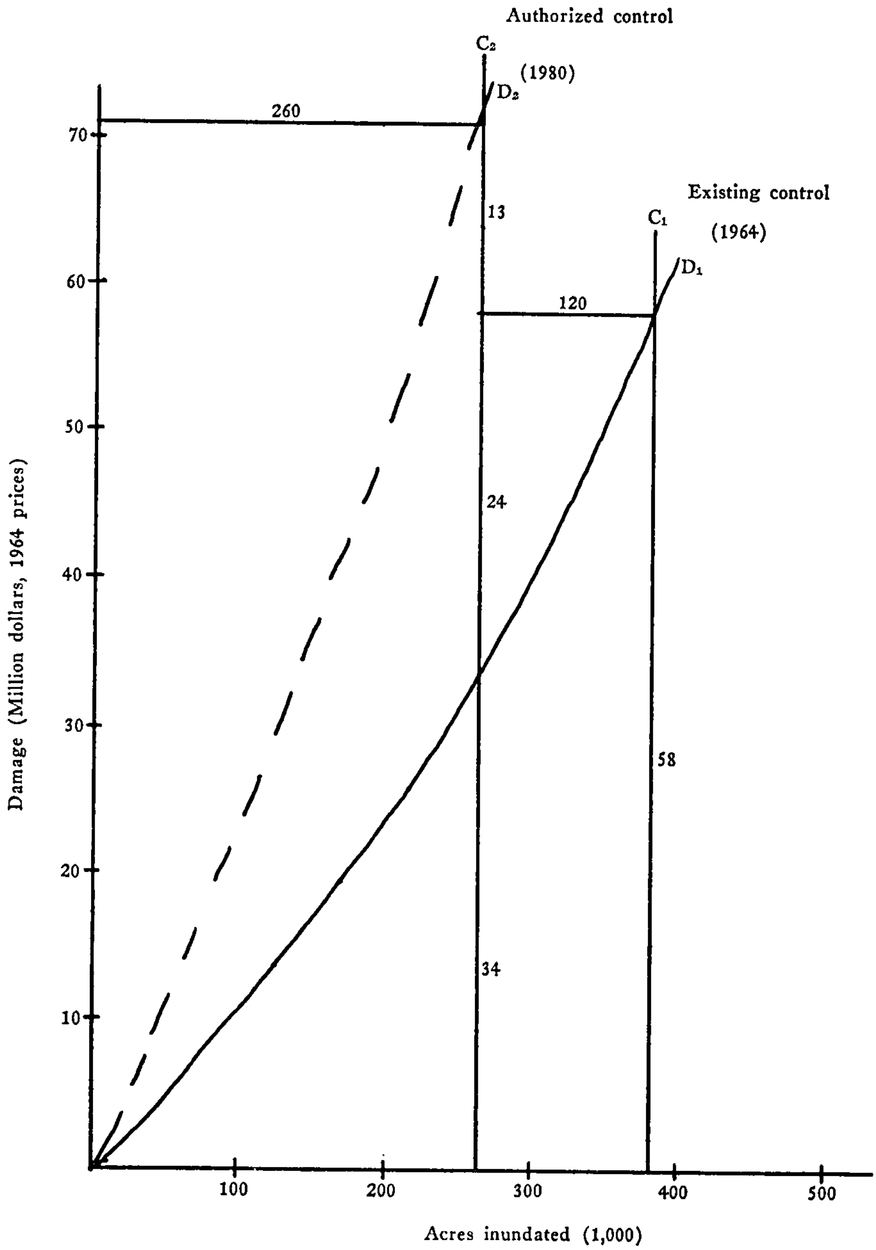
Will the three reservoirs now being constructed and the four authorized for construction reduce future flood damage? The addition of these reservoirs will provide a total flood control capacity of about two million acre-feet at a cost of some 500 million dollars.

Using the 1964 flood as a benchmark, projection of damages under assumed conditions can be made. Lines C_1 and C_2 in Figure 3 indicate the acreage subject to inundation by the 1964 flood under conditions of existing flood control (7 reservoirs) and authorized control (14 reservoirs), respectively. Curve D_1 represents the 1964 inundation-damage relationship and curve D_2 represents the relationships that might prevail in 1980 if development on the floodplain continues at the same rate it has in the past 16 years.

The additional reservoirs will further reduce the acreage inundated by a flood similar to that of 1964 by 120,000 acres. If the 1964 level of floodplain development was maintained, damage of 34 million dollars would occur, 25 million less than occurred in 1964. If, however, development on the floodplain continues at the same rate as in the past, by 1980 a flood equivalent to that of 1964 would cause 71 million dollars damage, 13 million more than occurred in 1964 with only 7 reservoirs in operation. Thus, additional reservoirs beyond those already authorized would be required just to hold annual flood losses at the present level.

In the absence of a flood management program we can expect losses to continue to mount despite heavy public investment in con-

FIGURE 3
INUNDATION-DAMAGE RELATIONSHIPS FOR CONDITIONS IN THE FLOODPLAIN IN 1964 AND 1980, WILLAMETTE RIVER, OREGON



trol structures. When losses reach a high enough level, more expenditures are made for flood control structures and the cycle continues until, theoretically, investment in reservoirs is sufficient to provide a level of protection that would never permit the river to exceed its banks. Attempts to provide this level of control are not only economically inefficient, but according to hydrologists, physically impossible.

In addition to efficiency considerations, a flood prevention program based solely on control structures lacks flexibility. Other potential benefits, now unforeseen, but far more important, may be forgone because flood control and other purposes are not always complementary in the operation of reservoirs. To cite an example, consider Fern Ridge Reservoir, which was constructed primarily for flood control in 1941. Recreational uses have increased annually and recreationists propose extending the season in which the reservoir is held to full capacity. However, to be of maximum value for flood control, the reservoir storage must be increased in anticipation of fall floods. The point is, a continued policy of limiting flood control to structural measures may someday result in a valley with development to the banks of the river and a system of reservoirs that must be operated primarily for the purpose of flood control. Little opportunity for changing the regulation for other uses will be possible under such conditions.

Efforts to reduce the annual absolute flood damage by flood protection measures alone have been unsuccessful. What are the deficiencies in this program and what changes might be made to more effectively achieve flood damage reduction?

II
CONDITIONS NECESSARY FOR AN EFFICIENT FLOOD MANAGEMENT PROGRAM

A. Knowledge of Flood Hazard and Economic Loss

The first condition necessary for an efficient flood management program is that owners or potential owners of floodplain lands have an awareness of the flood hazards for specific land areas and the potential flood losses associated with a given use. Assessment of flood hazard is necessary before any valid economic evaluation can be made of the suitability of floodplain land for a specific use.

1. Economic Investment Criteria

A method commonly used by investors in determining the feasibility of an investment is capitalization of income. The value of land and adjunct improvements is established by its productivity or anticipated productivity. Value may be calculated by capitalizing annual income by the formula $V = (I-C)/r$ where V = value, I = gross annual income, C = costs of production, and r = rate of return on investment. If a change in any of the variables is anticipated, the present value is more adequately reflected by the summation of future flows of income and costs over a period of time by the formula: $V = \sum_{t=1}^{T} \frac{(I-C)}{(1+r)^t}$, where T = time horizon in years.

If this principle is used, the annual flood losses become a component of costs (C). The value of land susceptible to flood hazards would be less than comparable flood-free land by an amount equal to the annual losses caused by flooding divided by the rate of return. The decision as to whether or not to use a parcel of floodplain land would be guided by the alternative (opportunity cost) of investing in flood-free land.

The values of suitable flood-free land and the "going rate of return" are generally not difficult for an investor to ascertain. To determine the flood losses (costs) associated with the use of a flood hazardous area is another matter. In order to compute the annual flood losses for a given tract of land for a given use data must be available concerning:

1. The probabilities of various magnitudes of floods and the water stages (depths), the duration and time of occurrence, and the velocities associated with each possible flood.
2. The water stage-damage relationships for the contemplated use.

Lacking this information, the investor could not use economic criteria in planning floodplain land use.

2. Application of Economic Criteria

To what extent are the economic criteria outlined above used for making investment decisions in flood-prone areas? Use of the criteria hinges on an understanding and interpretation of flood probabilities and the associated water depths for specific parcels of land. Since this information is meager and not widely disseminated, knowledge of flood hazards is generally based on an individual's ability to interpret experiences of past floods. Because of the wide difference in both past experience and interpretation of this experience, judgment of flood hazard is subject to a high degree of variation. At one end of the scale are individuals who have experienced floods in a given area over a period of time and are knowledgeable of the lands subject to flooding. On the other end of the scale are individuals who have not experienced floods in a given area and are completely unaware of the hazard.

One would logically expect individuals knowledgeable of flood hazards to include potential losses from floods as a cost in their floodplain investment decisions and those unaware of the hazard to exclude the cost. However, an individual aware of the hazard but not a potential loss bearer might exclude the cost of flood losses in the same manner as one who was completely unaware of the hazard.

Comparison of flood damage by the 1964 flood in two areas of the Willamette floodplain supports this theory. One area with substantial damage was a new housing subdivision planned and built by real estate developers in the suburb of Keizer, north of Salem. The initial investment decision for this development was made by individuals who did not stand to bear the potential flood loss and consequently had little incentive to consider the cost of flood damage, even if they were knowledgeable of the hazard involved.

About two miles downstream in the Windsor Island area, flooding was also widespread. Though the whole island was seemingly under water, a closer examination after the waters had receded revealed that damage to buildings was negligible. Buildings had been constructed on higher elevations out of the reach of flood water. Most of the people residing in this area are long-time residents who had experienced several floods and were aware of the hazardous areas. They were also the potential recipients of loss stemming from their own floodplain investment decisions. Thus, evidence suggests that costs of flood losses were included in the investment decisions in the Windsor Island area but were excluded in the Keizer area. A logical conclusion is that many of the residents of the Keizer subdivision were unaware of the flood hazard when first locating in the area. If this is true, a program of mapping flood hazard information could lead to a more efficient use of floodplain lands if provisions were made to insure that prospective residents were aware of flood hazards prior to the time they acquired the property.

There is no question that once development is established in the floodplain incentives to remain are strong despite flood losses.

Roder[7] cites several reasons why people remain in flood hazardous areas.

1. The public may be reluctant to abandon fixed public investment in the area.
2. Some of the residents become attached to their communities and prefer to stay for psychological reasons.
3. Financial institutions holding papers of indebtedness on property exert pressure on residents to remain and rehabilitate.
4. Aid is often available for rehabilitation but not for relocation.

It is also likely that the inevitable drop in property value that follows a flood is an incentive for the owner to remain, especially in areas where the frequency of floods is not great. Rather than sell at a loss, an owner may stay until the post-flood hysteria has passed and then sell to the unwary at the pre-flood price.

3. Flood Hazard Information, a Prerequisite to Efficiency

In the Willamette Basin, the important question is not so much in regard to land use by present floodplain residents but by future potential dwellers. After completion of presently authorized reservoirs, a larger part of the present development will be protected. Historical flood probabilities will be altered which will prevent judgment of hazards on the basis of past experience. Since flood hazard information is the basis for evaluating the feasibility of developing a given parcel of floodplain land, there is little opportunity for use of economic criteria unless these data are available. It was estimated that the benefit-cost ratio of a flood mapping program in Northeastern Illinois was 40 to 1.[8]

A program of mapping and dissemination of flood hazards information is an essential step to a more efficient use of floodplain lands. True, all potential investors might not "act rationally" in light of the information but it is difficult to conceive of investors knowingly making investments in developments that have a high probability of financial failure. An important point here is that the information should reach the potential owner who would bear the loss.

Information on stage-damage relationships for various types of commercial and residential structures should also be made available. Some of this information is presently available in government

7. G. White, *et al.*, Papers on Flood Problems 77-78 (University of Chicago Dept. of Geography Research Paper No. 70, 1961).

8. J. Sheaffer, Economic Feasibility and Use of Flood Maps, a paper presented before the Highway Research Board Conference, Washington, D.C., Jan. 1964.

agency files. Widespread distribution of this information would give managers a better understanding of potential losses for given land uses.

The availability and use of flood hazard information alone will not assure efficient floodplain land use for reasons explained later; however it should reduce losses while other management practices are being considered, and it is a necessary perequisite to implementation of an efficient flood management program.

B. Use of the Most Efficient Flood Management Practices

The second condition necessary for an efficient flood management program is that the most feasible flood management practices be utilized to alleviate flood losses. There are several alternative practices available for reducing flood losses.

1. Alternative Private Management Practices

The alternatives open to private floodplain managers as outlined by White[9] include: (1) bearing the loss; (2) flood proofing measures to protect structures and contents; (3) emergency actions to remove and protect property during the flood; and (4) changes in land use. The optimum plan for an individual manager may include one or a combination of these adjustments.

If the floodplain manager is to consider the various adjustments that might be made to reduce flood losses, not only must knowledge of the alternatives be available but also cost of these adjustments and the value of the reduction in flood losses associated with them.

If potential flood losses and costs of alternative adjustments were known and used, the pricing system would tend to direct the most efficient use of each individual parcel of land. This does not mean, however, that the sum of the individually derived decisions will result in optimum social use. This is because the pricing system does not consider some important interrelationships between land uses on the flood plains. For instance, one user may find it economically feasible to build a dike around his land which would cause flooding on adjoining land. Although the dike may cause losses to owners of adjoining land that are greater than the gain to the owner of the protected land, there is no pricing mechanism operating to discourage this social cost. On the other hand, a dike built by one owner may protect another's property. In this case, even though others may

9. G. White, Choice of Adjustment to Floods (University of Chicago Dept. of Geography Research Paper No. 93, 1963).

be benefited, unless they are willing to contribute to the cost of the dike voluntarily, the pricing system will not effectively discriminate between those who want the service and those who do not.

Another type of social cost that has been recognized is what is commonly referred to as "indirect damage" in project analysis. Examples are the loss in income to workers unemployed because of interruption of production in plants located on the floodplain and costs of rerouting traffic because of flood-caused road damage. Since prices will not necessarily direct floodplain land uses and management practices that will in all cases result in optimum social use, an institutional arrangement that will perform this function is needed.

Although much has been written outlining the details of adjustments available to private managers for reducing flood losses and studies indicate that in many cases they are economically feasible,[10] adoptions by private managers have been meager. This is explained in part because knowledge of flood hazards is incomplete. Unless there is reasonable knowledge of the losses that might be sustained by using flood lands, users can hardly be expected to adopt measures to reduce these losses.

The other factor that partially explains why these adjustments have not been adopted is a lack of institutional arrangements for effectively dealing with the external social costs and benefits.

2. Alternative Public Management Practices

The major public policy for dealing with the social costs of floods has been federally financed protective works for the benefit of "to whomsoever they may accrue." Because of this policy, the choice in the Willamette Basin, as in most areas of the United States, has been between incurring flood losses or investing in reservoirs and other flood protection structures. Since losses are borne primarily by floodplain dwellers and costs of protection are borne by the public at large, it is easy to understand why the floodplain resident prefers protection over other alternatives. Given the lack of knowledge of flood hazards and the incentive to pass on costs of flood protection to the public, floodplain land uses are not likely to be the most efficient.

One of the criticisms often leveled at the "irrational" flood-plain dweller is that he does not consider the opportunity cost of locating outside the floodplain. How do public agencies consider the alternative means of meeting needs? In addition to benefits from reducing losses through protection of present development on the flood-

10. *Id.*

plain, benefits resulting from "land enhancement" are estimated. Land enhancement benefits accounted for about 14 per cent of the annual benefits in the Corps' 1950 Willamette River development plan. These benefits are ordinarily estimated without considering the opportunity of locating in areas other than the floodplain. An implicit assumption is made that further development on the floodplain is the most economical means of meeting needs. Considering the large supply of available land outside the Willamette floodplain, this is not a valid assumption. The result of such a practice is that public investments are made in protective works which gives further incentive to floodplain encroachment and may lead to a further aggravation of the problem that the investment was made to solve. Any estimation of future benefits stemming from "land enhancement" values should consider the opportunity costs of locating outside the floodplain. Such an analysis would yield an estimation of *net* benefits. As long as public agencies follow a policy of subsidizing development of floodplain lands, managers of these areas can hardly be blamed for obliging.

While flood protective works have been the major public means of coping with the flood problem in the Willamette, other measures have been used in conjunction with rather than as alternatives to flood protective works.

Watershed land treatment measures such as keeping plant cover on the soil and strip cropping help reduce peak runoff, and farmers are given technical as well as financial aid for using these practices. The degree to which land treatment measures reduce flood runoff is still a matter of controversy, but there is general agreement that these measures are more important for solving erosion, sedimentation, and other problems than for solving flood problems on the main stem of a river.

Public flood warning and relief measures are well known and were extensively used before, during, and following the December flood on the Willamette. The Weather Bureau, the Red Cross, National Guard, Small Business Administration, and a host of other public agencies served in various rescue, cleanup, and rehabilitation capacities. An important consequence of relief measures is shifting of costs of floods from private to public through extensive relief measures which gives further incentive to inefficient use of floodplain lands.

Another alternative available in theory but not in practice is flood insurance. The American Insurance Association has studied the feasibility of flood insurance and concluded that "specific flood insurance on fixed location properties in areas subject to recurrent floods cannot be successfully written."[11] Adverse selection and the difficulty and cost of accurate evaluation of risk are the major reasons why insurance companies have not ventured into the flood-insurance field. Because of adverse selection the spreading of risks essential to sound insurance is lacking, since all properties insured would be subject to periodic loss by flooding. The spreading of risk from year to year appears to be more of a problem than spreading risks across individuals or geographic areas. A catastrophic flood in a given year could result in heavy losses that could bankrupt even a large company.

One suggestion is for the Federal Government to underwrite the insurance companies against catastrophic losses.[12] The reasoning is that since different river basins are hydrologically almost independent of others, the Federal Government could absorb the losses resulting from the large infrequent floods without difficulty, and the insurance companies could insure against the smaller floods.

Congress enacted the Federal Flood Insurance Act in 1956,[13] but no flood insurance was ever written because of a lack of funds. In the opinion of many, this law would in its present form increase flood damage because the rate structure would encourage further development in the floodplain. At a conference of planners and engineers sponsored by the Council of State Governments,[14] several changes in the law were recommended. Among other things, this group recommended that the law should clearly and specifically require the establishment of rates in accordance with risk and make all future expenditures of federal funds for protective works yielding primary localized benefits contingent upon regulatory action by state and local governments to control further encroachment upon floodways.

Schemes to reduce the incentive for floodplain occupancy by associating costs of flood protection measures with beneficiaries have been proposed. Renshaw[15] suggests a policy of (1) levying taxes on floodplain uses that cause losses to others and (2) compensating users receiving the damage.

Krutilla[16] suggests a similar but more comprehensive scheme of compulsory flood insurance in which each floodplain occupant would

11. Interstate Conference on Water Problems 3rd Annual Meeting Report, Chicago, Illinois, Dec. 5-6, 1960.

12. G. White, *supra* note 7, at 35.

13. Federal Flood Insurance Act, 42 U.S.C. sec. 2401-21 (1956).

14. Conference on Flood Plain Regulation and Insurance, Chicago, Illinois, December 1-2, 1958.

15. G. White, *supra* note 7, at 29.

16. Krutilla, *An Economic Approach to Coping with Flood Damage*, 2 Water Resource Research (1966).

be charged a premium based on the loss individual occupancy caused others, the losses to which the occupant was subjected, plus the administrative costs of the program. Premiums would be used to pay for losses and to finance feasible flood damage reduction measures. The excess of benefits over costs for any flood reduction measure would be used to reduce insurance premiums.

An institutional arrangement for dealing with flood problems currently receiving attention is land-use regulation. This involves establishing and enforcing various zoning, building codes, and subdivision regulations for the purpose of reducing flood losses. The primary advantages of land-use regulation are that it could be integrated with existing federal policy. According to a spokesman for the Corps:[17]

> It appears that ample authority exists, not only for the Corps of Engineers but for other Federal Agencies as well, to recommend in project reports that local agencies regulate or control the use of the floodplain as a condition of Federal participation in the construction of flood protection works. One must look for reasons other than Federal authority or policy to explain why floodplain regulation has not been recommended more often in the past as a method of providing flood damage reduction.
>
> To summarize, the Corps of Engineers may, under existing authority, recommend that state or local governments regulate the use of the flood-plain to prevent development which would add to the hazard or risk of flood damage. This authority has been reflected in the various administrative devices implementing acts of Congress. But the actual implementation of the policy—the action required to accomplish floodplain regulation or zoning—is a function of state and local governments in the exercise of the police power.

Thus, it appears that the Corps of Engineers stands ready to cooperate in a floodplain land-use regulation program. The flood mapping program for the Upper Willamette recently completed by the Corps at the request of Lane County reflects this policy. But the impetus for further work of this nature must clearly come from state and local governments.

III
DEVELOPMENT OF A FLOOD MANAGEMENT PROGRAM

Flood control structures have not been effective in reducing flood damage in the Willamette Basin, and in the absence of a flood man-

17. G. White, *supra* note 7, at 183-84.

agement program, flood losses will continue to mount despite heavy public investment in control structures. Furthermore, continuation of a flood control policy without supporting management practices could result in an inflexible water management program as control structures must be operated primarily for flood control.

It is not the intent of this article to minimize the worth of existing storage reservoirs. Little doubt exists that damage from the 1964 flood would have been much greater had not these controls been in place. As to how much less development there would be in the floodplain in the absence of reservoirs is a moot question. The investment has been made in reservoirs and permanent structures which will remain, as will most of the present development in the floodplain.

Additional reservoirs that have been authorized will further decrease the area flooded. Whether or not flood damage will continue to mount despite additional structural control will depend on policy regarding flood management. Several alternative flood management practices are available but few have been used because of: (1) inadequate knowledge of flood hazards, and (2) the policy of federal subsidization of flood control structures to the exclusion of all other practices.

A necessary step in solving the first problem is the completion of the flood hazard mapping program for the entire Willamette River floodplain. The delineation of zones subject to flooding by various magnitudes of floods will provide individual managers and planners a basis for assessing the probability of flooding on specific parcels of land. Widespread distribution of this information should lead to a better understanding of flood hazards, which is a prerequisite to any flood management program. Flood hazard information provides the foundation of basic physical data needed to assess alternative flood management practices.

The second problem involves economic efficiency. Economic efficiency is now a major consideration in river basin planning. Senate Document 97, the national guide for basin planning, states that

> planning for the use and development of water and related land resources shall be on a fully comprehensive basis so as to consider . . . all relevant means (including nonstructural as well as structural measures) singly, in combination, or in alternative combinations reflecting different choice patterns for providing such uses and purposes.[18]

18. Policies, Standards, and Procedures in Formulating, Evaluation and Review of Plans for Use and Development of Water and Related Land Resources, S. Doc. No. 97, 87th Cong.

Implementation of this policy in the form of a flood management program will require several changes in planning procedures. First, it will be necessary to devise a suitable methodology for adequately evaluating the effects of the various alternative measures in reducing flood losses and, second, it will be necessary to devise and improve institutional arrangements for implementing those measures deemed most desirable.

The key to devising an efficient flood management program lies in the ability to separate the private costs and benefits of floodplain occupance from public (social) costs and benefits. If private and public costs and benefits can be associated with specific land uses and flood management practices, the economic efficiency of various proposed management schemes could be evaluated.

A suggested method for determining private and public costs and benefits follows. Flood damage data should be collected for broad categories of use, including agricultural, recreational, housing, and industrial by flood hazard zones. These data would provide a basis for estimating private and public flood losses for each type of use in each flood hazard zone.

A simulation model could be used to test the economic efficiency of various management schemes. Projected private and social flood losses (costs) could be estimated for several assumed conditions including:

(1) Authorized flood control and no land use restrictions or other flood management practices.

(2) Land use restrictions on those land uses in zones associated with high social costs.

(3) Land use restrictions and other flood management practices including flood proofing measures, public acquisition of the most hazardous areas, and a better flood warning system.

The cost of each management scheme could be estimated and compared with the related damage reduction benefits. Policy makers would have estimates of the economic efficiency for a range of alternative flood management proposals. As a byproduct, data from the model would provide estimates of private and public costs and benefits that could be used as guidelines for establishing equitable cost sharing.