Increasing the Economic Efficiency and Affordability of Storm Drainage Projects

by

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Colorado Water

Resources Research Institute

Completion Report No. 126

Colorado State University

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Contract Report For

Colorado Commission on Higher Education
State Supported Organized Research Program
1550 Lincoln Street, Second Floor
Denver, Colorado 80203

with funding assistance by

Colorado State University Experiment Station
Fort Collins, Colorado 80523

Colorado Water Resources Research Institute
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Norman A. Evans, Director

September 1983

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FOREWORD AND ACKNOWLEDGMENTS

This report on improvements to the evaluation methods used for storm drainage projects was completed by the Department of Agricultural and Natural Resource Economics at Colorado State University under contract with the State Supported Organized Research Program of the Colorado Commission on Higher Education. Research for this report was conducted over the period from September 1982 to August 1983.

The evaluation improvements discussed in this report are designed to increase the economic efficiency and affordability of storm drainage projects. These improvements should be useful to: (1) city managers and city councils who must decide on the appropriateness and funding levels of proprosed drainage projects, (2) city engineers and planners who must determine the nature of stormwater flooding hazards and develop measures for dealing with the problems that exist, (3) city staff or outside consultants charged with formulating and evaluating alternative stormwater management plans, and (4) concerned citizens and public interest groups who wish to participate in the process of selecting the best solution for their community.

We have attempted to be as non-technical as possible in order to reach the largest possible audience. Further information and assistance can be obtained by contacting either of the authors.

This report benefited from nearly continuous interaction and comments from the staff of the Fort Collins Engineering Department and the members of the Fort Collins Storm Drainage Board. We are indebted and grateful to these individuals.

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September, 1983

INTRODUCTION

The purpose of this report is to explain several improvements to the conventional analysis of storm drainage projects. The intent of these improvements is to increase the efficiency of public expenditures on storm drainage. The improvements proposed are well grounded in the economic theory of cost-benefit analysis and are not radical ideas, but simply represent corrections of deficiencies in many present evaluations.

The need for these extensions arises out of the conflict between increasingly tight municipal budgets and growing demands for storm drainage improvements. For various reasons the financial resources of cities are not keeping pace with the demands placed upon them. At the same time, continued growth of many cities is necessitating the provision of an essentially new service--storm drainage.

Except in the wake of severe flooding, requests for large expenditures on storm drainage systems are not likely to be popular. Storm drainage improvements must compete with other more popular municipal projects, such as swimming pools and performing arts centers. It is not sufficient that storm drainage improvements are necessary for the physical and economic well being of the community. These improvements must also be economical.

To be economical does not simply mean cheap or low cost, though that is certainly part of it. Municipal decision-makers are obviously interested in minimizing the cost of storm drainage improvements so as to be able to fund these projects along with the other functions of the city. But economical also refers to benefits and responsible city administrators realize that they should not only cut costs, but also maximize net benefits. That is, storm drainage costs must be affordable, but also yield the largest possible surplus of benefits over costs.

Four improvements to the conventional cost-benefit analysis of storm drainage projects are presented here. These improvements refine the conventional analysis such that projects emerging from the analysis with a recommendation to adopt are more affordable and efficient. The improvements relate to the: (1) level of protection provided by the project, (2) timing of project implementation, (3) disaggregation of a drainage into reaches and interdependence, and (4) mixing of structural (e.g. dams, levees, channelization) and nonstructural (e.g. land use planning, insurance, warning systems) adjustments to flooding.

The nature of the improvements is explained and illustrated using examples from the City of Fort Collins, Colorado. Fort Collins provides a typical example of the situation many small to intermediate size, growing cities are facing. A major portion of the city has no provision for handling stormwater runoff. Development has taken place within the natural flood plains of several drainages and new development is exacerbating the flood hazard. While there has been no major flooding in the city in over fifty years, it is estimated that a major storm (i.e. 100-year event) could cause $23 million of direct flood losses at the present time and that these losses are likely to double in the next twenty-five years.

The estimated cost of improvements to storm drainages recommended by master plan studies of the drainages in Fort Collins is $32 million. This amount represents more than five times the city'y annual budget, and debt payments on such an expenditure at a modest 10 percent interest would exceed half of the annual budget. It is not surprising that the

Fort Collins City Council has been less than enthusiastic about pursuing such improvements.

Two specific drainagers in Fort Collins and their master plans are used to illustrate problems with and corrections to standard evaluation techniques. The Dry Creek drainage runs in a south eastern direction through the northern part of the city; a map of the drainage is given in Figure 1. The Spring Creek drainage flows to the east through the central part of the city; a map of the drainage is given in Figure 2. Master plans for these drainages were prepared for the city by a major engineering consulting firm in Denver.

Level of Protection

The conventional analysis of storm drainage improvements typically assumes projects designed for a standard event, usually the 100-year flooding event. That is, projects are designed to accomodate runoff from storms having a one in a hundred chance of occurring in a given year. From an economic standpoint, however, the 100-year level of protection may not be optimal. The costs of the project may likely be reduced while simultaneously increasing the overall net returns from the project by a protection level of less than the 100-year event.

The net benefits of a drainage project are equal to the difference between the benefits of the project, measured in terms of reduced expected losses, and the cost of the project. The value of reduced expected losses is equal to the difference between the value of expected losses with and without the project. Since expected losses without the project are a constant value, the net benefits of the project will be maximized by selecting that level of protection which minimizes the sum of expected losses with the project and the cost of the project.

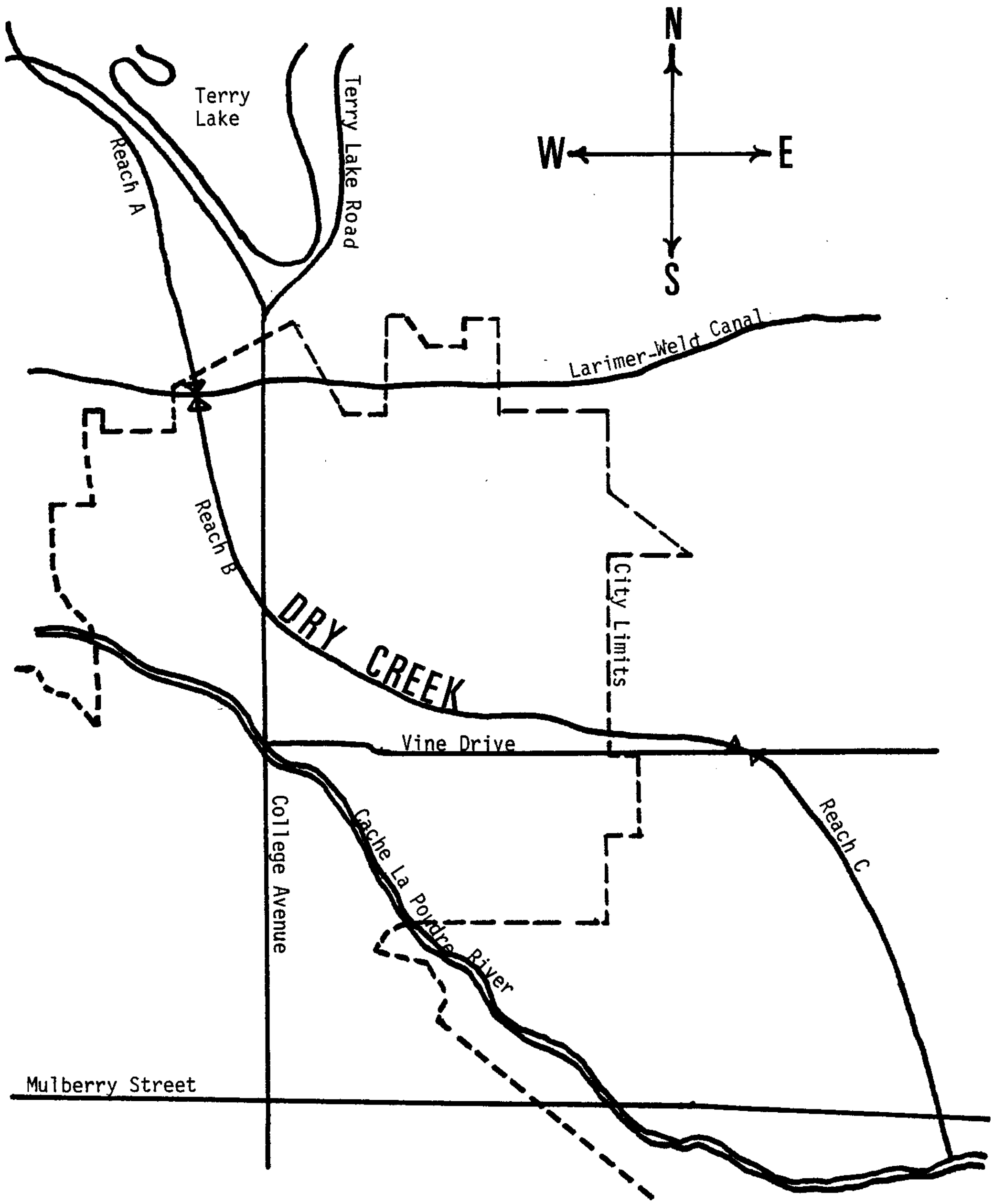

Figure 1. Map of Dry Creek

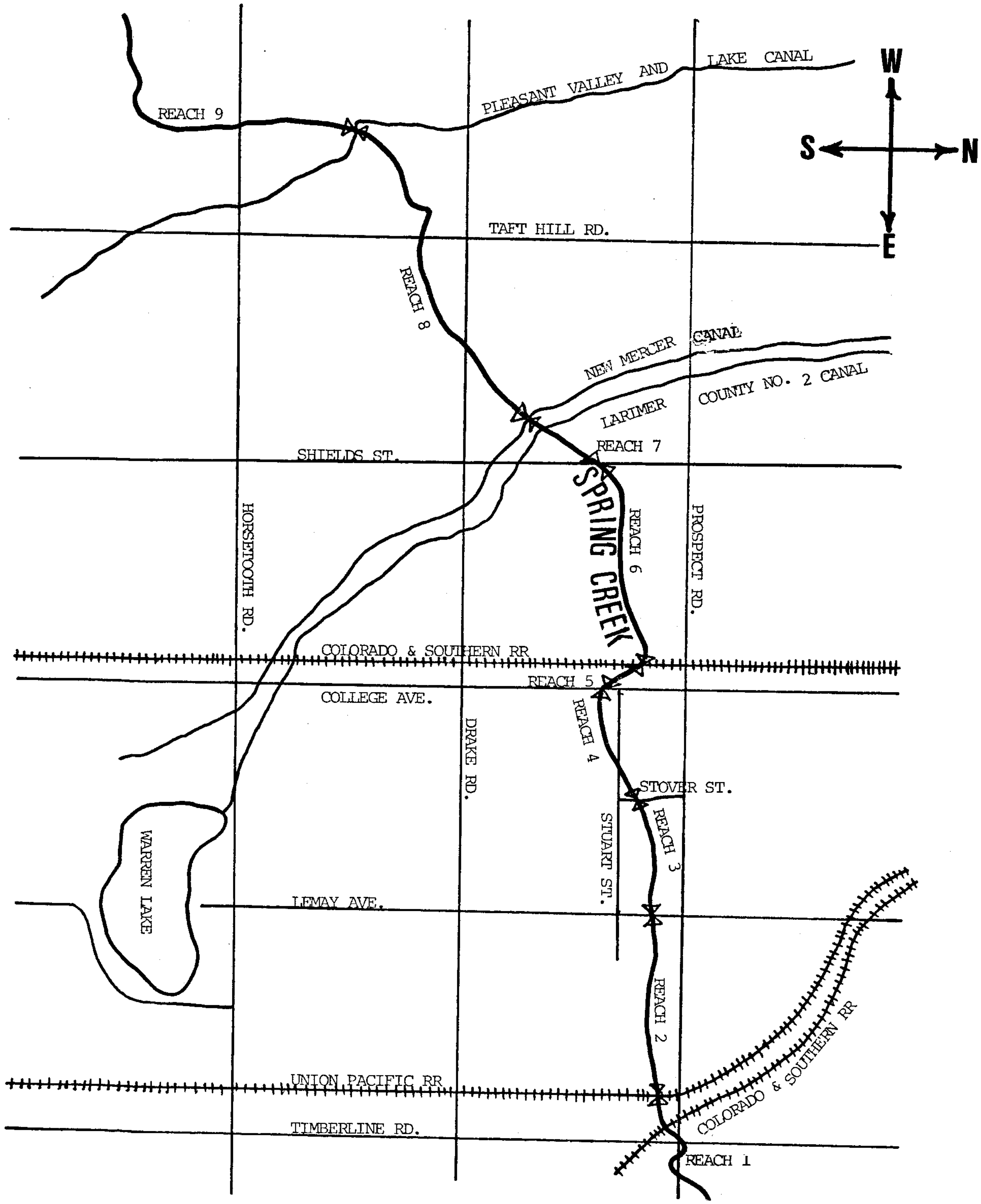

Figure 2. Map of Spring Creek

In other terms, the net benefits (NB) of a drainage project are calculated as:

$$NB = B - C$$

where: B = benefits, measured in terms of reduced expected losses; and

C = cost of the project.

The benefits (B) of the project are calculated as:

$$B = L_{w/o} - L_w$$

where: $L_{w/o}$ = expected losses without the project, and

L_w = expected losses with the project.

Therefore,

$$NB = L_{w/o} - L_w - C$$
$$= L_{w/o} - (L_w + C)$$

and since $L_{w/o}$ is constant it can be seen that NB are maximized when $(L_w + C)$ is minimized.

The value of expected losses with protection (L_w) and the cost of the project (C) are inversely related with respect to the level of protection provided by the project. As the level of protection increases, the expected losses decrease, but the cost of the project likely increases. That is, a trade-off exists such that lower expected losses can be achieved by incurring higher project costs, or lower project costs can be realized by accepting higher expected losses. The economically optimum level of protection minimizes the sum of these two costs.

For example, the City of Fort Collins' master plan for its Spring Creek drainage calls for $280,900 of structural adjustments in reach 5 of the drainage. These adjustments are designed for the 100-year flooding event and are expected to have a present value of reduced losses equal to $768,584. That is, the proposed structural measures designed for the 100-year event would yeild a net present value of $487,684 or a benefit-cost ratio of 2.74.

Both the net present value and the benefit-cost ratio of the project can be increased by reducing the level of protection. Figure 3 shows the estimated values of expected flood losses, costs of structural adjustments and the total costs for levels of protection ranging from 0 to the 100-year event. The minimum total cost level corresponds with the optimum protection level.

The optimum level of protection is at approximately the 5-year level. The estimated cost of the structural adjustments is $21,350 and the present value of expected benefits is $565,760. That is, the 5-year level of protection would yield a net present value of $544,410 and a benefit-cost ratio of 26.50, as compared with $487,684 and 2.74, respectively, for 100-year protection. Optimum sizing of the project results in an increase in net benefits of $56,726 and a reduction in construction costs of $259,550.

For this case, a relatively low protection level is optimum because of the nature of the flood loss curve shown in Figure 3. The total value of reduced flood losses is equal to the area under the flood loss curve up to the level of protection being considered. Since this curve is relatively high and steep over the smaller levels of protection, the implication is that most of the benefits of protection are exhausted by relatively small projects. Moreover, as shown by the cost of adjustments curve in Figure 1, these adjustments are relatively cheap. More protection, however, provides only small additions to benefits, but large additions to costs.

It should be noted that the curves in Figure 3 are representative of the situation and are not intended as precise measures. The flood loss

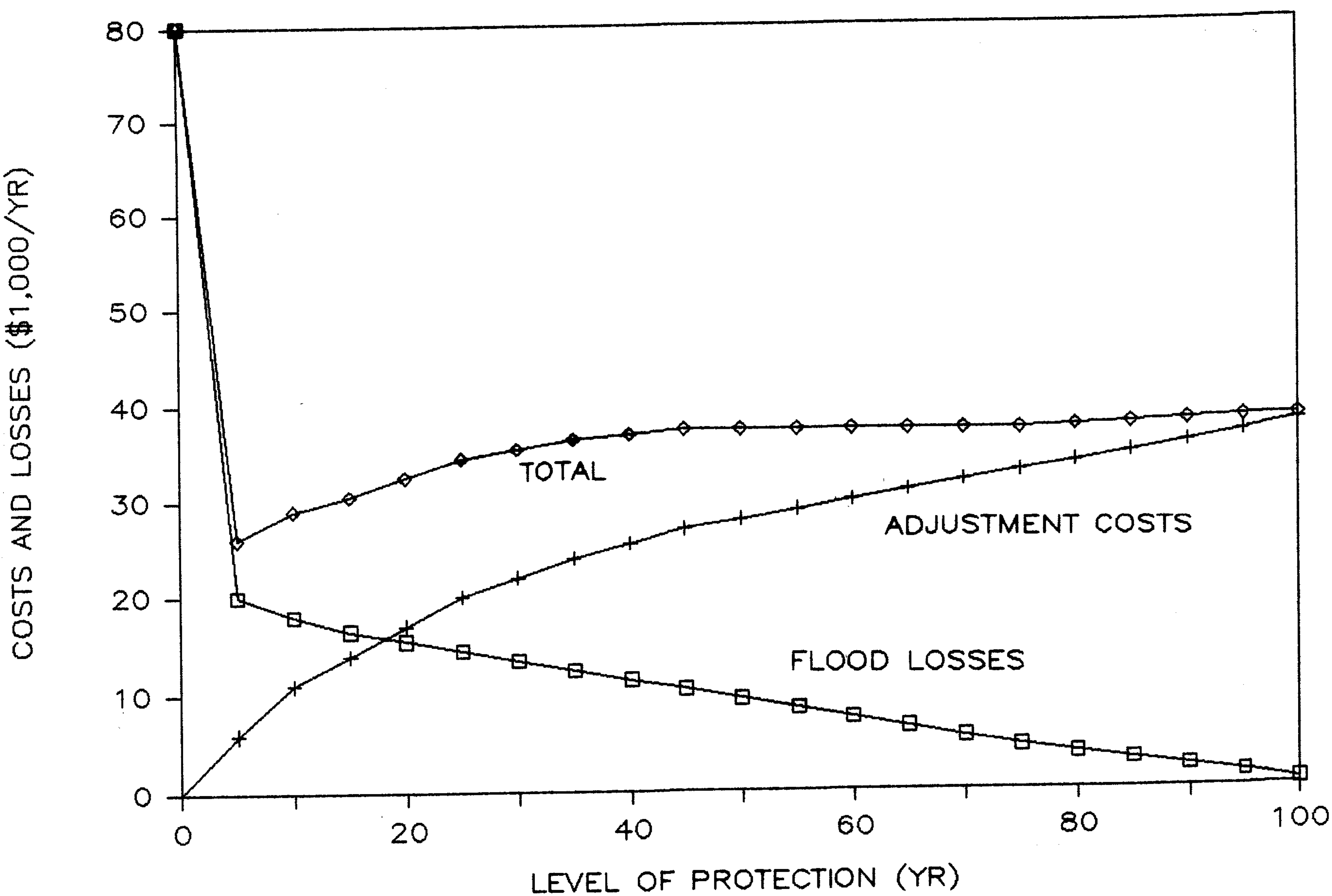

Figure 3. Optimum Level of Protection: Reach 5 of Spring Creek

curve is reasonably accurate, but the adjustment cost curve is extrapolated from data in the master plan that pertains to larger flood events. The adjustment cost curve may not be continuous, due to lumpiness of adjustment costs, so that the optimum level of protection may be further to the right. An improved analysis would measure this cost relation more accurately. But the optimum is definitely less than the 100-year protection level and is probably no greater than the 25-year protection level.

Finally, the economically optimum level of protection may not correspond with the socially optimum level. The 5-year level of protection leaves residual losses of $202,824 to be borne over the 50-year life of the project; there is no threat of loss of life. Aversion to risk and inconvenience may determine a desired level of protection greater than the 5-year level.

The level of acceptable risk is a public judgement, not the decision of engineers or economists. Elected representatives appropriately must decide the issue, but they should do so with full information. The analysis of projects should inform decision-makers of the trade-offs between protection and the costs and net benefits of the projects. Decision-makers may rationally decide that the public interest is best served by accepting some risk in order to save public resources for other purposes, or they may decide that no risk is acceptable. The decision is theirs and should not be precluded by the analysis.

Timing of Projects

The conventional analysis typically evaluates the feasibility of implementing drainage projects in only the present time period. However, delaying a project may increase its benefits more than its costs. The optimum time to implement a project is when its net benefits are maximized. Moreover, by extending the conventional analysis to determine the optimum timing of projects, the way is opened for optimally scheduling drainage projects along with other public investments.

The benefits of a proposed drainage project may increase over time due to urbanization, which increases both the quantity and the value of the property to be protected. That is, the benefits of the project, as measured by the value of losses averted, may grow significantly over time. The benefits of a project are calculated as the difference between the present value of the future stream of expected losses with and without the project. Figure 4 illustrates how these benefits are influenced by the passage of time, assuming growth in the value of property at risk. If the project is constructed in the present time period ($t = 0$) and has a life of n years, then the present value of the benefits equals area (A + B). On the other hand, if the project is delayed until $t = t^*$, then the present value of the benefits equals area (B + C). If area C is greater than area A, then the benefits of the project are increased by the delay.

Delaying implementation of a drainage project, however, also has associated costs. The longer the delay, the greater are the expected losses, since the floodprone areas are exposed to the risk of flooding for a longer time and the value of property at risk is likely rising. Furthermore, the costs of implementing the project (e.g. construction costs, land acquisition expenditures) may also be growing.

The issue of timing is also often confused with the effects of inflation. While increases in the general price level (i.e. inflation) may cause some distortions in the allocation of resources, it is

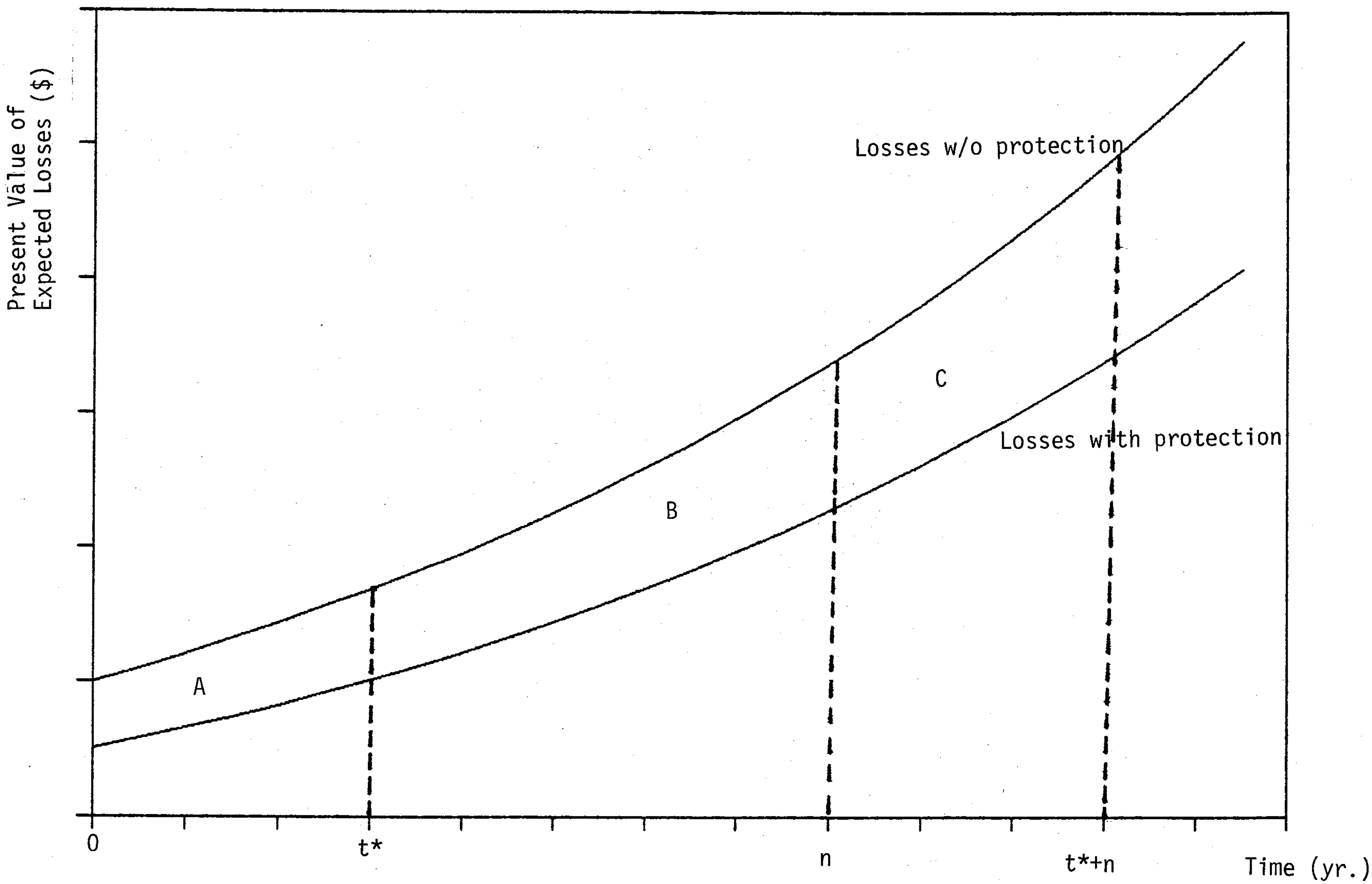

Figure 4. Influence of Time on the Present Value of Expected Losses With and Without Protection.

nevertheless a pecuniary phenomenon which should not be mistaken for future gains in the value of real output from the investment under consideration [Krutilla and Ciccletti, 1973]. Growth induced benefits and costs, therefore, are properly included in the analysis only when calculated in constant dollar terms. Mixing nominal and real values in the same analysis will render the conclusions erroneous [Henke, et. al., 1975].

If the costs of implementing the project are added to the value of losses with protection in Figure 4, then the net benefits of a project implemented in time period t* can be conceptualized as shown in Figure 5. That is, the net benefits of a project are equal to the difference between the value of losses without protection and the sum of losses with protection and the cost of the project providing the protection.

If the value of expected losses without protection is initially greater than the sum of expected losses with protection plus the cost of the project, then the situation is depicted by Figure 5(a). This is a situation where the project is feasible in the present time period, but may yield greater returns by delaying the project. That is, the net benefits of the project represented in Figure 5(a) would increase by the difference between area U and area S if it were delayed until time period t*. From an economic standpoint, the optimum time to implement the project is that t* such that area (W + U) is maximized.

Implicit in the above discussion is the assumption that funds will not be available for modifying or replacing in the future projects presently being considered. If funds are expected to be available for similar projects in the future, there is less justification for delaying economically feasible projects. Uneconomical projects may still benefit from delay. But the assumption of limited future funds seems justified

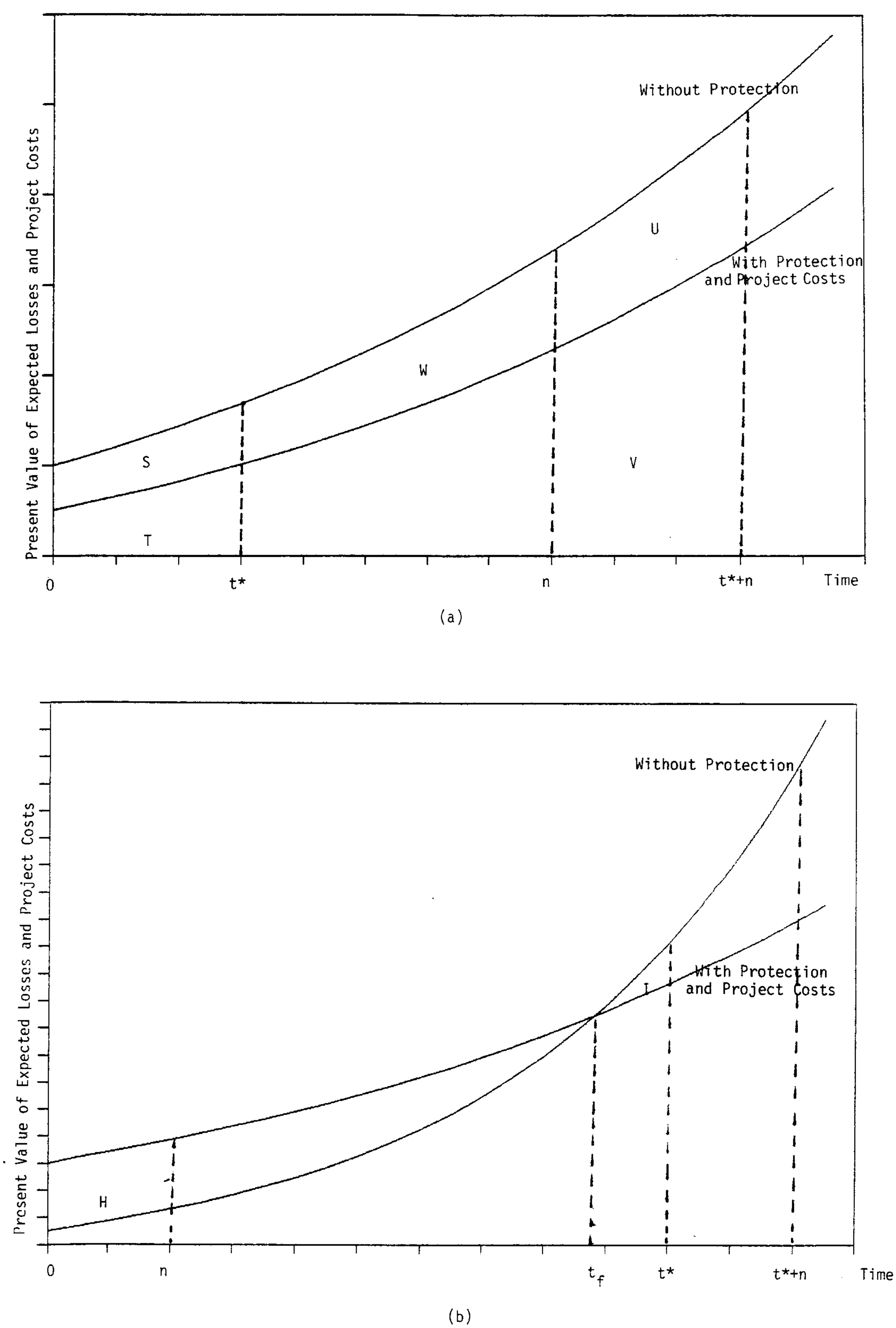

Figure 5. Present Value of Expected Losses and Project Costs.

in light of the current plight of municipal finances. That is, fiscal imbalances are influencing municipalities to make careful expenditures that do not necessitate further investments in the future.

From a political standpoint, there is another issue. By waiting to implement the project until time period t*, expected losses equal to area S in Figure 5(a), which could have been averted by implementing the project in the present time period, are incurred. That is, while social net benefits are maximized by waiting until time period t*, it may be difficult for deicision-makers to explain to the public why these losses were not averted. Moreover, politicians are likely to value immediate returns more than future returns for the simple reason that they are more important in re-election campaigns. The economically optimum time to implement the project may not correspond with the politically optimum time. This should not affect the analysis, but may affect the adoption of the recommendations of the analysis.

Figure 5(b) represents another common situation with respect to timing. Conventional analyses often show a net present value of a project to be negative, but the project is still recommended, since future urbanization is anticipated to increase the expected returns. Such analyses are obviously confused. For example, in Figure 5(b), if a project with a life of n years is implemented in the present period, then negative net benefits equal to area H would be incurred. The project should not be adopted before time period t_f at the earliest and is optimally adopted at that t* which maximizes area I. Urbanization effects should be considered, but they should be used to optimally time projects, not arbitrarily recommend them.

The gains from optimally timing storm drainage improvements are illustrated by the Dry Creek drainage plan in Fort Collins. The master plan for this drainage recommends drainage improvements costing $4,401,300 and yielding expected benefits with a present value of $5,124,700. That is, the recommended improvements are expected to yield net benefits of $723,700 or a benefit-cost ratio of 1.16.

Much of the Dry Creek drainage, however, is not heavily developed. By delaying the recommended drainage improvements 10 years, growth within the drainage will increase the present value of expected benefits to $10,740,800. If construction costs are assumed to increase at the rate of inflation, so that the present value of constructing the project remains $4,401,300, then the net benefits of the project would be increased to $6,339,500 and its benefit-cost ratio to 2.44 by delaying implementation 10 years.

Again, political considerations may dictate an earlier implementation date. But since waiting does increase the net return of the project, this project should not be a high priority item in current budgets.

Disaggregation and Interdependence

Conventional analyses of storm drainage projects typically divide the drainage into reaches. These divisions, however, are often not fine enough to identify the sources of expected flooding losses, so that adjustments are more extensive and expensive than necessary. Also, an associated disaggregation problem in many conventional analyses is that while the reaches of a drainage are generally considered hydrologically interdependent, they are sometimes treated as independent in the economic analysis, thus leading to an erroneous counting of benefits and costs for drainage projects. These two problems are addressed in turn below.

The conventional analysis calculates expected losses by using damage curves and estimates of property values at risk. Damage curves represent damage as a percent of the total structure value for varying flood depths. Structure values are estimated from field survey's of the project area. Estimates of individual structure values are aggregated to obtain value estimates by reach.

Structure values and expected damages are not generally homogeneous by reach. Some segments of a reach may be more important than others in driving the value of expected losses for the reach. The conventional analysis, by treating the reach as a whole, may devise and justify adjustments for the reach which are not necessary for all parts of the reach and may even fail to correct the major source of the expected losses.

For example, reach 8 of the Spring Creek drainage in Fort Collins is expected to incur average annual damages of $182,000. In response to these losses, the master plan calls for structural adjustments to the reach which will cost $367,500 and are expected to reduce losses over the life of the project by a present value of $2,742,000. That is, the project is calculated to yield a net present value of $2,374,500 and a benefit-cost ratio of 7.46.

Losses in reach 8, however, are driven by two houses at the upstream end of the reach. Together these houses are expected to incur annualized flood losses of $134,000 or 74 percent of the total losses for the reach. A relatively small culvert under a high road embankment immediately downstream of these houses causes these inordinately large expected losses. Moreover, none of the structural adjustments recommended for reach 8 addresses the flooding hazard to these houses.

What appears to have happened is that the designers of the master plan, by aggregating losses for the entire reach, lost sight of the major source of the expected flooding losses. As a consequence, the adjustments recommended fail to correct the most serious flooding hazard, while dealing with the less severe problems of the reach with relatively extensive and expensive measures. Correcting the flooding hazard to the two houses would likely cost less and yield a greater return than the measures proposed. The master plan is not efficient.

The second problem associated with the disaggregation of drainage relates to the miscounting of benefits and costs. It is standard engineering practice to incorporate hydrologic interdependence into the design of storm drainage improvement. The influence of any modification to the upstream channel would be considered in selecting a strategy for managing downstream flows. It is precisely due to this interdependence that channel improvements are initiated first along a basin's lower reaches. It is less common, however, for master plans to properly address the economic consequences of interconnected projects. Normally the analyst will array a series of alternatives each of which is consistent from the standpoint of the basin's hydrology. The economic analysis would then consist of the estimated net benefits, where the benefits are computed as the difference in expected losses with and without adopting the given measures. The with/without approach would make perfect sense if the economic effects of upstream improvements were completely separable from those downstream. However, such is normally not the case. A wide variety of possibilities could emerge, some of which may result in external benefits, while others may heighten losses elsewhere. The general principles for correctly measuring these impacts are discussed below. The example which follows illustrates the significance of the error which could result.

To simplify the problem it is assumed that the floodplain can be divided into two reaches, A and B. Reach A, the upper reach, is affected by a substantial catchment basin, whereas the basin affecting reach B is relatively small. Assume that the city is exploring the possibility of diverting flood flows at the lower end of reach A away from the urban area and then enlarging the channel to reach B to carry the residual flows.

There are two ways in which the benefits of the proposed projects could be estimated.

1. The difference in expected annual flood losses with and without protection would be determined without considering the effect of the diversion on downstream losses.
2. The impact of the diversion on downstream losses would be determined before introducing the channel improvement in reach B. Only then would the losses and subsequent benefits in reach B be estimated.

Which approach is correct? The first measures the reduction in losses. However, this simple with/without comparison hides the true effectiveness of the channel improvement. In using this approach it would be impossible to sort out whether the benefits in reach B are a result of the diversion or due to the enlarged channel. It is incorrect to assign all changes in annual losses to the improvements made in reach B. It would be better to analyze reach A first and correctly assign both the benefits upstream as well as downstream to the diversion. Only then should the influence of improving the channel capacity in reach B be estimated.

A similar line of reasoning applies to projects which are interdependent, but in a negative fashion. For example, assume that a channel improvement is under consideration for reach A. How should the benefits of the two projects be estimated? Following the same reasoning as offered above it would be incorrect to just subtract the losses with and without the projects. The improvement in reach A will worsen flood problems downstream. Hence, the true benefits resulting from improvements in the carrying capacity of the upstream channel should be computed as follows. First, the extent to which the improvment reduces damages and disruption in reach A would be determined. Next, the degree to which losses are expected to rise in reach B as a result of the increase in flood peaks downstream would be computed. The additional losses sustained in reach B would then be subtracted from the benefits estimated for reach A. Lastly, the influence of protecting floodprone areas in reach B is determined assuming that upstream improvements are in place. Failure to follow such a procedure could lead to ludicrous results. For example, in using the with and without approach, increasing the carrying capacity in reach A boosts losses in reach B, thereby obligating the city to undertake expensive measures there as well. Under such circumstances it appears that the net benefits of the two projects are sizable. In reality they could be quite small in that the city's actions upstream are creating problems downstream. It could even turn out that in some instances the overall costs of protecting reach A exceed the reduction in losses in both reach A and B. This point raises several interesting issues regarding the tradiational way of implementing protection, i.e. from the lower reachs to the upper reaches.

Dry Creek is one of nine drainages which crisscross the City of Fort Collins. The name aptly describes the nature of the channel. The upper reaches of the drainage are quite large, comprising almost 65 square miles. The relatively low flow which can be observed outside the city limits is intercepted by the Larimer-Weld Canal. As a consequence, the channel below the canal is dry under all but extreme conditions. The channel is so ill defined that in some locations it is nearly invisible, having been covered over by roadways, trailer parks, and parking lots.

Five alternative flood protection schemes were considered in drawing up the basin's master plan. All five options contained some mechanism to divert the upper flows away from the Larimer-Weld canal to the Poudre River. Safety of the residents below the canal's embankments appeared to be the overriding concern. However, benefit-cost analysis did play a role in selecting the final design. The consultant estimated the flood losses with and without the proposed projects and concluded that a 10 year channel improvement was warranted upstream, a diversion structure should be constructed at the Larimer-Weld canal to handle runoff from the 100-year storm, and the downstream channel should be enlarged to carry the residual flows. See Figure 1. The total cost of the recommended improvements was estimated to be $4.4 million.

In reviewing the master plan it became evident that the effects of interdependence were not recognized. Table 1a summarizes the costs and benefits of all three projects. The upstream measures appear to be well worth the investment, yielding almost $4.6 million and $700 thousand in benefits, respectively. Despite the negative net benefits resulting from improving the channel in the lower reach, the consultant recommended going ahead with the project. It was pointed out that the hydrologic interdependence of the reaches required the drainage be treated as a single system. Since 100 year protection was recommended for the upper reach, the same should apply elsewhere. Given the potential for growth in the lower reach, the consultant's recommendation appeared to be sound.

For reasons pointed out above, however, this approach is incorrect. Table 1b correctly separates the effects of the diversion from the channel enlargement in reach C. Note that the diversion is responsible for almost $1.3 million of reach C's benefits. This leaves only $171 thousand in benefits which can be attributed to downstream protection, which would cost $1.8 million to construct. When viewed in this light the project planned for reach C is no longer simply marginal; it should never be built.

Table 1a illustrates the incorrect calculation of the impact of the drainage project on flood damages. When interdependence is ignored it appears that the improvements in reach B are beneficial. Losses decline by $270 thousand per annum yielding discounted benefits of nearly $2.677 million. Since the total cost of projects slated for reach B amount to only $1.5 million. However, as Table 1b points out, the benefits are deceiving. The diversion constructed in reach A reduces losses in both reaches A and B, by $400 thousand and $200 thousand, respectively. And, once in place the residual losses in reach B are quite low, only $100 thousand. This means that the downstream improvements contemplated for reach B could at best result in benefits equivalent to these residual losses. A glance at the table reveals that $30 thousand in damages is still anticipated. Hence, the benefits accruing to reach B are only $70 thousand, not the $270 thousand indicated by the before-after analysis displayed in Table 1a.

Mixing of Adjustments

Typically, storm drainage management is attempted through structural means such as dams, levees and channel improvements. These structural adjustments have at least two major shortcomings. First, strucutural

Table 1a. Benefits and Costs for Dry Creek Drainage Protection Measures: Project Evaluation Without Considering Interdependence

	Annual Loss Before	Annual Loss After	Annual Benefits	Discounted Benefits (@8%)	Project Cost	Net Benefits
Reach A	601,000	163,000	438,000	5,358,266	800,000	4,558,266
Reach B	209,000	4,000	205,000	2,507,864	1,800,000	707,864
Reach C	131,000	7,000	124,000	1,516,952	1,804,000	(287,048)

Table 1b. Benefits and Costs for Dry Creek Drainage Protection Measures: Project Evaluation Considering Interdependence

	Annual Loss Withouth A & B	Annual Loss With A & B	Annual Benefits	Discounted Benefits (@8%)	Project Cost	Net Benefits Due to A & B	Total Net Benefits
Reach A	601,000	163.000	438,000	5,358,266	800,000	4,558,266	6,611,814
Reach B	209,000	4,000	205,000	2,507,864	1,800,000	707,864	
Reach C	131,000	21,000	110,000	1,345,683	0	1,345,683	

	Annual Loss Without C	Annual Loss With C	Annual Benefits	Discounted Benefits (@8%)	Project Cost	Net Benefits
Reach C	21,000	7,000	14,000	171,269	1,804,000	(1,632,731)

adjustments to flooding problems may provide a false sense of security to existing and potential floodplain occupants, thus leading to univise development in the flood hazard area and, subsequently, to increased flood losses. Second, structural adjustments are relatively expensive and may place a heavy financial burden on the resources of the community.

These shortcomings of structural measures can be ameliorated by the concurrent use of nonstructural measures for flood control. Such measures include land use control and management (e.g. floodplain zoning, outright purchase and land use conversion), flood insurance, warning and evacuation systems, flood proofing of structures at risk and relief and rehabilitation programs. The use of nonstructural measures, particularly land use control and management, can reduce floodplain encroachment induced by the increased level of protection. Moreover, nonstructural measures may be used directly to augment the effectiveness and, possibly, reduce the costs of structural measures.

The conventional analysis of storm drainage improvements typically treats structural and nonstructural adjustments to the flooding problem as being independent. That is, such analyses assume that either a set of structural measures are implemented or nonstructural measures are utilized. Rarely are mixes of the two evaluated. Moreover, such analyses typically pay little attention to the nonstructural measures, only vaguely alluding to land use planning as a possible, but difficult to evaluate, alternative. The reasons for such poor evaluations of alternative measures to reduce flooding losses vary from the analyst's lack of familiarity with nonstructural measures to the admitted difficulty of measuring the benefits and costs of some nonstructural measures.

There is, however, a strong pecuniary incentive for incorporating nonstructural measures in the mix of adjustments considered, even if their inclusion complicates the analysis. The use of nonstructural measures along with structural measures can significantly reduce the overall costs of storm drainage projects. Two examples of such savings follow.

The earlier example of reach 8 on Spring Creek provides an excellent example of the potential for the use of flood insurance. Recall that the master plan for this drainage recommends an expenditure of $367,500 for structural measures in this reach, but that 74 percent of the expected flood losses are attributable to two houses at the upstream end of the reach that are not protected by these structural measures. This appears to be an appropriate place for the use of flood insurance. Ideally, the properties should be insured against flooding losses until they are significantly damaged by flooding and then they should not be permitted to be rebuilt in the floodway.

The appraised values of the two houses is approximately $170,000 each. Flood insurance premiums would total about $1,000 per year. That is, insuring against the expected annual $134,000 of flooding losses to these houses would yield a benefit-cost ratio of 134 to 1. Moreover, if 50 percent or more of a house is destroyed by flooding, the federal flood insurance program prohibits reconstruction in the floodway.

Who should buy the insurance? It is less expensive for the city to buy the insurance than to protect these two houses with structural measures. However, this appears to be a situation where the benefits of the adjustment to flooding are strictly private, so that is it inappropriate for the costs to be borne by the public. Purchase of flood insurance by the homeowners resolves the flooding problem by internalizing both the benefits and the costs with the easily identified affected individuals.

Another example of the potential use of nonstructural adjustments is in reach 5 of Spring Creek. The railroad embankment at the upstream end of reach 5 currently also serves as a detention dam for floodwaters. Uncertainty exists regarding the safety of this embankment as a detention dam.

Using standards developed for an earthen dam holding water at capacity for a prolonged time, a Denver engineering firm calculated that the railroad embankment has a safety factor of 1.2 (i.e. is 20 percent stronger than necessary) with a train load and 2.5 without a train load. The Colorado State Engineer's Office recommends a safety factor of 1.5 for earthen dams, but has no standard for railroad embankments.

Should the railroad embankment be brought up to the safety standard of 1.5 with a train load? Probably not. On the one hand, the railroad embankment will neither be required to hold water to the full depth of the embankment nor to hold water for more than a few hours. The standard is likely to high. On the other hand, failure of the embankment could result in the loss of lives in the downstream trailer park. This risk to lives could be dealt with by increasing the safety factor of the embankment to 1.5 with a train load, but the cost would exceed $1 million. A more economical adjustment would seem to be a warning system that would halt train traffic in the unlikely event that the embankment was holding water at capacity. The railroad company can protect its property (i.e. the embankment and its trains) and the city can maintain the safety factor of the embankment at 2.5 with a simple and inexpensive warning system which eliminates the risk of a train crossing an already stressed embankment. Such a system might simply entail the dispatch of a police car to the scene when the potential for flooding exists. Lives and property would be protected and at a cost significantly less than $1 million.

These examples illustrate that the structural fix is not necessarily the most economical or effective. But how should one proceed to determine the optimum mix of adjustments? There have been a number of attempts to formalize the procedure for selecting the optimal mix of structural and nonstructural adjustments to flooding [e.g. Morin, Meier and Nazaraj, 1981]. Our impression, however, is that such procedures are beyond the technical expertise and available data of the typical storm drainage project evaluation. What appears to be needed and is of greater value than formalized models is creative thinking on the part of the analyst. An awareness of nonstructural measures, an understanding of their potentials and limitations, and a sincere desire to return the greatest benefits at the lowest cost to the city are probably of more value than a formal model.

Conclusions

Developing an equitable and balanced approach to storm drainage involves a variety of compromises. In many communities the interests of land developers play a powerful role in shaping not only a city's overall strategy for coping with storm drainage but they exert political influence on the means by which drainage projects are financed. Despite public pronouncement to the contrary, storm drainage projects clearly would not be widely adopted if it were not for the existence of basin master plans. No doubt a purely voluntary system of drainage control would form a patchwork solution which by all expectations could be worse than doing nothing at all.

Engineering consultants make up the other end of the spectrum. Their analyses of storm drainage problems tend to be one sided, often overemphasizing structural measures. In many instances, nonstructural alternatives such as redirecting urban growth away from floodprone areas are either dismissed out of hand or are deemphasized due to the consultant's inability to measure the benefits and costs of implementing such options. Consider the following quote taken from a master plan study performed by a large and reputable Denver based consultant.

> "It is safe to say that engineering consultants error consistently on the side of safety. They need not pay for the added protection, they may be held liable for under-sizing projects, and they may even benefit monetarily in that master plan consultants are often called upon to do detailed followup design work."

In short, the interests of this group runs counter to that of the community of developers.

Existing homeowners and agricultural interests outside of the urban fringe add another dimension to the conflict. Continued development and the consequential drainage problems it creates alienates both parties. The sensitivity of the former stems from the belief that they were charged for drainage improvements once when their homes were first built. They feel that subsequent charges imply subsidize growth. The farmers concerns are based on the perceived impact of city's stormwater on their ability to pursue their livlihood. Runoff contaminates irrigation channels and floods fields often damaging crops.

Lastly, the planning process is complicated by the question "what level of risk does the city staff and city council perceive as politically acceptable." Just as in the case of engineering consultants, staff engineers may not be rewarded for balancing the costs against the benefits of flood protection. It is ironic that the safest strategy from a legal standpoint is for a municipality to not study the flood problem at all. If studies are commissioned and constructive steps are not taken to protect against hazards, cities could be held liable. It is not surprising, therefore, that some communities tend to overdesign structures.

The task of planning municipal drainage systems is both extremely complicated and one which must be addressed with a great measure of political savvy. In writing this report we were not so much concerned with nor did we attempt to unravel the mysteries of planning for any single community. It will of course differ from one community to another. We did find, however, that the role economics played in storm drainage problems was slight. This we believe is due in part to the fact that many of the preconceptions about how an economic study should be performed were either wrong or misleading. The following observations were gleaned from experiences gathered in the process of evaluating storm drainage plans for the City of Fort Collins. The misconceptions will be stated as we either read or heard planners discuss them.

"<u>The city is required to protect property from the 100 year storm. The Federal Flood Insurance Administration requires us to do so</u>." This is not so! It is true that the FIA is concerned about the 100 year flood boundary, but for different reasons than indicated in the quote. The floodplain maps delineating the flood fringes and floodway are used to prod developers to take prudent precautions. No mention is made of requiring a channel improvement to withstand the 100 year flood. Under certain circumstances it would be possible to conclude that such a requirement is

tantamount to a channel improvement which eliminates the 100 year floodplain. This might be the case where developable land was selling at a premium. Furthermore a community which is too lax in its administration of the 100 year floodplain (i.e., one which issues a substantial number of variances) could jeopardize its participation in the Flood Insurance Program. That is, flood plain occupants could lose the option of purchasing federally subsidized flood insurance.
IN SUMMARY: if the city is bent on constructing projects to meet 100 year design requirements then do it. However, do not cloud the issue by suggesting that the decision was dictated by the FIA in Washington.

"Land is too valuable to waste in the floodplain." This statement may or may not be true depending upon the availability of alternative sites within the community. Participants in the Flood Insurance Program are required to restrict growth within the designated floodplain. Banks are not permitted to make loans available to prospective home buyers without first informing them about the flood hazard; flood insurance is supposed to be one of the preconditions for finalizing financing. The requirements placed on home building is even more restrictive. All new construction within the 100 year flood boundary must be insured at a rate reflecting the site's risk, which is often prohibitively high. It is little wonder that the department of public works tends to attract the attention of development interests. Projects which reduce the width the floodplain improve site values by an amount equivalent to the discounted stream of insurance payments. The argument which is put forward to support their position runs as follows. "Floodplain land is too valuable to waste. If both the land's value and the benefits derived from a reduction in flood losses are added together, they far outweigh the costs of affording protection." The argument is fallacious in at least one sense. Although it is true that failing to provide flood protection diminishes the value of land parcels within the floodplain, it should have just the opposite effect in the case of adjacent sites. In short, whatever is lost by one developer may be gained by another. Hence, the gains claimed do not benefit the entire community; they simply represent a redistribution of income from one development interest to another. It should be noted, however, that things may not be so clear cut if the floodplain site is inherently more valuable than alternative locations. Such would be the case if, for example, utilities and a system of streets are in place.

"The basin must be treated as a single system. Hydrologic interdependence must be recognized. Because the drainage behaves as a single system, a uniform design criterion should be chosen for each and every reach. It would be unwise from the standpoint of engineering design to vary the level of protection from reach to reach." No doubt an uneven level of protection in each reach could spell problems, especially if channel enlargements are contemplated. Channeling upstream flows will increase downstream peaks. It does not necessarily follow however that an equivalent level of protection is warranted downstream. The merits of improving the carrying capacity of a channel in any one segment of the basin should be weighted against its cost. It is possible to imagine a heavily populated upper reach which would benefit significantly from a drainage project. Yet the lower part of the basin may be sparsely populated. As a result the higher downstream flood peak may not produce sizable losses. Consequently, it may be more economical to purchase the property at risk or to implement a lower level of protection (paid for by the upstream residents). A devotion to the principle of system efficiency could lead to an uneconomic solution.

"<u>The longer we wait the more it will cost so let's do it now. The city is growing rapidly and protection will eventually be required</u>." The fallacy in this often heard argument is that waiting has its benefits as well. Each year construction outlays can be postposed the city avoids interest payments. In fact, the current relationship between the rate of inflation and interst tilts the decision heavily in favor of waiting. Long term municipal bond rates hover around 10 percent while inflation is a mere 2-5 percent. Waiting may also prove to be efficient in light of anticpated growth.

"<u>The rate of discount used to compute the benefits of a project should be the same as that used by the Corps of Engineers</u>." The selection of a discount rate is as critical as any other factor in evaluating a project. For years economists argued whether government should use a rate which reflects the cost of funds or use a lower rate. The debate, although never settled to the accademicians satisfaction, was resolved by opting for a rate proportional to the cost of borrowing. It is not uncommon to review drainage master plans in which unrealisticly low discount rates are utilized. These tend to boost benefits and exaggerate the desirability of drainage improvements. Consultants should be required to use the municipality's bond rate, so that a true measure of the project's effectiveness can be determined.

"<u>The financing plan can be developed independently of the economics in the master plans</u>." The amount of financing necessary to undertake improvements recommended in the basin master plan is no doubt tied at least in part to the economics of the projects considered. However, economics and financing are also linked in a more subtle way. If the benefit-cost analyses are carried out so as to recognize the extent to which the various reaches within a basin are interdependent, an equitable system of fees could be formulated. What would such a fee structure look like for Dry Creek, for example? Recall that the upstream diversion results in significant benefits for the lower reaches, so much so that the channel enlargements recommended for Reach C cost ten times the benefits received. The lower part of the basin should pay a share of the diversion's cost proportional to the benefits received. In eliminating the channel modifications in reach C the fees charged the property owners would drop significantly in proportion to the benefits such a project would generate.

If instead of diverting water upstream the master plan called for a system of levees to contain flood flows upstream, the fee structure would be quite different. Such a modification to the channel is likely to result in higher flood losses downstream. In such an instance the residents in reach A should be required to pay for 100 percent of the cost of constructing the levees plus the cost of the projects required in reach C to accomodate the greater discharge. The residents in reach C would then pay the difference between the cost of protection required and that desired. The principle is simple. Fees should reflect both the benefits received and the external benefits and costs created.

Most financing schemes are not designed based on these criteria. Sales taxes spread the costs to everyone in the community regardless of their exposure to risk. Basin fees, such as assessed in Fort Collins, represent a significant improvement over sales taxes in that each basin is required to pay an amount to cover the cost of the projects recommended in the master plan. However, within the basin the fees are sensitive only to the characteristics of the properties (e.g. lot area, impervious area, use, etc.). The reasons for not incorporating an approach more sensitive to the forementioned principles is not clear. One possibility is that the economic analysis performed in the master plans did not recognize interdependence and, therefore, did not provide the information necessary to differentiate fees within a basin. It also may have been thought that such refinements would be unwieldy to manage.

It is worth speculating whether the fee structure played a role in shaping the master plan. It is not unreasonable to deduce that once the financing arrangements were finalized, planners felt obligated to provide a single level of protection in each reach. They may have reasoned as follows. Since everyone is paying the same amount, everyone is entitled to the same level of protection. The problem with such logic is that it fails to account for interdependence. The diversion, for example, provides the equivalent of 50 year protection in reach C although it is constructed in reach B. It is doubtful whether the residents in C would be willing to pay an additional $1.8 million to receive $171 thousand in benefits derived from enlarging their channel.

We see no reason why the economic analyses embedded in a master plan cannot be utilized to construct a financing system. If properly done the resultant fee structure would reduce the extent to which one region subsidizes another, and would likely result in a more efficient mix of projects.

"The problem with the land use management alternative is that it does not solve the problem." It is difficult to evaluate this oft made statement without first asking what the problem is. No doubt that if the problem is defined as channeling the rivers's flow, then it is correct. However, if the problem is flood damages, as opposed to flood flows, then the statement may not be correct. Flood damages can be treated in a variety of ways, including altering the use of floodprone areas. Damages can be avoided by either keeping water away from structures or structures away from water. Which of the two options solves the "problem" hinges in part on their respective costs.

"Economists and engineers will never agree. The engineer is always trying to build something while the economist is trying to tear it down." This statement reflects a conflict of values rather than a disagreement about the facts. Both professions are guilty of adhering to a particular stance. The engineer is likely to place emphasis on achieving a design which is balanced, reliable and aesthetically pleasing. The economist is less concerned with technical aesthetics, but is instead preoccupied with the trade-offs required to solve the problem in the least costly fashion. Since trade-offs involve sizing projects and interjecting nonstructural options, the resultant economic solution may appear to violate design principles employed by the engineers. Economists, for example, are not shy to recommend uneven levels of protection for different reaches within the same basin. It is not surprising that engineers are going to perceive economists as indicated in the above quote.

This controversy is complicated by value stances held by others. Political entities tend to favor designs which strengthen the institutions of government. In such a setting economics may play a secondary role. Property owners are likely to exhibit an altogether different stance, one which emphasizes civil liberties as specified by the U.S. Bill of Rights. Such an orientation places a lower premium on engineering and economic aesthetics, fostering instead solutions which maximize the choices to affected parties.

The design which is ultimately adopted is not likely to please all the parties involved. Engineering aesthetics, economic efficiency, institutional considerations, and the preservation of choice will all be compromised to a certain extent. The degree to which any one dominates the others depends upon the predominant value orientation of the community involved.

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