FLOOD DAMAGE ESTIMATION FOR PROPOSED INDUSTRIAL DEVELOPMENT ON POTTERSBURG CREEK, LONDON, ONTARIO

By

James E. Windsor

A Practicum Submitted
In Partial Fulfillment of the
Requirements for the Degree of
Master of Natural Resource Management

The Natural Resource Institute
University of Manitoba
Winnipeg, Manitoba, Canada
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ABSTRACT

Increasing pressures for land development, especially in the urban areas of Ontario suggest that present flood plain regulations may be too restrictive and that outright prohibition of development of the flood plain may be economically unjustifiable. Accordingly, the Ontario Ministry of Natural Resources in co-operation with the Ministry of Housing commissioned the consulting firms of M. M. Dillion and J. F. MacLaren to undertake a review of current flood plain management policies. On the basis of their report to the Ontario Government's Flood Plain Study Steering Committee, nine recommendations were made to government. One recommendation, that the Ontario government adopt a "two-zone floodway - flood fringe" concept for flood plain regulation, forms the rationale for this Practicum.

This concept divides the flood plain into the floodway and the flood fringe. Development in the floodway, with the exception of some types of open-space land-use would not be permitted. The flood fringe is the remainder of the flood plain and certain types of developments would be permitted here provided certain conditions were met.

The study analyses the undeveloped upper reaches of Pottersburg Creek where it flows through the industrially zoned northeastern section of London, Ontario.

Development is presently prohibited here as a great portion of the industrially zoned land lies within the flood plain boundary as determined by the Upper Thames River Conservation Authority. A two-zone concept is proposed to be adopted for this

site. Two plans for the construction of industrial malls have already been submitted to the city.

The objectives of this study are to determine the potential for flood damage to such industrial mall developments should the two-zone concept be implemented and construction allowed. Some of the potential economic effects of the proposed developments are analyzed.

As Pottersburg Creek is ungauged much of the data was synthesized. Use was made of the HEC-2 computer programme for the determination of water surface elevations. To determine the average annual damages for various flood frequency estimates, a stage/damage relationship used previously in the Thames River Valley was adopted. The present value of these damages was determined for a range of discount rates.

Damage estimates were very sensitive to the choice of flood frequencies and of discount rate. In all cases, though, damage costs were found to be less than potential benefits. However, the study showed that the most important determinant of economic viability of allowing development on the Pottersburg Creek flood fringe was not a comparison of the costs and benefits per se but rather of the availability of alternative industrial development sites.

Nine recommendations concerning development of the Pottersburg Creek flood fringe were advanced at the end of the study. These ranged from suggestions concerning building design to questions concerning equitable taxation.

ACKNOWLEDGEMENTS

Acknowledgements are always hard to write. There are many people whose support in the completion of this study has been so important that simple mention on this page is far from sufficient thanks. It is my hope, therefore, that the individuals listed here are aware of my deep appreciation.

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I am also indebted to Mr. Russ Powell, General Manager, UTRCA, for his moral and financial support and to Nancy King, Project Engineer UTRCA for guiding me through the intricacies of the HEC-2 programme.

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B	value of buildings
cfs	cubic feet per second
C	building construction costs
d	discount rate
D	average annual flood damage in dollars
DA	drainage area in square miles
e	expected life of buildings
i	inflation rate
I	value of total flood fringe investment
IE	value of inventory and equipment
k	a constant
$\bar{k}$	the mean of the k values
Σk	the sum of the k values
L	the value of flood fringe land
m	order number in a ranked decending series
maf	mean annual flood, in cfs. (the mean of the annual maximum mean daily discharges)
n	total number of events
P	cumulative probability in percent
Qd	annual maximum mean daily discharge in cfs.
Qp	annual instantaneous peak discharge in cfs.
r	risk of flood during design life of buildings
T	recurrence interval in years
ubc	ultimate building coverage, (building area to land area).

GLOSSARY OF TERMS

Alluvium	Sediment carried, deposited and reworked by a river or stream.
Annual Maximum Mean Daily Discharge	That average daily flow which is the greatest of all the average daily flows of all the days of a year.
Bank-full Capacity	The maximum flow which is contained within the stream banks. Also referred to as: Bank-full discharge; Channel Capacity; Channel-forming discharge.
Channel	A natural or artificial watercourse of perceptible extent, with definite bed and banks to confine and conduct continuously or periodically flowing water. The top of the banks form the dividing lines between the channel and the flood plain.
Design Flood (Flow)	A flood of specific magnitude used for delimiting flood lines and for designing flood control, flood prevention and other structure such as bridges along the watercourse.
Flood	An overflow of water from a river, stream or other body of water producing a temporary innundation of lands not normally covered by water and which are used or useable by man.
Flood Damage Stage	The stage or elevation in a stream or body of water at which damage becomes significant in the reach or area in which the elevation is measured. Sometimes erroneously equated with "Flood Stage".
Flood Frequency	The probability that a flood of given magnitude will occur in any given year.
Flood Fringe	The area between the floodway boundary and the outer limits of the flood plain.
Flood Line	A line delimiting the extent of flooding caused by a specific flooding event.

Flood Plain	The land adjoining a water course and which will be flooded by a specific design flood.
Flood Stage	The stage or elevation at which overflow of the natural banks of a stream or water body begins in the reach or area in which the elevation is measured.
Floodway	The stream channel and as much of the adjoining flood plain designated by a regulatory agency as necessary to reasonably provide for the passage of the bulk of the flood waters.
Fuller's Formula	The formula used to determine Fuller's Ratio.
Fuller's Ratio	The ratio of instantaneous discharges to mean daily discharges for a watershed.
Hazel Flood	The flood produced in a watershed by Hurricane Hazel.
Hurricane Hazel Storm	A decadent tropical storm which passed across Ontario from South to North on October 15-16, 1954. The greatest 24 hour rainfall recorded was 7.02 inches. Wind and rain damage was widespread. Eighty-one people lost their lives and hundreds were left homeless.
Instantaneous Discharge	The peak flow volume measured in an instant of time.
Mean Annual Flood	The arithmetic mean of the annual peak discharges for each year of record at a given location.
Recurrence Interval	The return period (usually in years) of a given magnitude flood. A 1 in 100 year flood (1% probability of occurrence) does not mean that this flood will positively occur once every one hundred years. It does mean that it will occur on average once every one hundred years. Thus a 1 in 100 year flood could occur two years in a row. Also, probabilities are not additive. Thus, there is a 39% probability (not a 50% probability) that a 1 in 100 year flood will occur in any given 50 year period.

Regional Storm	A storm which is used to calculate flood lines for various regions of Ontario. The Regional Storm concept originated as a result of the severe damage and loss of life experienced in the aftermath of Hurricane Hazel and the Timmins Storm.
Regional Flood	The flood produced in a watershed by the Regional Storm.
Runoff	That portion of precipitation or snowmelt which finds its way into surface channels and is not absorbed into the soil or lost to the ground - water system.
Stage-Discharge Curve	A graph or curve showing the relationship between the gage height and the amount of water flowing in a channel, expressed as volume per unit of time (usually in cfs). Also commonly referred to as a "rating curve".
Storm	A natural meterological disturbance of great magnitude or duration.
Timmins Storm	A severe thunderstorm which travelled across northern Ontario from west to east on August 31 - September 1, 1961. It was most severe as it passed over Timmins. Maximum rainfall for a 12 hour period was 8.0 inches. Five people lost their lives and severe damage was inflicted.
U.T.R.C.A.	Acronym for Upper Thames River Conservation Authority.
Watershed	A drainage area, a drainage basin or a catchment area.

CHAPTER 1

INTRODUCTION

1.1 Current Situation

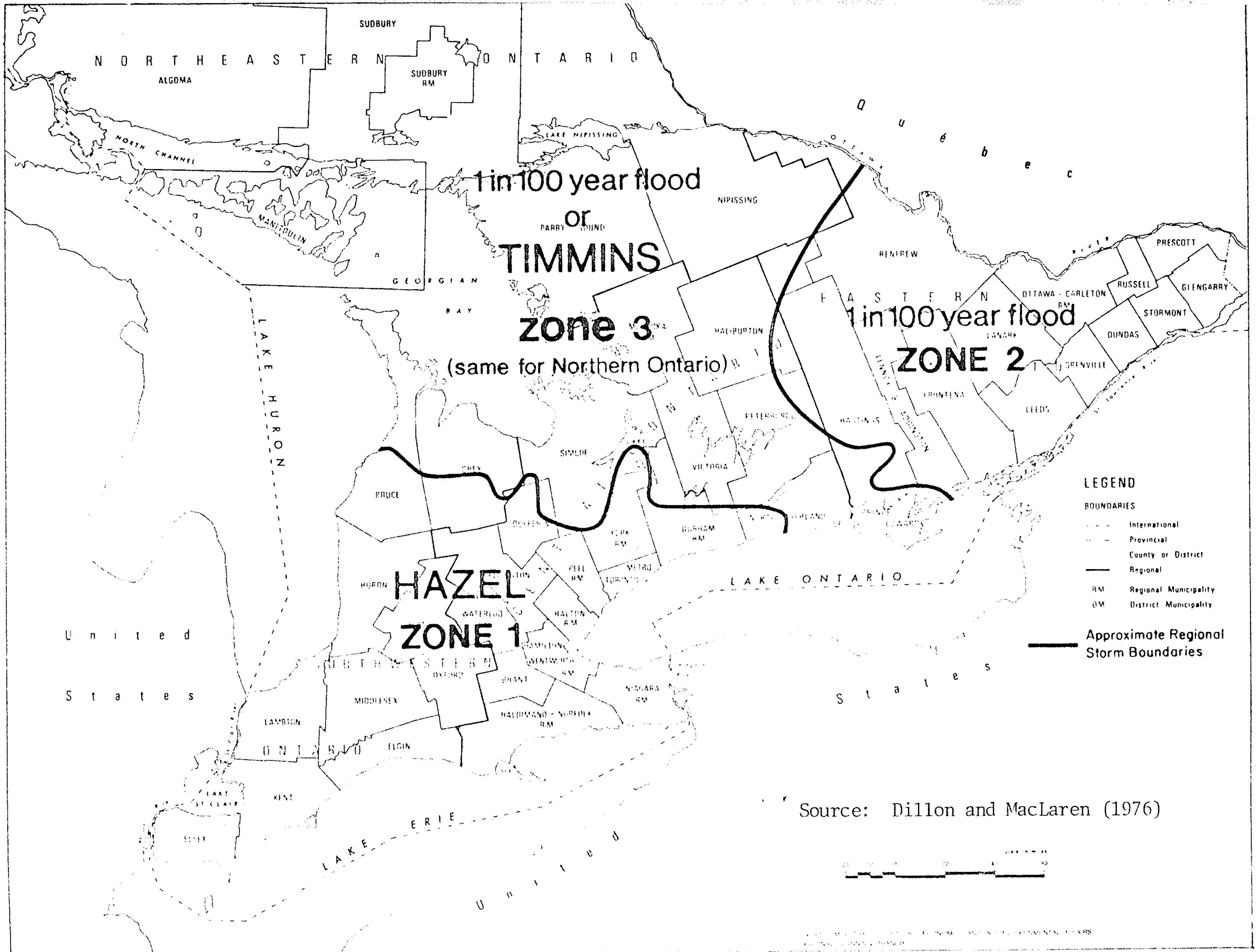
In recent years in Ontario, there has been growing support for a review of existing flood plain management policies. Areas defined as "flood plain" have been criticized as being too large and policies which regulate development within the flood plain are felt to be economically unjustifiable. This is particularly true for areas subject to only shallow flooding.

In Ontario, responsibility for flood plain management is vested in the Ministry of Natural Resources. Present flood plain management policies encompass two principal objectives. These are:

1. The prevention of loss of life and the minimization of damage due to flooding.
2. The prevention of additonal developments on flood plain lands.

The method employed by which lands are designated as flood plain is the determination of flood lines. These lines are established on the basis of the Regional Flood. Historically, the regional flood has been determined on the basis of the Regional Storm. Depending upon location within the province, the regional storm could be Hurricane Hazel or the Timmins Storm. For other parts of the province, the Regional Flood is deemed to be the 1 in 100 year flood (see Map 1-1).

In many areas within the province, the Regional Flood exceeds actual observed floods in the watersheds. It must be



Map 1-1 Regional Flood Zones

noted, however, that our periods of record are short. In this study, as will be detailed later, some records of flow used to produce a frequency distribution, are as short as twelve.

Under present policies, flood plain regulations generally permit no development within the prescribed flood plain boundaries. This ensures that flood levels will not be increased either upstream or downstream due to encroachments onto the flood plain.

In addition, in many parts of the province, a programme of flood-prone land acquisition is being actively pursued. This is especially true for areas where a great deal of urban flood plain development has occured. More than 50% of the provincial urban flood plain land is located within the municipalities of Metropolitan Toronto, the Regional Municipality of Peel, the City of Brantford and the City of London, the study location (Dillion and MacLaren, 1976).

As a result, in recent years, concern has been expressed that present flood plain regulations may be too restrictive and may jeopardize the future growth and development of these and other centres. This has led to a growing pressure for a review of present policies. Some municipalities have stated that more flexibility is needed in flood plain policies to accomodate unique local conditions.

In addition, both the Conservation Authorities[1] and the municipalities have recognized the need to integrate land and water planning at the local level, especially in those areas where the pressures of urban growth are the keenest.

In response to these concerns, the Ontario Ministry of Natural Resources, in collaboration with the Ontario Ministry of Housing commissioned the consulting firms of M. M. Dillon and J. F. MacLaren to undertake a review of current flood plain management policies. The consultants produced working papers covering engineering, planning and economic considerations, and a summary report (Dillon and MacLaren, 1976). These were submitted to the Ontario Government's Flood Plain Study Steering Committee. This committee made nine recommendations to the Ontario government. The most significant of these and the one providing the basis for this study, is that the Ontario government adopt a "two-zone floodway - flood fringe" concept for flood plain regulation.

1.2 The Two-Zone Concept

The two-zone floodway-flood fringe concept was first advanced by the American Society of Civil Engineers (ASCE) (1962) and was subsequently adopted by a number of U.S. states, most

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[1]The Conservation Authorities in Ontario (38 at time of writing) draw their authority from the Conservation Authorities Act of 1946. The Act provides for the forming of corporate bodies, the Conservation Authorities representative of all participating municipalities within a watershed, for the purpose of effecting conservation programmes and natural resource management.

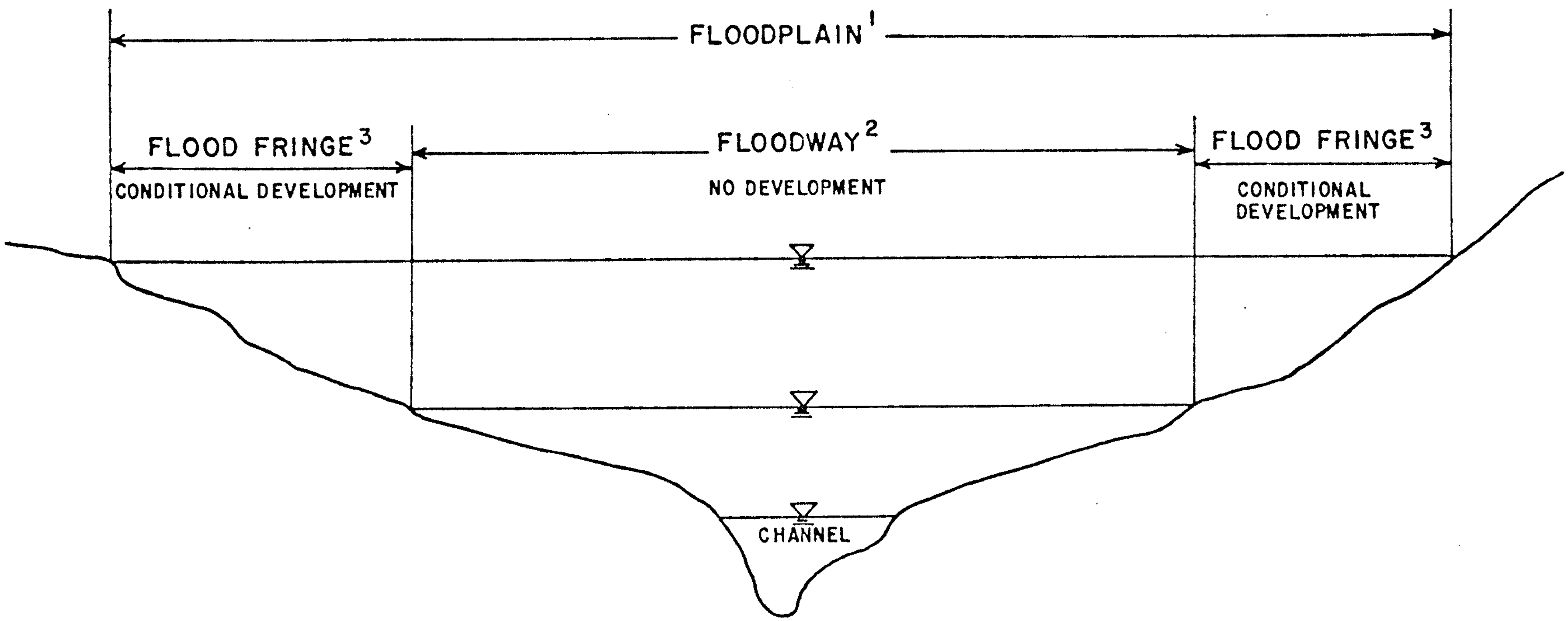
notably Iowa (Dougal 1969). Under such a plan existing flood plain land is zoned either as "floodway" or "flood fringe", (see Figure 1-1). The purpose of a two zone designation is to allow for greater flexibility in land use planning yet still be consistent with the flood hazard. If adopted, this policy will result in more flood plain land becoming available for development (with certain restrictions).

The floodway zone, which passes the greatest portion of the flood waters, includes the stream channel and as much of the adjacent flood plain as is necessary to convey the design flood. Velocities and depths are greatest in this zone as is the potential for loss of life and severe damage to property. Developments which are either subject to flood damage or which would have a detrimental effect on the hydraulic capacity of the floodway would be prohibited in this zone. Allowable land-uses would include crop production, recreation, parking and so forth. Only open-space developments would be permitted.

The flood fringe is the remainder of the flood plain. As presently defined, the boundaries of the flood plain are determined on the basis of the Hazel Storm, the Timmins Storm or the 1 in 100 year flood, depending on location within the province. Although the flood fringe is subject to periodic innundation, depths are generally not great and flow velocities are low. These areas serve mostly a storage function.

Any building or filling in the flood plain will tend to increase flood peaks due to the resulting reduction in storage capacity. If, however, such building or filling is limited

THE TWO-ZONE FLOODWAY-FLOOD FRINGE CONCEPT



1. The floodplain would be defined by the Hazel flood, the Timmins flood or the 1 in 100 year flood, depending upon the location in the Province.
2. Floodway is defined as the danger zone in which no building or filling to be permitted.
3. Flood fringe is the area, where filling and development may be permitted if special flood protection measures are adopted.

Source: Flood Plain Study Steering Committee (1977)

Fig. 1-1 The Two-Zone Concept

to the flood fringe areas, the increase in flood peaks is generally slight.

Thus, developments could be permitted in the flood fringe as shown in Figure 1-2, provided certain conditions were met. These conditions might include regulations establishing minimum ground floor elevations, flood proofing or mandatory flood insurance. This last proposal is somewhat tenuous due to the reluctance of insurance companies to provide insurance against flooding.

The most difficult problem associated with the two-zone concept is the determination of criteria for selection of floodway limits. Many factors must be considered in determining this boundary. Dillon and MacLaren (1976) list the following criteria:

(1) water profile rise limitations;

(2) product factors of velocity and depth;

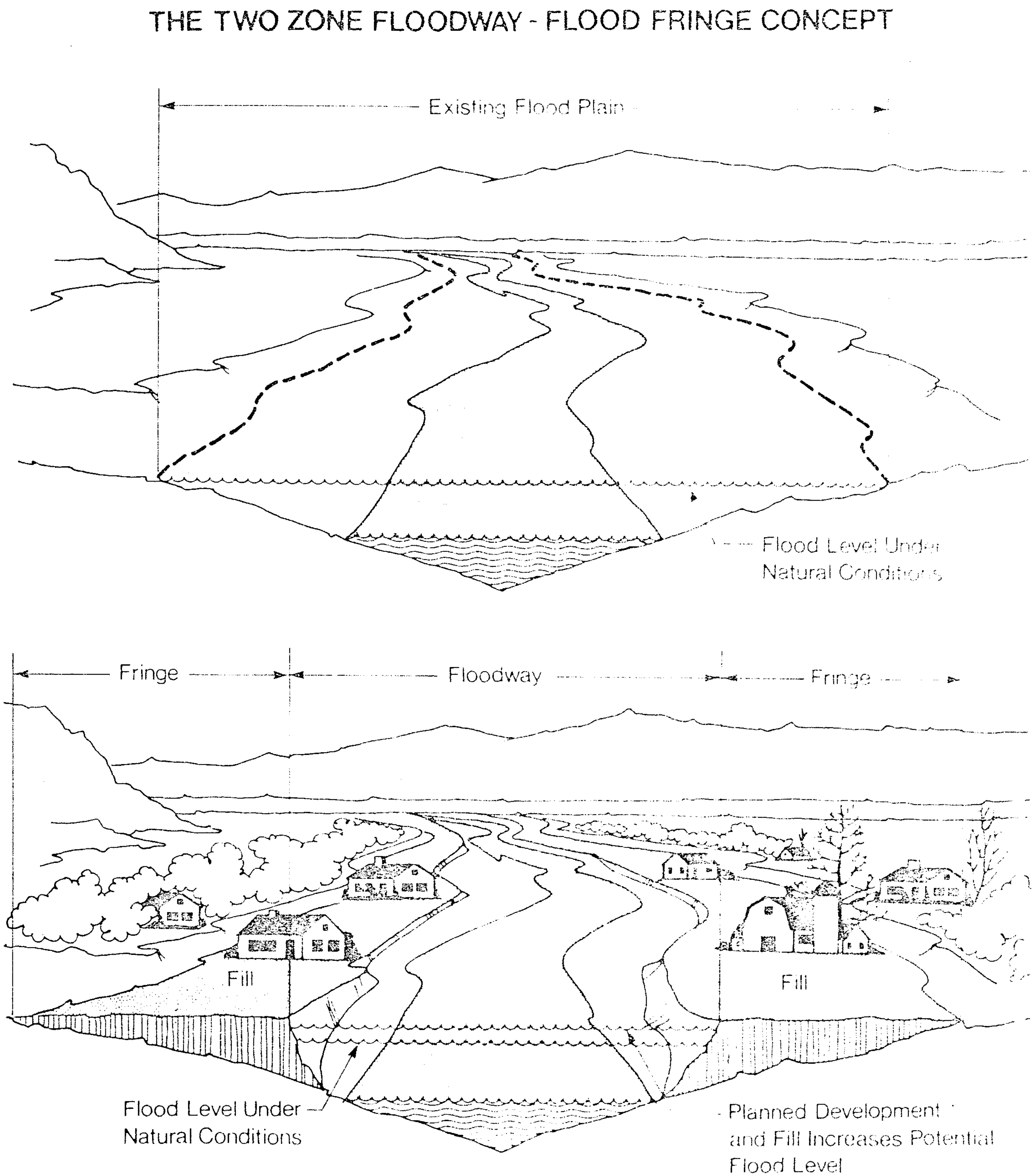
(3) limitation on velocity and depth; and

(4) lesser flood frequency flood plain limits.

The U.S. Army Corps of Engineers has advocated the water profile approach while Crook (1978), although prefering velocity/depth restrictions, has recognized the difficulties in implementing this approach. Accordingly, minimum flood frequency criteria have been suggested and it is this approach which has been used in this study.

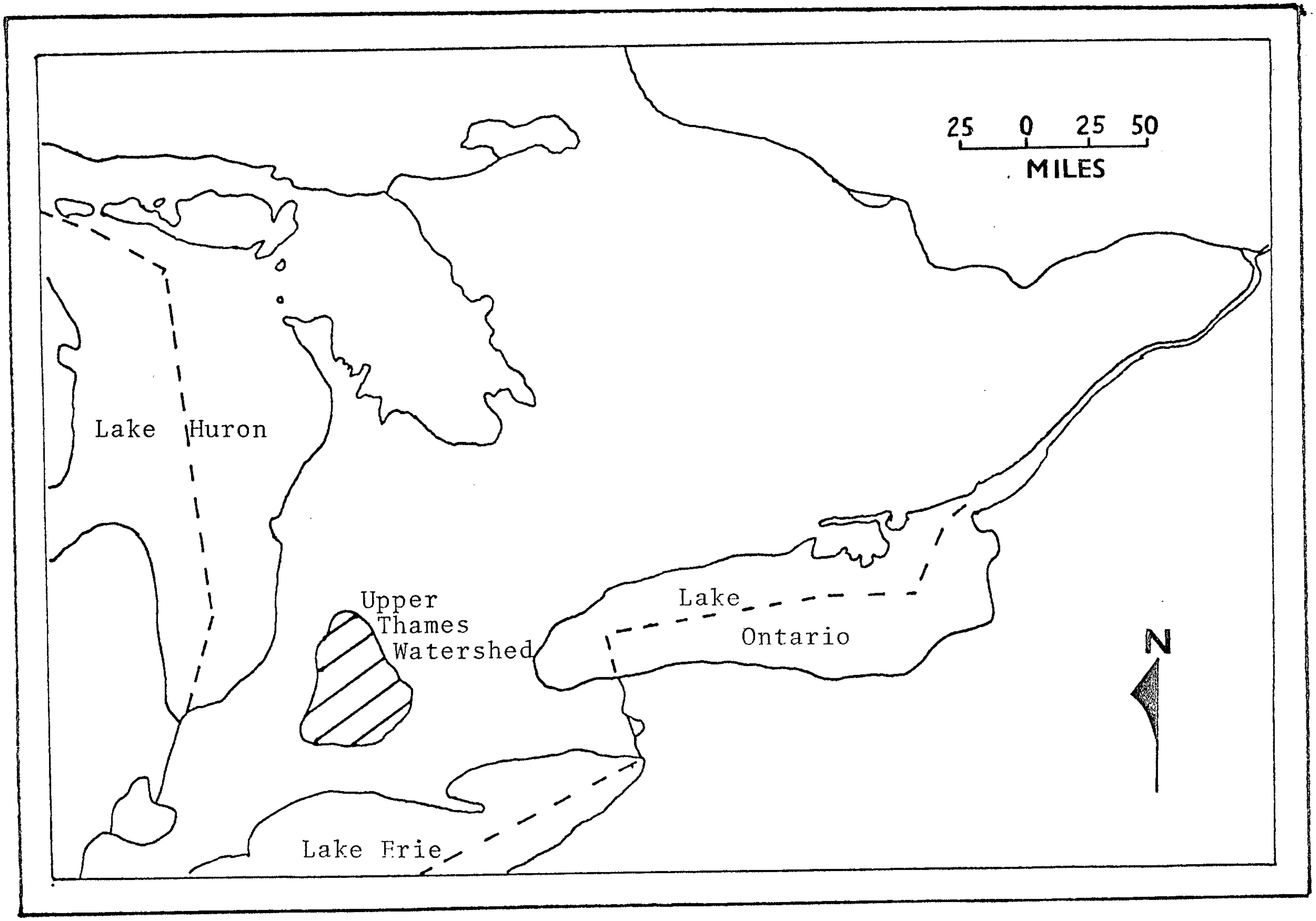
1.3 Study Site

The Upper Thames River watershed is located in central southwestern Ontario (see Map 1-2). The Upper Thames River



Source: Dillon and MacLaren (1976)

Fig. 1-2 Flood Fringe Developments



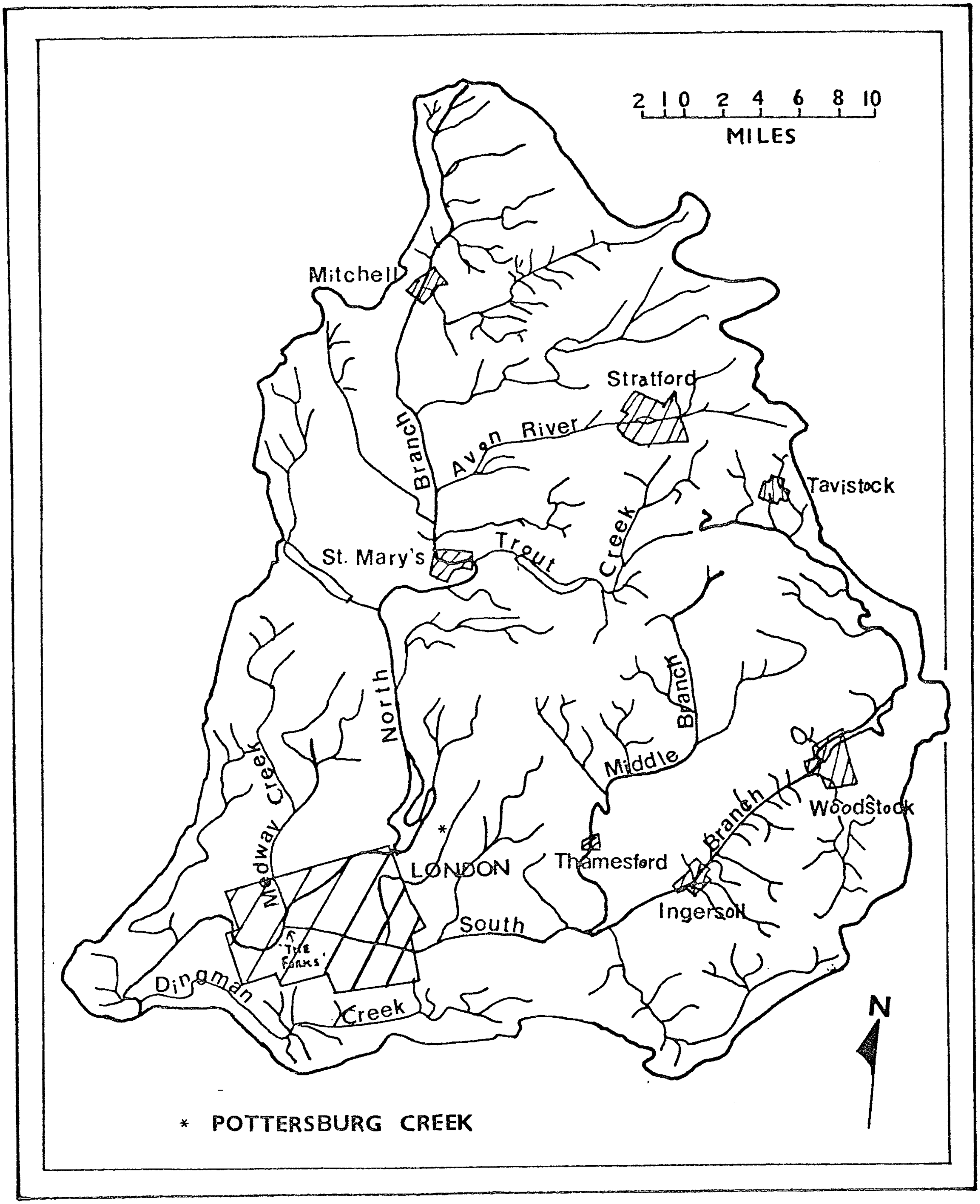
Map 1-2. **Location of Upper Thames Watershed**

Conservation Authority (UTRCA) has responsibility, under the Conservation Authorities Act, to provide for watershed planning within the Upper Thames basin. The headquarters of the UTRCA are located at the Fanshawe Conservation Area at London.

The Thames River rises in the highlands of Perth and Oxford counties and flows 190 miles through the heart of southwestern Ontario to empty into Lake St. Clair. The Upper Thames watershed comprises that portion of the Thames watershed above the confluence of Dingman Creek with the main river some ten miles southwest (downstream) of London).

The characteristics of the watershed are: length - 51 miles, maximum width - 37 miles; average width - 26 miles; total drainage area - 1,326 square miles. It is drained by two main branches of the Thames River, the North Branch and the South Branch which meet at "The Forks" near the southwesterly limits of downtown London. The Middle Branch, its confluence being approximately 16 miles above "The Forks" is the main tributary of the South Branch (see Map 1-3).

Most of the watershed is rural and contains some of the best farmland in Canada, especially in Middlesex, Perth and Oxford counties. Parts, however, are highly urbanized. Many smaller centres such as Ingersoll, Woodstock, St. Mary's, Thamesford, Mitchell and Stratford, among others, are located within the watershed boundaries. The city of London is the largest centre in the watershed. It serves as a regional administrative centre for many Ontario government and some federal government departments. In addition, London is the main industrial and commercial centre for much of southwestern Ontario.



Map 1-3. Upper Thames Watershed

Pottersburg Creek, the focus of this study, rises just to the northeast of the city limits of London. This is a highly developed agricultural area and the headwaters of the creek receive the outflows from numerous agricultural drains.

From here, the creek flows generally southwestward toward London where it is re-routed, in an artificial channel, across the southern part of the London Airport.

It then follows a somewhat rambling course through the industrially zoned northeast section of the city from Crumlin Road to Clarke Roade. Below Clarke Road, Pottersburg Creek passes through predominantly residential areas to flow ultimately into the South Branch of the Thames River in the south of London.

This study site was divided into five sub-areas.[2] Sub-area 1 is that portion of the creek from Clarke Road (cross-section #2.6) upstream to the first bend in the creek (cross-section #4.1)

Sub-area 2 is that portion of the creek from the first bend (cross-section #4.1) upstream to the downstream side of the General Motors railway crossing (cross-section #6.1).

Sub-area 3 is from the upstream side of the General Motors

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[2]The choice of the 5 study sub-areas was based on field observation and represents areas within the study site possessing common topography, cross-section and land-use. The boundaries were, in all cases save one, determined by the existence of a bridge or embankment or other construction. The discreteness of these five sub-areas was later substantiated when an analysis of the data indicated significant water surface elevation differentials occuring at the sub-area boundaries.

railway crossing (cross-section #6.5) upstream to the downstream side of the Industrial Road bridge (cross-section #10.1).

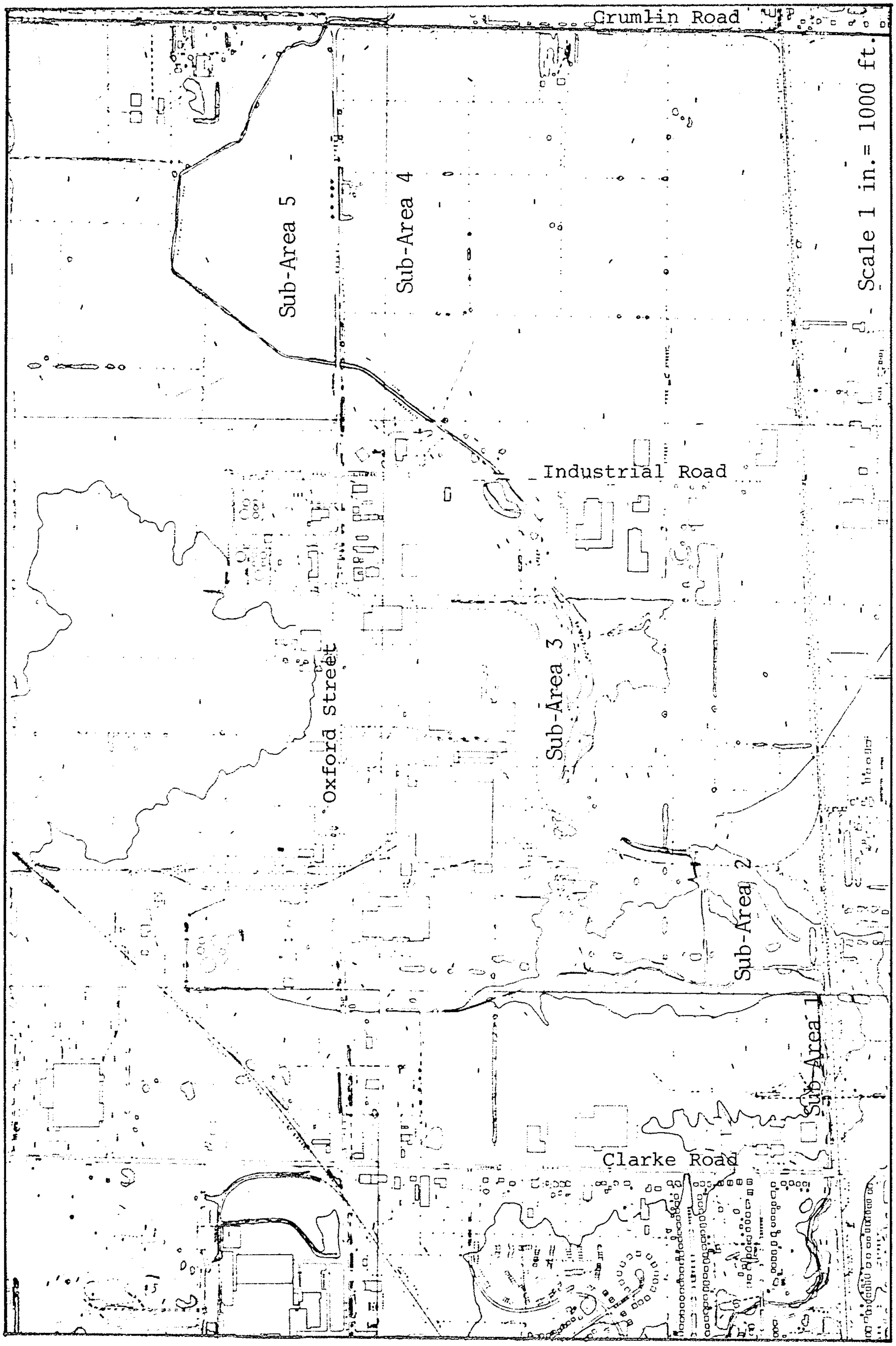
Sub-area 4 runs from the upstream side of the Industrial Road (cross-section #10.6) upstream to the downstream side of the Oxford Street bridge (cross-section #12.1).

Lastly, sub-area 5 is the remainder of the study area from the upstream side of the Oxford Street Bridge (cross-section #12.6) upstream to Crumlin Road (using cross-section #14.0 as representative). All five sub-areas are shown in Map 1-4.

1.4 Problem Statement

Much of the industrially zoned land bordering Pottersburg Creek (where development has not already occured) is within the Hazel flood line. Thus, under present policy, new development cannot take place. Although the city has zoned the land for industrial use only, provincial restrictions, through the UTRCA, prevent that type of land use.

The study site is one of the last significant parcels of industrially zoned and utility-serviced land in the City of London. It is the only significant parcel of industrial zoned land in this area of London. The area's proximity to other industries and to rail and road transportation links makes it a prime area for future expansion. If the city is not able to grant building permits for industrial development here, a necessary alternative, short of possibly seeing prospective industries go elsewhere, might be to acquire (by purchase or annexation) suitable land outside of the present city boundaries. In addition to the costs of acquisition would be the (probably)



Map 1-4. Study Sub-Areas

greater costs of municipal servicing (hydro, sewers, and the like). Two proposals for the construction of industrial malls have already been submitted to the city for development of some of the land within the study site. According to the Market Researcher for the Industrial Commissioner for the City of London, all prospective developments in the area are expected, to be of industrial mall construction. The city would prefer that such developments be permitted and the UTRCA does not wish to see development restricted unnecessarily.

1.5 Study Objectives

The principal objective of this study is to determine the potential for flood damage (direct damage to buildings and contents) to the proposed industrial malls should the 1 in 100 year flood be adopted as the regulatory level rather than the regional storm. Specifically, an estimation of average potential annual flood damage will be made for the area lying between the 1 in 100 year boundary and the present regional storm boundary.

A secondary objective of this study will be to analyze the potential effects that the proposed development may have on local, regional and national economics.

1.6 Methods

A flow/frequency curve for Pottersburg Creek was prepared. As there were not flow records for this creek, the graph was synthesized. Using computer simulation, stage/discharge curves (rating curves) were produced for those reach lengths of the creek which are of interest in this study.

Next, the acreage of all industrially zoned land lying within the proposed flood fringe was determined. A stage/damage relationship was produced based on work done by Acres (1972) in the Thames River Valley.

The stage/damage and stage/discharge curves were combined to produce a discharge/damage relationship. The discharge/damage and discharge (flow)/frequency curves were combined to produce a damage/frequency relationship.

From the damage/frequency tables, an estimate was made of the average annual potential damages from flooding to the proposed developments. The present value of these annual damages was determined for a range of discount rates.

1.7 Study Parameters

1.7.1 *Floodway/Flood Fringe Boundaries*

Recommenation #2 of the Flood Plain Study Steering Committee was that flood plains in Ontario be based on the 1 in 100 year flood or the Regional Flood, whichever is greater.

Thus, for the purposes of this study and after consultation with the UTRCA, the flood plain boundaries were based on the Hurricane Hazel Flood. For calculation purposes, this is assumed to be the 1 in 500 year flood (Ontario Ministry of Natural Resources, 1977; Dillon et. al. 1976).

The floodway boundaries were based on the 1 in 100 year flood, as suggested by the UTRCA. It is also the boundary deemed minimally acceptable to the Ontario Ministry of Natural Resources

Regional Office (Crook, 1978).[3]

1.7.2. *Expected Project Life (Planning Horizon)*

The proposed industrial mall construction was deemed to have an expected life of 50 years. This is an average life expectancy for the anticipated building type (steel girder and concrete block). This estimate was determined from discussions with various commercial building contractors in Winnipeg and in London and with the Chief Estimator for Canadian Forces Base, Winnipeg.

In addition, Dillon et al. (1976) states:

> "If loss of life is not expected and all benefits and losses are expressible in monetary terms, a design life of 50 years is recommended in the literature as a realistic figure".

Thus, in discounting monetary values, 50 years was used as the planning horizon. This is also expressed as the expected life (e).

It should be pointed out that the use of any finite planning horizon is, of itself, something of an approximation. In all likelihood, construction, renewals and re-development would continue to occur throughout the 50 year period and beyond. The choice of a finite horizon assumes that all buildings would be constructed in the first year and fully discounted by

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[3] Other methods for determining Floodway and Floodplain boundaries have been used elsewhere. These include maximum flood depth, velocity/area parameters etc. Crook points outs, however, that "further research (in the above methods) is required before criteria can be set". Thus, Floodway and Floodplain boundaries are based on flood frequency.

the end of the 50th year. Clearly this is not likely as some new buildings might always be under construction while some older ones were being taken out of use. Given this caveat, however, the use of a finite planning horizon equal to the average life expectancy of a typical structure is a widely used approximation which will be followed in this study.

1.7.3. *Accounting Stance*

Ideally, the accounting stance taken would be that of the owners (or lessees) of the proposed developments if it could be assured that the damages from flooding would accrue only to them. The history of flooding (not just in Ontario, but in the rest of Canada and in the U.S. as well) has, however, shown that the costs associated with flooding are often borne by the public treasury. This is generally the case even when only privately owned property is affected.

According to Dillon et al. (1976), more than $100 million was paid out in Canada as flood damage assistance to 1970. Since 1969, Federal assistance has been through the Federal Disaster Assistance Program following an established dollar per capita formula. Thus, at least some of the costs associated with flooding are borne nationally.

Some of the costs of flood damage (street repair and clean-up as an example) accrue to the city. In addition, there may be other municipal costs associated with the proposed developments. These include expansion of the sewage treatment facilities, street widening and increased traffic control and increased snow removal costs associated with an increase in the number of streets and the amount of traffic in the area.

The economic benefits of the proposed developments are distributed among a number of parties as well. Much of the benefit accrues to the owners and lessees of the industrial malls. The municipality benefits from increased tax revenues. There are also benefits nationally (and to a lesser extent, provincially) from added tax revenues both from corporate enterprises and from the wages paid to their employees. Thus, the benefits and costs were viewed from the following three different perspectives: the potential developers, the City of London, and the nation.

1.7.4. *Discount Rate*

Present values of costs and benefits were calculated for a range of discount rates. These were 2, 4, 6, 8, 10 and 12 percent. These rates were net discount rates, that is, nominal rates minus inflation and are deemed to represent the real cost of money. Section 3.7 presents a more detailed analysis of the discount rate determination.

1.7.5. *Types of Flood Damage Investigated*

In this report only direct damage was investigated. Direct damage is defined as damage to structures and to inventories and equipment contained within. A discussion of types of flood damages and their importance in past studies is found in Section 2.5.

CHAPTER 2

HISTORICAL BACKGROUND/LITERATURE REVIEW

2.1 Introduction

Human use (and mis-use) of flood plains is long established. Flood plain areas are frequently the most attractive for human settlement. An obstacle in dealing with problems of flood plain land use is that a precise definition of the term "flood plain" remains somewhat elusive.

Geomorphologists define a flood plain as that part of a river valley covered by alluvial deposits (often represented by river terraces). Hydrologists define the flood plain as that area of a river valley that is usually dry but periodically overflowed by water in excess of the stream channel capacity. Water management agencies, such as conservation authorities, define flood plains, for purely practical purposes, on the basis of the recurrence interval of given floods. Thus, there is the 1 in 500 year flood plain, the 1 in 100 year flood plain and so forth.

Regardless of which definition is selected, the importance of flood plains cannot be underestimated. River valleys and their flood plains are almost always the least expensive routes for railroads, highways and other transportation and communication corridors. In addition, flood plains are aesthetically attractive (often they are important breaks in otherwise featureless landscapes) and represent important wildlife habitat area.

Existing undeveloped flood plain lands, especially in urban areas, not only retain those features which originally attracted man to them, but have actually become increasingly attractive for industrial development. Generally, this is due to their proximity to existing communities and the reduction in the number of alternative nearby building sites. Thus, flood plains are occupied because it is both convenient and profitable to do so. This occupancy is not without risk, however.

2.2 Flooding

Floods are generally natural occurences and are as much a part of the landscape as are hills and valleys.[1] They are natural features which man must learn to live with and to adjust to. Before the arrival of man, flood water made their way to lakes and to the sea in their normal channel and over their normal flood plains.

Now, however, these channels are often restricted and constricted by bridge piers, sewer outlets, dykes, levees, pipelines, abutments and other obstructions. And the flood plains are occupied by factories, houses, waterworks, railroads and highways. The cumulative effect of these conditions is generally to raise flood peaks.

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[1]Historically, floods have been regarded as natural events or "acts of God". Certainly this is frequently the case, especially for the low frequency, high magnitude events. There is much reason to believe, however, that many floods, especially the high frequency, low magnitude ones, are not natural but are, in fact, the result of the "cumulative acts of men". Man's activities upstream can, in the opinion of this author, precipitate increased peak flows downstream.

Flooding has been likened to a tax (White, 1961) imposed by nature upon residents of the flood plain. Although there may be instances where this tax is negative (i.e. increased soil fertility due to sediment deposition), most often the tax is positive. It reduces the income stream of the flood plain occupants below a level which would be the case in the absence of flooding.

In addition, White (1961) notes that nature's taxes, unlike public ones, are not offset by the provision of public goods and services. Thus, they represent a real loss to the community. Also, the collection of nature's taxes is sporadic and less certain than for public taxes.

2.3 The Flood Hazard

Skeehan and Hewitt (1969) rank floods as first in terms of world-wide natural disasters which occured from 1947 to 1967. Typhoons, hurricanes and cyclones combined constituted number two. On a world scale, floods alone caused 39.2% of the total loss of life in natural disasters.[2] Floods are, of course, not the only natural disaster. Indeed, Hewitt and Burton (1971) discuss the following hazards as possible in the London, Ontario area:

1. Flood Hazard
2. Hail Hazard
3. Drought Hazard

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[2] Their list was not, however, restricted to river flooding.

4. Heavy Rainfall Hazard
5. Freezing Rain
6. High Winds
7. Tornadoes
8. Heavy Snowfall, and
9. Hurricanes.

In dealing with the flood hazard, Hewitt and Burton determined that it was comprised of the following components:

1. Damage to property. This could be due to loading and abrasion caused by the mechanical efects of flood waves or currents or saturation damage (especially to building contents) resulting from water contact.
2. Drowning
3. Communication barrier effect
4. Contamination of food and water
5. Housing loss
6. Disruption of socio-economic activity
7. Interference with water-borne transport (including transport of municipal wastes) and despoilation of agricultural land.

2.4 Risk of Flooding and Flood Frequencies

The return period of a given flood has often been used as the risk factor. As Dillon and MacLaren (1976) note, this has "grave disadvantages". In order to provide a realistic interpretation of risk, no less than three factors must be considered. These are the flood recurrence interval in years (T), the design life or expected life span of the building or other developments (e) and the risk of flooding during that design life (r). These factors are related as follows:

$$r = 1 - \left(1 - \frac{1}{T}\right)^{e} \qquad 2.1$$

From equation (2.1) it can be seen that the 1 in 100 year flood has a 39% chance (and not a 50% chance) of occuring during any 50 year period.

The statistical analysis of stream flow records is designed to allow for the estimation of the magnitude or frequency of flow events beyond the limits of the historical record. This estimation is accomplished by fitting a regression line (probability distribution) to the observed data. The most widely used statistical methods presently employed in much of North America are the Gumbel extreme value and Log-Pearson III distributions. Dillon and MacLaren (1976) note that there does not appear to be any one probability distribution which is best suited for Ontario (the location of the Pottersburg Creek study site).

The interpretation of estimated recurrence intervals for flood events can often be confusing. The 1 in 100 year flood is not the flood that occurs one hundred years apart but is the flood which will occur on average, once every one hundred years. Thus, in any one year, there is, on average, a 1% probability of the 1 in 100 year flood occuring and this flood could occur two years in succession.

Flood frequency estimates are predicated on the following three assumptions: (1) each flood event is a random event and independent of all other flooding events on the stream; (2) all floods are homogeneous (i.e. there have been no changes in climate or significant alterations in land-use which would affect the run-off characteristics of the basin); and (3) recorded floods will be representative of future floods. The reliability of the third assumption is particularly sensitive to the length of the historical record (of flood events).

2.5 Flood Damage

There are several methods of classifying flood damages. The classifications used by the U. S. Army Corps of Engineers, Kates (1965) and Shaeffer (1960) distinguish between tangible and intangible damages. Other methods distinguish between direct, indirect and intangible losses (Barrows, 1948). Direct losses are defined as the cost of repair or replacement of physical damage due to flooding. Indirect losses are the value of business (revenue) or services actually lost. Intangible losses are those losses not easily compensated for monetarily. These include loss of life (actually a rarity in industrial flooding events), effects on health, social and economic security, uncompensated labour (volunteer sand-bagging, for example) and emotional distress.

The U. S. Army Corps of Engineers while retaining the intangible damage category, refer to the direct damages as primary damages and the indirect as secondary damages.

A distinction could also be made between immediate and post flood damages. Immediate damages are those readily ascertained at the time of flooding while post-flood damages are those which do not become apparent until a later date. The most common example of this latter type is foundation settling. Such damages are often missed in immediate post-flood damage surveys.

There are two general methods used to determined values for (potential or future) flood damages. These are:

1. Collection of data on previous levels of flooding and on losses reported for each of these levels by local residents and authorities; and

2. Use of synthetic depth/damage relationships based on hypothetical flood conditions.

The use of the first method for Pottersburg Creek is impossible (as it is for much of the Upper Thames Watershed) as flood damage records are incomplete or non-existent. Where records do exist, they are only for one level of flooding (usually Hurricane Hazel). In addition, the quality of the data is questionable. Double-counting has frequently occured and some figures reported are replacement values while others are depreciated values.

In a study of American disasters (Dacy, 1969), it was estimated that reported damages tended to be exaggerated by a factor of three over the final figures submitted by damage appraisors.

In this study damages are classified as tangible and intangible. Due to the difficulties in quantifying intangible damages, they have not been considered here.

Tangible damages were further sub-divided into direct and indirect. Various agencies including the Metropolitan Toronto and Region Conservation Authority and the United States Department of Agriculture (Acres 1968) and a Royal Commission (Manitoba 1958) have attempted to calculate indirect damages as a percent of direct damages. The resulting percentage estimates have been inconsistent, variable (from a low of 5% to a high of 75%) and lacked generality. Because of this, and a general lack of data, an estimate for indirect damages has not been made.

Thus, only direct damages were considered in this study. These include structural damages along with inventory and equipment losses. This categorization is, with slight modification, that used by Kates (1965).

Dillon and MacLaren (1976) report that between the years 1950 and 1970, more than 430 floods were reported in Ontario newspapers. The most devastating, Hurricane Hazel, caused $75 million damage and resulted in 80 deaths. Following this flood, provincial flood plain management programmes were accelerated and by 1976 more than $170 million had been spent by conservation authorities.

Despite the continuing flood losses during this period, flood plain management efforts proved to be effective. Damage levels increased only slightly (Dillon and MacLaren, 1976) unlike the U. S. experience wherein flood losses have increased every year despite massive amounts (some $4 billion between 1936 and 1957) spent on flood control (White 1958). If flood control efforts are to be effective in Canada, it is important to understand the reasons for their lack of effectiveness in the United States. White (1958) reports that yearly increases in flood damage were not due solely to rising prices (although this was a partial cause). White contends that there are three reasons why the actual amount of damage has increased, flood control measures notwithstanding. Firstly, there has been an actual increase in the serverity of flooding. Generally, floods are becoming more 'flashy'[3], generally because of greater up-stream urbanization, farm drainage networks and other land-use changes.

A second factor is better reporting. As floods became more common and more severe, more damage surveyors were trained and survey methods were improved. Thus, the accuracy and the extent of flood damage data increased. More credence was given to previously unsuspected flood damages such as basement settling.

The third, and perhaps most insidious factor, was the continuous invasion of the flood plain. Increasing developments meant that any given return period flow produced increasing levels of damage.

Homan and Waybur (1960) found that:

> "... a relationship exists between flood depth, market value of structure and market value of contents on one hand, and total flood damage on the other. This relationship can be of value in estimating the expected losses (from flooding)."

Dillon and MacLaren (1976) confirmed this relationship, in part, in reviewing the 430 flood events which occured in Ontario between 1950 and 1970. They found that water levels, rather than water velocity or sediment deposition, were cited as the main cause of damage.

2.6 Flood Plain Regulation

The main objectives of Ontario flood plain management polices are to prevent loss of life and to minimize flood damage

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[3]This is generally seen as an increase in the flood peak and a corresponding decrease in the flood to peak interval (or lag time).

to existing and proposed flood plain developments. Section 27(1) of the Conservation Authorities Act provides the conservation authorities with the power to pass regulations which prohibit or regulate the construction of buildings in areas susceptible to flooding during a regional storm.

Regulations can also be enacted under the Act which limit or prohibit the dumping of fill where it may contribute to flooding (by constricting the channel or reducing over-bank storage). The same restrictions may be applied to other forms of development that threaten to reduce the normal storage and flow capacity of the valley.

At the discretion of individual Conservation Authorities, more intensive developments may be allowed where:

(1) development pressures are keen (predominantly urban areas) or,

(2) flood control measures are impractical or prohibitively expensive or,

(3) no other development opportunities are available.

Such developments are generally contingent upon all buildings in the flood plain being flood-proofed. In the case of the proposed two-zone system, new developments will most likely be required to be flood-proofed to the design storm (Hurricane Hazel) elevation.

2.7 Flood-Proofing

Flood-proofing measures range from structural modifications through installation of special equipment or materials to reinforcing basement walls, permanent sealing of all exterior openings, elevation of flood vulnerable utilities, installation of sump pumps and so forth.

The term "flood-proofing" is somewhat misleading as no building could, within reasonable expense, be made completely flood-proof. A more accurate term might be "flood damage reduction".

Structural flood-control measures such as dams, dykes, floodways and others are often employed where their cost can be economically justified in terms of reduction of damage to existing and future developments.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The methodology employed in this study is quite similar to that commonly used by the U. S. Army Corps of Engineers. It has been adapted for use by others, including Sheaffer (1960), White (1964) and Kates (1965). There are, however, two very important areas in which this study's methodology differs from that employed or adapted elsewhere. Past studies have dealt with flood damage to existing developments on gauged streams with (reasonably) long records of flow. For the purposes of this study, the methodology is being adapted to estimate future flood damage to proposed developments. In addition, Pottersburg Creek is not, nor never has been, gauged. Thus, there are no flow records and much of the data must be synthesized.

3.2 Step One - Flow/Frequency Relationship

Flow data for four gauged streams in the vicinity of Pottersburg Creek and in the same (Upper Thames) watershed were utilized. These data were obtained from the offices of the Water Survey of Canada at Guelph, Ontario.

The four streams were: Dingman Creek, Medway Creek,[1]

[1]Medway Creek is referred to as the Medway River in the Water Survey of Canada data. Locally, however, it is called Medway Creek and it is this name which has been used throughout this report.

Waubuno Creek and Wye Creek.

The data used were taken from the following recording stations:

1. Dingman Creek - Station #02GE005 (12 years of record) located below Lambeth near the confluence of Dingman Creek and the Main Branch of the Thames River.

2. Medway Creek - Station #02GE008 (32 years of record) located at London near the confluence of Medway Creek and the North Branch of the Thames River.

3. Waubuno Creek - Station #02GD020 (12 years of record) located near Dorchester.

4. Wye Creek - Station #02GD013 (23 years of record) located near Thorndale.

It was originally hoped that data on instantaneous peak flows could be used. This was based on the assumption that industrial damage would result from water contact alone and not necessarily from prolonged immersion.

Data on instantaneous discharges proved, however, to be too scanty. Indeed, such data has only been available since the installation (generally in the early 1970's) of automatic recorders. As a result of this, annual maximum mean daily discharge data were used. This data was extracted for each year of record for each station.

Most floods (excluding the Hazel flood) in southern Ontario have a snowmelt component (Sangal and Kallio, 1977). That is to say, they are spring floods. In the past, many streams in southern Ontario were gauged only during the snowmelt period. As a result, for years in which there existed only a partial record of flows, a figure was recorded as the annual maximum mean daily discharge if it could be concluded that the spring flood had been recorded. This was assumed to have occured for each year of record for each station.

Of the four creeks chosen, the largest was Medway with a drainage area of 70 square miles. The smallest was Wye Creek at 15 square miles. These figures represent that portion of the basins above their respective recording stations. By comparison, Pottersburg Creek, above the lower limit of the study area (Clarke Road), has a drainage area of 17.25 square miles which was determined from the 1:50,000 Topographic Sheets for the area as produced by the Surveys and Mapping Branch of Energy, Mines and Resources, Canada. Measurement was done using an Alpha Zero Setting Compensating Polar Planimeter (serial #41079). Two sheets were required: the St. Thomas sheet, number 40 I/14 (edition 4) and the Luncan sheet, number 40 P/3 (edition 3).

For each of the four creeks, the maximum annual mean daily peaks were tabulated by year and then ranked (in descending order of magnitude). In order to more easily compare the data between streams, the data were reduced to a dimensionless state by converting the values for each annual maximum mean daily peak to a ratio to the mean of all the peaks. This was done for each station's data. These ratios were tabulated by their year of occurence.

Using the Weibel formula:

$$P = \frac{m}{n+1} \qquad (3.1)$$

where: P = cumulative frequency in percent

m = rank in descending order of magnitude

n = number of events,

each year of record (for each stream) was assigned a frequency.

For each stream, the data were plotted on logarithmic probability paper. The ratio to the mean was plotted on the abscissa and the frequency on the ordinate axis.

Best fit lines were added by eye. For each stream three such lines were drawn. These were labelled A, B and C. Lines A and C represent regression lines biased toward high frequencies and low frequencies respectively. In both cases these lines were biased only so far as they could reasonably be fitted given the scatter of the data points. Lines B represent the median fit. Three lines were drawn (rather than one best fit) so as to enable a later determination of the sensitivity of the damage estimations to the frequency selection.

All four (one for each creek) of the A frequency lines were re-drawn on a separate graph. The same was done for the B and C frequencies. For each of these three graphs the mean was determined by calculating the mean slope and the mean intercept (at the 98% probability discharge vertical) of the four lines for each graph.

The resulting three lines were then drawn together on one graph. They were deemed to represent a high, a median and a low estimate of the relationship between ratio to the mean (of annual maximum mean daily discharge) and frequency for

Pottersburg Creek.

To convert this to values for annual maximum mean daily discharges, an estimation of the mean annual flood is required. The mean annual flood is defined as the mean of the annual maximum dean daily discharges. To obtain this estimation, the following process was used.

For each of the four gauged streams, a value was determined for the relationship between mean discharge and drainage area by using the following formula:

$$k = \frac{DA}{maf} \qquad (3.2)$$

where: k = a constant

DA = drainage area (in square miles)

maf = mean annual flood (cfs.)

The mean of the resulting values was determined using the formula:

$$\bar{k} = \frac{\sum k}{n} \qquad (3.3)$$

where: $\bar{k}$ = the mean of the k values

$\sum k$ = the sum of the k values

n = the number of events

The resulting values was used as the k value for Pottersburg Creek, assuming the relationship:

$$k_{(Pottersburg)} = \bar{k} \qquad (3.4)$$

Re-writing equation (3.2), results in:

$$maf = \frac{DA}{\bar{k}} \qquad (3.5)$$

By substitution, the maf for Pottersburg was determined. Using this value the figures for ratios to the mean were converted to flow figures. This distribution is, however, for annual maximum mean daily discharges. For the purposes of this study, an instantaneous flow/frequency distribution is required.

To convert the derived values for maximum annual mean daily discharges to instantaneous flow values, Fuller's formula may be used:

$$Qp = Qd\ (1 + 2\ DA^{-0.3}) \qquad (3.6)$$

where: Qp = annual maximum instantaneous peak discharges

Qd = annual maximum mean daily discharges

DA = drainage area (in square miles)

However, as noted earlier, most floods in southern Ontario, and hence most instantaneous peaks, occur during spring floods. In recognition of this, Sangal and Kallio (1977) have modified Fuller's Formula to:

$$Qp = Qd\ (1 + 6\ DA^{-0.3}) \qquad (3.7)$$

and have suggested that, in this form, Fuller's Formula produces "... an upper bound for maximum ratios". This was based on data from various stations (with varying lengths of flow records) in southern Ontario.

As there is no evidence to suggest that Fuller's ratio for Pottersburg Creek would approach the maximum observable (or the minimum), Fuller's formula has been modified to represent the mean of equations (3.6) and (3.7).

Thus, for the purposes of this study, Fuller's formula was deemed to be:

$$Qp = Qd\ (1 + 4\ DA^{-0.3}) \qquad (3.8)$$

This formula, which produces a Fuller's ratio of 2.7, was used to convert the derived annual maximum mean daily discharge values for Pottersburg to values for instantaneous discharges.[2]

The flow/frequency distributions were then re-drawn. Because of the relatively small area of the study site, these frequency estimates, although representing the downstream boundary of the study site, were assumed to be representative of the entire study site.[3]

3.3 Step Two - Stage/Discharge Relationship

There was no determined relationship between depth and flow for Pottersburg Creek. To overcome this, a computer simulation was used. The programme is known as HEC - 2.[4] The output from this programme is a series of computer water surface elevations at pre-determined stream cross-sections and for specified flow volumes.

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[2]This form of Fuller's Formula was used as it was the choice of Sangal and Kallio (1977) in their work in southern Ontario. The original form of Fuller's formula was $Qp = Qd\ (1 + .08 \log T)$. Because the ratio produced is, in this form, a function of the logarithm of the flood return period, it increases with the recurrence interval. The result is to produce a regression line for instantaneous peaks steeper than that for daily peaks.

[3]The frequency determination methodology used in step one is known to be sound. It's application here (due solely to the short history of record of the four creeks examined), carries less confidence. A more accurate relationship might be obtained through the use of some sort of flow simulation model. The time and cost associated with such modelling techniques were, however, beyond the resources available to this study. This problem is compounded by the fact that, as noted by Dillon and MacLaren (1976), there is currently no generally approved method in Ontario for the prediction of peak flows on ungauged streams.

[4]HEC-2 is a water surface profile computer programme developed in the late 1960's by the U.S. Army Corps of Engineers at the Hydraulic Engineering Centre (hence HEC) in Sacramento, California. See Appendix 1 for a brief description of the programme.

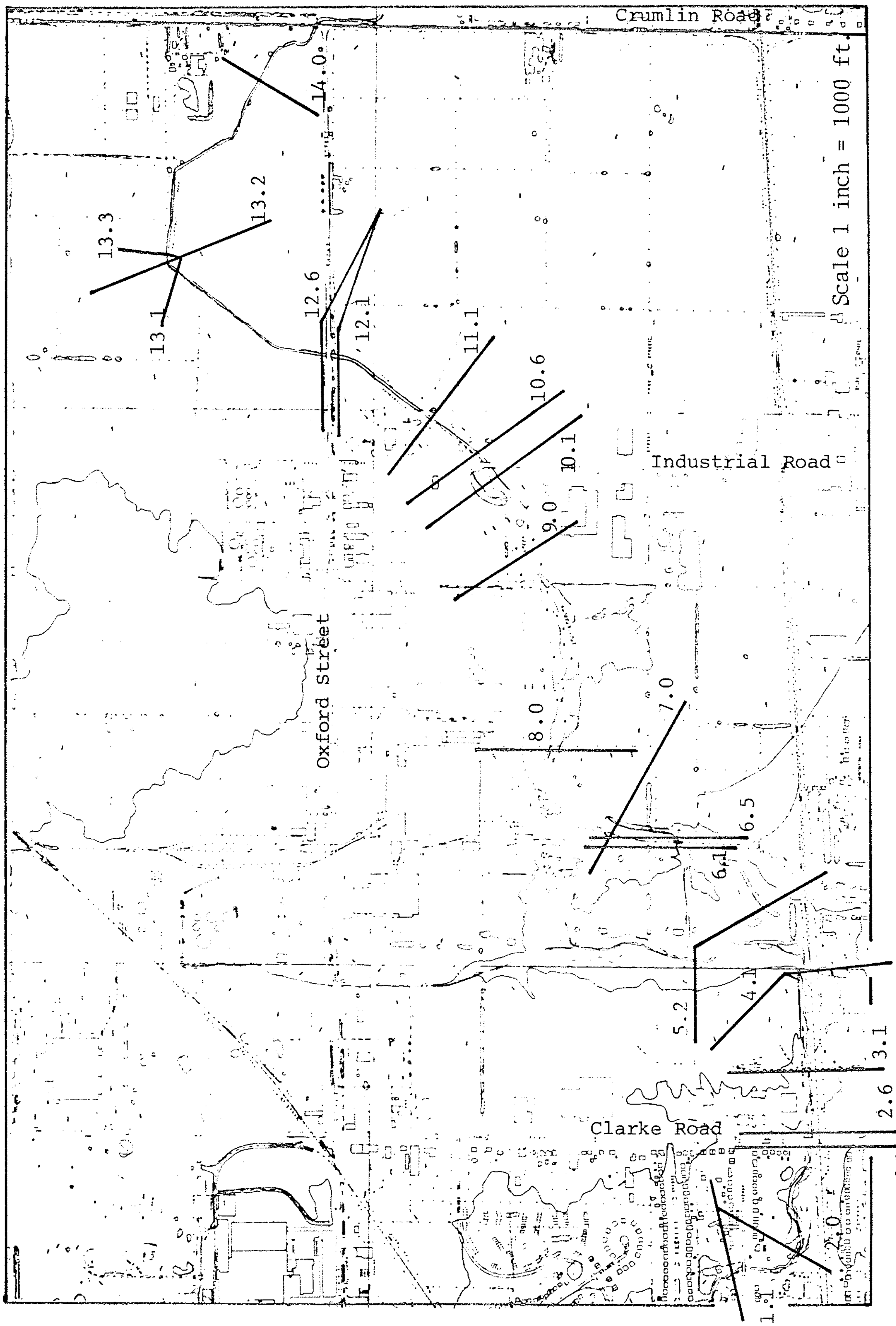
The input is in the form of stream cross-sections, flow volumes and a starting water surface elevation at a control section. Location of the cross-sections is determined by the dictates of the programme which requires, at a minimum, that cross-sections be taken at all constrictions (especially bridges), at major bends and wherever there is a major change in the cross-sectional form.

The locations of the cross-sections taken in the study site are shown in Map 3-1. As required by the programme, a number of cross-sections were taken downstream of the lower end of the study site.

In all, more than 50 cross-sections were surveyed. More than one cross-section was taken at certain points such as at curves in the stream. Bridges required up to six cross-sections each. Some cross-sections, although surveyed once, were used more than once in the programme.

All cross-sections were surveyed, with the support of various members of the UTRCA staff, during June and July of 1978. A John Wood's metric measure three section stadia rod was used for both elevations and distance measures. It was read through a Wild NA-O engineer's level (serial #392093). Measurements were recorded in a Faber-Castell S360 field book. Some shorter linear distances were measured with a 50 metre Yamayo Stilon steel tape.

The metric measures were converted to imperial units using conversion factors accurate to four decimals and then rounded to two decimals. All cross-sections were plotted and checked.



Map 3-1 Location of Stream Cross-Sections

The data points for each cross-section were then entered, following the HEC-2 required format, on General Purpose Data Forms (8 column fields). The entire data entry required 26 such sheets.

The forms were sent to the Ministry of Natural Resources in Toronto (the use of whose computer was made available for this study to the UTRCA) where the data were punched on 80 column cards, entered into the computer and the programme run. The data were entered on punch cards (rather than on tape) so as to facilitate the removal and insertion of cross-sections. Thus, a sensitivity analysis (as to the minimum number of cross-sections required to maintain accurate results), can be conducted. The programme was run four times, once each for 1,000 cfs., for 2,000, and for 4,000 and for 6,000 cfs.

At flows greater than bankfull capacity, the course of the stream deviates from the low-flow channel. The most common alteration was the short-cutting of meander bends.

Thus, the number of cross-sections required by the programme varied for the different programme runs. Generally, fewer cross-sections were required for the higher flows (the reach lengths being shorter).

For each cross-section, for each of the computer runs, a water surface elevation was computed. Using this data, a rating curve can be produced for each cross-section. Rating curves were required, however, not for specific points (cross-sections) along the creek, but for reach lengths within the five sub-areas of the study site. Thus, five rating curves were produced. For the reach length from Clarke Road upstream to the first bend in the Creek (sub-area 1), the average of the rating curves at cross-section 2.6 (Clarke Road bridge) and 4.1 (cross-section at the first upstream bend) was used. For the reach length from this first bend upstream to the General Motors railway embankment (sub-area 2), the average of the rating curves at cross-sections 4.1 (creek bend) and 6.1 (G.M. embankment) was used. For the reach length from the General Motors embankment upstream to Industrial Road (sub-area 3), the rating curve used was an average for those at cross-sections 6.5 and 10.1. For the reach length between Industrial Road and Oxford Street (sub-area 4), the rating curve was an average of those for cross-sections 10.6 and 12.1. Finally, the average rating curve for cross-sections 12.6 and 14.0 was used for the reach length between Oxford Street and Crumlin Road (sub-area 5).

3.4 Step Three - Determination of Flood Fringe Acreages

The acreage of industrially zoned and undeveloped land within the study site and flood fringe boundaries was determined. This was accomplished by first drawing in the 1 in 500 year and 1 in 100 year flood lines on the 1:4,800 topographic sheet as produced by the City of London. These lines were based on flood elevations obtained from the rating curves produced in step two. The rationale for using these lines as the floodway and flood fringe boundaries was explained in section 1.7.1. The resulting flood fringe area was measured from the topographic sheet using an Ott Areo Compensating Polar Planimeter (serial #116996).

The accuracy of this mapping series has since been called into question from a number of sources including the UTRCA (Anderson, 1979).

For all five sub-areas, the flood fringe areas were found to be too small or too discontinuous for industrial development purposes. If the floodway boundary were based on the 1 in 100 year flow, none of the flood plain lands would be freed for development parcels large enough to justify the investment.

One of the proposed revisions to present flood prone land management policies is that the conservation authorities be granted the power to designate certain areas as "special policy areas". In these areas, a lower standard of protection (i.e. a less prohibited area) could be adopted.

In consideration of this and given the economic importance of the Pottersburg industrial lands to the City of London, new floodway boundaries were drawn. These were based on the 2,500 cfs. flow (the minimum suggested by the UTRCA) which is approximately the 1 in 17 year flood in the B frequency estimate. Even at this reduced level only sub-area 4 contained parcels of land within this enlarged flood fringe large enough for industrial development.

Sub-areas 1, 2 and 3 contained virtually no flood fringe lands, the bulk of their flood plains being occupied by the floodway. This is a product of the more deeply incised nature of the creek in these areas. Because of its flatness and uniform topography, sub-area 5 is perhaps the most ideal site from an industrial construction point of view. This area would be almost completely innundated by the 2,500 cfs. flow.

All flood fringe area measurements were exclusive of present developments. Thus, for example, portions of property owned by General Motors, Wilcox Canada and others that are within the flood fringe were not included in the measured acreage.

3.5 Step Four - Discharge/Damage Calculation

This step involved the generation of a discharge/damage relationship for those portions of flood fringe lands large enough to be attractive to industrial mall developers. As noted above, this was limited to sub-area 4.

Data on projected industrial developments, industrial construction costs and on building/area densities were obtained from the Industrial Commissioners Office for the City of London, the Official Plan for the City of London, the Regional Tax Assessment Office and representatives of various local insurance agents and local contractors. Based on this information the value of building construction per acre of flood fringe land was estimated and the total value of potential industrial construction within the study site was determined.

As a result of discussions with a number of real estate agents, industrial insurance agents and industrial mall developers, it was determined that, for existing industrial malls in the City of London, the value of inventory and equipment averaged 100% of the total value of land and buildings.

Thus, to determine values for Inventory and Equipment, the following formula was used:

$$IE = B + L \qquad (3.9)$$

where: IE = value of inventory and equipment

B = value of buildings

L = value of land.

Projected land values were determined, again through discussions with officials of the Planning Office, the Tax Office and the Office of the Industrial Commissioner of London.

To determine a value for total investment (per acre), the following formula was used:

$$I = B + IE \qquad (3.10)$$

where: I = value of total invesment

B = value of buildings

IE = value of inventory and equipment

This can be simplified to:

$$I = 2B + L \qquad (3.11)$$

and this formula was used to determine values for total damageable investment.

Equation 3.11 appears somewhat deceptive in the sense that it shows land (L) as an addition when, in fact, land is explicitly being excluded (in this study) as being flood damageable. If attempting to arrive, however, at a value for total capital investment (including land), the following formula could be used:

$$I = 2B + 2L \qquad (3.12)$$

Damages due to flooding, for various depths of flooding, were calculated using a formula first developed by the

Stanford Research Institute (1960) and adapted for use by Acres (1972) in its Thames River Flood Damage Report. This method calculates flood damage as a percentage of total investment (in this study: buildings plus inventory and equipment) for various depths of flooding. Using this formula, a graph showing the relationship between depth of flooding (in the building)[5] and the percentage of total investment damaged by flooding was constructed.

For each level of flooding, the total volume of flood waters present on the flood fringe were averaged over the entire flood fringe. Thus, for each flood discharge a corresponding average depth of flooding for the entire flood fringe was obtained. This relationship was graphed. By combining the above two graphs (damage/depth and flow/depth) a damage/flow relationship was obtained.

3.6 Step Five - Potential Average Annual Damage Estimate

For each frequency estimate the damage potential for each flow was multiplied by the frequency corresponding to that flow.

3.7 Step Six - Present Value Calculation

This step involved the determination of the present value

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[5]It was assumed, based on the evidence of existing industrial malls in the city, that the proposed buildings would be of one storey construction, have no basements and that the elevation of the building floor would be the same as the outside ground elevation. This was also the opinion of the Industrial Commissioner's Office in London.

of the average annual damages.[6] The reasoning here is based on the principle that the main purpose of most economic analysis (and certainly of all benefit-cost comparisons) is to determine if the addition of a particular development to the existing capital base is worthwhile. This determination is made on the basis of present values which has generally been accepted as the proper mechanism for the evaluation of future streams of costs and benefits.

The present value criterion is based on the postulate that the value of benefits and costs in the future is less than it is today. Thus, future value must be discounted.

The choice of discount rate is the subject of much debate in economic literature. Various authors have supported the choice of a discount rate equal to the rate of return on capital in the private sector.[7] This is the so-called social opportunity cost rate and is basically the free-market interest rate adjusted as necessary to correct for known market defects, inflation and income taxes. Proponents of this approach argue that society's resources will be wasted if used to finance a project the returns

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[6]The damage figures obtained by this method are expected values (based on flood probabilities) assuming a normal distribution of flood events. Given that, in the real world, floods tend not to occur with any sort of normal distribution, a more stable indicator of potential flood losses, and a means by which the assumptions concerning the magnitude and pattern of the frequency estimations can be tested, is the use of a flood simulation model. Such a model derives the probability of flooding in a specific year rather than the probability of a specific flood in any year (as done in this study). Thus, the present value figures for flood damages can account for, for example, long periods in which no flooding might occur and short periods in which severe flooding might occur.

[7]See, for example, Baumol, 1968.

from which were not as great as could have been realized elsewhere.

A second school of thought is that the discount rate should equal society's time preference rate. Proponents of this approach argue that the rate (which is usually lower than the opportunity cost rate) should reflect society's views as to the optimum allocation of resources between the present and the future (Marglin 1963). This rate need reflect no relationship with rates of return in the private sector, interest rates or other market phenomena.

The choice of discount rate is also a function of the accounting stance taken (see section 1.7.3). From the point of view of project developers, a discount rate used to evaluate a project should reflect current rates of interest on borrowed capital.

In this regard, the Treasury Board (1976) notes that the weighted social rate of return on capital in Canada was estimated at about 9.5% for the period 1965-1969. During this same period the rate of return in the manufacturing sector was, at 15.1% the highest for all sectors of the economy. The Treasury Board also notes, however, that some authors have found this long term rate to be as low as 5%.

Herfindahl and Kneese (1974) state that "some economists believe that ... the (discount) rate for public projects should reflect opportunity costs of capital in the private sector which they estimate to be 8 to 10 percent."

From the city's accounting stance, the proper rate would be the long-term municipal bond interest rate. From the national perspective, some lower rate, reflecting society's time preference, might be chosen.

Even within each accounting stance, there is no agreement as to the "correct" discount rate. In respect of this difficulty, the Treasury Board (1976) has recommended that the present values of costs and benefits be calculated for a range of discount rates.

Following this recommendation, present values were calculated for 2, 4, 6, 8, 10 and 12 percent. These rates were deemed to be net discount rates (nominal discount rates less inflation).

The formula used for these calculations is the present value formula for annuities:[8]

$$PV = \frac{D\,[(1 + d)^n - 1]}{d(1 + d)^n} \qquad (3.13)$$

where: PV = present value of damages

D = average annual damage

d = discount rate

n = number of events (years)

[8] If actual inflation rates and discount rates are known, a more accurate determination of present values can be made using the following formula:

$$PV = D\,\frac{(1+i)}{(d-i)} \times \left[1 - \frac{(1+i)^n}{(1+d)^n} \right]$$

where: PV = present value
D = average annual damage
d = discount rate
i = inflation rate
n = number of events (years)

This formula was used for a few of the calculations and compared with the results using formula (13). The difference in determined values was found to be minimal. The use of net discount rates tends to produce more conservative estimates of present values than does the above formula. In addition, the magnitude of the error was found to increase with the magnitude of the inflation and discount rates, but in all cases, the discrepancy was less than five percent.

CHAPTER 4

STUDY RESULTS

4.1 Flow/Frequency Distribution

The results of the analysis of the four gauged streams are presented in Tables 4-1 to 4-4. For each of these creeks, frequency curves were drawn (by plotting column 4 and 5 data points) on logarithmic probability paper. These frequency graphs are shown in Figures 4-1 to 4-4. The three frequency lines (representing a high estimate, a low estimate and a median estimate) are shown.

Figure 4-5 shows the four high frequency ('A' lines) estimates for the four gauged creeks. Figure 4-6 reproduces the 'B' lines and Figure 4-7 the 'C' lines.

Tables 4-5 to 4-7 show the determination of the mean slopes and mean intercepts for each of the four line sets of Figures 4-5 to 4-7. Data from these three tables were used to produce the three frequency estimates shown in Figure 4-8. These three lines represent a high, a median and a low flow/frequency estimate for Pottersburg Creek based on ratios to the mean annual flood (annual maximum mean daily discharges).

In order to convert these values from ratios to the mean to actual flow values, a determination of the mean annual flood for Pottersburg was required. This was found to be 375 cfs based on a value of .046 for the mean of the k values of the four gauged streams. This was determined as follows:

since: $\bar{k} = \frac{\Sigma k}{n}$

and $k_{(Pottersburg)} = \bar{k}$

therefore:

$$k_{(Pottersburg)} = \frac{\Sigma k}{n}$$

$$= \frac{0.60 + 0.39 + 0.51 + 0.35}{4}$$

$$= .046$$

and since:

$$k_{(Pottersburg)} = \frac{DA}{maf}$$

therefore:

$$maf_{(Pottersburg)} = \frac{DA}{k}$$

$$= \frac{17.5 \text{ mi}^2}{0.46 \text{mi}^2/_{cfs}}$$

$$= 375 \text{ cfs}$$

However, as it is instantaneous discharges and not mean daily flows that are required, Tables 4-8 to 4-10 were used to convert the ratio to the mean values to daily flows and thence to instantaneous flows. The daily flows were converted to instantaneous flows using a Fuller's Ratio of 2.7. This was determined, using the bracketed factor of equation (3.8) as follows:

$$\text{Fuller's ratio} = 1 + 4DA^{-0.3}$$

$$= 1 + 4 (17.25^{-0.3})$$

$$= 1 + 4 (.4256)$$

$$= 1 + 1.70$$

$$= 2.7$$

The three frequency/instantaneous peaks relationship of Tables 4-8 to 4-10 were drawn together in Figure 4-9. These represent high, median and low frequency estimates for Pottersburg Creek.

4.2 Stage/Discharge (Rating) Curves

Table 4-11 plots the computed water surface elevations for designated flows for the study area. This data was extracted from the HEC-2 programme print-out.

Rating curves were produced for all five study sub-areas. As noted on page 41 of Chapter 3, these rating curves represent averages of upstream and downstream boundary cross-sections. These five ratings curves are shown in Figures 4-10 to 4-14.

4.3 Depth/Damage Relationship

Table 4-12 shows the depth/damage relationship used by Acres (1972) in its Thames River study. This same relationship was assumed for the Pottersburg Creek flood fringe. From this table, Figure 4-15 was drawn. A linear relationship was assumed for the interval from zero inches of flood depth to six inches of flood depth.

4.4 Flood Fringe Acreage Estimates

The acreage of industrially zoned and still undeveloped land within the study site and within the flood fringe boundaries was determined for each of the five sub-areas. These acreages were determined for a flood plain boundary for a flow of 6,000 cfs. and for floodway boundaries for each of two flows of 2,500 cfs. and 4,000 cfs. The measured acreages are shown in Table 4-13.

Only sub-area 4, with the floodway boundary at 2,500 cfs was found to have a flood fringe large enough to make it (along with the adjoining industrially zoned but non-flood plain land) attractive to developers. The flood fringe of sub-area 5 (with the floodway boundary at 2,500 cfs), although comprising slightly more than 40 acres, is isolated from adjoining industrially zoned non-flood plain lands and would be surrounded by the flood waters of even the 1 in 17 year flood (2,500 cfs in the 'B' frequency estimate). Thus, only sub-area 4 was considered for further analysis. The location of the flood plain and floodway boundaries for all five sub-areas are shown in Map 4-1.

4.5 Discharge/Damage Estimate

Figure 4-16 plots flood discharge against the average depth of flooding. This average flooding depth was determined by averaging the volume of flood waters associated with each flood level over the entire flood fringe. Thus, for example, one foot of flood depth over half of the flood fringe (and no flooding on the other half) was equated with a uniform six inch flooding depth over the entire flood fringe. A similar assumption is made concerning flood damage. The damage associated with a six inch uniform depth of flooding is assumed to be the same as that associated with one foot of flooding on one half of the flood fringe and no flooding on the remaining half.

Data from the various London sources listed in Chapter 3 were analyzed and the following average values were determined:

L = \$30,000 per acre

C = \$18.00 per square foot

ubc = 14,500 square feet per acre

where: L = the value of flood fringe land

C = building construction costs

ubc = ultimate building coverage (building area to land area)

Equation 3.11 was used to determine the value of the potential investment in the flood fringe of sub-area 4 as follows:

$$I = 2B + L$$

$$= 2\ (\$18.00 \times 14,500) + \$30,000$$

$$= \$552,000 \quad \text{(per acre)}$$

where: B = value of buildings

Thus, total potential investment in the sub-area 4 flood fringe was \$34,251,600. (\$552,000 per acre x 62.05 acres) or \$34.25 million.

Using this result, and combining Figures 4-15 and 4-16 to produce a relationship between flow and the percent of total investment damaged by flooding, Table 4-14 was produced. This shows the total potential flood damage in dollars as a function of flood discharge.

Three estimates of potential average annual damage corresponding with the three frequency estimates were determined, using:

(1) the three frequency estimates of Figure 4-9 and,

(2) the data of Table 4-14.

The resulting average annual damage estimates are shown in Tables 4-15 to 4-17.

4.6 Present Value Estimates

The present value of the average annual damages was calculated for discount rates of 2, 4, 6, 8, 10 and 12 percent for a 50 year period. The resulting values are shown in Table 4-18. The relationship between the present value of annual damages and discount rate for each of the three frequency estimates is shown in Figure 4-17.

TABLE 4-1

Frequency Analysis

DINGMAN CREEK
(station #02GE005)

1 Year	2 Daily Peak (in cfs)	3 Rank (m)	4 Ratio to the Mean	5 Frequency $(P = \frac{m}{n+1})$
1965	383	12	.46	.92
1966	642	8	.77	.62
1967	870	5	1.04	.39
1968	2,080	1	2.49	.08
1969	960	3	1.15	.23
1970	414	11	.49	.85
1971	509	10	.61	.77
1972	780	6	.93	.46
1973	602	9	.72	.69
1974	775	7	.93	.54
1975	952	4	1.14	.31
1976	1,080	2	1.29	.15

Parameters

n = 12
DA = 50.3 mi^2
maf = 837.25 cfs.
k = .060

TABLE 4-2

FREQUENCY ANALYSIS

Medway Creek
(station #02GD008)

1 Year	2 Daily Peak (in cfs)	3 Rank (m)	4 Ratio to the Mean	5 Frequency $(P = \frac{m}{n+1})$
1945	1,720	14	.95	.42
1946	1,470	20	.81	.61
1947	3,780	1	2.09	.03
1948	2,360	9	1.31	.27
1949	1,940	12	1.07	.36
1950	2,220	11	1.23	.33
1951	2,710	5	1.50	.15
1952	1,590	18	.88	.55
1953	755	29	.42	.88
1954	3,390	3	1.88	.09
1955	1,380	21	.76	.64
1956	1,490	19	.82	.58
1957	565	32	.31	.97
1958	685	30	.38	.91
1959	1,160	24	.64	.73
1960	2,460	7	1.36	.21
1961	1,080	26	.60	.79
1962	775	28	.43	.85
1963	1,890	13	1.05	.39
1964	640	31	.35	.94
1965	2,340	10	1.29	.30
1966	3,160	4	1.75	.12
1967	2,500	6	1.38	.18
1968	3,700	2	2.04	.06
1969	1,640	16	.91	.49
1970	955	27	.53	.82
1971	1,310	22	.72	.67
1972	1,160	24	.64	.73
1973	1,280	23	.71	.70
1974	1,660	15	.92	.45
1975	1,640	16	.91	.49
1976	2,440	8	1.35	.24

Parameters

n = 32
DA = 70 mi^2
maf = 1,807 cfs
k = .039

TABLE 4-3

Frequency Analysis

WAUBUNO CREEK
(station #02GD020)

1 Year	2 Daily Peak (in cfs)	3 Rank (m)	4 Ratio to the mean	5 Frequency $(P= \frac{m}{n+1})$
1965	248	12	.30	.92
1966	836	5	1.02	.39
1967	686	8	.84	.62
1968	1,960	1	2.40	.08
1969	799	6	.98	.46
1970	338	11	.41	.85
1971	541	9	.66	.69
1972	930	4	1.14	.31
1973	540	10	.66	.77
1974	797	7	.98	.54
1975	980	3	1.20	.23
1976	1,150	2	1.41	.15

Parameters

n = 12
DA = 41.6 mi^2
maf = 817.08 cfs.
k = .051

TABLE 4-4

Frequency Analysis

WYE CREEK
(station #02GD013)

1 Year	2 Daily Peak (in cfs)	3 Rank (m)	4 Ratio to the mean	5 Frequency ($P = \frac{m}{n+1}$)
1954	539	7	1.26	.29
1955	510	10	1.19	.42
1956	694	5	1.62	.21
1957	129	21	.30	.88
1958	87	22	.20	.92
1959	223	17	.52	.71
1960	530	9	1.23	.38
1961	67	23	.16	.96
1962	185	18	.43	.75
1963	696	4	1.62	.17
1964	141	20	.33	.83
1965	336	13	.78	.54
1966	534	8	1.24	.33
1967	620	6	1.44	.25
1968	1,020	1	2.38	.04
1969	975	2	2.27	.08
1970	275	15	.64	.63
1971	234	16	.55	.67
1972	144	19	.34	.79
1973	378	12	.88	.50
1974	380	11	.89	.46
1975	304	14	.71	.58
1976	875	3	2.04	.13

<u>Parameters</u>

n = 23
DA = 15 mi^2
maf = 429.4 cfs.
k = .035

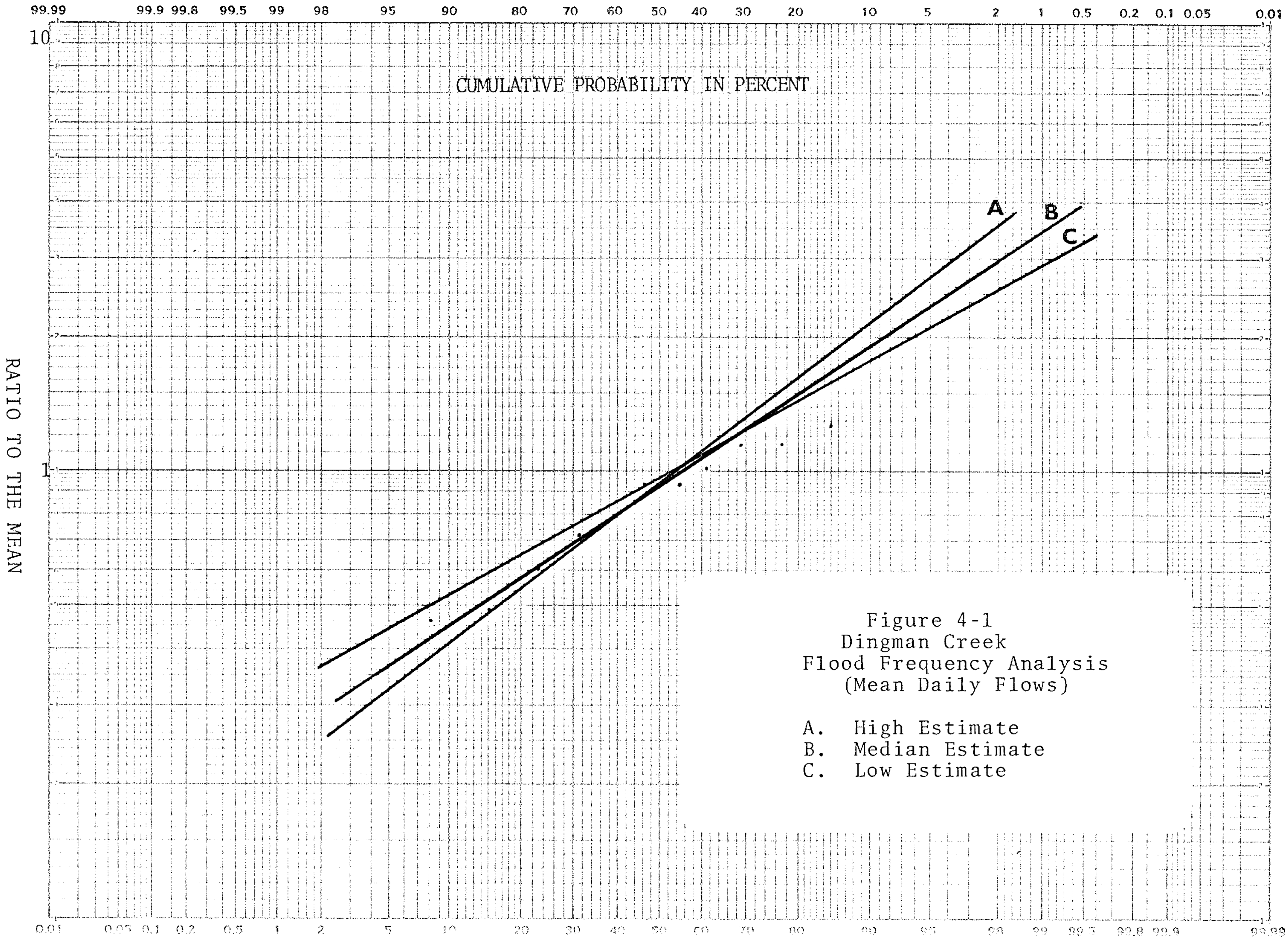


Figure 4-1
Dingman Creek
Flood Frequency Analysis
(Mean Daily Flows)

A. High Estimate
B. Median Estimate
C. Low Estimate

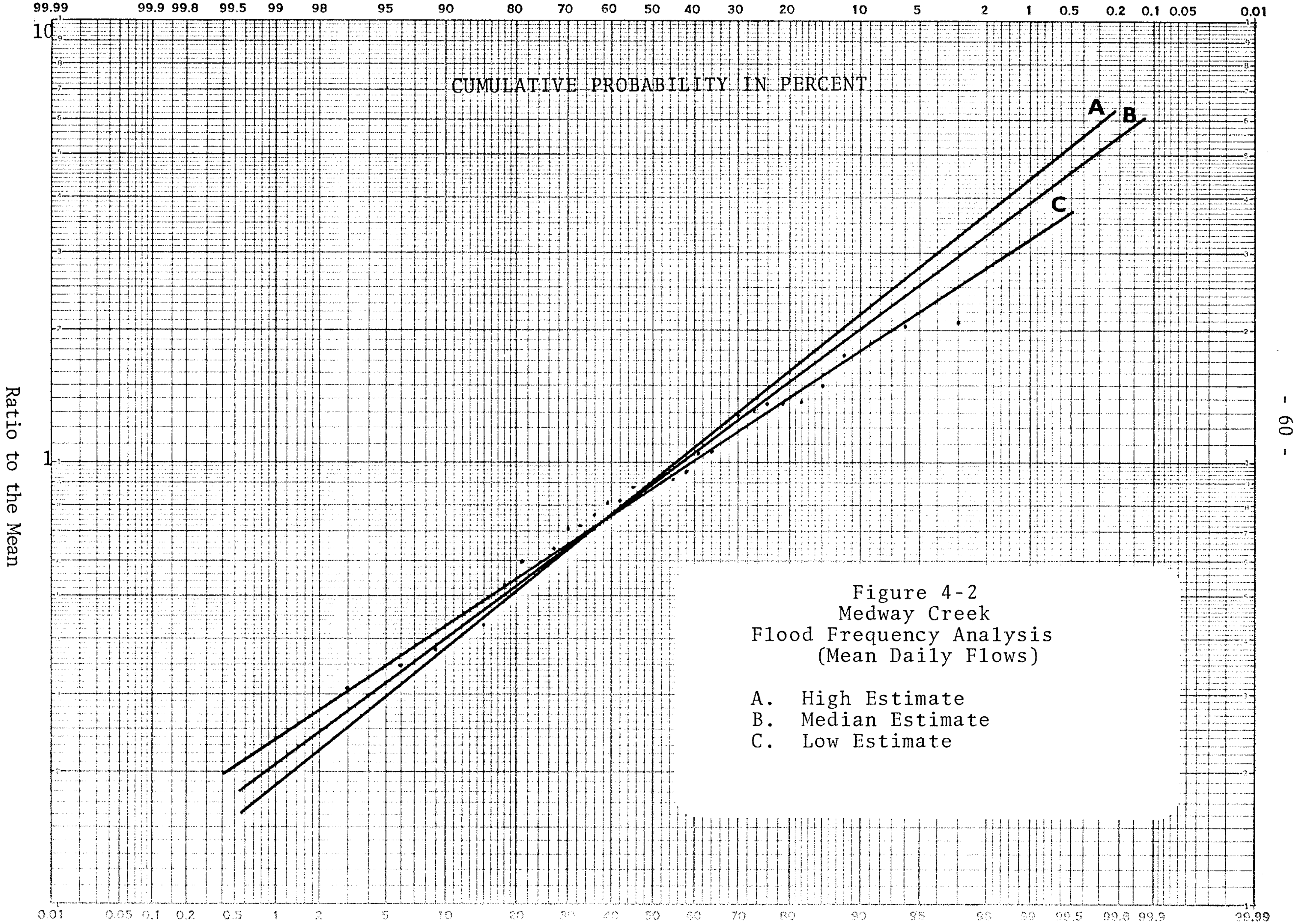


Figure 4-2
Medway Creek
Flood Frequency Analysis
(Mean Daily Flows)

A. High Estimate
B. Median Estimate
C. Low Estimate

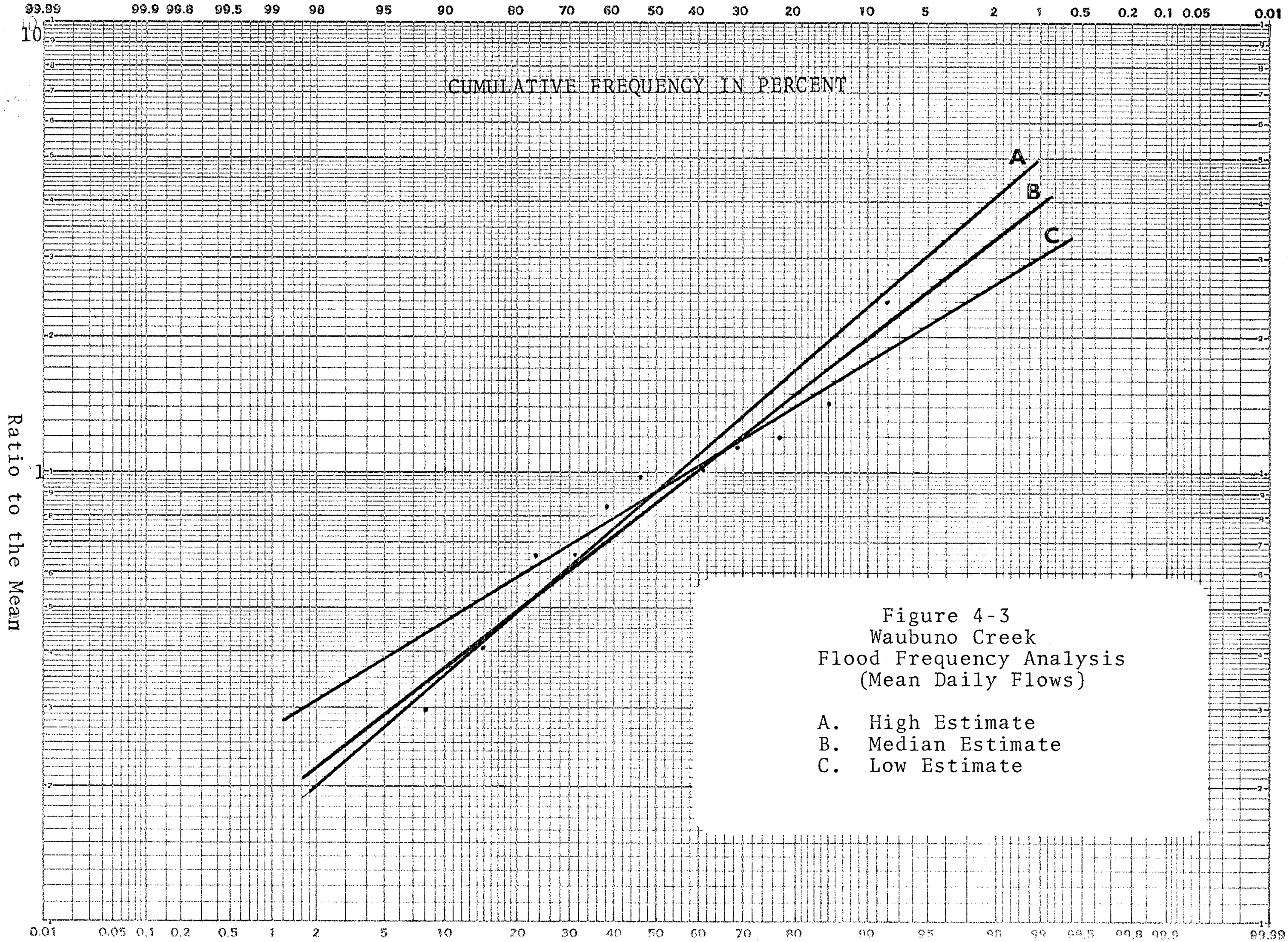


Figure 4-3
Waubuno Creek
Flood Frequency Analysis
(Mean Daily Flows)

A. High Estimate
B. Median Estimate
C. Low Estimate

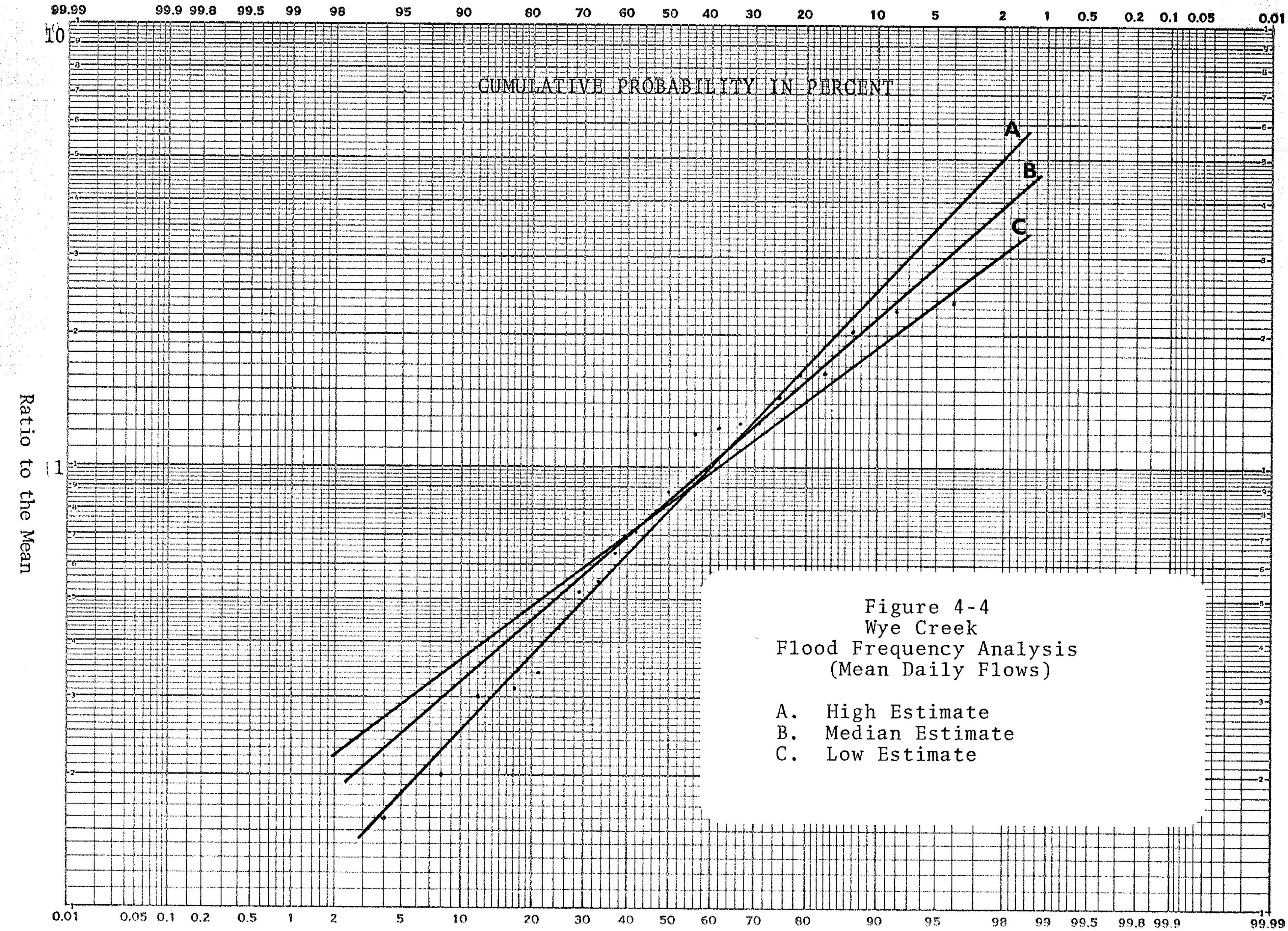


Figure 4-4
Wye Creek
Flood Frequency Analysis
(Mean Daily Flows)

A. High Estimate
B. Median Estimate
C. Low Estimate

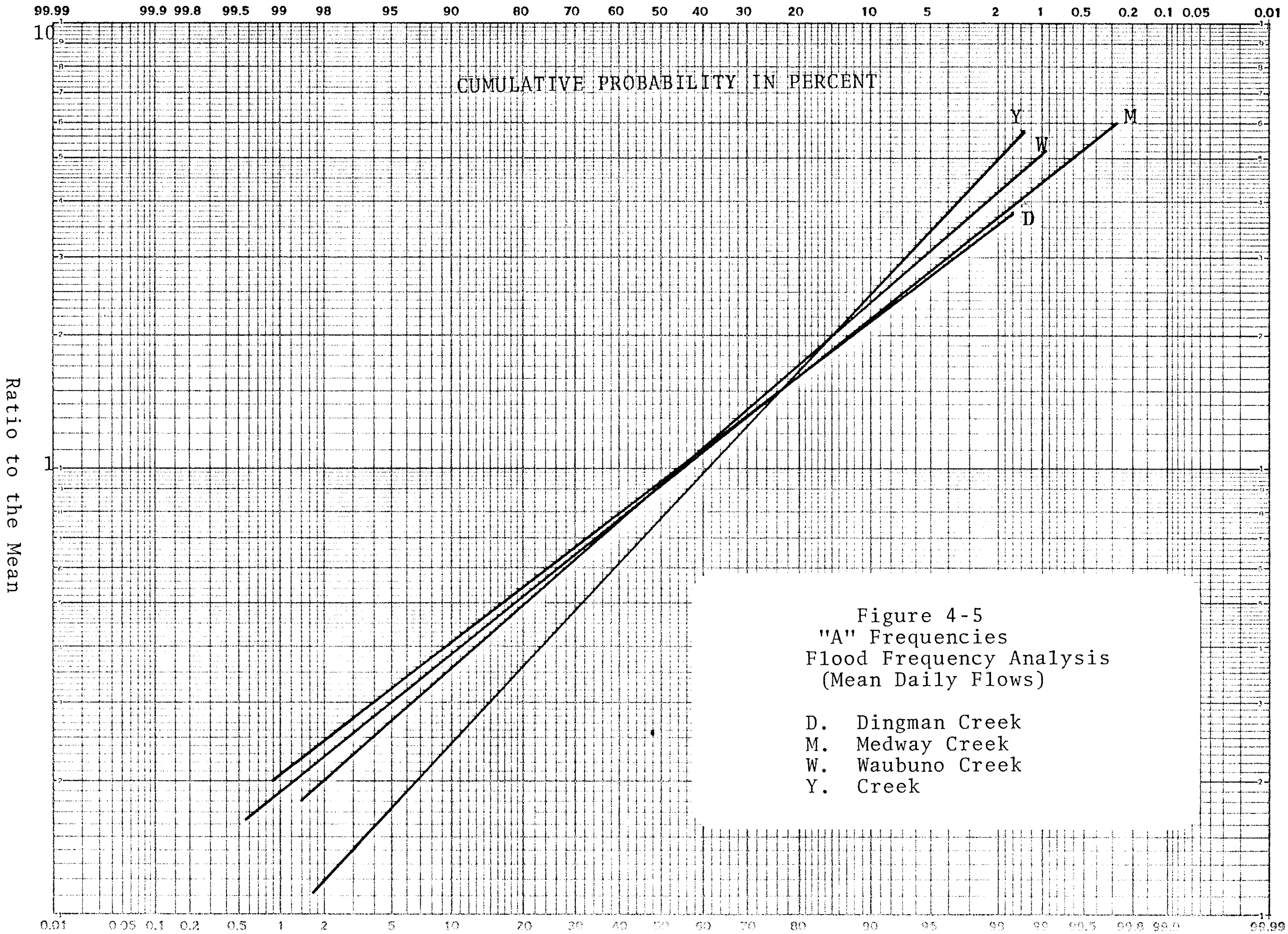


Figure 4-5
"A" Frequencies
Flood Frequency Analysis
(Mean Daily Flows)

D. Dingman Creek
M. Medway Creek
W. Waubuno Creek
Y. Creek

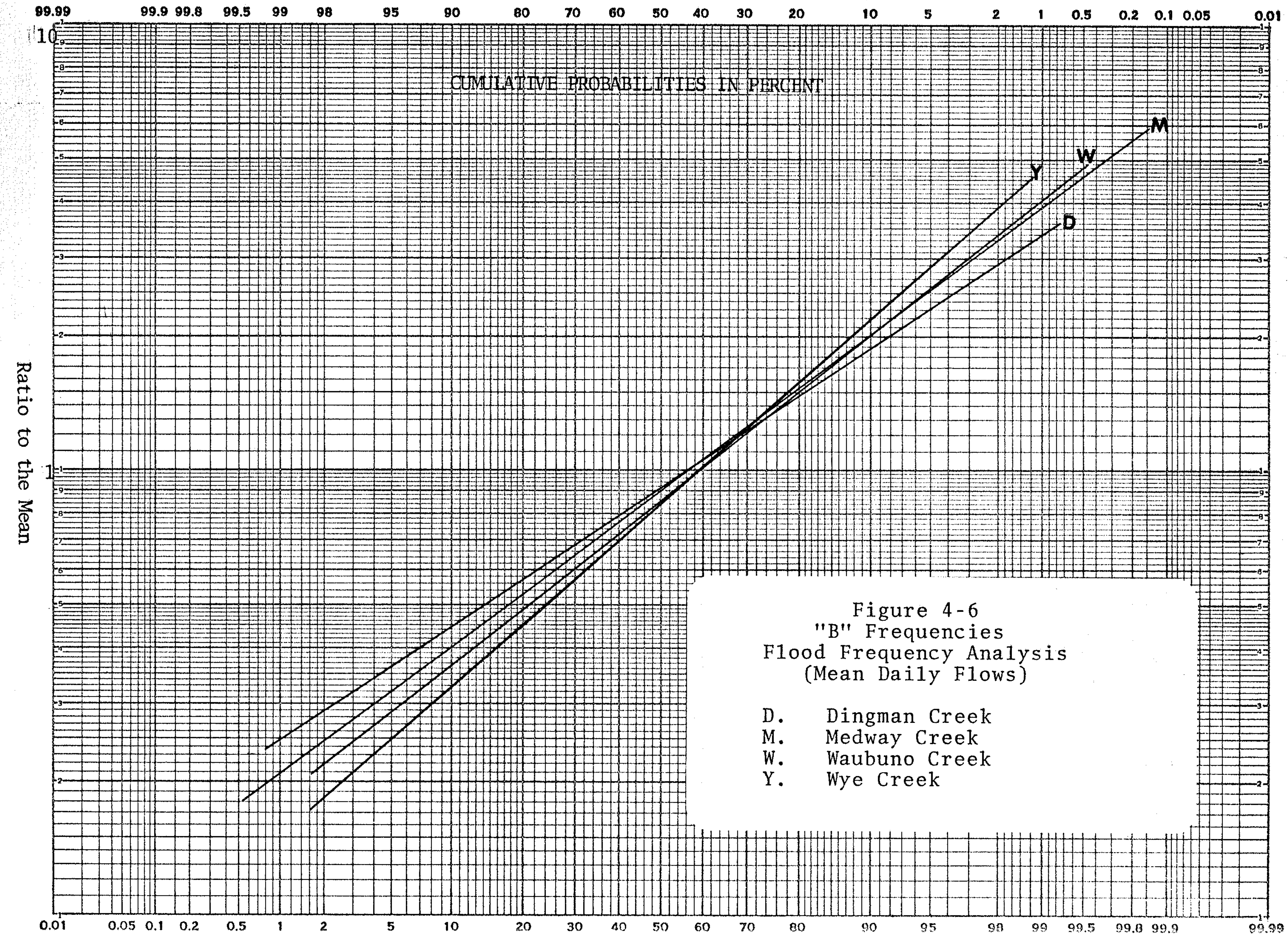


Figure 4-6
"B" Frequencies
Flood Frequency Analysis
(Mean Daily Flows)

D. Dingman Creek
M. Medway Creek
W. Waubuno Creek
Y. Wye Creek

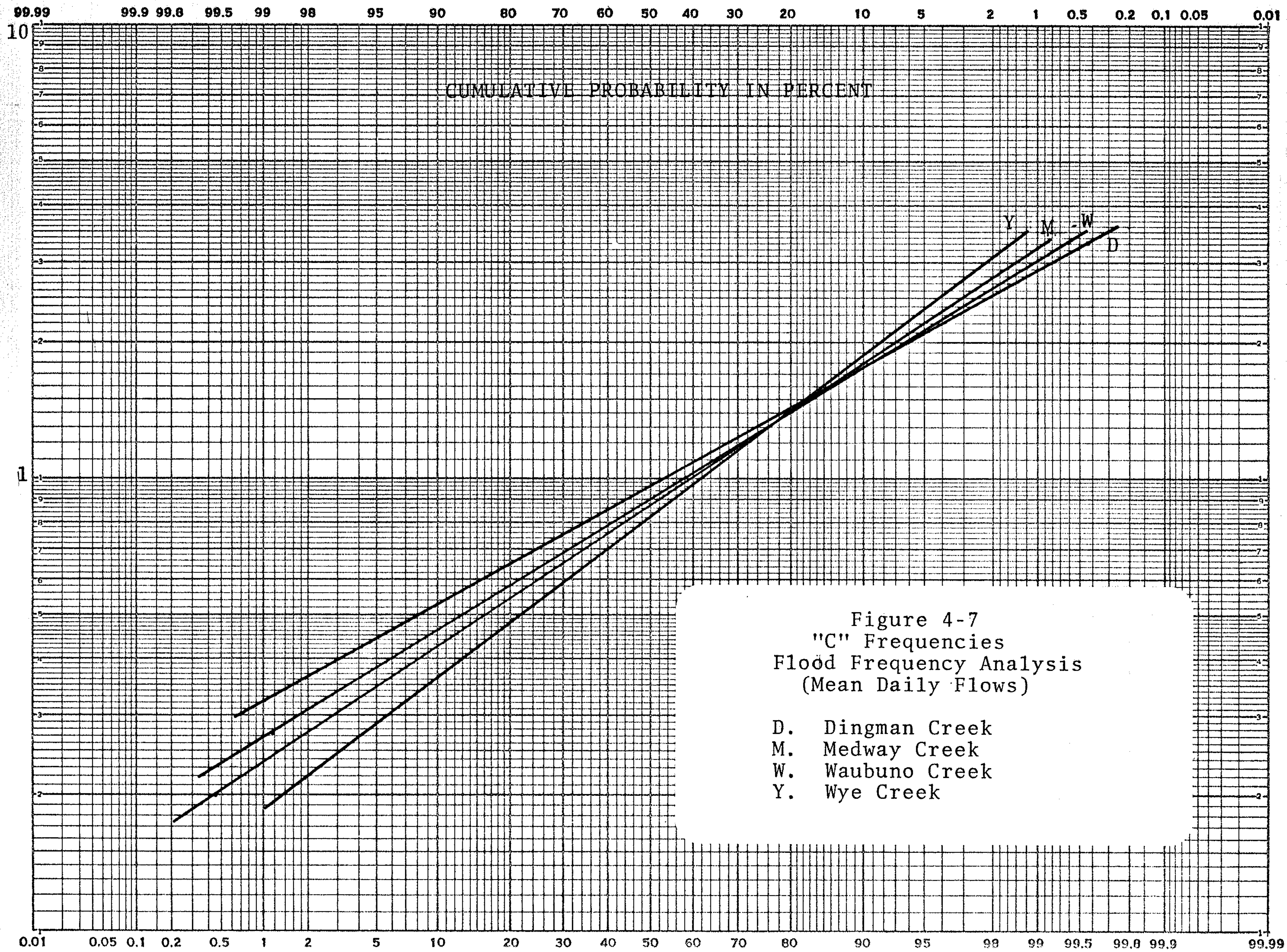


Figure 4-7
"C" Frequencies
Flood Frequency Analysis
(Mean Daily Flows)

D. Dingman Creek
M. Medway Creek
W. Waubuno Creek
Y. Wye Creek

TABLE 4-5

MEANS OF "A" FREQUENCIES

1 Creek	2 Intercept at the 98% Probability Vertical	3 Slope of the Regression Line
Dingman	2.05	38.5°
Medway	2.25	39.0°
Waubuno	2.00	41.0°
Wye	1.20	47.0°
Means	1.875	41.375°

TABLE 4-6

MEANS OF "B" FREQUENCIES

1 Creek	2 Intercept at the 98% Probability Vertical	3 Slope of the Regression Line
Dingman	2.90	33.5°
Medway	2.48	37.0°
Waubuno	2.20	38.0°
Wye	1.83	41.5°
Means	2.35	37.5°

TABLE 4-7

MEANS OF "C" FREQUENCES

1 Creek	2 Intercept at the 98% Probability Vertical	3 Slope of the Regression Line
Dingman	3.65	29.0°
Medway	2.75	34.0°
Waubuno	3.10	31.5°
Wye	2.20	37.0°
Means	2.925	32.875°

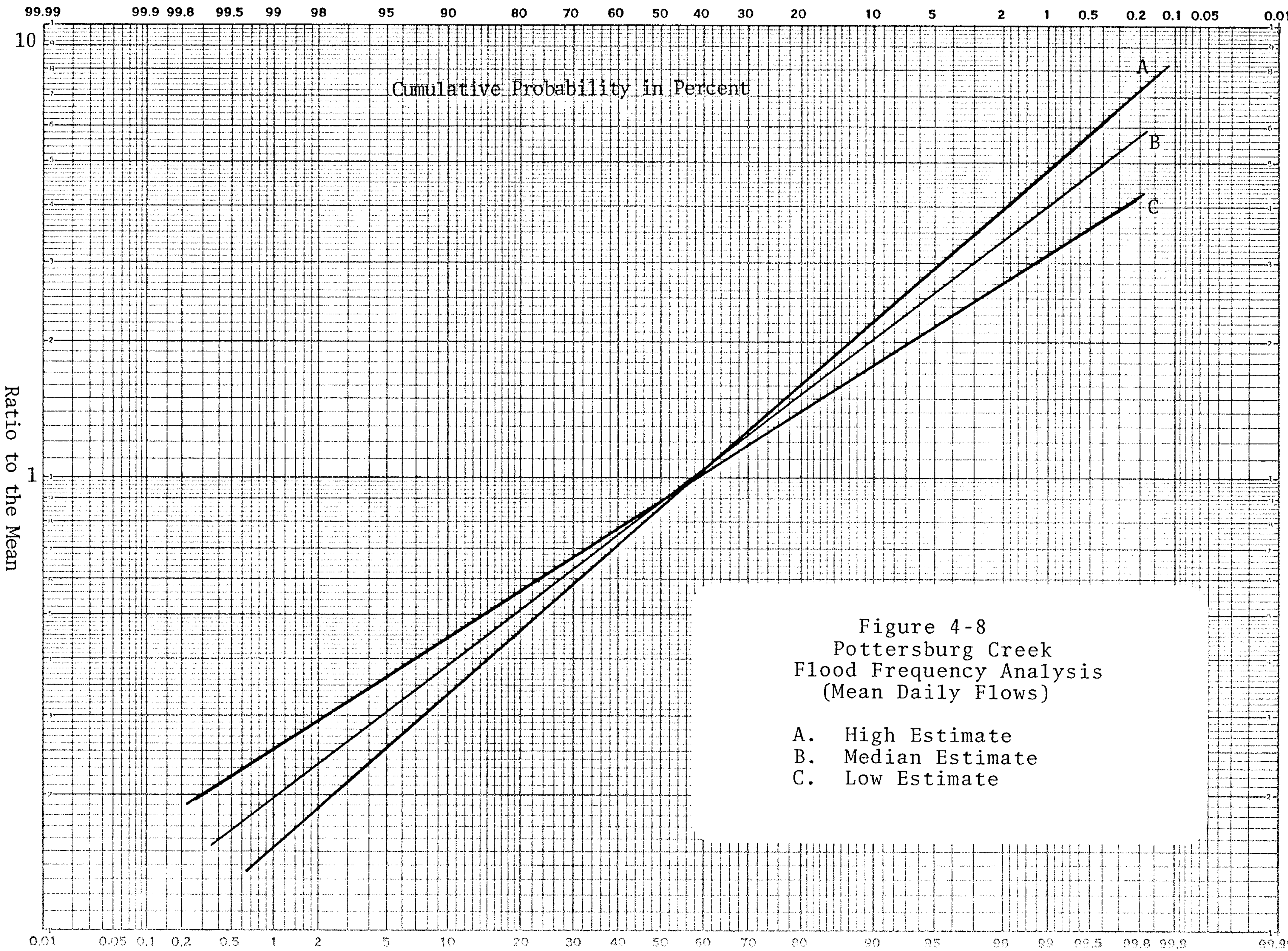


Figure 4-8
Pottersburg Creek
Flood Frequency Analysis
(Mean Daily Flows)

A. High Estimate
B. Median Estimate
C. Low Estimate

TABLE 4-8

"A" Frequency Estimation

POTTERSBURG CREEK
(maf = 375 cfs.)

1 Probability (in percent)	2 Ratio to the Mean	3 Annual Maximum Mean Daily Discharge (in cfs)	4 Instantaneous Discharge (column 3 X 2.7)
99	.15	56.25	151.875
98	.19	71.25	192.375
95	.25	93.75	253.125
90	.36	135.00	364.500
80	.46	172.50	465.750
70	.58	217.50	587.250
60	.70	262.50	708.750
50	.86	322.50	870.750
40	1.05	393.75	1,063.125
30	1.28	480.00	1,296.000
20	1.60	600.00	1,620.000
10	2.40	900.00	2,430.000
5	2.90	1,087.50	2,936.250
2	4.00	1,500.00	4,050.000
1	4.80	1,800.00	4,860.000
.2	7.20	2,700.00	7,290.000

TABLE 4-9

"B" Frequency Estimation

POTTERSBURG CREEK
(maf - 375 cfs.)

1 Probability (in percent)	2 Ratio to the Mean	3 Annual Maximum Mean Daily Discharge (in cfs)	4 Instantaneous Discharge (column 3 X 2.7)
99	.197	73.88	199.48
98	.235	88.13	237.95
95	.305	114.38	308.83
90	.385	144.38	389.83
80	.515	193.13	521.45
70	.630	236.25	637.88
60	.750	281.25	759.38
50	.880	330.00	891.00
40	1.050	393.75	1,063.13
30	1.250	468.75	1,265.63
20	1.540	577.50	1,559.25
10	2.030	761.25	2,055.38
5	2.570	963.75	2,602.13
2	3.360	1,260.00	3,402.00
1	4.000	1,500.00	4,050.00
.2	5.800	2,175.00	5,872.50

TABLE 4-10

"C" Frequency Estimation

POTTERSBURG CREEK
(maf - 375 cfs)

1 Probability (in percent)	2 Ratio to the Mean	3 Annual Maximum Mean Daily Discharge (in cfs)	4 Instantaneous Discharge (column 3 X 2.7)
99	.25	93.75	253.125
98	.29	108.75	293.625
95	.36	135.00	364.500
90	.44	165.00	445.500
80	.56	210.00	567.000
70	.67	251.25	678.375
60	.78	292.50	789.750
50	.98	367.50	992.250
40	1.02	382.50	1,032.750
30	1.18	442.50	1,194.750
20	1.40	525.00	1,417.500
10	1.75	656.25	1,771.875
5	2.15	806.25	2,176.875
2	2.70	1,012.50	2,733.750
1	3.10	1,162.50	3,138.750
.2	4.25	1,593.75	4,303.125

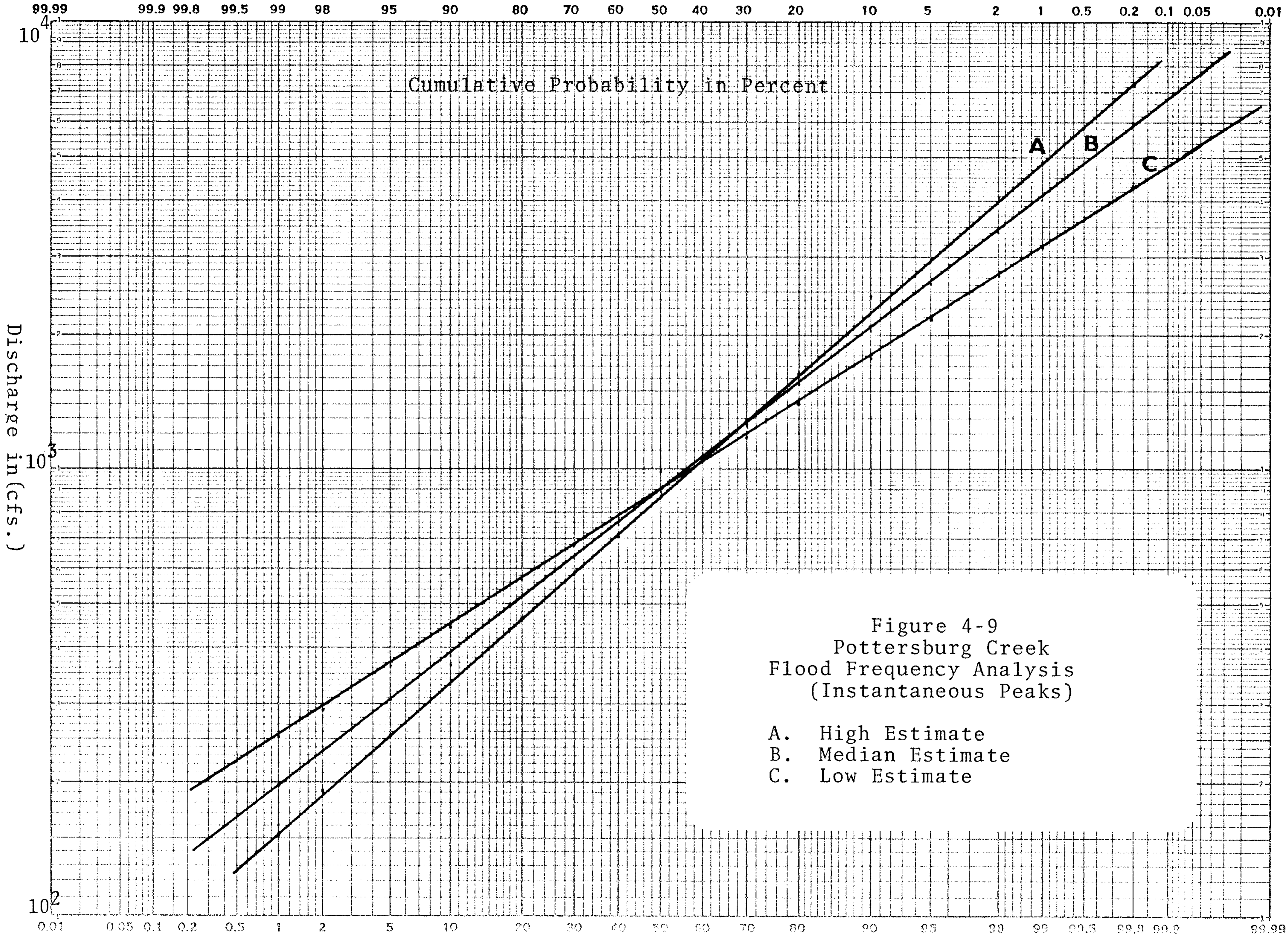


Figure 4-9
Pottersburg Creek
Flood Frequency Analysis
(Instantaneous Peaks)

A. High Estimate
B. Median Estimate
C. Low Estimate

TABLE 4-11

HEC-2 COMPUTED WATER SURFACE ELEVATIONS
(in feet above datum)

Cross-Section Number or Sub-Area	Flow in Cubic Feet per Second					
	0	1,000	2,000	2,500	4,000	6,000
2.6	859.01	866.13	867.86	868.50	869.97	871.75
4.1	862.13	869.33	872.13	873.25	875.46	877.07
6.1	867.08	872.04	873.03	873.60	875.65	877.26
6.5	867.52	875.12	878.25	879.60	883.18	887.12
10.1	874.79	879.41	881.09	882.25	884.02	887.49
10.6	872.25	883.77	885.84	886.25	887.27	887.99
12.1	874.11	883.91	886.01	886.50	887.58	888.47
12.6	874.20	884.58	886.15	886.60	887.67	888.56
14.0	878.40	884.30	886.12	886.60	887.68	888.59
Sub-Area 1	860.57	867.73	870.00	870.88	872.72	874.41
Sub-Area 2	864.61	870.69	872.58	874.53	875.56	877.17
Sub-Area 3	871.16	877.27	879.67	880.93	883.60	887.31
Sub-Area 4	873.18	883.84	885.93	886.38	887.43	888.23
Sub-Area 5	876.30	884.44	886.14	886.60	887.68	888.58

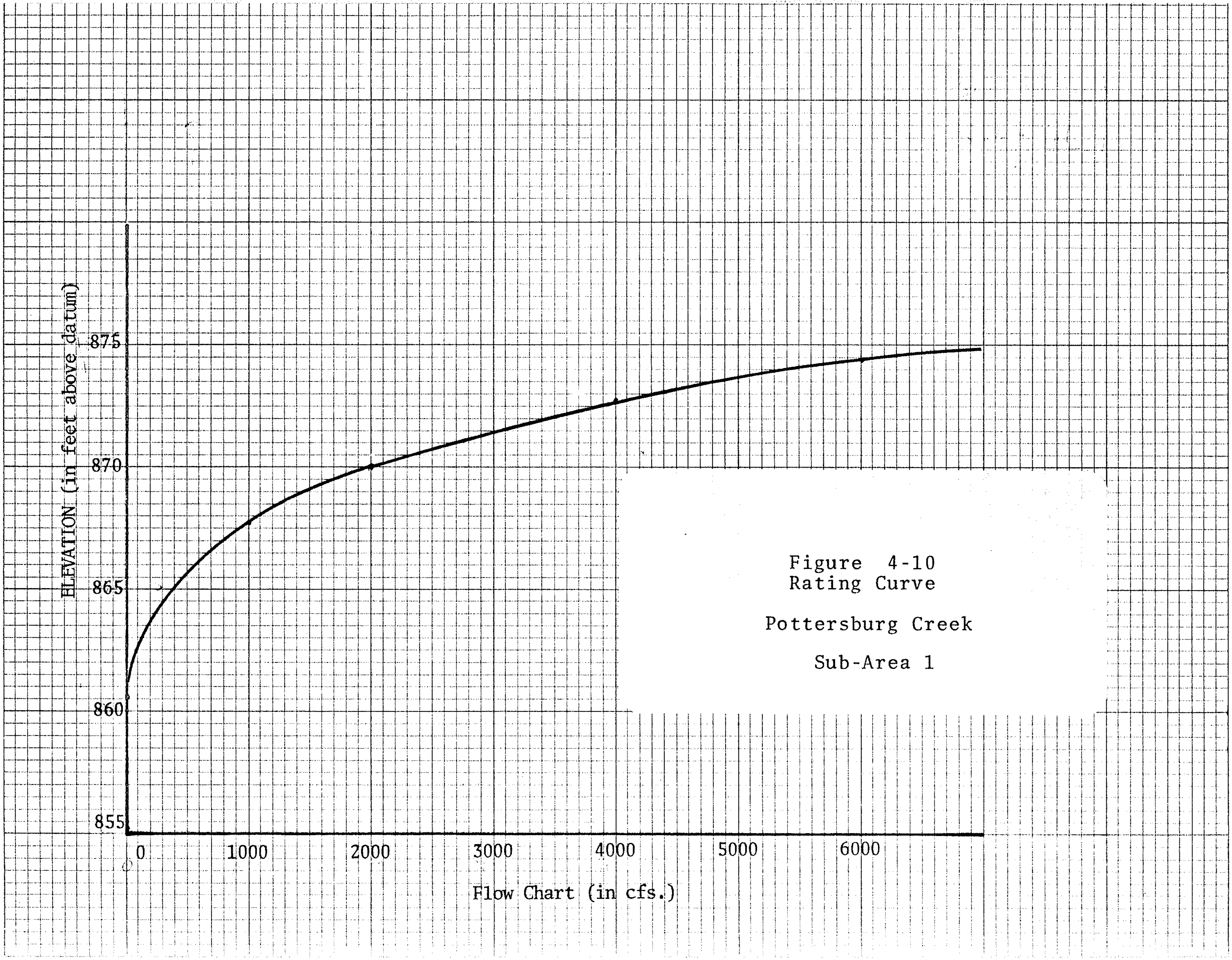


Figure 4-10
Rating Curve

Pottersburg Creek

Sub-Area 1

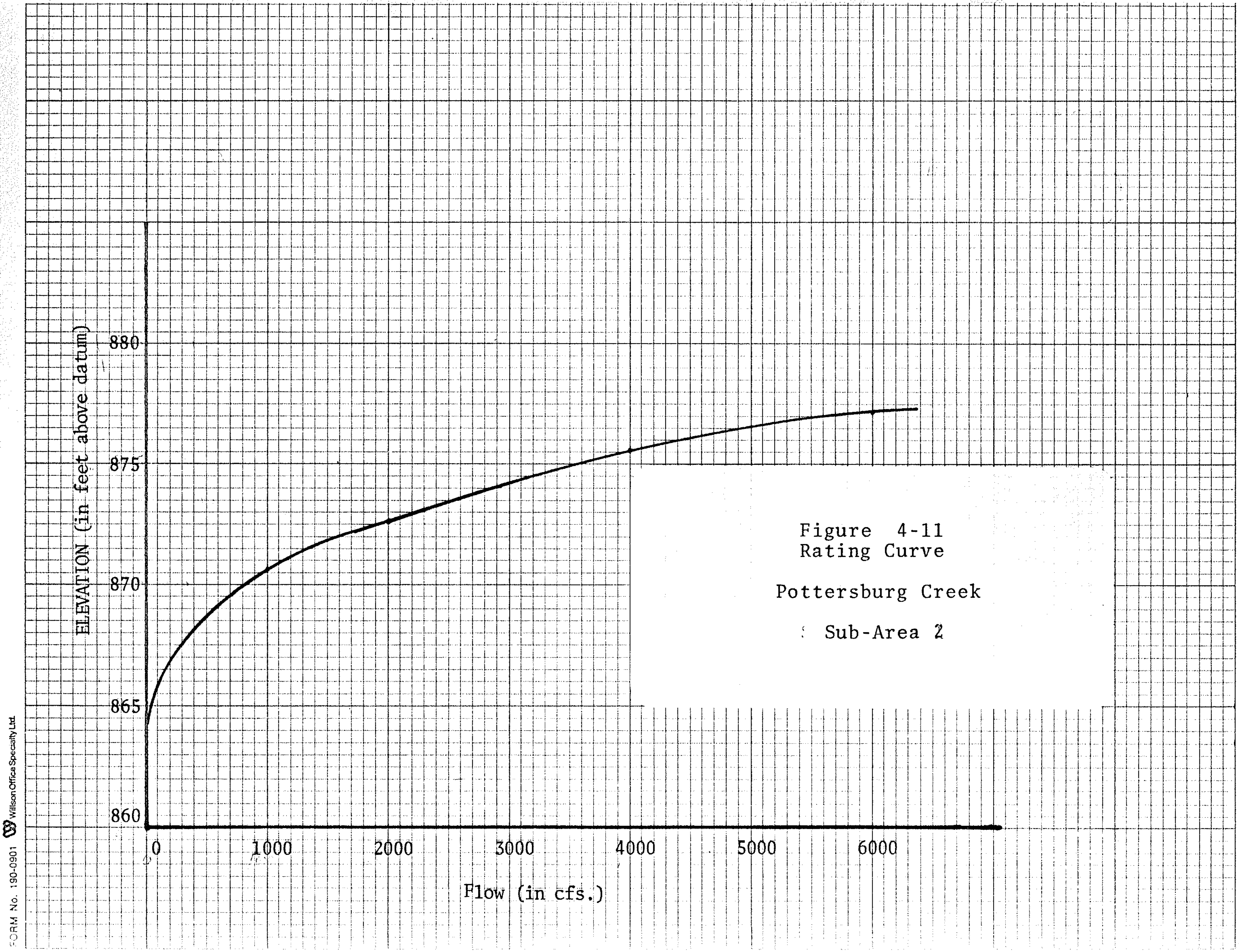


Figure 4-11
Rating Curve

Pottersburg Creek

Sub-Area 2

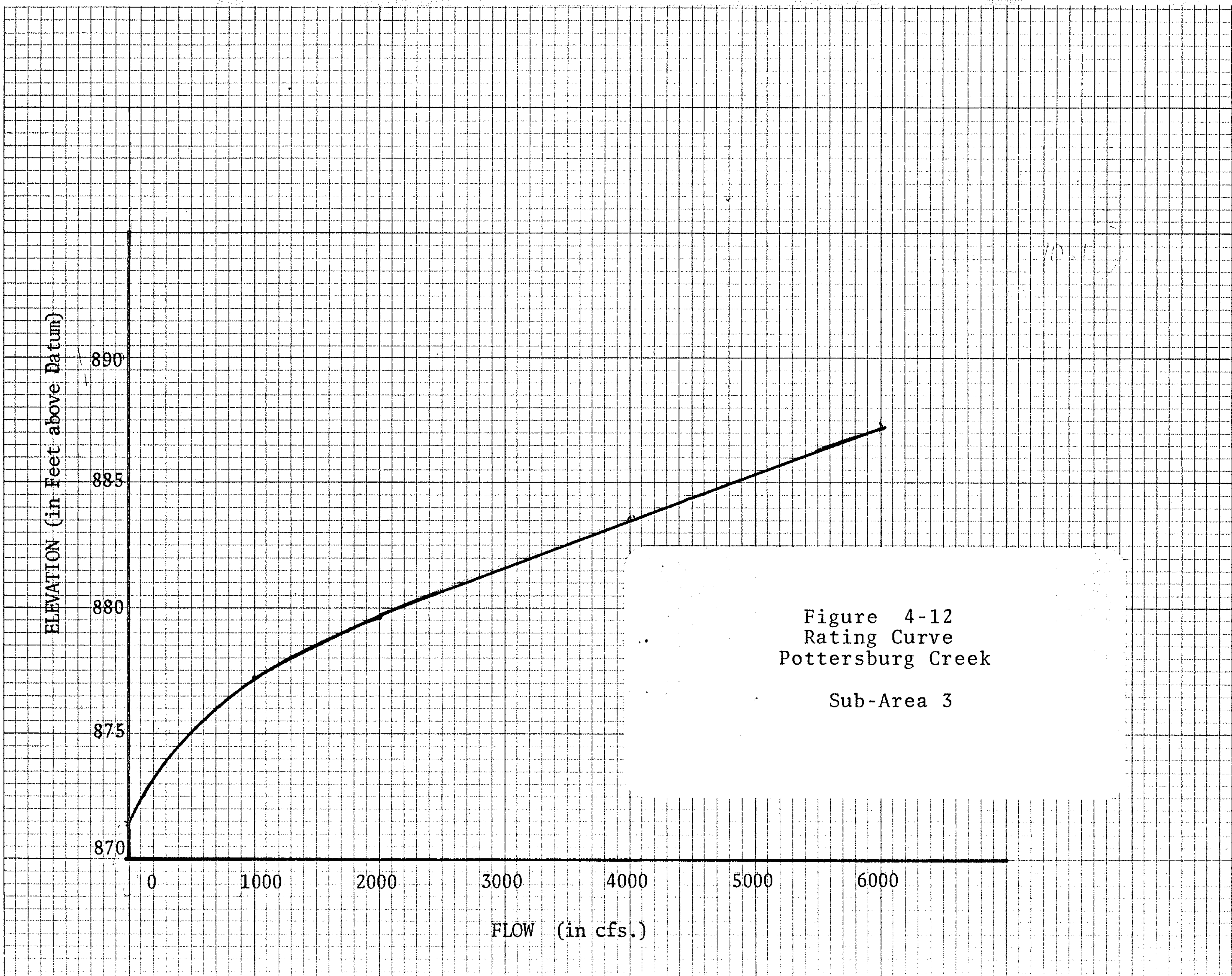


Figure 4-12
Rating Curve
Pottersburg Creek

Sub-Area 3

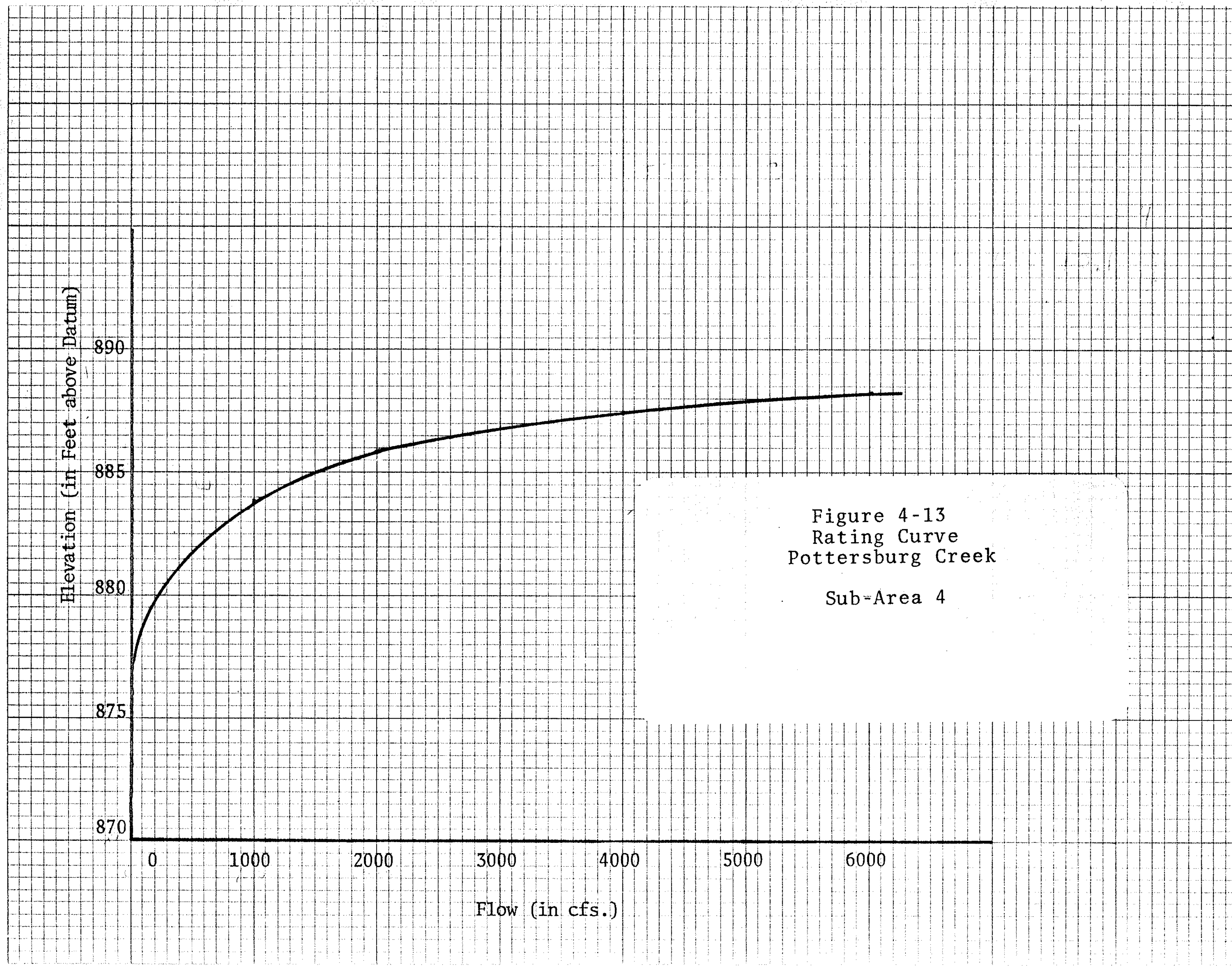


Figure 4-13
Rating Curve
Pottersburg Creek

Sub-Area 4

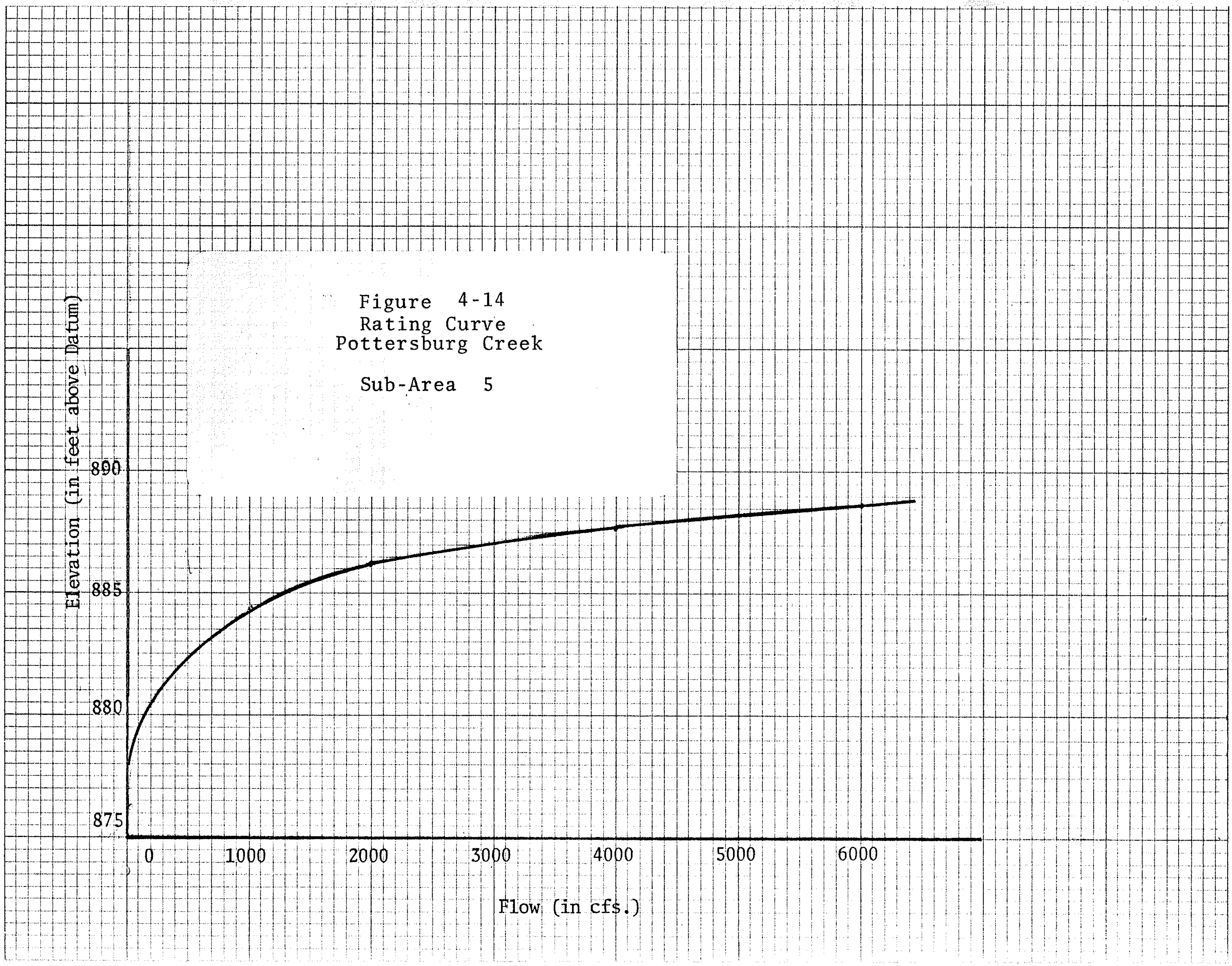


Figure 4-14
Rating Curve
Pottersburg Creek

Sub-Area 5

TABLE 4-12

METHOD OF CALCULATING DIRECT INDUSTRIAL FLOOD DAMAGE*

Flood Depth in Structure (in inches)	Percentage of the Total Value of An Industrial Establishment Damaged by Flooding
0	--
6	.005
12	2.300
18	6.100
24	9.500
30	17.800
36	25.600
42	59.300
48	63.500

* From Acres (1972)

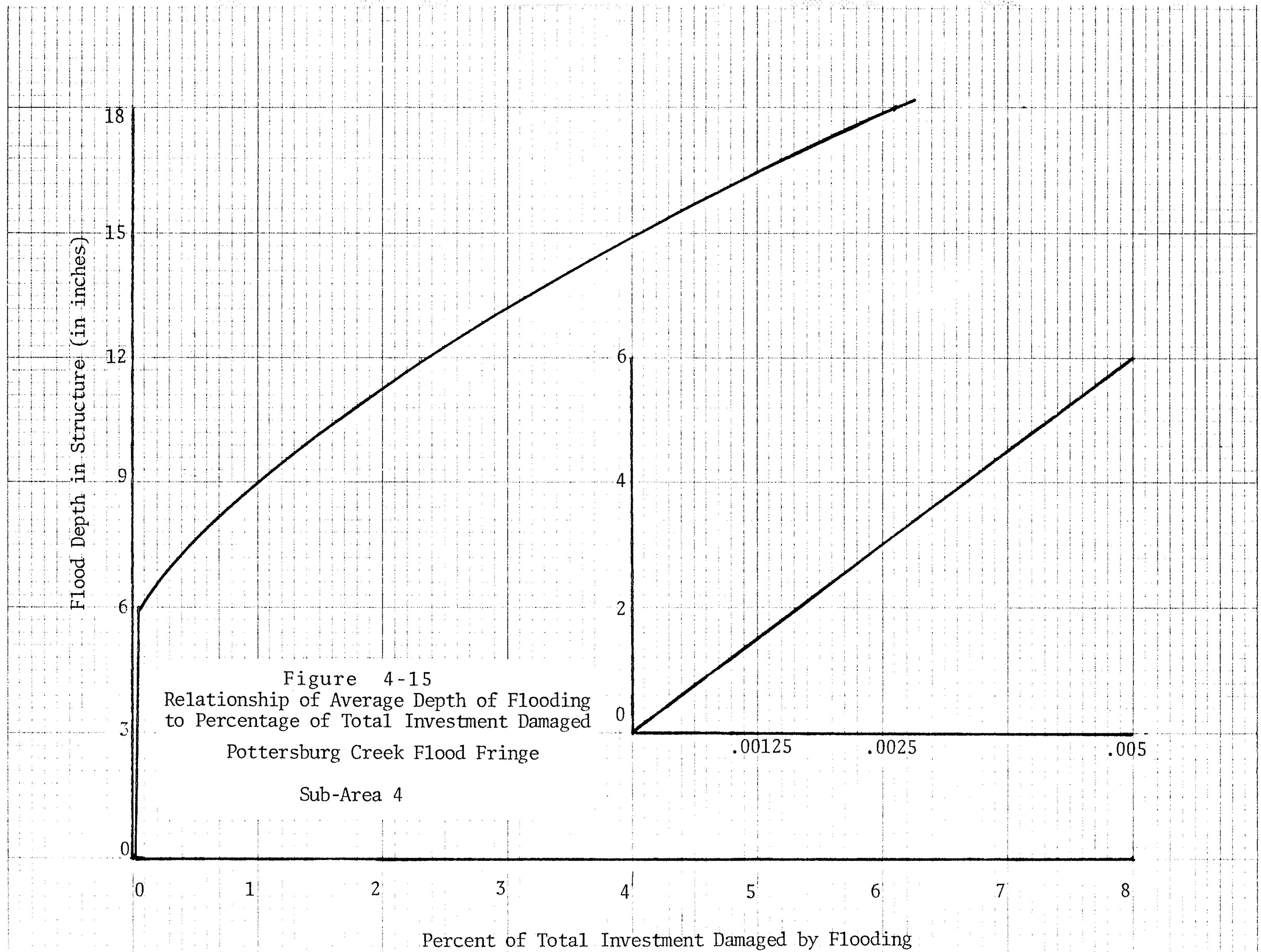


Figure 4-15
Relationship of Average Depth of Flooding to Percentage of Total Investment Damaged

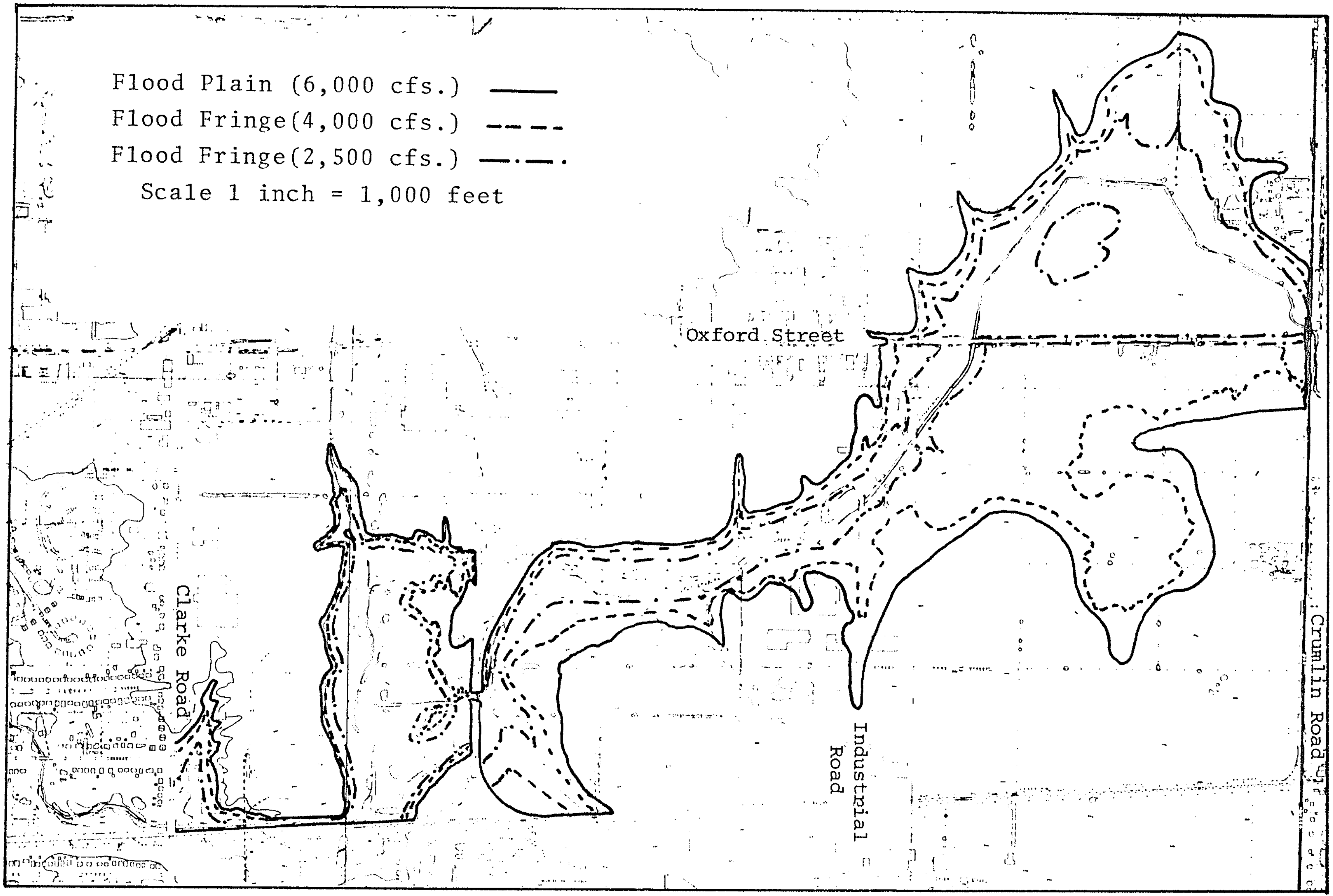
Pottersburg Creek Flood Fringe

Sub-Area 4

TABLE 4-13

FLOOD FRINGE ACREAGES

1	2	
	Area (in acres)	
Sub-Area	Floodway Boundary at 2,500 cfs.	Floodway Boundary at 4,000 cfs.
1	4.26	2.34
2	7.33	7.33
3	12.04	4.25
4	62.05	23.96
5	40.51	10.28



Map 4-1 Flood Plain and Flood Fringe Boundaries

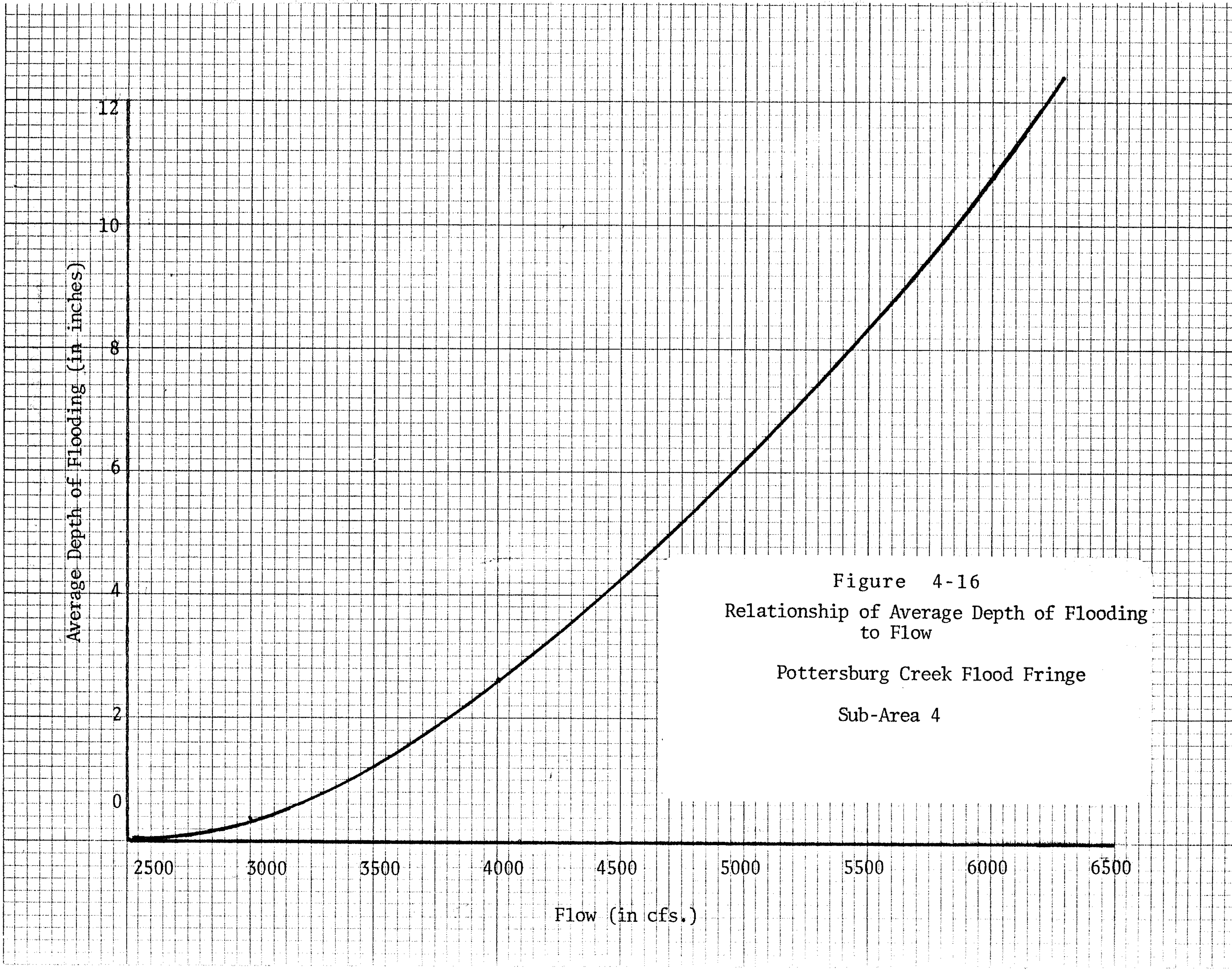


Figure 4-16

Relationship of Average Depth of Flooding to Flow

Pottersburg Creek Flood Fringe

Sub-Area 4

TABLE 4-14

DISCHARGE/DAMAGE RELATIONSHIP
POTTERSBURG CREEK

1	2	3	4	5
Discharge (in cfs.)	Average Flooding Depth (in inches)	Damages as a Percentage of Total Investment	Total Investment in $Millions	Total Damage in Dollars
2,500	0	0	34.25	0
3,000	.40	.00033	34.25	113.03
4,000	2.62	.00220	34.25	753.50
5,000	6.20	.07500	34.25	25,687.50
6,000	10.80	1.50000	34.25	513,750.00
7,000	13.65	3.00000	34.25	1,027,500.00
8,000	17.40	5.50000	34.25	1,883,750.00

TABLE 4-15

AVERAGE ANNUAL DAMAGE
POTTERSBURG CREEK

Frequency "A"

1	2	3	4	5	6
Discharge (in cfs)	Frequency (in percent)	Interval (in percent)	Damage (in dollars)	Average Damage per Interval (in dollars)	Total Damage (in dollars)
2,500	7.5		0		
		2.5		57.00	1.00
3,000	5.0		113.00		
		3.0		434.00	13.00
4,000	2.0		754.00		
		1.1		13,221.50	145.00
5,000	.9		25,688.00		
		.45		269,719.75	1,214.00
6,000	.45		513,750.00		
		.20		770,625.00	1,541.00
7,000	.25		1,027,500.00		
		.12		1,455,625.00	1,747.00
8,000	.13		1,883,750.00		
			Average	Annual Damages	$4,660.00

TABLE 4-16

AVERAGE ANNUAL DAMAGE
POTTERSBURG CREEK
Frequency "B"

1	2	3	4	5	6
Discharge (in cfs)	Frequency (in percent)	Interval (in percent)	Damage (in dollars)	Average Damage per Interval (in dollars)	Total Damage (in dollars)
2,500	6.0		0		
		2.5		57.00	1.00
3,000	3.5		113.00		
		2.0		434.00	9.00
4,000	1.5		754.00		
		1.05		13,221.00	139.00
5,000	.45		25,688.00		
		.25		269,719.00	674.00
6,000	.20		513,750.00		
		.12		770,625.00	925.00
7,000	.08		1,027,500.00		
		.04		1,455,625.00	582.00
8,000	.04		1,883,750.00		
			Average Annual Damages		$2,330.00

TABLE 4-17

AVERAGE ANNUAL DAMAGE
POTTERSBURG CREEK

Frequency "C"

1 Discharge (in cfs)	2 Frequency (in percent)	3 Interval (in percent)	4 Damage (in dollars)	5 Average Damage per Interval (in dollars)	6 Total Damage (in dollars)
2,500	3.0		0		
		1.6		57.00	1.00
3,000	1.4		113.00		
		1.1		434.00	5.00
4,000	.3		754.00		
		.23		13,221.00	30.00
5,000	.07		25,688.00		
		.45		269,719.00	1,214.00
6,000	.02		513,750.00		
		.015		770,625.00	116.00
7,000	.01		1,027,500.00		
		0		1,455,625.00	~~0~~
8,000	<.01		1,883,750.00		
			Average Annual Damages		$1,366.00

TABLE 4-18

PRESENT VALUE OF POTENTIAL ANNUAL FLOOD DAMAGE

Frequency Estimate	Present Value of Damage in Dollars for 50 Years					
	Net Discount Rate in Percent					
	2	4	6	8	10	12
A (D=$4,660)	146,499	100,194	73,482	57,030	46,224	38,718
B (D=$2,330)	73,218	50,053	36,725	28,503	23,102	19,351
C (D-$1,366)	42,894	29,323	21,515	16,698	13,534	11,336

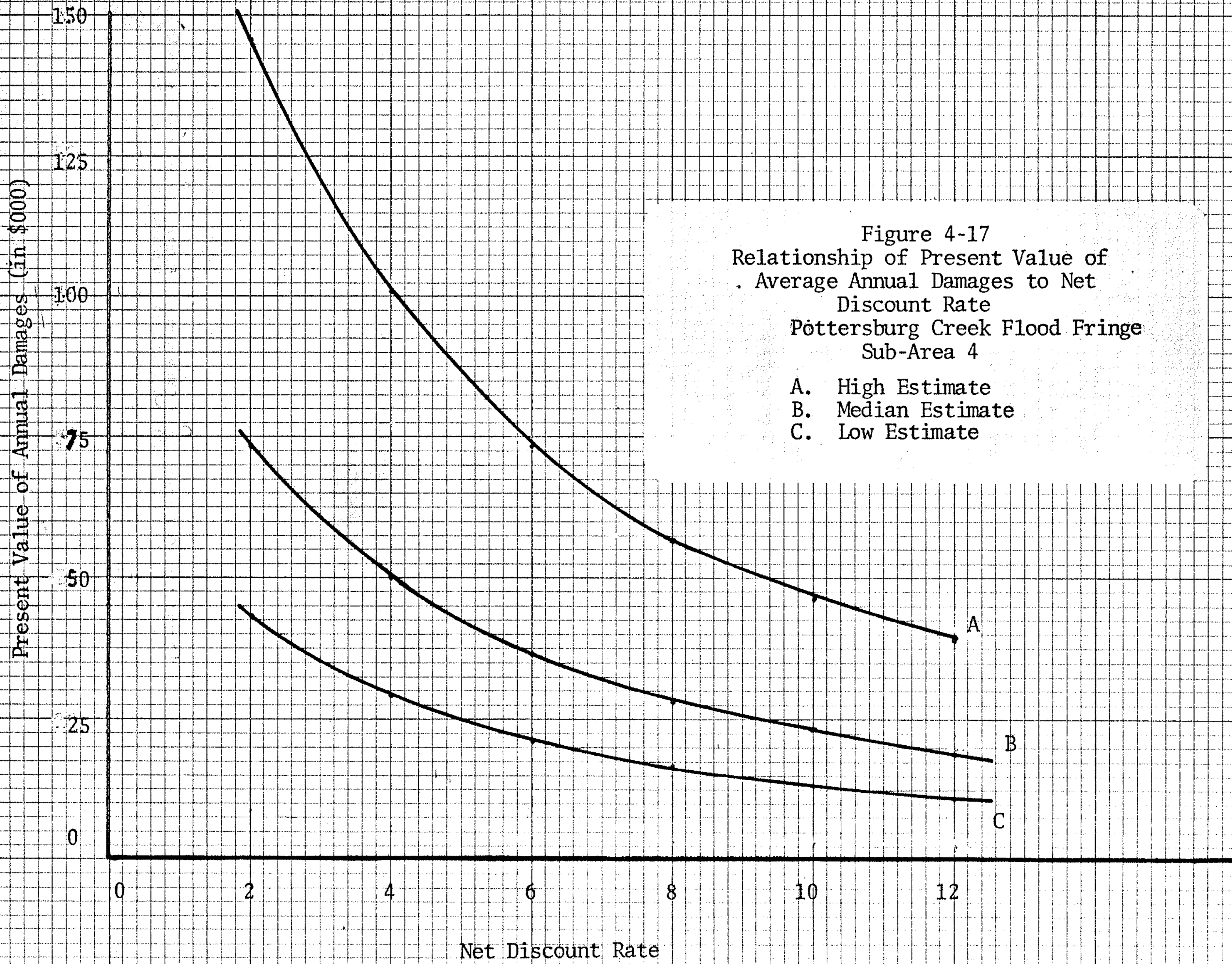


Figure 4-17
Relationship of Present Value of Average Annual Damages to Net Discount Rate
Pottersburg Creek Flood Fringe
Sub-Area 4

A. High Estimate
B. Median Estimate
C. Low Estimate

CHAPTER 5

DISCUSSION OF RESULTS

The annual flood damage figures produced in this study are reasonable indicators given the following assumptions:

(1) the flow/frequency estimates derived for Pottersburg Creek are appropriate;

(2) the value chosen for Fuller's ratio is an accurate representation of the relationship of instantaneous peaks to mean daily flows for Pottersburg Creek;

(3) the depth/damage relationship adopted from the Acres (1972) study is applicable to the proposed industrial development on the Pottersburg Creek flood fringe;

(4) the damageable investment relationship is accurate; and

(5) the proposed structures (one-storey, slab-on-grade, concrete block, randomly located buildings) are acceptable approximations of reality.

The flood damage figures produced in this study were found to be very sensitive both to the frequency estimate and to the choice of discount rate. The present values of the annual damages for the 'A' frequency estimate consistently exceeded 3.4 times the 'C' frequency estimate regardless of the discount rate.[1] This magnitude of variation suggests that a more rigorous estimate of the discharge/frequency relationship for Pottersburg Creek should be undertaken.

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[1]It should also be noted that, whatever the frequency selected, to regard flood losses as a stream of disbenefits that are uniform in magnitude and which flow evenly into the future is not in keeping with the perceptions of most flood plain dwellers. Most people (flood plain occupants included) regard flooding (quite correctly) as episodic in nature. For a detailed discussion of flood hazard perception, see Burton (1964) and Kates (1962, 1963 and 1964).

For all frequency estimates, the present value of the damages discounted at the lowest rate (2%) were consistently more than 3.7 times greater than when discounted at the highest rate (12%). The choice of discount rate (and thus of the present value figure) is an uncertain one. Not only do different groups value future costs differently, but within each group the rate chosen as most appropriate could change over time.

From the point of view of economic efficiency (the national accounting stance) there would be no economic reason to prohibit flood fringe occupancy, provided the present value of the anticipated benefits to the occupant from his location in the flood fringe exceeded the sum of:

1. the costs incurred by reason of damage due to flooding.

2. the cost of those measures undertaken by others in rescue and clean-up operations, utility and other repairs and such related activities, and,

3. the damage (or increase in damage) that the occupant's presence in the flood fringe inflicts upon others as a result of his encroachment onto the flood plain (generally resulting in a decrease in over-bank storage).

Thus, it can be said that the value of the flood fringe location to the potential industrial mall owner must exceed all losses or costs to whomever they may accrue. As a result, the net product or economic well-being of society is increased.

This is an example of the Kaldor-Hicks criterion that a policy be changed or a project be recommended if, as a result, some persons would be better off and some would be worse off and if the gainers could compensate the losers in such a way that, in total, everybody was better off. In such a situation, economic welfare would be increased. Considerable debate has ensured as to whether it is sufficient that adequate compensation could be made or whether it is necessary that it actually be made.

In theory, it is assumed that compensation (which is a redistribution of benefits) is both perfectly efficient and costless and that (usually by government means) the welfare maximizing distribution will be implemented. This assumption is a somewhat heroic one but its acceptance is necessary if, in turn, the Kaldor-Hicks criterion to be accepted as an appropriate one with which to assess policy changes or development proposals affecting economic efficiency.

Frequently, where compensation cannot or will not be paid, the policy change or project development cannot bring about an unambiguous Paretian improvement.[2] Gains and losses (costs and benefits) will continue to accrue to those experiencing them. The Paretian improvement criterion is, of course, a more rigorous one and defines a narrower set of possibilities.

Regardless, however, of which of the above criteria is applied, such analyses deal only with economic efficiency and not with equity (income distribution), thus they avoid interpersonal comparisons. It is not possible to equate the benefits enjoyed by project gainers with the disbenefits to those adversely affected by a project. For example, if flood peaks, and

[2] A Paretian improvement is an improvement in total societal well-being such that some individuals are made better off but no one is made worse off.

resulting damages to residents downstream are increased as a result of the proposed industrial mall development, dollar for dollar compensation may not be appropriate. A one dollar loss to the downstream residents due to increased flood damages may be more valuable than a two dollar gain in value to the flood fringe occupants. This is especially true in cases where there exists a substantial income gap between the two groups. In such situations both the Kaldor-Hicks and Paretian improvement criteria are inappropriate because they ignore the income effects of policy changes and project developments.

The correct measure, then, of any contribution to society's economic well-being is not simply the excess of benefits over costs at the flood fringe location. Rather it is the difference in the efficiency (the net revenue) of performing an economic function on the flood fringe as opposed to an alternative non-flood plain location.

In the absence of alternative locations, national and private interests become one. Society's well-being is increased simply if the process of conducting business in the flood fringe produces gross revenues in excess of gross costs (including the flood damage costs).

Whenever an alternative location (non-flood fringe) exists, the situation is changed. Society will then only be better off if the net revenue (gross revenue minus costs, including flood damage costs) of the flood fringe location exceeds the net revenue which could be had in a non-flood fringe location. The increment to societal well-being is equal to the incremental net revenue.

In this regard it would be prudent to determine the availability (or non-availability) of alternative sites. In addition, a survey should be undertaken to determine the added cost (of annexation and of servicing) of acquiring new industrial sites. Possible locations in the London area could include land north of the Thames River (North Branch) and east of Highbury Avenue and land adjoining the new Highway 100.

Given the increase in costs (due to the annual flood damages) associated with the flood fringe location, gross revenues (from sales or services) of the flood fringe business would need to be at least equal to the potential gross revenues if they were located elsewhere plus the annual value of the flood damage. This must be so if society is not to be left worse off by the decision to allow development in the flood fringe.

Gross revenues can be expected to be greater for industrial malls on the Pottersburg Creek flood fringe than for similar businesses located elsewhere as the Pottersburg area is central to the industrial section of London. Since most existing industrial malls in London are occupied by service companies catering to larger manufacturing firms,[3] companies locating on the Pottersburg flood fringe can expect to enjoy a competitive sales advantage if located here. Indeed, the increased sales revenues (or rather the profit from them) can

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[3]Personal communication with Mr. David Lees of John Thiel Real Estate, a major industrial developer in London.

be seen as a capture of some of the economic rent[4] embodied in the flood fringe location.

Warehouse space for lease on the Pottersburg Creek flood fringe should command a premium price (higher than that for other new sites) because of the savings in energy, labour and operating expenditures associated with the operation of businesses close to the industrial users of their products or services.

The locational premium of industrial malls in the Pottersburg Creek flood fringe cannot be exactly determined relative to other locations not experiencing flood losses. However, there are a number of developers anxious to be permitted to build inside the existing regional flood line. This desire on the part of the developers could be interpreted as a belief on their part that the premium associated with the locational advantages of the site is at least equal to the annual flood damage.

On the other hand, this desire could be seen as a belief on the part of potential developers that annual damage costs will not accrue to them. The practice of seeking public compensation for flood-damaged private property is a well established one.

Krutilla (1966) lists four reasons why individuals are willing to locate on flood plains. These are:

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[4]Economic rent is a short-run economic surplus that a production factor (in this case, land) can earn because of a demand/supply imbalance. This short-run surplus is generally seen as a surplus in income above the minimum supply price it takes to bring a factor into production.

1. An ignorance of the hazards and the actuarial costs.

2. An overestimation of protective measures.

3. Their ability to shift all or a substantial part of the cost that their occupance of the flood plain entails either to taxpayers generally or to other members of the community ignorant of the risks assumed.

4. the receipt of benefits in some other way without the associated costs of a flood plain location being assumed.

If society is to avoid the potential of being charged with the costs of flood damage and seeing the economic rent captured by the flood fringe occupants, it may be desireable to require prospective industrial mall owners to waive their claim to public compensation in the event of flooding.

As noted on page 91, there are three costs associated with flood plain occupance. In this study, values have been derived for the first of these, namely the cost of damage to the occupant caused by flooding. The second of these, the cost of rescue and clean-up operations, will probably be borne by the city. It would be appropriate, in further study, to determine an estimate of these future costs and to require flood fringe occupants to be responsible for them (rather than the general taxpayer), perhaps through an addition to their tax levy.

The third cost, that of damage caused to downstream flood plain occupants as a result of the flood fringe occupants' encroachment onto the flood plain, is a more difficult one. Generally, the result of upstream flood plain encroachment is an increase in downstream flood peaks (due to a loss in up-stream over-bank storage). The magnitude of these increased downstream peaks could be determined using computer modelling. The increase (if any) in flood damages caused because of them could be determined. The value of these incremental annual damages could then be charged against the prospective developments, again perhaps as an addition to their tax levy. The fact that the flood fringe properties are in a flood-prone area and may be subject to a flood damage and/or a flood clean up tax should be required by law to be noted on the property deed. In addition, flood easements could be purchased on the flood affected downstream properties.

Because, as noted earlier, it is impossible to determine in advance what the effect will be on business revenues as a result of the locational advantage of the Pottersburg Creek flood fringe, it is, therefore, also impossible to determine a level of total economic rent accruing to ownership of the land. An attempt can be made, however, to determine if there is any incremental rent associated with the locational advantage of the flood fringe site.

It is a basic premise of the theory of economic rent that rent does not determine price but rather that price determines the value for economic rent. It is also a basic premise that no economic rent can accrue to land (or other resource) when that resource is not scarce.[5] Land can be scarce in both

[5]Scarcity, in economic terms, refers to the fact that resources are finite such that there is never (in the long run) a supply (in this case, of industrial land) so plentiful that everyone can have as much as they would like.

quantitative and qualitative terms.

When land is scarce in quantity terms, the rent which accrues to it, by virtue of the fact that demand exceeds supply, is called scarcity rent.

When land of secondary quality begins to be used, economic rent automatically accrues to land of higher quality. This type of rent, that of first quality land over land of secondary quality, is called differential rent. This is the type of rent of interest in the Pottersburg Creek flood fringe. The differential rent of this area is a function of its locational advantage. However, this is not the only price influence present. At the same time as the locational attractiveness of the flood fringe property is placing an upward pressure on the price of that land, the flood hazard is generating a downward influence.

If we assume that those who are interested in industrial mall development on the flood fringe are aware of the hazards and costs of flooding in this location, then we can also assume that, in the absence of flooding, the price which the land could command would be higher. Part of the potential rent (or attractiveness) of the property has been dissipated due to the flood hazard.

If another industrially zoned undeveloped parcel of land existed in London which possessed all the same attributes as the Pottersburg Creek flood fringe lands, including some notion of locational attractiveness, but which was free of the flood hazard, the highest price that the Pottersburg Creek site could command would be the price of the alternative site minus the present value of the average annual flood damages. If, however, the Pottersburg Creek site possessed a locational advantage not shared by the hypothetical alternative site, the differential rent associated with this locational advantage would command a higher selling price. In a case where the value of this differential rent was exactly equal to the present value of the average annual flood damages, the selling prices of the two properties would be the same.

The 1978 data projections of the Industrial Commissioners Office in London showed an average selling price for industrially zoned land purchased for industrial mall development of $30,000 per acre.[6] The estimated average selling price per acre for the Pottersburg Creek flood fringe lands is $31,000 per acre.[7]

Taking a median figure for the present value of the average annual flood damages of $459. per acre ('B' frequency estimate at a discount rate of 8%; see Table 4-18) and assuming that the projected selling price of $31,000. per acre for the Pottersburg Creek flood fringe lands reflects an awareness of this damage potential, the selling price of this land in the absence of the flooding hazard would be $31,459. per acre. The difference between this value and the average selling price of other industrial land is $1,459. per acre and represents the differential rent associated with the locational advantage of Pottersburg Creek site.

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[6] Personal communication with M.L. Taylor, Market Researcher for the Industrial Commissioner's Office.

[7] Personal communication with Mr. David Lees, op.cit.

As noted, however, a portion of this differential economic rent is offset by the damages associated with the flood hazard. The net differential economic rent is thus $1,000. per acre (31,000 - $30,000). The net social gain by allowing development on the Pottersburg Creek flood fringe in sub-area 4 and including a consideration of the flood hazard, is, therefore, $62,050 ($1,000 x 62.05 acres).

If, however, it is assumed that the selling price ($31,000 per acre) does not reflect an awareness of potential flood damages, then the value of the land becomes $30,541 per acre ($31,000 - $459.). The net differential economic rent per acre is thus only $541 ($30,541 - $30,000). The net social gain of allowing development here is, thus, only $33,570 ($541 x 62.05 acres).

It should be emphasized, however, that this figure represents the capture of only a portion of the differential rent. All of the differential rent could be taxed and the area would still be developed.

In summary, from the national or societal accounting stance, the efficient use of the Pottersburg Creek flood fringe requires that the following condition be met:

> The net benefit of the flood fringe location to the firm located there must be at least equal to the social costs involved; that is, no aggregate social loss be incurred as a result of the industrial mall development on the flood fringe.

If society is to be left better off (a Paretian improvement) as a result of allowing development of the Pottersburg Creek flood fringe, then the following, more restrictive condition must apply:

> The contribution (in present value terms) to societal well-being by these individuals or firms as a result of their occupance of the flood fringe must not only exceed the social costs (the present value of the average annual flood damages to the individuals or firms in question) but must also exceed the contribution that they could have made had they located on a non-flood fringe site elsewhere.

From the municipal point of view, the response to the proposed development changes only with respect to where the alternative building sites are located. If they are within the City of London, then the same conclusions hold. If the city is not to be liable for any flood damages, it would welcome the proposed development, not only for the potential tax revenue, but also for the job creation benefits.

If, however, the municipality were to ultimately become responsible for at least some of the flood damages then it would want to ensure that revenues from the development covered these flood costs. If there were no alternative building sites (i.e. non-flood fringe) available, it would be sufficient to ensure that the tax revenues from the proposed developments at least equalled that portion of the damage which would accrue to the city.

On the other hand, if we assume that alternative sites for industrial mall development are available in London, there may be no advantage to the city of allowing development on the flood fringe. Given roughly equivalent tax assessments (if the proposed developments were built on the Pottersburg Creek flood fringe or were channeled onto alternative non-flood fringe sites) the city would receive the same tax revenues but would avoid the costs (or their portion of the costs) associated with the flood damages. Development of the flood fringe simply represents a transfer of income from the owners of the alternative sites to the owners of the flood fringe sites and the possible accrual of all or some of the flood damage costs to the city.

Assuming for the moment that there are no alternative building sites, the following approximate relationships would apply. The present (1978) commercial tax rate for the City of London is .14277. Thus, the annual commercial tax per acre (based on 14,500 square feet of buildings per acre and building costs of $18.00 per square foot and a land price of $31,000 per acre) would be $41,688.84. To this would be added the average $3,550.00 per acre annual business tax[8] for an annual revenue of $45,188.84 per acre. For sub-area 4 of the Pottersburg Creek flood fringe, the total annual tax revenue would be $2,803,967.50. This is far in excess of even the highest (the 'A' frequency) estimate of annual damage of $4,662.00.

The above figure represents the amount of tax that the City would collect even were the proposed malls located in a non-flood prone area. Should the city be responsible for the annual flood damages, these annual tax revenues would be reduced accordingly. The City might wish to levy an additional

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[8]All tax and assessment average figures were obtained from Mr. Kim Creamer of the Regional Assessment Office in London.

tax on these developments in order to cover these losses. Column 5 of Table 5-1 shows, for each of the three frequency estimates, the incremental mill rate (in addition to the normal commercial rate) which would have to be applied to these developments to cover the annual flood damage costs. Additional taxes could also be levied in an attempt to capture the locational premium associated with the Pottersburg site. Taxes on the flood fringe site could be increased up to the point where the potential developer was indifferent between the Pottersburg location and a more distant site. The effect of this would be to create a price differential between the flood prone land and an alternative non-flood prone site.[9]

If no alternative building sites existed, the City of London might wish to investigate the costs and feasibility of acquiring new industrial land, probably by annexation. If the annual costs of such land acquisition (capital costs amortized over the 50 year planning horizon) were less than the annual flood damage costs on the Pottersburg Creek flood fringe, the City might choose to pursue such an acquisition program and to disallow industrial development in the study area. It is believed, however, that the annual cost of the acquisition of new alternative building sites would be substantially larger than the annual flood damages. This question deserves further investigation.

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[9] A more detailed discussion of the price differential effect can be found in Appendix 2.

TABLE 5-1

FLOOD DAMAGE PER $000 OF INVESTMENT

1	2	3	4	5
Frequency Estimate	Annual Damages (in dollars)	Annual Damages per acre (in dollars)	Value of Buildings & Land per acre (in dollars)	Mill rate required to cover annual flood damage costs
A	4,660	75.10	291,000	.258
B	2,330	37.55	291,000	.129
C	1,366	22.01	291,000	.076

From the individual developer's accounting stance, the analysis is even more clear-cut. Let us return for a moment to the previous example of a hypothetical alternative building site equal in all respects to the Pottersburg Creek site but free of the flood hazard. As mentioned earlier, the average price for a parcel of land free from flooding but otherwise identical to the Pottersburg site was estimated to be $30,000 per acre, while the estimated price of the Pottersburg Creek flood fringe land was $31,000 per acre. Using again a median figure of $28,503.00 for the present value of the average annual flood damages ('B' frequency estimate at a discount rate of 8%), the present value of the damages per acre in sub-area 4 is $459.36. If the Pottersburg Creek flood fringe site were identical to this hypothetical alternative site and thus possessed no locational advantage, the most that a purchaser would pay for a site on the flood fringe would be the price of the alternative site minus the present value of the flood damage. This would be a price of approximately $29,500. ($30,000 - 459.36) per acre.

If potential industrial mall developers are willing to pay the estimated asking price of $31,000 per acre for land in sub-area 4, this can be seen as an unequivocal statement on their part that there is a locational advantage (net of flood damage costs) associated with the Pottersburg Creek site. The value of this net locational advantage (differential economic rent) is approximately $1,500 per acre. If, for whatever reasons, the city wished to discourage development in this area, this is the amount of extra tax that would have to be levied on the sale of these lands in order to render potential purchasers indifferent (in economic terms) in their choice of building location.

In summary, then, this study has shown that, from an economic point of view, a decision to allow or to prohibit development of the Pottersburg Creek flood fringe will be based on two principle considerations. These are:

1. A comparison of the relative costs and benefits of proceeding with industrial construction on the flood fringe. Values involved were found to be highly sensitive both to the flood frequency estimate and to the choice of discount rate.

2. The presence or absence of alternative building sites (flood-free) is an important determinant of the economic efficiency of allowing development on the flood fringe.

CHAPTER 6

LIST OF RECOMMENDATIONS

1. Pottersburg Creek between Crumlin Road and Clarke Road should be designated a special policy area.
2. A more rigorous flow/frequency relationship should be produced for Pottersburg Creek.
3. A survey of available industrial development sites within the City of London should be undertaken. Also, the costs of annexation and development of new sites for industrial development should be investigated. A thorough knowledge of the alternative industrial sites is necessary if the true costs (in economic efficiency terms) of allowing development on the Pottersburg Creek flood fringe are to be known.
4. Should development be allowed, all property owners and/or lessees should be required to sign hold-harmless agreements releasing all public bodies of any responsibility (financial or otherwise) in the event of flooding. In addition, a caveat detailing the flood-prone nature of the property should be required to be appended to all deeds or leases.
5. An estimate should be made of the future costs of damage to city-owned utilities and of rescue and clean-up operations in the area which would be borne by the City should flood-fringe development proceed. These costs should be levied against the

prospective flood fringe occupants rather than added to the general levy.

6. A determination should be made of the effect that the proposed developments will have on downstream occupants. Any downstream costs associated with the proposed flood fringe encroachments in the study area should be charged to the owners or lessees of those developments.

7. The final design of the industrial malls should incorporate all flood damage reduction measures which are economically feasible. At a minimum, this should include floodproofing of buildings up to the Hazel flood elevation and a design layout which places structures furthest from the stream channel and parking lots and outdoor storage areas closer to it.

8. An engineering study should be undertaken to determine the costs and hydraulic feasibility of re-channelling the sub-area 5 portion of Pottersburg Creek into a channel south of Oxford Street between Crumlin Road and Industrial Road. This would free sub-area 5, which is a highly attractive site, for industrial development. Again, the potential costs of such channelization including study costs and any resultant downstream damage costs should be compared with the potential benefits from such a project.

9. More accurate and up-to-date topographical mapping of the study area, and any other areas where flood fringe developments are proposed, is required.

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APPENDIX 1

DESCRIPTION OF HEC-2 PROGRAM

The HEC-2 computer program computes water surface elevations for river channels of any cross-section for either supercritical or subcritical flow conditions. Special allowance is made for bridges, culverts, dykes and other constrictions.

For all normal cross-sections the standard step method is used to determine the depth at the next section. Subcritical computations proceed upstream and supercritical computations downstream. In addition to friction losses, expansion and contraction losses are evaluated by either a normal or a special bridge routine. The normal bridge routine considers the bridge the same as any other cross section with the exception that the area and wetted perimeter are altered by the bridge structure. The special bridge routine evaluates losses for low flow, pressure flow and weir flow as well as combinations of these.

The entire river cross-section is divided into three areas. These are left overbank, channel and right overbank. The discharges for each of these areas is determined separately and a discharge weighted velocity head is calculated for the entire section.

If large changes in velocity occur between the user supplied cross-sections the program can supply up to three interpolated cross-sections. These interpolated sections are geometrically similar to the previous cross-section supplied to the program but are shifted in elevation and horizontal stationing.

The HEC-2 program is a powerful tool for use in flood-plain studies. It may also be used to test the effect of anticipated or proposed flood plain encroachments, dyke or levee construction or sediment scour or deposition.

APPENDIX 2

LAND PRICE DIFFERENTIALS

Table 5-1 on page 104 lists, for the three frequency estimates, the annual mill rates which would have to be applied (in addition to the normal commercial rate of .14277) to the Pottersburg Creek flood fringe developments in order for the city to recoup the annual flood damage costs. Recouping these costs would mean that the city would receive the same net tax revenues from the proposed developments regardless of whether they were located on the Pottersburg Creek flood fringe or an alternative non-flood fringe location. If there existed no difference between two such locations (i.e. one possessed no locational advantage over the other), the imposition of this incremental tax to cover flood losses would discourage developers from locating on the flood fringe.

Assuming, however, that there is some locational advantage associated with the Pottersburg Creek site, the situation is changed. Now, it would be necessary to assign some tax rate to the property, higher than the rates shown in Table 5-1, if some or all of the economic rent associated with this locational advantage is to be captured by the city. Such incremental taxes would, of course be levied only on the flood fringe sites. The capitalized value of these incremental annual taxes would, if the locational advantages of the flood fringe sites was not recognized, equal the difference in the price of the non-flood

TABLE A2-1

POTENTIAL DIFFERENCE IN THE PRICE
OF FLOOD FRINGE LAND AND ALTERNATIVE
SITES (in dollars per acre)*

Incremental Tax Rate per $000 of Assessed Value of Buildings plus Land	Net Discount Rate (in percent)		
	.02	.04	.08
.25	2286	1563	890
.50	4572	3125	1780
1.00	9144	6251	3560

*Assumes all other municipal taxes equal.

fringe sites. The value of the locational advantage, then would be the present value of the maximum amount of incremental tax that potential developers would be willing to pay before they were rendered indifferent as to choice of location. This would result in a differential in land values.

Table A2-1 shows these potential differential land values (present values for different discount rates and tax rates). Thus, for a discount rate of 2% and an incremental tax rate of .25, flood fringe sites, in the absence of a locational advantage, would sell for $2286. per acre less than non-flood fringe sites.

Near the bottom of page 105, a figure of $1500. per acre is suggested as the value for the economic rent of the flood fringe location for a discount rate of 8% and given a suggested selling price of $31,000 per acre. Assuming this to be a fair estimate of probable selling prices, it can be seen, in Table A2-1, that, at an incremental tax rate of .50 and a discount rate of 8%, the price differential would be $1,780. If this amount of incremental tax were levied, developers would be discouraged from locating on the flood fringe as the economic advantage of doing so would, at $1500, be less than the additional tax. If the city wished to capture all of but no more than the $1500 of economic rent associated with the flood fringe site, the incremental tax rate would need to be .4214 (discount rate equal to 8%).