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Joint Task Force on Water Conservation Projects in Southern Ontario

GUIDELINES FOR ANALYSIS

Streamflows, Flood Damages, Secondary Flood Control Benefits

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The results of this study owe much to the advice and comments of two consultants to Acres Research and Planning Limited. Dr. Ian Burton, Associate Professor of Geography at the University of Toronto, was involved in our early discussions of field methods and interviewing techniques, and reviewed the study in its final draft form. Mr. Donald L. Clough, Professor of Systems Engineering at the University of Waterloo, also reviewed the final draft of this report.

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3 - STUDY OF FLOOD DAMAGES

The formulation of an optimal plan for the multi-purpose development of any river system involves a careful consideration of the reduction in potential flood losses that would result from each of several possible alternative flood control projects.[1] The main requirement for such an analysis is a valid estimate in dollars of the amount of damage incurred by the rural and urban flood plain areas at different stages of flooding. Without this information it is difficult to fully evaluate alternative mixes of possible flood control structures, flood proofing programs, and flood plain zoning, in conjunction with alternative levels of pollution abatement, water supply, and recreation facilities, and thereby establish the basic components of the optimal plan for the multipurpose development of a particular river system.

At the present time, there is a definite need for such stage-damage relationship curves for application to structures and properties on flood plains in Southern Ontario. In the past, the lack of such curves and the usual constraints of limited time and money have forced those involved in benefit-cost studies of proposed flood control projects to make wide generalizations from limited data[2] and dubious assumptions on the nature, extent, and amount of damage that occurs at particular levels of flooding on flood plains in Southern Ontario. The results of a recent study of flooding along the lower part of the Thames River, between Chatham and Wallaceburg, have helped to clarify the type and amount of damage that occurs when rural areas are subjected to various depths of floodwater.[3] However, there is still a need for reliable stage-damage relationships that are applicable to the many urban areas on flood plains in the province.

This study represents one attempt to derive such stage-damage curves. It endeavours to establish the relationship between depth of flooding and the amount of damage in urban areas through a detailed examination of properties and structures in Galt, Ontario.

This particular community was chosen on the basis of the client's suggestion and the favourable results of a preliminary reconnaissance of the area. This area has a long history of heavy flooding, and contains numerous structures of varied types that are typical of those likely to be encountered along rivers elsewhere in the province.

The damage curves which resulted from the study reflect the difficulties involved in trying to establish any comprehensive set of curves for use throughout Southern Ontario. However, while they may not take into account all of the structures on flood plains in the province, the applicability of these curves is sufficiently wide to facilitate comparison of potential flood losses from city to city, and from flood plain to flood plain throughout the southern part of the southern part of the province.

The development of these curves should make it much easier to compare and evaluate a much wider range of possible alternatives for reducing flood losses in Ontario than has previously been possible. These curves can be used to provide not only an estimate of reduction in flood damages that would result from the implementation of flood plain zoning, and flood proofing measures, but also an estimate of the amount of potential damage that would be averted by construction of the usual types of flood control structures. Therefore, the potential of these curves would not be realized if they were applied only to an evaluation of flood control benefits that would result from the construction of a dam. Evaluation of the possible benefits of alternative adjustments to the flood hazard must also be made for a project analysis.

FOOTNOTES

(1) Maynard Hufschmidt, and Myron Fiering, Simulation Techniques for Design of Water Resource Systems (Cambridge, Mass.: Harvard University Press, 1966).

(2) Ian Burton, "Investment Choices in Public Resources Development," in The Prospect of Change: Proposals for Canada's Future, ed. by Abraham Rotstein for the University League for Social Reform (Toronto, Ontario: McGraw-Hill Book Company, Limited, 1965), p. 107.

(3) James F. MacLaren Limited, Report on the Lower Thames River Channel and Dyke System From Chatham to Lake St. Clair for the Lower Thames Valley Conservation Authority (London, Ontario: James F. MacLaren Limited, October 1967), pp. 174-176. See also the discussion in Edgar E. Foster, "Evaluation of Flood Losses and Benefits," Transactions, American Society of Civil Engineers, Vol. 107, (1942), pp. 903-909.

3.1 - Review of the Present State of the Art

Prior to the actual study of Galt and the formulation of stage-damage curves for use in Southern Ontario, a review was made of the present state of the art in the province and elsewhere in North America. The results of this overview of damage analysis methods are presented in this initial section to provide the required perspective for viewing the methods and results of the Galt study.

3.1.1 - Previous Studies

As early as 1950, the Select Committee on Conservation of the Ontario Legislature drew attention to the lack of information on losses due to flooding along rivers in the province.(1) However, a definitive study of such damages has yet to be carried out. At the present time, there are two common methods for deriving rough estimates of potential flood losses in Ontario urban areas. Both depend heavily on data collected in the field -- often on a hit or miss basis -- during or shortly after an actual flood. One method involves the use of a ratio of estimated flood damages to observed river flow in a previous flood to estimate the potential damages from other probable flood flows on the same river.(2) The second method relates estimated flood damage to the amounts and types of urban land inundated during a previous flood. These ratios then are applied to the amount of land that would be submerged at other probable flood levels, yielding an estimate of potential flood losses.(3) Both methods are questionable on the grounds that the original assessment of flood damage is often erroneous, and the assumed linear relationship between levels of flooding and amount of flood damage is still an untested hypothesis.(4)

Other areas in North America have attempted to develop more valid methods of flood damage analysis. While all have encountered problems and often have been forced to make certain assumptions about flood damages, their techniques and experience do suggest possible methods of flood damage analysis for use in Ontario.

In the United States, the Army Corps of Engineers has had considerable experience in establishing stage-damage curves for use in evaluation of proposed flood control projects. Although the Corps has not always been totally objective in its estimates of the flood damage which would be prevented by a given dam or reservoir, it has adopted many of the suggestions made by the critics of its techniques. Thus, the Corps' method of damage estimation has slowly evolved from the rough surveys and crude estimates of actual damages used in the early 1930's, through standardized postflood survey procedures used in the 1950's, to a present-day interest in establishing unit-damage tables that permit rapid and accurate appraisal of both actual and potential damage at various levels of flooding.[5] Although the Corps' work along these lines is still in the formative stage, it does suggest the possible advantages of standardized cost estimates for the types of structures often found on flood plains, and for their contents.

Other agencies in both the United States and Canada have attempted to construct generalized stage-damage curves using estimates of the actual damages that occurred at different levels of flooding. The most widely known of these studies were carried out by the Manitoba Commission on Flood Cost-Benefit,[6] and by the Stanford Research Institute under contract with the United States Soil Conservation Service and the California State Division of Soil Conservation.[7] Both studies relied heavily on estimates of actual losses provided by owners of flood plain establishments. Because personal definitions of admissible flood damages often vary considerably, difficulties were experienced in both studies in plotting curves relating depth of flooding and total damages for various classes of flooded structures. The Manitoba Commission overcame this problem by choosing to draw a highly generalized stage-damage curve and omitting points on the published diagrams. Stanford Research Institute included points on their depth-damage plots, revealing considerable variation in estimated damage at each level of flooding. The Stanford team acknowledged this and, in its recommendations, dwelt at length on the need for uniform procedures and survey methods to obtain more reliable figures on flood losses.(8)

Later studies of human adjustments to flood hazards, carried out by White(9) and other geographers at the University of Chicago,(10) independently developed and made considerable use of the type of standardized damage schedules recommended by Stanford Research Institute.(11) The Chicago studies utilized standard evaluation procedures and costs to construct synthetic damage curves which facilitated direct comparisons of the potential flood losses to a community under alternative possible adjustments to a flood hazard.(12) In effect, the Chicago studies represented the first attempt to put flood damage studies on a more objective basis.

3.1.2 - Definitions

A review of the previously mentioned studies of flood damage analysis showed that several schemes are currently used to classify flood damages. The most common way is to define direct, indirect, and intangible damages.(13) Direct damages usually are defined as the actual physical losses that can be evaluated on the basis of the cost of restoring an object to its preflood condition -- either by repair or replacement. Indirect damages are losses brought about by interruption of normal activities for which compensation cannot be obtained in other areas or at a later date. Intangible damages are those which cannot readily be evaluated in direct monetary terms -- such as loss of life, and suffering of adverse effects on health, social and economic security.

Distinction also should be made between immediate and postflood damages. Immediate damages are those immediately ascertainable at the time of flooding or in the clean-up period which follows. Postflood damages are those which do not manifest themselves until a later date -- such as foundation sapping, which is a common example of this type of flood damage.(14) Such damages are often overlooked in on-the-spot surveys of actual flood losses.

Flood damages are classified also under general headings such as commercial, residential, industrial, and an all-inclusive category such as "additional" or "other". This rough classification simplifies the collection of data and the calculation of actual damages.(15)

3.1.3 - Damage Factors Established Elsewhere

A number of factors which give rise to sizeable variations in total damages from community to community and from year to year have been identified in previous studies. The following have been shown to be particularly important.

Time of Flooding: The amount of flood damage can vary significantly with the time of flooding. Early Spring floods, followed by a sudden cold spell while water is still inside buildings, often give rise to more damage (primarily caused by expansion of ice in wall and floor cracks) than floods which occur in the late Spring and early Fall. Early Spring floods often carry ice heavy enough to smash windows and damage trim.

The time of day at which a flood strikes also influences the final damage figure. Obviously a flood that rises rapidly during the night has a greater potential for destruction than one that builds up during the day in full view of the flood plain inhabitants.(16)

Velocity of Flood Waters: Flood damages vary significantly with the velocity of the flood. Fast moving flood waters can sweep many structures off their foundations, erode lawns and shrubbery, and undermine roads and sidewalks.[17]

Depth of Flooding: As depth of flooding increases, the amount of damage tends to rise due to two main factors. First, the greater the depth of flooding the greater the potential for heavy damage to the contents of any structure. Secondly, hydrostatic pressure increases with depth at such a rate that even four feet of water against a wall exerts a pressure of 250 pounds per square foot.[18] Under such pressure, leaks develop and materials rapidly become saturated.

Duration of Flooding: As might be expected, the duration of flooding has been shown to influence the amount of damage recorded for any particular flood.[19]

Sediment Load: Flood waters carrying large amounts of sediment usually necessitate additional expenditures for clean-up and repairs.[20]

Function of the Flooded Area: The level of flood damage also varies with the function of the area under water. Discounting a flood's varying effects on different types of structures, considerable variation remains in damages due to interference with activities in the area. Obviously damages would be greater in a high-class commercial area than in a low-class commercial area.

Value of Structure and Contents: The Stanford Research Institute studies substantiated the belief that the value of a structure or its contents helps to dictate the level of flood damages.[21] While this relationship between value and damage is not linear, it is real and does lead to variations in damages from place to place.

Frequency of Flooding: Urban areas subjected to near-annual flooding probably will have made adjustments to cope with this frequent hazard, thereby reducing the level of damage brought about by smaller floods.[22]

Warning Time: Given sufficient warning time, many flood plain dwellers could take steps to reduce the amount of flood damage they would suffer.

Flood Proofing: The greater the attention given to flood proofing of structures along a given flood plain, the more likely it is that there will be a reduction in flood damages due to minor levels of flooding.

Several studies of flood losses have pointed out the role played by the human factor in producing significant variations in flood damages under similar conditions of flooding.[23] While man has little control over the time, duration, velocity, and sediment load of any particular flood, he does have the ability to flood proof structures and to provide and make use of an adequate flood warning system. The fact that some men do choose to exercise these options, while some do not, often leads to a considerable range of flood damages to urban structures and properties subjected to the same flood levels.

3.1.4 - Actual and Synthetic Damage Estimates

The present state of the art of flood damage analysis provides two methods of assessing urban area losses under various flood conditions. One method involves the compilation of estimates of flood levels and actual damages reports provided by flood plain residents. The other requires the analyst to make synthetic estimates of the possible damages that could occur to flood plain structures at different levels of flooding.

Of the two methods, the collection of actual damage figures is open to the most criticism. Previous studies[24] have pointed out that this method ignores the following facts:

(1) - Respondents often use the cost of replacement rather than the actual depreciated value of flood damaged goods.

(2) - Many people overestimate the actual damage to their goods and equipment. Although a motor may have a present-day value of $50, it may cost only $15 to clean and dry out the windings, rendering the motor reusable.

(3) - The salvage value of flood damaged furniture, stock, and equipment, is often not considered.

(4) - Postflood damages are seldom taken into account.

(5) - The cost of clean-up -- often done by the owner himself or with the help of volunteer labour -- is usually underestimated or even omitted.

(6) - Many estimates of actual flood damages involve double counting.

(7) - Damages suffered in one community are often of benefit to an adjacent area, or to the same community at a later date.

(8) - Actual damage figures are available only for previous flood levels. Derivation of an estimate of the damage that would occur at higher levels of flooding necessitates an extrapolation based on data that is questionable.

A number of difficulties are also associated with the formulation of synthetic damage estimates. Because these estimates are based on hypothetical flood conditions, considerable research may be necessary to establish realistic costs of restoration, salvage values, and lifetimes for various structures and contents. This type of preliminary research is often impossible, given the limited time and money which usually are made available for the complete economic analysis of any water resource project. Moreover, the synthetic depth-damage relationships which do result from such studies are open to criticism because of their purely hypothetical nature. However, their merits more than outweigh their drawbacks, since damage estimates formulated on the basis of a set of conservative economic assumptions and standardized restoration schedules avoid the subjective elements which are inherent in actual flood damage figures.

FOOTNOTES

(1) Ontario, The Select Committee on Conservation, Report To The Ontario Legislature (Toronto, Ontario: The King's Printer, 1950), p. 89.

(2) Metropolitan Toronto and Region Conservation Authority, Plan For Flood Control And Water Conservation (Woodbridge, Ontario, 1959), pp. 103-104.

(3) J.M. Thomlinson and Associates, General Report On The West Montrose And Ayr Reservoir (Galt, Ontario: The Grand River Conservation Authority 1964).

(4) Gilbert F. White, Choice of Adjustment to Floods, University of Chicago, Dept. of Geography Research Paper No. 93 (Chicago, Illinois: Dept. of Geography, 1964), p. 57.

(5) John R. Sheaffer, Flood Proofing: An Element In A Flood Damage Reduction Programme, University of Chicago, Dept. of Geography Research Paper No. 65 (Chicago, Illinois: Dept. of Geography, 1960), pp. 77-84; and Ibid., pp. 2-5.

(6) Manitoba, Royal Commission on Flood Cost-Benefit, Report Of The Royal Commission On Flood Cost-Benefit 1958 (Winnipeg, Manitoba: The Queen's Printer, 1958), pp. 51-57.

(7) A. Gerlof Homan, Analysis of Factors Affecting Flood Damage (Menlo Park, Cal.: Stanford Research Institute, 1958); and A. Gerlof Homan and Bruce Waybur, A Study Of Procedure In Estimating Flood Damage To Residential, Commercial, and Industrial Properties In California (Menlo Park, Cal.: Stanford Research Institute, for The U.S. Soil Conservation Service and the California State Division of Soil Conservation, 1960).

(8) Ibid., p. 5.

(9) White, op. cit.

(10) Robert S. Kates, Hazard and Choice Perception In Flood Plain Management, University of Chicago, Dept. of Geography Research Paper No. 78 (Chicago, Illinois: Dept. of Geography, 1962), and Industrial Flood Losses: Damage Estimation In The Lehigh Valley, University of Chicago, Dept. of Geography Research Paper No. 98 (Chicago, Illinois: Dept. of Geography, 1965).

(11) The Chicago standarized schedules for estimating synthetic losses grew out of a suggestion by Edward F. Renshaw. See his remarks on "The Relationship Between Flood Losses And Flood Control Benefits," in Papers On Flood Problems, ed. by Gilbert F. White, University of Chicago, Dept. of Geography Research Paper No. 70 (Chicago, Illinois: Dept. of Geography, 1962), pp. 41-43.

(12) White, Choice Of Adjustment To Floods, op. cit., pp. 48-49.

(13) Sheaffer, _op. cit._, pp. 81-82

(14) Sheaffer, _op. cit._

(15) Kates, _Industrial Flood Losses ..._, _op. cit._, pp. 8-10.

(16) _Ibid._, pp. 54-58.

(17) White, _Choice Of Adjustment To Floods_, _op. cit._, p. 62.

(18) Sheaffer, _op. cit._, p. 29.

(19) White, _Choice Of Adjustment To Floods_, _op. cit._, p. 62.

(20) Edward Kuiper, _Water Resources Development_ (London, England: Butterworths Ltd., 1965), pp. 418-425.

(21) Homan and Waybur, _op. cit._, p. 1.

(22) Robert W. Kates, "The Synthetic Estimation Of Flood Damages: A New Approach" (paper presented at the Pennsylvania Conference of Economists, Haverford, Pennsylvania, June 13, 1963), p. 14.

(23) Gilbert F. White, _Human Adjustment To Floods_, University of Chicago, Dept. of Geography Research Paper No. 29 (Chicago, Illinois: By the author, 1945).

(24) William G. Hoyt and Walter B. Langbein, _Floods_ (Princeton, N.J.: Princeton University Press, 1955), pp. 79-81.

3.2 - The Galt Case Study: Background Information

3.2.1 - Hydrologic Record

The Grand River Conservation Report[1] provides a complete history of flooding on the Grand River from about 1790 to 1954. On the basis of the diaries and newspaper accounts cited in the report, it is apparent that flooding along the Grand River has always been a severe problem. Although many communities on the river's flood plain have been subjected to frequent flooding, Galt has often been particularly hard hit, due to the fact that its sizeable commercial, industrial, and residential areas lie close to the river. Floods have struck Galt 11 times in this century.[2] Ten of these floods took place in the early Spring, and were both sudden in occurrence and short in duration. The 1948 flood -- the greatest Spring flood at Galt on record -- rose overnight and receded from the community within a day.[3] Many homes, industries, and commercial establishments were flooded to a depth of several feet, and losses were severe in many cases. Hurricane Hazel, which struck Southern Ontario in the Fall of 1954, did not strike the Grand River watershed in its full intensity. However, enough rain fell on the upper reaches of the Grand River to produce the maximum flow ever recorded at Galt. This peak moved downstream in less than a day but, once again, damage was reported to be considerable.[4]

3.2.2 - Sources and Limitations of Existing Damage Figures

In terms of the amount of readily available and reliable information on past flood damages that have occurred, Galt appears to be a typical flood plain community. Valid estimates of total direct and indirect flood damages at various depths of flooding are virtually non-existent. Newspaper accounts of the 1948 and 1954 floods provide an incomplete account of flood levels and direct flood losses, and many of the damages reported involve possible double counting and substantial exaggeration. Little information is available on indirect flood damages.

The Grand River Conservation Authority has sponsored several surveys of possible direct flood damages. In 1952, the Commission obtained rough estimates of probable flood losses from the managers of many of the industries situated on the flood plain.[5] Pinola later utilized this information in a cost-benefit study of a proposed system of reservoirs along tributaries of the Grand River.[6] Unfortunately, the Authority no longer has these damage estimates in its files.[7] Other consultants also have carried out flood damage surveys for the Authority.[8] However, these surveys usually have been restricted in terms of comprehensiveness and accuracy because of the limited funds made available for this purpose.

FOOTNOTES

(1) Ontario, Department of Lands and Forests, Conservation Authorities Branch, Grand River Conservation Report: Hydraulics, 2nd edition (Toronto, Ontario: Dept. of Lands and Forests, 1962), Chap. 3.

(2) Ibid.

(3) Ibid., pp. 82-84.

(4) Ibid., Appendix C.

(5) J.M. Thomlinson and Associates, General Report on the West Montrose and Ayr Reservoirs (Galt, Ontario: The Grand River Conservation Authority, 1964), p. 27.

(6) Rudolph Pinola, A Benefit-Cost Analysis: Ayr and West Montrose Reservoirs, February, 1964 (Fergus, Ontario: The Grand River Conservation Commission, 1964).

(7) In a personal interview on June 21, 1968, Mr. Ilmar Kao of the Grand River Conservation Authority stated that the files containing the 1952 survey have been misplaced and consequently are no longer available to those studying flood damages at Galt.

(8) Grand River Conservation Authority, Brief on Flood Control and Water Conservation for the Grand River Watershed (Galt, Ontario: The Grand River Conservation Authority, August, 1966), Appendix A.

3.3 - Synthetic Direct Damage Curves

The lack of reliable information on previous flood losses in Galt illustrated the need for realistic stage-damage curves that could be utilized to estimate potential flood damages in any urban area of Southern Ontario.

This study represents the first detailed attempt at appraisal and evaluation of flood damages, utilizing data collected in Southern Ontario. The Galt area was chosen for the collection of the data necessary to construct synthetic direct damage curves, because this flood plain provides many examples of the types of commercial, residential, and industrial structures likely to be found on flood plains in the province. Additional information, required to evaluate suggested ratios of indirect to direct damages for application to direct damage figures derived from these curves, was gathered through interviews with local officials and managers in Galt.(1)

3.3.1 - Choice of Flood Type

The limited time available for this study ruled out a complete analysis of the effect which various combinations of velocity, duration, timing, and sediment load, have on the damages brought about at different levels of flooding.(2) Therefore, following a preliminary review of accounts of earlier floods on the Grand River and on other rivers in Southern Ontario,(3) a hypothetical flood was formulated for study purposes.

In line with the conservative approach(4) to flood damage analysis used in this study, this hypothetical flood was assumed to be of low velocity (less than 5 m.p.h.), of short duration (two days), and to contain only a small amount of sediment in suspension (one-half inch of silt being the maximum amount deposited in any structure). It was assumed that such a flood struck the selected Galt structures during the early Spring, since most floods in Southern Ontario occur during this time of the year.(5)

The choice of actual flood levels utilized in formulating stage-damage curves involved a number of considerations. Past and potential flood level figures were available for Galt,(6) and these could have been applied to each structure. However, these flood levels might not have been appropriate for use on larger or smaller rivers in the province. Accordingly, an arbitrary decision was made to apply flood levels of 6, 12, 24, 48, and 60 inches to structures at Galt. An additional measurement was made at 36 inches in retail establishments because of content layout. Analysis was made of the effects of from 6 to 60 inches of water in the basement, on the first floor, and above and below the first floor level on the outside of each establishment. The study attempted to estimate the potential damage to structures and contents at each of these flood levels.

3.3.2 - Definitions of Structural Categories

A preliminary reconnaissance of Galt revealed the variety of structures to be found in the study area. Three basic structural categories were defined, to ensure the formulation of stage-demand curves that could be readily applied elsewhere in the province. These categories were based on the general function of the structure -- residential, commercial, or industrial.(7)

The residential and commercial categories were further subdivided. Residential structures were classed as either wooden or brick, and three subcategories were defined for each of these. The general elements of this scheme are set out in Table 1. This system of classification, while not without its faults, does conform to a scheme devised by the Department of Municipal Affairs.(8) Moreover, a handbook published

TABLE 1

RESIDENTIAL CLASSIFICATION SCHEME

Class	Department of Municipal Affairs Designation	General Criteria[a]
1. Wooden (or stucco) AW	D-7 to D-10	Solid, architect-designed wooden structure. May be ultra-modern or older two-storey. High-class, solid construction and materials.
BW	D-4 to D-6	Double wall frame home. Typical of middle-class housing developments. Most wooden homes fall into this class.
CW	D-1 to D-3	Rough frame structure, thin walls. May have stucco or imitation brick coating.
2. Brick (or stone) AB	C-8 to C-10	Mansion-like or ultra-modern appearance. Very high quality in construction and materials.
BB	C-6 to C-7	Typical mass-produced ranch-style or two-storey home.
CB	C-4 to C-5[b]	Cheap brick or concrete block bungalow.

[a]See Appendix A for illustrations and further clarification.

[b]The D.M.A. Handbook does not list type C-1 to C-3 homes or provide an explanation of their omission.

by the Department contains a detailed description and cross section of the types of homes found within each of these subcategories.[9] These have been reproduced and are included in this report as Appendix A. Their use would facilitate rapid field classification of residential structures elsewhere in the province.

Several methods for classifying commercial structures were considered. The most appropriate appeared to be one which considered damages to --

(1) - the contents of various types of commercial establishments;

(2) - the various types of structures housing commercial functions.

The use of this simple classification avoided the problem which would have resulted if similar commercial functions were found in buildings constructed of markedly different building materials, i.e., wood, cement blocks, brick, and reinforced concrete. Obviously, the structural damage to drug stores at a given level of flooding would be different if some stores were housed in wooden structures and others in brick. Aggregating such damage figures would lead only to meaningless stage-damage relationships.

While several possible schemes for classifying industrial structures were considered in the study, it was soon evident that the variety and complexity of industrial operations necessitated stage-damage appraisals on a plant by plant basis.

3.3.3 - Sampling Procedures

The structures and functions examined in this study were chosen on the basis of a stratified random sample of establishments in Galt.[10] Variations in the numbers and characteristics of the structures and functions that fell within each of the previously defined categories necessitated adjustments in the method of stratification and sampling from category to category.[11] The following is a detailed explanation of the procedures used.

Residential Sampling

Each residence on the Galt flood plain was classified according to the defined structural subcategories. Initial classifications were based on field observations made during a two-day reconnaissance of the study area. These preliminary classifications were later verified during interviews.

The initial classification revealed the lack of a sufficient number of high-class wood and brick homes on the flood plain. Accordingly, an area of Galt above the actual flood plain was used to augment the number of these homes available.

The address of each home was listed under the appropriate subcategory of residential types and assigned a number. A sample of 15 of the addresses in each subcategory was then chosen, using a table of random numbers. While the size of this sample was largely determined by the time available for field work in Galt, it was felt that 15 homes would provide a reasonable indication of the damages to structure and contents within each of the six residential subcategories.

Commercial Sampling

The range and number of commercial functions found on the Galt flood plain was determined by using the City Directory.[12] Six types of common commercial functions were chosen, and the addresses of those found in the study area were listed under the appropriate headings -- drug stores, grocery stores, shoe stores, men's wear stores, ladies' wear stores, and furniture stores. Numbers were assigned to each address within these subcategories, and five of each type of commercial function then were chosen by using a table of random numbers. Once again, the limited amount of time available for field work necessitated a small sample size and an examination of only the more common types of establishments. However, it was felt that several of these commercial functions could be used as substitutes when others not covered in this study were encountered on Southern Ontario flood plains.

Industrial Sampling

Since structure and contents varied widely from industry to industry in Galt, sampling was not carried out. Instead, a number of interviews were held with plant managers and officials to review the types of damage which could be produced by flooding. It was hoped that the results of these meetings and plant inspections would permit the formulation of procedures for appraising potential industrial losses at various levels of flooding on flood plains throughout Southern Ontario.

3.3.4 - Questionnaire Design

Following preliminary discussions and a review of the available literature on techniques for estimating potential flood losses, the following conclusions were reached and therefore extended great influence on the design of the questionnaires used in this study.

(1) - It was decided to design two questionnaires -- one for use for residential structures and the other for use for commercial establishments. No attempt was made to design a questionnaire suitable for industrial operations. Instead, a number of discussion points were agreed upon prior to visiting an industry, and the rest of the interview was carried out on an open-end basis.

(2) - It was decided that any sizeable variations in potential damages within any one subcategory would largely be due to differences in the contents of structures rather than in the actual structures. Therefore, the questionnaire was designed to focus on direct damage to contents. Structural damage estimates were provided for a smaller number of structures by an engineer with extensive experience in the construction industry.

(3) - To facilitate the calculation of the damage to contents at each level of flooding, it was decided that an inventory should be made of the contents of the basements, first floors, and grounds of residential and commercial structures. This type of approach permitted the application of standardized rates of depreciation, salvage values, clean-up and restoration costs to the goods inventoried in the office at a later date, and allowed the field team to cover a greater number of structures in the time available.

(4) - It was decided that an attempt should be made to gather sufficient information to calculate indirect damages and test the validity of a number of ratios of direct to indirect damages often used in flood damage studies in the United States.

(5) - It seemed imperative that some check be made on the validity of the stage-damage curves established in this study. To this end, a decision was made to probe for previous flood levels and past flood damages in both questionnaires.

The residential and commercial questionnaires used in this study reflect these decisions (see Appendix B). The reasoning behind many of the questions, and the use which was made of the information collected, are detailed in the following section.

3.3.5 - <u>Construction of Direct Damage Curves</u>

The results of the Galt surveys were used to construct curves relating direct structural and content damages to levels of flooding in commercial and residential establishments. The methods used in the construction of, and the assumptions inherent in, each of these curves are discussed below.

(1) - <u>Residential Property: Content Damages</u>

To estimate the damage that would occur to the contents of the homes sampled, it was necessary to determine whether a given article could be restored to its original condition or whether it would have to be replaced by an article in similar condition and of similar value. In no case was the value of a replaced or restored article to exceed the depreciated value of the original article, and the less expensive of these two alternatives would represent the damage cost.

Prior to the survey, two or three cost classes were established for each article which might be found in the basements, on the first floor, in the garage, or on the grounds of residences in the Galt study area. In the field, the interviewer indicated on his questionnaire the cost class appropriate for each article and, when necessary, modified the original cost estimates on the basis of his field experience.

Determination of depreciated values (i.e., preflood values), required establishment of the expected lifetimes associated with each cost class of a given article. A minimal depreciated value greater than zero was set for appliances in working condition and for some of the larger pieces of furniture. A straight line depreciated value then was assigned over the lifetime of the article until the minimal depreciated level was reached. Direct observation and interviews with furniture and appliance dealers provided the basis for establishing these cost classes, expected lifetimes, and minimal values (Appendix C).

The extent of direct flood damage to various objects was established through contacts with experienced dealers and servicemen. It was apparent that for some articles (e.g., mattresses and cheap veneer woods) flooding results in total destruction while other contents (e.g., well-finished wooden furniture) suffer much less damage. Moreover, it was evident that inexpensive repairs are possible for many items. Motor can be dried, drawers can be refitted, certain types of carpets and drapes can be cleaned, and furniture can be re-upholstered. Repair costs associated with the extent of inundation for each cost class of each article were checked with several furniture and appliance dealers.

A final consideration was the calculation of clean-up costs for first floors and basements. Again, individuals with experience in this area were interviewed to provide valid figures for clean-up costs per square foot or hardwood, linoleum, tile, concrete, and wall areas. A list of the repair and clean-up costs used is contained in Appendix C.

Calculations:

For each home, depreciated values of contents were calculated on the basis of the cost and age of each article inventoried by the interviewer and the depreciation rates discussed above. The field survey also recorded the distance between the floor and the main part of each article.

(distance from floor to table tops, lower edges of sofas, chair seats, etc.) to provide the heights of damage-prone levels. By referring to these critical levels in conjunction with the repair costs and the depreciated value of each article, it was a simple matter to determine the extent of damage at various depths of flooding.

For articles which were assumed to be totally destroyed, the depreciated value was taken as the replacement cost when the water level reached the critical level of that article. For articles which could be repaired, the repair cost associated with the degree of flooding (as dictated by the critical levels) was taken as the amount of damage, unless the replacement cost was less. Although at six inches of water it was considered cheaper to repair an article, at four feet it often was felt to be less expensive to replace it with one of a similar age and value. Neither repair nor replacement costs were assigned to those articles which were allowed to depreciate to zero value, with the exception of drapes and carpets. Because it usually is possible to clean and restore drapes and carpets to near preflood condition, cleaning costs were counted as a flood damage.

Finally, the cost of clean-up was added to the content damage. The area in square feet of hardwood, linoleum, tile, and concrete in each home was calculated and an appropriate rate for clean-up applied. Since the estimates of structural damage included the costs of repainting or rewallpapering walls at flood levels greater than two feet, clean-up costs for walls were levied only for 6" and 12" water levels.

A total damage figure then was calculated for the first floor and basement of each home, at the five levels of flooding. From this, the average amount of damage to each type of home (AB, BB, etc.) was calculated. These average damage costs are shown in Tables 2 and 3. Damages to grounds and garages are not shown, since the results of the survey indicated that the value of garage contents was usually small and, therefore, the average loss was negligible. A thorough analysis of

TABLE 2

FIRST FLOOR
AVERAGE DAMAGE TO CONTENTS, BY TYPE OF HOME

Water Level	Type of Home					
	AB	BB	CB	AW	BW	CW
6"	$ 266	$105	$ 82	$ 205	$109	$101
12"	846	310	241	722	264	333
24"	1,122	450	362	952	376	483
48"	1,341	515	389	1,108	402	514
60"	1,344	521	392	1,115	418	517

TABLE 3

BASEMENT
AVERAGE DAMAGE TO CONTENTS,[1] BY TYPE OF HOME

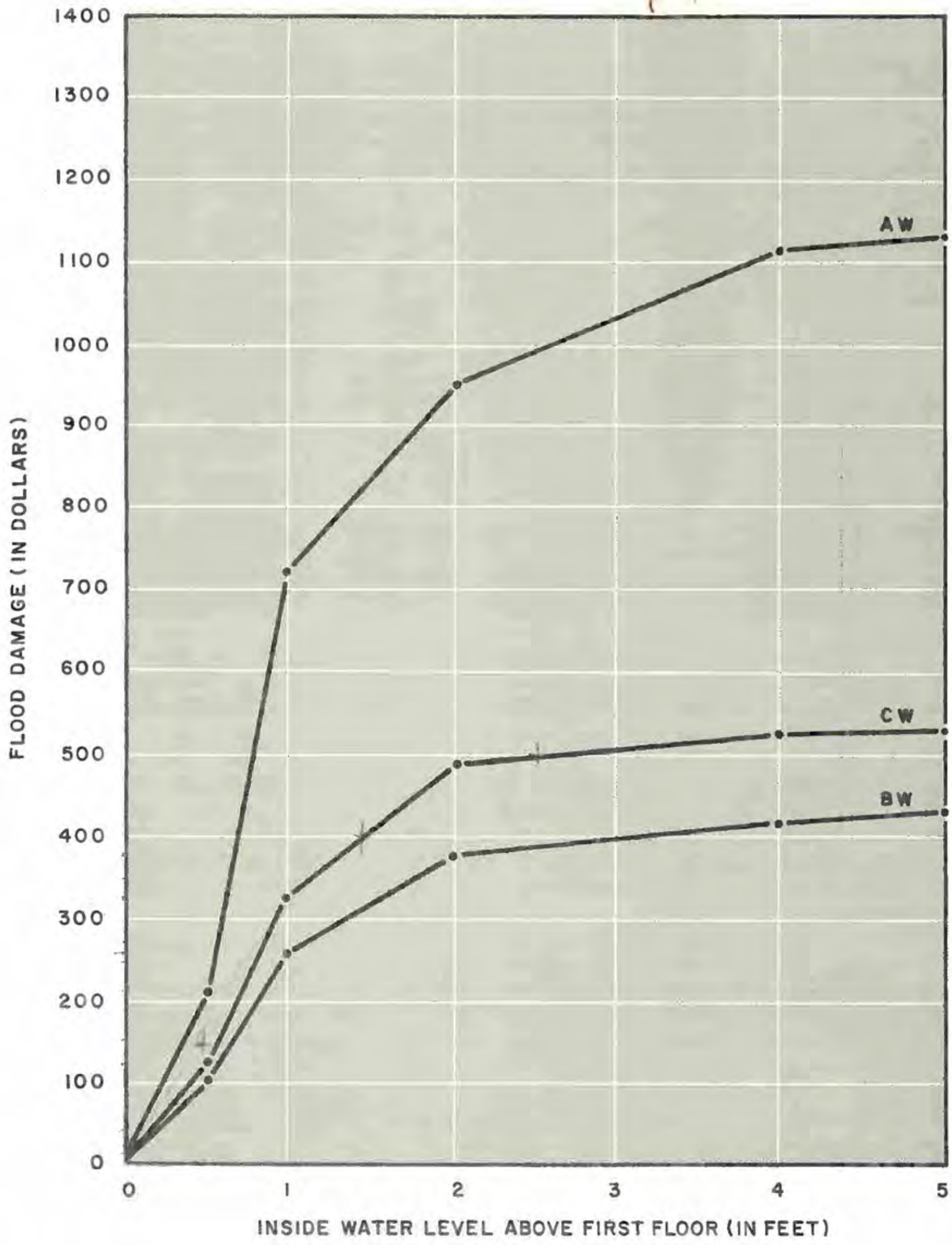
Water Level	Type of Home					
	AB	BB	CB	AW	BW	CW
6"	$ 77	$15	$ 9	$ 73	$19	$10
12"	171	15	9	158	19	12
24"	225	31	24	215	37	27
48"	262	33	24	234	40	27
60"	264	33	24	237	40	27

(1) Does not include the furnace, hot water heater, floor covering, or built-in cupboards etc. These items are included in the structure curve.

damage to residential grounds was not possible, due to collection of insufficient data. However, it should be pointed out that an early Spring, low velocity flood usually results in little damage to lawns and shrubbery. Since the hypothetical flood was defined as one of short duration and low velocity, damages to grounds were assumed to be limited to the cost of clean-up of debris.

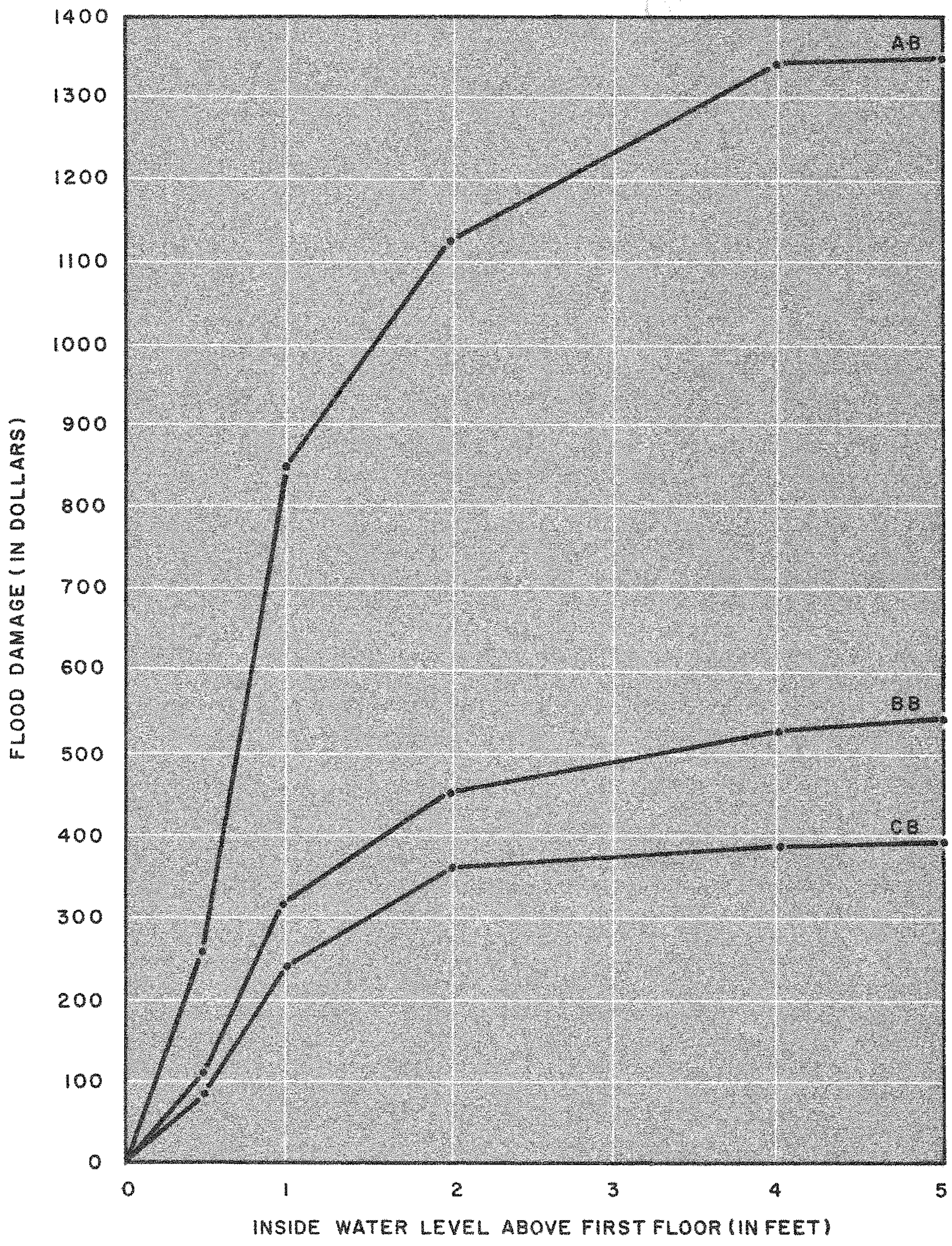
The stage-damage curves which resulted when average first flood content damage figures were plotted for the various flood levels are shown in Figures 1 and 2. Separate curves were constructed for the basement and first floor contents of each residential subcategory.

For both brick and frame homes, it is obvious from these curves that damage to the better type of home is most extensive. This reflects the fact that these homes contained new, high-quality furniture, antiques, and wall-to-wall carpeting. Also, 40 percent of the AB homes and 33 percent of the AW homes contained pianos (which were totally ruined at a four-foot water level), while almost 60 percent of these homes had bedroom damage losses on the first floor level. As shown on Figures 1 and 2, AW homes show slightly lower losses than AB homes due to the broader range of homes which fell in the AB category. With the exception of CW homes, lower- and middle-class homes usually contained older furniture, meaning that the depreciated value of an article was often very small. For those articles that had depreciated to zero value, no damage cost resulted unless the article was drapery or carpeting; for those that would have to be replaced, the replacement cost was low; and for those that could be repaired, it was often found that the replacement cost was even lower. The result was that the total damage to these homes was less than half of that of the better homes. However, it was suprising to note that the damage to CW homes was higher than that to BW homes. A closer examination revealed that the contents of the CW homes were often quite new, that 27 percent had pianos as compared with 0 percent of the BW class, and that 53 percent had first floor bedrooms as compared with only 30 percent of the BW class (see Table 4).



AVERAGE DAMAGE TO
CONTENTS OF WOODEN HOMES:
FIRST FLOOR

FIGURE 1



AVERAGE DAMAGE TO
CONTENTS OF BRICK HOMES:
FIRST FLOOR

FIGURE 2

These differences led to considerably higher replacement repair costs in CW homes, but the original inexpensiveness of the articles placed the damage at a much lower value than in AW homes.

TABLE 4

PERCENTAGE OF HOMES HAVING
PIANOS AND FIRST FLOOR BEDROOMS

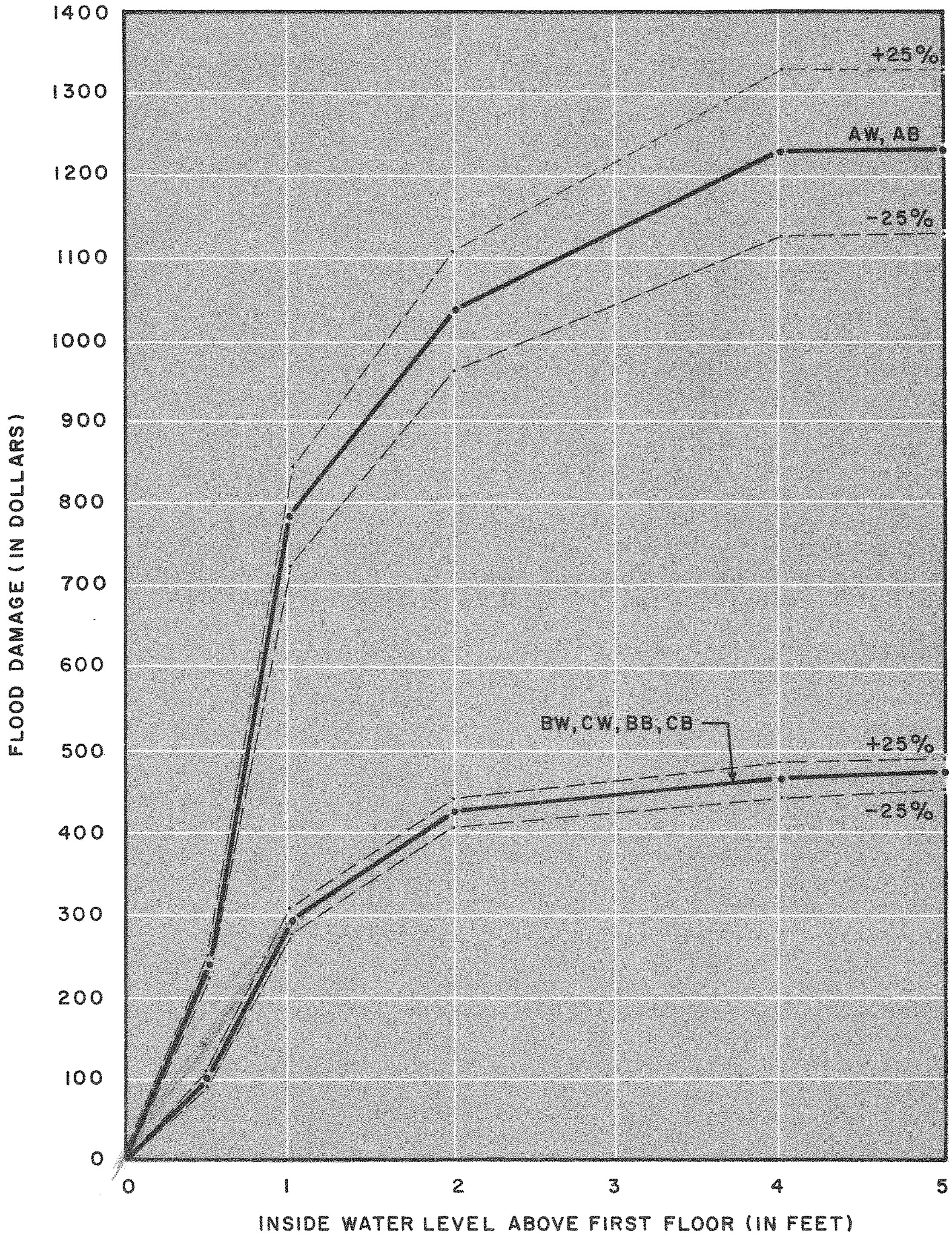
	Type of Home					
Item	AB	BB	CB	AW	BW	CW
Pianos	40	21	9	33	0	27
First Floor Bedrooms	60	57	30	56	30	53

A visual comparison of Figures 1 and 2 suggested that the average damage figures used to construct the AW and AB curves, and the BW, CW, BB, CB curves, were from the same sample populations. Tests of significance were carried out and the following null hypotheses were accepted at the .95 level of confidence:

(1) - There are no significant differences between AW and AB first floor content damage figures at each level of flooding.

(2) - There are no significant differences among BB, CB, BW, and CW first floor content damage figures at each level of flooding.

On the basis of these calculations, two composite curves for first floor content damages were constructed (Figure 3). An upper curve relates depth



NOTE: ±25% DENOTES LEVEL OF CONFIDENCE

AVERAGE DAMAGE TO CONTENTS OF ALL HOMES: FIRST FLOOR

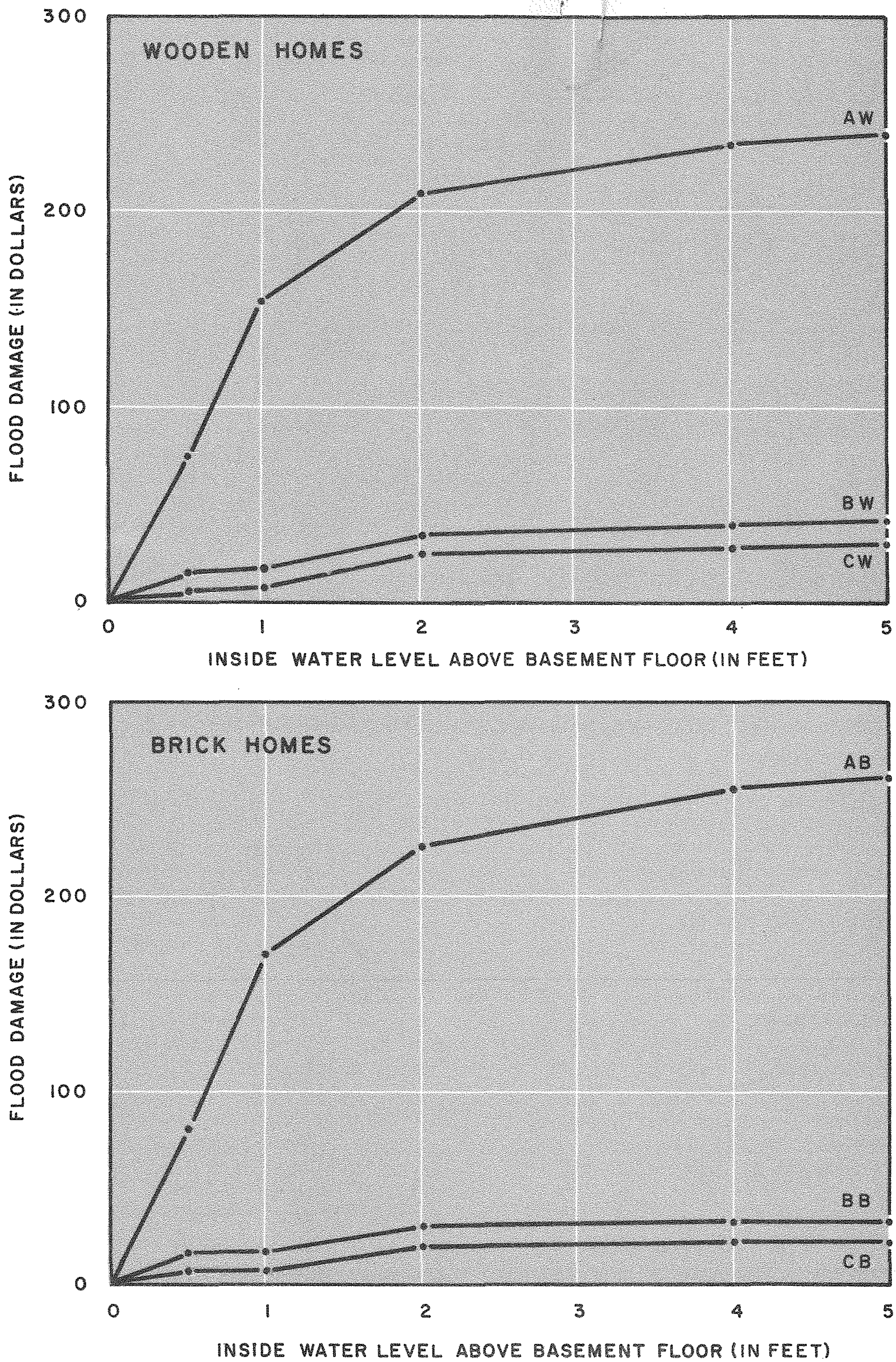
FIGURE 3

of flooding to average content losses in all high quality homes (AW and AB). A lower curve presents the same relationship for all low quality homes (BW, CW, BB, and CB). A null hypothesis of no significant difference between these two curves was rejected at the .95 level. Confidence limits of ±25 percent were calculated for both of these curves. In other words 50 percent of all observations fall within the upper and lower limit. A similar aggregation of average figures resulted from an examination of damages to basement contents in each type of home. Figure 4 shows the separate curves that can be drawn for basement contents of AW, BW, CW and AB, BB, CB homes. However, there are no significant differences between several of these curves, and Figure 5 actually represents the depth-damage relationships for residential basements more accurately. Once again, ±25 percent confidence limits have been placed on the content damage curves for the basement of high quality (AB, AW) and low quality (BB, BC, BW, CW) homes.

(2) - <u>Commercial Property: Content Damage</u>

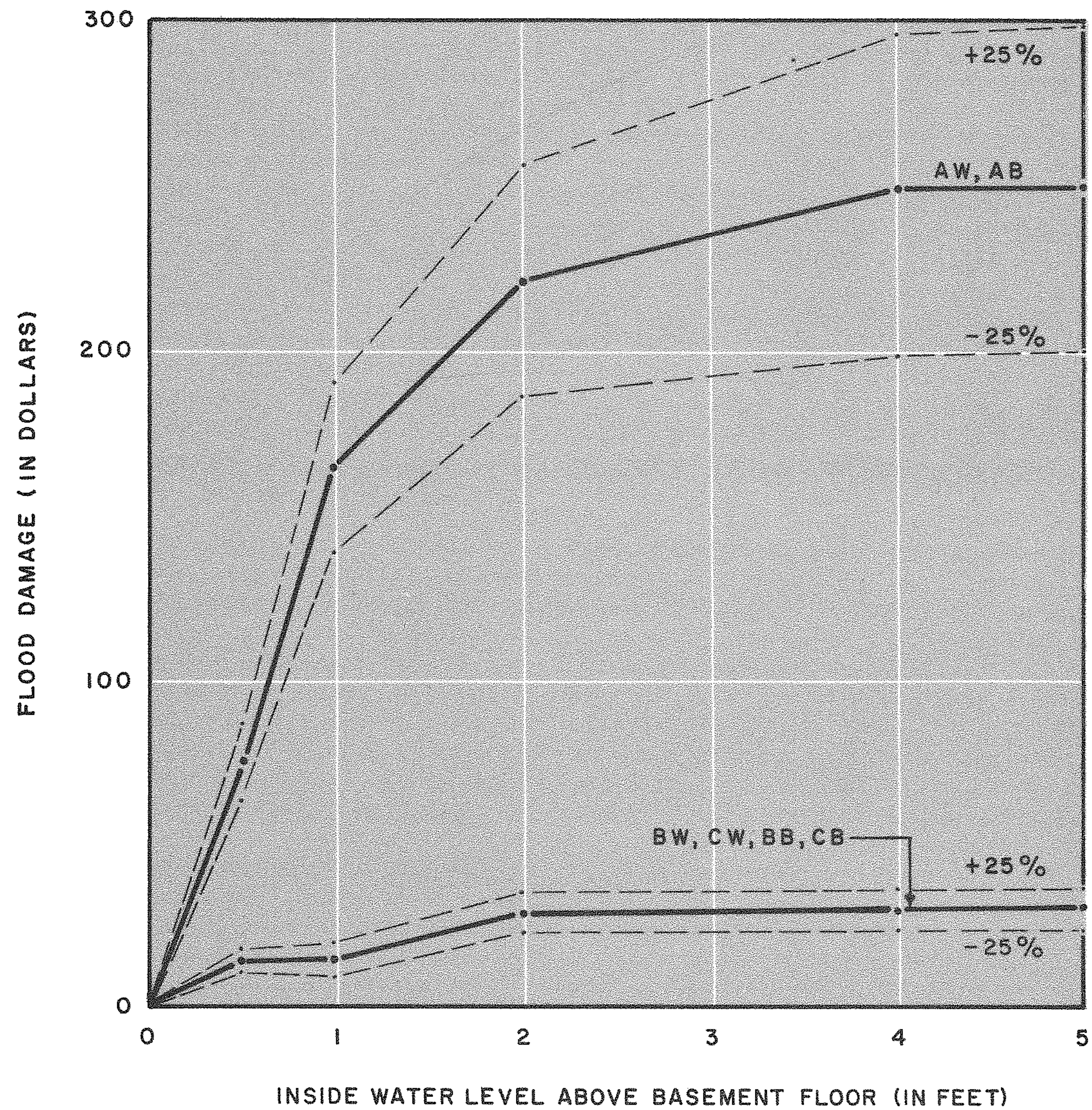
As mentioned previously, a stratified random sample of commercial establishments was made, based on the Galt City Directory classification. Because of the limited extent of the study area, five stores were randomly chosen in each group. This was further reduced in a few cases because some operators were unwilling to give certain information. In most cases, available information was supplemented and compared with Dun and Bradstreet reports [13] to provide greater accuracy.

The cost estimation procedures previously outlined for residential curve construction were also utilized in this part of the study. A few minor adjustments were made, the most significant being an increase in wall clean-up costs by one cent per square foot, to reflect the extra time required to clean shelving and sliding doors.



AVERAGE DAMAGE TO CONTENTS OF WOODEN AND BRICK HOMES: BASEMENT

FIGURE 4



NOTE: ±25% DENOTES LEVEL OF CONFIDENCE

AVERAGE DAMAGE TO CONTENTS OF ALL HOMES: BASEMENT

FIGURE 5

In the questionnaire designed for use in commercial structures, a division was made between selling and storage areas. After making damage calculations, it was decided that the differences between the two areas were minor, and that the simpler practice of using total floor area would yield comparable results. The practice in modern retailing of having little or no storage area adds further justification to this grouping.

In some cases, the resulting curves lacked critical levels, thereby differing from the residential curves. Near straight-line relationships between flood levels and average damages were suggested. It may be that this linearity reflects the cancelling-out effects of the variety of different types and heights of shelving and display racks found in Galt. A more detailed discussion of the construction and shape of each curve is given below.

Grocery Stores:

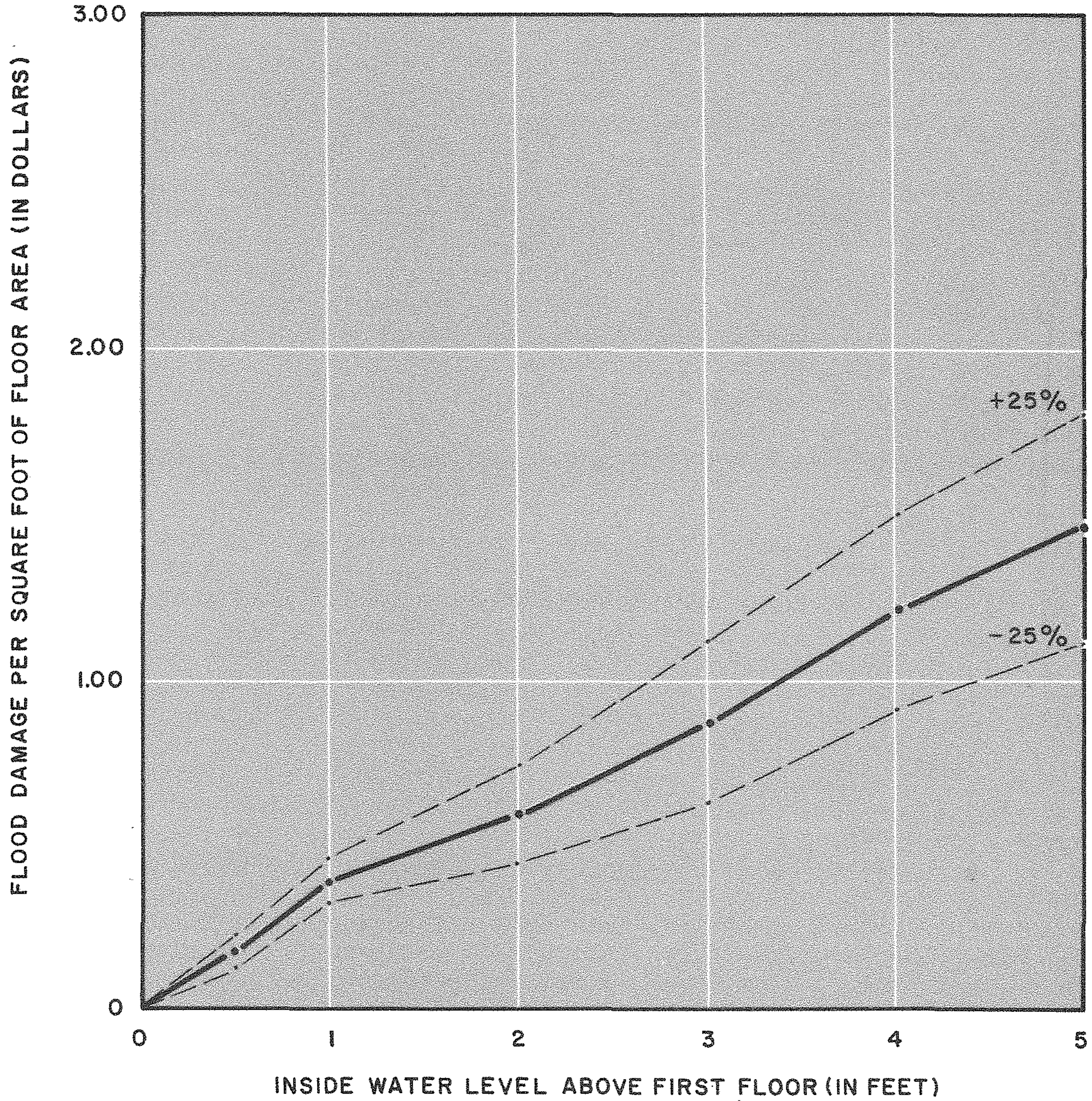
Four grocery stores located on the flood plain in Galt were examined. As in the case of other structures and functions studied, it was necessary to make a number of assumptions regarding the types and amounts of damage that would occur. Although the Ontario Department of Health felt that no generalizations could be made regarding flood losses in food stores because each situation would be unique, the Department did feel that damages would probably be quite high.(14) In face of this lack of specific information, it was decided to follow the method used by White in a recent study of flood damages in Lafollette, Tennessee.(15) It was assumed that foodstuffs touched by flood waters were a total loss.

An appraisal of food store shelving systems revealed that approximately 90 percent of the stock on display or in storage would be inundated at a flooding level of 5 feet. Since inundation was assumed to produce total damage, a simple procedure for estimating damages was devised. First, the value of the stock below five feet in height was estimated (90 percent of the total inventory).[16] This figure then was divided by ten to produce the increase in damage that would occur for each six-inch increase in depth of flooding. Then the amount of damage that would occur at the previously chosen flood levels of 6", 12", 24", 48", and 60", was calculated, followed by calculation of the damages to furniture and fixtures and of clean-up costs at similar flood levels. These figures were added together to produce an estimate of total direct damage to the contents of the store in question at the five levels of flooding. These damage figures then were converted into estimates of total damage per square foot of floor area of the store in question. This additional calculation was made to produce damage estimates that were easily applicable in field situations. The entire procedure was repeated for each store, and average damages were calculated at each flood level. Plotting the resulting figures against the appropriate measurement of depth produced a direct stage-damage curve for grocery stores. Accuracy levels of $\pm$25 percent were calculated.

The resulting stage-damage curves for the contents of basements and first floors exhibit two important characteristics of this type of retail establishment (Figures 6 and 7). A large increase in damage occurs in the basement between the two- and three-foot levels of flooding. The pumping devices for the refrigeration units on the main floor area often located at this level, and the cessation of these pumps results in extensive damage to perishables.

The main characteristic of the first floor curve is its near linearity. This is easily explained by the fact that the shelving in these stores is set up so that, as the flood level rises, damages increase at a near constant rate.

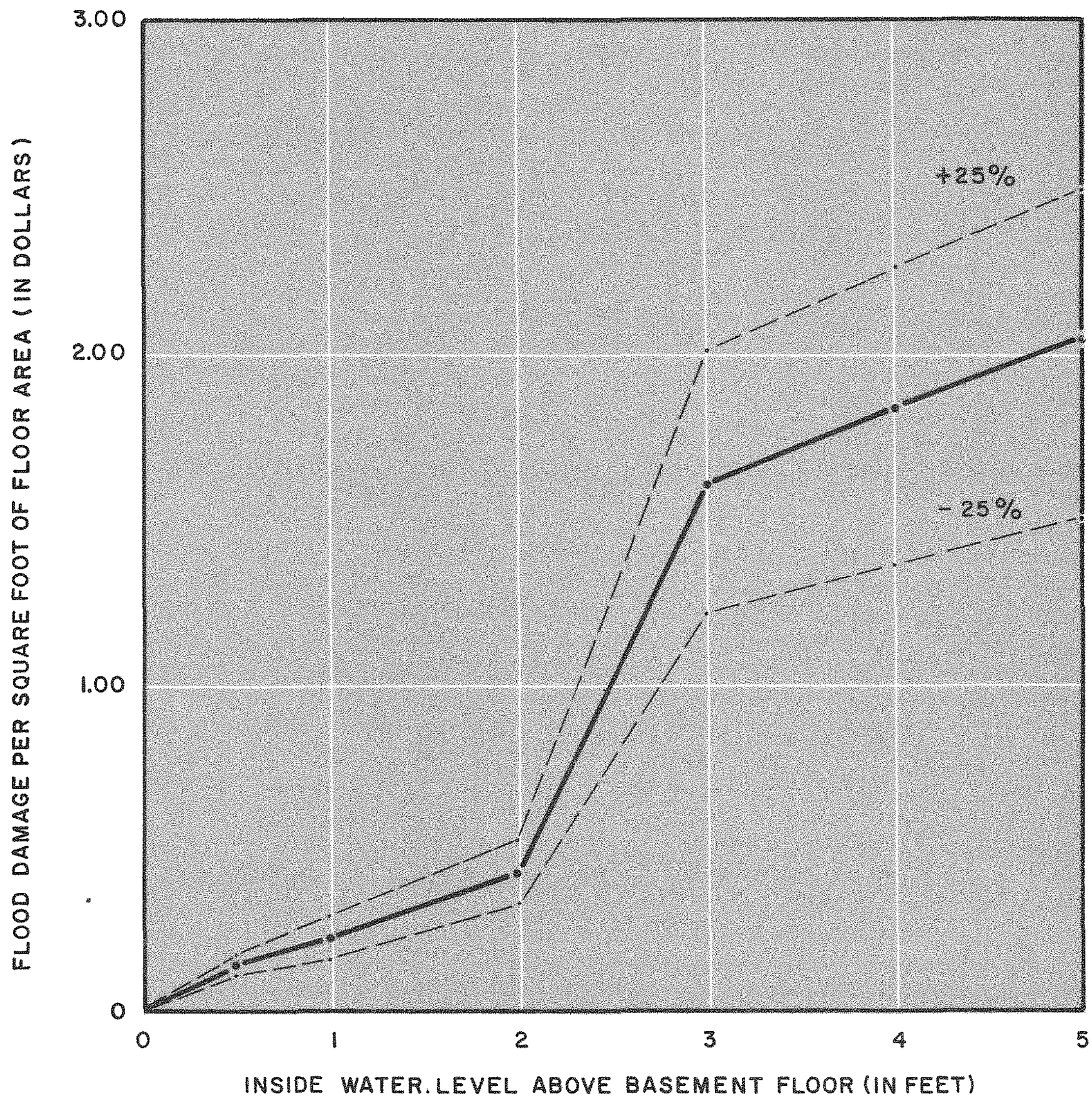
The Galt survey provided one estimate of previous direct flood damage to food stores, which appeared to substantiate the synthetically derived stage-damage curve. The manager of one store placed a figure of



NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE DAMAGE TO CONTENTS OF GROCERY STORES: FIRST FLOOR

FIGURE 6



NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE DAMAGE TO CONTENTS OF GROCERY STORES: BASEMENT

FIGURE 7

$20,000 on his direct damages during the 1954 flood, at which time total basement flooding occurred. The synthetic damage in such an event was estimated to be $26,900. Some of the divergence between the synthetic and actual damage estimates may be explained by the increases in prices since 1954, and by the general nature of the $20,000 damage figure.

Drug Stores:

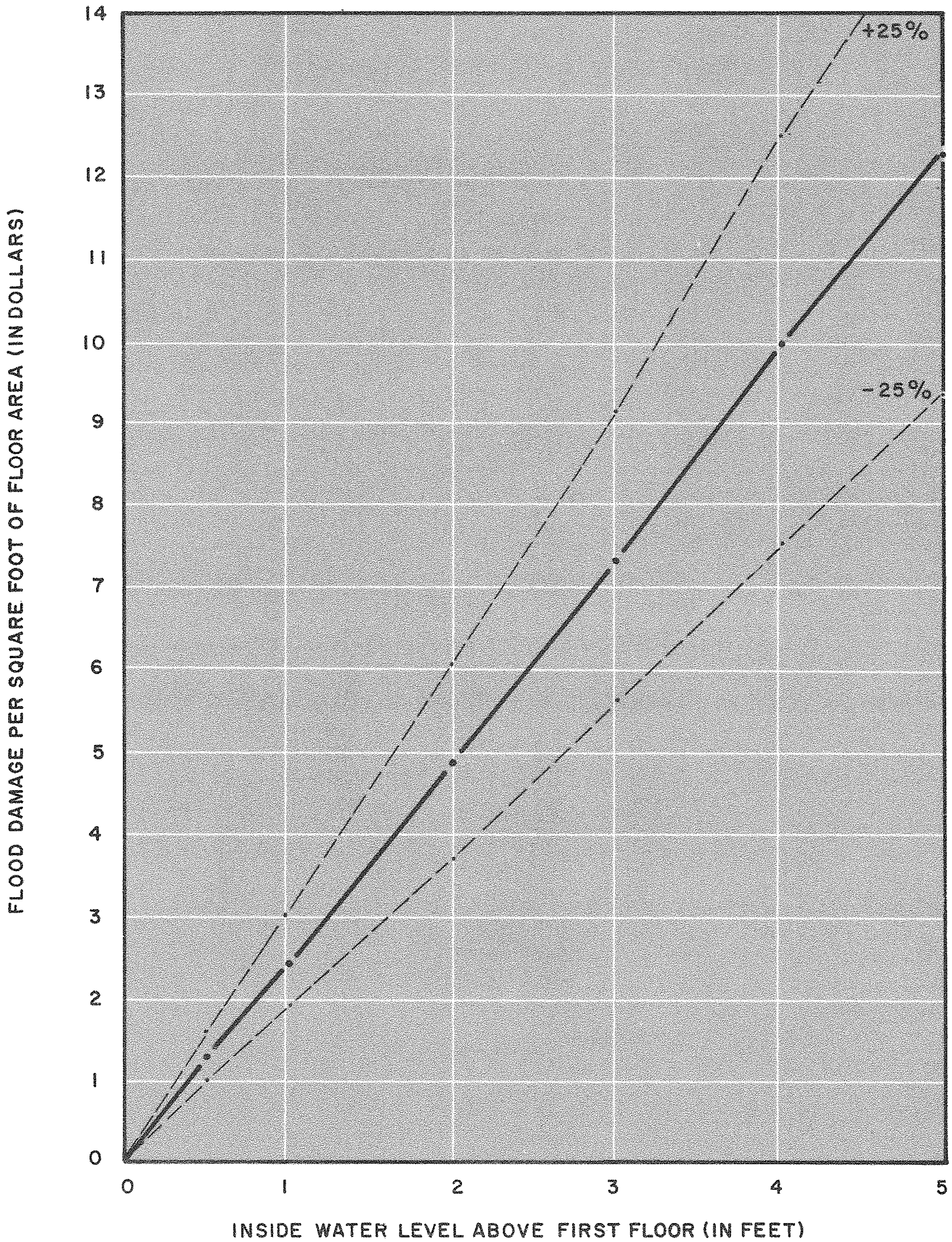
Four drug stores were examined. Conversations with the druggists confirmed White's estimate that 90 percent of the stock in such stores would have to be thrown away if subjected to flood waters.(17)

The damage potential at various flood levels in drug stores appeared to be similar to that noted in food stores. Damage was mainly a function of depth of flooding. Accordingly, a similar method of damage calculation was used.

Figures 8 and 9 present the stage-damage curves derived for the contents of the basements and first floors of drug stores. Basement damages were very low at Galt because of the limited amount of stock stored below the first floor level. While it may be hypothesized that this represents a conscious adjustment to the flood hazard presented in this city, it is most unlikely. Each of the druggists noted that modern retail practices no longer necessitate large basement storage areas. Most goods are placed directly on display in the store and reordered at various times throughout the year. The fact that many retail establishments are now constructed without basements is a further indication of this shift in the demand for storage space.

Furniture Stores:

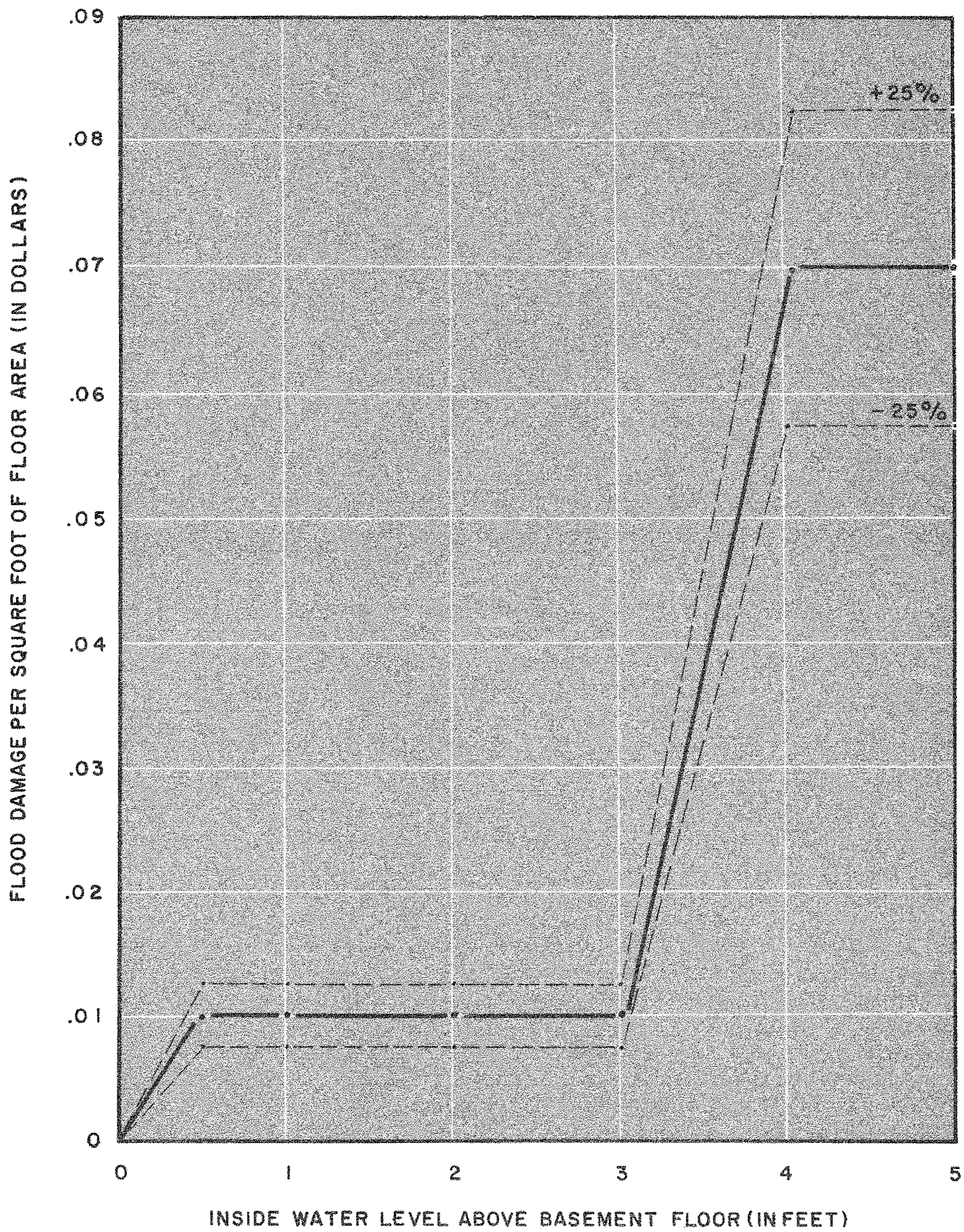
The sample of furniture stores consisted of three establishments. The results of interviews and conversations with representatives of the furniture



AVERAGE DAMAGE TO CONTENTS OF DRUG STORES: FIRST FLOOR

NOTE: ±25% DENOTES LEVEL OF ACCURACY

FIGURE 8



NOTE: ± 25% DENOTES LEVEL OF ACCURACY

AVERAGE DAMAGE TO
CONTENTS OF DRUG STORES:
BASEMENT

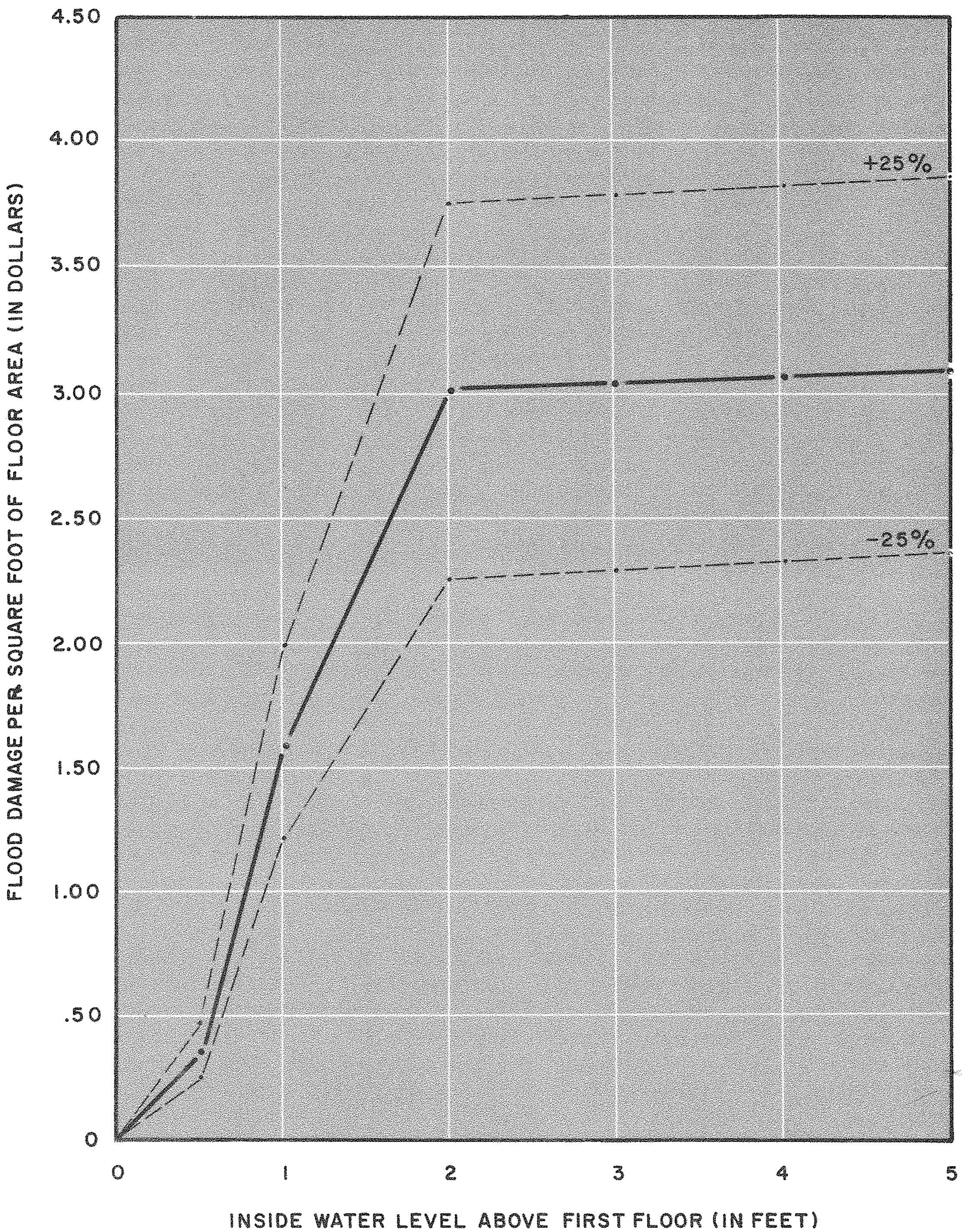
FIGURE 9

industry helped to formulate the assumptions necessary to construct stage-damage curves (Figures 10 and 11). The inventory was divided equally into totally lost and salvageable proportions. At six inches, 10 percent of the value of the inventory was assumed to be affected by flood waters; 50 percent of this was salvageable; the remainder was lost.[18] Ninety percent was assumed to be affected at 12 inches, while 100 percent was subject to flooding at 24 inches of water.

Repair costs were set at an across-the-board level of 20 percent of inventory value.[19] The problems associated with the value of salvageable inventory, and the effects of "flood sales" on total flood losses, were examined at some length.[20] In constructing the final stage-damage curves, it was assumed that the lost profits, due to reductions in selling prices of flood damaged goods, would be more than offset by the increased volume of sales generated.

In Galt, the minor extent of damage to furniture stores during previous floods made comparisons between actual and synthetic figures extremely difficult. Owners tended to forget the water damage to pieces of furniture. But few forgot the increased sales that took place once they were able to place an ad pointing out the existence of "flood damaged" furniture in the local papers.

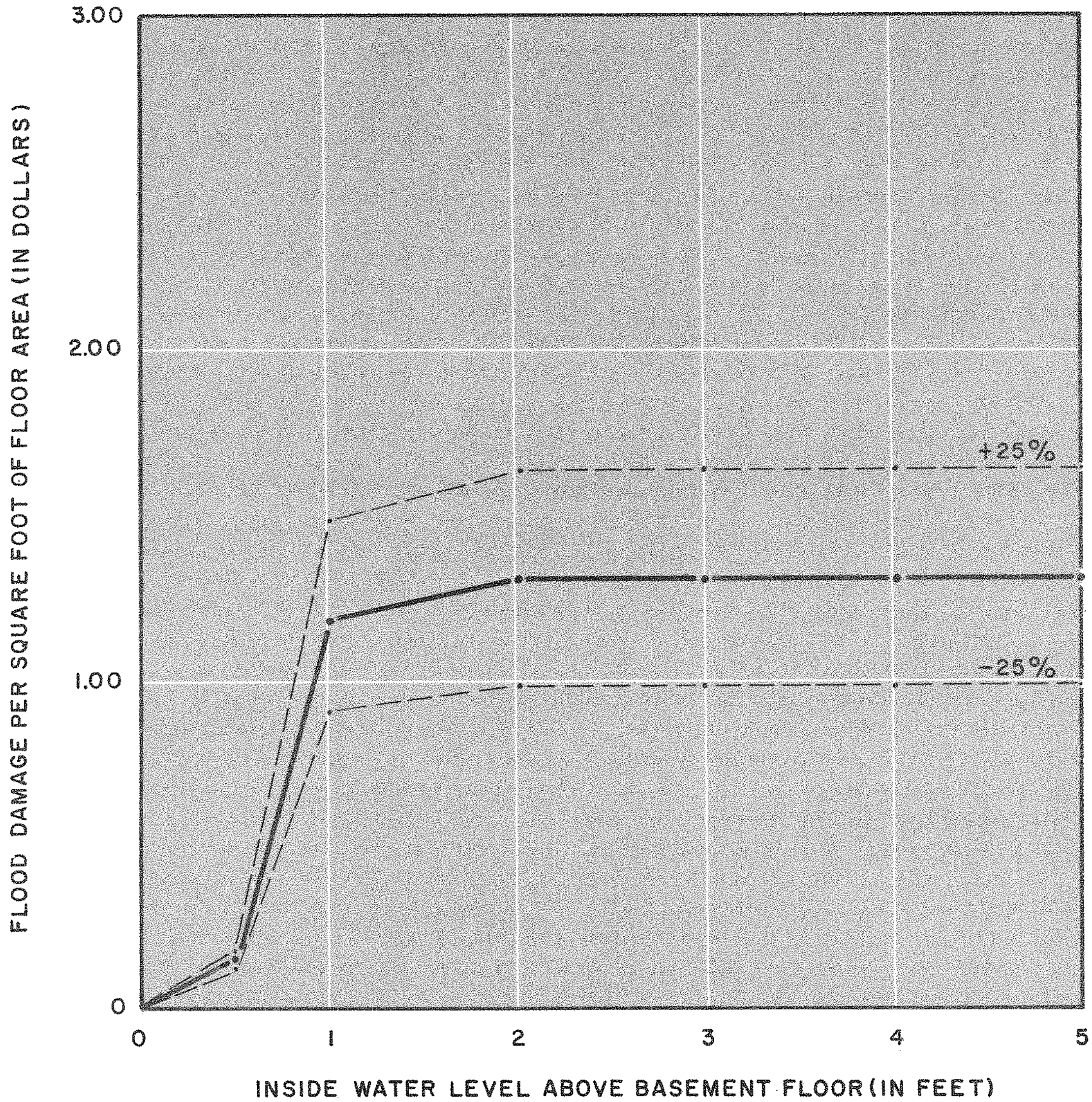
The fact that the majority of the inventory in the basement and on the first floor rests directly on the floor led to very similar stage-damage curves for the contents of both areas (Figures 10 and 11).



NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE DAMAGE TO
CONTENTS OF FURNITURE STORES:
FIRST FLOOR

FIGURE 10



NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE DAMAGE TO CONTENTS OF FURNITURE STORES: BASEMENT

FIGURE 11

Shoe Stores:

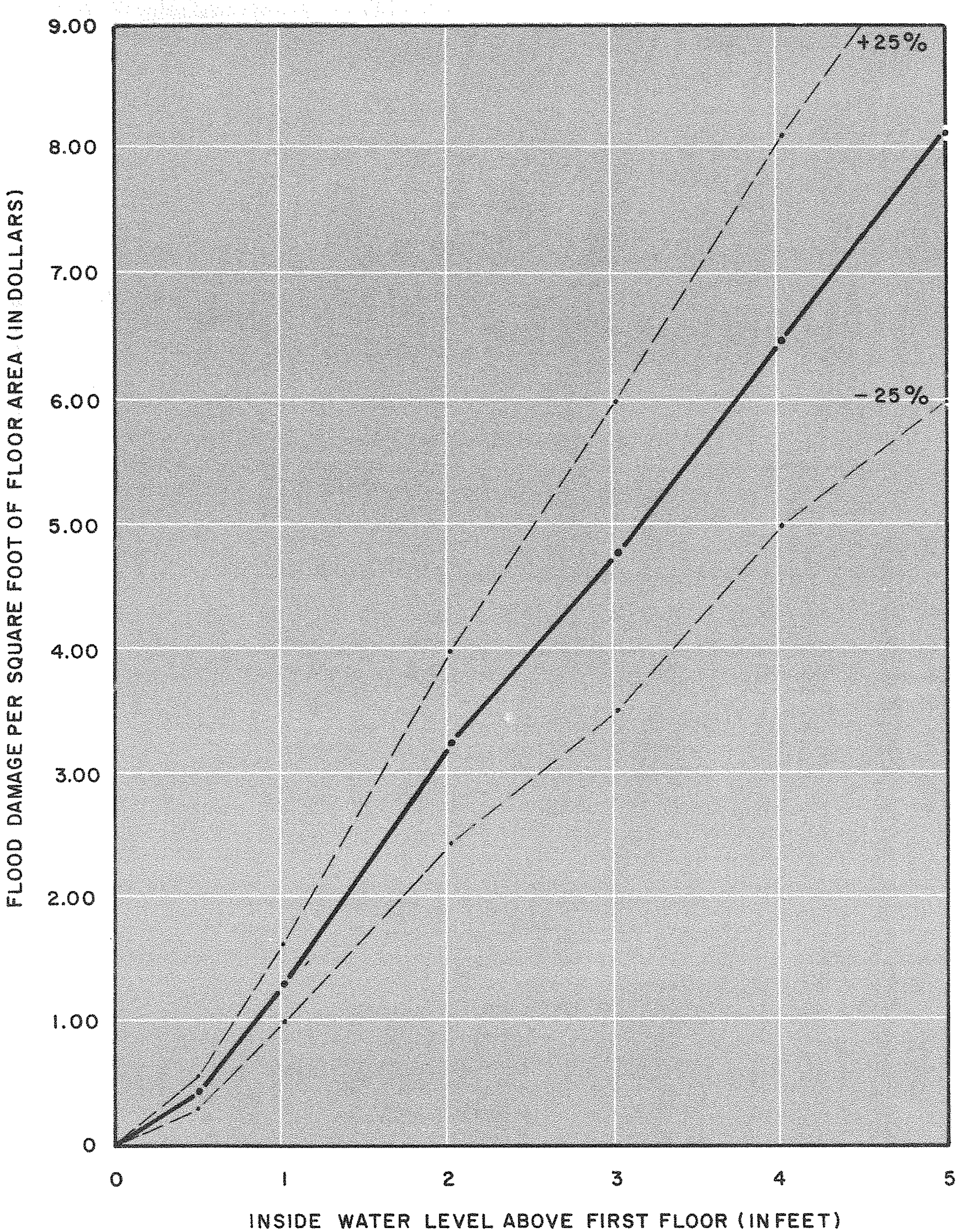
Five shoe stores in the study area were examined. Basement inventory was given a salvage value of one-third, while the first floor inventory received a salvage value of one-tenth. Experience at Galt showed that basement inventories consisted mainly of rubber footwear, which is less susceptible to flood damages. The damage figure of 10 percent was chosen on the basis of damage to a shoe store during a recent flood in Dresden, Ontario, and from the results of interviews at Galt.[21] Calculation of the damage to contents involved computation of the amount of shelf area at each level. It was assumed that the value of inventory was constant at each of the different levels. This value per square foot of shelf area then was converted to a value per square foot of first floor area to facilitate application of the curves in field applications. Figures 12 and 13 show the resulting stage damage curves.

It was impossible to compare actual with synthetic curves in the study area. All of the shoe stores that had experienced flooding were able to remove stock to higher levels and, as a result, suffered minimal damage.

Men's Wear Stores:

A sample of five stores was used to construct the damage curve for this type of retail establishment (Figures 14 and 15). The inventory was equally divided into total loss and salvageable proportions, with a 5 percent of inventory cost being assessed for restoration -- mainly for items requiring dry cleaning. As in the other types of retail establishments in which goods were salvageable, the assumption was made that the increased sales due to price reductions would result in no loss of net returns.

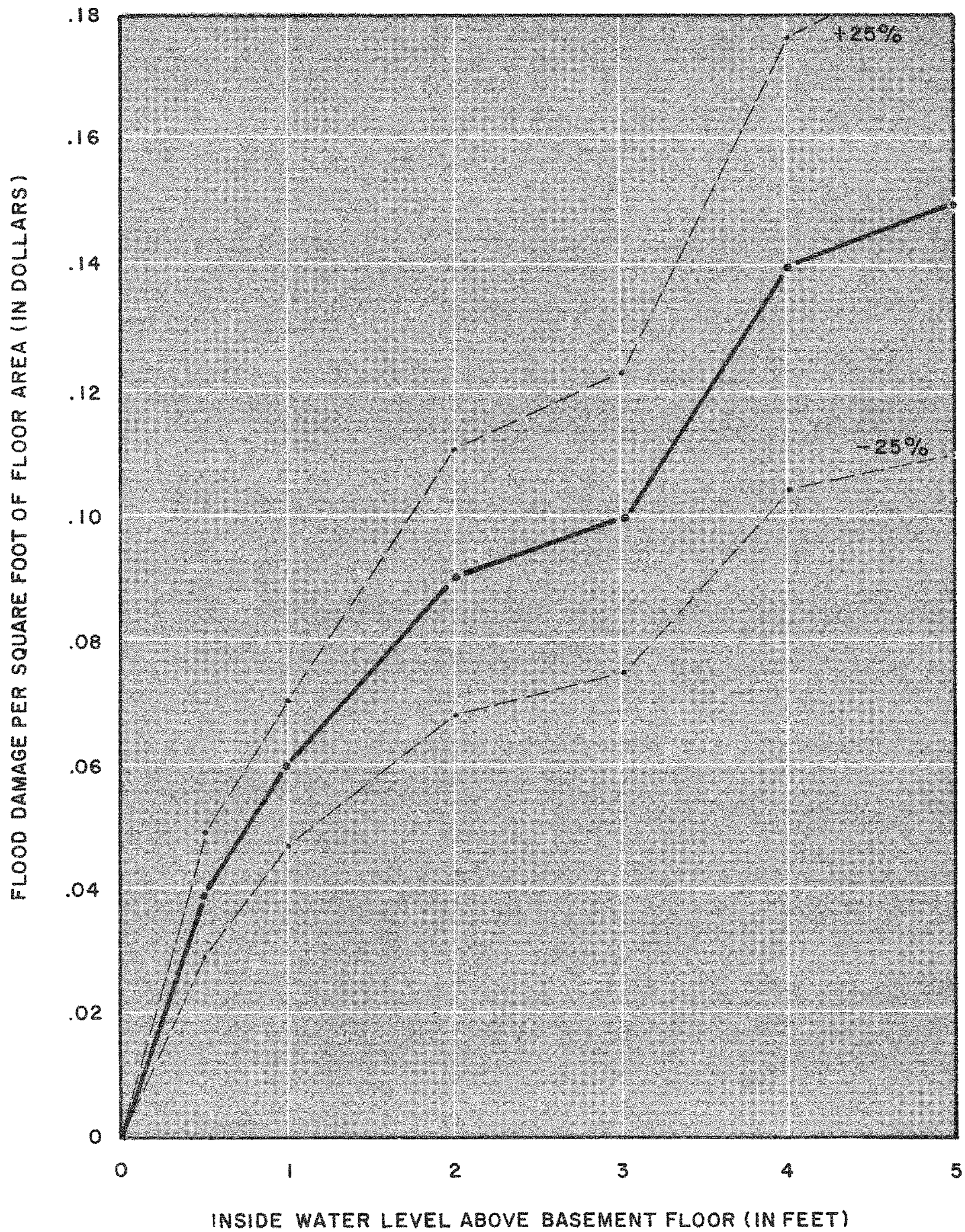
For this functional classification, the total shelf and display area was calculated in square feet and then converted to a value based on first floor area. In the case of clothing racks, the area lying



NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE DAMAGE TO CONTENTS OF SHOE STORES: FIRST FLOOR

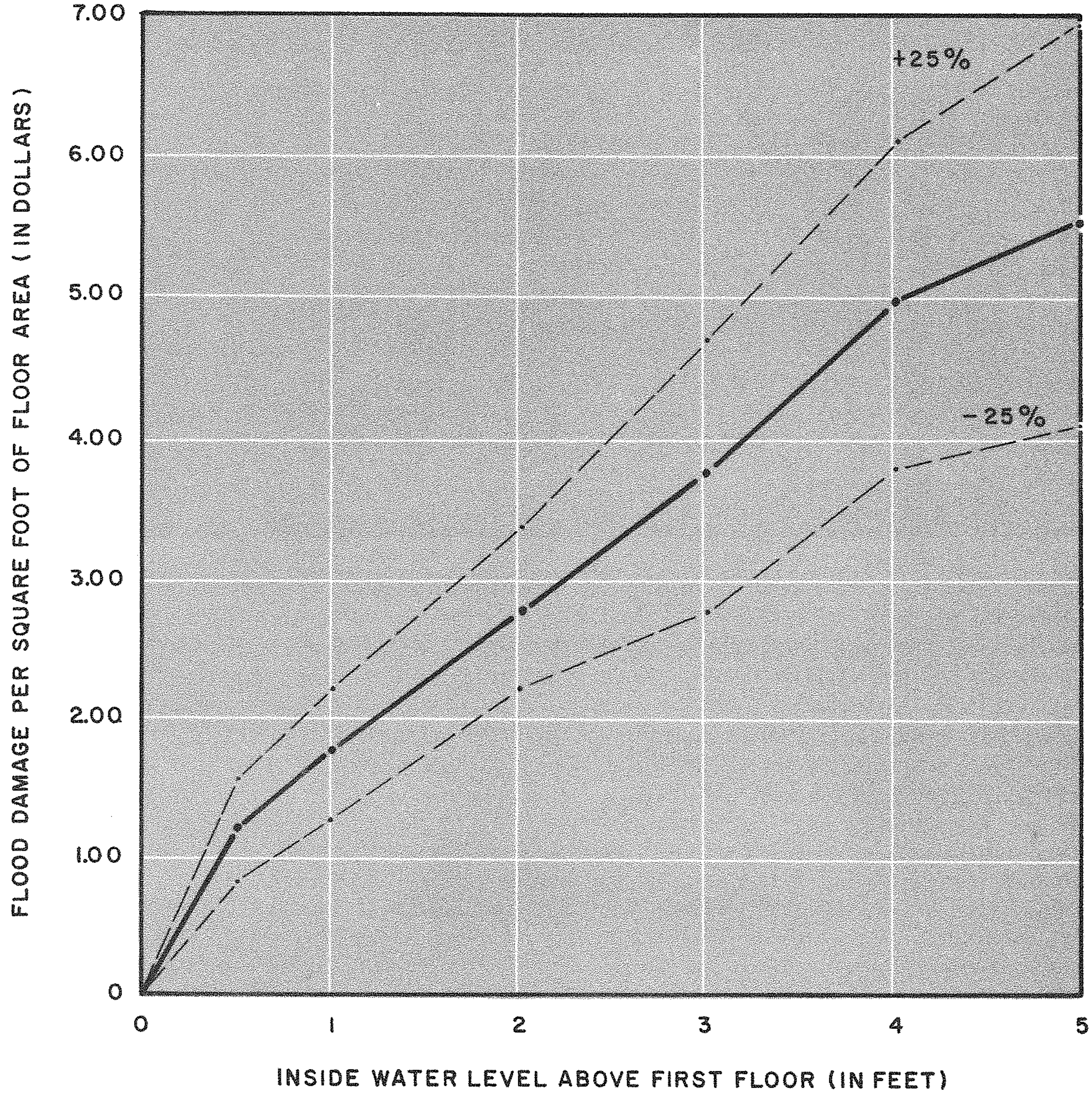
FIGURE 12



NOTE: ± 25% DENOTES LEVEL OF ACCURACY

AVERAGE DAMAGE TO
CONTENTS OF SHOE STORES:
BASEMENT

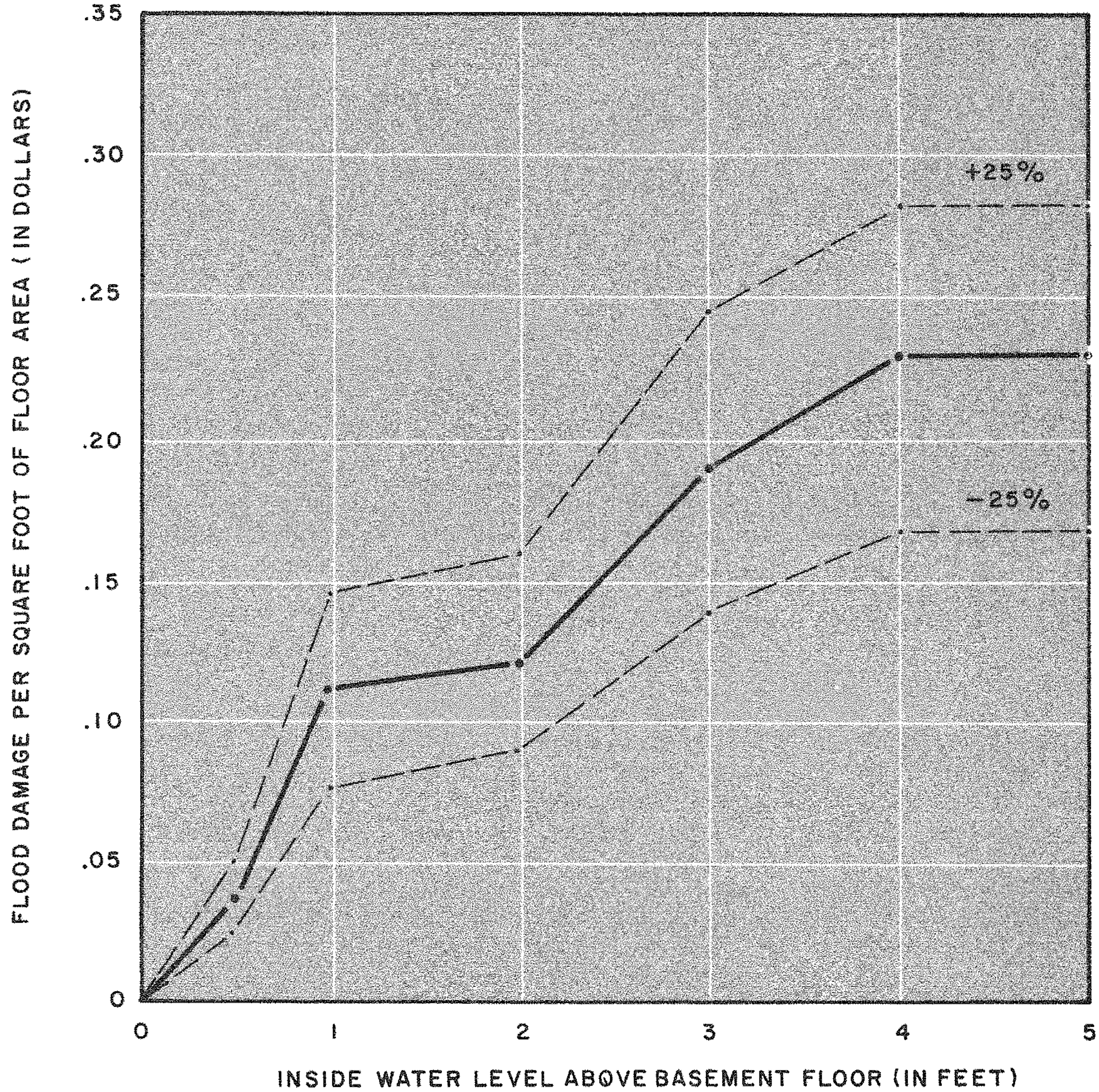
FIGURE 13



NOTE: ± 25% DENOTES LEVEL OF ACCURACY

AVERAGE DAMAGE TO
CONTENTS OF MEN'S WEAR STORES
FIRST FLOOR

FIGURE 14



NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE DAMAGE TO
CONTENTS OF MEN'S WEAR STORES:
BASEMENT

FIGURE 15

beneath was calculated as the shelf area. Total damage was assessed to a rack of clothing as soon as the water level reached the base of the clothing.

Ladies' Wear Stores:

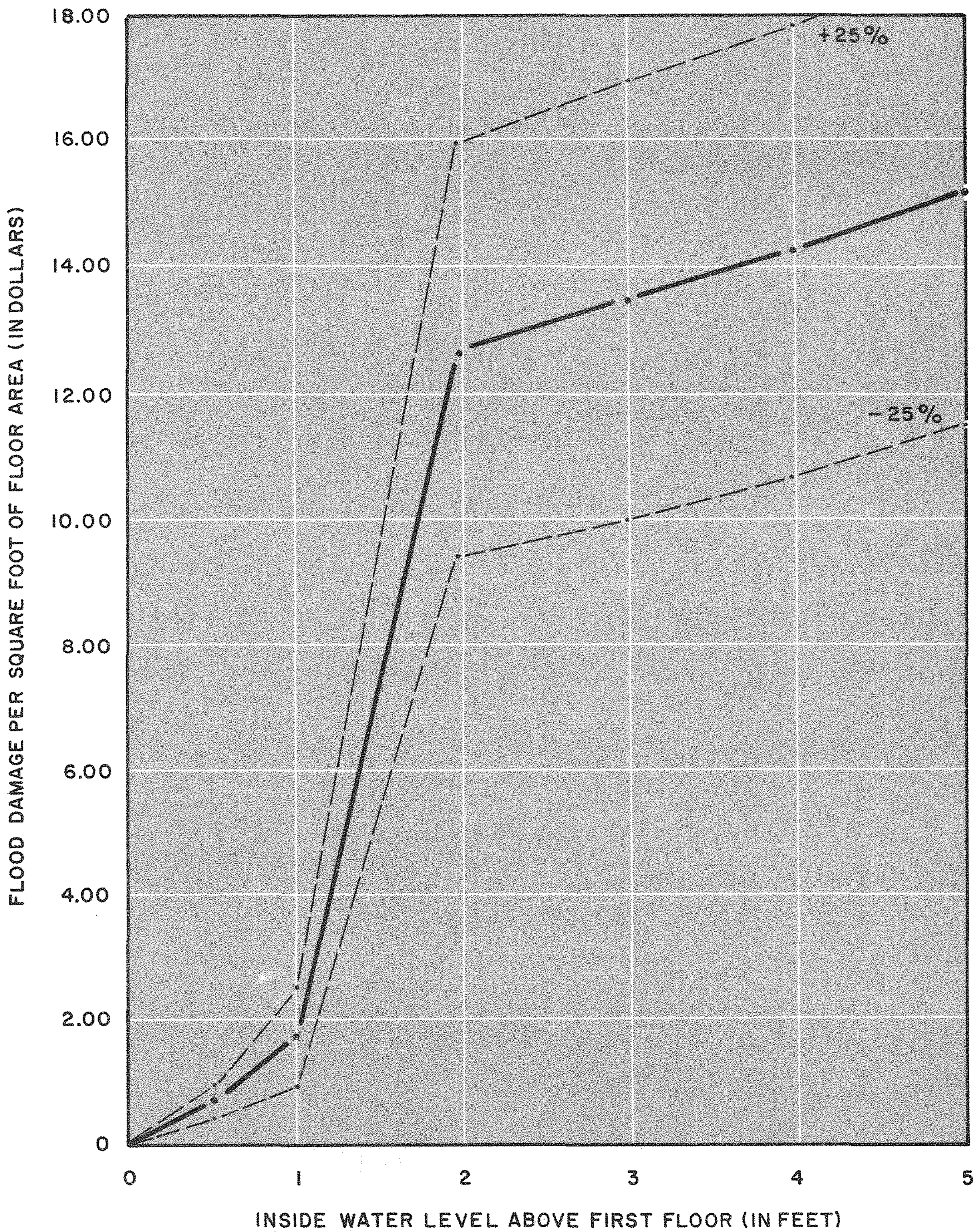
The direct damage curves (Figures 16 and 17) for ladies' wear stores are based on a sample of four stores. The same decisions regarding amounts and types of damages were made as for men's wear stores and calculations were carried out in the same manner.

Examination of the curves shows a great increase in damages between the one- and two-foot levels. This can be explained in the sample by the extensive use of racks in this business, resulting in large damages when the bottom of the clothing is reached by flood waters. A greater variety of shelf spacing would result in a straight line relationship similar to the curves for the men's wear stores.

(3) - Residential and Commercial Properties: Structural Damage

Structural damage curves for direct damages to commercial and residential properties were supplied by a structural engineer who made a field examination of each type of structure in Galt. The classification used in deriving residential contents damage curves was also used here. For commercial structures, the detailed functional classification was dropped, and two overall curves for (a) brick, concrete block, and stone structures, and (b) wooden structures, were constructed.

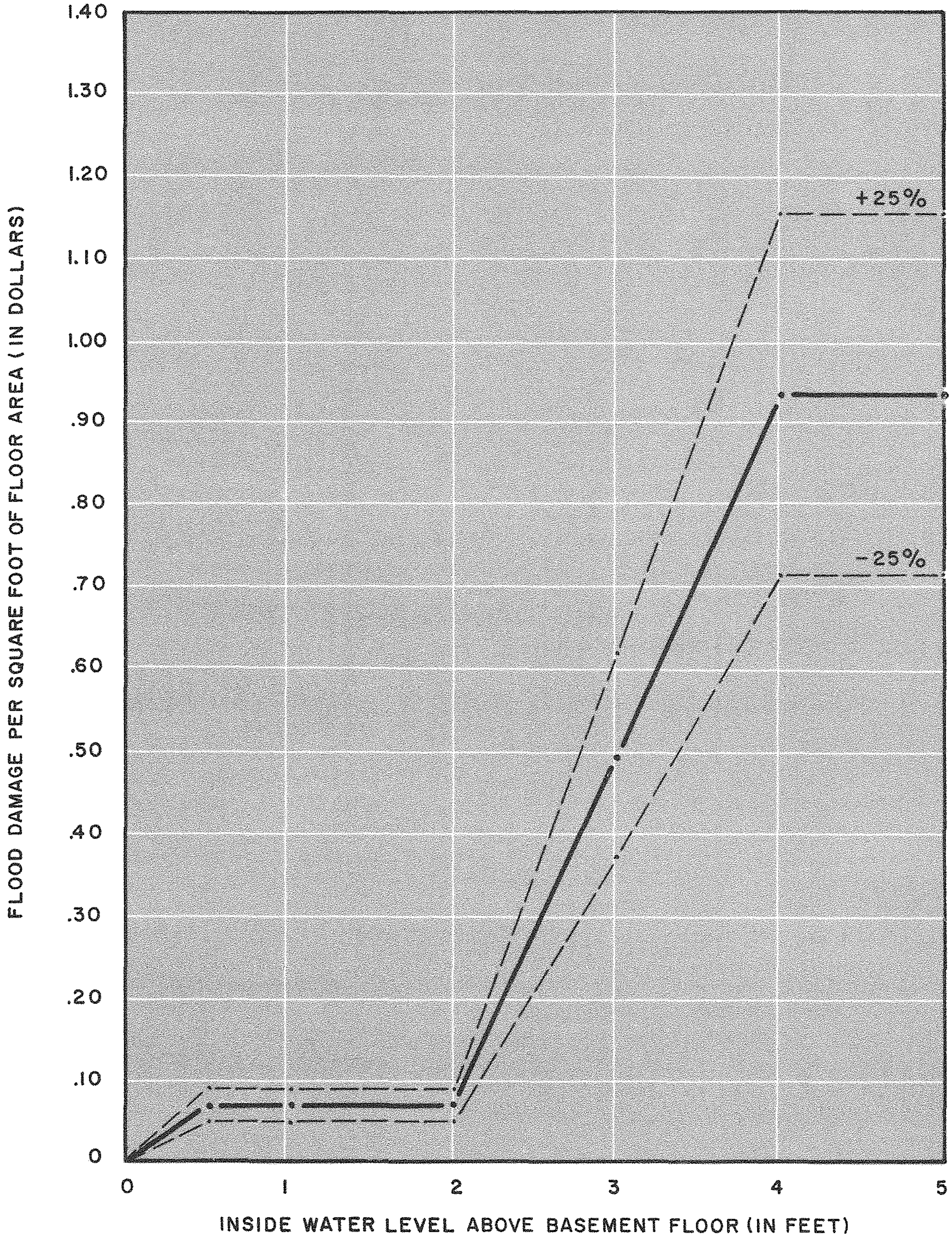
All curves reflect costs of repair or restoration. An arbitrary figure of 5 percent was used to depreciate replacement costs to restoration values. This would avoid the over-estimation of damages often brought about by the fact that one cannot give a building a five-year-old coat of paint.



NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE DAMAGE TO
CONTENTS OF LADIES WEAR STORE:
FIRST FLOOR

FIGURE 16



NOTE: ± 25% DENOTES LEVEL OF ACCURACY

AVERAGE DAMAGE TO
CONTENTS OF LADIES WEAR STORES:
BASEMENT

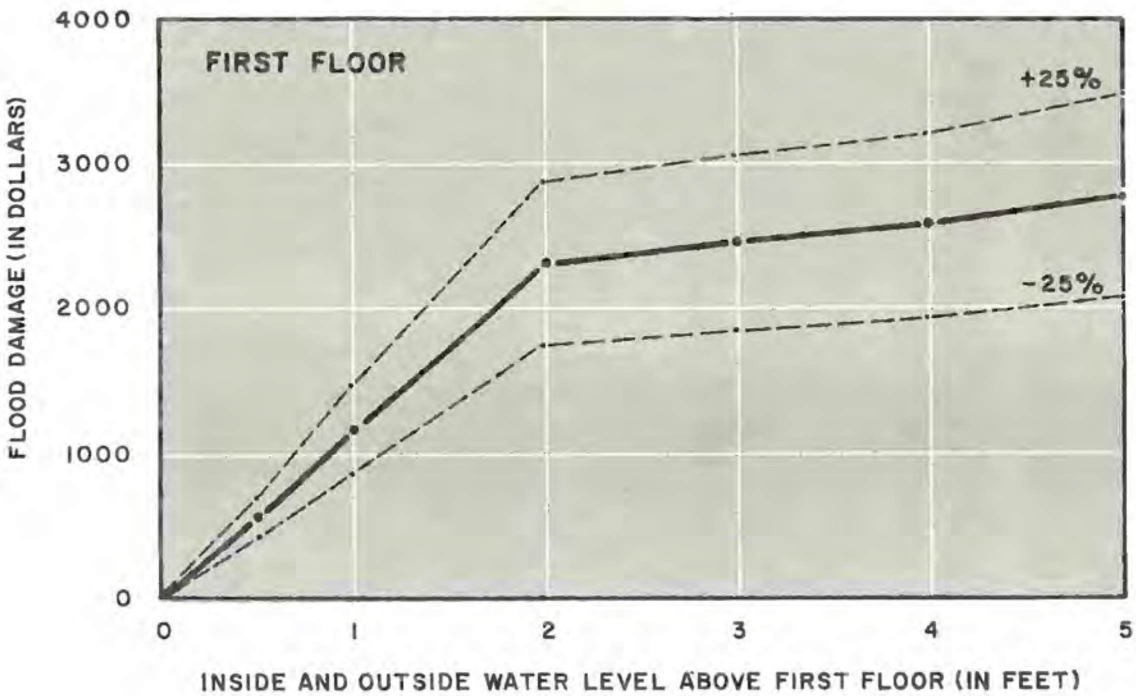
FIGURE 17

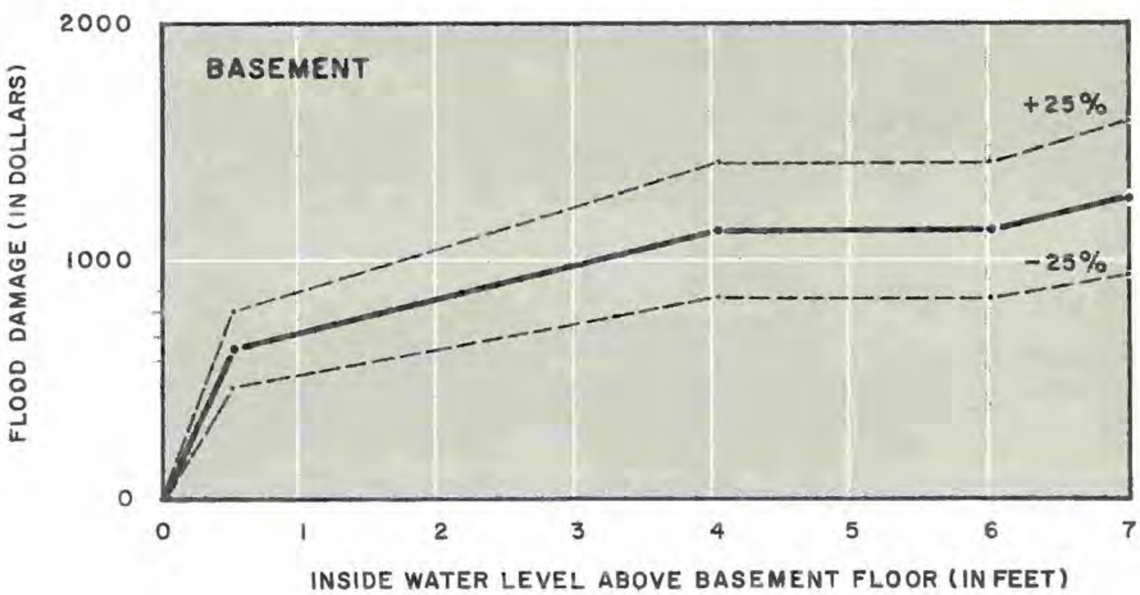
Most structures have heating plants and hot water heaters permanently fixed in the basement and, therefore, repair costs for these are included in the curves. Damage resulting from basement flooding varied with the amount of finished area in each basement. Water levels reaching the underside of ground floor level joists were found to cause a great deal of damage to floors. The level at which this damage would occur varies with the structural type. It was generally found that AT, BB and AW homes had seven-foot basements whereas the other types (CB, BW, and CW) had six-foot basements. Water on the first floor greatly increased costs because of the large amounts of painting and plastering required for repair.

The costs of damage repairs are based upon 1968 prices in the Galt area.[22] Sources of information for these were local contractors, known labour rates, and the Means Handbook of Building Cost Data.[23] Structural damages to residential properties at various levels of flooding are depicted in Figures 18 to 23. To clarify the types of structural damages that were considered in constructing these curves, a typical case will be examined. A small amount of basement flooding will likely result in some floor cracks, which would be repaired. The walls in the basement sustain little damage at any level of flooding. With increased flooding, insulating damages to both furnaces and water heaters occur. In many residences, electrical outlets and entrance fuse boxes suffer basement water damage. It should be noted that basement water levels depend not only on outside flood levels but also on the permeability of basement walls and the possibility of sewer backup.

Considerable damage occurs on the first floor. Doors and trim warp, replastering and repainting are often needed, and some damage to electrical outlets and wiring occurs. Although damage to floors and baseboards occurs with few inches of water on the floor, this factor is not reflected on the damage curves until the one-foot level. The cost of restoring these damages was estimated on the basis of present-day Galt material and labour costs.

During field investigation at Galt, it was found that few differences existed between structural damages to residential and commercial buildings and only slight differences were evident for damages to commercial buildings of wood exterior and those of brick, stone, or concrete block exteriors.

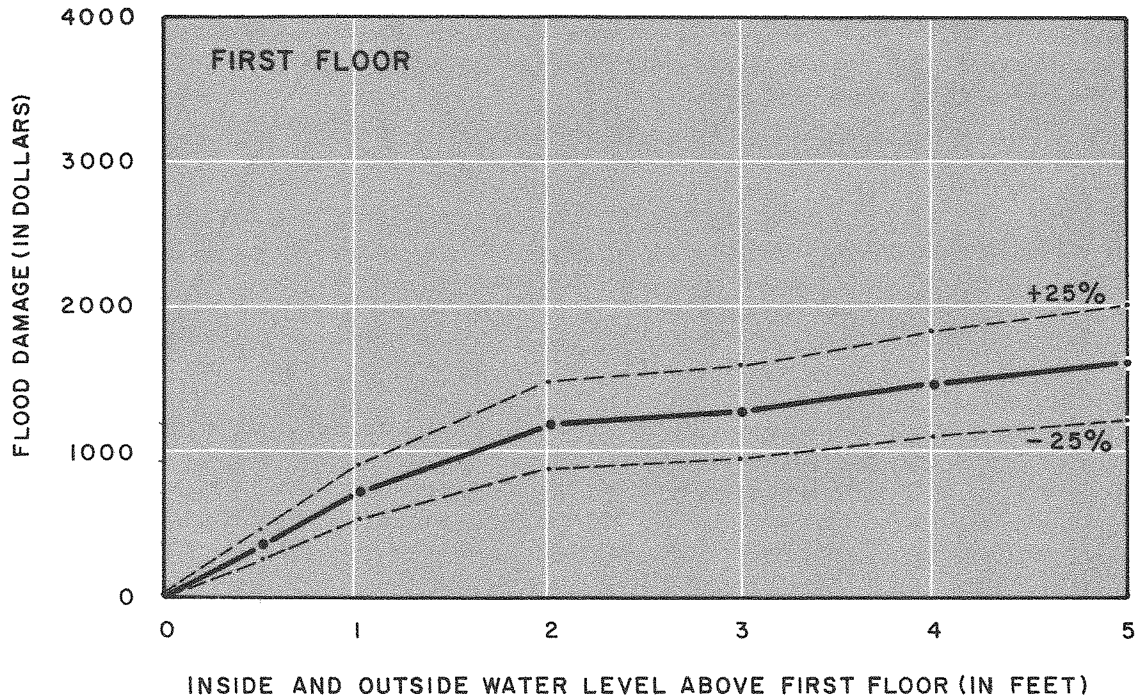


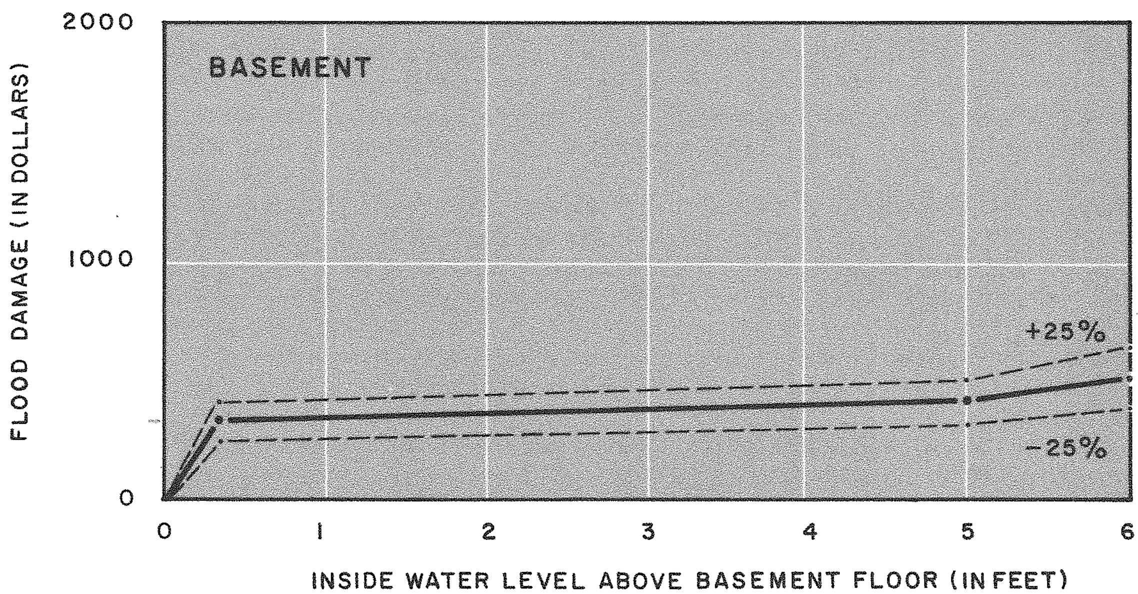


NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE STRUCTURAL DAMAGES:
A W HOMES

FIGURE 18

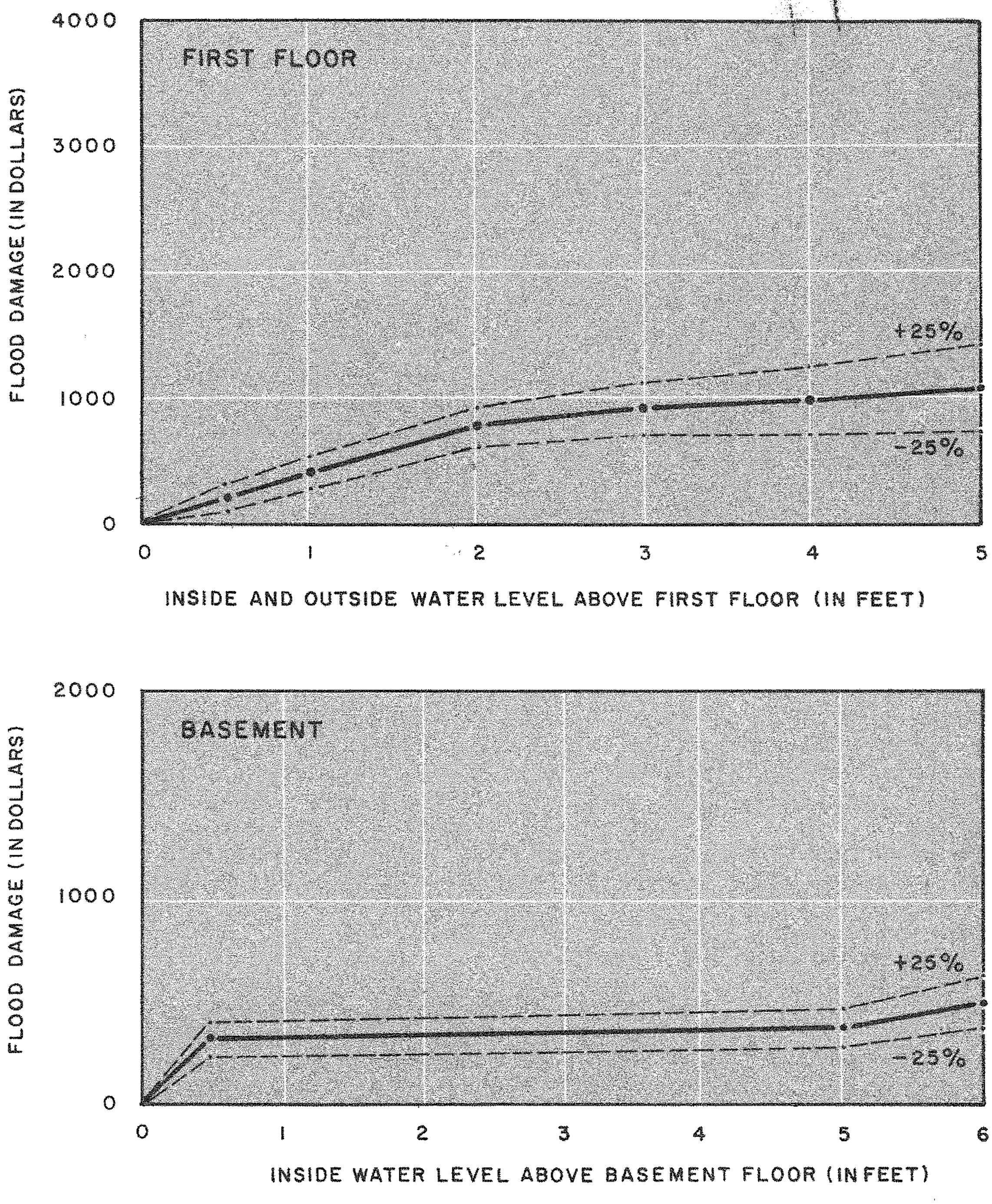




NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE STRUCTURAL DAMAGES:
B W HOMES

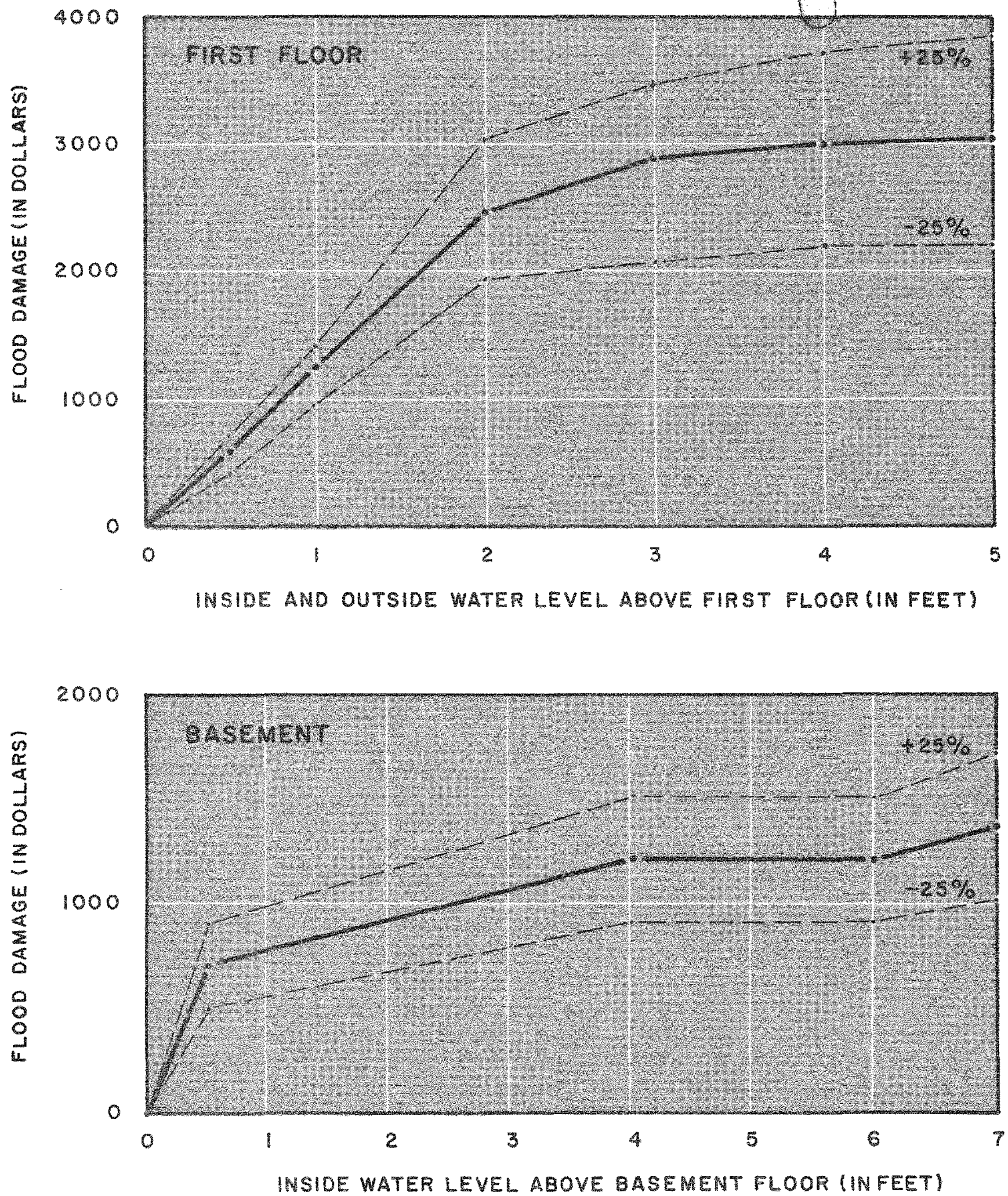
FIGURE 19



NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE STRUCTURAL DAMAGES:
C W HOMES

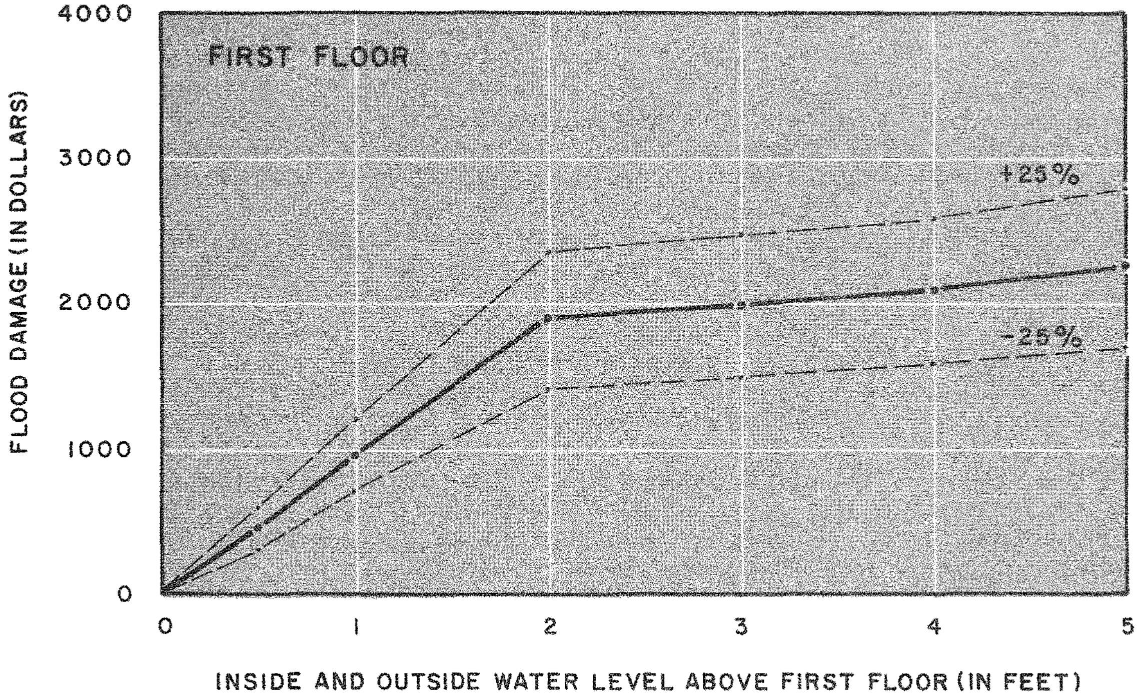
FIGURE 20

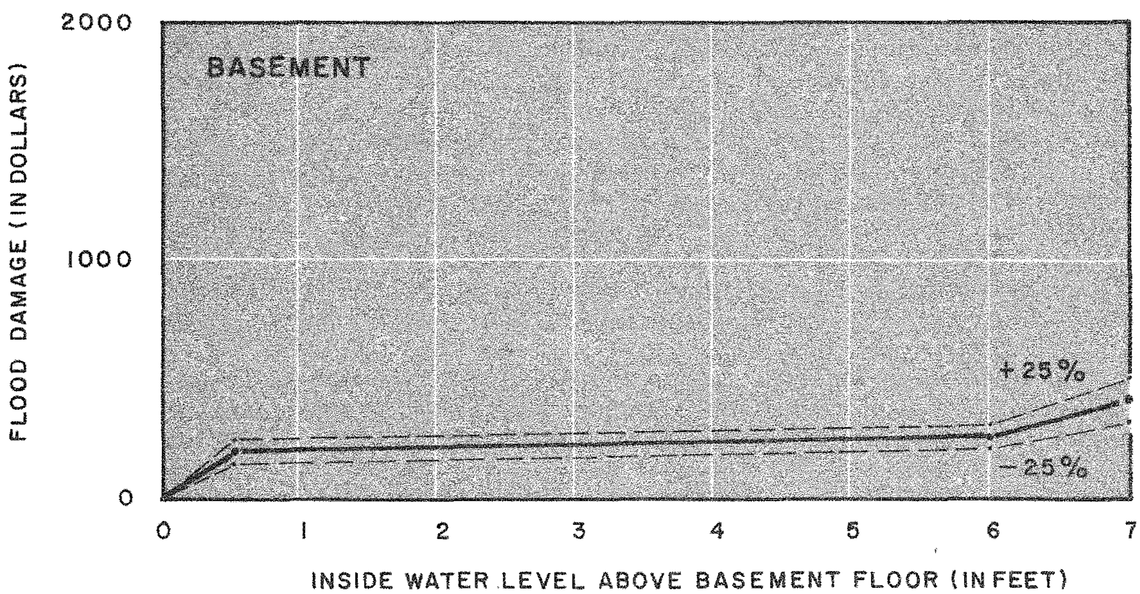


NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE STRUCTURAL DAMAGES:
A B HOMES

FIGURE 21

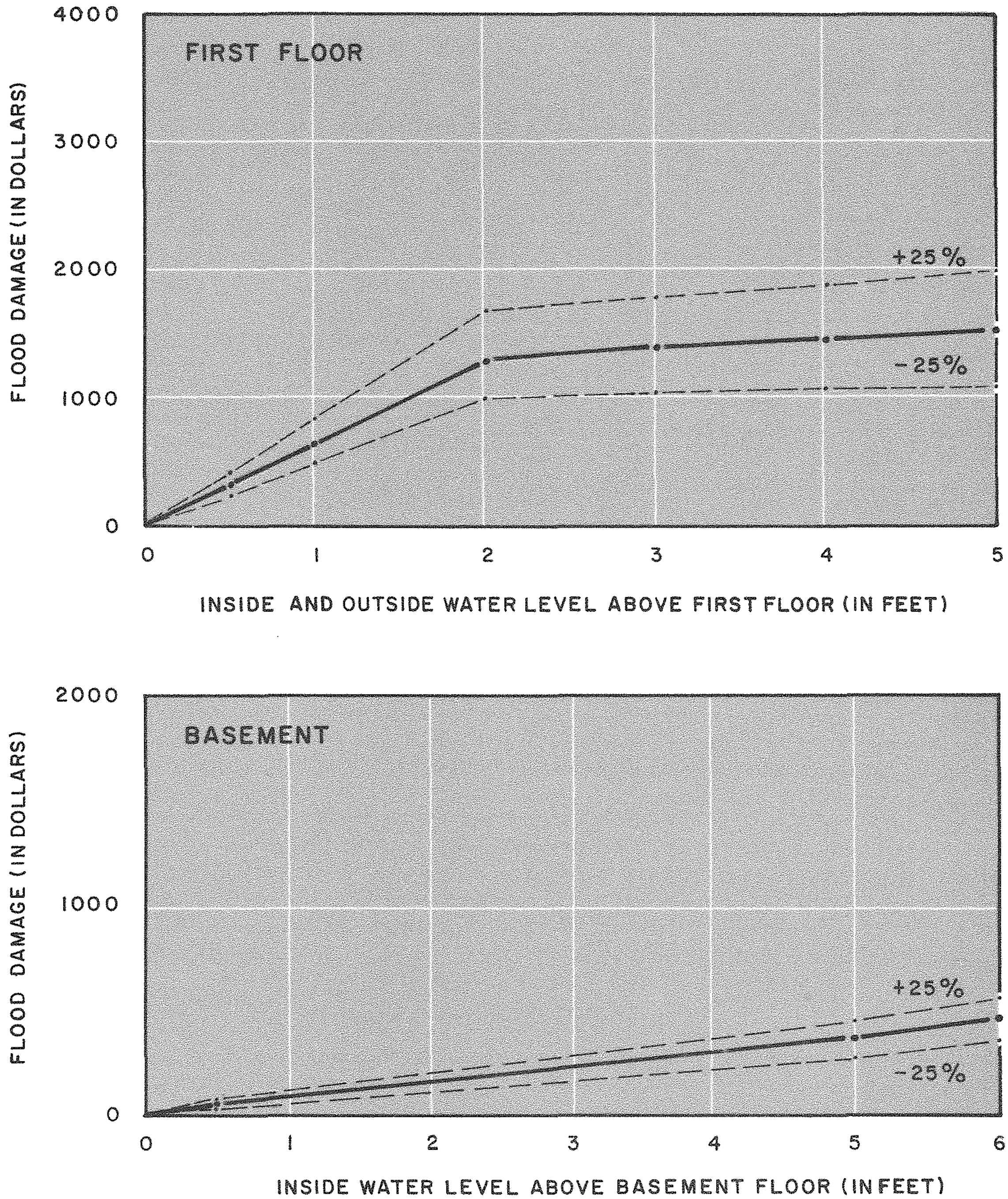




NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE STRUCTURAL DAMAGES:
B B HOMES

FIGURE 22



NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE STRUCTURAL DAMAGES:
CB HOMES

FIGURE 23

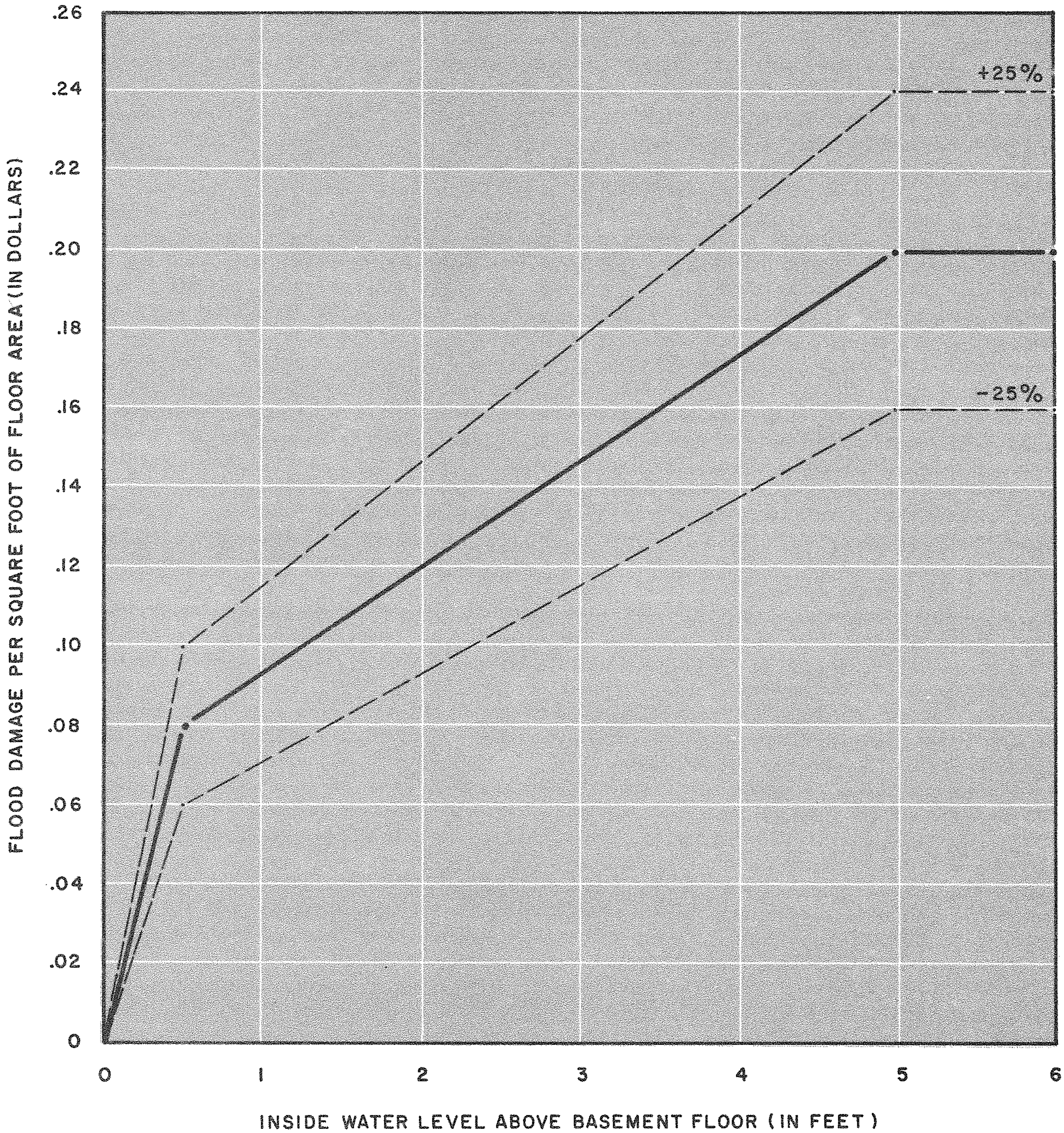
The curves for commercial damages were formulated on a square footage basis, to facilitate their application to actual field situations (see Figures 24 to 26). It was felt that this would yield a more meaningful curve, in view of the great differences in sizes of these types of buildings. As residential structures were of more uniform sizes within each classification, simple total damage curves were presented.

A list of the cost factors used to derive these curves is provided in Appendix C.

(4) - Industrial Damages

Interviews with managers and plant personnel in the majority of industries on the Galt flood plain confirmed the initial feeling that generalized stage-damage curves for industries are impossible, given the mix of structures and contents that is possible.[24] There is a wide variety of industry types, and no generalizations can be made of content and structural characteristics within these types, since this is determined by the unique production requirements of each plant. Therefore, a functional or structural classification, such as those used for residential and commercial establishments, would not be meaningful for industrial stage-damage analysis.

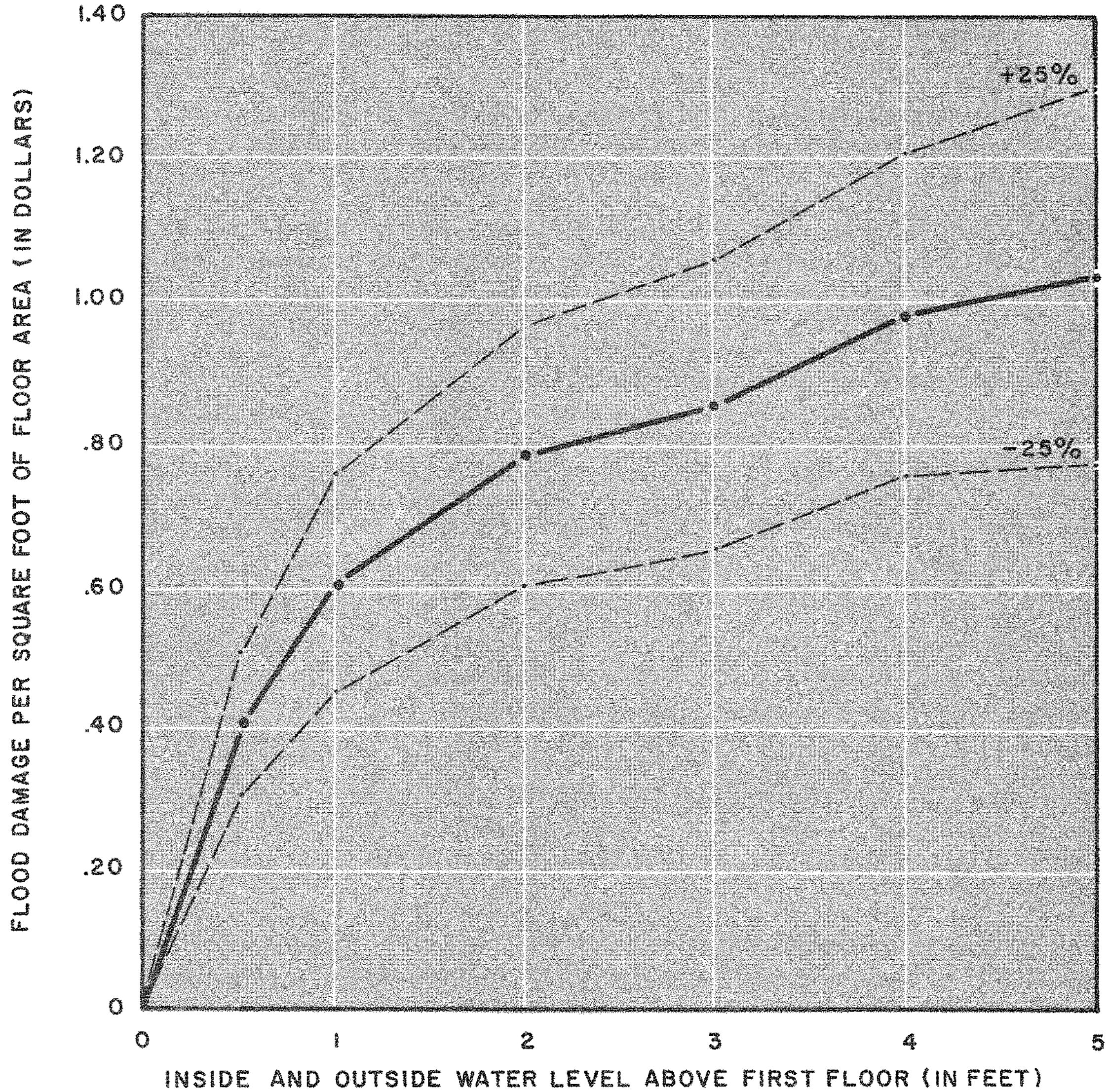
Aggregate industrial complexes on flood plains also do not have any characteristics that can be said to be typical, so an aggregate stage-damage function derived for industrial losses at Galt, or even in the entire river basin, would not be valid elsewhere. Potential industrial damages are unique for each location, and no form of generalization can be made. Therefore, it is recommended that stage-damage functions for industrial losses should be derived and applied on an individual basis.



NOTE: ± 25% DENOTES LEVEL OF ACCURACY

AVERAGE COMMERCIAL STRUCTURAL DAMAGES: BASEMENT

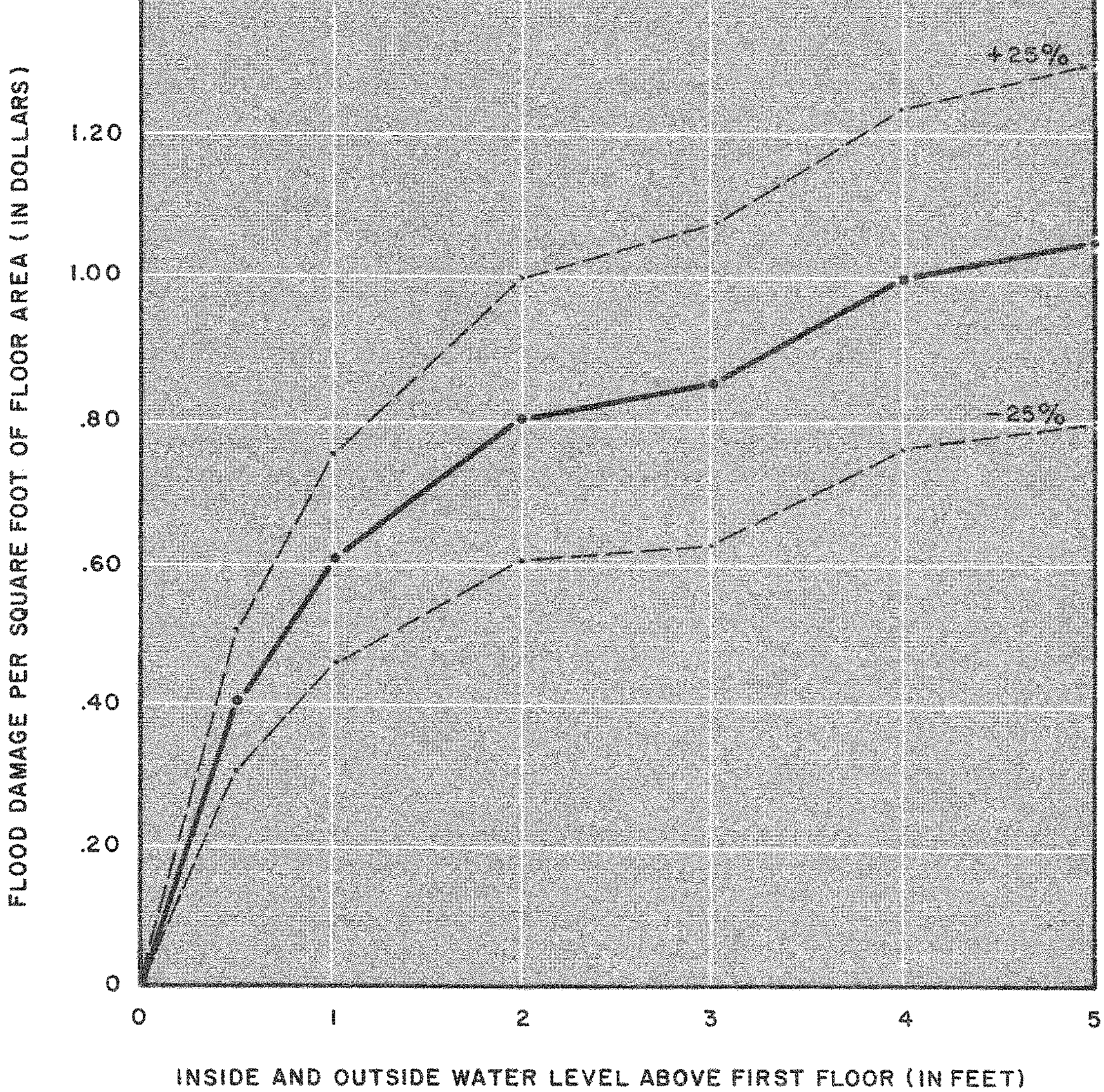
FIGURE 24



NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE COMMERCIAL STRUCTURAL DAMAGES: FIRST FLOOR, BRICK, CONCRETE, OR STONE

FIGURE 25



NOTE: ±25% DENOTES LEVEL OF ACCURACY

AVERAGE COMMERCIAL STRUCTURAL DAMAGES: FIRST FLOOR, WOOD

FIGURE 26

A general framework for estimating industrial flood losses on a flood plain has been set up by Robert Kates in a study done in the Lehigh River Valley of Pennsylvania.[25] Stage-damage functions were established for all industries on the flood plain, and the aggregate was related to hydrologic and human adjustment factors. A similar approach would be advisable for estimating industrial damages in Southern Ontario river basins.

When developing stage-damage functions of this nature, experience in Galt has shown that there are various key levels to be kept in mind. Electric motors are generally located within 12 inches above the floor. However, critical levels for machinery such as lathes and precision instruments are between 3 and 4 feet. This is significant, since damage to the latter can be more costly than in the case of electrical equipment which only needs drying to restore it to its preflood condition. Economic values can be obtained for structure and contents at various levels, and aggregated to obtain a final stage-damage function for sections of a river basin.

Because of the long history of flooding of industries at Galt, certain minor adjustments have been made to cope with the flood hazard. Flood proofing measures (flood walls, hoists for machinery, and removable electric motors, etc.) were common in industries which had experienced flooding. These adjustments must also be considered as a major damage factor in estimating losses to industrial establishments.

3.3.6 - Comparison With Existing Damage Figures

Considerable research was carried out at Galt in an effort to determine actual damages from previous major floods. It was hoped that these figures could then be compared to the synthetic damage curves derived in this study. However, the resultant data was incomplete and unreliable.

Interviewers probed for damages to the homes in past floods (see Appendix B) but, due to the time that has elapsed, many changes in ownership have occurred. Those property owners who did occupy the same establishment often could not place dollar values on the damages, or had neglected to repair the damage. Thus, the few actual damage values obtained were not objective appraisals.

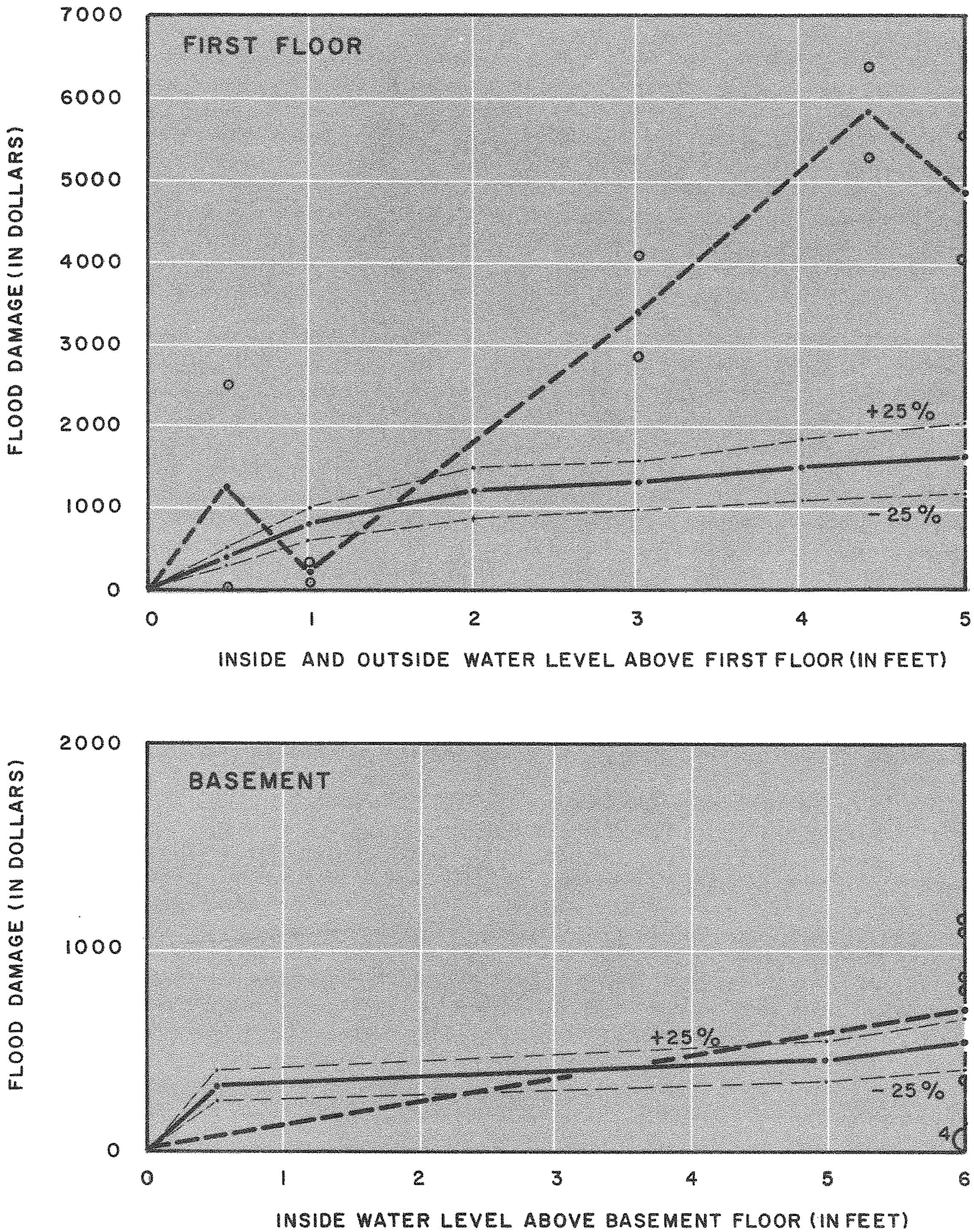
A search of newspaper accounts of the past flooding produced some aggregate damage figures but, because of the general and often sensational nature of these accounts, they were considered unreliable for the purpose of comparison with depth-damage curves. Insurance companies could not produce estimates of previous damages, since most of the vulnerable properties in Galt were not insurable.

However, appraised structural damage reports, completed by government appointed appraisers following Hurricane Hazel, were available for a large number of establishments throughout Southern Ontario.[26] Many difficulties were encountered in comparing these reports to the synthetic damage figures derived from this study. "Hazel" damages were calculated for each parcel of property. These figures included damages to outbuildings (in addition to garages) and roofs. However, these were not included within the average structural damage curves derived from this study. Other problems encountered in the use of the "Hazel" reports included changing 1954 dollars to 1968 dollars and classifying residences on the basis of the structural types used in this study.

With these problems in mind, an attempt was made to compare structural damage reports of "The Hurricane Homes and Building Assistance Board" to the synthetic structural damage curves derived from this study. A five percent random sample was made, following which the reports were classified into structural types. By using a residential building material price index of 3.1,[27] damages were converted to 1968 dollar values. The figures were also adjusted to exclude the damages to outbuildings, roof, etc. However, separation of wind damage from flood damage was not possible.

The nature of the flood caused by Hurricane Hazel was considerably different than the conservative hypothetical flood used in this study. It should be remembered that the hypothetical flood considered in this study was assumed to be of low velocity and short duration with relatively small amounts of sediment, whereas "Hazel" was distinguished by abnormally high rainfall, winds and water velocity. It is believed that the impact of this rapidly flowing water had a substantial affect on the amount of damage.

Figures 27 and 28 illustrate graphically the actual damages and average damages resulting from "Hazel" as compared to the synthetic structural curves for BW and CW homes. Although the number of observations is limited at certain water levels it would appear that the synthetic damage curves developed in the study are somewhat low. It is suggested that the higher velocity of "Hazel" flood waters is mainly responsible for the differences in the damage levels although this is difficult to document.



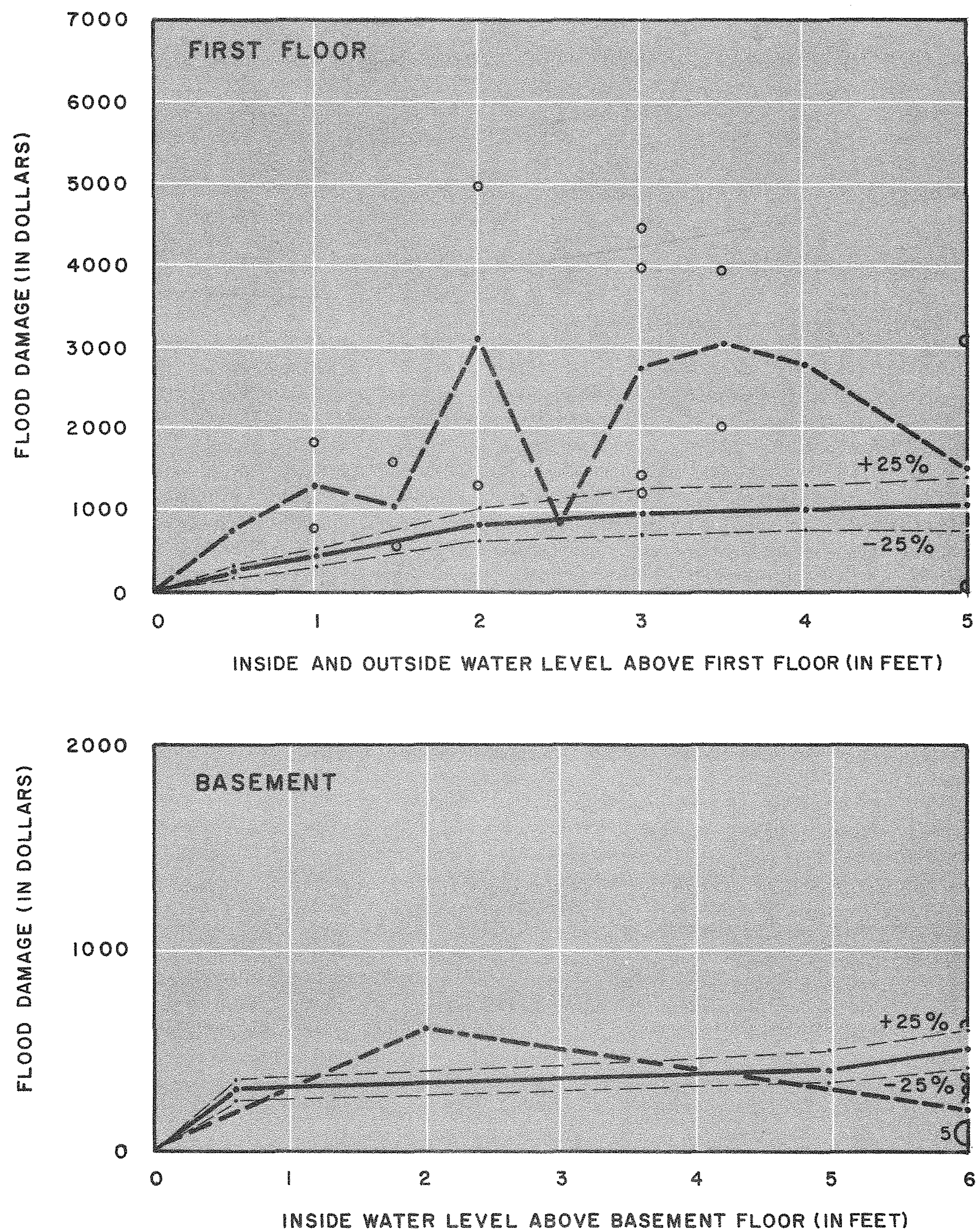
LEGEND: o REPRESENTS ACTUAL HURRICANE HAZEL OBSERVATIONS

—·—— REPRESENTS AVERAGE OF OBSERVATIONS

NOTE: ±25% DENOTES LEVEL OF ACCURACY

COMPARISON OF ACTUAL TO SYNTHETIC STRUCTURAL DAMAGES: BW HOMES

FIGURE 27



LEGEND: o REPRESENTS ACTUAL HURRICANE HAZEL OBSERVATIONS

—·— REPRESENTS AVERAGE OF OBSERVATIONS

NOTE: ±25% DENOTES LEVEL OF ACCURACY

COMPARISON OF ACTUAL TO SYNTHETIC STRUCTURAL DAMAGES: CW HOMES

FIGURE 28

One weakness which exists in the construction of the average actual damage curves is that not all the points are based upon the same number of observations. From the assessor's reports it was possible to make a maximum of two observations for each establishment. It should be noted that at the six-foot level in the basement, where the largest number of observations occurred, in the "Hazel" reports, the synthetic and actual curves are very similar.

A complete list of the sample properties compared is contained in Appendix F.

FOOTNOTES

(1) These interviews were carried out in Galt during the period from June 3 to June 22, 1968.

(2) Gilbert F. White, Choice of Adjustment To Floods, University of Chicago, Department of Geography Research Paper No. 93 (Chicago, Illinois: Department of Geography, 1964), p. 62.

(3) Grand River Conservation Authority, Brief On Flood Control And Water Conservation For The Grand River Watershed (Galt, Ontario: The Grand River Conservation Authority, August 1966), Appendix A; and E. Karuks, Prediction of Average Flood Flows For Southern Ontario, Ontario Joint Highway Research Programme Report No. 21 (Toronto, Ontario: Department of Civil Engineering, University of Toronto For The Ontario Department of Highways 1964).

(4) Edward F. Renshaw, "The Relationship Between Flood Losses and Control Benefits," Papers on Flood Problems, edited by Gilbert F. White, University of Chicago, Department of Geography Research Paper No. 70 (Chicago, Illinois: Department of Geography, 1960), pp. 41-44

(5) Karuks, op. cit.

(6) The Grand River Conservation Authority has mapped past and potential flood levels along the flood plain. The maps are available for inspection in their office at Galt, Ontario.

(7) The choice of these categories follows White, Choice of Adjustment To Floods, op. cit., and Robert W. Kates, Hazard And Choice Perception In Flood Plain Management, University of Chicago, Department of Geography Research Paper No. 78 (Chicago, Illinois: Department of Geography, 1962).

(8) Ontario, Department of Municipal Affairs, Assessor's Handbook Of Cost Factors (Toronto, Ontario: Department of Municipal Affairs, 1964).

(9) Ibid., pp. 17-34.

(10) Brian J.L. Berry, Sampling, Coding And Storing Flood Plain Data, Agricultural Handbook No. 237 (Washington, D.C.: U.S. Dept. of Agriculture, 1962); Brian J.L. Berry and Alan M. Baker, "Geographic Sampling," Spatial Analysis, ed. by Berry and Duanne F. Marble (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1968), pp. 91-100.

(11) *Ibid.*, and John Holmes, "Problems in Location Sampling," *Annals*, Association of American Geographers, Vol. 57, No. 4 (Dec., 1967), pp. 757-780.

(12) Vernon Directories Ltd., *Galt Preston (Ontario) Directory - 1968* (Hamilton, Ontario: Vernon Directories Ltd., 1968).

(13) Confidential Dun and Bradstreet Reports on these commercial establishments provided inventory values.

(14) Telephone conversation, Ontario Dept. of Health, June 7, 1968.

(15) White, *Choice of Adjustment to Floods*, *op. cit.*, p. 50.

(16) *Ibid.*

(17) *Ibid.*

(18) Personal interview with Mr. Martin Kagan of Kagan's Household Furniture, Toronto, June 6th, 1968.

(19) *Ibid.*

(20) Kates, *op. cit.*

(21) Personal interviews with shoe store owners in Dresden and Galt, Ontario.

(22) Several local contractors in Galt confirmed estimates and figures suggested by experts within the Acres Group.

(23) Robert Snow Means Ltd., *Means Handbook of Cost Factors, 1968* (Duxburry, Mass.: Robert Snow Means Ltd., 1968).

(24) Robert W. Kates, *Industrial Flood Losses: Damage Estimation In The Lehigh Valley*, University of Chicago, Department of Geography Research Paper No. 98 (Chicago, Illinois: Department of Geography, 1965).

(25) *Ibid*.

(26) Data supplied by M.K. McCutcheon, Executive Director, Ontario Department of Energy and Resource Management.

(27) Calculated from *Price and Price Indexes*. Dominion Bureau of Statistics, No. 52-002.

3.4 - Indirect Damages

3.4.1 - Types of Indirect Damages

In order to simplify their calculation, indirect damages were divided into two major types -- those affecting establishments (i.e., homes and businesses) in the flooded area, and those affecting the entire community. Further divisions are made within each of these groups.

In estimating indirect damages, care must also be taken to avoid the double counting of damages that may have already been accounted for elsewhere. For example, an individual may be briefly unemployed due to an interruption of production at his place of employment and consequently suffer a loss of wages. However, he may be employed for part of this time to clean up and repair damages resulting from the flood. Double counting would occur if both the loss in productive wages to the individual, as well as wages paid for clean-up by the firm, are counted as indirect damages.

Establishments

Indirect damages to establishments arise from the interruption of normal daily activities.(1) In general, these include loss of sales and production to businesses, the disruption of residential living conditions, the costs of flood fighting, and long-term flood proofing.

Depending on the nature of the flood, individual businesses may lose returns due to loss of sales and production for the duration of the flood and during periods of preparation and clean-up. If production or sales cease, wages to individuals may also be lost.[2]

There also are indirect damages involved in the extra work required to prepare for a flood, the costs of flood fighting, and long-term flood proofing. Among the preparatory work costs are the expenses involved in removing stock and production equipment from the vulnerable areas, hiring flood fighting equipment and extra staff, and paying exta wages to existing staff.[3]

The very fact that an establishment exists on a flood plain results in certain long-term diseconomies to land use. Experience in Galt has shown that use and design of buildings often have taken into account the flood hazard. Among the precautions taken are disuse of basements during the Spring run-off period, locating of furnaces and other such facilities on first or second floors, installation of special pumping equipment, and the construction of water retaining walls for individual buildings.

It can be assumed that the occurrence of floods will render a property less desirable for use. The cost of this indirect damage will be reflected in a drop in the capital value of the property.

Residential units also suffer indirect damages as well as direct damages. Costs incurred due to evacuation, employment lost due to flood fighting, the costs of long-term flood proofing, and decreases in capital value of the property, are the major residential indirect damages.

Community

Indirect damages to the area of the community not directly affected by the flood, are generally in the nature of inconvenience. The extent of these damages depends on the functional importance of the flooded area to the entire community. The disruption of public utilities and delays in transportation, resulting in disruption of normal daily activity elsewhere, are examples of this type of damage.

In addition, substantial but hidden administrative costs often exist. Municipal councils, engineering departments and police and fire departments, often spend considerable amounts of time on emergency measures during and after any heavy floods.

3.4.2 - Sources of Information

Information necessary to estimate possible indirect damages at Galt was obtained from four main sources:

(1) - Interviews with businessmen, plant managers, and residents, who had had past experience with flooding;

(2) - Organizations, such as Canada Manpower and Dun and Bradstreet, supplied wage and sales figures for individual establishments and for the entire area;

(3) - Interviews with utilities and public agencies that would be affected;

(4) - Reports on other flood damage studies.

Information from these sources was then analysed, to estimate the damages listed in the previous section.

(1) - Commercial and Residential Interviews

During the course of interviewing residential, commercial, and industrial establishments at Galt, the interviewers searched for indirect damages suffered in previous floods (see Appendix B). Interviewers also probed for indirect damages that might occur at various flood levels in the future.

Realistic figures were difficult to obtain through this method, primarily because of each respondent's unawareness of the existence of indirect damages, and wide variety of possibilities.

(2) - Organizations

Annual sales figures for some retail establishments were obtained from Dun and Bradstreet. Weekly and daily sales were examined and used in estimating indirect damages to retail establishments.

The average wage for Galt was obtained from the Canada Manpower Centre. This was used to derive a rough estimate of wages lost during the period of flooding.

(3) - Public and Private Utilities Organizations

Interviews were conducted with personnel of utilities and emergency organizations to ascertain the availability of information on general flood fighting costs and indirect damages to the community resulting from interruption of services.

Emergency organizations, such as the Red Cross, Emergency Measures Organization[4] and the Salvation Army, were able to give costs for specific floods. However, because of the uniqueness of each flood and the informal bookkeeping systems of these organizations, no average figures for flood fighting costs were available.

Interviews with utilities, such as the Bell Telephone, Consumer's Gas, and Ontario Hydro, showed that cost figures on damages to their facilities in previous floods are sometimes available.[5] However, since these organizations are not liable for inconveniences caused by disruption of services, no cost figures of indirect damages were available.

(4) - Other Studies

Other figures and estimating techniques for evacuation and flood costs were obtained from previous flood damage studies, and were adjusted to current price levels.[6]

Thus, it was found that some information of estimating indirect damages to individual commercial and residential establishments is available, but no data could be obtained for estimating costs of inconveniences to the community as a whole. Therefore, no estimates of total indirect damages could be made.

3.4.3 - Estimating Techniques

The complexity of indirect damages and of their estimation usually has necessitated calculation of these as a percent of direct damages. However, these rough percentage estimates vary considerably with specific instances, and no rule is applicable in all cases.

The Metropolitan Toronto and Region Conservation Authority, in line with earlier American practices, estimated total indirect damages at 75 percent of direct damages in the Humber River area for a flood of Hazel's magnitude.(7)

The United States Department of Agriculture, Soil Conservation Service, suggests the following ranges for indirect damage:(8)

Type of Direct Damage	Percentage Range
Agricultural	5 - 10
Residential	10 - 15
Commercial and Industrial	15 - 20
Highways, Bridges, and Railroads	15 - 25
Utilities	15 - 20

These percentages would be subject to change in special cases.

This study attempted to test the applicability of these estimating techniques to the Galt area. The two major indirect losses to typical Galt commercial and residential establishments -- loss of business and evacuation costs -- were estimated with the data obtained. No techniques exist for estimating other indirect costs such as long-term flood proofing and hazard adjustments. Also, losses to the rest of the community, as a result of direct damages to transportation networks and utilities, could not be estimated at this time. This would involve a detailed study of traffic flows and the application of monetary values to increases in travel time.

Indirect costs arising from direct damages to residential areas were estimated by the technique used by the Royal Commission on Flood Cost-Benefit in Manitoba.[9] These damages consist of the costs involved in obtaining alternative accommodation, extra food, and wages lost by the household.

Alternative accommodation costs were based on the rental value of the evacuated home, accounting for the variation in costs of alternative accommodation available. Monthly rental value was calculated at 2.5 percent of the assessed value, or 1 percent of the market value.

Extra food costs for household were estimated by the cost of eating in places other than the home, less the cost of eating at home.

Loss of wages to a household was estimated on the basis of the average wage in the Galt area.[10]

Loss of revenue to commercial establishments was estimated by a normal mark-up on sales for the duration of the flood.

3.4.4 - Analysis of Indirect Damages

Residential

Residential indirect damages were calculated for a typical BB class home in Galt, and expressed as a percent of direct damages derived in the previous section. An evacuated period of two days was assumed. The results were as follows:

(1) - Cost of Alternative Accommodation

This was estimated on the basis of the rental value of a BB class home for 2 days.

Monthly rental value = 1% of \$18,000[11] = \$180.00 per month

Rental value for 2 days = $\frac{180}{30} \times 2$ = \$ 12.00

(2) - Extra Food Costs:

This was estimated on the basis of extra food costs incurred by a family.

Estimated food costs:

\$5/person/day for eating out of home
\$1/person/day for eating in home

Therefore, extra food cost is \$4/person/day
Average Galt household size is 3.5 persons[12]

Therefore, Total extra food costs
= \$4 x 3.5 x 2 = \$ 28.00

(3) - Wages Lost by Household:

The average Galt wage in 1967 was \$75/week, or \$15/day.

Total wage loss to household
(assuming 1 worker per family)
2 x \$15.00 = **\$30.00**

Total Indirect Damages = **\$70.00**

Direct Damages to a BB Home:		Indirect Damages
at 6" = \$1,400	$\frac{70}{1,400} \times 100$	= 5%
at 12" = \$1,461	$\frac{70}{1,461} \times 100$	= 3%

The same procedure was used to calculate indirect damages to a CW home.

(1) - <u>Cost of Alternative Accommodation</u>:

Monthly rental value

= 1% of 12,000 = $120.00 per month

Rental value for 2 days

$= \frac{120}{30} \times 2$ = $ 8.00

(2) - <u>Extra Food Costs</u>:

This was estimated to be the same as to a BB home.

$4 x 3.5 x 2 = $ 28.00

(3) - <u>Wages Lost by Household</u>:

This was estimated to be the same as to a BB home

$15 x 2 = $ 30.00

Total Indirect Damages = $66.00

Direct Damages to a CW home:		Indirect Damages
at 6" = 806	$\frac{66}{806} \times 100$	8%
at 12" = 1,439	$\frac{66}{1,439} \times 100$	5%

If relief costs are paid, these should be subtracted from the indirect damages in order to avoid double counting.

It must be remembered that the above calculations were based on a set of assumptions and average figures. Moreover, indirect damages such as loss in capital value and long-term adjustment costs were not calculated. The above also assumes no warning time for the occupants, which results in maximum direct damages, and reduces the percentage figure of indirect damages to a minimum. It would appear that, with the above adjustments, the range of 10 to 15 percent used by the United State Soil Conservation Service is sufficiently accurate for estimating the minimum amount of indirect damages at Galt. The choice of a figure in excess of this level (e.g., 50 percent or 75 percent) still must remain a subjective decision for the analyst to make after a careful appraisal of all utilities, transportation facilities, and industries along a particular flood plain.

Commercial

An attempt also was made to estimate potential indirect damages to commercial establishments. Since a certain amount of business losses to commercial establishments are merely deferred and can be made up in sales at a later date, the extent of real economic loss is difficult to establish. The amount of sales which can be made up varies, depending on the nature of the goods sold. Food stores closed during the flood period probably would suffer more real economic loss than a clothing or furniture store.

In the case of Galt, a food market with annual sales of $150,000 was chosen as an example. It was assumed that three days, or $1,500 in sales, would be permanently lost due to flooding. Real economic loss to the establishment would be that portion of the selling price which brings returns to labour, management, and capital. An average markup of 20 percent was assumed, and used as an indicator of real economic loss.

Loss of sales for 3 days	3 x 500	=	$1,500
Real economic loss	20% of 1,500	=	$ 300

Expressed as a percentage of estimated direct damages to the store, the indirect damage figure ranges from 8 to 23 percent depending on the depth of flooding.

The above example is based on many assumptions which are subject to debate. However, with adjustments made for sales that can be made up, the estimate made by the U.S. Soil Conservation Service of 15 percent to 20 percent would seem to be reasonable at this time.

Industrial Indirect Damages

Indirect damages to industrial establishments can be measured by loss of returns to management, labour, and capital, due to interruption of production. Although there have been many inventories of flood losses in the United States and Canada, no thorough analysis of losses resulting from interruption of production can be found. Various means of assessing real economic losses have been developed, but all are subject to dispute.(13)

Methodology for measuring indirect damages has been very general in nature, and reliable data cannot be obtained. The following technique is recommended for estimating industrial indirect damages in Southern Ontario:

(1) - Obtain an average daily value of gross production;

(2) - Obtain per diem flood damage figures by identifying that portion of gross daily production which represents genuine flood damages, and which has not been counted in other ways. The fact that production can sometimes be transferred or deferred without extra cost must also be taken into consideration. A plant operating at full production would suffer greater losses than one working at less than full production;

(3) - Relate production losses to flood stages and levels of direct damage. This might then be used to estimate production losses in other areas.

3.4.5 - Damage Factors

Three factors figure prominently in determining the extent of indirect flood damages at Galt and, in most cases, these factors should also apply to the remainder of Southern Ontario. They are: the duration and level of the flood, the time of the flood, and the amount of flood proofing.

The duration and level of the flood is of particular significance when estimating indirect damages of Southern Ontario floods. Studies have shown these floods tend to be relatively flashy, and are limited in areal extent.(14) As a result, indirect damages such as evacuation costs, loss of commercial business, and loss of industrial production, will probably be of a smaller magnitude than those suffered in areas experiencing longer and more extensive floods.

In the case of Galt, the areal extent of previous first floor flooding has been limited to the east side of the Grand River, and flood-to-peak periods have generally not been longer than 24 hours.[15] Thus, indirect damages arising from the presence of flood waters are relatively small.

Additional research should be conducted to derive more definitive relationships between indirect damages and the level and duration of floods.

The time of the flood occurrence is also of importance. Indirect damages will vary with season, time of week, and even time of day. Winter floods probably will result in greater evacuation costs, since homes would be uninhabitable with furnaces out of operation. In a community that has a history of Spring flooding and has adjusted to it, a flood during any other season may catch people unaware and unprepared. Indirect costs of loss of production, sales, and wages, would be different on the weekend than during the week. This was the case in the 1954 flood at Galt which occurred on a Saturday. Commercial sales were affected, but there was little loss in production or wages at industrial establishments.

The third major factor affecting indirect damages is flood proofing and adjustment. In Galt, commercial and industrial property owners are quite aware of the flood hazard and, as a result, flood proofing measures are extensive. Removable electric motors, furnaces hanging from ceilings, pumping systems, false floors, flood walls, and the practice of decreasing basement inventories before Spring run-off, were among some of the measures mentioned in the Galt interviews. Also, utilities tend to locate major installations away from vulnerable areas, reducing the probability of extensive indirect damages to the functioning of the community.

The above measures, taken primarily to reduce the probability of incurring direct damages, may be counted as long-term indirect costs of locating in a flood hazard area. However, these adjustments also tend to reduce indirect damages in the event of a flood. Postflood sales by stores, and increased production before the flood aid in minimizing indirect costs. As a result, most losses are not permanent, but are merely deferred until after the flooding period. Flooding in a community such as this is accepted in its way of life and, to a great extent, indirect damages are absorbed as normal costs.

When estimating possible indirect damages to Southern Ontario communities, the above three factors must be taken into account. Assumptions must be made on the time of the flood, while the physical and the social factors must be adjusted to each particular site.

3.4.6 - Recommendations For Use Of Estimation Techniques

In light of the above findings on indirect damages at Galt, some comments can be made regarding estimating techniques of indirect damages for the rest of Southern Ontario. Because of the many unpredictable variables involved and the uniqueness of each case, no rule can be said to apply in all cases.

Although indirect damages are not exclusively a function of physical damages, they should be estimated in those terms due to the lack of data and synthetic estimating techniques available at this time. The figures used by the U.S. Soil Conservation Service (see Section 3.4.4) appear to be most applicable to the type of flood which occurs in Southern Ontario. However, these percentage figures should be applied with caution, and allowance made for more exact calculations that might be possible in specific instances. Additional research is necessary to determine relationships between indirect damage and direct damage to agricultural lands, industries, utilities, and transportation facilities. Until these studies are carried out, the figures used by the U.S. Department of Agriculture's Soil Conservation Service for commerical and residential indirect damages may be adopted as a minimum.

FOOTNOTES

(1) Gilbert F. White, Human Adjustments to Floods, University of Chicago, Department of Geography Research Paper No. 29 (Chicago, Illinois: By the Author, 1945): and William G. Hoyt and Walter B. Langbein, Floods (Princeton, N.J.: Princeton University Press, 1955), pp. 71-94.

(2) Robert W. Kates, Industrial Flood Losses: Damage Estimation in the Lehigh Valley, University of Chicago, Department of Geography Research Paper No. 98 (Chicago, Illinois: Department of Geography 1965), pp. 47-60.

(3) Ibid.

(4) Personal interviews with Mr. Smith of the Toronto office of the Emergency Measures Organization and Mr. Gumption of the Toronto office of the Canadian Red Cross Society, June 10, 1968.

(5) Personal interviews and telephone conversations with Mr. Heasley of Consumers' Gas Limited and representatives of Bell Canada Limited and the Ontario Hydro-Electric Power Commission.

(6) United States, Department of Agriculture, Soil Conservation Service, Economics Guide for Watershed Protection and Flood Prevention (Washington, D.C.: U.S. Government Printing Office, 1964), Chapter 3, pp. 31-32.

(7) A .75 ratio of indirect to direct benefits has been used on some flood plains in Ontario. See for example Metropolitan and Toronto Region Conservation Authority Plan for Flood Control and Water Conservation (Woodbridge, Ontario: The M.T.R.C. Authority, 1959), p. 113.

(8) U.S. Department of Agriculture, Soil Conservation Service, op. cit., p. 32.

(9) Manitoba, Royal Commission on Flood Cost-Benefit, Report of the Royal Commission on Flood Cost-Benefit, 1958 (Winnipeg, Manitoba: The Commission, 1958), pp. 40-41.

(10) Information was obtained from the local Canada Manpower Office.

(11) Market values for homes at Galt were obtained from local real estate firms.

(12) Canada, Dominion Bureau of Statistics, Census of Canada, 1966, Volume 2, Part 3, April 1968.

(13) Kates, op. cit.

(14) E. Karuks, Prediction of Annual Flood Flows for Southern Ontario, Ontario Joint Highway Research Programme Report No. 21 (Toronto, Ontario: University of Toronto, Department of Civil Engineering for the Ontario Department of Highways, 1964).

(15) Ibid., and the Ontario Department of Lands and Forests, Conservation Authorities Branch, Grand River Conservation Report: Hydraulics, 2nd Edition, (Toronto, Ontario: Department of Lands and Forests, 1962).

3.5 - Stage-Damage Relationships

The stage-damage curves for all types of home have approximately the same shape. Damages expected at each level of flooding are expressed in Table 5 as percentages of the total direct and indirect damage expected at five feet.

TABLE 5

TOTAL DAMAGE AT EACH LEVEL OF FLOODING,
AS A PERCENTAGE OF
TOTAL DAMAGE AT FIVE FEET OF FLOODING
(by type of home)

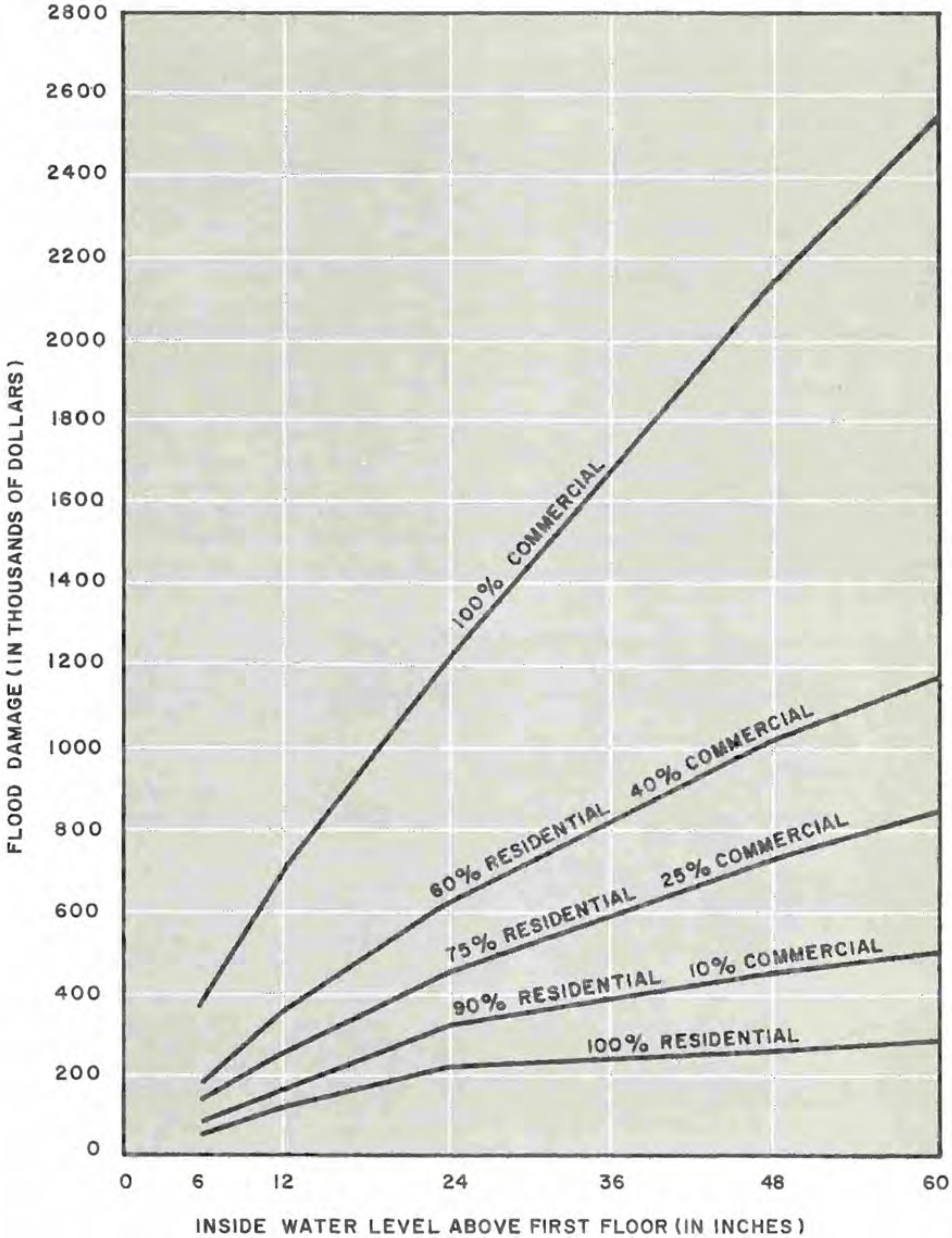
Depth of Flooding (inches)	AW,AB	BW,CW,BB,CB
6	20	22
1	60	63
2	88	92
4	99	99
5	100	100

From this table, it is apparent that approximately 20 percent of the damages resulting from a five-foot flood also would result from a six-inch flood. These damage costs will include restoration of, or compensation for, carpeting and draperies, most appliance motors, and some wooden furniture (e.g., desks, chests).

A one-foot flood level will cause more than 60 percent of the damage resulting from a five-foot flood, as it necessitates the restoration or replacement of major household articles (e.g., sofas, armchairs, box springs of beds, television sets, and stereos) as well as the same or further damage to those articles affected at six inches. When the water level reaches two feet, almost 90 percent of the damage which occurs at five feet has taken place.

In addition to the damage incurred at one foot, most veneer woods (e.g., coffee tables, side tables), chairs with upholstered seats, and mattresses, also will require attention. Two feet, then, appears as the critical water level in all homes -- further flooding can result in little additional content damage. This low critical level is a reflection of the fact that most household articles sit on the floor, and even for those that are three to five feet in height, damage to the lower part usually results in damage costs as great as those for total submersion (e.g., a sofa must be reupholstered whether it is flooded at the one-foot or the five-foot level).

An additional aspect of stage-damage relationships was briefly examined in the course of this study. The mix of structures and functions on a flood plain can vary significantly from urban area to urban area, leading to variances in total losses under similar conditions of flooding. As an illustration of this effect, a hypothetical series of floods was applied to an imaginary urban area containing 100 structures. Because insufficient data is available on potential industrial flood losses, two types of functions were assigned to the area. First the area was considered to be totally low quality residential in nature, and a damage curve relating total direct and indirect losses to flood levels was derived (Figure 27). Then, a similar calculation was carried out to produce a curve representing total damages to a high quality commercial area under various levels of flooding. Since most urban areas contain a mix of commercial and residential structures, additional curves were constructed to illustrate total flood losses to the same area under alternative percentages of high quality commercial and low quality residential properties (Figure 27). When all of these curves are examined together, two things are quite apparent. First, as might be expected, the percentage of commercial structures along any flood plain plays a significant role in determining the magnitude of



THE EFFECTS OF
ALTERNATIVE MIXES OF ESTABLISHMENTS

FIGURE 29

total flood damages at various levels of flooding. Secondly, this effect is most apparent at greater depths of flooding. Thus, it is apparent that total flood damages can vary significantly from community to community under the same levels of flooding, particularly when the flood is of a considerable magnitude.