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CHAPTER IX

FLOOD HAZARD EVALUATION

Robert W. Kates and Gilbert F. White

The year 1960 has seen a surge of interest in regulatory activities, as evidenced by work in California and Ohio, by a widespread awakening of zoning activity by county and municipal agencies, and by a momentous enlargement of Corps of Engineers authority to prepare flood hazard reports. If the rate of increase in flood-plain zoning activity of the past two years is maintained for another two years, we may expect a veritable flood of new ordinances.

Can this new regulatory activity be expected to serve its aims? A corollary question would be what is the proper place of flood-plain regulation in relation to other measures for flood-loss reduction and for land-use regulation? For regulation obviously is only one tool in a kit including engineering, structural changes, flood warnings, and insurance. The answers to such questions involve political, economic, legal, and geographical appraisal of land use in the shifting rural-urban fringe. We do not venture full answers here. But whether new ordinances are wise solutions or not, they will not be so unless they are based upon a thoughtful and accurate appraisal of flood hazard. It is important and practicable to sharpen the hydrologic and geographic concepts upon which regulation can be based.

We propose to analyze the present state of the art of flood hazard evaluation, and to suggest guide lines which may serve the aims of further efforts at regulation. It is no misnomer to speak of guide lines; the crux of much regulatory work, whether it be recorded in zoning ordinances, building ordinances, subdivision plats, or encroachment lines, is the setting of lines in relation to hydrologic and human considerations. Our attention is focussed upon the possible, practicable, and wise ways of defining lines on flood plains.

The Present State of the Art of Flood Hazard Evaluation

Since 1936, flood control and related hydrologic investigations have been concentrated largely in the hands of Federal agencies. With the advent of flood-plain regulation, responsibility diffuses to the states, and in turn to minor governmental units. Thus, the diversity of flood hazard evaluations reflects a diversity of evaluating organizations. The extremes are shown in two examples.

Lewisburg, Tennessee: A TVA Evaluation.- As described in Chapter X the

nnessee Valley Authority provided the city of Lewisburg, Tennessee a detailed
od hazard evaluation that includes: a descriptive, one hundred year flood history, estimate of the maximum probable flood (aptly called the "maximum flood of sonable, regional expectancy"), maps and high water profiles. The subsequent ing ordinance as adopted by the city with the advice of the State Planning Comsion relies in great part upon these materials.

Laona Township, Illinois: A Local Evaluation.- In contrast is the hazard evalon described in a mimeographed bulletin by a representative of Laona Township, ois.

> "They tell me that a storm drainage plan involves engineering analysis, appraisal of land form, gradient, static and fluid capacity, outfall, watershed and time capacity factors, and determination of the amount of periodic rainfall. But this would take thousands of dollars, months if not years, and a distinct line drawn on zoning maps. But it would still be an opinion. And it would remain an opinion until some future flood wiped it out. No, we in Laona Township were too conscious of nature and man's foolishness to wait without protection. Simple minimum standards had to be found and secured by zoning.
>
> "So every stream and draw in Laona Township that drains water from more than 500 acres is labeled floodway. All future structures and fences, other than agricultural fences, must be at least 150 feet back from the center line of the stream. We figured a 300 foot wide channel was enough to allow a gentle swale and avoid a public ditch. No building may be built with a floor elevation lower than fifteen feet above the stream at its lowest point."

If the latter evaluation distresses the professional sensitivities of engineers ydrologists, it should be remembered that it represents the considered opinion lled land-water managers, Illinois farmers, who in effect, are regulating them-s.

Steps in Flood Hazard Evaluation

Despite the diversity of approach, all practitioners of the art of flood hazard tion tread similar paths. The underlying unity arises from the fact that de- ophistication of data or technique, flood hazard evaluators are human beings, ng on some assessment of past flood behavior and peering into a future clouded ncertainty.

Assumptions as to the nature of the flood plain.- All evaluators of flood hazke some tacit assumption as to the geographical nature of the flood plain. lly, it is that the flood plain in a particular reach is unique, and the evalua- cordingly is based on physical relationships peculiar to the given reach. Two ssumptions are also made. One is that the flood plain in question is similar s in its region, and stream and storm data may be safely transposed from place. This assumption is often used in calculating some measure of the m probable flood, as in the case of Lewisburg. The other assumption is

made in the course of exploring ways and means of reducing the cost in time and money of flood hazard evaluation. It views the properties of flood plains as being subject to significant degrees of generalization, and it seeks to identify such relationships. A case in point is the decision to set the encroachment lines in the state of Connecticut at from five to seven times the mean annual flood.

Basic data collection.- All flood plain evaluators collect basic data on the reach in question or for a larger area depending upon the assumptions made. The data may range from word-of-mouth reports to the records of established precipitation and stream gaging stations. Besides the hydrometeorological information, topographic data usually is obtained, often in the form of maps with two-foot contour intervals.

Inference.- Some inferential process follows. It may be a simple assumption that one observed flood is a standard of future hazard. It may involve frequency analysis of the historical flood record. It may involve the forecast of a flood based on a combination of conditions that have never yet appeared in recorded time. In any case, there is some observance of past occurrence, if only of one event of the total absence of recorded events. From that observation, some inference as to future occurrence is made.

Hazard demarcation.- Following this inferential process and depending in great measure on it, is the demarcation of the flood hazard in an areal sense. Commonly, this takes the form of maps delimiting the flood plain as indicated by high-water profiles of selected flood events.

Relation of hazard evaluation to flood-plain regulation.- In general, the flood hazard evaluation process focuses on the flood plain as an independent physical phenomenon. It commonly leaves to the land-use planner the problem of comparing the estimate of hazard with present and future land-use requirements. Some agencies appear reluctant to make estimates such as the maximum probable flood, which involve large degrees of uncertainty. In part, this reluctance stems from their own uncertainty as to the use of such estimates.

While the essential steps of hazard evaluation are the same, the methods may be widely different, ranging from elaborate computations to arbitrary drawing of lines.

What does a flood-hazard evaluation cost? As we have stressed previously, anyone can make an estimate of the future and just about everybody does. To make such estimates with increasing assurance requires correspondingly increasing amounts of skill, time and money. For small communities flood-hazard evaluation by agencies already equipped with data and personnel have cost on the order of $10,000. Some mapping work by the U. S. Geological Survey has required about $200 per mile of stream. Where consultants and private engineering firms were employed, the cost has run many times that figure. However, if Congress supports ith adequate appropriations its intention to make available to communities the vast ·sources of the Corps of Engineers, as indicated in Chapter XII, the high commun- · cost as well as the per unit cost for each study will decrease.

Some Problems of Current Practice

At least six problems arise in connection with efforts to set some type of line r the land-use planner.

Regulation vs. Exclusion.- One common difficulty is the tendency of the unini- ted to treat land-use regulation as though its sole purpose is to exclude any kind human occupance from the reach of floods and thus to prevent all flood damage. ıes are then set either to exclude occupance from the entire flood plain or from ne smaller zone which is believed to be politically defensible. Obviously, such approach is wide of the mark of ordinary regulatory measures and it discredits role of regulation in flood-loss reduction.

Separation of Functions.- With the exception of state agencies enforcing chan- encroachment laws, agencies evaluating flood hazard do not, as a rule, develop carry out the regulatory functions. The choice of a "design" flood is as impor- : in regulation as it is in the construction of engineering works (from whence the m comes) but by the separation of functions that choice becomes the task of a ıicipal or county council or planning body. While the use of the trained outside sultant is a common feature of zoning practice, the analogous situation for flood ns might be that of the consultant who provided only population projections and the balance of the planning and zoning functions to his client. This is acutely in smaller communities on the borders of growing urban areas where decisions pace set aside for flood waters must be made before the land is developed and rporated into the city that ultimately will be faced with flood losses. In some ·s, for example Tennessee, the State Planning Commission strives to bridge the between professional evaluator and local regulatory bodies.

Confusion of Terminology.- The increase of regulatory legislation has brought it a welter of terminology. Floods, experienced and prophesied; flood-plains, g and dead; floodways, natural and artificial; all matters of scholarly concern lisagreement, suddenly become endowed with statutory powers as the lawyer the friendly debate of the geographer, engineer, and hydrologist.

The oft-repeated query is: now, just what is a flood plain? In answer, we can an array of flood plains. (See Figure IX-1) A physical geographer might think : physiographic flood plain, a relatively flat morphological feature composed of ium deposited by a river during over-bank flow. The hydrologist might consider ood plain as the wetted perimeter of a range of floods, both experienced and cted events. Planners, lawyers, and legislators might endow areas bordering ms with such statutory titles as flood plain; zone A, B, C or X; conservancy

district; agricultural or valley zone; and the like.

It is our hope that this paper by stimulating a discussion of terminology may eventually lead to some generally accepted set of definitions.

The Risks of Generalization.- Laudable efforts have been made to find generalized hydrologic guides to flood-plain regulation, but always at the risk of undue generalization. The effort in Connecticut centered on multiples of the mean annual flood. What can happen by the addition of one more flood to a long record (in some cases the pre-1955 maximum flood is the largest in a 300 year record) is seen in a dramatic way in the following table. The August, 1955 flood drastically changed the pre-1955 relationship which was on the order of 3.5:1.

In some other places, frequency evaluations center on the 50-year flood. The problem of selecting the suitable frequency is demonstrated by a flood study of Illinois.[1] In Northern Illinois a regional flood graph shows the 50-year flood as one point on a fairly lineal relationship between discharge and frequency. Some 150 miles to the south the relationship is curvilinear and the 50-year flood is a point on a curve where discharge sharply increases relative to frequency.

The Evaluation of Damage and Use Potential.- The high quality of hydrologic flood hazard evaluation found in much current practice has not been matched by similar standards of inquiry into the damage and use potentials of the flood plain. These include damages, direct and indirect, tangible and intangible, created by different flood events and the present and potential utility of flood plain location. Flood frequency is estimated with care while little attention is given to the effect of this frequency upon the utility of the land for residential or commercial uses. This failure to deal with damage and use characteristics issues in part from the fact that flood plain regulation legally suffers no test of economic feasibility, a test, however imperfect, which would require assembly of data of this type.

A Line is a Levee.- It has been noted[2] that levees along with other flood-protection works encourage increased use of land so protected, thus increasing the damage potential when the works fail. A line marking a flood-plain zone on a map is a levee in reverse, barring channelward expansion of human occupance. This line can also encourage expansion into the defined area by encouraging the inference among land users that it limits the area of safety. When such a line fails, as surely it will if it is anything short of the maximum possible flood it, like the levee, may be guilty of setting the scene for catastrophe.

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[1] W. D. Mitchell, Floods in Illinois: Magnitude and Frequency, (Springfield: State of Illinois, 1954).

[2] White, et al., Research Paper No. 57.

TABLE IX-1

EFFECT OF FLOOD OF AUGUST 1955 ON RATIO OF MAXIMUM TO MEAN ANNUAL FLOOD FOR SELECTED CONNECTICUT STATIONS

Station	Drainage Area (sq. miles)	1953 Mean Annual Flood (18-25 yrs.) (cfs)	Ratio of Maximum to Mean Annual Flood Pre-1955	1955
ugatuck R. near 'homaston	72	3600	2.8:1	11.6:1
epaug R. near loxbury	133	3400	3.1:1	14.8:1
n Mile R. near aylordsville	204	3000	4.2:1	5.8:1
inebaug R. at utnam	331	4000	5.2:1	12.0:1
rmington R. at ainbow	584	8000	3.7:1	8.6:1
isatonic R. at aylordsville	994	11000	3.2:1	4.7:1

Sources: Floods of August-October 1955, New England to North Carolina, U.S.G.S. W.S.P. 1420, Flood Flow Formula for Connecticut, U.S.G.S. Circ. 365.

A Framework for Flood Plain Regulation

From this assessment of current practice and experience we now suggest a nework within which the setting of lines for further regulatory work might take ·e.

The Outer Limits.- Two lines may be regarded as delimiting the arena for ıe form of regulation. These are: a) the mean low-water mark of the channel; b) the maximum probable flood. The former sets the upper limit for the chan- area usually under water, and the latter the maximum extent of hazard. In the ·ammatic cross-section of Figure IX-2 these are shown respectively as A and Z. dentifies the point at which over-bank flow begins.) Neither can be defined with :ision in all situations. In arid regions where streams are ephemeral the mean ·water line can not be set on the usual discharge data and must be taken from norphic features. At the other extreme, there is no clear agreement among hy- ogists as to the maximum probable event. It may mean maximum for a given ability, maximum possible in terms of hydrological or meteorological poten- , or maximum estimated from transposition of extreme events from similar s.

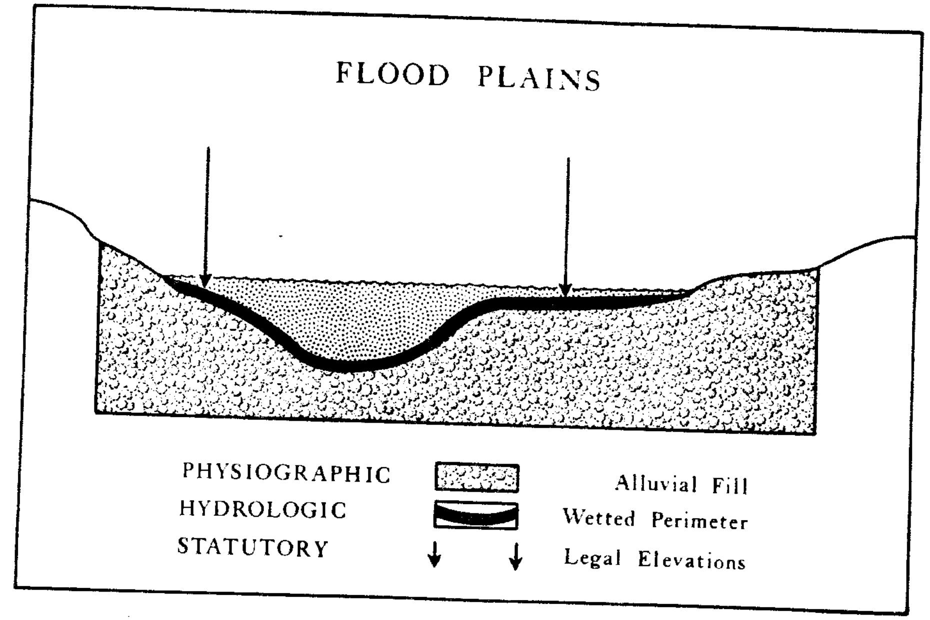

Fig. IX-1

Floodway Line.- A third line may be defined in theory as the division between that part of a flood plain required to carry a given flow and that part which could be removed from water transport without causing significant increase in flow line. This is the usual distinction between "floodway" and "pondage". It may be shown as C on the cross-section. But we must note at once that it always applies to a flood of a given magnitude and recurrence interval, and that the pondage of a frequent flood might be the floodway of a rarer event.

The Culturally Defined Line.- Still a fourth line may be defined in theory. It is the line between (a) areas whose use may be considered to have a major effect upon the consequences of flooding for the community, and (b) those areas whose use may be considered to have either minor or highly infrequent effects. This can be shown as M on the cross-section. While it may be hydrologically labeled, it always is culturally defined for a given area and time; the frequency or magnitude of flooding is chosen on grounds of anticipated effects upon the community.

Three Proposed Zones.- Using these four lines as a framework, the flood plain may be seen as dividing into three zones as follows:

Prohibitive - A-C -- That zone where any encroachment would, without clear justification to the contrary, be presumed to be against the public interest.

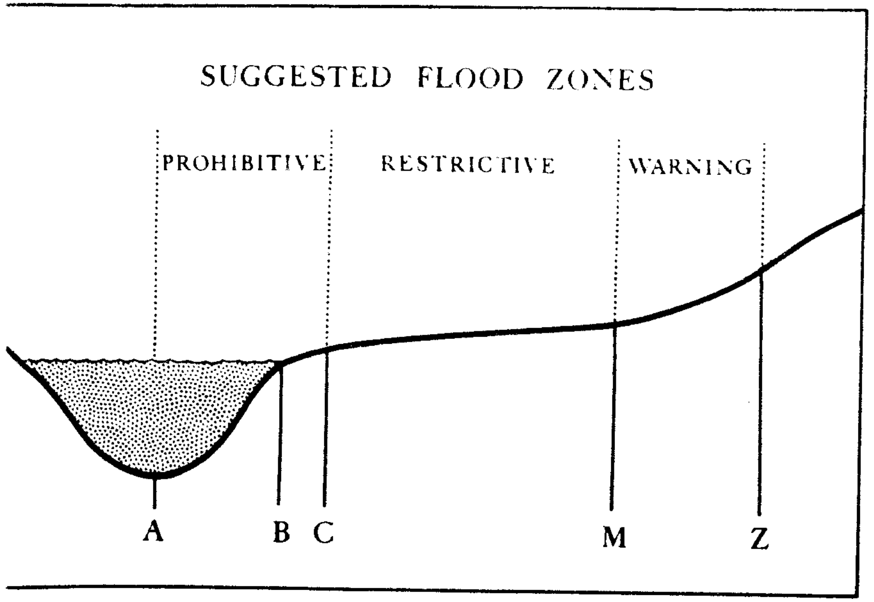

Fig. IX-2

ℝestrictive - C-M -- That zone where it would advance the general land-use aims of the community to restrict uses in relation to flood hazard.

Varning - M-Z -- That zone where it would be in the interest of property managers to receive warning of the risks involved but in which restriction is not deemed desirable.

ıarrow valley with steep sides the prohibitive zone might embrace the entire lain. For a valley with a deeply incised channel and highly infrequent over-ow there might be no restrictive zone. There would always be a prohibitive nd there would always be at least a restrictive zone or a warning zone. The e combinations are illustrated in Figure IX-3.

Guides for Setting Regulation Lines

'e have sought guides that are susceptible to relatively easy determination t are readily interpreted to property owners and public officials. For each ıar zone, we suggest the following criteria.

rohibitive Zone. - A minimum requirement for such a zone would be the pre-ɔn of the present carrying capacity of the channel for the maximum flood of

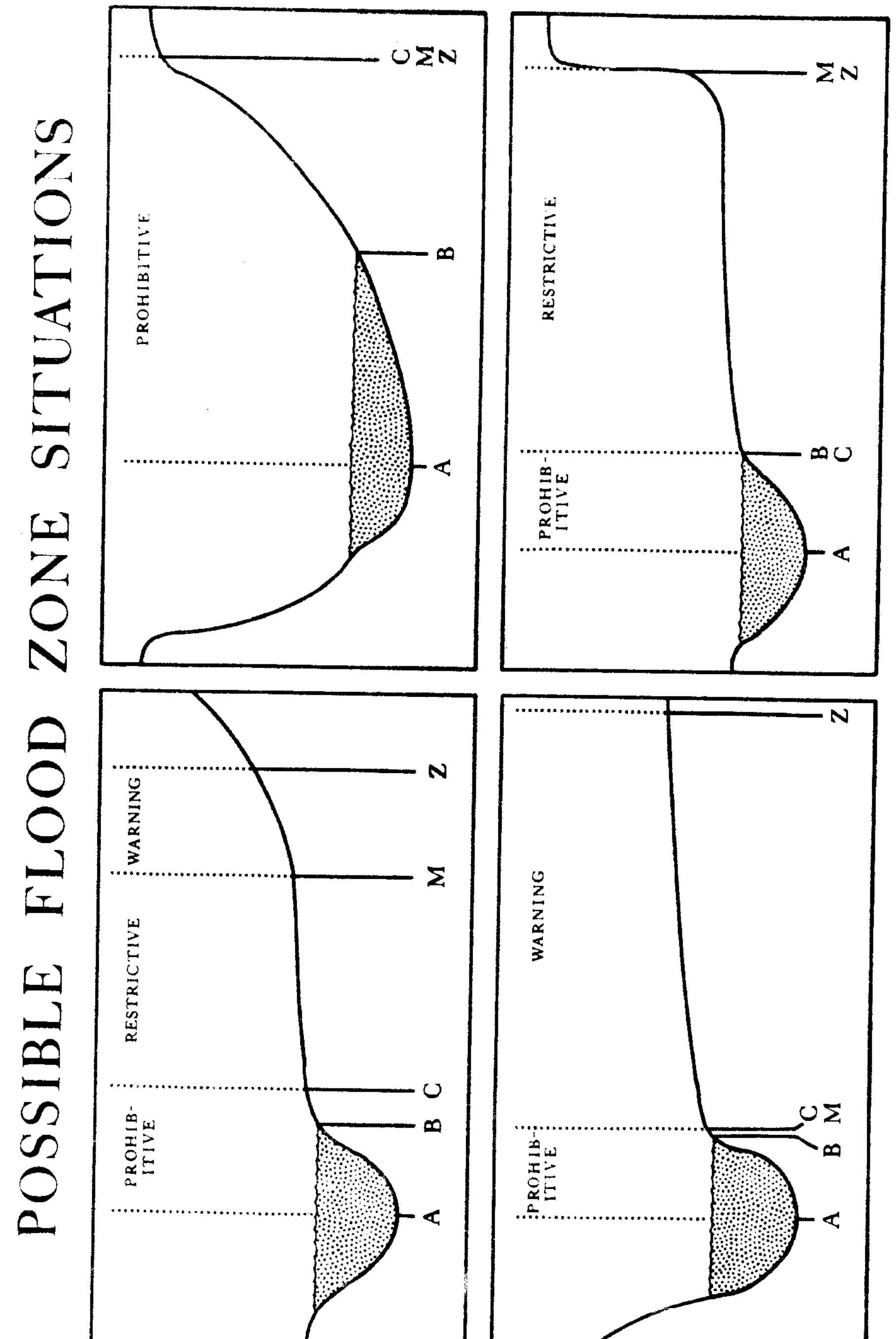

Fig. IX-3

ecord. Beyond that we suggest in urban or rural-urban areas the maintenance of channel with capacity sufficient to carry the flow of projected storm drainage sys-ms. A study of the hydraulic geometry of channels at over-bank flow might yield lditional guides for setting such lines.

Restrictive Zone.- No line may be wisely set for such a zone without the re-onsible organization clearly defining to itself the object of regulation. Dunham ggests that aims of government regulation have included a) preventing unwise in-vidual choices, b) curbing action which would cause damage to others, c) prevent-; victimization of individuals, and d) reducing public expenditures.[3] Of these, the st is considered untenable on legal grounds. In practice, the other aims are ex-essed in four types of results.

(1) Reduction of flood losses.- Generally speaking these losses are to "whom-ver they may accrue."

(2) Decrease in human suffering.- This is often the dominant factor behind nmunity sentiment.

(3) Reduction of direct governmental costs.- These are out-of-pocket costs urred through flood-fighting, relief, rehabilitation, flood protection, or the re-cement of government-owned facilities.

(4) Provision of indirect benefits.- These consist of such peripheral benefits he increase in open space, green belts, or the joint planned benefits where flood n regulation is linked to urban renewal, park development, off-street parking, other improvements.

The logical conclusion of such a set of objectives would be to restrict flood n use to either open or elevated uses. In practice, an important set of restraints erative, for the aims of flood loss reduction must be reconciled with broader s of optimum land use.

(1) Minimum reduction in land utility.- Where restrictive zoning impedes ty of land it must be clearly in the public interest to do so.

(2) Alternate flood adjustments.- An upper limit to land regulation is the al-itive social or dollar costs posed by other adjustments, such as flood proofing,[4] ieering works, and emergency evacuation. A levee may obviate the need for iction. The requirement of flood proofing in a building ordinance may be suf-it restriction upon use.

(3) Projected land needs.- The extent of flood-plain regulation is determined

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[3]Allison Dunham, "Flood Control Via the Police Power," University of sylvania Law Review, 107 (1959), pp. 1098-1132.

[4]John R. Sheaffer, Flood Proofing: An Element in a Flood Damage Reduction ram (Chicago: University of Chicago, Department of Geography Research No. 65, 1960).

in the context of an over-all plan which includes projections of future land-use requirements.

(4) Available financing.- To the extent that regulation is dependent on some other program i.e. urban renewal, the financial limitations of such schemes act as a restraint on regulation.

(5) Viable political decision.- As we see it, there are two sets of requirements for a viable political decision. The first is that regulation be workable, explainable, and enforceable. The second is that it should fall into that broad area of action that the political scientists pertinently label as "the possible."

Given a set of objectives and restraints and their translation into quantified data, there exist statistical techniques capable of identifying with precision that point at which certain objectives are maximized subject to certain restraints.[5] Such a program, however, awaits conceptual definitions and quantified data that we do not as yet possess.

Therefore, we suggest the "next-best" approach, a series of quantified indicators, readily available, of some of the objectives and restraints. These are simple measures of area, land use, population, value, inventories, sales, employment, and residence. They can be plotted against flood hazard and thus become measures albeit imprecise, of the damage and use potential of the flood plain. They can be studied in the light of the land-use requirements of the area.

Warning Zone.- We have indicated previously that the warning zone should be some measure of the maximum probable flood, which we indicated was difficult considering the wide variation found in the literature as to its meaning and calculation. We suggest, then, that the upper limit of warning zone represent, at least, that area inundated by some transposed regional storm or flood properly routed through the reach under study. It is viewed as the zone in which property managers, given suitable warning, may exercise some degree of self regulation.

Let us now illustrate some of these points by reference to one relatively simple flood plain.

La Porte St., Plymouth, Indiana - An Example

The Yellow River, tributary to the Kankakee, swings through the heart of Plymouth, Indiana draining an upstream area of 284 square miles. La Porte Street crosses the river via a foot bridge and it is the site of a U.S.G.S. gage. In 1954, the flood of record poured across the whole meander in which our study area lies.

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[5]Walter Isard, Methods of Regional Analysis: An Introduction to Regional Science (New York: Technology Press, 1960).

Data.- Figure IX-4 represents the cross section of the area in question divided frequency zones of <10, >10, >20, >75 year recurrence intervals, and an un- n frequency representing the uncalculated maximum probable flood. (The fre- :y data are estimated from material lent by the District Office of the Corps of ieers.) The area is marked by a low density of population, and the old wooden :s are well cared for. The simple measures of area, population, employment, tion, tenure, and length of time at site were obtained by rapid field observation. e show that homes and population increases with flood frequency, and business mployment decreases with frequency.

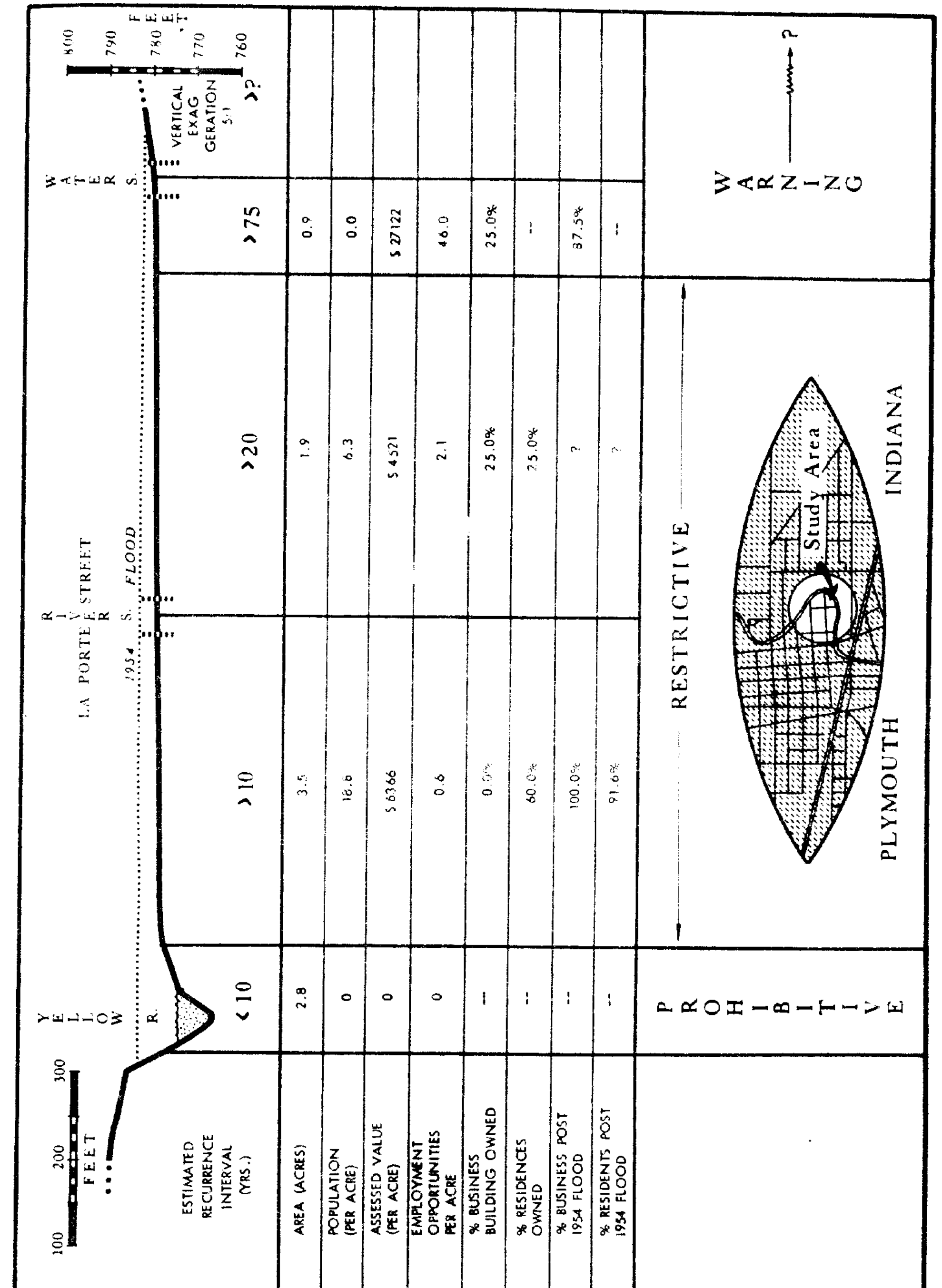
Using the combined hydrologic and land-use data three zones may be suggest- t is assumed that no further local protection would be feasible.

Prohibitive zone.- This zone is set at the channel bank because high-water es indicate no backwater effect at this point. Prohibition of structures and parently would preserve the present channel capacity.

Restrictive zone.- The relation of present development and frequency sug- a restrictive zone in which additional structures would be permitted only if ed against flood losses. If Plymouth grows there will be pressure to extend 3D into this zone, and already some of it is being done in the form of a park- t. This would be permitted under this type of zoning provided there were one f fill added and no basements.

Warning zone.- Lacking the proper hydrologic data, we would locate the extent warning zone at a sharp break in slope lying outside the sketch. Present and users of this area might consider the advantages of elevated refrigeration ating equipment and other simple protective measures; but, given the warn- e decision would be theirs.

Without regulation and with enough construction of new structures in the area investment in flood protection works will be justified under present policies. e more the channel capacity is reduced the greater will be the justification. n any area where urban growth impinges upon or increases the size of flood some combination of regulatory measures is essential to minimizing flood consistent with the land use needs of the community. Without them the only outcome of urban growth is an enlarged annual toll of flood losses and a ng bill for protection works which will continue to lag behind urban invasion. ral-urban fringe is a major sector for this invasion, the other being vacant thin built-up areas. Discerning use of regulatory measures rejects their de- simply keep all occupance out of flood hazard areas. It requires hydrologic graphic judgment at each of four steps in hazard evaluation. We believe it expedited by setting lines to distinguish three types of zones for regula- tion: the prohibitive, the restrictive and the warning zones.



ESTIMATED RECURRENCE INTERVAL (YRS.)	< 10	> 10	> 20	> 75
AREA (ACRES)	2.8	3.5	1.9	0.9
POPULATION (PER ACRE)	0	16.6	6.3	0.0
ASSESSED VALUE (PER ACRE)	0	$ 6366	$ 4521	$ 27122
EMPLOYMENT OPPORTUNITIES PER ACRE	0	0.6	2.1	46.0
% BUSINESS BUILDING OWNED	--	0.5%	25.0%	25.0%
% RESIDENCES OWNED	--	60.0%	25.0%	--
% BUSINESS POST 1954 FLOOD	--	100.0%	?	87.5%
% RESIDENTS POST 1954 FLOOD	--	91.6%	?	--

Fig. IX-4 Cross-section of Flood Plain at Plymouth, Indiana