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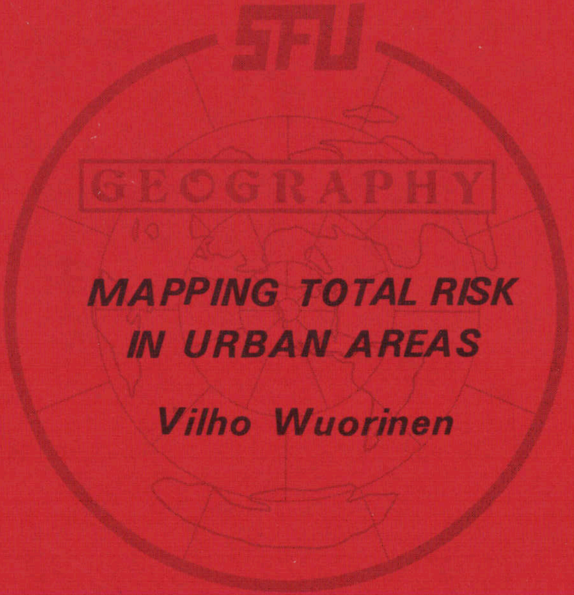

MAPPING TOTAL RISK IN URBAN AREAS

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A) Introduction

Ideally, land-use planning decisions are based on thorough analysis of accurate data compiled on all relevant factors bearing on the issue in question. A common method of analysis is the preparation of data maps for each variable, overlaying them, and drawing inferences from the composite maps so produced. Steinitz et al. note that the overlay technique has been in use at least since 1912[1].

An elaborate example of the technique is illustrated in the Richmond Parkway Study directed by Ian McHarg.[2] Six elements of physiographic obstructions and ten elements of social values were separately mapped, using three shades of light and dark to differentiate between the three zones used in each map. The maps were then photographed as transparent prints and superimposed upon one another to produce one composite suitability map. The least desirable areas for arterial roadway location were represented by the darkest tone. It can be seen that with 32 possible shades, discrimination of discrete zones becomes very difficult.

With the advent of computers into general use in planning, the disadvantages of inefficiency and inflexibility associated with hand-drawn maps can be overcome. By assembling the basic data for each variable in a computer data file instead of displaying it on a data map as is done in the traditional overlay process, the data are available for recall and recoding in various forms. If additional data become available, or amendments to data or its weighting becomes necessary, such changes can be accommodated in the data file, and a revised map is readily produced.

In their review of the history of hand-drawn overlays, Steinitz et al. note that a serious lack of methodological documentation has existed in the literature concerning methods of analysis.[3] The following discussion is a brief description of a methodology developed to map total risk from natural hazards in urban areas through the use of a computer programme which integrates values from a series of base maps.[4]

B) Risk Mapping

1) Need for Risk Maps

Although little, if any evidence exists to suggest that catastrophic natural events are occurring any more frequently now than in the recent geologic past, losses from natural disasters have continued to grow as world population has increased and the earth's surface has been more extensively developed. Concentration of the population-at-risk in cities and towns has further increased man's vulnerability to natural hazards.

At the present level of scientific and engineering capability little can be done to prevent extreme natural events, but their effects can be alleviated through adequate planning. The first step in hazard mitigation planning is vulnerability analysis, usually presented in the form of hazard maps. Past efforts have been largely devoted to small-scale, single-hazard maps, whereas comprehensive urban planning requires large-scale, multi-hazard risk maps which show expected local variations in severity over small areas.

In 1972, the Office of Emergency Preparedness submitted to Congress a comprehensive study of the types of major natural disasters experienced in the United States. This report analyzed the causes and effects of natural disasters and offered findings and potential solutions to prevent or minimize loss of life and damage to property. The urgent requirement for systematic analysis of the vulnerability of communities was emphasized:

> Vulnerability analysis is a prerequisite to effective disaster preparedness. The variety in types and frequency of natural disasters and the differences in effect and damage make it clear that an assessment of vulnerability must be made for each community as a first step in formulating regulations, plans, and programs to reduce hazards and prepare for disasters.[5]

In British Columbia, the Association of Professional Engineers recommended in 1977 that provincial legislation be enacted to ensure that natural safety hazard considerations were a prime concern during land development.[6] It was suggested that a provincial hazard committee be formed, with responsibility for: assessing risk levels at new development sites; mapping areas which may be affected by natural disasters; starting investigation where there is concern for public safety; and designating unsafe areas and land use restrictions.

2) Problems with Risk Mapping

In their report, the Office of Emergency Preparedness discussed the need for risk maps, and commented on problems with the present standard of mapping:

> The result of vulnerability analyses are generally presented in the form of "risk maps", which portray the type and degree of hazard represented by a particular natural phenomenon in a given geographic location. Earthquake risk mapping, for example, identifies faults and the underlying geological conditions of the locality, flood plain mapping indicates the areas likely to be covered by water during floods of given magnitudes, tsunami risk maps delineate the areas that would be inundated as a result of waves of varying heights, and forest-cover mapping estimates the vulnerability of woodlands to fire.[7]
>
> ... The techniques and procedures for conducting this vital step of the process are generally known except in the case of earthquakes, where additional research is required. Instrumentation to gather more data, notably for earthquakes and volcanoes, is much needed. Furthermore the activities to date have left untouched some geographic areas known to be susceptible to certain disasters (e.g., earthquake-prone areas not on the West Coast). The rate of progress has also been slow, as in the mapping of East Coast areas susceptible to storm surges. The risk maps prepared, moreover, often have not been of a sufficiently small geographic area or have not included adequate details to be useful as a basis for promulgating local regulations that contain strong hazard reduction features.[8]

In summarizing their work on geological phenomena which pose the severest hazards to society, Bolt et al. note that the concentration of population in urban areas has heightened such threats to levels where large-scale planning to reduce hazards has become essential. However, lack of data is a problem:

> Not only must planners rely generally on incomplete and uneven statistics to predict, from past occurrences future catastrophes, but the available data must be worked into a form that allows some quantitative comparison between various geological hazards... Many variations on the techniques for studying hazard mitigation can be found. The

> following account is aimed at establishing (i) the need for interaction between those professions which deal with urban development, such as town and county planners, architects and engineers, insurers, local government and public works officials; and (ii) a direction in which improvement can be made in presenting geologic data for environmental studies so that they are comprehensible, less piecemeal and, at the same time more open to estimates of uncertainty.[9]

Authorities quoted above have pointed out many of the weaknesses and deficiencies apparent in past examples of risk mapping designed for use in local planning:

1. insufficient data
2. no quantitative comparison between various hazards
3. piecemeal information
4. not enough detail
5. not comprehensible
6. lack of communication between people involved
7. not widely disseminated

The methodology for risk mapping discussed here attempts to overcome some of these deficiencies. Insufficient data will continue to seriously hamper natural hazard researchers, but the mapping system described facilitates the input of new information as it becomes available. A common unit of measurement is suggested, to allow cross-hazard comparison. The integration of a series of single-hazard maps into one total risk map is the major innovation. Since the amount of detail possible on a map is a function of available data and the scale of mapping, the maps illustrated here are at a scale of 1:25,000, but the system is readily adjustable to larger scales if greater detail is required. The choice of a monetary unit of measurement for the overall risk map enhances comprehensibility as well as communication between people working with the map, and should promote wider dissemination of the information to the public.

The fact that few risk maps have been developed for urban centres may be attributable to the costs being considered excessive or to the lack of qualified personnel to complete such mapping. The bulk of the work involved in producing maps in the manner developed here can be carried out by relatively untrained staff under the guidance of a person trained in earth sciences, since much of the required data may already be recorded in different form. The computer mapping programme (SYMAP) is available at most universities, so no programming expertise is required. Once the computer mapping system is established, the risk map can be kept current by simply adding new information or amending data as required to keep abreast of new developments in natural hazard research.

C) Urban Hazards

1) Typology of Urban Hazards

A comprehensive, although not necessarily exhaustive, list of phenomena considered to be natural hazards is contained in table I. At first glance, it might be argued that any of these hazards could represent a threat to the urban environment. In the context of large-scale urban mapping, however, it can be seen that not all hazards qualify for serious consideration.

Three questions will be asked about each natural event included in table I to determine whether it should be subjected to a more detailed analysis: is this an urban problem, is the spatial variation in intensity such that it can be discriminated at a scale of 1:25,000, and if spatial variation is discernible at this scale, is it random or predictable?

To answer these questions, it is obvious that some value judgements will have to be made. Glacial surges are not considered to be an urban problem, since towns are not normally built at glacier termini. Similarly, wildland fire should not be included in a list of urban hazards because, by definition, towns do not exist in wildlands. Coldwaves, drought, and hail certainly affect urban areas, but are of much greater significance to agricultural enterprises.

Hazards which are eliminated from detailed consideration as urban problems due to lack of predictable local spatial variation are all meteorological phenomena. The physical effects of coldwaves, droughts, freezing rains, heatwaves, sand or dust storms, and snowstorms are usually spread fairly evenly over a much larger area than that occupied by one urban centre. The same qualification applies to hurricanes and other windstorms, although to a lesser degree, in that exposure to high winds varies with elevation and aspect. Advection and upslope fog are usually widespread phenomena, while radiation fog is localized. The latter type of fog collects in low-lying areas, but the overall extent varies

TABLE I

NATURAL HAZARDS

Event	Urban Problem	Local variation	Variation predictabl
Avalanche	X	X	X
Coastal erosion	X	X	X
Coldwave (frost)	?		
Drought	?		
Earthquake (ground shaking, fault displacement, liquefaction, differential settlement)	X	X	X
Expansive soils	X	X	X
Flood (rainstorm)	X	X	X
Fog	X	X	
Freezing rain	X		
Glacial surge		X	X
Hail	?	X	
Heatwave	X		
Hurricane (typhoon, cyclone)	X	?	
Landslide (boils, surge waves)	X	X	X
Lightning	X	X	
Meteorite strike	X	X	
Sand storm (dust storm)	X		
Snowstorm	X		
Soil erosion	X	X	X
Storm surge	X	X	X
Subsidence	X	X	X
Tornado	X	X	
Tsunami	X	X	X
Volcanic eruption	X	X	X
Wildland fire			
Windstorm	X	X	

with atmospheric conditions, and with diurnal temperature changes, areas at higher elevations become affected, making accurate prediction difficult. When viewed within the constraints of a small area and the present state of predictive capability, natural events such as hail and tornadoes occur at random. Lightning strikes are attracted to tall structures and prominent natural features, but their overall spatial distribution is random. Although some of the meteorological phenomena discussed may display a limited degree of variation in local intensity, such variation is not sufficiently predictable to enable large-scale mapping to be carried out.

2) Hazards in the Victoria Metropolitan Area

For hazards where the answers to all three questions posed earlier are affirmative, mapping local variation in intensity should be possible. Of the eleven natural hazards considered to be "urban" hazards in this study, only one or two can be rejected out of hand as not being applicable to the study site, the Victorian Metropolitan Area. Avalanches pose no problem since sufficient snow is not accumulated due to scanty snowfall, its rapid melting, and the low elevations of the mountainous regions. The nearest active volcano is Mount Baker, approximately 100 kilometres to the east. During an eruption, Victoria might be subjected to ashfall, but only in the unlikely event that upper level winds were from the east. At any rate, the ash would be more or less evenly distributed, obviating the necessity to map local variation.

Available data indicate that tsunamis, storm surges, and subsidence are experienced, but no significant losses have been recorded as a result. The maximum tsunami crest in Victoria from the May 1960 seismic sea wave was 73 centimetres.[10] The latter tsunami caused damage estimated at over ten million dollars on the west coast of Vancouver Island, but no losses were reported from Victoria. Although earthquakes centred in the Strait of Georgia may be tsunamigenic, there is no record of waves large enough to cause damage being generated. Storm surges occur during severe windstorms, especially when the air flow is from the southeast. When this happens, coastal erosion is accelerated and the flood potential is increased in low-lying coastal areas, mainly due to backing up of storm sewers. These factors are included in the consideration of coastal erosion and flooding, so a separate accounting is not warranted. Extremely localized subsidence may take place in areas underlain by Victoria Clay, but only very slowly under large structures. Sixty-five years of records indicate that the Empress Hotel, built on 6 metres of fill over 30 metres of Victoria Clay, has settled only 75 centimetres, with no discernible damage.[11]

Two hazards which have a potential for creating loss in the area, but have not been mapped in this study, are landslides and expansive soils. Mass movement occurs periodically along the exposed coastline, but since its effects are included in coastal erosion, it would be wrong to double account for these losses. Landslides seldom occur in non-coastal areas, and no data are available on damages incurred. Fine grained clay soils that are subjected to periods of wetness have a high shrink-swell potential. Such conditions exist in the study area, but unfortunately the available soil stability maps do not differentiate between expansive soils and other soils, such as silt and organic deposits with high water tables, which have poor stability characteristics. The definitive soil study of the area by Day and others, being concerned primarily with agricultural implications, makes no mention of expansive soils.[12]

3) SYMAP Hazard Mapping

The remaining four natural hazards have been mapped for the Victoria Metropolitan Area. Earthquakes, floods, and coastal erosion are major problems. Surface erosion is a lesser problem, but nevertheless it represents a source of loss which should not be disregarded in an overall risk survey. Parts of each hazard map are illustrated in appendix C. The data used to develop these maps will not be discussed in detail here[13], but a few comments on the computer mapping programme used, SYMAP (Synagraphic Mapping System), are appropriate. Version 5.20 of SYMAP has been modified at Simon Fraser University to accommodate 5000 data points. The computer used in producing the maps included in this study was an IBM 370/155K. A brief outline of basic programme components follows; examples of programme input appear in appendix A.

Two types of maps which can be produced by SYMAP are particularly applicable to risk mapping at a large scale. Conformant maps are normally used when the data have been obtained by averaging over defined zones are are assigned a single value for the entire zone. In addition to areas, zones may also be defined to display data values at a point along the line. The "line" conformant map is ideal for mapping hazard zones where the threatened area is linear, such as coastal erosion, tsunamis, storm surges, and riverine flooding. Contour maps consist of contour lines which connect all points having the same value. The contours shown on the map are for specified values which are assumed to vary smoothly over the interval between any two adjacent contour lines forming a continuous surface. The values have been obtained by sampling at the data points and SYMAP uses these data to interpolate the values at intervening locations, basing these interpolated values upon the values at data points and the distances between them.

Input to the programme is in the form of punched cards organized into a number of packages, each containing a specific type of information. Six packages are used in this study (appendix A). Used only with conformant maps, the A-CONFORMOLINES package specifies the boundaries of the data zones (areas, points, or lines). The A-OUTLINE package similarly specifies the outer boundaries for contour maps. Locations of the points for which data values are provided (sampling locations or centroids of data zones) are specified in the B-DATA POINTS package. THE C-OTOLEGENDS package is used to specify the relative position and content of supplementary information such as names, scale, and other special symbolism. Data values associated with each data point in the B-DATA POINTS package or with each data zone in the A-CONFORMOLINES package are named in the E-VALUES package. The F-MAP package instructs the programme to produce a map from the information provided and specifies the form of output through the use of various electives.

Any combination of 38 different electives may be included in the F-MAP package to define or modify various aspects of the output map. The electives used in the production of Maps 1-4 are indicated in appendix A. The use of any elective is optional, since every elective includes a default value, enabling a map to be produced in any event, but a note of caution is required on the use of Elective 25. This elective suppresses the appearance of all data point symbolism on the output map, replacing these with symbolism for the value at that print location. By default, data point symbolism will be printed. When this elective is <u>not</u> used, the reader of the output map is in a position to determine the density of data points, enabling him to evaluate the relative precision over the entire map surface.

D. Mapping Total Risk

1) Elements in Evaluating Loss Potential

It is suggested that the following elements are fundamental to any evaluation of variation in total loss potential for planning purposes within an urban area:

1. intensity of possible damaging natural events;
2. local spatial variation in intensity;

3. frequency of events of different intensities;
4. damage expected over a specified time period;
5. casualties expected over a specified time period.

The first two items refer specifically to the natural hazard, the last two describe the level of risk. The middle item, frequency, can be used to further describe the hazard, and it must be considered in evaluating the risk. It is obvious that not all risk determinants are included in the list. For example, season of the year, time of day, and prevailing weather conditions will affect potential losses. Damage and casualties are not the only results of natural disasters; indirect losses such as societal disruption and economic degradation can only be inferred from direct losses. Despite such limitations, it is considered that the five elements form a realistic framework for the development of risk maps.

The local variation in intensity of possible damaging natural events is portrayed on the individual hazard maps, where areas of different risk susceptibility have been assigned numerical values ranging from 1 to 3 or 4. Summing these values for any specific location in order to derive a total loss potential rating would be meaningless. This is because the assigning of the number 1, for example, to a point in the earthquake microzonation does not necessarily imply the same loss potential as assigning that number to a location on the coastal erosion hazard map. Before a realistic attempt can be made to determine total risk, a common unit of measure must be established.

2) Unit of Measurement

Many possible units of measurement can be contemplated. A weight factor could be applied to each hazard, based on such criteria as expected casualties, or estimated dollar loss per unit area. For example, if losses in a Zone 2 earthquake area are expected to be three times as high as those expected in a Zone 2 flooding area, then the ratio between these zones must remain at 3:1, regardless of the base established.

To enhance the value of loss potential maps to planners, the unit of measurement should be one in common use and suitable for comparison with the factors evaluated in the planning process. Monetary units appear to have several advantages over other possible systems of measurement. Since losses connected with disasters are usually assigned dollar values, it appears logical that risks should also be presented in a similar manner. This system simplifies the adjustment of values to account for inflationary or deflationary fluctuations. Perhaps the most important advantage of a monetary unit is that it is more readily understandable than any abstract numerical scale. Its major disadvantage is that it necessitates assigning monetary values to human life and injury, if all losses are to be considered.

The establishment of a monetary unit, referred to hereafter as a dollar unit, although any unit used in the study area would be equally applicable, leads to two further questions. Into what size base units will the study area be divided, and how will dollar losses per unit area be determined? The scale of current hazard maps varies from urban studies at a scale of 1:4,800 to international maps at one of 1:300,000,000. Information from maps ranging in scale from 1:2,400 to 1:50,000 was used to establish hazard ratings in this study. In determining the optimum size of the base unit, a choice had to be made between an area which would be too large to allow for considerations of urban planning and an area which would be so small as to require excessive interpolation for meaningful interpretation.

The base unit chosen for this study was one hectare, or 107,600 square feet. Since the available hazard maps and computer programme use the metric UTM grid as a co-ordinate system, a metric areal unit is appropriate. The area represented by any single co-ordinate is one hectare. One-tenth of a hectare, ten ares, or 10,760 square feet, is approximately equivalent to the average size of a large urban lot. It is simple, therefore, to convert losses per hectare to losses per average lot. A ten are unit might have been used in the first place, but it would give the impression of greater precision in the input values than actually exists.

3) Assessment of Potential Loss

Establishing dollar values for potential loss for a one hectare unit is difficult for regions which are not subject to frequent disasters, since there are little available data. However, values for losses caused by infrequent events can be estimated with some degree of precision by extrapolation and comparison with disaster prone regions where similar conditions, such as population density, standard of living, type of architecture, and methods of construction prevail. In this manner, potential losses for the Victoria Metropolitan Area can be estimated from the experience of California, an area which is both more frequently subjected to natural disasters and where these events have been analyzed in considerable detail. Accordingly, where data are non-existent for Victoria, information from the Urban Geology Master Plan for California is used in this study.[14]

The dollar losses per hectare developed below for each natural hazard are based on the assumption that the area in question is fully urbanized. To calculate the average value of one fully developed hectare, the market or actual value of both land and improvements in Victoria, Oak Bay, and Esquimalt (table II) has been used, since these areas are now almost completely developed.[15] For this purpose independent values for land and improvements are required since different events produce losses to various combinations of investments. For example, earthquakes affect improvements only, while coastal erosion destroys the land as well as buildings. The bottom line in table II indicates the average value per hectare of property, both public and private, which is at risk in a fully developed area.

TABLE II

VALUE OF LAND AND IMPROVEMENTS

	Land area (ha)	Land ($)	Improvements ($)	Total value ($)
Victoria	1878	962,095,830	1,122,153,380	2,084,249,210
Oak Bay	1046	301,611,664	259,579,698	561,191,362
Esquimalt	631	222,506,880	235,153,334	457,660,214
Totals	3555	1,486,214,374	1,616,886,412	3,103,100,786
Value/ha		418,063	454,820	872,883

SOURCE: British Columbia Assessment Authority, 1978.

4) Natural Hazard Losses

a) Earthquakes

In the Victoria Metropolitan Area, earthquakes are considered to be the only "urban" hazard likely to generate events of sufficient intensity to cause loss of life and injuries. No data on casualties attributable to earthquakes in the study area are available. It is probably safe to assume that no deaths have been caused by these events during the period of European settlement, since they would surely have been recorded. A similar assumption regarding injuries is more tenuous, as they are less likely to be considered newsworthy, and injury causes are seldom clearly identified in medical records. However, casualties from future, more intensive, earthquakes can be expected to be more extensive, and they should be considered in the estimation of total potential losses. Since local data are not available, the determination of possible casualties from earthquakes in the Victoria area follows the method used by the United States National Oceanic and Atmospheric Administration in their study of losses in San Francisco Bay Area.[16] Some gross assumptions must be made in order to do this.

Since construction methods and urban settlement patterns are similar in Seattle and Victoria, it will be assumed that casualty patterns will also be similar. A death rate of one per 100,000 population was experienced in the intensity VIII earthquake which struck the Puget Sound area in April 1949.[17] To establish the death rate for other intensities, further assumptions must be made. Based on the effects of the June 1946 earthquake in Victoria, no casualties are expected when intensities are VII or lower. Above intensity VIII, the death rate is expected to increase by one order of magnitude for each increment in Modified Mercalli intensity, so that at intensity IX it is one in 10,000 and at intensity X it is one in 1,000. This procedure coincides with that used in the California Urban Geology Master Plan and the rate for intensity X is the same as that used by Friedman in his loss simulation studies.[18] A ratio of ten serious injuries for each death is used here, the same rate as that used in the Puget Sound Council of Governments study.[19] These rates were converted to the common base of one hectare by dividing the average population density per hectare.[20]

Since the highest intensity and therefore the most casualties would be experienced in Zone 3 during an earthquake, potential losses for this zone were calculated (table III). A value of 200,000 dollars was placed on human life and 20,000 dollars was used as an average figure for costs associated with a serious injury. Although the parameters used in these calculations are not considered to be overly conservative, the cumulative total annual casualty losses per hectare for Zone 3 are only five cents per year. This sum is not included in the final loss totals which have been rounded out to the nearest dollar in each case.

In order to calculate potential losses from earthquakes for each zone, it is necessary to estimate the damage which would be sustained at different levels of intensity as well as the frequency of events at each level.

The limitations of various studies dealing with earthquake impact on urban infrastructures have been discussed by Foster and Carey.[21] For example, Whitman and associates were concerned only with buildings of a particular design, while Friedman generalized liberally on building types and land use. The method used by Foster and Carey to simulate anticipated earthquake damage, based on a building survey, cannot be applied to the present study which considers future damage to structures not yet built.

TABLE III

ZONE 3 EARTHQUAKE CASUALTY LOSSES

MMI	Death rate/ha	Injury rate/ha	Cost/ha/ event($)	Probability of annual exceedence	Annual loss/ha($)
VII	-	-	-	.036	-
VIII	.0000003	.000003	0.12	.015	0.0018
IX	.000003	.00003	1.20	.0081	0.0097
X	.00003	.0003	12.00	.0033	0.0396
Total loss/ha/year					0.0511

SOURCE: Probability of annual exceedance from W.G. Milne.

The set of damage ratios used here (table IV) was developed by Steinbrugge and associates for the San Francisco-Oakland Standard Metropolitan Statistical Area, and are the figures used to evaluate earthquake damage in the California Urban Geology Master Plan. These damage ratios, which are defined as the ratio of full cost of repairs to replacement cost of a dwelling, are based on a careful analysis of 28,785 dwellings to determine the probable level of damage that would occur if they were subjected to each level of intensity.[22]

Since the age of buildings, type of architecture, method of construction, and density of development in the San Francisco-Oakland area are relatively comparable to those in the Victoria area, it does not seem unreasonable to use similar damage ratios. Although these ratios are based on damage to residential units only, they are the best estimates available at this time.

TABLE IV

EARTHQUAKE DAMAGE RATIOS

Intensity (M M I)	Damage ratio	Loss/ha/ event($)
V	0.00103	468
VI	0.00476	2165
VII	0.02520	11461
VIII	0.08268	37605
IX-XII	0.12128	55161

SOURCE: Damage ratios from California Division of Mines and Geology Program Group, A Method of Setting Priorities, p. 3-19.

The last column in table IV shows the expected loss per hectare per event for each level of earthquake intensity. These figures were calculated by multiplying the appropriate damage ratio by the value per hectare of improvements only ($454,820) as given in table II. Some data are available to check the validity of the figures shown in table IV. The 1971 San Fernando earthquake has been more thoroughly analyzed than any previous seismic event, and far better data on property damage are available for this disaster than for any other American earthquake.[23] As discussed earlier, conclusions based on California data are fairly applicable to Victoria. Damage resulting from the 1971 intensity VIII-XI earthquake has been assessed at $104,720,000 (1977 dollars) for San Fernando city which has an area of 603 hectares, or the equivalent of \$173,665 per hectare,[24] indicating that the estimates in table IV may err on the conservative side.

Based on a statistical analysis of earthquakes experienced in Canada since 1899, probabilities of annual exceedence for various values of peak horizontal ground acceleration have been estimated and published as a supplement to the National Building Code.[25] Intensities are obtained from acceleration by applying the formula

$$\log_{10} A = \frac{I}{3} - 3.5$$

where A = acceleration in percent gravity

I = intensity as defined by the Modified Mercalli scale.

Probabilities of exceedances can be obtained for any site in Canada by writing to the Seismology Division, Earth Physics Brnach, Department of Energy, Mines and Resources. Probabilities for Victoria are shown as part of table V.[26]

Since the acceleration amplitudes used in computing the probabilities are the peak horizontal amplitudes on firm ground,[27] these probabilities are directly applicable to Zone 2 areas. For each level of probability, the intensity in Zone 1 areas will be reduced by one increment and increased by one in Zone 3 areas, as shown in table V. In each case the loss per hectare is calculated by multiplying the loss per hectare per event (from table IV) by the appropriate probability of annual exceedance. The cumulative annual loss per hectare for each zone is the value used as input for compilation

TABLE V

EARTHQUAKE LOSSES BY ZONE

Probability of annual exceedance	MMI	ZONE 1 Loss/ha ($)	MMI	ZONE 2 Loss/ha ($)	MMI	ZONE 3 Loss/ha ($)
.150	III	-	IV	-	V	70
.065	IV	-	V	30	VI	141
.036	V	17	VI	78	VII	413
.015	VI	32	VII	172	VIII	564
.0081	VII	93	VIII	305	IX	447
.0033	VIII	124	IX	182	X	182
Total loss/ ha/year		266		767		1817

SOURCE: Probability of annual exceedance from W.J. Milne.

of the total risk map. Estimated annual losses per hectare are 266 dollars in Zone 1, 767 dollars in Zone 2, and 1817 dollars in Zone 3.

b) Floods

Losses from floods are usually perceived as problems experienced only on floodplains of large rivers. Less dramatic but far more frequent and widespread is the inundation of low lying areas and the overflowing of minor water courses.

No major rivers exist in the study area and while local streams such as Bowker Creek have a history of flooding, comparatively little erosion damage results from these events.

For this reason, only inundation damage is considered here, with damage ratios based on the December 1956 Victoria flood. Damages from this event were estimated at 1,270,000 dollars, with claims per flooded home ranging between 350 and 700 dollars.[28] These claims represent one and two percent of total home value.

The vulnerability of residential structures to damage from flooding bears a direct relationship to the depth of inundation, which in turn is a function of the intensity of short duration rainfall.[29] By combining these two factors, a first estimate of future flood losses is possible.

There are several ways of estimating the design flood for small drainage systems. Formulae based on frequency analyses of floods of gauged streams can be used, if such data are available. In small areas, where it can be assumed that the rainfall intensity is uniform in time for the duration of the storm, that the rainfall is evenly distributed spatially, and that a single runoff coefficient is applicable, the Rational Formula may be applied:

$$Q = C I A$$

where Q = peak discharge

C = runoff coefficient

I = rainfall intensity for a selected return period

A = drainage basin area.[30]

One evaluation of flooding in the Victoria area, the Bilston Creek Study, employs the Rational Formula to develop the design flood.[31] Since accurate data, in particular the runoff coefficient, which is difficult to estimate for fully developed urban areas, are not available, the Bilston Creek Study data are used here to establish the return period of damaging floods. It was estimated that a flood of the 1956 magnitude can be expected once every 20 years, while a flood reaching 60 percent of this maximum can be expected once every 10 years.[32]

As discussed earlier, the level of inundation can be used to set the extent of expected flood damage. In calculating the figures for table VI, it was assumed that the level of inundation necessary to cause two percent damage would occur only in Zone 3 (frequent flooding) areas under maximum (20 year) flood conditions, while one percent damage could be expected in intermediate (10 year) floods. Similarly, Zone 2 (occasional flooding) areas would only suffer one percent damage under maximum flood conditions. In Zone 1 areas, flooding occurs rarely, if ever, so no losses are expected. A density of 13 dwellings per hectare was used in calculating the loss per year per hectare shown in the final column of table VI.[33]

TABLE VI

FLOOD LOSSES BY ZONE

Zone	Loss/dwelling/ event ($)		Average loss/ year($)	Loss/ year/ ha($)
	10 year flood	20 year flood		
1	0	0	0	0
2	0	350	17.5	227
3	350	700	70	910

c) Surface Erosion

Losses from surface erosion would be relatively simple to estimate if the annual erosion rate for the various Victoria area soils were known, since they are adequately mapped. Unfortunately, these erosion rates have not been determined, and very little has been done in Canada on this problem.[34] Soil losses from sheet and rill erosion may be estimated by using the Universal Soil Loss Equation:

$$A = RKLSCP$$

where A = average annual soil loss in tons per acre
R = rainfall factor
K = soil erodibility factor
L = length of slope factor
S = steepness of slope factor
C = cropping and management factor
P = supporting conservation practice factor.[35]

An attempt has been made here to apply the equation to representative soil and geomorphic conditions for surface erosion Zone 2 (moderate susceptibility) and Zone 3 (high susceptibility). Zone 1 areas have only very slight erosion potential, their losses are negligible, and therefore are excluded from further consideration. Each factor in the equation will be discussed in turn before evaluating the erosion potential in each zone.

The rainfall factor (R) expresses the capacity of the locally expected rainfall to erode soil from a cultivated fallow field. By recording the product of the total kinetic energy of a storm and its maximum 30-minute intensity from rainfall records, maps showing isoerodents, lines connecting points that have the same average annual rainfall erosion index, have been compiled for the United States. Extrapolating from areas in the state of Washington which receive similar rainfall, an R value of 15 can be derived for the Victoria Metropolitan Area.[36]

The soil erodibility factor (K) reflects the fact that variation in physical properties such as texture, size and stability of structure, permeability, and organic matter content leads to erosion at different rates. Again, no data on the K factor of Victoria area soils are available but comparisons based on soil descriptions are possible. Various soils are represented in soil erosion Zone 2, but sandy loams (Cadboro, Langford, Shawnigan) appear to predominate.[37] K factors of .28 to .22 have been assigned to sandy loam in the United States.[38] Since the local sandy loams grade toward loamy sand (K factors .10 to .08), the lower value (.22) has been allotted to Zone 2 soils. Clay and clay loams (Cowichan, Saanichton) predominate in Zone 3 areas. An average K factor of .31 (United States range .36 to .26) has been assigned to soils in this zone.

In applying the soil loss formula, the equations for length and steepness of slope are usually combined. The factor (LS) is the ratio of loss for any steepness and length of slope with the arbitrarily selected standard of a 9 percent, 22.1 metre slope. It would be incorrect to attempt to apply overall averages of slope length and gradient to compute soil loss in a complex watershed.[39] Instead, as with factor K, a representative slope for Zone 2 and 3 has been used. For

Zone 2, this was a 7%, 426 metre slope, which yields 1.7 as an LS factor.[40] A typical Zone 3 slope was one of 12%, 457 metres, for an LS factor of 3.6.

Factors C and P are expected to be the same for both soil erosion zones. The cropping-management factor (C) is the expected ratio of soil loss from land cropped under specified conditions to that from continuous fallow. The average urban "crop" is grass cover with no appreciable canopy, yielding a C factor of .013.[41] No conservation practices are expected to be carried out, so factor P is set at 1.0.

Before a final estimate for soil erosion per hectare can be made, two more factors must be considered. In fully developed regions of the Victoria urban area, approximately one-third of the surface is covered by buildings, roads, driveways, or parking lots, confining that portion susceptible to erosion to 66 percent of the total area.[42] Finally, to convert tons per acre to metric tons per hectare, a conversion factor of 2.2439 is used.

Using the Universal Soil Loss Equation and taking into consideration the two factors mentioned above, soil erosion in Zone 2 is estimated to be:

$$15 \times .22 \times 1.7 \times .013 \times 1 \times .66 \times 2.2439$$

or 0.1080 metric tons per hectare. For Zone 3 it would be:

$$15 \times .31 \times 3.6 \times .013 \times 1 \times .66 \times 2.2439$$

or 0.3223 metric tons per hectare. These results are shown in table VII.

The most productive surface soils are the ones first lost to erosion. Topsoil prices in Victoria in 1978 averaged eleven dollars per metric ton.[43] The direct cost of soil losses is, therefore, $1.19 per hectare in Zone 2 and $3.55 in Zone 3.

Erosion is a process in which soil is removed, transported, and eventually deposited. In calculating damage to urban areas, the cost of siltation or deposition resulting from erosion must be included. Experience in California indicates that with an erosion rate of 3.7995 metric tons per hectare, the cost per hectare of cleaning and repairing street,s drains, and sewers is estimated to be $11.06 per hectare.[44] By adjusting these figures to take cognizance of Canadian wages in 1978, equipment costs, and the erosion rates in Zones 2 and 3, indirect costs resulting from sediment deposition per hectare are derived,[45] and are shown in table VII.

TABLE VII

SURFACE EROSION LOSSES

Zone	Erosion (metric tons/ ha)	COSTS ($)		
		Direct	Indirect	Total
1	0	0	0	0
2	0.1080	1.19	1.75	2.94
3	0.3223	3.55	5.21	8.76

The total annual losses from surface erosion are \$2.94 per hectare in Zone 2 and \$8.76 per hectare in Zone 3 (table VII). It should be emphasized that these figures underestimate the impact of this hazard since they do not include the cost of such items as siltation of reservoirs, loss of aquatic life, degradation of lake and river recreational developments, and damage to structures which may occur during high storm flows. During construction, when the ground cover is completely removed, factor C in the Universal Soil Loss Equation can reach 1.0. As a result, erosion rates may be multiplied hundredfold.[46]

d) Coastal Erosion

Coastal erosion rates for the study area have been mapped by Foser.[47] He estimated annual erosion rates for each of four zones (table VIII); average 100-year erosion rates have been calculated from these figures.

Since any point identified on the coastal erosion hazard map represents 100 metres of coastline, this length is used in table VIII to illustrate the expected losses. In any area, actual losses from coastal erosion will be restricted to the immediate coast, not throughout the area. However, losses are permanent. Cliff recession occurs, so that over a 100-year period, inland areas are eroded. The size of the area ultimately affected in such a time period reflects the speed of erosion.

In calculating annual loss from coastal erosion, the value of both land and improvements must be included, representing a current value of 872,883 dollars per hectare (table II) for an urbanized area. These losses for each zone are shown in the final column of table VIII.

TABLE VIII

COASTAL EROSION LOSSES

Zone	Rate of erosion (m/100 years)	Average erosion (m/100 years)	Area eroded/100m of coastline (ha/year)	Annual loss ($)
1	0	0	0	0
2	7-15	11	0.0011	960
3	15-30	22	0.0022	1920
4	> 30	33	0.0033	2880

SOURCE: Rate of erosion from Foster, "Coastal Erosion", p. 165.

5) Integration of Total Losses

A new computer programme was developed to convert hazard ratings to the dollar values just discussed (summarized in table IX), and to permit the integration of these values into a single map. Had the final map been intended as a one time output, the first step would have been superfluous, as the dollar value could have been inserted in the first instance. Since it is intended to revise the map each time significant new information becomes available, the procedure of conversion used in the programme allows a revision in dollar losses to be accomplished by changing only one data card per hazard rather than amending each E-VALUES card. The complete programme is

TABLE IX

SUMMARY OF POTENTIAL ANNUAL DOLLAR LOSSES

Hazard	Zone 1	Zone 2	Zone 3	Zone 4
Earthquake	266	767	1817	-
Flooding	0	227	910	-
Surface erosion	0	3	9	-
Coastal erosion	0	960	1920	2880

shown in appendix B.

In brief, what the programme does is as follows. The SYMAP programme is run, producing individual maps for each hazard, and recording the data on a disk file. A symbolism scale is read in, allowing a range of 36 classes for output later. For each data point, the hazard ratings are read, and placed into the appropriate dollar value (DOLVAL) class, as shown in table X. The DOLVAL class is converted to the symbolism scale and printed as the output map.

The greatest advantage of this method of mapping potential losses due to natural hazards may be the fact that losses are portrayed as dollar values, while a further big advantage is the ease with which the final map can be amended as new information becomes available. Some possible amendments are discussed below.

The integrating programme works on data from the SYMAP programme, so changes in the latter are reflected in the final map. Since these were commented on earlier, it need only be mentioned here that changes in map scale, or the rating for any data point only entails changing one card. Revising the number of classes of rating a hazard would require changing the entire E-VALUES set of cards for that hazard.

It is expected that in actual planning use the dollar values (table II) will be amended annually to reflect changes in the value of land and improvements. Reassessment of losses for various hazard rating levels would also necessitate changing input values in all the tables based on data from table II,

TABLE X

DOLLAR VALUE (DOLVAL) UPPER LIMITS

10 Classes

DOLVAL upper limit	560	1120	1680	2240	2800
Symbolism scale	35	32	31	30	28
DOLVAL upper limit	3360	3920	4480	5040	5616
Symbolism scale	23	19	17	13	07

36 Classes

DOLVAL upper limit	155	310	465	620	775	930	1085
Symbolism scale	36	35	34	33	32	31	30
DOLVAL upper limit	1240	1395	1550	1705	1860	2015	2170
Symbolism scale	29	28	27	26	25	24	23
DOLVAL upper limit	2325	2480	2635	2790	2945	3100	3255
Symbolism scale	22	21	20	19	18	17	16
DOLVAL upper limit	3410	3565	3720	3875	4030	4185	4340
Symbolism scale	15	14	13	12	11	10	09
DOLVAL upper limit	4495	4650	4805	4960	5115	5270	5425
Symbolism scale	08	07	06	05	04	03	02
DOLVAL upper limit	5616						
Symbolism scale	01						

and adjusting the upper limits in table X accordingly.

Up to 36 different classes of dollar value can be selected for printing on the final total risk map. Two maps are illustrated in this study, one with 10 classes for a better visual appreciation of hazard zoning, and one with 36 classes to allow the finest discrimination possible for each print point. Upper class limits were chosen at regular intervals, but this is optional. For example, it would be possible to individually portray each of the 27 combinations of values for inland data points, leaving 9 additional classes for coastal points. Details on the changes required to amend the number of classes are given in appendix B.

The type of symbolism used in printing the map can be controlled by choosing appropriate DATA NAMES programme cards. Appendix B shows the cards required to produce a shading scale through overprinting. The accompanying maps illustrate two types of symbolism. The gray scale index used in Map 5 produces a graphic presentation of data. However, when the number of classes approaches 36, it becomes difficult to differentiate between classes with this system. To overcome this problem, a new scale was devised, as illustrated on Map 6. Although the visual impact is lost, actual values at any point can be readily interpreted.

Four natural hazards were used in this study, but the programme can be readily altered to accommodate a lesser or greater number of hazards. Again, details for such a revision are included in appendix B. Two versions of the total risk map were produced (Maps 5 and 6).

It should be clearly understood that risk maps produced in this manner are subject to the accumulated effects of errors in the input data. As discussed, the hazard maps are based on the best available data, but they reflect a limited historical record. For example, the earthquake hazard map is based on information from a single event in the Victoria area, augmented by results of studies elsewhere in the world. Figures used to calculate annual dollar losses per zone are subject to errors of unknown magnitude stemming either from the data or from the assumptions made. However, these drawbacks do not detract from the methodology developed here, but rather emphasize the advantage of a technique which facilitates timely incorporation of new data.

E) Conclusion

Five significant variables which should be incorporated into a single map have been outlined. To produce one such map using traditional techniques would be a formidable task. It would require cumbersome calculations of various combinations of numbers and the use of handdrawn overlay maps to develop the most rudimentary total risk map. To amend such a map every time important new data became available, or when key variables changed, would be unthinkable. Fortunately, the speed and flexibility of computers is such that constraints of time and money expenditures are overcome. The computer allows rapid input of data, provides large storage capacity, allows manipulation of stored data, and permits output results to be shown in various formats for clear understanding of the results.

The methodology which has been reviewed here is designed to facilitate the production of large-scale total risk maps to portray annual losses from urban natural hazards. It appears to offer many improvements over earlier techniques used in risk mapping. Quantitative comparison between any number of different hazards is now possible, and a major innovation is in the programme to integrate data from various hazards into a single total risk map. Where applicable, the probability of events of different magnitudes is incorporated into the data base in order to advance the final map from a portrayal of relative risk to that of probabilistic risk. The technique is very flexible in that it can be applied universally to any number of hazards. Changes in scale, output format, numbers of intensity levels, or amendments made necessary by revised or additional new data can easily be accommodated. Since a computer is used both to do most of the calculations and to print the maps, production costs are reduced and results are available in a minimum of time. The final product appears in a form that is readily comprehensible by both layman and scientist.

Development of the integrating programme was initiated only after it had been established that data from four hazard maps with three or four levels of intensity needed to be summed. This sequence of events no doubt affected the final form of the programme, because at this stage, the flexibility to change input and output variables was of secondary importance.

Only when the programme successfully performed the summation of the four data sets and printed a map was attention turned to added refinements. As a result, it is obvious that modifications could be made which would simplify changing both the input and output parameters.

Although this programme was developed specifically to integrate values from discrete hazard maps, it appears readily adaptable for use in many situations where the overlay technique is required.

FOOTNOTES

[1] Carl Steinitz et al., "Hand-Drawn Overlays: Their History and Prospective Uses," Landscape Architecture (September 1976): 444-455.

[2] Ian L. McHarg, Design With Nature (Garden City, N.Y.: The Natural History Press, 1969), pp. 35-40.

[3] Steinitz, "Hand-Drawn Overlays," p. 448.

[4] For a more comprehensive account, see Vilho Wuorinen, "A Methodology for Mapping Total Risk in Urban Areas," Ph.D. dissertation, University of Victoria, 1979.

[5] Office of Emergency Preparedness, Disaster Preparedness, Vol. 1 p. 3.

[6] Vancouver Sun, 28 April 1977, p. 12.

[7] Office of Emergency Preparedness, Disaster Preparedness, Vol. 1, p. 125.

[8] Ibid., p. 131.

[9] B.A. Bolt et al., Geological Hazards (New York: Springer-Verlag, 1975), p. 283.

[10] S.O. Wigen, "Tsunami of May 22, 1960- West Coast of Canada," Victoria, n.d., p. 3.

[11] C.B. Crawford and J.G. Sutherland, "The Empress Hotel, Victoria, British Columbia. Sixty-Five Years of Foundation Settlements" Canadian Geotechnical Journal 8 (1971): 77.

[12] J.H. Day, et al., Soil Survey of Southeast Vancouver Island and Gulf Islands, British Columbia, Report No. 6 of the British Columbia Soil Survey (Ottawa: Queen's Printer, 1959).

[13] See Wuorinen, "Methodology for Mapping Total Risk," pp. 128-164, for detail.

[14] California Divisions of Mines and Geology Program Group, *Urban Geology Master Plan for California, Phase 1: A Method for Setting Priorities* (Sacramento; State of California, 1971), p. 3-6.

[15] Market values for 1978 were obtained from the Capital Area Assessment Office, British Columbia Assessment Authority, Victoria; land areas from municipal governments, 1978.

[16] National Oceanic and Atmospheric Administration, *A Study of Earthquake Losses in the San Francisco Bay Area* (Washington: U.S. Government Printing Office, 1972).

[17] Ibid., p. 110.

[18] Don G. Friedman, *Computer Simulation in Natural Hazard Assessment* (University of Colorado: Institute of Behavioral Science, 1975), p. 43.

[19] Puget Sound Council of Governments, *Regional Disaster Mitigation Technical Study for the Central Puget Sound Region*, Vol. II (Seattle: N.p., 1975), p. 145.

[20] For Victoria, Oak Bay, and Esquimalt, the total population in 1976 was 95,262, yielding a density of 26.8 persons per hectare. This was rounded out to 30 persons per hectare, to allow for some increase in density in the future. A rate of 1 per 1000, for example, is equivalent to 30 ÷ 1000 x .001 or .00003 per hectare.

[21] Harold D. Foster and R.F. Carey, "The Simulation of Earthquake Damage", in *Victoria: Physical Environment and Development*, ed. H.D. Foster (Victoria: University of Victoria, 1976), pp. 221-240.

[22] California Division of Mines and Geology Program Group *Urban Geology Master Plan for California: Phase I: A Method for Setting Priorities* (Sacramento: State of California, 1971), p. 3-19.

[23] Gordon B. Oakeshott, ed., *San Fernando, California, Earthquake of 9 February 1971* (Sacramento: California Division of Mines and Geology, 1975).

[24] Ibid., p. 326. The dollar loss estimated in 1971 was $70,000,000. This has been inflated to a 1977 level, in order to have comparability with the values in table XXIII, by using the United States Consumer Price Index (1971 = 121.3; 1977 = 181.5).

[25] Associate Committee on the National Building Code, *Commentaries on Part of the National Building Code of Canada* (Ottawa: National Research Council, 1977), p. 92.

[26] W.G. Milne, private communication, 11 September, 1978.

[27] Associate Committee on the National Building Code, *Commentaries on Part 4*, p. 93.

See pp. 148-9 for details.

[28] *Victoria Daily Times*, 11 December 1956, p. 15. The $359,000 loss estimated in 1956 was inflated to a 1977 level, using the Residential Building Construction Input Price Index (1956 = 49.6; 1977 = 175.5).

[29] Don G. Friedman, *Computer Simulation in Natural Hazard Assessment* (University of Colorado: Institute of Behavioral Science, 1975), p. 120.

[30] J.P. Bruce and R.H. Clark, *Introduction to Hydrometeorology* (Toronto: Pergamon Press, 1966), p. 245.

[31] W.S. Jackson, "Preliminary Drainage Report Bilston Creek Improvement District April 1959" File 0215736.

[32] Ibid., p. 7.

[33] According to the 1971 census, there were 24,740 dwellings in the city of Victoria (area = 1878 ha.).

[34] For one notable exception, see L.J.P. Van Vliet, et al., "Effects of Agricultural Land Use on Potential Sheet Erosion Losses in Southern Ontario", *Canadian Journal of Soil Science* 56 (November 1976): 443-451.

[35] R.P. Beasley, *Erosion and Sediment Pollution Control* (Ames, Iowa: The Iowa State University Press, 1972), pp. 39-68.

[36] United States Department of Agriculture, *Sheet and Rill Erosion Control Guide: State of Washington* (Spokane: Soil Conservation Service, 1976), p. 3.

[37] Soil Map of Vancouver Island, Victoria-Saanich Sheet, 1958.

[38] Beasley, Erosion and Sediment Pollution Control, table 4.3, p. 44.

[39] W.H. Wischmeier, "Use and Misuse of the Universal Soil Loss Equation", Soil Erosion: Prediction and Control, (Ankeny, Iowa: Soil Conservation Society of America, 1976), p. 374. The use of representative slopes to determine LS values is suggested in Erosion Control Guide: State of Washington, p. 4.

[40] From chart 1, Erosion Control Guide: State of Washington, p. 7.

[41] Ibid., p. 22.

[42] Estimated by the author from a study of airphotographs of Victoria, Oak Bay, and Esquimalt.

[43] Victoria Daily Times, 10 July 1978, p. 25.

[44] California Division of Mines and Geology Program Group, A Method of Setting Priorities, pp. 3-48 and 3-49. It was estimated that it takes 1/10 man-year of employment and equivalent amounts for cost of equipment and repairs to clean one urban unit (area = 97.6 ha.).

[45] With an erosion rate of 3.7995 tons/ha., it will take one year to clean 976 ha. At an erosion rate of .108 tons/ha., one year's effort would clean 34,336 ha. Similarly, at a rate of .3223 tons/ha., 11,506 ha. could be cleaned. The annual cost of a man, machines, and repairs are $60,000 (private communication, Victoria Public Works, 15 August, 1978).

[46] United States Department of Agriculture, Erosion Control Guide: State of Washington, p. 29.

[47] Harold D. Foster, "Coastal Erosion: A Natural Hazard of the Saanich Peninsula, Vancouver Island", in Victoria: Physical Environment and Development, ed. H.D. Foster (Victoria: University of Victoria, 1976), pp. 131-184.

APPENDIX A

SYMAP PROGRAMME

```
C
C  THE PROGRAMME CARDS USED TO PRODUCE HAZARD MAPS ARE
C  LISTED BELOW, COMPLETE EXCEPT THAT ONLY EXAMPLES OF
C  A-OUTLINE, A-CONFCRMOLINES, AND B-DATA POINTS
C  CO-ORDINATES, AND C-OTOLEGENDS AND E-VALUES INPUT ARE
C  INCLUDED.  WHEN RUNNING THE SYMAP PROGRAMME, ALL COMMENT
C  CARDS MUST BE REMOVED.  THE FIRST PACKAGE INCLUDES
C  CONTROL CARDS, WHOSE USE MAY VARY WITH THE FACILITY BEING
C  USED.
C
//A560VALW JOB (****,*****),'WUORINEN',MSGLEVEL=(1,1),
//  TIME=15
/*JOBPARM LINES=20
// EXEC SYMAP,REGION.GO=240K
//GO.FT08F001 DD DSN=WYL.SC.TKP.VAL1,
// UNIT=1DAY,SPACE=(TRK,(10,10)),DISP=(,CATLG,DELETE),
// DCB=(RECFM=VSB,LRECL=524,BLKSIZE=5244)
//GO.FT08F002 DD DSN=WYL.SC.TKP.VAL2,
// UNIT=1DAY,SPACE=(TRK,(1,1)),DISP=(,CATLG,DELETE),
// DCB=(RECFM=VSB,LRECL=524,BLKSIZE=5244)
//GO.FT08F003 DD DSN=WYL.SC.TKP.VAL3,
// UNIT=1DAY,SPACE=(TRK,(1,1)),DISP=(,CATLG,DELETE),
// DCB=(RECFM=VSB,LRECL=524,BLKSIZE=5244)
//GO.FT08F004 DD DSN=WYL.SC.TKP.VAL4,
// UNIT=1DAY,SPACE=(TRK,(1,1)),DISP=(,CATLG,DELETE),
// DCB=(RECFM=VSB,LRECL=524,BLKSIZE=5244)
//GO.SYSIN DD *
C
C  THE A-OUTLINE PACKAGE DEFINES THE OUTLINE OF THE STUDY
C  AREA, WITH THE VERTICES LISTED IN CLOCKWISE ORDER AROUND
C  THE AREA. IN ALL THE PACKAGE TITLE CARDS, ANY SYMBOL IN
C  COLUMN 25 SUPPRESSES PRINTOUT OF THE INPUT LISTING. 456
C  VERTICES WERE USED TO OUTLINE THE VICTORIA METROPOLITAN
C  AREA.
C
A-OUTLINE                X
                    -610       590
                    -670       590
                    -668       604
99999
C
C  ONE B-DATA POINTS PACKAGE WAS USED FOR ALL THE CONTOUR
C  MAPS, IDENTIFYING 1423 SAMPLING LOCATIONS.
C
B-DATA POINTS            X
                    -610       590
                    -610       595
                    -610       600
99999
C
C  THE C-OTOLEGENDS PACKAGE SPECIFIES THE RELATIVE POSITION
C  OF THE REFERENCE GRID, LEGEND, AND NAMES ON THE MAPS.FOR
```

```
C  EACH STRING OF CHARACTERS TWO CARDS ARE REQUIRED: THE
C  FIRST CARD IDENTIFIES THE STARTING LOCATION AND DIRECTION
C  (A MINUS IN COLUMN 1 INDICATES THAT THE STRING IS TO BE
C  PRINTED VERTICALLY, FROM TOP TO BOTTOM), THE SECOND CARD
C  SPECIFIES WHAT IS TO BE PRINTED.
C
C-OTOLEGENDS                X
-   3    P      -608         590
590
   15    P      -921         611
SCALE IN METRES
99999
C
C  A SEPARATE E-VALUES PACKAGE IS REQUIRED FOR EACH HAZARD.
C  THESE CARDS MUST BE READ IN THE SAME ORDER AS THE
C  CORRESPONDING DATA POINTS. IF DATA IS MISSING FOR ANY
C  POINT INCLUDED IN THE B-DATA POINTS PACKAGE, A BLANK CARD
C  IS INSERTED IN THE PROPER SEQUENCE, AND ELECTIVE 18 IS
C  USED IN THE F-MAP PACKAGE. 1423 DATA VALUES WERE
C  AVAILABLE FOR THE EARTHQUAKE HAZARD MAP, 1360 FOR THE
C  FLOODING AND SURFACE EROSION MAPS.
C
E-VALUES                    X
                       1

                       2
                       1
99999
C
C  A SEPARATE F-MAP PACKAGE IS REQUIRED FOR EACH HAZARD MAP.
C  THE CHOICE OF ELECTIVES CONTROLS THE FORM OF THE OUTPUT
C  MAP.
C
C  ELECTIVE 1 SPECIFIES THE MAP DIMENSIONS, AND ELECTIVE 2
C  SPECIFIES THE MAP WINDOW. THESE TWO CARDS MUST BE AMENDED
C  IF THE MAP SCALE IS CHANGED. SEE CHAPTER 5 FOR DETAILS.
C
C  ELECTIVE 3 SETS THE NUMBER OF CLASS INTERVALS, UP TO A
C  MAXIMUM OF 10.  IF THE NUMBER OF SEVERITY ZONES FOR A
C  HAZARD IS CHANGED,THIS CARD MUST BE AMENDED ACCORDINGLY.
C
C  ELECTIVE 8 SUPPRESSES PRINTING OF CONTOUR LINES AND
C  BOUNDARIES.
C
C  ELECTIVE 9 SUPPRESSES PRINTING OF THE HISTOGRAM.
C
C  ELECTIVE 17 SUPPRESSES PRINTING OF THE TABULAR OUTPUT
C  DATA.
C
C  ELECTIVE 18 SETS ANY VALUE (0 IN THIS CASE) AS AN INVALID
C  DATA VALUE.
C
C  ELECTIVE 21 CREATES A SYMVU TAPE WHICH IS REQUIRED TO
C  PROVIDE INPUT TO THE INTEGRATING PROGRAMME.
C
```

```
C  ELECTIVE 23 SUPPRESSES THE PRINTING OF SYMBOLISM OVER
C  POINTS WITH INVALID DATA VALUES AS DECLARED IN ELECTIVE
C  18.
C
C  ELECTIVE 36 SETS THE NUMBER OF POINTS USED FOR
C  INTERPOLATION, UP TO A MAXIMUM OF 10.
C
C  ELECTIVE 10 ALLOWS THE PRINTING OF UP TO 30 CARDS OF
C  EXPLANATORY TEXT.
C
F-MAP
EARTHQUAKE MICROZONATION OF VICTORIA METROPOLITAN AREA
SCALE 1:25000
BASED ON 1423 DATA POINTS
    1          53.23     35.43
    2          -943.      585.     -605.      810.
    3             3.
    8
    9
   17
   18             0.
   21
   23
   36                      4.
   10
MAP 1 - EARTHQUAKE MICROZONATION
LEVEL 1 = MODIFIED MERCALLI INTENSITY INCREMENT OF MINUS 1
LEVEL 2 = MODIFIED MERCALLI INTENSITY INCREMENT OF ZERO
LEVEL 3 = MODIFIED MERCALLI INTENSITY INCREMENT OF PLUS 1
9999
99999
C
E-VALUES                X
                   1
                   1
                   1
99999
C
F-MAP
FLOODING AND PONDING IN VICTORIA METROPOLITAN AREA
SCALE 1:25000
BASED ON 1360 DATA POINTS
    1          53.23     35.43
    2          -943.      585.     -605.      810.
    3             3.
    8
    9
   17
   18             0.
   21
   23
   36                      4.
   10
```

```
MAP 2 - FLOODING AND PONDING
LEVEL 1 = NO FLOODING OR PONDING
LEVEL 2 = OCCASIONAL FLOODING OR PONDING
LEVEL 3 = FREQUENT FLOODING OR PONDING
9999
99999
C
E-VALUES                 X
                    1
                    1
                    1
99999
C
F-MAP
SURFACE EROSION IN VICTORIA METROPOLITAN AREA
SCALE 1:25000
BASED ON 1360 DATA POINTS
    1          53.23     35.43
    2          -943.      585.      -605.      810.
    3             3.
    8
    9
   17
   18             0.
   21
   23
   36                      4.
   10
MAP 3 - SURFACE EROSION
LEVEL 1 = SLIGHT SUSCEPTIBILITY TO SURFACE EROSION
LEVEL 2 = MODERATE SUSCEPTIBILITY TO SURFACE EROSION
LEVEL 3 = HIGH SUSCEPTIBILITY TO SURFACE EROSION
9999
99999
C
C  THE A-CONFORMOLINES PACKAGE DEFINES THE BOUNDARIES OF
C  DATA ZONES FOR THE CONFORMANT MAP.THE FIRST CARD FOR EACH
C  ZONE (LINE IN THIS CASE) ASSIGNS A REFERENCE NUMBER IN
C  COLUMN 5 AND THE STARTING CO-ORDINATES. THE E-VALUES
C  PACKAGE CONTAINS ONLY 4 VALUES, SINCE THE REFERENCE
C  NUMBER USED TO IDENTIFY EACH ZONE CORRESPONDS TO ONE OF
C  THE 4 LEVELS OF COASTAL EROSION.
C
A-CONFORMOLINES          X
    1    L      -610      643
                -610      590
                -720      590
99999
C
E-VALUES                 X
                    1
                    2
                    3
                    4
99999
```

```
C
F-MAP
COASTAL EROSION IN VICTORIA METROPOLITAN AREA
SCALE 1:25000
BASED ON ORIGINAL STUDY BY HAROLD D. FOSTER, UVIC
    1          53.23     35.43
    2          -943.      585.      -605.       810.
    3             4.
    8
    9
   17
   18             0.
   21
   23
   25
   10
MAP 4 - COASTAL EROSION
LEVEL 1 = NEGLIGIBLE (LESS THAN 7.62 CM/YEAR)
LEVEL 2 = SMALL (7.62 TO 15.24 CM/YEAR)
LEVEL 3 = MODERATE (15.24 TO 30.48 CM/YEAR)
LEVEL 4 = RAPID (MORE THAN 30.48 CM/YEAR)
9999
99999
999999
/*
```

APPENDIX B

INTEGRATING PROGRAMME

THE PROGRAMME HAS THE FOLLOWING BASIC PARTS:

A. DECLARATIONS AND INITIALIZATION
B. INPUT OF THE INFORMATION DEFINING THE VARIOUS SEVERITY LEVELS.
C. CALCULATION AND PRINTING OF THE RISK MAP, ROW BY ROW.
D. PRINTING OF THE LEGEND

```
//KEDUNNER JOB (****,*****),'INTEGRATING PROGRAMME',
//   TIME=(4,59),MSGCLASS=R
/*JOBPARM LINES=100
// EXEC FORTGCLG,REGION.GO=210K
//FORT.SYSIN DD *

      EQUIVALENCE (XINK,LINK)
C
C THE FOLLOWING CARD MUST BE AMENDED IF THE NUMBER OF SEVERITY
C LEVELS IS CHANGED, OR THE NUMBER OF HAZARDS IS CHANGED.
C FOR EXAMPLE, IF THE NUMBER OF SEVERITY LEVELS FOR
C EARTHQUAKES WERE CHANGED FROM 3 TO 5, AND A LANDSLIDE
C HAZARD WITH 2 SEVERITY LEVELS WERE ADDED, THEN THE CARD
C WOULD BECOME:
C     DIMENSION EAQU(5),FLOD(3),SEROS(3),COROS(4),SLIDE(2),
C    1DOLVAL(36)
C
      DIMENSION EAQU(3),FLOD(3),SEROS(3),COROS(4),DOLVAL(36)
C
C EARTHQUAKE, FLOODING, SOIL EROSION AND COASTAL EROSION
C DATA PER HECTARE
C DOLVAL = DOLLAR VALUE FOR THE OUTPUT GROUP
C
      INTEGER ROWS,NCOLS,COLS
      REAL RND
C
C THE FOLLOWING DIMENSION CARD MUST BE AMENDED IF AN EXTRA
C HAZARD MAP IS INCLUDED.  FOR EXAMPLE, ADD XIN5(131) AND
C IN5(131)
C
      DIMENSION XIN1(131),XIN2(131),XIN3(131),XIN4(131),
     1IN1(131),IN2(131),IN3(131),IN4(131),
     2OUT(131),IOUT(131)
      INTEGER INDEX(36),UT(131,5)
      DIMENSION NAMES1(37),NAMES2(37),
     1NAMES3(37),NAMES4(37),NAMES5(37),NL(36)
      DATA NAMES1/'M','M','M','M','M','M','M','H','H',
     1'H','H','H','X','H','X','O','Z','W','M','N','H',
     2'O','O','S','=','I','*','+','+','=',':','-','.',
     3'-','''','.',' '/
```

```
      DATA NAMES2/'W','W','W','W','W','W','W','#','#',
     1'#','*','+','+','-','-','-','-',' ',' ',' ',' ',
     2' ',' ',' ','=',' ',' ','-',' ',' ',' ',' ',' ',
     3' ',' ',' ',' '/
      DATA NAMES3/'#','#','#','#','#','O','O','+','-',
     1' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',
     2' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',
     3' ',' ',' ',' '/
      DATA NAMES4/'O','O','O','O',' ',' ',' ',' ',' ',
     1' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',
     2' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',
     3' ',' ',' ',' '/
      DATA NAMES5/'O','+',' ',' ',' ',' ',' ',' ',' ',
     1' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',
     2' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',
     3' ',' ',' ',' '/
      DATA NL/36*0/
C
C REMEMBER, THE PROGRAMME GETS DATA FROM SYMAP AND WORKS ON
C ONE LINE AT A TIME
C
C IF THE NUMBER OF SEVERITY LEVELS IS CHANGED, THE
C CORRESPONDING CARDS BELOW MUST BE CHANGED. FOR EXAMPLE, IF
C 'EAQU(3)' IN THE DIMENSION STATEMENT WAS CHANGED TO
C 'EAQU(5)', THEN
C 'READ(5,1002) (EAQU(I),I=1,3)' WOULD BECOME
C 'READ(5,1002) (EAQU(I),I=1,5)'
C
C IF AN EXTRA HAZARD IS ADDED, AN EXTRA 'READ' CARD IS
C REQUIRED, FOR EXAMPLE:
C     READ(5,1002) (SLIDE(I),I=1,2)
C
      READ(5,1002) RND
      NLEV = RND
      READ(5,1002) (EAQU(I),I=1,3)
      READ(5,1002) (FLOD(I),I=1,3)
      READ(5,1002) (SEROS(I),I=1,3)
      READ(5,1002) (COROS(I),I=1,4)
      READ(5,1002) (DOLVAL(I),I=1,NLEV)
C
C ALL CARDS EXCEPT LAST: DATA WITH DECIMAL POINTS, MAXIMUM
C 6 PER CARD, FIRST 10 COLUMNS EMPTY, THEN 10 COLUMNS PER DATA
C
C FIRST CARD: NUMBER OF DOLVAL CATEGORIES
C
C IF THE NUMBER OF SEVERITY LEVELS IS CHANGED FOR ANY
C HAZARD, THE CORRESPONDING DATA CARD MUST BE AMENDED
C ACCORDINGLY.
C
C SECOND CARD: UPPER LIMITS FOR ANNUAL DOLLAR LOSS PER
C     EARTHQUAKE ZONE (3)
C THIRD CARD: UPPER LIMITS FOR ANNUAL DOLLAR LOSS PER FLOODING
C     ZONE (3)
C FOURTH CARD: UPPER LIMITS FOR ANNUAL DOLLAR LOSS PER SURFACE
C     EROSION ZONE (3)
```

```
C FIFTH CARD: UPPER LIMITS FOR ANNUAL DOLLAR LOSS PER COASTAL
C     EROSION ZONE (4)
C
C THE FOLLOWING CARDS MUST BE CHANGED IF THE NUMBER OF DOLVAL
C CATEGORIES IS CHANGED.
C
C SIXTH AND SUBSEQUENT CARDS: UPPER LIMITS FOR TOTAL ANNUAL
C     DOLLAR LOSS PER HECTARE
C LAST CARD: SYMBOLISM SCALE INDEX, TWO COLUMNS PER NUMBER,
C     MAXIMUM 36
C
C IF AN EXTRA HAZARD IS ADDED, AN EXTRA 'READ' CARD IS
C REQUIRED, FOR EXAMPLE:
C     READ(12) SINK
C
      READ(5,1003) (INDEX(I),I=1,NLEV)
      READ(8) (IN1(I),I=1,2)
      READ(9) SINK
      READ(10) SINK
      READ(11) SINK
      WRITE(13,1018) (IN1(I),I=1,2)
      ROWS = IN1(1)
      NCOLS = IN1(2)
C
C THIS CALCULATES THE NUMBER OF STRIPS THAT WILL BE PRESENT
C
      RND = ((NCOLS+2)/131)+1
      I5 = RND
C
C NOW WE CALCULATE THE NUMBER OF COLUMNS IN THE LAST STRIP
C
      NLEFT = NCOLS - ((I5-1) * 130) + 1
C
C I5 IS THE NUMBER OF STRIPS
C NOW WE LOOP FOR THE NUMBER OF STRIPS
C
      DO 303 I6=1,I5
C
C THIS BIT DECIDES HOW MANY COLUMNS THERE ARE IN THE
C PRESENT STRIP
C
      IF(I6.NE.1) GO TO 301
C
C THIS IS PROCESSED BEFORE THE FIRST STRIP
C
      IF(NCOLS.LE.130) COLS = NCOLS
      IF(NCOLS.GT.130) COLS = 130
      GO TO 305
  301 IF(I6.NE.I5) COLS = 131
      IF(I6.EQ.I5) COLS = NLEFT
C
C FOR EACH STRIP WE LOOP FOR THE NUMBER OF ROWS
C WE SKIP TO A NEW PAGE FOR THE PRINTING
C
```

```
  305 WRITE(13,1017)
      WRITE(13,1017)
C
C HERE WE CLASSIFY THE DATA
C
      I00 = ROWS
      DO 99 K=1,I00
C
C IF AN EXTRA HAZARD IS ADDED, AN EXTRA 'READ' CARD IS
C REQUIRED, FOR EXAMPLE:
C     READ(12) (XIN5(I),I=1,COLS)
C
C THIS REQUIRES A CORRESPONDING INPUT FILE. THIS FILE
C MUST BE DEFINED IN THE JCL AT THE END OF THE PROGRAMME,
C FOR EXAMPLE:
C
C //GO.FT12F001 DD DSN=WYL.SC.KED.VAL5,DISP=SHR
C
C MUST BE INCLUDED WITH THE SIMILAR CARDS AT THE END OF
C THE PROGRAMME.
C
      READ(8) (XIN1(I),I=1,COLS)
      READ(9) (XIN2(I),I=1,COLS)
      READ(10) (XIN3(I),I=1,COLS)
      READ(11) (XIN4(I),I=1,COLS)
C
C  THIS LOOKS AT EACH OF THE COLUMNS TO CLASSIFY IT
C
      DO 1 I=1,COLS
      XINK = XIN1(I)
      IF(LINK.NE.25) GO TO 711
      XIN1(I) = 0.
      GO TO 71
  711 IN1(I) = XIN1(I)+.5
      IN1I = IN1(I)
      XIN1(I) = EAQU(IN1I)
   71 XINK = XIN2(I)
      IF(LINK.NE.25) GO TO 721
      XIN2(I) = 0.
      GO TO 72
  721 IN2(I) = XIN2(I) + .5
      IN2I = IN2(I)
      XIN2(I) = FLOD(IN2I)
   72 XINK = XIN3(I)
      IF(LINK.NE.25) GO TO  731
      XIN3(I) = 0.
      GO TO 73
  731 IN3(I) = XIN3(I) + .5
      IN3I = IN3(I)
      XIN3(I) = SEROS(IN3I)
   73 XINK = XIN4(I)
      IF(LINK.NE.25) GO TO  741
      XIN4(I) = 0.
      GO TO 1
```

```
  741 IN4(I) = XIN4(I) + .5
      IN4I = IN4(I)
      XIN4(I) = COROS(IN4I)
C
C IF AN EXTRA HAZARD IS ADDED, ADDITIONAL CODING IS REQUIRED,
C FOR EXAMPLE:
C
C  75 XINK = XIN5(I)
C     IF(LINK.NE.25) GO TO  751
C     XIN5(I) = 0.
C     GO TO 1
C 751 IN5(I) = XIN5(I) + .5
C     IN5I = IN5(I)
C     XIN5(I) = SLIDE(IN5I)
    1 CONTINUE
C
C THIS ACCUMULATES THE RESULTS FROM THE CORRESPONDING COLUMN
C IN EACH ROW FROM THE HAZARD MAPS
C
      DO 11 I=1,COLS
C
C IF AN EXTRA HAZARD IS ADDED, THE FOLLOWING CARD MUST
C BE AMENDED, FOR EXAMPLE:
C     OUT(I) = XIN1(I) + XIN2(I) + XIN3(I) + XIN4(I) +
C    1XIN5(I)
C
      OUT(I) = XIN1(I) + XIN2(I) + XIN3(I) + XIN4(I)
      IF(OUT(I).GT.0.) GO TO 111
      IOUT(I) = 37
      GO TO 110
  111 DO 12 J=1,NLEV
      IF(OUT(I).GT.DOLVAL(J)) GO TO 12
      IOUT(I) = INDEX(J)
      IF((I.EQ.1).AND.(I6.GT.1)) GO TO 110
      NL(J) = NL(J) + 1
      GO TO 110
   12 CONTINUE
  110 CONTINUE
   11 CONTINUE
C
C THIS SETS UP THE ARRAY UT WHICH WILL CONTAIN THE INFORMATION
C TO PRODUCE THE OVERPRINTED MAP
C
      DO 13 I=1,COLS
      IOUTI = IOUT(I)
      UT(I,1) = NAMES1(IOUTI)
      UT(I,2) = NAMES2(IOUTI)
      UT(I,3) = NAMES3(IOUTI)
      UT(I,4) = NAMES4(IOUTI)
      UT(I,5) = NAMES5(IOUTI)
   13 CONTINUE
C
C THIS PRINTS A ROW OF THE MAP
C
```

```
      WRITE(13,1015) (UT(I,1),I=1,COLS)
      DO 14 J=2,5
      WRITE(13,1016) (UT(I,J),I=1,COLS)
   14 CONTINUE
C
C THIS ENDS THE LOOP FOR THE ROWS
C
   99 CONTINUE
C
C THIS ENDS THE LOOP FOR THE STRIPS
C
  303 CONTINUE
C
C THIS AREA PRINTS THE LEGEND
C FIRST SET UP SOME VARIABLE SO IT RUNS PROPERLY
C  NDO: THE NUMBER OF LEGEND BOXES ACROSS IN ANY ROW
C  M :  THE STARTING BOX FOR THE ROW
C  ITEMP: THE NUMBER OF BOXES LEFT TO PRINT
C  ITEMP1: THE LAST BOX IN THE ROW
C
      NDO = 11
      ITEMP = NLEV + 11
      ITEMP1 = 0
C
C NOW FOR THE REAL LOOP
C
      WRITE(13,1007)
      WRITE(13,1006)
      WRITE(13,1006)
  210 ITEMP = ITEMP - NDO
      IF(ITEMP.EQ.0) GO TO 3000
      M = ITEMP1 + 1
      L = 0
      NDO = MIN0(11,ITEMP)
      ITEMP1 = M + NDO - 1
      NC = (NDO*10) + NDO - 1
C
C THIS LOOPS ONCE FOR EVERY BOX IN THE LEGEND
C
      DO 205 I=M,ITEMP1
      IND = INDEX(I)
C
C SINCE THE BOX IS 10 ACROSS THIS LOOPS 10 TIMES TO FILL IT
C
      DO 201 J=1,10
      L = L+1
      UT(L,1) = NAMES1(IND)
      UT(L,2) = NAMES2(IND)
      UT(L,3) = NAMES3(IND)
      UT(L,4) = NAMES4(IND)
      UT(L,5) = NAMES5(IND)
  201 CONTINUE
```

```
C
C THIS PUTS A BLANK COLUMN BETWEEN THE BOXES
C
      L = L+1
      UT(L,1) = NAMES1(37)
      UT(L,2) = NAMES2(37)
      UT(L,3) = NAMES3(37)
      UT(L,4) = NAMES4(37)
      UT(L,5) = NAMES5(37)
  205 CONTINUE
C
C THIS WRITES OUT THE ROW
C
      DO 203 K=1,5
      WRITE(13,1004) (UT(I,1),I=1,NC)
      DO 202 J=2,5
      WRITE(13,1005) (UT(I,J),I=1,NC)
  202 CONTINUE
  203 CONTINUE
C
C THIS SETS UP THE RANGES TO BE PRINTED UNDER THE BOXES
C
      L = 1
      IF(M.GT.1) IN4(L) = DOLVAL(M-1) + 1
      IF(M.EQ.1) IN4(L) = 0
      DO 204 I=M,ITEMP1
      L = L+1
      IN4(L) = DOLVAL(I)
      L = L+1
  204 IN4(L) = DOLVAL(I) + 1
C
C THIS PRINTS OUT THE RANGES
C
      WRITE(13,1006)
      L = NDO * 2
      WRITE(13,1008) (IN4(I),I=1,L)
C
C NOW WE WRITE OUT THE FREQUENCY DISTRIBUTION
C
      WRITE(13,1006)
      WRITE(13,1009)
      WRITE(13,1006)
      WRITE(13,1012) (NL(I),I=M,ITEMP1)
      WRITE(13,1006)
      WRITE(13,1006)
      GO TO 210
 1002 FORMAT(10X,6F10.0)
 1003 FORMAT(36I2)
 1004 FORMAT(' ',' ',129A1)
 1005 FORMAT('+',' ',129A1)
 1006 FORMAT(' ')
 1007 FORMAT('1 RANGE OF ANNUAL DOLLAR LOSS PER HECTARE')
 1008 FORMAT(' ',11(I5,'-',I5))
```

```
 1012 FORMAT(' ',11(1X,I7,3X))
 1009 FORMAT('  FREQUENCY')
 1015 FORMAT(' ',131A1)
 1016 FORMAT('+',131A1)
 1017 FORMAT('1')
  1018 FORMAT(' THE NUMBER OF ROWS AND COLUMNS = ',2I10)
 3000 STOP
      END
//GO.FT08F001 DD DSN=WYL.SC.KED.VAL1,DISP=SHR
//GO.FT09F001 DD DSN=WYL.SC.KED.VAL2,DISP=SHR
//GO.FT10F001 DD DSN=WYL.SC.KED.VAL3,DISP=SHR
//GO.FT11F001 DD DSN=WYL.SC.KED.VAL4,DISP=SHR
//GO.FT13F001 DD SYSOUT=$,SPACE=(TRK,(20,10),RLSE),
//  DCB=(RECFM=FBSA,LRECL=133,BLKSIZE=665)
//GO.SYSIN DD *
          10.
          266.      767.      1817.
          0.        227.      910.
          0.        3.        9.
          0.        960.      1920.     2880.
          560.      1120.     1680.     2240.     2800.     3360.
          3920.     4480.     5040.     5616.
353231302823191713O7
/*
```

APPENDIX C

MAPS 1-6

Map 1

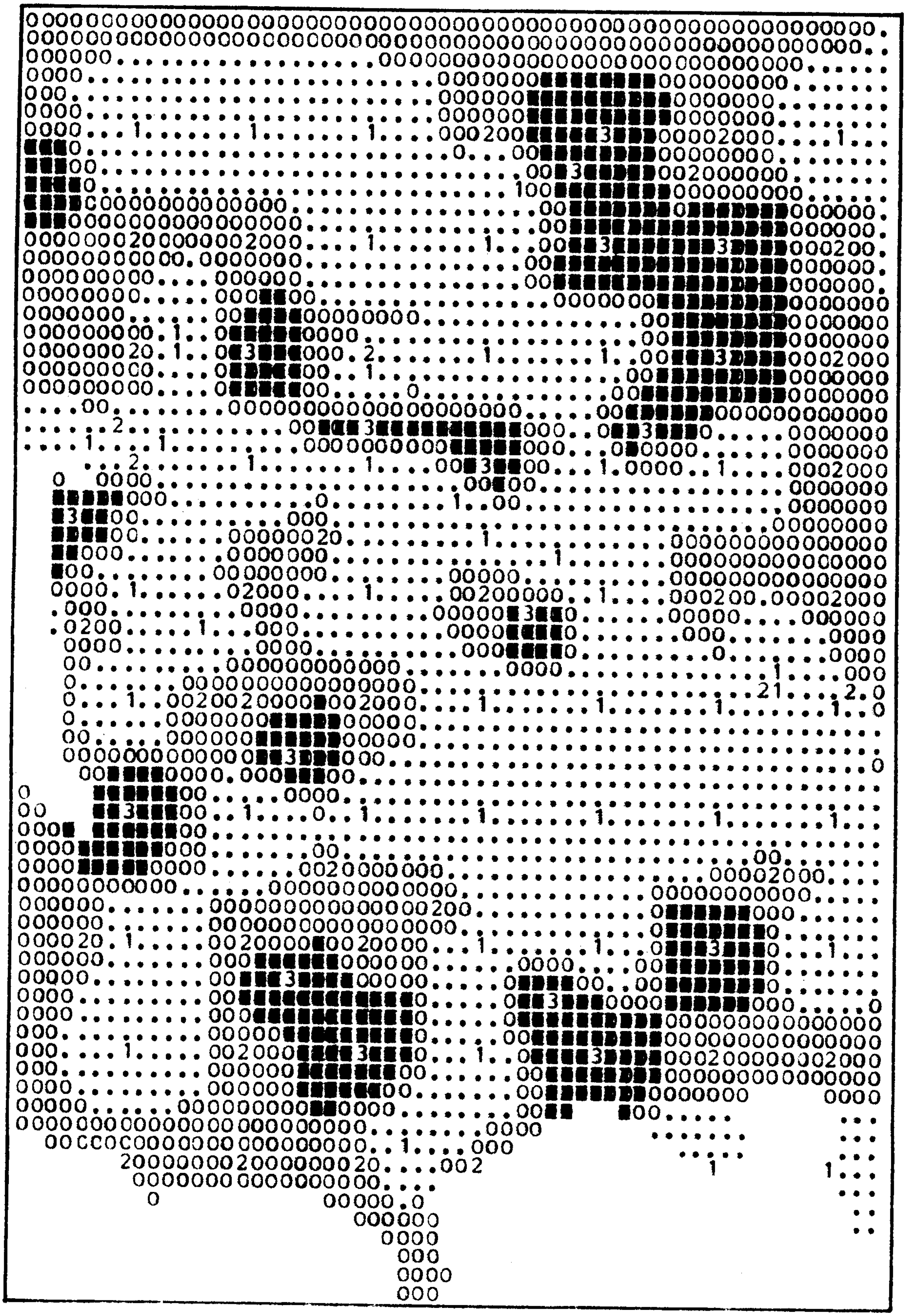
```
EARTHQUAKE MICROZONATION OF VICTORIA METROPOLITAN AREA

SCALE 1:25000

BASED ON 1423 DATA POINTS


LEVEL 1 = MODIFIED MERCALLI INTENSITY INCREMENT OF MINUS 1
LEVEL 2 = MODIFIED MERCALLI INTENSITY INCREMENT OF ZERO
LEVEL 3 = MODIFIED MERCALLI INTENSITY INCREMENT OF PLUS 1


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL             1          2          3
            ===============================
            .........  000000000 █████████
            .........  000000000 █████████
  SYMBOLS   ....1....  000020000 ████3████
            .........  000000000 █████████
            .........  000000000 █████████
            ===============================
  FREQ.        597        759        67
```



Map 2

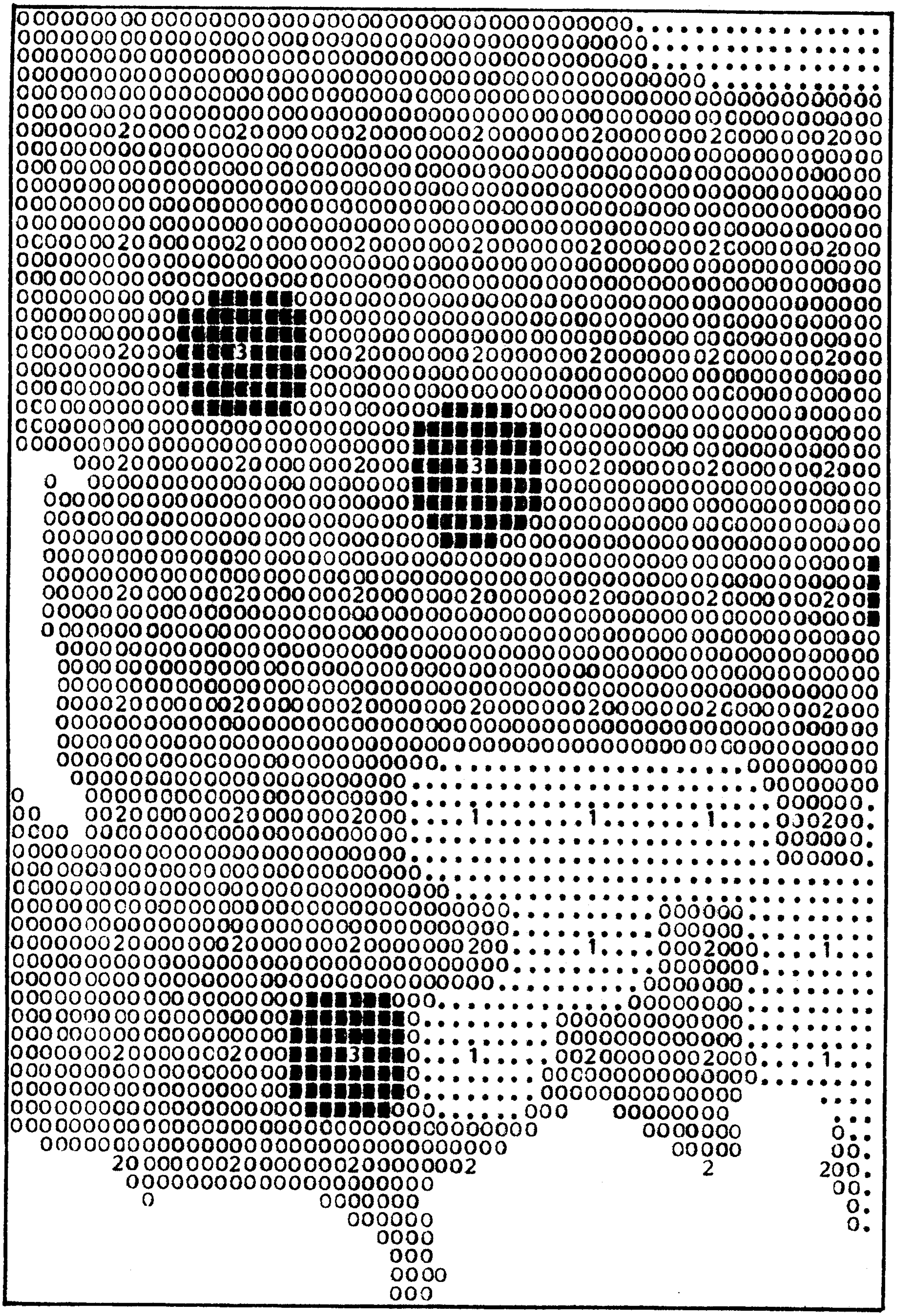
```
FLOODING AND PONDING IN VICTORIA METROPOLITAN AREA

SCALE 1:25000

BASED ON 1360 DATA POINTS


LEVEL 1 = NO FLOODING OR PONDING
LEVEL 2 = OCCASIONAL FLOODING OR PONDING
LEVEL 3 = FREQUENT FLOODING OR PONDING


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3
          ===============================
           .........  000000000 █████████
           .........  000000000 █████████
  SYMBOLS  ....1....  000020000 ████3████
           .........  000000000 █████████
           .........  000000000 █████████
          ===============================
  FREQ.       459        700       201
```



Map 3

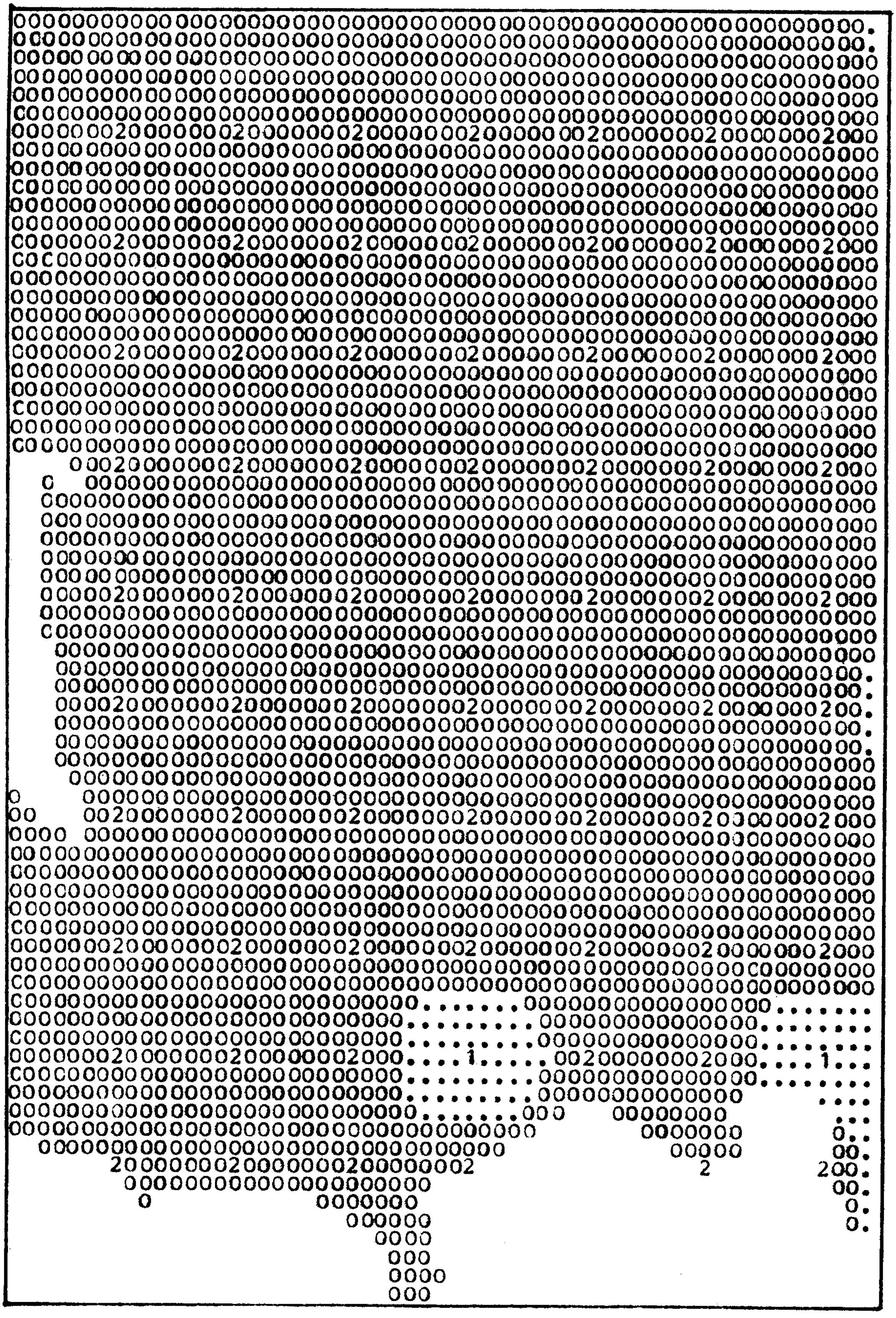
```
SURFACE EROSION IN VICTORIA METROPOLITAN AREA

SCALE 1:25000

BASED ON 1360 DATA POINTS


LEVEL 1 = SLIGHT SUSCEPTIBILITY TO SURFACE EROSION
LEVEL 2 = MODERATE SUSCEPTIBILITY TO SURFACE EROSION
LEVEL 3 = HIGH SUSCEPTIBILITY TO SURFACE EROSION


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL         1          2          3
          ==============================
           .........  000000000 ■■■■■■■■■
           .........  000000000 ■■■■■■■■■
  SYMBOLS  ....1....  000020000 ■■■■3■■■■
           .........  000000000 ■■■■■■■■■
           .........  000000000 ■■■■■■■■■
          ==============================
  FREQ.        500        616        244
```



Map 4

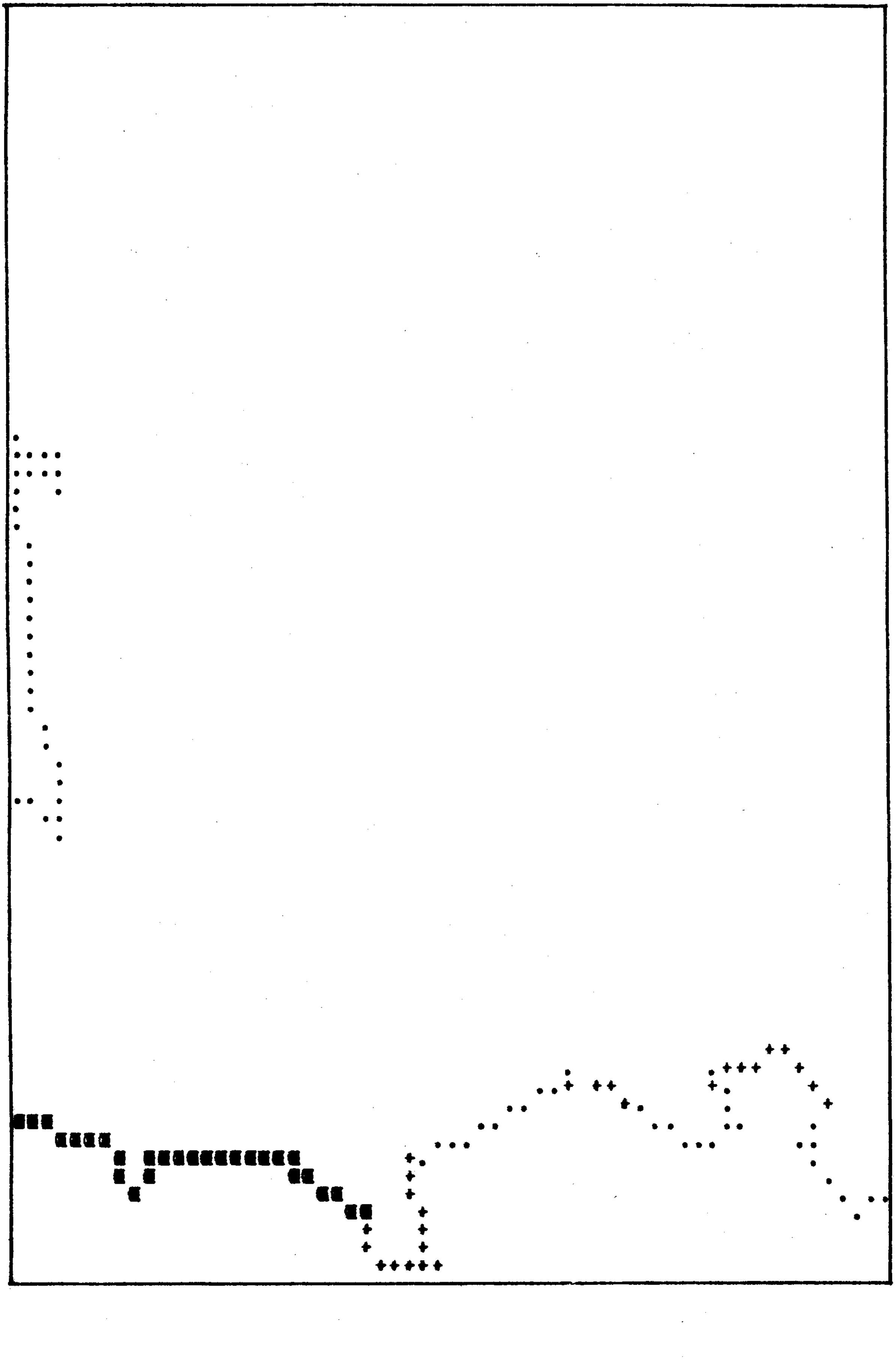
```
COASTAL EROSION IN VICTORIA METROPOLITAN AREA

SCALE 1:25000

BASED ON ORIGINAL STUDY BY HAROLD D. FOSTER, UNIVERSITY OF VICTORI


LEVEL 1 = NEGLIGIBLE (LESS THAN 7.62 CM/YEAR)
LEVEL 2 = SMALL (7.62 TO 15.24 CM/YEAR)
LEVEL 3 = MODERATE (15.24 TO 30.48 CM/YEAR)
LEVEL 4 = RAPID (MORE THAN 30.48 CM/YEAR)

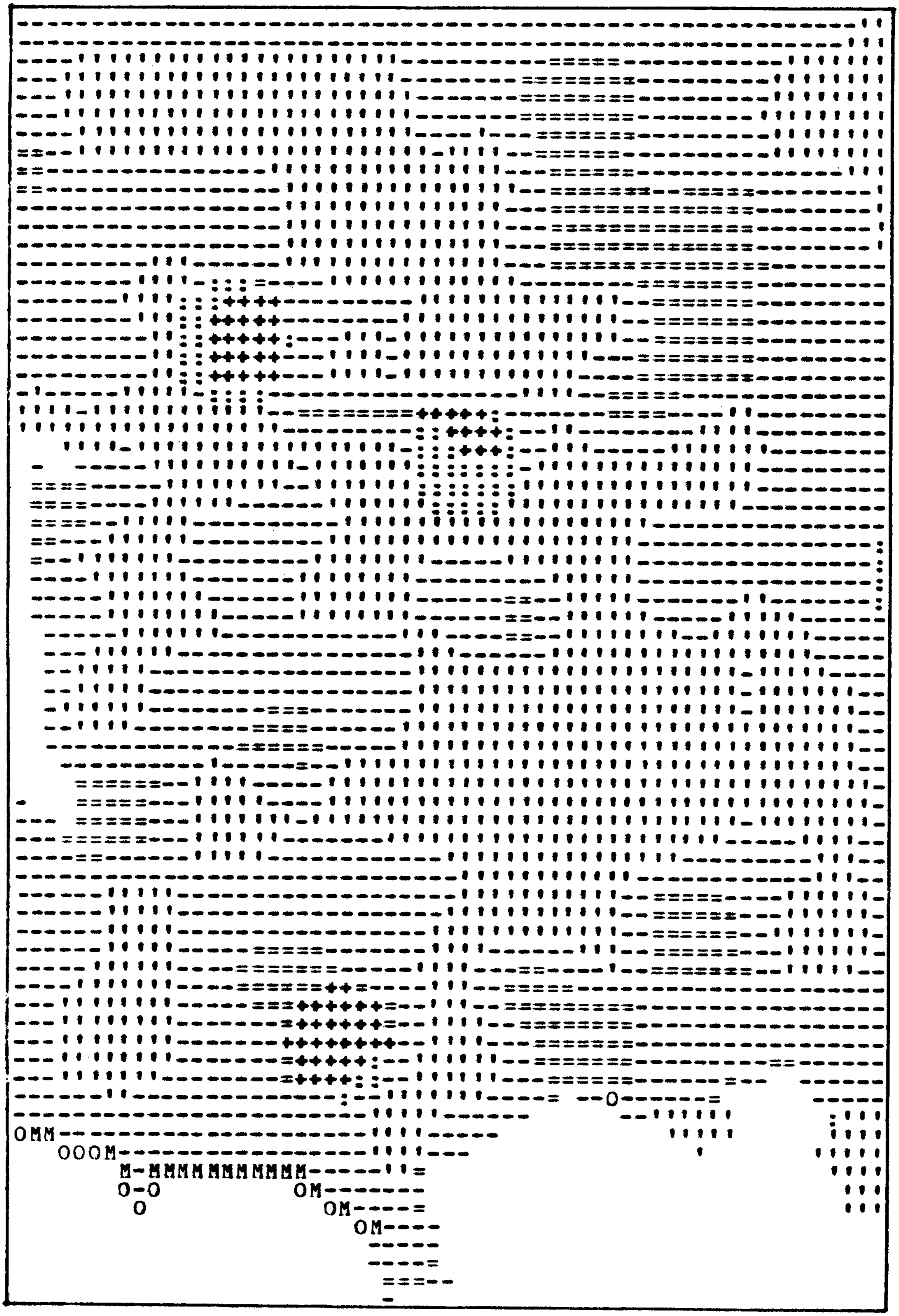

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL         1         2         3         4
          ========================================
           .........  +++++++++ 000000000 █████████
           .........  +++++++++ 000000000 █████████
  SYMBOLS  ....1....  ++++2++++ 000030000 ████4████
           .........  +++++++++ 000000000 █████████
           .........  +++++++++ 000000000 █████████
          ========================================
  FREQ.        19        23        11         5
```



Map 5

RANGE OF ANNUAL DOLLAR LOSS PER HECTARE

		FREQUENCY
'	0- 560	26396
-	561- 1120	29199
:	1121- 1680	4295
=	1681- 2240	5417
+	2241- 2800	961
0	2801- 3360	101
M	3361- 3920	100
8	3921- 4480	0
X	4481- 5040	7
■	5041- 5616	0



RANGE OF ANNUAL DOLLAR LOSS PER HECTARE

```
.......... 1111111111 2222222222 3333333333 4444444444 5555555555
.......... 1111111111 2222222222 3333333333 4444444444 5555555555
.......... 1111111111 2222222222 3333333333 4444444444 5555555555
.......... 1111111111 2222222222 3333333333 4444444444 5555555555
.......... 1111111111 2222222222 3333333333 4444444444 5555555555

  0-  155  156-  310  311-  465  466-  620  621-  775  776-  930

FREQUENCY
        0      15689          0      10707       4904         39


6666666666 7777777777 8888888888 9999999999 AAAAAAAAAA BBBBBBBBBB
6666666666 7777777777 8888888888 9999999999 AAAAAAAAAA BBBBBBBBBB
6666666666 7777777777 8888888888 9999999999 AAAAAAAAAA BBBBBBBBBB
6666666666 7777777777 8888888888 9999999999 AAAAAAAAAA BBBBBBBBBB
6666666666 7777777777 8888888888 9999999999 AAAAAAAAAA BBBBBBBBBB

 931- 1085 1086- 1240 1241- 1395 1396- 1550 1551- 1705 1706- 1860

    24253        402          0         19       7876        320


CCCCCCCCCC DDDDDDDDDD EEEEEEEEEE FFFFFFFFFF GGGGGGGGGG HHHHHHHHHH
CCCCCCCCCC DDDDDDDDDD EEEEEEEEEE FFFFFFFFFF GGGGGGGGGG HHHHHHHHHH
CCCCCCCCCC DDDDDDDDDD EEEEEEEEEE FFFFFFFFFF GGGGGGGGGG HHHHHHHHHH
CCCCCCCCCC DDDDDDDDDD EEEEEEEEEE FFFFFFFFFF GGGGGGGGGG HHHHHHHHHH
CCCCCCCCCC DDDDDDDDDD EEEEEEEEEE FFFFFFFFFF GGGGGGGGGG HHHHHHHHHH

1861- 2015 2016- 2170 2171- 2325 2326- 2480 2481- 2635 2636- 2790

      282        748         65         14          0        947


IIIIIIIIII JJJJJJJJJJ KKKKKKKKKK LLLLLLLLLL MMMMMMMMMM NNNNNNNNNN
IIIIIIIIII JJJJJJJJJJ KKKKKKKKKK LLLLLLLLLL MMMMMMMMMM NNNNNNNNNN
IIIIIIIIII JJJJJJJJJJ KKKKKKKKKK LLLLLLLLLL MMMMMMMMMM NNNNNNNNNN
IIIIIIIIII JJJJJJJJJJ KKKKKKKKKK LLLLLLLLLL MMMMMMMMMM NNNNNNNNNN
IIIIIIIIII JJJJJJJJJJ KKKKKKKKKK LLLLLLLLLL MMMMMMMMMM NNNNNNNNNN

2791- 2945 2946- 3100 3101- 3255 3256- 3410 3411- 3565 3566- 3720

       90          1         10          0          0         52


OOOOOOOOOO PPPPPPPPPP QQQQQQQQQQ RRRRRRRRRR SSSSSSSSSS TTTTTTTTTT
OOOOOOOOOO PPPPPPPPPP QQQQQQQQQQ RRRRRRRRRR SSSSSSSSSS TTTTTTTTTT
OOOOOOOOOO PPPPPPPPPP QQQQQQQQQQ RRRRRRRRRR SSSSSSSSSS TTTTTTTTTT
OOOOOOOOOO PPPPPPPPPP QQQQQQQQQQ RRRRRRRRRR SSSSSSSSSS TTTTTTTTTT
OOOOOOOOOO PPPPPPPPPP QQQQQQQQQQ RRRRRRRRRR SSSSSSSSSS TTTTTTTTTT

3721- 3875 3876- 4030 4031- 4185 4186- 4340 4341- 4495 4496- 4650

        0         48          0          0          0          7


UUUUUUUUUU VVVVVVVVVV WWWWWWWWWW XXXXXXXXXX YYYYYYYYYY ZZZZZZZZZZ
UUUUUUUUUU VVVVVVVVVV WWWWWWWWWW XXXXXXXXXX YYYYYYYYYY ZZZZZZZZZZ
UUUUUUUUUU VVVVVVVVVV WWWWWWWWWW XXXXXXXXXX YYYYYYYYYY ZZZZZZZZZZ
UUUUUUUUUU VVVVVVVVVV WWWWWWWWWW XXXXXXXXXX YYYYYYYYYY ZZZZZZZZZZ
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4651- 4805 4806- 4960 4961- 5115 5116- 5270 5271- 5425 5426- 5616
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