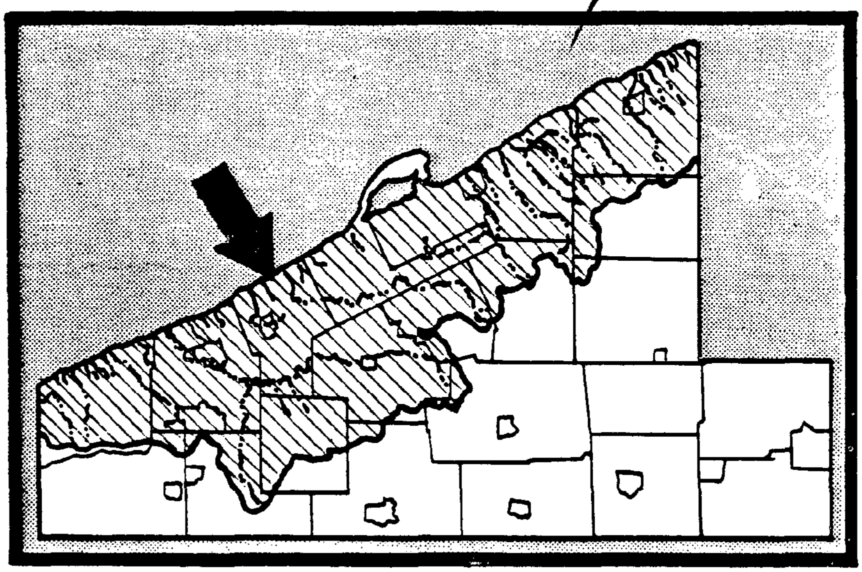
# STORM WATER MANAGEMENT PLAN



# LAKE ERIE & ELK CREEK WATERSHEDS

## VOLUME 1

## ERIE COUNTY DEPARTMENT OF PLANNING
## COMMONWEALTH OF PENNSYLVANIA





October 1981

PREPARED BY
NORTHWEST INSTITUTE OF RESEARCH - WOODRUFF, INC.

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Volume 1

Prepared For

Commonwealth of Pennsylvania

Department of Environmental Resources

and

Erie County Department of Planning

Prepared By

Northwest Institute of Research - Woodruff, Inc.

As a Consortium

October 1981

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## Section 1

## INTRODUCTION AND SUMMARY

This report is Volume 1 in a series of 14 volumes prepared for the Erie County Department of Planning. It has been prepared in accordance with the provisions of the Pennsylvania Storm Water Management Act P.L. 864, Act 167 dated October 4, 1978 and is a pilot study under that Act. The Northwest Institute of Research of Erie, Pennsylvania and Woodruff, Inc., Consulting Engineers of Cleveland, Ohio, have formed a consortium for the purpose of developing a pilot storm water management plan for the Lake Erie and Elk Creek Watersheds. The entire study has been conducted under the guidance and direction of the Pennsylvania Department of Environmental Resources, Bureau of Dams and Waterway Management, Division of Storm Water Management and the Erie County Department of Planning.

Volume 1 is the technical document written for the individual interested in the more detailed aspects of the study. Included in this report is a description of the methodology used in the development of the plan. Calculations for factors such as storm water runoff, requirements for storm water detention basins, justification for selecting the particular design storm and the related standards and criteria for storm water management are provided. In addition it provides a description of the background contained in later volumes.

The remaining volumes in the series, Volumes 2 through 14, represent applications of the plan developed in this volume to specific features of the various subwatersheds within the Lake Erie and Elk Creek Watershed Area. The specific subwatersheds studied and the related volume numbers are as follows:

| | Volume Number |
|---|---|
| Walnut Creek | Volume 2 |
| Elk Creek | Volume 3 |
| Turkey Creek | Volume 4 |
| Raccoon Creek | Volume 5 |
| Fourmile Creek | Volume 6 |
| Trout Run | Volume 7 |
| Sixteenmile Creek | Volume 8 |
| Sixmile Creek | Volume 9 |
| Mill Creek | Volume 10 |
| Crooked Creek | Volume 11 |
| Sevenmile Creek | Volume 12 |
| Eightmile Creek | Volume 13 |
| Twelvemile Creek | Volume 14 |
| Twentymile Creek (combined with Sixteenmile Creek) | Volume 8 |

While all of the above, with the exception of Elk Creek, are actually subwatersheds within the larger Lake Erie Watershed, they will be referred to individually as watersheds in their respective volumes as listed above. Direct drainages, those relatively shorter streams feeding directly into Lake Erie, are discussed briefly in Section 6 of Volume 1.

Under the provisions of Act 167 every Pennsylvania County is responsible for developing a storm water management plan for each watershed situated within its boundaries. In addition, once a county storm water management plan has been adopted by the County legislative body, each municipality located within the watershed is responsible for adopting and enforcing ordinances or regulations which serve to implement the County storm water management plan.

In accordance with the Storm Water Management Act, the fundamental premise of this Plan is that a serious effort must be made to preserve and restore the flood carrying capacity of the streams and creeks which empty into Lake Erie. The methods used to achieve this goal must also serve to eliminate or significantly reduce localized flooding which often results from land development.

Having established these goals, one of the first tasks undertaken in the storm water management planning process involved the use of a computer model to estimate the volume of water which flows past selected points along each creekbed. The estimates were based upon soil conditions, existing land use and a "design storm" which is equivalent to just under 5 inches of rainfall occurring over a 24-hour period. A detailed account of the design storm and the computer model's calculating procedures may be found in Appendix C and Appendix D, respectively of Volume 1. The actual water runoff estimates for any specific watershed may be found in Section 6 of the appropriate Volume.

The runoff estimates provided by the computer model establish the base flow data for the Lake Erie and Elk Creek watersheds, meaning that these are the stream flows which through proper storm water management techniques, will not significantly increase over time. In order to restrict these flow volumes to their 1981 levels the storm water management techniques recommended in this plan recognize a natural runoff volume on undeveloped land. Any post-development increase in this natural runoff volume is the amount of storm water runoff which the developer is required to manage. The developer shall manage this increased runoff through landscaping and construction techniques designed for the purpose and approved by the local governing body. Appendix A, Table 1-4 lists acceptable stormwater management techniques which a developer may use. Appendix E of Volume 1 details the method by which the post-development increase in storm water runoff may be calculated.

The Lake Erie and Elk Creek Storm Water Management Plan will be implemented at the local level through the adoption of a storm water management ordinance or through amendments to existing subdivision or zoning regulations. The ordinance or amendments will allow municipalities to review individual storm water management projects when the property is subdivided or when a building permit is requested. With this approach all authority and responsibility involved with implementing and administering the storm water management program shall rest with the local government, or at the option of a local government, their legal representative. Full details about implementing the Lake Erie and Elk Creek Storm Water Management Plan are given in Section 7 of Volume 1.

The Lake Erie and Elk Creek Storm Water Management Plan has been developed with considerable input from the Watershed Advisory Committee, consisting of representatives from each municipality in the study area, the Department of Agriculture's Soil Conservation Service, and the Northwestern Pennsylvania Homebuilders Association. With the assistance of these three groups this plan has been tailored to recognize the unique and varied stream characteristics, soil conditions and development trends of northern Erie County. Because this Plan is one of the first storm water management plans prepared under Pennsylvania Act 167, the proposals recommended by this document, while theoretically sound, have not yet been tested under Pennsylvania law on as large and diverse an area as northern Erie County. To better monitor the effectiveness of this Plan it is recommended that the Lake Erie and Elk Creek Storm Water Management Plan be reviewed by the Erie County Department of Planning, the Watershed Advisory Committee and the Northwestern Pennsylvania Homebuilders Association at least two years, but not longer than five years after the plan is adopted by Erie County Council.

## Section 2

## BACKGROUND AND PURPOSE

The objective of storm water management is to eliminate or at least reduce the adverse impact resulting from excessive storm water runoff. In the past, the basic approach to managing this runoff has been to achieve maximum convenience at a given site by discharging to the nearest convenient location any excess surface water as quickly as possible following a storm. This removal has been accomplished most typically by conveying the water through a storm sewer or other closed system. As is noted in the Storm Water Management Guidelines, this process of passing on storm water runoff merely shifts the location of the problem and all too often aggrevates the situation downstream and creates a flood hazard in other communities. An additional concern created by this approach is that groundwater supplies in the area may be diminished.

Even in areas where there has been no flooding problem in the past, there is cause for concern. As land development continues, the percentage of impervious land surface increases in once rural or semi-rural areas. Paved roads, sidewalks, rooftops, parking lots and other improvements all contribute to the problem. Areas that previously had no flooding begin experiencing problems; areas where flooding has been a problem now may begin to experience an even more serious problem.

The solution of passing one's own water problems downstream is no longer acceptable. The potential damage created by such a practice cannot be tolerated as development continues.

Clearly, storm water management is needed. A storm water management plan is needed which protects our land and our streams while also permitting reasonable development. This new approach must strike a compromise between local convenience upstream and flooding hazards elsewhere. The present series of reports reflect this new approach. One significant feature of this approach is the planned detention of storm water either on-site or in regional basins built for that purpose.

According to the provisions of the Storm Water Management Act, municipalities in Pennsylvania will be required to adopt ordinances, codes and regulations which are consistent with storm water management plans approved for each watershed, and the purpose of this report is to provide a workable and acceptable storm water management plan for those communities within the Lake Erie and Elk Creek Watersheds.

## Section 3

## METHODOLOGIES USED IN THE STUDY

The purpose of this study is to prepare for the management of excess storm water in the Lake Erie and Elk Creek Watersheds. (Plate 1-1 is a map showing the political subdivisions of Erie County, and Plate No. 1-2 is a key map for the Lake Erie Watershed.) To achieve this goal, it is necessary first to determine the existing amount of storm water runoff and then to estimate the amount of future runoff taking into account future development. The difference between these amounts is the excess storm water runoff which must be controlled to provide adequate storm water management. In the following pages, the various methods used in calculating runoff, analyzing stream flow and determining storage requirements are discussed.

### 3.1 Soil Conservation Service Method

This study utilized the Soil Conservation Services (SCS) "Unit Hydrograph Method" to predict storm water runoff, the SCS "Channel Routing Method" to analyze stream flow and the SCS "Storage-Indication Method" of flood routing to determine reservoir storage requirements. All these procedures are characterized by their use of runoff hydrographs. A runoff hydrograph is a calculated relationship between the flow rate and time at a specified location.

#### 3.1.1 Unit hydrograph method

The unit hydrograph method is the starting point of this analysis. It converts a given rainfall pattern over a drainage area into a storm water runoff hydrograph. Not all of the rainfall from a storm runs off the land to streams and lakes. Some of this water is either evaporated into the atmosphere, absorbed by plants, collected for later use or infiltrated into the soil. The unit hydrograph method accounts for these losses when calculating the runoff hydrograph.

Three important pieces of information are needed to calculate a runoff hydrograph. These include:

1. determination of the soil types and surface conditions;

2. identification of areas within a watershed or subwatershed;

3. calculation of time of concentration.

### 3.1.1.1 Soil and surface conditions

An important aspect of this study is to determine the amount of storm water which infiltrates into the soil. Different types of soils can absorb varying amounts of water. A soil which absorbs more water is said to be pervious while one which absorbs little water is said to be impervious. Soils are classified by the Soil Conservation Service and asssigned a "curve number" whose value is used to predict storm water runoff. These values are presented in Tables 1-2 and 1-3.

The various soil types found in Erie County were taken from the Soil Survey for Erie County, Pennsylvania, prepared by the Soil Conservation Service. The soils are described as follows:

Soil No. 1 - Silty and clayey soils, chiefly on the lake plain (Wallington-Birdsall-Williamson and Collamer).

Soil No. 2 - Sandy soils of lake plain (Rimer-Wauseon-Berrien).

Soil No. 3 - Gravelly and sandy soils of the beach ridges (Conotton-Ottawa-Fredon).

Soil No. 4 - Gravelly soils of the outwash terraces (Howard-Phelps-Fredon-Halsey).

Soil No. 5 - Deep, medium-textured soils in moderately limy till of the glaciated upland (Erie-Ellery and Alden-Landford).

Soil No. 6 - Deep, medium-textured soils in slightly limy till of the glaciated upland (Volusia-Mardin).

Soil No. 7 - Deep, silty and clayey soils of the glaciated upland flats (Trumbull-Mahoning-Miner).

Soil No. 8 - Deep, silty and clayey soils of the gently or moderately sloping glaciated upland (Platea-Birdshall).

Soil No. 9 - Shallow, medium-textured soils of the glaciated upland and the lake plain (Allis-Ellery and Alden).

Soil No. 10 - Silty and clayey soils of glacial lakebeds (Canadice-Caneadea-Birdsall).

As development occurs, these soils will be covered over with impervious surfaces such as rooftops, roadways and parking lots. The Soil Conservation Service has taken these urbanizing factors into account by developing additional curve number values. Weighted values are calculated to account for more than one land use and soil type in a drainage area.

#### 3.1.1.2 Subwatershed area

The watershed of a given stream is that area of land which slopes toward the stream such that storm water runoff travels towards that stream and contributes to its flow. Each watershed area is further divided into subwatersheds. A subwatershed is that portion of a larger watershed which drains to a single branch or specific portion of the mainstream. The area of each subwatershed is calculated for the purposes of creating a hydrograph describing the runoff for that subwatershed.

#### 3.1.1.3 Time of concentration

The time of concentration of a subwatershed is a theoretical concept which is used to calculate the amount of time it takes for a raindrop to travel from the most remote location in the subwatershed to a point of interest. For example, it might be the point at which it empties its flow into the next body of water (branch streams, mainstream, pond, lake, etc.). For this study, concentration times are calculated for each subwatershed using the California Highway Formula which is described further in Appendix C.

### 3.1.2 Channel routing method

Channel routing is a procedure which predicts the movement of water through streams and channels. Physical characteristics of the channel have an effect on the flood wave and are taken into account in this procedure.

The runoff hydrograph from the uppermost subwatershed is routed through the downstream section to the first branch. Then the runoff hydrograph from the local subwatershed area is added to the routed flow. This is the runoff hydrograph just upstream of the first branch. The upstream runoff hydrograph is added to the branch runoff hydrograph. The result is the total downstream hydrograph at the branch. This total is then flood routed to the next branch. The process continues to the final point of analysis.

It is assumed for this study that the flood wave passes through all culverts and channels. All of the culverts and bridges should have been originally designed to pass at least the 10-year storm and more probably one of even higher return frequency. When those structures not capable of passing the 10-year, 24-hour storm are replaced, the applicable design criteria will probably require that the structure have sufficient capacity to pass a storm greater than the 10-year storm. Thus, the watershed should more closely approach the free-flow condition assumed in the development of the computer model.

### 3.1.3 "Storage-indication method" of reservoir routing

The "storage-indication method" is a specific flood routing method which routes a runoff hydrograph through a detention basin. The operation of the outlet control structure of the basin and the storage volume of the basin are very important in the application of this method.

The outlet control structure allows varying amounts of discharge for various water levels in the reservoir. Therefore, knowledge of the volumetric storage in the reservoir enables one to calculate the rate of discharge through the control structure. Thus the name "strorage-indication." In other words, the usual application of this method is to determine discharge rate based on a known storage volume.

For the purposes of this study, however, the procedure is reversed. That is, a specified discharge rate is used to calculate required storage volume for a given detention basin.

Step-by-step calculation procedures for Soil Conservation Service methods are presented in Appendix C. Additional procedures and examples can be found in the National Engineering Handbook as listed in the bibliography.

### 3.2 Methods Used for Direct Drainage Areas

Storm runoff for shorter streams near Lake Erie (defined as direct drainages for the purposes of this study) were calculated by means of the rational method. This method calculates runoff as the product of the runoff coefficient, the intensity, and the area. Discharge rates and storage volumes may be determined by this technique in direct drainage areas only if the designated design storm, as presented in this study, is used.

### 3.3 Concluding Remarks

The Soil Conservation Service provides a very accurate and intricate method of analyzing stream flows and runoff rates. Not only are peak flows presented, but the flows at any particular time of the storm are available as well through storm runoff hydrographs. Flows and times are very easily converted to runoff volumes. The ability to calculate changes in flow with time, volume of runoff, and channel and reservoir flood routings is essential for the purposed of this study. There are, of course, other methods in current practice which also provide this information. Should a developer choose to use another equivalent method to predict runoff, he may do so as long as the proper design storms are used and the method is approved by the appropriate reviewing body.

## Section 4

## STANDARDS AND CRITERIA FOR STORM WATER MANAGEMENT

The following are the recommended standards and criteria for storm water management of Lake Erie and Elk Creek Watersheds. A discussion of the derivation and justification of these standards is included in Appendix D of this volume.

The most fundamental standard of this study is that the amount of flow in any creek must not be allowed to increase above existing flows at any location along the creek. These flows are obtained from a computer model developed expressly for each creek using the design storm described below. This will insure that the flow characteristics of the creeks will remain at their 1981 levels for storms equal to or less than the design storm.

### 4.1 Basis for Selection of Design Storm

The design storm for this study has been determined to be the 10-year, 24-hour storm. The choice of this storm is justified in Appendix D of this volume. The 10-year, 24-hour storm is a theoretical storm of 24-hour duration that will occur statistically once in ten years. This storm would result, on the average, in approximately 4.80 inches of rainfall over its 24-hour duration. As was previously mentioned, this is the storm used to derive the magnitude of flow at any point along the creek.

### 4.2 Definition of Type 1 and Type 2 Channels

Because some of the channels that make up the drainage systems of the various creeks are more able to carry increased flows than are others, criteria and standards have been devised for each of the types of channels. The first, Type 1 Channels, are characterized as mainstream channels. Cross sections of Type 1 Channels are accentuated by well defined banks and flood plains which can handle increased flows very easily. The second are referred to as Type 2 Channels and these are characterized as branch stream channels. Type 2 Channels typically are the drainage reaches which serve the outlying peripheral minor watersheds. The smaller Type 2 channels empty into the larger Type 1 Channels. Plate No. 1-3 in Appendix A shows an example of a channel system in a typical watershed.

In the individual discussions for each creek, the watershed area is divided into two classes: those watersheds which initially discharge their runoff into Type 1 Channels and those which initially discharge their runoff into Type 2 Channels. This clearly separates those areas subject to Type 1 Standards and Criteria from those subject to Type 2 Standards and Criteria.

## 4.3 Criteria for Type 1 Channels (Main Stream)

For those sites which are to discharge their runoff into a Type 1 Channel, it will be required that the increased runoff as a result of development be managed by any of the recommended methods discussed in Section 5. This is to say, the runoff due to the 10-year, 24-hour storm is to be calculated for each site using existing conditions. The runoff is then calculated again for the same site and storm taking into account the specific proposed development. The difference between these two runoffs is that which must be managed.

## 4.4 Criteria for Type 2 Channels (Branch Streams)

For those sites which will discharge their runoff into a Type 2 Channels, a more stringent standard is to be applied. This is necessary because these channels typically are too small to accommodate increased runoff. They have no flood plain to act as a cushion.

In this situation, the amount of storm water that must be stored is the difference in runoff between that from 10-year, 24-hour storm for the proposed land use and that from a mean annual storm [1] for the existing land use conditions. The mean annual storm is calculated by taking the largest storm for each year on record and averaging them. Statistically, the mean annual storm is equivalent to a storm with a return frequency of 2.33 years. Whereas side branches generally are able to handle the more frequent mean annual storm, this more stringent criterion would protect them against flooding for all storms up to and including the 10-year, 24-hour storm.

## 4.5 Refinements and Special Cases

As part of the implementation of this storm water mangement plan, it is recommended that all municipalities involved prohibit the outlet of residential roof drains and gutters into storm sewers, sanitary sewers, or roadside ditches. This would reduce the possibility of unnecessarily overburdening these facilities. Effective alternative methods of disposing of rooftop water include: (1) Simply allow the water to be discharged over lawns or gardens where it will be absorbed into the earth, and (2) use dry wells or abandoned septic tanks to store this runoff. This could be done as long as an appropriate method of outlet from these temporary holding areas is provided.

The criteria which applies to any specific development shall be determined in the manner presented below.

A development which is located in the same area into which its runoff is to be discharged must meet the criteria established for that specific area. For example, a site in a Type 1 area which will discharge storm water runoff into the Type 1 watershed must meet the Type 1 criteria.

In cases where a development is located among both a Type 1 and a Type 2 area and through storm water management techniques its discharge will be directed into only one area, then the criteria which applies to the development is that which is consistent with the watershed into which the runoff will be discharged. If runoff will be discharged into both Type 1 and Type 2 watersheds then the more stringent Type 2 criteria must apply. For example, a development situated in both Type 1 and Type 2 areas which will be landscaped so that all of its runoff is discharged into a Type 1 watershed must meet the less stringent criteria for Type 1 areas. If instead the same development were landscaped so that some of its runoff is discharged into a Type 1 watershed and the remainder discharged into a Type 2 watershed than the more stringent criteria for Type 2 watersheds must apply to the entire development.

In cases where a development is located within one specific Type area but through storm water management techniques it will discharge all of its runoff into the other Type area the criteria which must apply is the criteria for the watershed into which the runoff is being discharged. For example, a development in a Type 2 area which is very close to a Type 1 area may discharge all of its runoff into the Type 1 watershed and then be bound by the less stringent Type 1 criteria.

### 4.6 Standards and Criteria for Direct Drainage Areas

As defined in Section 3.2, direct drainage areas are those relatively shorter streams which discharge directly into Lake Erie. Runoff from development in direct drainage areas may be piped directly to Lake Erie with no flow restrictions. However, construction methods such as tunneling or boring must be used so as not to disturb the coastal bluff. All work must be done in accordance with the Bluff Recession and Setback Act (1980).[1] Runoff from development in locations which discharge to streams must conform to those standards and criteria specified for Type 2 Channels in previous sections.

[1]Copies of this document are available at the Erie County Department of Planning.

## Section 5

## ALTERNATIVE METHODS FOR STORM WATER MANAGEMENT

The discussion in Section 2 points to the need for some means of controlling increased runoff due to development in the Lake Erie and Elk Creek Watershed areas. The standards and criteria recommended to establish storm water management in the Lake Erie and Elk Creek Watershed Areas were discussed in Section 4. There are several methods by which these criteria may be achieved.

### 5.1 Specific Storm Water Control

Among the storm water management options available for the Lake Erie and Elk Creek Watersheds are the following:

1. take no action;
2. prohibit or limit development;
3. increase the hydrologic capacity of culverts, channels and bridges;
4. institute an on-site detention program;
5. institute a regional approach to detention.

A discussion of each of these approaches is presented below.

#### 5.1.1 The "no action" alternative

At one extreme a municipality could allow development to take place without regard to the increased runoff caused by that development. This policy would be likely to cause excessive erosion, siltation or flooding problems due to insufficient channel capacity. The results would be additional flood damage, degradation of the streams, and diminished ground water supplies. Under the Pennsylvania Storm Water Management Act (P.L. 864, Act 167, October 4, 1978), such a policy would be illegal as well as undesirable. For these reasons, the "no action" alternative is considered completely unacceptable.

#### 5.1.2 Prohibiting or limiting development

At the other extreme a municipality could prohibit future development. With no new development there would, of course, be no increased runoff to control. In most cases, this is not a practical or desirable solution. On the other hand, judiciously limiting and timing development in an area would be a positive approach. When used in conjunction with other measures, it would also be effective in preventing a too-rapid expansion of an area prior to the addition or completion of effective storm water management facilties.

### 5.1.3 Increasing the hydraulic capacities of culverts, channels and bridges

A third storm water management alternative would be to increase the hydraulic capacity of existing channels, culverts and bridges as storm water runoff increases with development. This could be done by either increasing the size or by changing the characteristics of the channel lining.

There are several problems with this approach. First, it has the undesirable effect of getting rid of water by moving it downstream more quickly and thereby creating potential flooding problems there. Second, it is both very costly and environmentally undesirable. Finally, existing Pennsylvania law, rules and regulations require the prior approval of the Pennsylvania Department of Environmental Resources before channel work can be performed. Thus, this alternative does not appear to be a viable one for managing storm water.

### 5.1.4 Implementing an on-site detention approach

The on-site approach, as it has been developed for the purposes of this study, would require that the developer of a particular site be required to provide some method of on-site control that would restrict the runoff from the site to some specified amount. This allowable runoff is described in Section 4, Standards and Criteria for Storm Water Management. He would be allowed to use any of the methods listed herein or he may use another method that can be shown to be acceptable to the municipality or other governing authority.

The on-site approach, as the name implies, utilizes various storm water control procedures which operate to reduce runoff either by using holding facilities located on the site or by altering the runoff characteristics of the site in a specific manner. Table 1-4 in Appendix A lists various methods of on-site detention.

One of the simpler applications of this approach is to leave a large enough portion of a site in its natural or some other pervious state. The runoff from the impervious areas could then be discharged over the pervious areas and allowed to soak into the ground.

The runoff from parking lots may be reduced or controlled using a number of on-site methods. The use of porous pavement (gravel, porous or punctured asphalt, etc.) is one possibility. Vegetated ponding areas around parking lots is another.

Underground storage tanks for individual homes or group of homes would be effecive in reducing runoff from residential areas. Properly contoured landscaping could create detention areas to trap storm water and allow it to be absorbed into the ground. Surface pond storage is a very popular and effective means of storm water management.

### 5.1.5 Pros and cons of the on-site detention approach

Advantages and disadvantages of each kind of on-site storm water control are shown in Table 1-5 in Appendix A. In analyzing the on-site approach as a whole, there are some very positive features as well as some complications and drawbacks.

On the positive side, the developer is given a wide range of options from which to choose. This should allow him to tailor the storm water control method to the needs of his development. For example, porous pavement might work well for a commercial development. A man-made recreational lake might actually increase the value of a condominium development.

The cost of design and construction would be handled by the developer rather than the local governing bodies. Inclusion of appropriate clauses in each deed would place the responsibility of maintenance on the property owner. Maintenance bonds also could be posted to insure that the detention facilities are safe and functional.

Legislation has been enacted by the Commonwealth in order to prevent accelerated erosion and the resulting sedimentation during construction that requires earthmoving activities. Some of the acceptable means of achieving this control, sedimentation basins for example, might actually be used in a slightly modified form for storm water management purposes after construction is complete.

On the other hand, some means of checking the design and inspecting the construction and maintenance of these on-site facilities must be implemented by the Erie County Department of Planning or the municipality involved prior to the commencement of construction. This approval would be part of the building permit procedure. The zoning officer or building inspector have been previously suggested as suitable individuals for this activity. The municipal engineer, of course, would be the most logical person to handle this for communities which retain an engineer to deal with technical matters. The developer should be required to pay for all or part of the costs involved in the necessary inspection of any on-site facilities.

Another drawback of this on-site approach will result in the possibility of having a large proliferation of these on-site facilities scattered throughout the watershed. This would increase the possibility of having facilities that were poorly designed, improperly constructed, or allowed to fall into disrepair. In this case, the consequences could be more harmful than if no controls were construcrted at all. Extreme caution must be taken therefore as such facilities become more numerous to insure that the design, construction and maintenance of them is carried out in an acceptable manner. This task will become more demanding as the number of facilities increases.

### 5.1.6 Implementing a regional approach

Under the regional approach, all municipalities contained within the Lake Erie and Elk Creek Watershed Area would work together to manage the storm water runoff. Regional detention basins would be strategically located throughout the watershed. They would detain required amounts of storm water in such a manner that stream flows would be controlled at all locations. The amount of storm water that must be managed for a particular development site, as determined by the standards and criteria of this study, must be gathered at some point on the site and then must be piped to the detention basin designated to serve that site.

These basins would be owned and operated by an Authority specifically formed for this purpose. Construction would be paid for by fees charged to developers whose runoff would be discharged to a particular detention basin. Maintenance would be paid for by the property owners whose runoff would be discharged to a particular detention basin. To insure that maintenance is performed adequately and that funds are available for inspection of facilities, it would be advisable to require that bonds be posted for all such property.

Examination of recently constructed regional detention basins indicates that a good rough estimate of the cost of a detention basin is $8000 per acre-foot of storage provided. This can be further broken down to $.18 per cubic foot.

A theoretical solution to control water runoff for the Mill Creek Watershed Area (see Volume 10 for details of Mill Creek) was prepared using the regional approach. In this case, four detention basins were proposed. The storage for the first of these was estimated to be 46 acre-feet, and the construction cost was estimated to be $368,000. The second was estimated to require 90 acre-feet of storage with a construction cost of $720,000. The third would require 70 acre-feet of storage and had a construction cost of $560,000. The fourth was estimated to require 52 acre-feet of storage with a construction cost of $416,000. Thus, the total cost of the detention basins for the regional solution for the Mill Creek Watershed Area is approximately $2,064,000 in 1981 dollars. This does not include the cost of the land upon which the basins are to be built, nor does it include the cost of the pipes or ditches used to carry the runoff from the various developments to the regional basins which serve them.

### 5.1.7 <u>Pros and cons of the regional detention approach</u>

The regional approach is a more sophisticated method than the on-site approach. It is best suited to areas that are only moderately developed at the present time, but which are expected to develop quickly and heavily in the near future. It has been implemented and is working well in other rapidly developing areas.

The most important benefit of this approach is that the municipalities would control the management of storm water through the designated Authority in the Lake Erie and Elk Creek Watershed Areas. This would insure a uniform approach to the problem of design, construction and maintenance of detention facilities.

On the other hand, the system would be very expensive to implement. As shown in Section 5.1.6 above, the cost of building four detention basins in the Mill Creek watershed alone would be well over $2 million in 1981 dollars.

According to Pennsylvania law, it is not currently legal for municipalities to collect money for this purpose from developers. According to Act 247, Section 509, municipalities may collect and hold bond monies until storm water management facilties are built. This would work for the on-site approach but not the regional approach.

A more viable approach to managing the regional method would be to form a regional "Storm Water Management Authority". Under the provisions of the Municipal Authorities Act of 1945, such a regional authority would be independent of the municipalities which organize it. It would be formed for the purpose of acquiring, constructing, and maintaining the various flood control facilities. It would have the power to acquire by purchase, lease or otherwise, and to construct, improve and maintain any property necessary for carrying out the purpose of the storm water management in that region. Such an authority can be incorporated by one or several municipalities working jointly.

After an acceptable procedure for collecting the funds has been arranged, provision would have to be made for coordination over the entire region. Authorities so established could be separate for each of the individual subwatersheds (Mill Creek, Walnut Creek, Fourmile Creek, etc.) or there could be a county-wide authority such as "The Lake Erie and Elk Creek Storm Water Management Authority", for example.

To summarize the pros and cons of the regional approach, it has a number of advantages and would provide a sound storm water management program. The legal aspects could be resolved by forming an Authority. The major drawback to this approach is the cost. It is assumed that it is not economically feasible to implement the regional approach at this time in the Lake Erie and Elk Creek Watersheds.

5.1.8 Concluding remarks

The purpose of this report is to prepare a pilot study for an acceptable storm water management plan for Erie County. For that reason the plan must be flexible; it must afford the local authorities the ability to implement the plan. However, it must be recognized that this storm water management plan will not solve all the drainage problems in a community. In fact it is intended to prevent drainage problems from worsening. Therefore, the implementation should be done at the local level, by the people who have first hand knowledge of the situation and an interest in achieving successful results.

However, these same people must be tolerant of the proposed methods for storm water management and accept them as the most cost-effective solutions.

If it is necessary to extend storm water management beyond municipal boundaries, then cooperation between municipalities will be essential. Possible coordination of these joint programs could be accomplished with guidance and support of the Erie County Planning Department.

Although a storm water management authority was discussed, another agency is not needed. What is needed most are the following:

1. Recognition by the local authorities that a storm water management plan is needed to maintain a "status quo" condition of the watersheds in their municipality.

2. Acceptance of the storm water management plan as prepared by the Erie County Planning Department and Pennsylvania Department of Environmental Resources.

3. A genuine willingness to understand the storm water management plan and to cooperate in implementing it.

## Section 6

## DIRECT DRAINAGE AREAS

Results of the study of direct drainage watersheds are discussed in this chapter. Direct drainage areas can be defined as those which discharge their runoff to the lake in a relatively short period of time without a long meandering channel. Their location and topographic characteristics are illustrated on several different base maps of the larger watersheds discussed in Volumes 2 through 14. These areas generally are well developed at the present time. The largest development is expected in areas west of the City of Erie where the trend is projected to be towards industrial land use with some high density residential areas.

### 6.1 Design considerations and recommendations for direct drainage areas

The major flooding problems in these areas are due to the lack of storm sewer systems, culverts of inadequate capacity and ditches which are undersized and poorly maintained. Table 1-1 in Appendix A indicates that there is a projected increase in runoff due to land development. However, because of the proximity of these areas to the lake, the problems are different from those for the other subwatershed areas being studied.

For direct drainage, it is recommended that plans for on-site retention be combined with properly sized and maintained sewers, culverts and channels to provide adequate drainage for peak flows to pass directly to the lake. It is recommended that the rational method be used for design on all open channels, trunk sewers, and culverts. The recommended design storm is a 10-year storm of 24-hour duration. All culverts should be checked for a 10-year storm capacity. All proposed on-site retention and storm improvements are to be reviewed and approved by the local municipality or designated professional licensed by the Commonwealth of Pennsylvania to handle such plans.

Where storm sewers are to be installed through bluff lines along the lake, the last 500 feet shall be tunneled or bored in order to prevent erosion along the bluff. It is recommended that the number of such drainage points be kept as low as possible. Several discharges could be combined into one with adequate protection to beach escarpments provided.

## SECTION 7

## IMPLEMENTATION

### 7.1 Introduction

Every parcel of land has unique storm water runoff characteristics which inevitably change when the parcel is developed, usually resulting in an increase in storm water runoff from the site. When development takes place the increase in storm water runoff is magnified and serious problems can result. Prior to the development of this Plan there was no established method through which a municipality could require developers to take precautions against causing storm water runoff problems. The purpose of this Plan is to help correct the situation by establishing standards for storm water management and an administrative procedure whereby those standards can be applied by local governments to development within their jurisdiction.

The Storm Water Management Plan will be implemented by individual municipalities through the adoption of a storm water management ordinance or through amendments to existing subdivision or zoning regulations. Administration of the storm water management program will be accomplished through a combination of enforcement actions undertaken through the building permit process and through the subdivision review process, both of which are detailed later in this Section.

### 7.2 Special Considerations

Prior to discussing the specifics of the Building Permit Process and the Subdivision Review Process, two subjects which fall outside of the scope of this Plan's evaluation procedures will be discussed. The Building Permit and Subdivision Review evaluation procedures for storm water management apply to all forms of development and land use except development in areas with an existing storm sewer infrastructure and with respect to agricultural land.

In situations where development or redevelopment occurs in an area where direct access to an established storm sewer infrastructure is possible, the development or redevelopment is considered sufficient to manage its storm water runoff if its on-site storm drainage network is incorporated into the existing storm water infrastructure. By connecting with the existing storm sewer system, the development would be relieved of further obligations to manage storm water runoff in accordance with this Plan unless the municipal governing body perceives a potential storm water drainage problem or if the governing body wishes to correct an existing storm drainage problem. In these cases where the governing body desires a more stringent application of storm water management controls they may require that a detention/retention plan be developed which would alleviate the storm water drainage problem.

Evaluating agricultural land for compliance with storm water management controls is the second topic which falls outside of the scope of the Building Permit and Subdivision Review procedures. With respect to agricultural land, the recommended method of storm water management is to have a Soil Erosion and Sedimentation Control plan and/or permit prepared in accordance with existing State law and reviewed by the Erie County Soil Conservation Service. This applies only to cultivated land; agricultural accessory structures and residential structures should be evaluated by the municipality through the applicable method as outlined in the following sections.

## 7.3 Building Permit Process

If a proposed subdivision is defined by the host municipality's subdivision regulations as a minor subdivision (usually 10 lots or less) or if development is proposed involving no subdivision of property, then storm water management standards and criteria should be evaluated at the time when development is formally proposed via an application for a building permit. This system is designed so that smaller developments may occur without incurring added engineering expense and so that municipalities can implement storm water management requirements without incurring substantial administrative overhead expense.

The recommended technique to be followed when evaluating a minor subdivision or a development on an existing lot of record is presented here. First, all developments which fall into the above categories must meet each of the following standards:

Table 1-4 - Standards

1. Roof drains are not to be connected to streets, sanitary sewers or roadside ditches.

2. Runoff from the impervious areas must be drained to the pervious areas of the property.

3. Runoff is not to be collected or concentrated into an artificial conveyance and discharged onto adjacent property.

Next, the zoning officer must calculate the percentage of the parcel which will be covered by impervious surfaces after development is concluded. In this context impervious surfaces mean all land covered by a house, barn, garage, patio, driveway, etc. Information needed to calculate the percentage of impervious area should be readily available on the building permit application. Once the calculation is made the zoning officer should refer to the following table to determine how many storm water controls in addition to those listed above will be needed to comply with the standards of the Storm Water Management Plan. The additional controls can be found in Table 1-6.

Table 1-5 - Determination of Controls

| | |
|---|---|
| Less than 15% impervious | Table 1-4 controls only |
| 15% - 19.99% impervious | Table 1-4 controls plus one additional control |
| 20% - 24.99% impervious | Table 1-4 controls plus 2 additional controls |
| 25% - 30% impervious | Table 1-4 controls plus 3 additional controls |

The methodology outlined above is designed to be used for a proposed development which covers 30% or less of the parcel with an impervious surface. Under such circumstances the zoning officer can show the potential developer what storm water management controls are needed in order to receive the building permit. If the proposed development will cover greater than 30% of the parcel with an impervious surface or if the total impervious area exceeds one acre, then a licensed professional must be consulted to prepare a detention/retention plan which meets the approval of the governing body. An additional fee is recommended to be added to the existing building permit fee to cover the expense of administering the program.

## 7.4 Subdivision Review Process

If a development is defined by the host municipality's subdivision regulations as a major subdivision (usually more than 10 lots), the storm water management standards and criteria should be evaluated during the subdivision review process. This use of the subdivision review process is designed to ensure that large scale developments employ proper techniques to control storm water runoff and that these controls are firmly established prior to municipal or county approval of the subdivision plat. When a preliminary major subdivision plan is submitted for municipal review it shall be accompanied by detailed storm water detention/retention specifications which meet the critria of the Plan and which have been prepared by a professional licensed to perform such work in this Commonwealth. The proposed storm water detention/retention specifications shall be reviewed by the municipality and/or its engineer and shall satisfy the municipality before the major subdivision plan is approved. The municipality may require controls which are more stringent than those which meet the Storm Water Plan's criteria if circumstances dictate that such measures are needed to alleviate a current drainage problem or a suspected future drainage problem.

## 7.5 Conclusion

The Lake Erie and Elk Creek Storm Water Management Plan has been developed in accordance with Act 167 of 1978, the Pennsylvania Storm Water Management Act. Under the provisions of this Act, municipalities are granted certain powers and must assume certain responsibilities. One of the responsibilities which has been assigned to local governments by the Act is the responsibility to adopt implementing ordinances such as those described in this section. Another responsibility assigned to the municipality is that of properly enforcing the storm water management ordinances and regulations. Because of the responsibilities awarded to municipalities under Act 167, each municipality affected by this Plan should consult their municipal solicitor for a briefing about the extent of their obligations under the provisions of Act 167.

## Section 8

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APPENDIX A

**TABLES AND PLATES**

# DIRECT DRAINAGE SUMMARY

| WATERSHED | SWM 25: | AREA (ACRES) | Tc (MIN.) | $I_{10}$ (IN./HR.) | C (EXIST) | Q (ULT.) (C.F.S.) | C (EXIST) | Q (ULT.) (C.F.S.) |
|---|---|---|---|---|---|---|---|---|
| UNNAMED #1 | 2 | 246 | 41 | 2.4 | .36 | 213 | .40 | 236 |
| UNNAMED #2 | 3 | 255 | 42 | 2.35 | .36 | 216 | .40 | 240 |
| UNNAMED #3 | 5 | 631 | 63 | 1.9 | .36 | 432 | .43 | 516 |
| UNNAMED #4 | 6 | 1221 | 99 | 1.4 | .36 | 615 | .47 | 803 |
| UNNAMED #5 | 7 | 125 | 26 | 3.2 | .36 | 144 | .39 | 156 |
| UNNAMED #6 | 8 | 799 | 114 | 1.3 | .36 | 374 | .40 | 415 |
| DUCK RUN | 10 | 1165 | 93 | 1.4 | .36 | 587 | .40 | 652 |
| UNNAMED #7 | 12 | 1505 | 55 | 2.1 | .45 | 1420 | .60 | 1900 |
| UNNAMED #8 | 13 | 349 | 40 | 2.5 | .40 | 349 | .60 | 524 |
| GODFREY RUN | 14 | 2495 | 123 | 1.3 | .45 | 1460 | .65 | 2,110 |
| UNNAMED #9 | 15 | 558 | 49 | 2.2 | .36 | 442 | .62 | 761 |
| UNNAMED #10 | 16 | 294 | 27 | 3.1 | .36 | 328 | .55 | 501 |
| UNNAMED #11 | 18 | 455 | 38 | 2.5 | .38 | 432 | .65 | 799 |
| UNNAMED #12 | 20 | 641 | 45 | 2.3 | .40 | 590 | .51 | 752 |
| WILKINS RUN | 21 | 1288 | 67 | 1.8 | .40 | 925 | .70 | 1620 |
| MARSHALL RUN | 22 | 1719 | 69 | 1.7 | .48 | 1400 | .78 | 2280 |
| McDANNEL RUN | 24 | 1733 | 81 | 1.6 | .60 | 1660 | .68 | 1890 |
| FIVEMILE CREEK | 26 | 2087 | 71 | 1.7 | .50 | 1770 | .62 | 2200 |
| UNNAMED #13 | 29 | 241 | 51 | 2.1 | .38 | 192 | .58 | 294 |
| ORCHARD BEACH RUN | 33 | 1162 | 63 | 1.9 | .38 | 839 | .48 | 1060 |
| MIDDLE RUN | 34 | 1645 | 89 | 1.4 | .36 | 829 | .45 | 1040 |
| UNNAMED #14 | 35 | 298 | 28 | 3.1 | .36 | 333 | .42 | 388 |
| DEWEY RUN | 36 | 2696 | 97 | 1.3 | .36 | 1260 | .40 | 1400 |
| UNNAMED #15 | 37 | 212 | 37 | 2.5 | .36 | 191 | .42 | 223 |
| UNNAMED #16 | 38 | 122 | 34 | 2.6 | .36 | 114 | .42 | 133 |
| UNNAMED #17 | 39 | 111 | 26 | 3.2 | .36 | 128 | .40 | 142 |
| UNNAMED #18 | 40 | 94 | 23 | 3.3 | .36 | 112 | .40 | 124 |
| UNNAMED #19 | 42 | 230 | 36 | 2.5 | .36 | 207 | .40 | 230 |
| UNNAMED #20 | 43 | 116 | 33 | 2.7 | .36 | 113 | .40 | 125 |
| UNNAMED #21 | 44 | 505 | 61 | 1.9 | .36 | 345 | .40 | 384 |
| UNNAMED #22 | 45 | 55 | 20 | 3.7 | .36 | 73 | .40 | 82 |
| UNNAMED #23 | 46 | 267 | 41 | 2.4 | .36 | 231 | .40 | 256 |

TABLE 1-1

TABLE 1-2
WEIGHTED RUNOFF CURVE NOS.
FOR VARIOUS EXISTING LAND USES

| LAND USE \ SOIL AREA | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| OPEN | 75.00 | 75.00 | 69.00 | 75.00 | 80.00 | 79.00 | 84.00 | 80.00 | 79.00 | 84.00 |
| WOODED | 72.00 | 72.00 | 55.00 | 64.00 | 71.00 | 70.00 | 77.00 | 71.00 | 71.00 | 77.00 |
| CULTIVATED | 79.00 | 79.00 | 71.00 | 75.00 | 78.00 | 78.00 | 81.00 | 79.00 | 78.00 | 81.00 |
| RESIDENTIAL | 82.00 | 82.00 | 72.00 | 78.00 | 82.00 | 81.00 | 86.00 | 82.00 | 81.00 | 86.00 |
| COMMERCIAL | 94.00 | 94.00 | 92.00 | 93.00 | 94.00 | 94.00 | 95.00 | 94.00 | 94.00 | 95.00 |
| INDUSTRIAL | 91.00 | 91.00 | 88.00 | 90.00 | 91.00 | 91.00 | 93.00 | 91.00 | 91.00 | 93.00 |

NOTE: THE HIGHER THE RUNOFF CURVE NUMBER, THE MORE IMPERVIOUS THE SOIL OR COVER .

TABLE 1-3
WEIGHTED RUNOFF CURVE NOS.
FOR VARIOUS PROPOSED LAND USES

| LAND USE \ SOIL AREA | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| AGRICULTURAL - RESIDENTIAL | 80.00 | 80.00 | 72.00 | 76.00 | 80.00 | 80.00 | 84.00 | 80.00 | 80.00 | 84.00 |
| WOODED | 72.00 | 72.00 | 55.00 | 64.00 | 71.00 | 70.00 | 77.00 | 71.00 | 71.00 | 77.00 |
| COMMERCIAL | 94.00 | 94.00 | 92.00 | 93.00 | 94.00 | 94.00 | 95.00 | 94.00 | 94.00 | 95.00 |
| RESIDENTIAL | 82.00 | 82.00 | 72.00 | 78.00 | 82.00 | 81.00 | 86.00 | 82.00 | 81.00 | 86.00 |
| INDUSTRIAL | 91.00 | 91.00 | 88.00 | 90.00 | 91.00 | 91.00 | 93.00 | 91.00 | 91.00 | 93.00 |

NOTE: THE HIGHER THE RUNOFF CURVE NUMBER, THE MORE IMPERVIOUS THE SOIL OR COVER .

Table 1-6

VARIOUS ON-SITE STORM WATER CONTROL METHODS

| AREA | REDUCING RUNOFF | DELAYING RUNOFF |
|---|---|---|
| Large Flat Roof | 1. Cistern storage<br>2. Rooftop gardens<br>3. Pool storage or fountain storage | 1. Ponding on roof by constricted downspouts<br>2. Increasing roof roughness<br>a. Rippled roof<br>b. Gravelled roof |
| Parking Lots | 1. Porous pavement<br>a. Gravel parking lots<br>b. Porous or punctured asphalt<br>2. Concrete vaults and cisterns beneath parking lots in high value areas<br>3. Vegetated ponding areas around parking lots<br>4. Gravel trenches | 1. Grassy strips on parking lots<br>2. Grassed waterways draining parking lot<br>3. Ponding and detention measures for impervious areas<br>a. Rippled pavement<br>b. Depressions<br>c. Basins |
| Residential | 1. Cisterns for individual homes or groups of homes<br>2. Gravel driveways (porous)<br>3. Contoured landscape<br>4. Ground-water recharge<br>a. Perforated pipe<br>b. Gravel (sand)<br>c. Trench<br>d. Porous pipe<br>e. Dry wells<br>5. Vegetated depressions | 1. Reservoir of detention basin<br>2. Planting a high delaying grass (high roughness)<br>3. Gravel driveways<br>4. Grassy gutters or channels<br>5. Increased length of travel of runoff by means of gutters, diversions, etc. |
| General | 1. Gravel alleys<br>2. Porous sidewalks<br>3. Mulched planters | 1. Gravel alleys |

Source: Urban Hydrology for Small Watersheds.
Technical Release No. 55

Table 1-7

ADVANTAGES AND DISADVANTAGES OF VARIOUS ON-SITE STORM WATER CONTROL METHODS

| MEASURE | ADVANTAGES | DISADVANTAGES |
|---|---|---|
| A. Cisterns and Covered Ponds | 1. Water may be used for:<br>a. Fire Protection<br>b. Watering lawns<br>c. Industrial processes<br>d. Cooling purposes<br>2. Reduce runoff while only occupying small area<br>3. Land or space above cistern may be used for other purposes | 1. Expensive to install<br>2. Cost required may be restrictive if the cistern must accept water from large drainage areas<br>3. Requires slight maintenance<br>4. Restricted access<br>5. Reduces available space in basements for other uses |
| B. Rooftop Gardens | 1. Esthetically pleasing<br>2. Runoff reduction<br>3. Reduce noise levels<br>4. Wildlife enhancement | 1. Higher structural loadings on roof and building<br>2. Expensive to install and maintain |
| C. Surface Pond Storage (usually residential areas) | 1. Controls large drainage areas with low release<br>2. Esthetically pleasing<br>3. Possible recreation benefits<br>a. Boating<br>b. Ice skating<br>c. Fishing<br>d. Swimming<br>4. Aquatic life habitat<br>5. Increases land value of adjoining property | 1. Requires large areas<br>2. Possible pollution from storm water and siltation<br>3. Possible mosquito breeding areas<br>4. May have adverse algal blooms as a result of eutrophication<br>5. Possible drowning<br>6. Maintenance problems |

Table 1-7 (Continued)

| | | |
|---|---|---|
| D. Ponding on Roof by Constricted Downspouts | 1. Runoff delay<br>2. Cooling effect for building<br>a. Water on roof<br>b. Circulation through<br>3. Roof ponding provides fire protection for building (roof water may be trapped in case of fire) | 1. Higher structural loadings<br>2. Clogging of constricted inlet requiring maintenance<br>3. Freezing during winter (expansion)<br>4. Waves and wave loading<br>5. Leakage of roof water into building (water damage) |
| E. Increased Roof Roughness<br>a. Rippled roof<br>b. Gravel on roof | 1. Runoff delay and some reduction (detention in ripples or gravel) | 1. Somewhat higher structural loadings |
| F. Porous pavement (parking lots and alleys)<br>a. Gravel parking lot<br>b. Holes in impervious pavements (¼ in. diam.) filled with sand | 1. Runoff reduction (a and b)<br>2. Potential groundwater recharge (a and b)<br>3. Gravel pavements may be cheaper than asphalt or concrete (a) | 1. Clogging of holes or gravel pores (a and b)<br>2. Compaction of earth below pavement or gravel decreases permeability of soil (a and b)<br>3. Ground-water pollution from salt in winter (a and b)<br>4. Frost heaving for impervious pavement with holes (b)<br>5. Difficult to maintain<br>6. Grass or weeds could grow in porous pavement (a and b) |
| G. Grassed channels and vegetated strips | 1. Runoff delay<br>2. Some runoff reduction (infiltration recharge<br>3. Esthetically pleasing<br>a. Flowers<br>b. Trees | 1. Sacrifice some land area for vegetated strips<br>2. Grassed areas must be mowed or cut periodically (maintenance costs) |

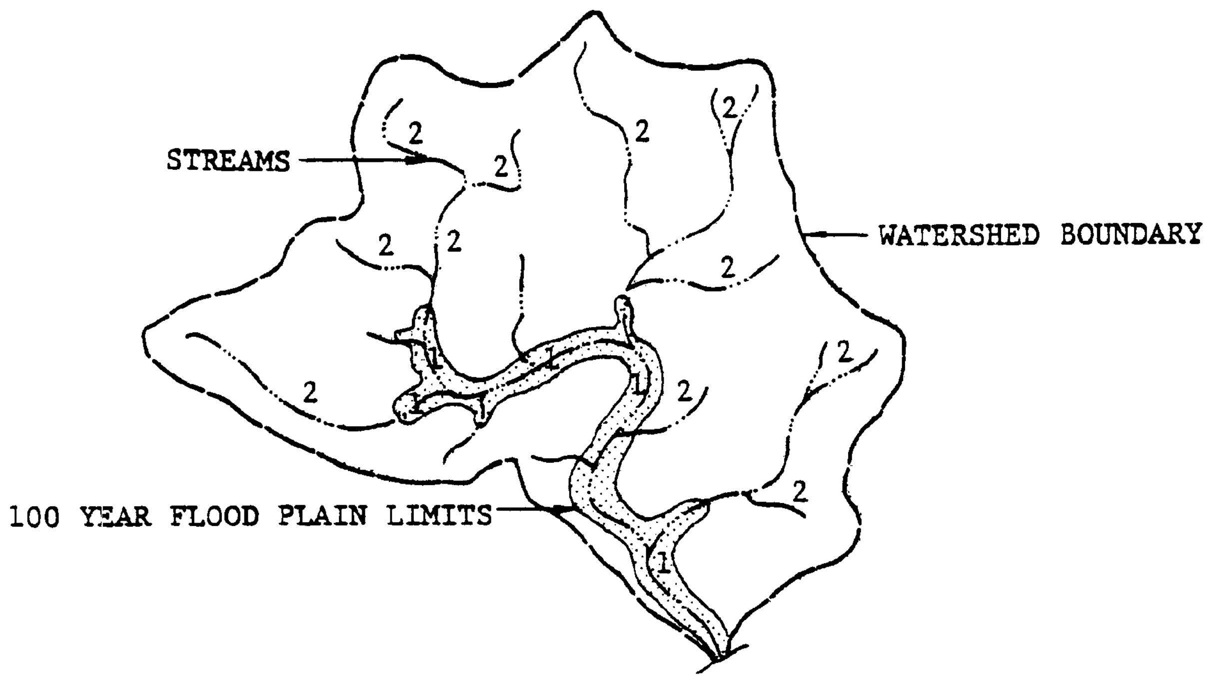
Table 1-7 (Continued)

| | | | |
|---|---|---|---|
| H. | Ponding and detention measures on impervious pavement<br>a. Rippled pavement<br>b. Basins<br>c. Constructed inlets | 1. Runoff delay (a, b, and c)<br>2. Runoff reduction (a and b) | 1. Somewhat restricted movement of vehicle (a)<br>2. Interferes with normal use (a and c)<br>3. Damage to rippled pavement during snow removal (a)<br>4. Depressions collect dirt and debris (a, b, and c) |
| I. | Reservoir or detention basin | 1. Runoff delay<br>2. Recreation benefits<br>a. Ice Skating<br>b. Baseball, football, etc. if land is provided<br>3. Esthetically pleasing<br>4. Could control large drainage areas with low release | 1. Considerable amount of land is necessary<br>2. Maintenance costs<br>a. Mowing grass<br>b. Herbicides<br>c. Cleaning periodically (silt removal)<br>3. Mosquito breeding area<br>4. Siltation in basin |
| J. | Converted septic tank for storage and ground-water recharge | 1. Low installation costs<br>2. Runoff reduction (infiltration and storage)<br>3. Water may be used for:<br>a. Fire protection<br>b. Watering lawns and gardens<br>c. Ground-water recharge | 1. Requires periodic maintenance (silt removal)<br>2. Possible health hazard<br>3. Sometimes requires a pump for emptying after storm |
| K. | Ground-water recharge<br>a. Perforated pipe or hose<br>b. French drain<br>c. Porous pipe<br>d. Dry well | 1. Runoff reduction (infiltration)<br>2. Ground-water recharge with relatively clean water<br>3. May supply water to garden or dry areas<br>4. Little evaporation loss | 1. Clogging of pores or perforated pipe<br>2. Initial expense of installation (materials) |
| L. | High delay grass (high roughness) | 1. Runoff delay<br>2. Increased infiltration | 1. Possible erosion or scour<br>2. Standing water on lawn in depressions |

Source: Urban Hydrology for Small Watershed
Technical Release No. 55

PLATE : 1-3

DEFINITION OF TYPE 1 AND TYPE 2 CHANNELS




HOW TO FIND TYPE 1 OR 2 CHANNELS

1.) LOCATE CHANNEL ON 100 YEAR FLOOD PLAIN MAPS FOR WATERSHED.

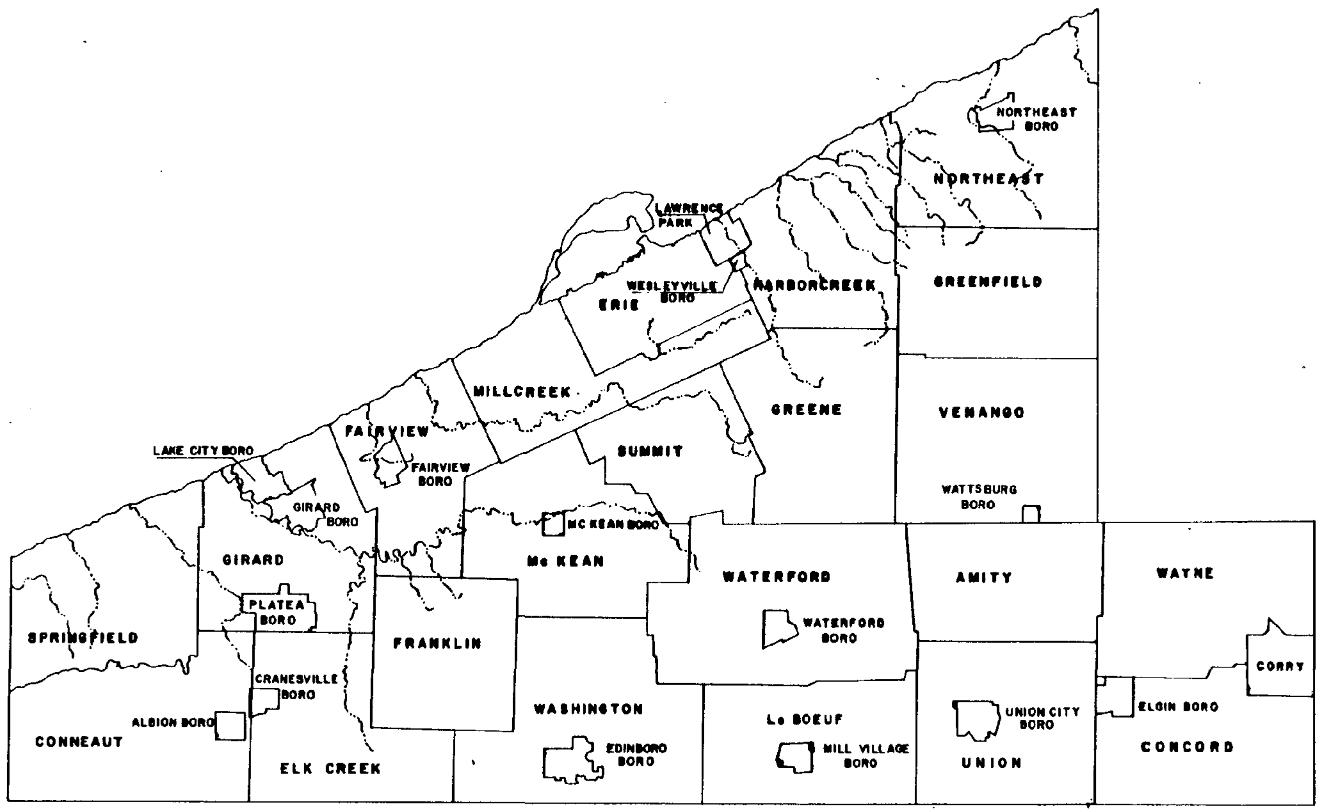
2.) IF CHANNEL IS LOCATED WITHIN THE SHADED FLOOD PLAIN LIMITS IT IS A TYPE 1 CHANNEL.

3.) IF CHANNEL IS OUTSIDE THE SHADED AREA IT IS A TYPE 2 CHANNEL.

LEGEND

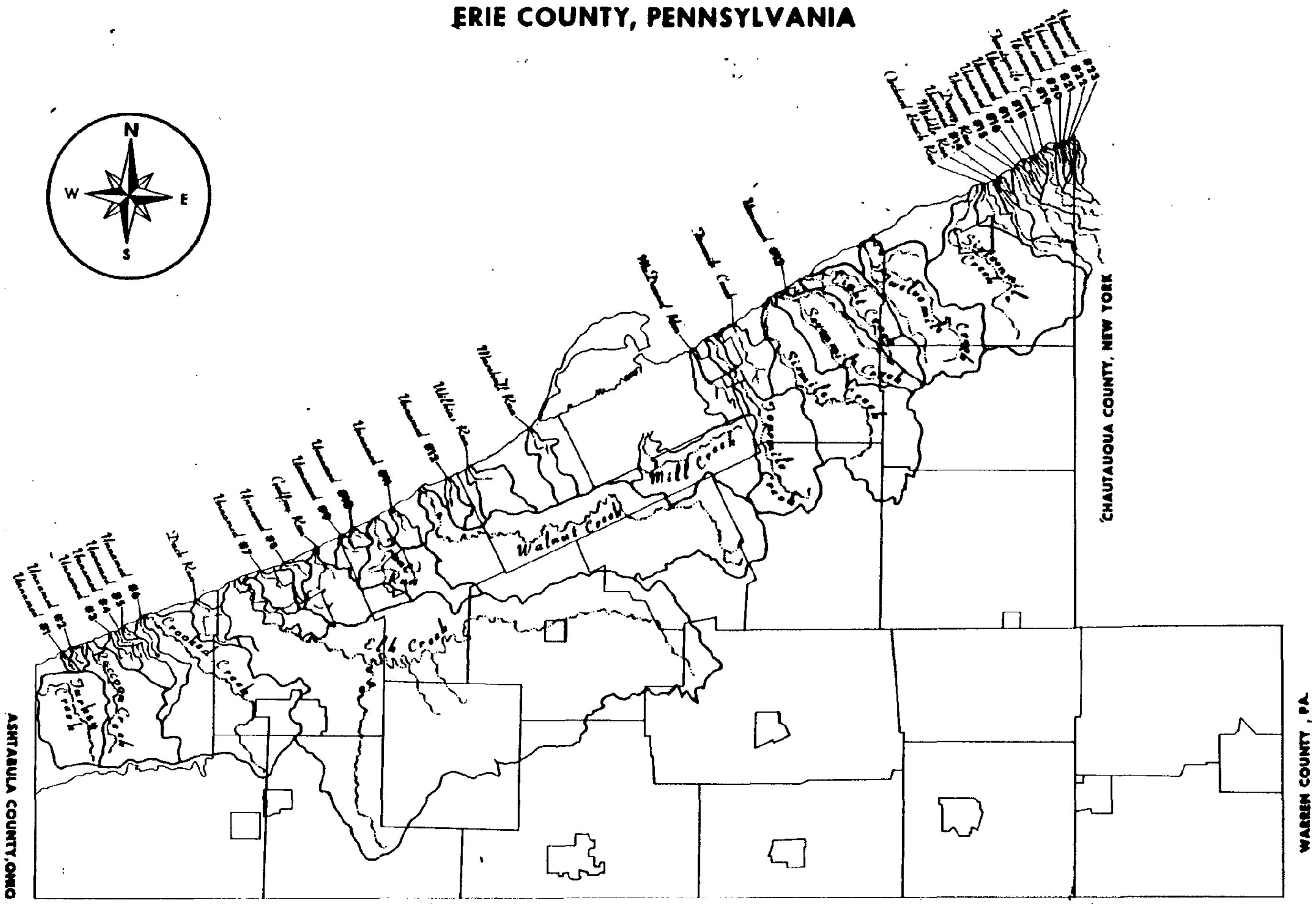
1 = TYPE 1 CHANNEL
2 = TYPE 2 CHANNEL

# ERIE COUNTY POLITICAL SUBDIVISIONS



# LAKE ERIE WATERSHED KEY MAP

## ERIE COUNTY, PENNSYLVANIA




| | |
|---|---|
| TURKEY CREEK | SWM 25:1 |
| UNNAMED #1 | SWM 25:2 |
| UNNAMED #2 | SWM 25:3 |
| RACCOON CREEK | SWM 25:4 |
| UNNAMED #3 | SWM 25:5 |
| UNNAMED #4 | SWM 25:6 |
| UNNAMED #5 | SWM 25:7 |
| UNNAMED #6 | SWM 25:8 |
| CROOKED CREEK | SWM 25:9 |
| DUCK RUN | SWM 25:10 |
| ELK CREEK | SWM 25:11 |
| UNNAMED #7 | SWM 25:12 |
| UNNAMED #8 | SWM 25:13 |
| GODFREY RUN | SWM 25:14 |
| UNNAMED #9 | SWM 25:15 |
| UNNAMED #10 | SWM 25:16 |
| TROUT RUN | SWM 25:17 |
| UNNAMED #11 | SWM 25:18 |
| WALNUT CREEK | SWM 25:19 |
| UNNAMED #12 | SWM 25:20 |
| WILKINS RUN | SWM 25:21 |
| MARSHALL RUN | SWM 25:22 |
| MILL CREEK | SWM 25:23 |
| McDANNEL RUN | SWM 25:24 |
| FOURMILE CREEK | SWM 25:25 |
| FIVEMILE CREEK | SWM 25:26 |
| SIXMILE CREEK | SWM 25:27 |
| SEVENMILE CREEK | SWM 25:28 |
| UNNAMED #13 | SWM 25:29 |
| EIGHTMILE CREEK | SWM 25:30 |
| TWELVEMILE CREEK | SWM 25:31 |
| SIXTEENMILE CREEK | SWM 25:32 |
| ORCHARD BEACH RUN | SWM 25:33 |
| MIDDLE RUN | SWM 25:34 |
| UNNAMED #14 | SWM 25:35 |
| DEWEY RUN | SWM 25:36 |
| UNNAMED #15 | SWM 25:37 |
| UNNAMED #16 | SWM 25:38 |
| UNNAMED #17 | SWM 25:39 |
| UNNAMED #18 | SWM 25:40 |
| TWENTYMILE CREEK | SWM 25:41 |
| UNNAMED #19 | SWM 25:42 |
| UNNAMED #20 | SWM 25:43 |
| UNNAMED #21 | SWM 25:44 |
| UNNAMED #22 | SWM 25:45 |
| UNNAMED #23 | SWM 25:46 |

ODRUFF, INC.
CONSULTING ENGINEERS
CLEVELAND OHIO

# APPENDIX B

## DEFINITIONS OF TERMS

## APPENDIX B

## DEFINITION OF TERMS

The following terms or phrases used in this report are defined as indicated below:

**Branch Streams** - Those sections of a creek which do not have a well established flood plain. Tributaries to a main stream also fall under this definition.

**Culvert** - A structure with appurtenant works which carries a stream under or through an embankment of fill.

**Detention Facilities** - Storage areas for storm water runoff that store water for a short period and release it at a controlled rate.

**Design Storm** - That storm of given duration and return frequency which is determined and justified in this study and is used to generate existing runoff flow data. Runoff due to this storm for proposed development is to be calculated and compared to that for existing land use.

**Development** - Any activity, construction, alteration, changes in land use or practices that affect storm water runoff characteristics.

**Direct Drainage Watershed** - Those smaller watersheds along the Lake Erie shoreline which discharge their runoff to the lake quickly due to their shorter length.

**Erosion** - The natural process by which the surface of the land is worn away by the action of water, wind, or chemical action.

**Flood** - A general but temporary condition of partial or complete inundation of normally dry land area caused by the overflow of streams, rivers, or other waters of the Commonwealth.

**Flood Control Project** - Any device or structure designed and constructed to protect a designated area from flood flows of a specified magnitude and probability (frequency) of occurrence.

**Flood Hazard Area** - A normally dry land area that has been, and is, susceptible to being inundated by surface or subsurface flow in addition to stream overflow. For regulatory purposes, the Flood Plain Management Act (Act of October 4, 1978, P.L. 851, No. 166) and regulations pursuant to the Act define Flood Hazard Areas and an area identified by FEMA (Federal Emergency Management Agency) as shown on the Flood Plan Map as being subject to flooding by a 100-year storm.

**Flood Plain** - A normally dry land area adjacent to stream channels that is susceptible to being inundated by overbank stream flows. For regulatory purposes, the Flood Plain Management Act (Act of October 4, 1978, P.L. 851, No. 166) and regulations pursuant to the Act define the flood plain as the area inundated by a 100-year flood and delineated on a map by FEMA.

**Freeboard** - The vertical distance between the water surface elevation experienced during the design storm and the crest elevation of a dam, levee, floodwall, or other embankment.

**Mean Annual Flood** - That flow at which the channel of a given stream is just full (called bank-full stage).

**Groundwater** - That part of the subsurface water which is below the zone of saturation.

**Groundwater Recharging Area** - Any surface area from which water penetrates and subsequently passes into the groundwater supply. Examples include networks of ditches, perforated pipe, dry wells, etc.

**Hydrology** - The science dealing with the waters of the earth and their distribution and circulation through the atmosphere. Engineering hydrology deals with the application of hydrologic concepts for the design of projects for use and control of water.

**Hydrograph** - A graph showing, for a given point on a stream or for a given point in any drainage system, the discharge, state, velocity, or other property of water with respect to time.

**Impervious Material** - Any material which prevents or inhibits the passage or entrance of water or other liquid through it.

**Infiltration** - The penetration and movement of water though the earth's surface.

**Mainstream** - Those sections of a creek which have a well established flood plain (that portion of a channel cross section which will contain the excess volume of flow during flooding conditions).

**Municipality** - A city, borough, town or township, or any county of other governmental unit when acting as an agent thereof, or any combination thereof acting jointly.

**Natural Storm Water Runoff Regime** - A watershed where natural surface configurations, runoff characteristics and defined drainage conveyances have attained the conditions of equilibrium.

**One-Hundred-Year Flood** - The highest level of flooding that, on the average, is likely to occur every one hundred years, that is, that has one percent chance of occuring each year.

**Pervious Material** - Material which permits the passage or entrance of water or other liquid.

**Porous Pavement** - Any pavement which permits the passage of surface water through it to the soil below.

**Rate of Storm Water Runoff** - Instantaneous measurement of water flow expressed as a given volume per unit of time, also referred to as discharge. Examples: cubic feet per second (cfs); gallons per minute (gpm).

**Retention Facilities** - Storage areas for storm water runoff that maintain a planned permanent level of water even after storm runoff has ceased.

**Runoff Characteristics** - The surface components of any watershed which affect the rate, amount and direction of storm water runoff. These may include, but are not limited to: vegetation, soils, slopes and man-made landscape alterations.

**Significant Obstruction** - Any structure or assembly of materials including fill above or below the surface of land or water, and any activity which might impede, retard, or change flood flows. The planting, cultivation, and harvesting of field and orchard crops or the grazing of livestock, including the maintenance of necessary appurtenant agricultural fencing, shall not be considered an "obstruction" under this definition and shall not be subject to regulation under the Stormwater Management Act.

**Storage Capacity** - The volume expressed in acre-feet of the impounded water to the maximum storage level, that is, the top of the dam.

**Storm Water** - Drainage runoff from the surface of the land resulting from precipitation or snow or ice melt.

**Storm Water Collection System** - Natural or man-made structures which collect and transport storm water.

**Subwatershed** - A hydrologically defined area within a designated watershed which drains to a specific point.

**Volume of Storm Water Runoff** - That quantity of water normally measured in inches, cubic feet, or acre-feet. This quantity is measured or determined analytically from (1) runoff coefficients; (2) rainfall/runoff ratios; and (3) areas underneath hydrographs.

**Watershed** - The entire region or area drained by a river or other body of water whether natural or artifical. A designated watershed is an area delineated by the department and approved by the Enviromental Quality Board for which counties are required to develop watershed storm water plans.

APPENDIX C

CALCULATION PROCEDURES

## APPENDIX C

## CALCULATION PROCEDURES

1. Rainfall - Storm rainfall was calculated from the intensity duration curves of point rainfall for Erie County. These curves are presented in Figure C-1. Intensities corresponding to various durations were taken from the curve. The total depth of rainfall was calculated for each duration, and the increments of depth corresponding to a selected time interval were computed. These increments were then rearranged to represent a typical rainfall pattern with the peak rainfall between one-third and one-half the storm duration. The ten-year, twenty-four hour rainfall pattern is shown in Table C-1.

2. Runoff Unit Hydrograph - In order to derive the runoff hydrograph, the area of the watershed must be known as well as the curve number (from land use and soil complexes) and the time of concentration.

   In this study, the time of concentration was calculated by utilizing the California Highway Formula:

   $$T_c = (11.9\ L^3/H)^{(0.385)} \times 60$$

   Where $T_c$ = overland flow time in minutes.
   L = length in miles from furthest contributing point to discharge point.
   H = difference in elevation in feet from furthest point to discharge point.

   The following steps and procedures are used to calculate the runoff hydrographs:

   A. Calculate the unit storm duration in hours:
   Delta D = $0.133\ T_c$

   B. Calculate the time to peak in hours from the beginning of the storm:
   $T_p = 0.667\ T_c$

   C. Calculate peak discharge for one inch of runoff in cubic feet per second:
   $q_p = 484\ (A)\ (Q)/T_p = 484\ (A)\ (1.0)/T_p$

   Where A = drainage area in acres:
   $q_p$ = runoff in inches

D. Calculate unit hydropraph:
$q_i = q_i/q_p \times q_p$
$t_i = t_i/T_p \times T_p$
Where $q_i$ = flow in cubic feet per second:
$t_i$ = time in hours
Values of dimensionless unit hydrograph are listed in Table C-3.

E. Change unit hydrograph into intervals of delta D units:

F. Calculate an accumulated rainfall curve from storm pattern at delta D increments:
$P_n = P_{(n-1)}+P_n$
Where $P_n$ = accumulated rainfall at delta D increments

G. Calculate an accumulated runoff curve at delta D time increments:
$Q_n = (P_n - 0.25)^2/(P_n + 0.85)$
$S = (1000 - 10CN)/CN$
Where CN = curve number:
Note: $Q_n$ is 0.0 until $P_n - 0.25$ is greater than 0.0

H. Change accumulated runoff curve to an incremental runoff curve.
$Qn = Q_n - Q_{(n-1)}$

I. Tabulate values of qn and Qn at delta D time increments:

J. Calculate final hydrograph:
$R_1 = q_1 (Q_1)$
$R_2 = q_1 (Q_2) + q_2 (Q_1)$
$R_3 = q_1 (Q_3) + q_2 (Q_2) + q_3 (Q_1)$

3. Channel Routing - Runoff hydrographs were flood routed through the main stream by the channel routing methods of the SCS. This method was derived from the inflow-outflow relationships cited earlier in this report.
Flows at two points on a stream were described by a routing or working equation:
$O_2 = (1-C)\, O_1 + CI_1$

Where I = inflow:
O = outflow
C = proportionality constant
Such that $C = (O_2-O_1)/(I_1-O_1)$

By determining relationships between inflow and outflow curves the following relationship was was derived:
$(O_2-O_1)/\text{Delta } t = (I_1-O_1)/K$
Where delta t = the time of flood travel
I = travel time for steady stream flow

These equations are combined resulting in the relationship:
$C = \text{Delta } t/K$

The variables were found by the following procedures:

A. Stream reaches were determined by the characteristics of the stream itself. The distance between points where branches joined the mainstream were used in most cases.

B. Determine K values: $K = L/3600\ V$

Where L = Reach length in feet

V = Routing velocity which is the velocity through the reach of flow equal to 75 percent of peak inflow in feet per second.

C. Determine C value: $C = V/(V + 1.7)$

D. Determine Delta t: Delta t = C x K. Occasionally this calculated Delta t was different from the Delta t of the inflow hydrograph. Therefore, as a rule of thumb, the preferred time interval was chosen to be less than or equal to $T_p/5$, where $T_p$ is the time from beginning of runoff to peak runoff. If Delta t was greater than $T_p/5$, the preferred time $t^* = T_p/5$ was used. It follows then that if Delta t is changed, L, K and C must also be changed to suit the time increment since they are specific for a single channel length.

E. Determine K*: K* = Delta t/c

F. Determine L*: $L^* = 3600\ V\ K^*$. If L* was less than the given reach length, L, the inflow hydrograph was repetitively routed until the difference between the sum of the L's and L became less than L*. The last routing in the reach L* was a fractional routing using C*.

G. Determine the outflow hydrograph using the working equation:

$$O_2 = (1-C)\ O_1 + CI_1$$

Flood hydrographs were found for each reach of each stream for existing land use conditions and ultimate land use conditions. Tributary branch flows were combined to channel flow by adding tributary hydrographs to channel hydrographs. In order to add hydrographs they had to convert to the same time increments. The peak from the resulting channel hydrographs was the greatest flow to be expected in the stream for the design storm used.

Table C-1

TEN-YEAR, TWENTY-FOUR-HOUR RAINFALL

| Duration (Hours) | Intensity (In./Hr.) | Total Rainfall (Inches) | Incremental Rainfall (Inches) | Storm Pattern (Inches) |
|---|---|---|---|---|
| 1 | 1.98 | 1.98 | 1.98 | 0.01 |
| 2 | 1.30 | 2.60 | .62 | .05 |
| 3 | .93 | 2.79 | .19 | .11 |
| 4 | .76 | 3.04 | .25 | .19 |
| 5 | .65 | 3.25 | .21 | .21 |
| 6 | .56 | 3.36 | .11 | .62 |
| 7 | .51 | 3.57 | .21 | 1.98 |
| 8 | .46 | 3.68 | .11 | .25 |
| 9 | .42 | 3.78 | .08 | .23 |
| 10 | .38 | 3.80 | .04 | .21 |
| 11 | .35 | 3.85 | .04 | .21 |
| 12 | .32 | 3.84 | .01 | .14 |
| 13 | .31 | 4.03 | .08 | .11 |
| 14 | .29 | 4.06 | .03 | .08 |
| 15 | .28 | 4.20 | .14 | .08 |
| 16 | .27 | 4.32 | .05 | .07 |
| 17 | .25 | 4.25 | .07 | .05 |
| 18 | .24 | 4.32 | .01 | .04 |
| 19 | .23 | 4.37 | .05 | .04 |
| 20 | .23 | 4.60 | .23 | .03 |
| 21 | .22 | 4.62 | .02 | .03 |
| 22 | .21 | 4.62 | .01 | .02 |
| 23 | .21 | 4.83 | .18 | .01 |
| 24 | .20 | 4.80 | .03 | .01 |

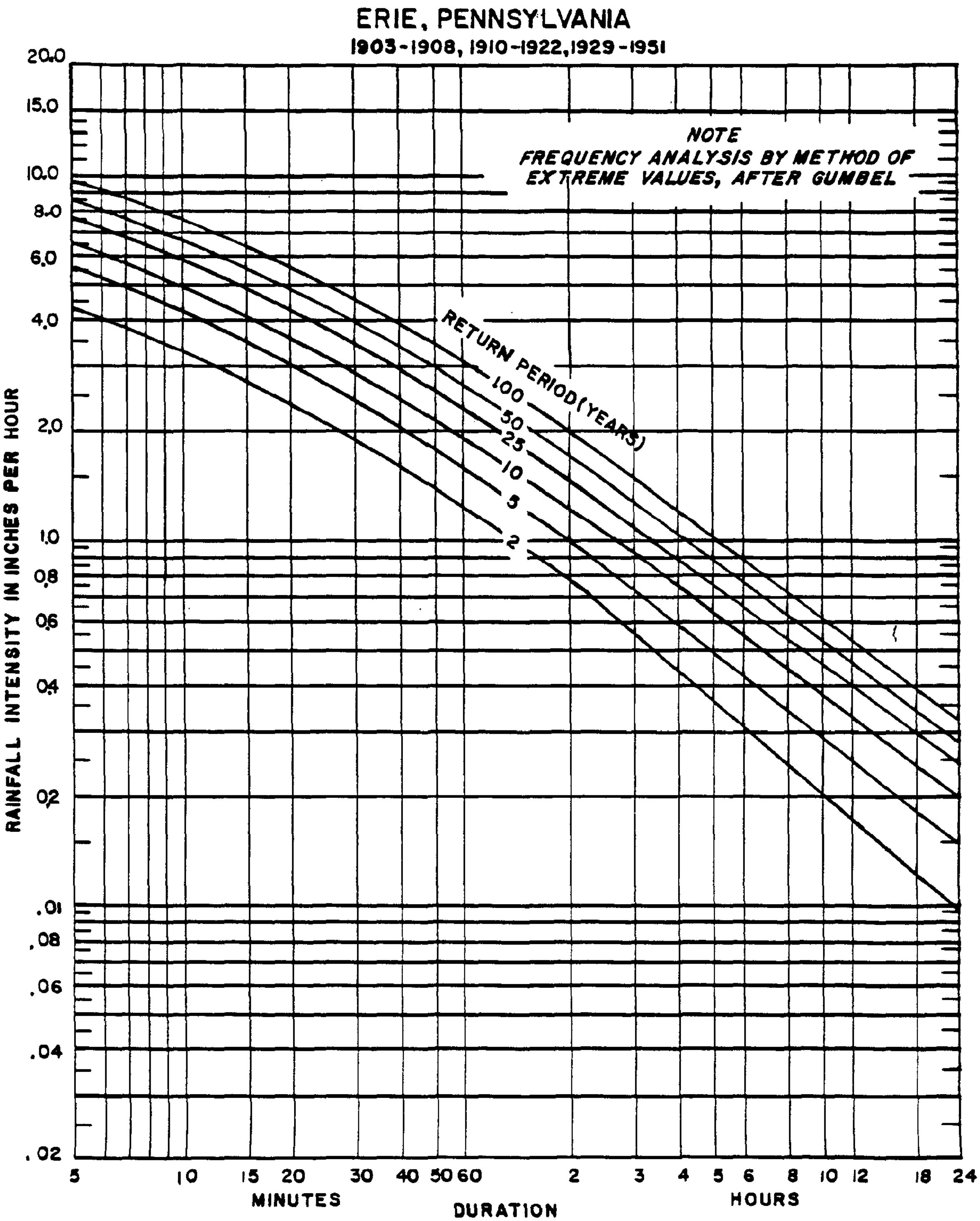
Table C-2

## 2.33 YEAR TWENTY-FOUR-HOUR DURATION

| Duration (Hours) | Intensity (In./Hr.) | Total Rainfall (Inches) | Incremental Rainfall (Inches) | Storm Pattern (Inches) |
|---|---|---|---|---|
| 1 | 1.40 | 1.40 | 1.40 | .01 |
| 2 | .85 | 1.70 | .30 | .05 |
| 3 | .62 | 1.86 | .16 | .06 |
| 4 | .50 | 2.00 | .14 | .07 |
| 5 | .41 | 2.05 | .05 | .10 |
| 6 | .35 | 2.10 | .05 | .30 |
| 7 | .31 | 2.17 | .07 | 1.40 |
| 8 | .28 | 2.24 | .07 | .16 |
| 9 | .26 | 2.34 | .10 | .14 |
| 10 | .24 | 2.40 | .06 | .08 |
| 11 | .22 | 2.40 | .01 | .07 |
| 12 | .20 | 2.42 | .02 | .06 |
| 13 | .19 | 2.47 | .05 | .06 |
| 14 | .18 | 2.52 | .05 | .05 |
| 15 | .17 | 2.55 | .03 | .05 |
| 16 | .16 | 2.56 | .01 | .05 |
| 17 | .155 | 2.64 | .08 | .04 |
| 18 | .15 | 2.70 | .06 | .04 |
| 19 | .145 | 2.76 | .06 | .03 |
| 20 | .14 | 2.80 | .04 | .02 |
| 21 | .135 | 2.84 | .04 | .02 |
| 22 | .13 | 2.86 | .02 | .02 |
| 23 | .125 | 2.88 | .02 | .01 |
| 24 | .12 | 2.88 | .01 | .01 |

FIGURE C-1

# INTENSITY - DURATION - FREQUENCY CURVES




SOURCE: STORM WATER MANAGEMENT GUDELINES. BUREAU OF DAMS AND WATERWAY MANAGEMENT, DIVISION OF

# APPENDIX D

## DESIGN STORM

# APPENDIX D

## "DESIGN STORM"

For purposes of this study, it was necessary to define a single theoretical storm. Calculations based on this storm were used to determine the amount of increased runoff due to development which must be managed. This "design storm" is used for the purpose of storm water management only. The design of other facilities such as culverts, bridges, and storm sewers must conform to those criteria already established for their design.

This design storm serves a twofold purpose. First, it is used to establish existing flows in the channel. A theoretical ultimate land use is proposed for the purpose of comparing flow changes due to changes in land use characteristics. Second, the design storm is used to determine the amount of storage required in order to maintain the existing flow as development proceeds. The soil conservation method used in this study is especially useful in determining these requirements.

The design storm therefore must be chosen so that mainstream flows reflect critical but adequate flow. That is to say, the flows must be high enough to provide a good basis for comparison without being so high that all existing bridges and culverts will become inadequate. The design storm also must produce a significant volume of runoff to justify storage facilities without being so high that development is discouraged due to the high cost of storm water management.

Subwatersheds were selected intentionally to be small areas in order to act as a basic unit of analysis with characteristics independent of the larger watershed of which they happen to be a part. Because it is at this subwatershed level that runoff characteristics are determined, the choice of which watershed or watersheds to use as representative for the purpose of choosing the design storm was no longer critical. Factors such as the length of the creek, amount of existing development in the watershed, shape of the watershed, or slope of the land within a watershed will affect only the magnitude of runoff. Its variation with time is determined by the characteristics of the individual subwatersheds.

In order to choose a design storm, it was necessary to consider both the proper duration and return frequency. In order to make this determination, a series of test storms of various return frequencies and durations were run. This was done for the upstream portions of Fourmile Creek. Storm frequencies of 2 years, 5 years, 10 years, and 25 years and durations of 2 hours, 6 hours, and 24 hours are presented for comparative purposes. Because of the nature of the soil conservation service methods of calculating runoff, a trend is set by this example which may be extrapolated to apply to all creeks in the study area. In all cases for a given storm duration, runoff is higher for higher return frequencies. On the other hand, for a given frequency, runoff obviously is higher for longer storm durations. This is illustrated in Table D-1. As was stated earlier, this trend is the same for all watersheds. Because it provides the largest amount of rainfall of any of the proposed durations, 24 hours was chosen as the duration for the design storm.

The results of the flood routing calculations are plotted for each storm duration in Figures D-1, D-2 and D-3. From the curves it can again be seen that at each location, as the return frequency of a storm goes up, both the runoff and depth increase. However, an increase in storm frequency results in an increasingly larger increment of runoff with a corresponding decreasingly smaller increase of depth. That is to say, the slope of the lines between points on the graph for each location along the stream increases with increased frequency. This further illustrates the trend previously discussed.

Because the main thrust of this study is geared toward some type of retention or detention method to reduce runoff flows, a comparison of storage requirements on branch streams for different storm events was made. When considering storage designs, the most critical concern is the volume of storm water runoff. Because a storm of 24 hour duration produces the highest relative volume of runoff, storms of lower duration were not used in this analysis. Figures D-4 to D-10 show plots of inflow and outflow hydrographs for the 5, 10, and 25 year storms. These hydrographs are for a theoretical area of 22 acres with a time concentration of 8 1/2 minutes. The assumptions made for this analysis are that:

1. The discharge rate for detention along branch streams is set to the mean annual flood as a defined standard of this study, and;

2. A freeboard of one foot above the design pool is provided. This freeboard may be used to store excess runoff from larger storm events. It is provided to insure marginal protection for storms above the design storm selected for this study.

The shaded area on the graph of Figure D-4 represents 1.25 acre-feet of storage volume which would be required should the 5-year frequency storm be used as a design storm. The peak inflow rate is about 22 cubic feet per second and the peak discharge allowed is reduced to 5 cubic feet per second. A 25-year storm was routed through this reservoir as illustrated in Figure D-6. As indicated on the graph, the reservoir would be filled in just less than 6.60 hours after the storm has begun. The additional storage required, that would be provided by the one foot freeboard area, is 0.75 acre-feet. This would decrease the peak flow to 30 cubic feet per second.

A 10-year storm hydrograph was also routed through this reservoir as shown in the graph on Figure D-6. The reservoir would fill in approximately the same time as it would for the 25-year storm. However, less volume would be needed in the freeboard area to control the discharge.

Using the 10-year storm as the design storm, Figure D-7 indicates that 2.05 acre-feet of storage would be required. In this case, a peak flow of 32 cubic feet per second would be reduced to 5 cubic feet per second. A 25-year storm was routed through this reservoir as indicated in Figure D-8. This storm would fill the reservoir after 6.80 hours. The additional storage in the one foot freeboard area would be only 0.36 acre-feet. Storms of lower frequency would not fill the reservoir as shown in Figure D-9.

A total storage of 3.33 acre-feet would be required should the 25-year storm be chosen as the design storm. The inflow and outflow hydrographs and storage requirements are illustrated in Figure D-10. Table D-2 summarizes the above required storage volumes for various design storm possibilities.

Should a storm of 5-year frequency or lower be used as the design storm, the majority of the mainstream channels and culverts would have adequate capacity to pass that storm. However, storms that exceed the 5-year design storm would have a relatively high probability of occurrence, resulting in more frequent flooding. Also, as shown in the reservoir calculations, the basins would fill before the peak runoff reached the basins. This would cause more frequent use of emergency spillways and would provide relatively little downstream protection. It is not practical to design for protection against flooding which occurs more often than once in ten years.

On the other hand, if a storm of higher frequency is used as the design storm, the mainstream channels and most of the culverts would probably be inadequate. Required detention volumes, as shown by the reservoir routing calculations, would be relatively large and development might be hindered due to the high cost of construction.

The reservoir routing calculations show only a 20 percent increase in total storage volume for a 5-year design storm would provide sufficient storage volume for a 10-year design storm. A 25-year design storm would require an increase in storage volume of 166 percent over the 5-year design storm or an increase of 62 percent over the 10-year design storm. Therefore, a 10-year design storm will provide sufficient storage volumes needed to practically and adequately regulate stream flow.

In conclusion, it has been determined in this discussion that the runoff from the 10-year storm produced the most realistic and reasonable flows in the major streams. A random test of culvert and bridge capacities indicates thay are for the most part capable of handling at least the 10-year storm. The depth of the 10-year storm were plotted with respect to low bank profile for all creeks. There were very few locations where the depth exceeded the low bank profile.

It is recommended, therefore, that the flow resulting from existing land use as shown in this study for the 10-year return frequency, 24-hour duration storm be used as the design storm. This storm will be used to determine storage requirements and to establish existing mainstream base flows. As the recommendations of this study are implemented, these flows will not be allowed to increase.

TABLE D-1
SUMMARY OF HYDYDRAULIC DATA FOR
A PORTION OF FOURMILE CREEK

AT POINT A

| DURATION | FREQUENCY | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2 YEAR | | 5 YEAR | | 10 YEAR | | 25 YEAR | |
| | DISCHARGE C.F.S. | DEPTH FT. | DISCHARGE C.F.S. | DEPTH FT. | DISCHARGE C.F.S. | DEPTH FT. | DISCHARGE C.F.S. | DEPTH FT. |
| 2 HR. | 62 | 0.45 | 254 | 1.06 | 456 | 1.49 | 658 | 1.84 |
| 6 HR. | 173 | 0.84 | 492 | 1.55 | 746 | 1.98 | 1232 | 2.63 |
| 24 HR. | 263 | 1.08 | 664 | 1.85 | 1069 | 2.43 | 1477 | 2.91 |

AT POINT B

| DURATION | FREQUENCY | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2 YEAR | | 5 YEAR | | 10 YEAR | | 25 YEAR | |
| | DISCHARGE C.F.S. | DEPTH FT. | DISCHARGE C.F.S. | DEPTH FT. | DISCHARGE C.F.S. | DEPTH FT. | DISCHARGE C.F.S. | DEPTH FT. |
| 2 HR. | 77 | 0.59 | 319 | 1.36 | 569 | 1.91 | 818 | 2.35 |
| 6 HR. | 217 | 1.09 | 617 | 2.00 | 931 | 2.53 | 1536 | 3.34 |
| 24 HR. | 332 | 1.40 | 831 | 2.37 | 1312 | 3.06 | 1832 | 3.69 |

AT POINT C

| DURATION | FREQUENCY | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2 YEAR | | 5 YEAR | | 10 YEAR | | 25 YEAR | |
| | DISCHARGE C.F.S. | DEPTH FT. | DISCHARGE C.F.S. | DEPTH FT. | DISCHARGE C.F.S. | DEPTH FT. | DISCHARGE C.F.S. | DEPTH FT. |
| 2 HR. | 200 | 1.02 | 786 | 2.27 | 1383 | 3.11 | 1965 | 3.78 |
| 6 HR. | 515 | 1.78 | 1428 | 3.17 | 2167 | 3.99 | 3536 | 5.19 |
| 24 HR. | 784 | 2.26 | 1930 | 3.74 | 3031 | 4.78 | 4194 | 5.68 |

TABLE D-2
SUMMARY OF STORAGE REQUIREMENTS
USING DIFFERENT DESIGN STORM FREQUENCIES

| | DESIGN STORM FREQUENCY | | |
|---|---|---|---|
| | 5-YEAR | 10-YEAR | 25-YEAR |
| TOTAL STORAGE (ACFT) | 2.00 | 2.41 | 3.33 |
| DESIGN STORAGE (ACFT) | 1.25 | 2.05 | 3.33 |
| FREEBOARD STORAGE (ACFT) | 0.75 | 0.36 | 0 |

FIGURE D-1

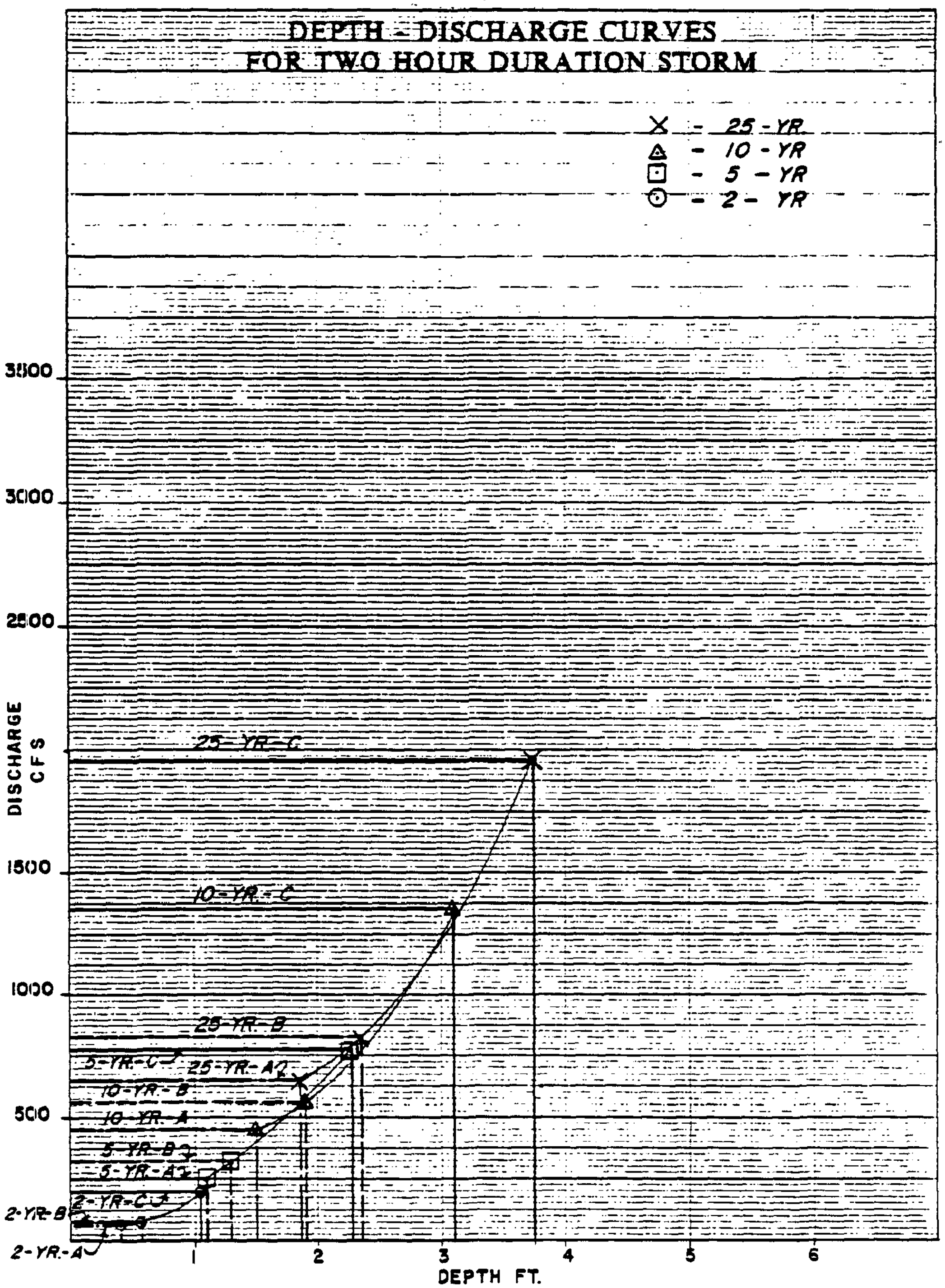

DEPTH - DISCHARGE CURVES
FOR TWO HOUR DURATION STORM
X - 25 - YR
△ - 10 - YR
□ - 5 - YR
⊙ - 2 - YR
3500
3000
2500
DISCHARGE CFS
25-YR-C
1500
10-YR-C
1000
25-YR-B
5-YR-C
25-YR-A
10-YR-B
500
10-YR-A
5-YR-B
5-YR-A
2-YR-C
2-YR-B
2-YR-A
1
2
3
4
5
6
DEPTH FT.

FIGURE D-2

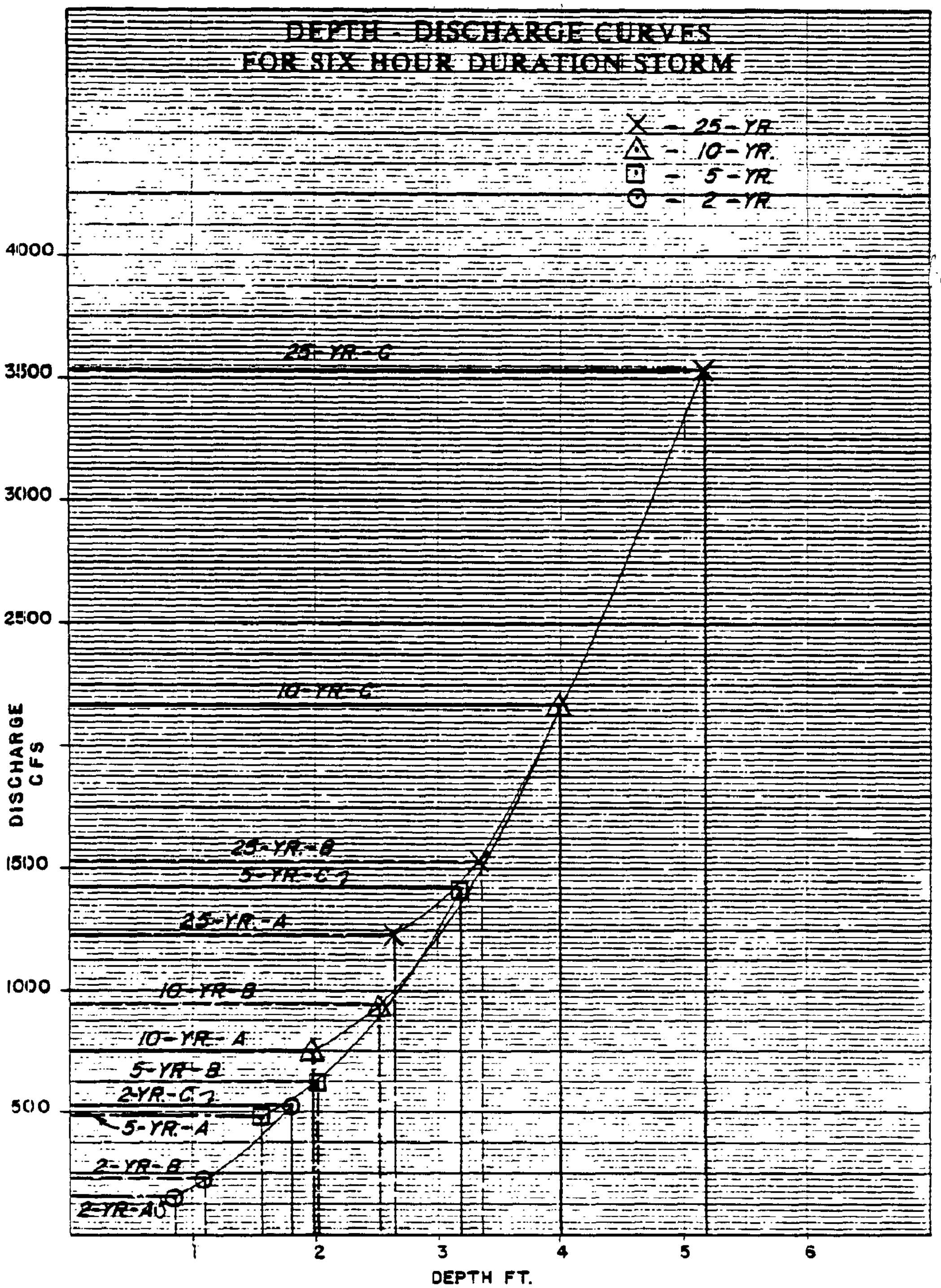
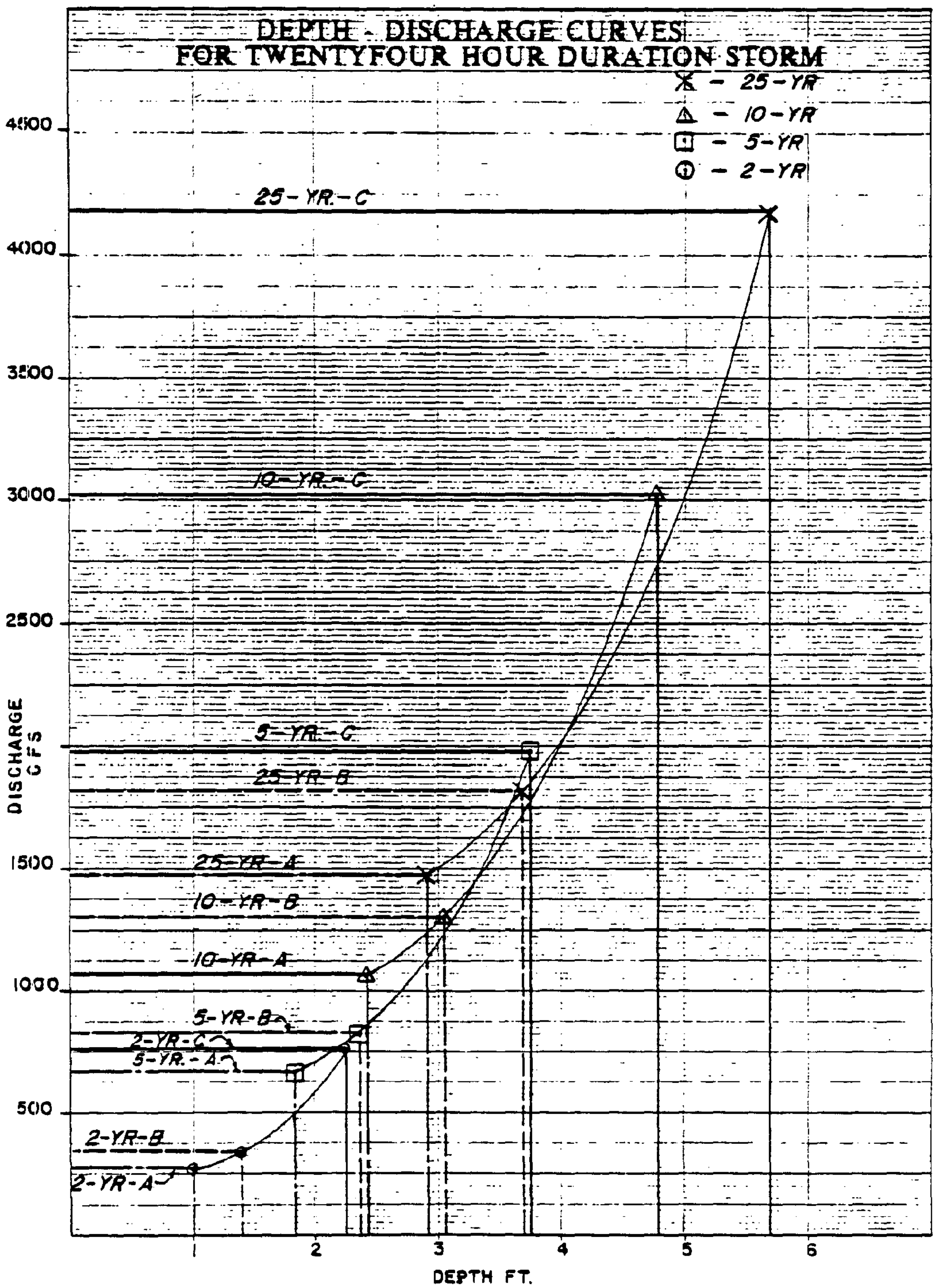

DEPTH - DISCHARGE CURVES
FOR SIX HOUR DURATION STORM
X - 25-YR
△ - 10-YR.
□ - 5-YR
⊙ - 2-YR
4000
3500
3000
2500
1500
1000
500
DISCHARGE
CFS
25-YR-C
10-YR-C
25-YR-B
5-YR-C
25-YR-A
10-YR-B
10-YR-A
5-YR-B
2-YR-C
5-YR-A
2-YR-B
2-YR-A
1
2
3
4
5
6
DEPTH FT.

FIGURE D-3



DEPTH - DISCHARGE CURVES
FOR TWENTYFOUR HOUR DURATION STORM
X - 25-YR
△ - 10-YR
⊡ - 5-YR
⊙ - 2-YR
25-YR-C
10-YR-C
5-YR-C
25-YR-B
25-YR-A
10-YR-B
10-YR-A
5-YR-B
2-YR-C
5-YR-A
2-YR-B
2-YR-A
4500
4000
3500
3000
2500
1500
1000
500
DISCHARGE CFS
1
2
3
4
5
6
DEPTH FT.

FIGURE D-4

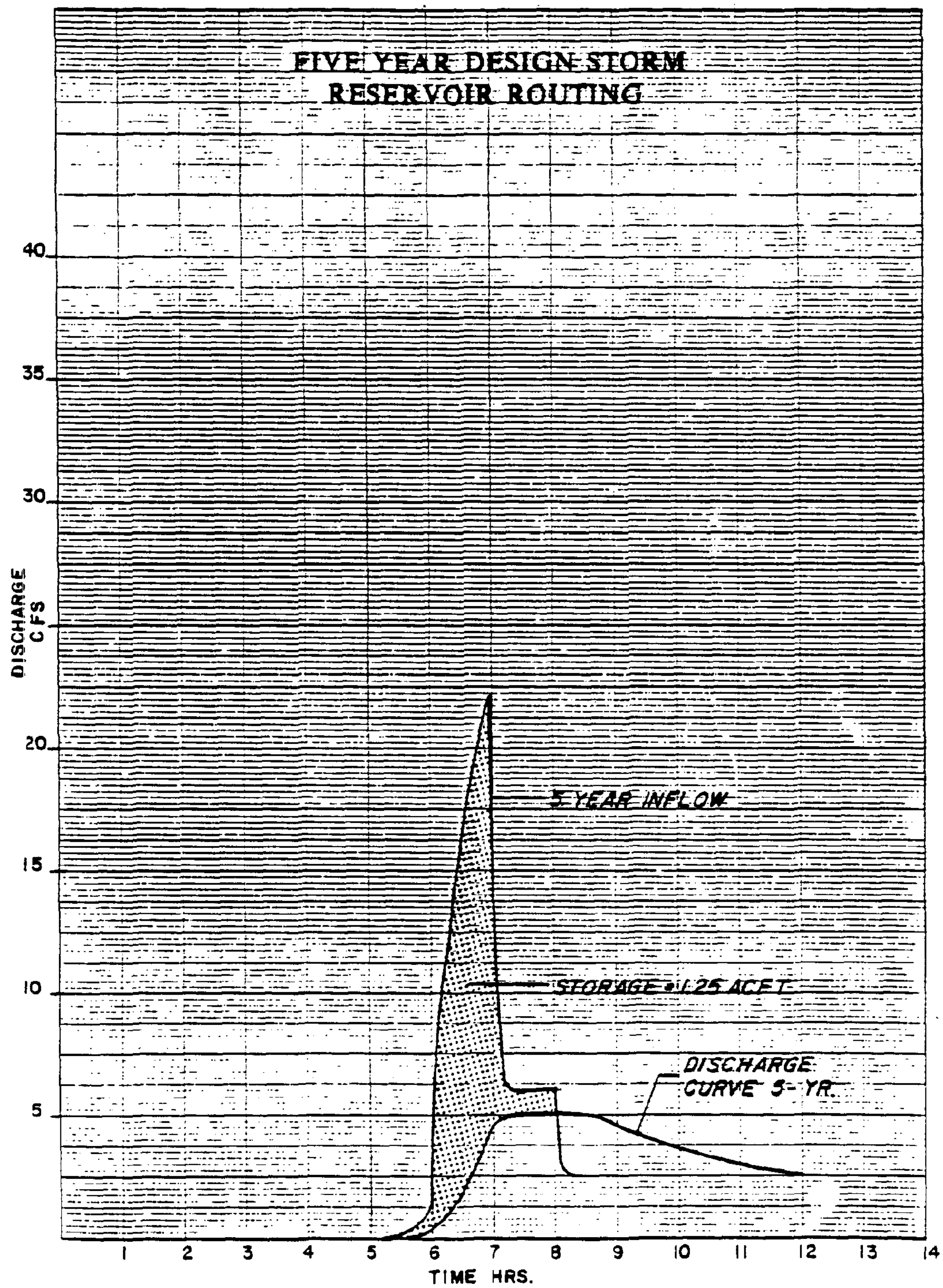
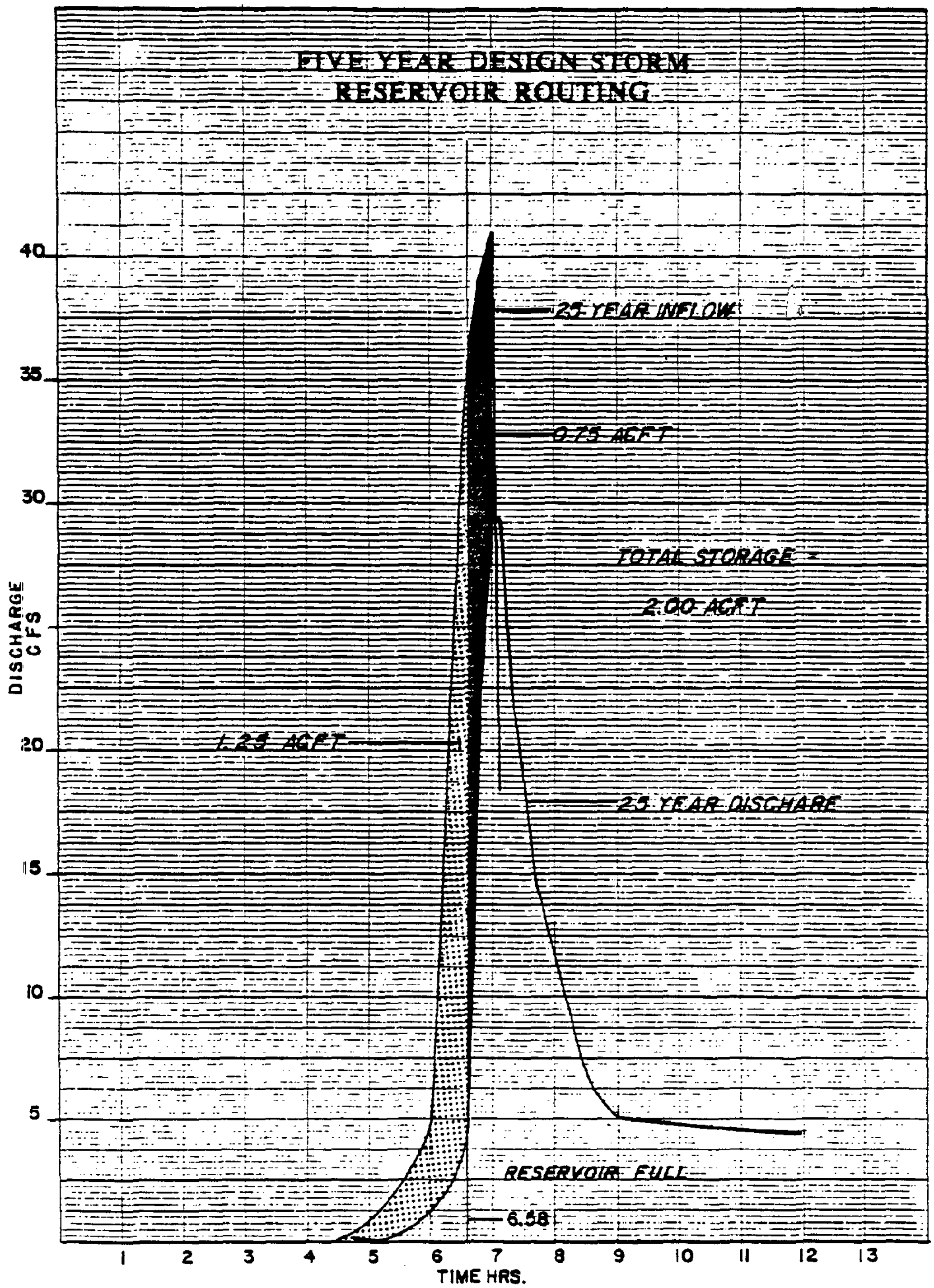
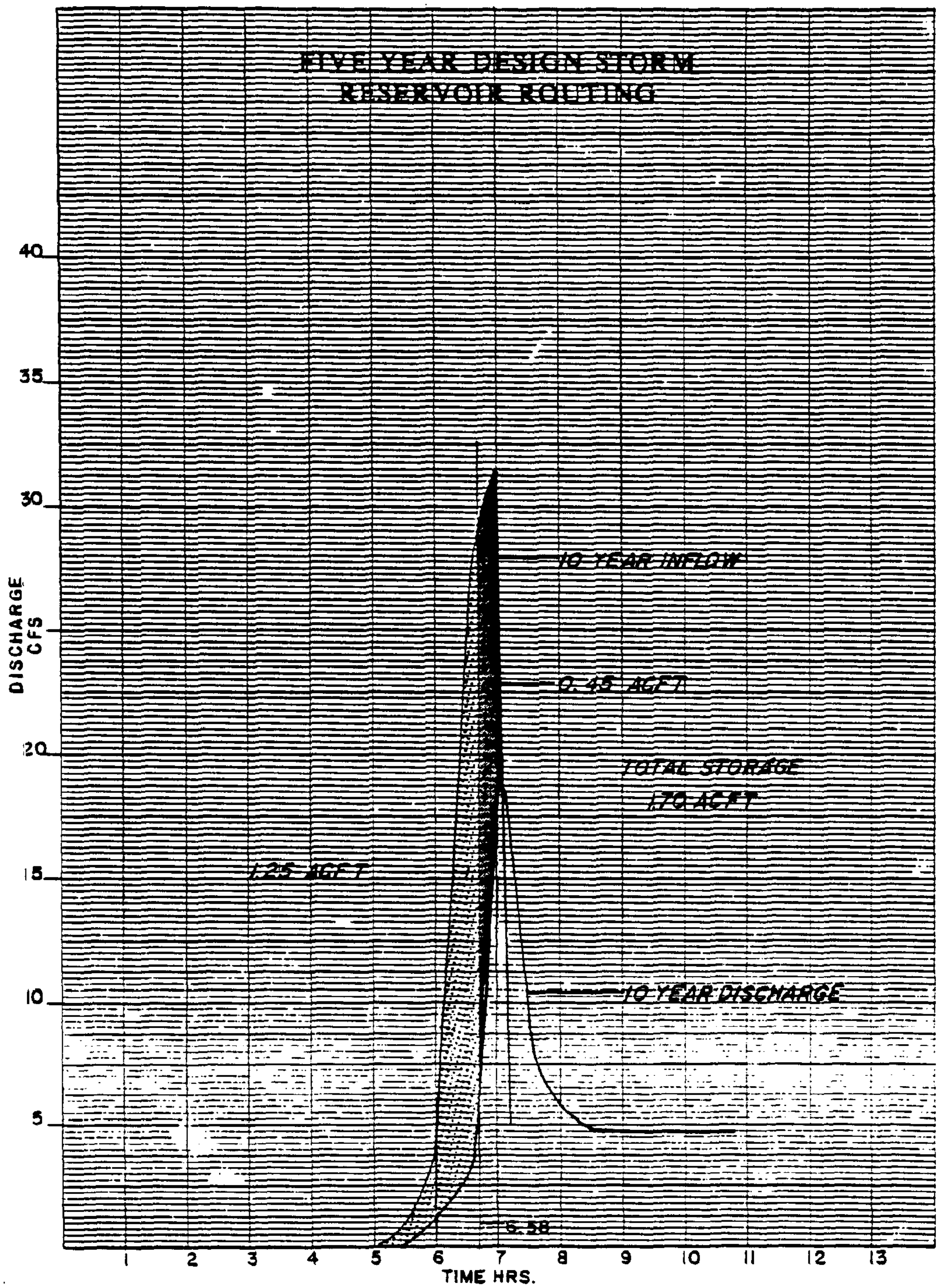

FIVE YEAR DESIGN STORM
RESERVOIR ROUTING
40
35
30
DISCHARGE CFS
20
15
10
5
5 YEAR INFLOW
STORAGE = 1.25 AC FT
DISCHARGE CURVE 5-YR.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
TIME HRS.

FIGURE D-5



FIVE YEAR DESIGN STORM
RESERVOIR ROUTING
25 YEAR INFLOW
0.75 ACFT
TOTAL STORAGE =
2.00 ACFT
1.25 ACFT
25 YEAR DISCHARE
RESERVOIR FULL
6.58
DISCHARGE CFS
40
35
30
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
TIME HRS.

FIGURE D-6



FIVE YEAR DESIGN STORM
RESERVOIR ROUTING
10 YEAR INFLOW
0.45 ACFT
TOTAL STORAGE
1.70 ACFT
1.25 ACFT
10 YEAR DISCHARGE
6.58
DISCHARGE CFS
TIME HRS.
40
35
30
25
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13

FIGURE D-7

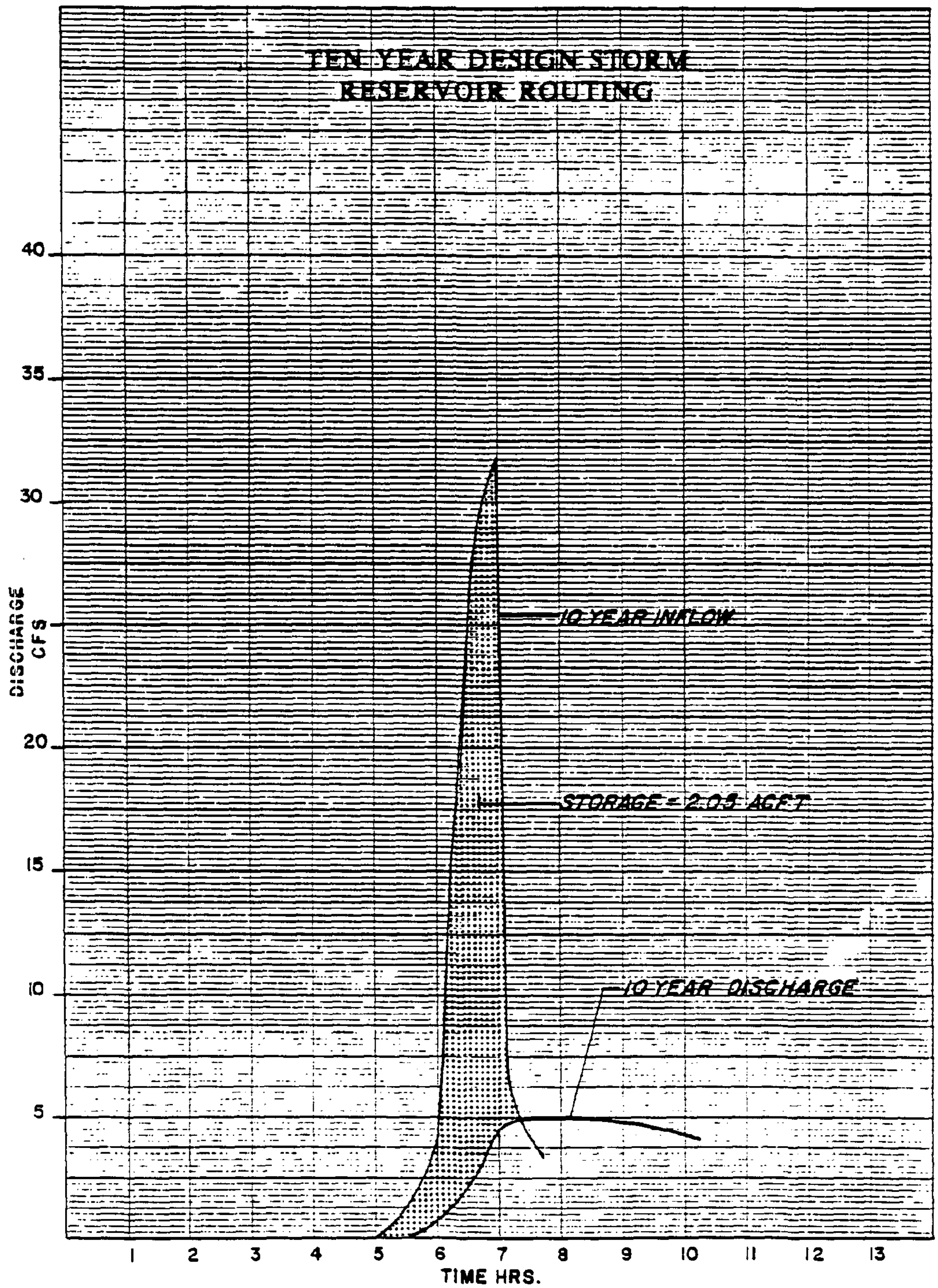

TEN YEAR DESIGN STORM
RESERVOIR ROUTING
DISCHARGE CFS
40
35
30
20
15
10
5
10 YEAR INFLOW
STORAGE = 2.05 AC.FT.
10 YEAR DISCHARGE
1
2
3
4
5
6
7
8
9
10
11
12
13
TIME HRS.

FIGURE D-8

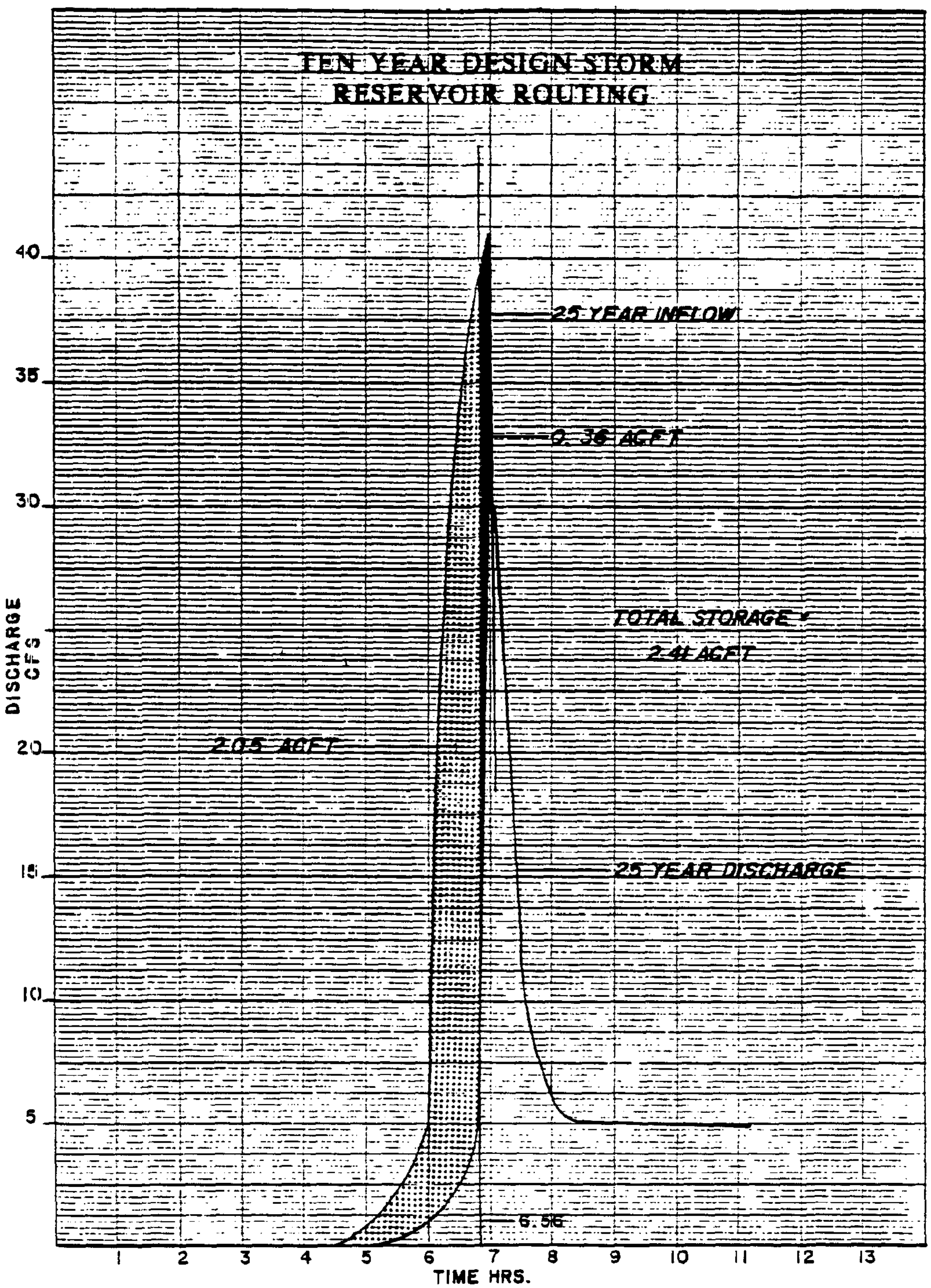

TEN YEAR DESIGN STORM
RESERVOIR ROUTING
25 YEAR INFLOW
0.36 ACFT
TOTAL STORAGE =
2.41 ACFT
2.05 ACFT
25 YEAR DISCHARGE
6.56
DISCHARGE CFS
40
35
30
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
TIME HRS.

FIGURE D-9

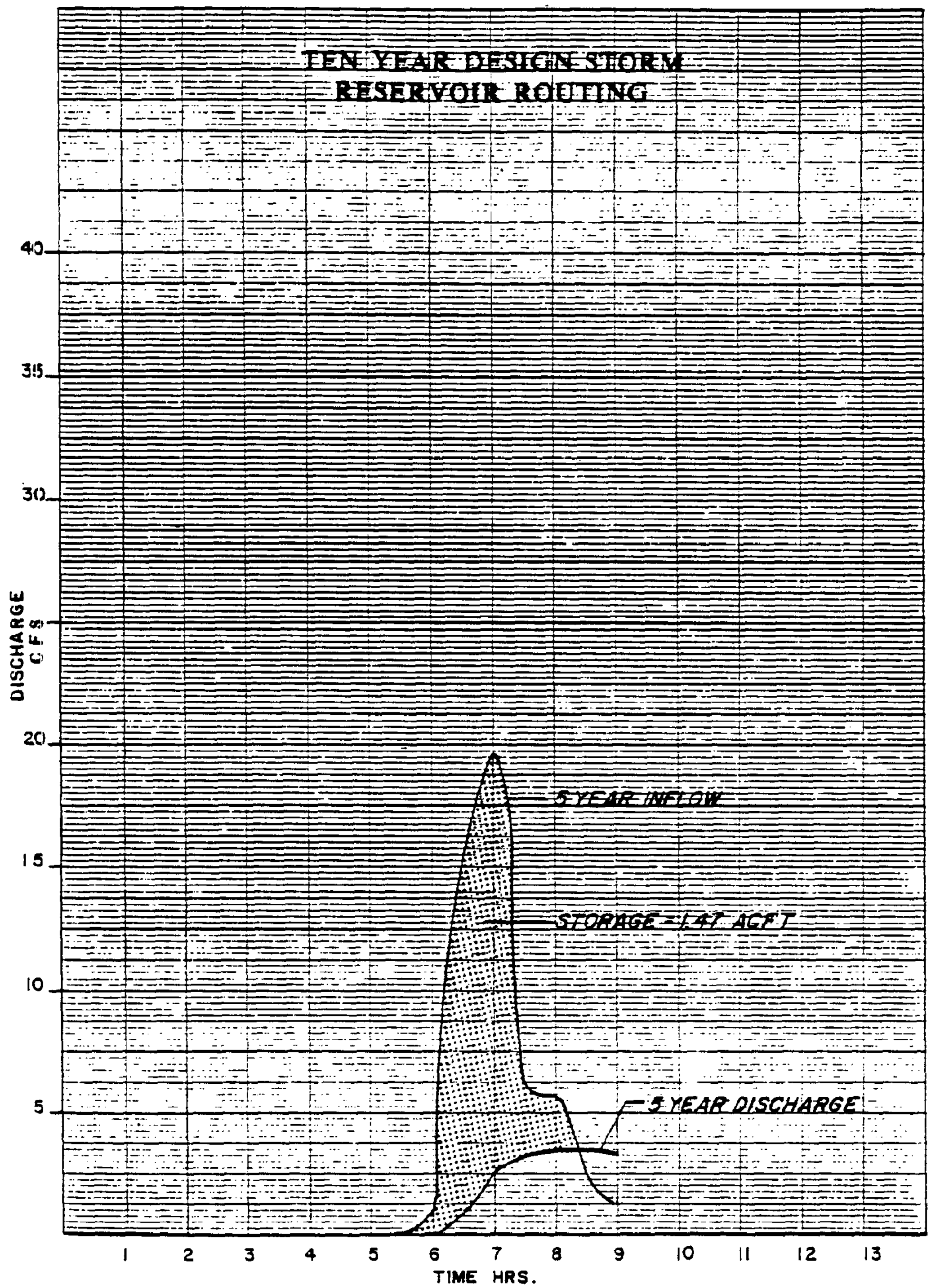
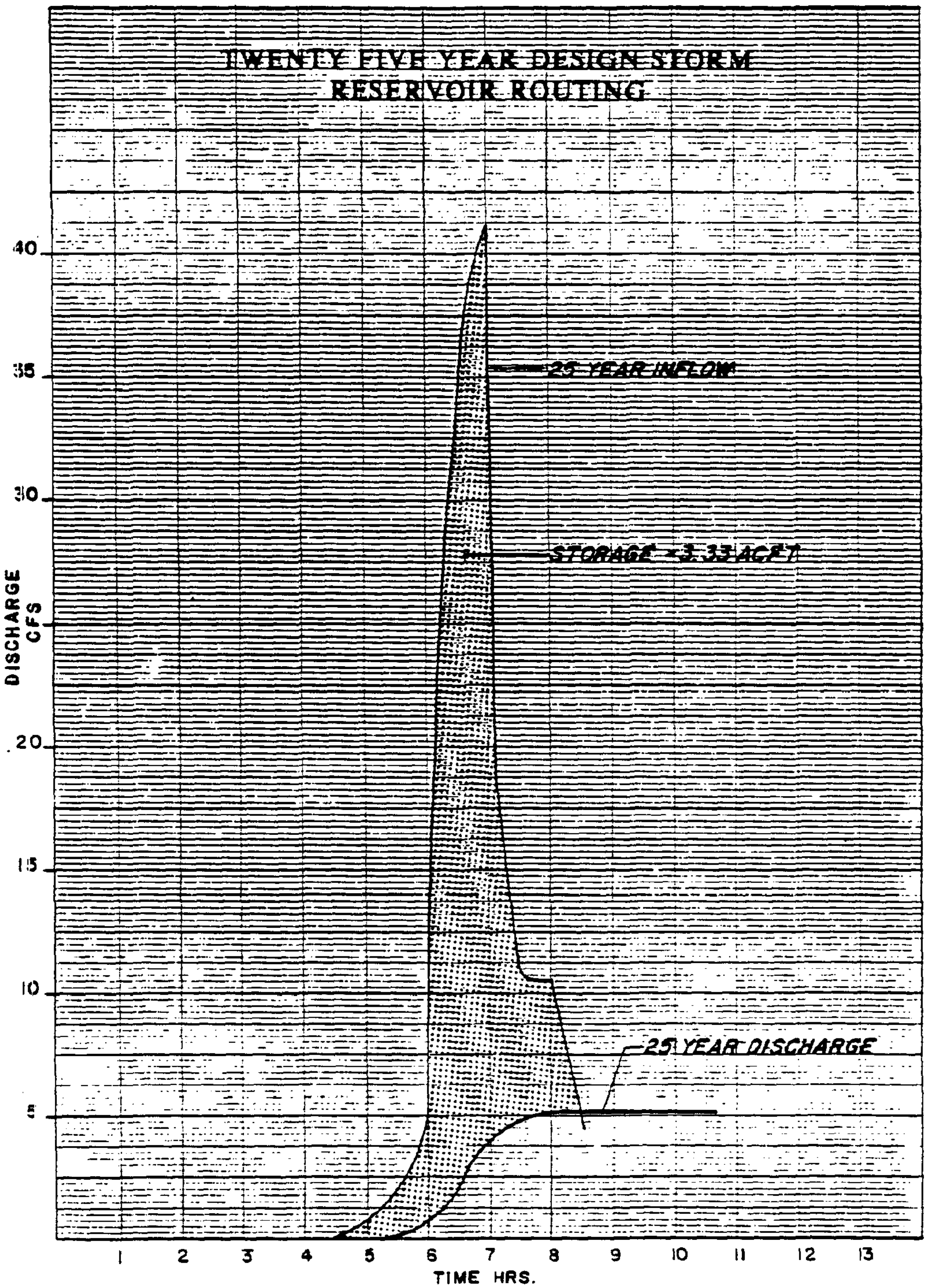

TEN YEAR DESIGN STORM
RESERVOIR ROUTING
5 YEAR INFLOW
STORAGE = 1.47 ACFT
5 YEAR DISCHARGE
DISCHARGE C.F.S.
40
35
30
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
TIME HRS.

FIGURE D-10


TWENTY FIVE YEAR DESIGN STORM
RESERVOIR ROUTING
25 YEAR INFLOW
STORAGE = 3.33 ACFT
25 YEAR DISCHARGE
DISCHARGE CFS
40
35
30
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
TIME HRS.

# APPENDIX E

## CALCULATIONS TO DETERMINE INCREASED RUNOFF
## AND
## EXAMPLES OF SPECIFIC ON-SITE STORAGE

## APPENDIX E

## CALCULATIONS TO DETERMINE INCREASED RUNOFF AND EXAMPLES OF SPECIFIC ON-SITE STORAGE

The procedures presented in this appendix are applicable to all unit developments which contain between 2500 square feet and 43,560 square feet of impervious surface area. Those exempt cases discussed in the text need not make the following calculations. Developments with more than 43,560 square feet of impervious surface area must consult a qualified professional person to aid in determining their excess storm water runoff volume.

By following these methods, the non-technical individual can easily determine the amount of excess storm water runoff which he is required to manage. The methods of control presented in this study, or any other approved innovative methods, may be used to manage this calculated runoff volume.

### Excess Storm Water Runoff Calculation Procedure

Step 1 Determine dimensions of proposed buildings, drives, patios or other impervious areas. These can usually be found on building site plans.

Step 2 Calculate impervious area. The more common shapes that will be encountered are rectangles, triangles or circles. Equations to calculate the areas of these shapes are as follows: (all dimensions are assumed to be in feet)

i) Rectangle: area (sq. ft.) = length (ft.) x width (ft.)

ii) Triangle: area (sq. ft.) = 1/2 x base (ft.) x height (ft.)

iii) Circle: area (sq. ft.) = 0.785 x diameter$^2$ (ft.)

Step 3 Refer to Section 4.2 and plate of volume describing the watershed in which construction is to take place. If construction is found to be along a Type 1 channel, then use Type 1 criteria. All others use Type 2 criteria.

Step 4 Use Figure E-1 to find excess runoff volume to be managed.

Example: Figure E-2 shows a typical site plan for proposed residential lot located along a Type 1 Channel. Determine the amount of excess runoff volume required to be managed.

(1) Dimensions as shown on Figure E-2.

(2) Impervious Area:

(a) Drive: 14' x 70' = 980 sq. ft.

(b) House: 40' x 80' = 3200 sq. ft.

(c) Patio: 1/2' x 20' x 20' = 400 sq. ft.

Total Impervious Area 6180 sq. ft.

(3.) Type 1 criteria as given.

(4.) From Figure E-1, excess runoff volume to be managed is 1150 cubic feet.

Note: One acre contains 43,560 sq. ft. One cubic foot contains 7.48 gallons of water.

# FIGURE E-1

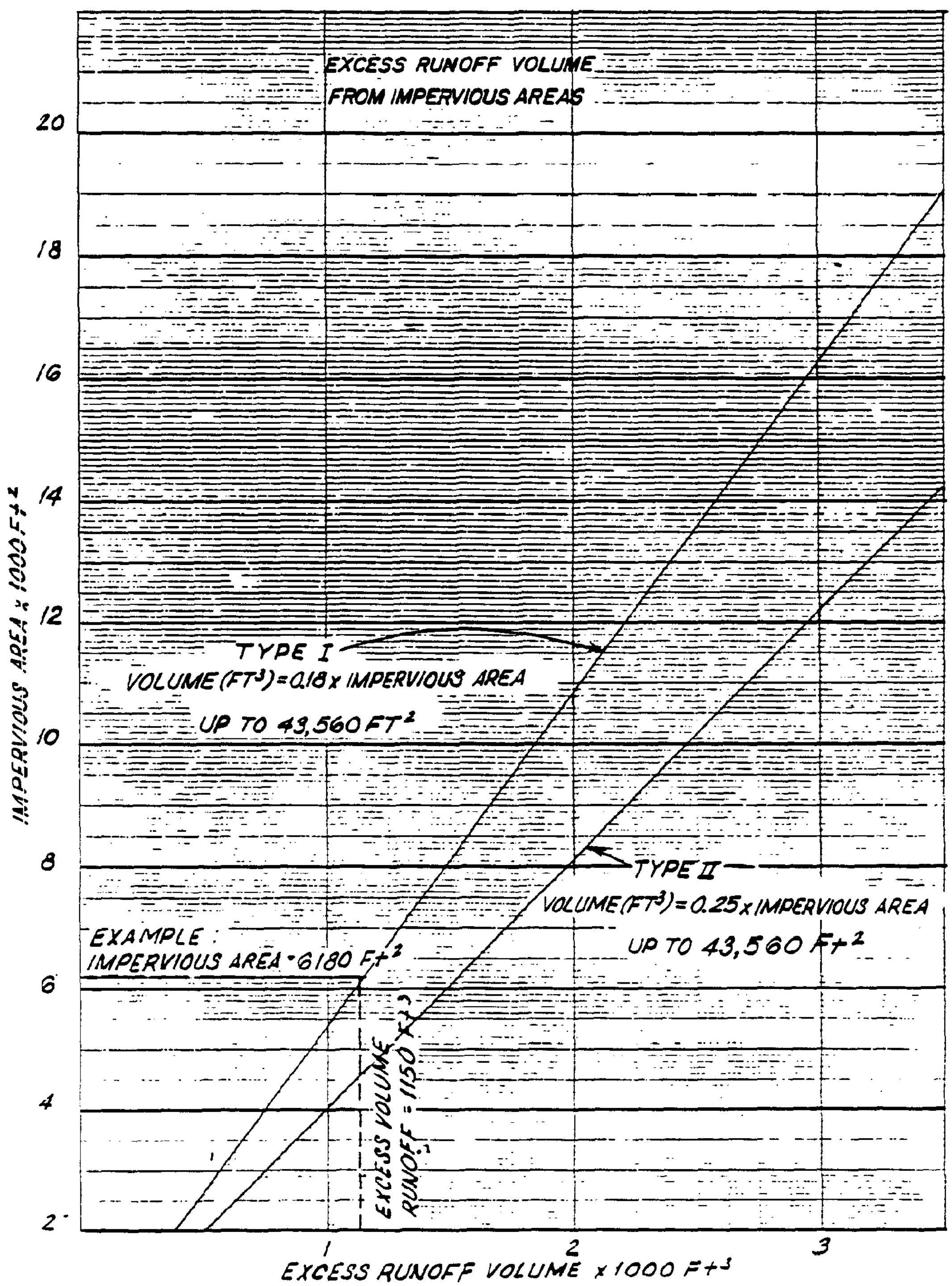

EXCESS RUNOFF VOLUME
FROM IMPERVIOUS AREAS
20
18
16
14
12
10
8
6
4
2
IMPERVIOUS AREA x 1000 Ft²
TYPE I
VOLUME (FT³) = 0.18 x IMPERVIOUS AREA
UP TO 43,560 FT²
TYPE II
VOLUME (FT³) = 0.25 x IMPERVIOUS AREA
UP TO 43,560 Ft²
EXAMPLE :
IMPERVIOUS AREA - 6180 Ft²
EXCESS VOLUME
RUNOFF = 1150 Ft³
1
2
3
EXCESS RUNOFF VOLUME x 1000 Ft³

FIGURE E-2
TYPICAL RESIDENTIAL SITE PLAN

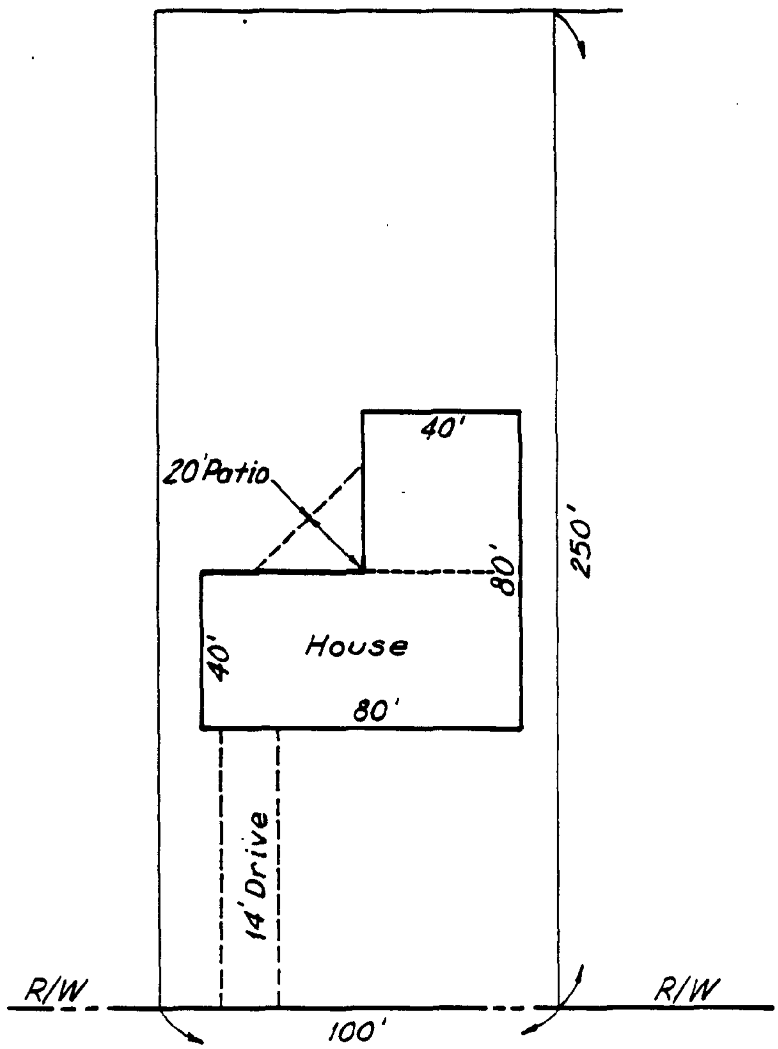


FIGURE E- 3

ON-SITE STORM WATER MANAGEMENT

ALTERNATE NO. 1

SURFACE STORAGE

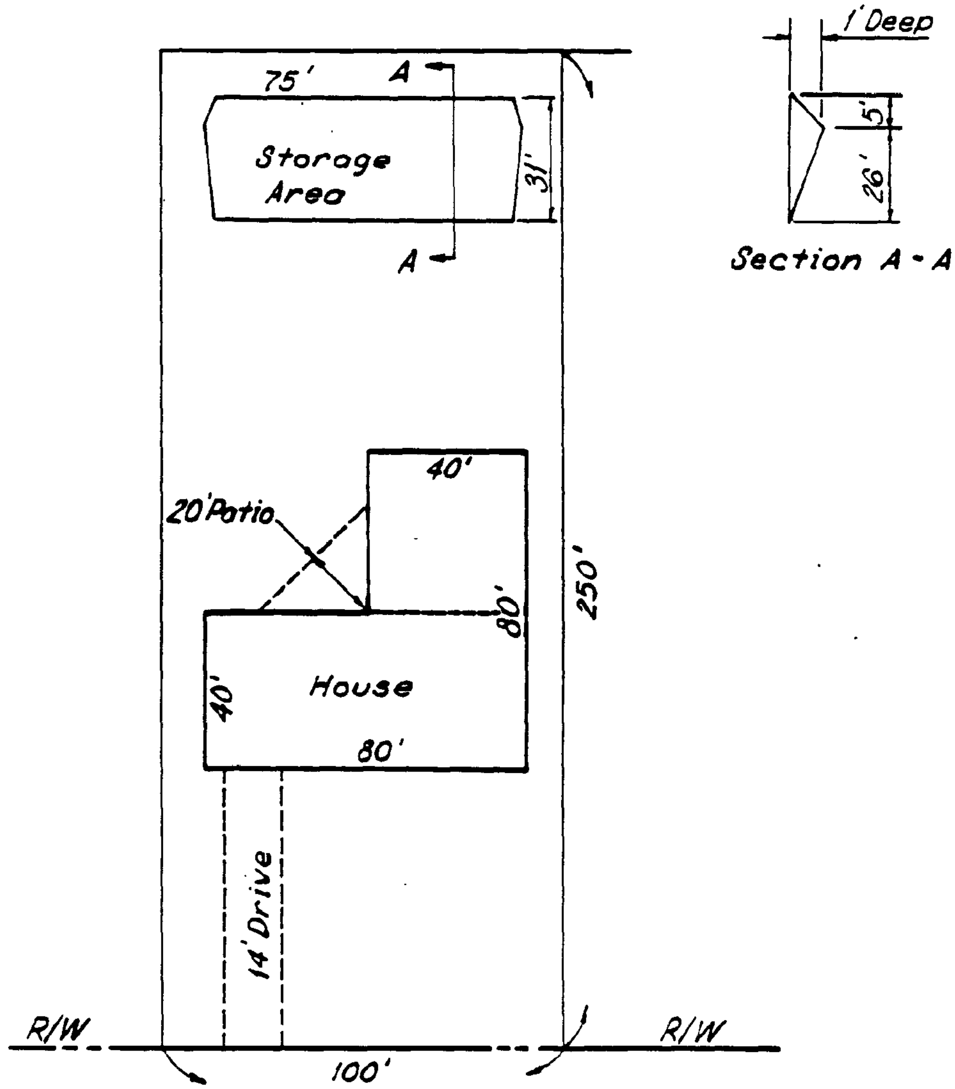


FIGURE E-4

ON-SITE STORM WATER MANAGEMENT

ALTERNATE NO. 2

OVERSIZED STORM SEWER PIPE

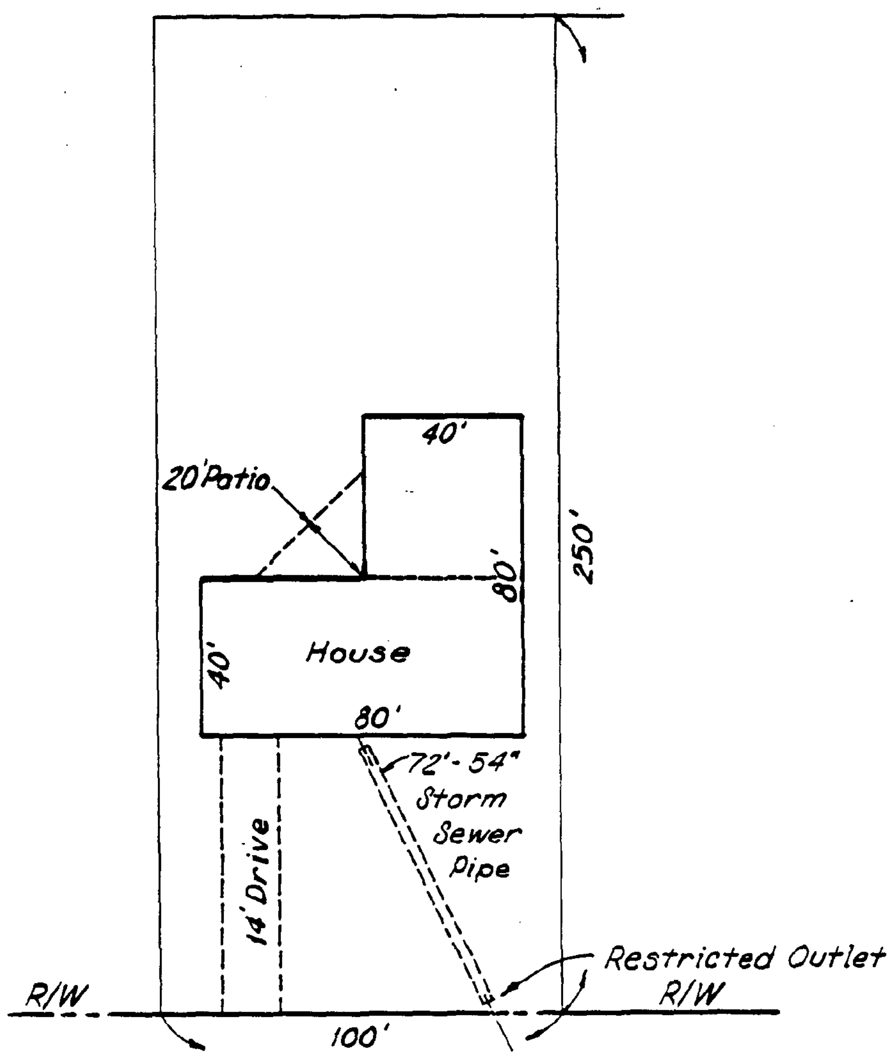


FIGURE E-5
ON-SITE STORM WATER MANAGEMENT
ALTERNATE NO.3
POND STORAGE

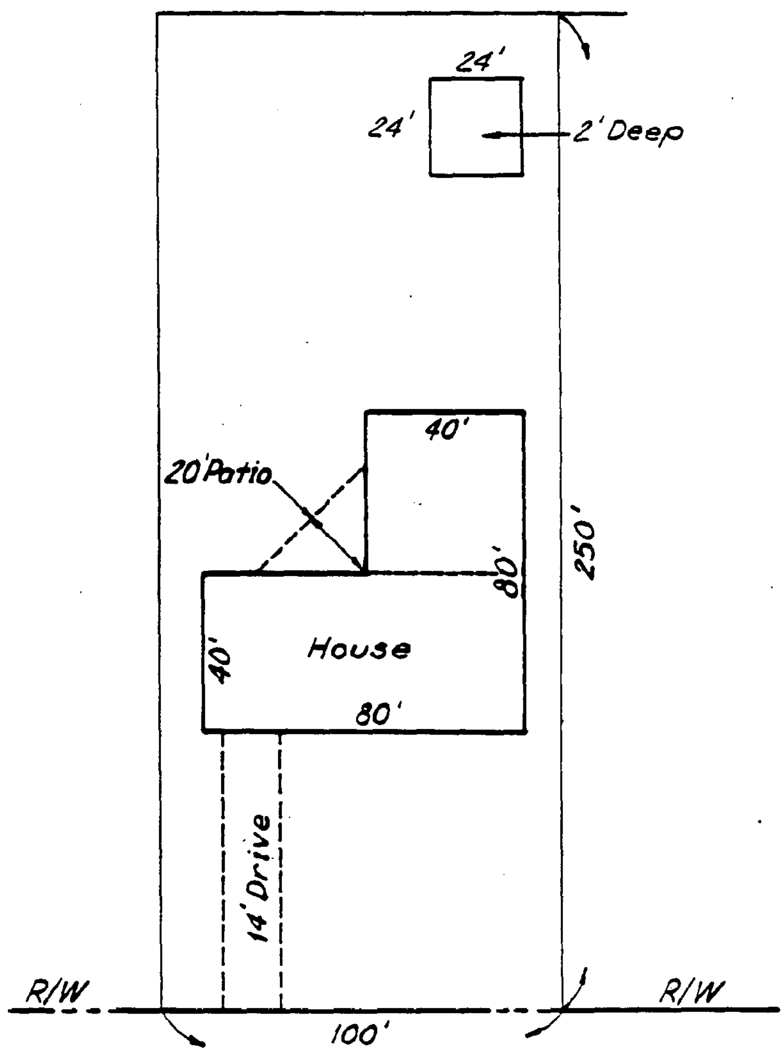


FIGURE E-6
ON-SITE STORM WATER MANAGEMENT
ALTERNATE NO. 4
UNDERGROUND TANK STORAGE