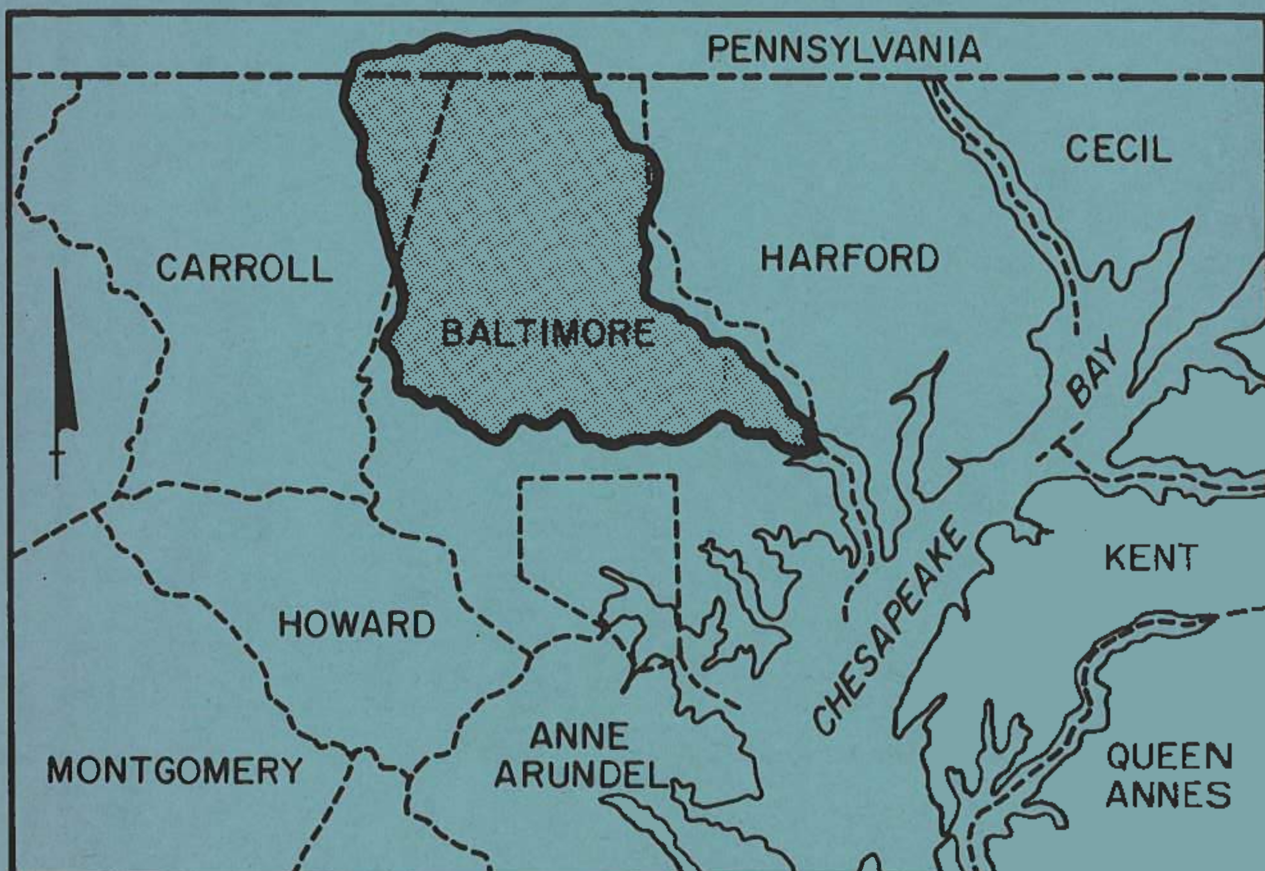
GUNPOWDER FALLS WATERSHED STUDY

PHASE II - WATERSHED HYDROLOGY & ANALYSIS OF FLOOD HAZARD AREAS

JOB ORDER NUMBER 4-316-1
OCTOBER 1985



PREPARED FOR

WATER RESOURCES ADMIN.
MARYLAND DEPARTMENT
OF NATURAL RESOURCES

BUREAU OF ENGINEERING
DEPT. OF PUBLIC WORKS
BALTIMORE COUNTY, MD.

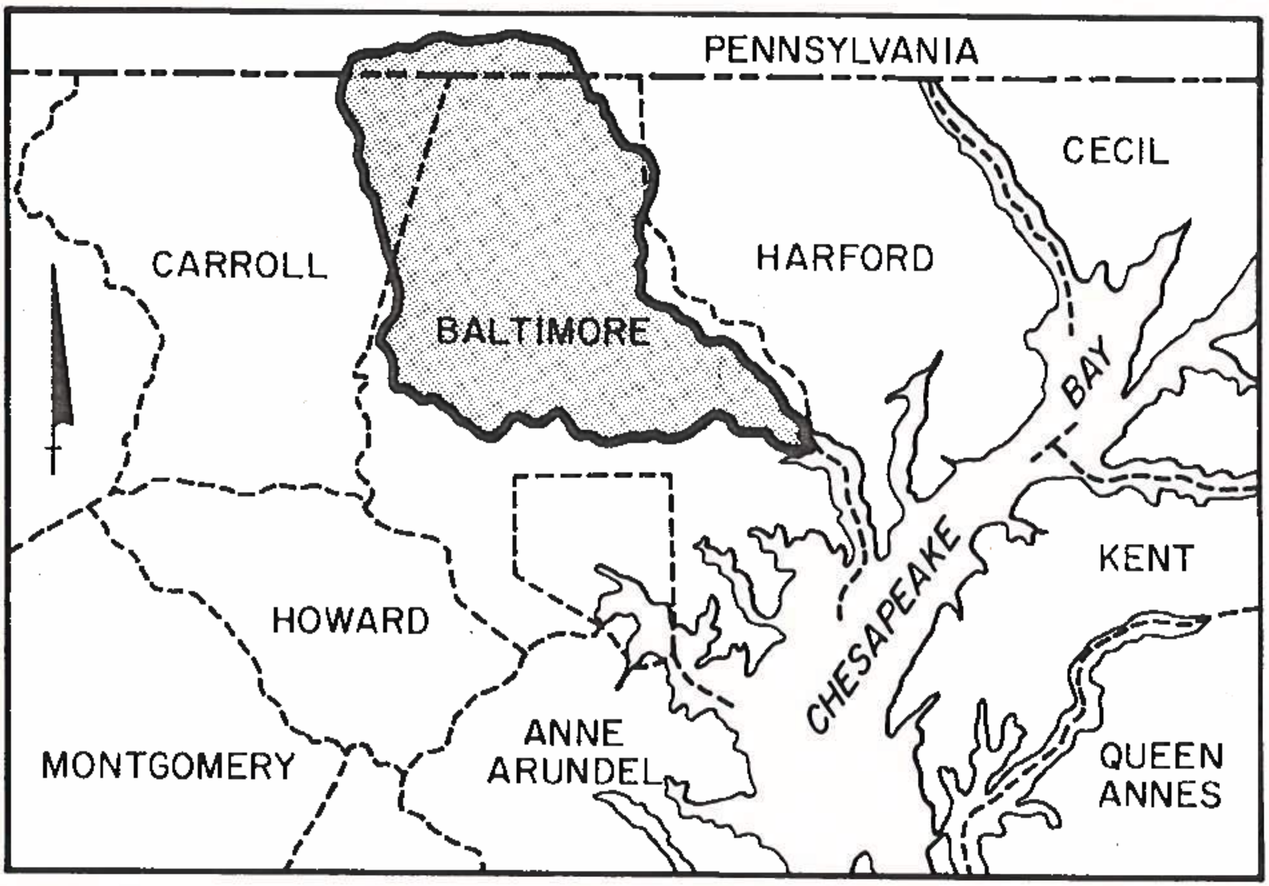
PREPARED BY

PURDUM & JESCHKE
CONSULTING ENGINEERS

GUNPOWDER FALLS WATERSHED STUDY

PHASE II - WATERSHED HYDROLOGY & ANALYSIS OF FLOOD HAZARD AREAS

JOB ORDER NUMBER 4-316-1
OCTOBER 1985



PREPARED FOR

WATER RESOURCES ADMIN.
MARYLAND DEPARTMENT
OF NATURAL RESOURCES

BUREAU OF ENGINEERING
DEPT. OF PUBLIC WORKS
BALTIMORE COUNTY, MD.

PREPARED BY

PURDUM & JESCHKE
CONSULTING ENGINEERS

Table of Contents

I. INTRODUCTION

The Baltimore County Department of Public Works and the State of Maryland Water Resources Administration, Department of Natural Resources have commissioned a study of the Gunpowder Falls Watershed for the purpose of identifying flood hazard areas and evaluating measures to prevent or reduce future flood damage.

The study covers the 349-square-mile drainage area of the Gunpowder Falls from the Chesapeake Bay upstream through Loch Raven and Prettyboy Reservoirs to its headwaters in York County, Pennsylvania. The Gunpowder Falls drainage area is shown in Appendix A, Figure 1. The scope of the study limited investigations to those areas within the State of Maryland and excluded the Little Gunpowder Falls watershed.

The Gunpowder Falls Watershed Study is divided into two phases, Phase I - Reconnaissance and Phase II - Watershed Hydrology and Analysis of Flood Hazard Areas. The Phase I - Reconnaissance portion of the study was completed in June, 1984. It included a survey of technical reports and data from federal, state, and local agencies, sources of hydrologic and meteorologic data, identification of flood hazard areas, a summary of findings, and recommendations of limits for detailed study in Phase II.

During Phase I of the study, 102 site investigations were made in the Gunpowder Falls watershed within which 85 residential structures were identified as being potentially subject to flooding. Flooding of the first floor or higher was predicted for 56 of these 85 residential structures. Historical flooding above the first floor has occurred previously in 28 of the structures.

Phase I recommended that the 85 residential structures be examined by various methods during Phase II to determine the flood elevation at the structures (see Table 6 from Phase I report). This is summarized as follows:

1. Flood levels for 25 residential structures be determined from previous studies reviewed during Phase I study.

2. Flood levels for 30 residential structures be determined by approximate methods.

3. Flood levels for 9 residential structures be determined from historical records.

4. Flood levels for 21 residential structures be determined by detailed hydraulic analysis of six site locations during Phase II study. These are listed and described in Appendix B, Table 1 and are shown in Appendix A, Figure 2.

This report, Phase II of the watershed study, includes: reconnaissance and acquisition of additional data, hydrologic modeling of the watershed, hydraulic modeling of the six detailed study streams including field surveys of cross-sections, screening and analysis of alternatives for remedial actions, preparation of a final report, and mapping.

Appendix F of this report contains 1" = 200' scale strip maps depicting the extent of flooding for the 100-year event under ultimate development conditions. Water surface profiles for the 10 and 100-year events under existing conditions are presented in Appendix G.

The following items have been delivered under separate cover:

1. 1" = 2,000' mylar sub-watershed overlay maps to the U.S.G.S. topographic quadrangle sheets.

2. 1" = 2,000' mylar TR-20 schematic overlays to the U.S.G.S. topographic quadrangle sheets.

3. Bound computational data for the 15 sub-watersheds containing attribute files, HYDPAR runs (runoff curve numbers) and time of concentration (t_c) computations.

4. TR-20 calibration results for Long Green Creek, Little Falls, and Western Run stream gages.

5. An album containing photographs and descriptions of the detailed study areas including photographs of all bridges and culverts.

6. Plotted stream cross-sections in the study areas at a scale of 1" = 5' vertically and 1" = 50' horizontally.

7. Copy of the survey notes.

8. A notebook of 5¼-inch data diskettes containing the subbasin, soils, land use, and zoning data.

9. A map of the watershed showing the potential stream bank erosion areas.

II. SCOPE OF STUDY

Purdum and Jeschke's agreement with Baltimore County and the Water Resources Administration requires that the following efforts will be necessary to generate the required data and perform the computer analysis:

1. Assemble all existing information such as soil classifications, zoning maps, 1" = 2,000' scale watershed maps, and 1" = 200' scale stream maps.

2. Prepare a 1" = 2,000' scale watershed map identifying hydrologic soil groups, current land uses, and current zoning for each of the subareas within the 15 sub-watersheds comprising the entire Gunpowder Falls watershed.

3. Determine existing and ultimate runoff curve numbers and times of concentrations for each subarea based on methods described in the Soil Conservation Service (SCS) National Engineering Handbook, Section 4, Hydrology.

4. Develop a hydrologic computer model (TR-20) for the Gunpowder Falls Watershed and develop peak stream flows for the 2, 10, and 100-year frequencies for both existing and ultimate development conditions for the six detailed study areas.

5. Develop a hydraulic computer model (HEC-2) for the six detailed study areas.

6. Investigate flood hazard mitigation alternatives for the six detailed study areas and recommend action to alleviate flooding problems.

7. Prepare a report presenting the data used, an evaluation of the results, and a summary of recommendations.

III. DESCRIPTION OF WATERSHED

A. NATURAL DRAINAGE BOUNDARIES

The drainage area of the Gunpowder Falls is approximately 349 square miles. Of this, 302 square miles are in Baltimore County, 35 square miles are in Carroll County, one square mile is in Harford County, and 11 square miles are in York County, Pennsylvania. The northern boundary of the watershed is just north of the Maryland-Pennsylvania line. The eastern boundary extends between New Freedom, Pennsylvania and the mouth of Gunpowder Falls. The southern boundary extends between Reisterstown and the mouth of the Gunpowder Falls. The western boundary is nearly coincidental with Maryland Route 30.

B. SUB-WATERSHEDS

The total drainage area of the Gunpowder Falls has been divided into 15 sub-watersheds for the major tributaries. Each of these is referred to by the name of the major tributary and by a two-letter code derived from that name. Table 2 in Appendix B lists the names, codes, and areas of the 15 sub-watersheds. Figure 2 in Appendix A shows their locations within the Gunpowder Falls watershed.

C. SUB-BASINS

Each sub-watershed is divided into subbasins averaging 200 acres. Subbasins are defined so that stream flow rates can be computed at cross roads and where tributaries flow together. The number of sub-basins in each sub-watershed varies between 40 and 122 with the average being 73.

D. SOILS

All four of the Soil Conservation Service hydrologic soil groups, A, B, C, and D, occur within the Gunpowder Falls watershed. These designations range from Group A, the most pervious, to Group D, the least pervious. The stream valleys consist mostly of C and D type soils which are relatively impervious and yield a high rate of runoff. Group B, the most predominant in the watershed, exhibits moderate infiltration and correspondingly moderate storm water runoff rates.

E. SLOPES

Watershed slopes vary considerably ranging from nearly zero percent in some stream areas to as high as 25 percent along hillsides in higher elevations.

F. LAND USE AND ZONING

The northern two-thirds of the Gunpowder Falls watershed is zoned predominantly agricultural and is covered by wooded areas, croplands, and pastures interspersed with small rural residential areas.

The land adjacent to Prettyboy and Loch Raven reservoirs is wooded and preserved for water supply protection by the City of Baltimore.

The southern third of the watershed is zoned predominantly residential and is highly urbanized. This area also includes the commercial and industrial areas along York Road from Timonium to Cockeysville as well as low to medium density residential development.

IV. FIELD INVESTIGATION

Field investigations were necessary to ensure proper modeling of the Gunpowder Falls watershed. The data gathered during field investigations are summarized as follows:

A. HYDRAULICS OF MAJOR STREAM REACHES

Field investigations were made of representative stream reaches for hydrologic modeling in each of the 15 sub-watersheds of the Gunpowder study. The channel size and shape were recorded to developed reach cross-section data for the TR-20 modeling.

B. DETERMINATION OF MANNING'S ROUGHNESS COEFFICIENTS

The six detailed hydraulic study areas were examined to determine ground conditions of the channel and overbanks. Existing ground conditions were recorded on 1" = 200' scale Baltimore County topographic maps. Photographs were taken at various points along the streams to document field conditions. This information was used to determine the Manning's "n" values for the HEC-2 model cross-sections.

The procedure to estimate "n" values is described in the Guide for Selecting Roughness Coefficient "n" Values for Channels (SCS Manual TR-24). It involved selecting a base "n" value and adding modifying values that reflect: (a) degrees of surface irregularity, (b) variation of shape and size of cross-section, (c) obstructions, (d) vegetation, and (e) meandering of channel within the floodplain. Photographs with assumed "n" coefficients were compared to similar photographs appearing in SCS Manual TR-24 and in Roughness Characteristics of Natural Channels (Geological Survey Water Supply Paper 1849).

C. FLOW REGIMES

A preliminary identification of flow regime (i.e., subcritical or supercritical flow) was made by walking the stream banks in the HEC-2 model study area and observing high flow characteristics. This information aided in programming the HEC-2 stream model.

D. EXAMINATION OF STRUCTURES

All structures within the six detailed hydraulic study areas were photographed and examined for evidence which might aid in better computer modeling. High water marks identified by debris suspended from the underside of a structure or along the brush on the stream banks indicated frequent flooding and provided insights into the hydraulic performance of the structure. Identification of likely flow paths for overtopping floods helped to later define the weir cross-section as well as other hydraulic modeling data for bridges and culverts.

E. OBSERVATION OF MINOR FLOODING

During the course of this study, there were several storms which resulted in flooding in portions of the watershed. No first-hand experience was obtained for any of these events, but interviews were conducted with flooded citizens afterwards. The information obtained further supported the data gathered during the Phase I study. No severe flooding events occurred in the six detailed hydraulic study areas during the course of this study.

F. INTERVIEWS WITH RESIDENTS

Interviews to gather historical data on past flooding conditions were conducted during the Phase I part of the study for the six detailed hydraulic study areas (see Chapter 4 of the Phase I report).

V. COMPUTER APPLICATIONS

The use of microcomputers for digital mapping, automated computation of hydrologic parameters, and hydrologic and hydraulic computations greatly reduced the volume of manual work normally associated with watershed studies of this size. All applications were performed on an IBM PC with peripheral equipment including hard disk storage, digitizer, and color monitor.

A. DIGITAL MAPPING - GEOGRAPHIC INFORMATION SYSTEM

The IRIS Geographic Information System (GIS) was used to store, display, and analyze map data which included watershed boundaries, subbasins, 1983 land cover, zoning classifications, Soil Conservation Service (SCS) soil types, and stream reaches. The microcomputer based IRIS GIS stores map data as well as any form of demographic data in grid cell form based on any cell size and reference data. For the Gunpowder Falls project a cell size of 200 feet by 200 feet (0.918 ac.) was selected as an appropriate size for calculation of hydrologic parameters for subbasins as small as 50 acres. The reference datum selected was the Maryland State plane coordinate system.

Map data was digitized and merged into 15 sub-watershed files for ease of analysis and backup. Digital (grid cell) data from the existing Baltimore County data base and LANDSAT land cover classification were also merged with these files to complete the data base for this project. Maps obtained from the Departments of Public Works of Carroll, Harford, and York (Pennsylvania) Counties were digitized and incorporated into the project data base.

B. EXISTING BALTIMORE COUNTY DATA BASE

Since the early 1970's, Baltimore County has maintained a digital map data base for planning applications. The existing SCS soil type file and zoning file were merged with the Gunpowder Falls project data base. The Baltimore County grid cell data was also referenced to the Maryland State coordinate system but is based on grid cell sizes of 400 feet by 500 feet. In order to merge cell data with that of the project, the County's cell data, therefore, had to be resampled to the 200 x 200 project cell size. The County data used included the SCS soil type files and the current zoning classifications.

C. IDENTIFICATION OF LAND COVER USING LANDSAT DATA

The LANDSAT series of satellites, beginning in 1972, provides the capability of land cover determination suitable for many purposes including watershed hydrologic modeling.[1] The LANDSAT satellite records the reflectivity of land surfaces using a multispectral scanner. The resolution of the LANDSAT grid cell images is 60 m (197 feet) by 80 m (262 feet) and is corrected for skew to a north-south orientation. The raw image data is classified into land cover types, resampled to the project 200 x 200 cell size and merged into the project data base.

Two LANDSAT scenes were obtained for the Gunpowder Falls watershed. A 1983 scene was used to model existing conditions, and a 1973 scene was used for calibration of the TR-20 watershed models.

The LANDSAT raw digital data image was reclassified into one of the following nine land cover classes: forest, pasture, cropland, residential medium density, residential high density, bare soil, industrial/commercial, wetlands and water.

For each of the desired classes, several "training" sites were selected from U.S.G.S. quadrangles. Positive identification of the land cover in each training site was established using field observations and air photographs. Training sites were located on the computer-displayed

---

1. U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, CA, "Determination of Land Use from LANDSAT Imagery: Applications to Hydrologic Modeling," November 1979.

raw LANDSAT image by referencing in relation to easily identifiable land features such as I-695 and Prettyboy and Loch Raven Reservoirs. Several training sites were chosen for each class in order to eliminate minor variations of image reflectivity in each class. For example, training sites for several types of water bodies (deep, highly turbid, slightly turbid, etc.) were used to define the "water" class.

D. AUTOMATED COMPUTATION OF HYDROLOGIC PARAMETERS

The manual computation of areas and SCS runoff curve numbers (RCN) for each of the nearly 1,100 subbasins in the Gunpowder Falls watershed for 1973, 1983, and ultimate (zoning) development periods would not be practical. To avoid this problem, a program module, HYDPAR, was added to the GIS software to compute these parameters. The HYDPAR program utilized the grid cell data bases created for soil types, land use, zoning, and subbasins to compute the RCN value and areas for each subbasin. Appendix C - TR-20 Models Drainage Area Summary presents the RCN's and areas for each sub-basin.

The RCN values derived from 1973 LANDSAT data and HYDPAR were compared to RCN values manually computed for "existing" land use from the 1973 Western Run Watershed Study by the Maryland Soil Conservation Service (SCS). RCN values computed from 1983 LANDSAT and GIS data were also compared to those manually computed for the 1984 Baltimore County Parkton study. A summary of these comparisons is shown in Table 3 of Appendix B.

E. WATERSHED HYDROLOGIC MODELS USING SCS TR-20

1. <u>Description of TR-20 Models</u>.

The U.S. Department of Agriculture, SCS program, TR-20 version, was used to model hydrology in each of the 15 sub-watersheds. This program uses the SCS runoff method, unit hydrograph procedure, stage-discharge reservoir routing, and modified attenuation-kinematic procedure for each routing to generate stream flow rates. The watershed subbasins were delineated on U.S.G.S. topographic maps (scale 1" = 2,000').

2. Times of Concentration.

Times of concentration were determined by charting flow paths on U.S.G.S. topographic maps with divisions for overland flow (forest, open, urban, or combined), swale or ditch flow, and stream flow. Velocities were obtained from:

Figure 3-1, SCS, Urban Hydrology for Watersheds, TR-55.

Figure SHA-61.1-402.2, Maryland State Highway Administration, Highway Drainage Manual, December 1981.

Times of concentration through Pretty Boy and Loch Raven Reservoirs were determined by computing the wave velocity across the reservoirs as described in the National Engineering Handbook, Section 4, Hydrology.

3. Derivation of Reach Routing Coefficients.

Two methods are available within TR-20 for specifying parameters needed to route runoff hydrographs through stream reaches. One method is to insert discharge-end area tables for representative stream reach cross-sections while the alternative is to specify X and M values. As discussed in detail in the TR-20 Users Manual, X and M are coefficients for the single valued flow area discharge relationship in the equation:

$$Q = XA^M$$

where Q = discharge in cubic feet per second

A = cross-sectional area of flow in square feet

For the Gunpowder Falls study, the latter method of specifying routing parameters was chosen.

For each sub-watershed, a pool of six to twelve typical cross-sections was derived from field and map data. From this pool of typical cross-sections, each reach section on the actual TR-20 schematics was assigned a cross-section. This selection was based on similarities in drainage area, location, and the shape of the cross-section. For example, each of the cross-sections required for the TR-20 model for sub-watershed FA was assigned one of the 12 cross-sections from the pool of typical cross-sections. Thus, it was possible for each of the typical cross-sections to be used more than once to represent a reach cross-section required by the TR-20 model.

For all 15 sub-watersheds, tabulations were made of the TR-20 sections and the typical cross-sections assigned to them. In addition, the slope of the channel bottom and reach length were measured from U.S.G.S. 2,000-foot scale topographic maps and listed with each section. This tabulation made it possible to determine the range of slopes in which each standard section was expected to operate.

Noting the method of determining the channel portion of the cross-sections, a brief sensitivity analysis was performed to investigate the impact of errors in estimating channel shapes on hydrograph shape and timing. Results from this brief study indicate that hydrograph shape is not highly sensitive to changes in the width of trapezoidal sections. Thus, this method of determining cross-section data was deemed appropriate, especially when calibration of the TR-20 models involved adjustment of the reach data.

Using these typical cross-sections, HEC-2 and TR-20 models were created to generate the desired X and M values for each reach. First, flow-versus-discharge rating tables were generated using the HEC-2 computer model. From this, rating tables for each typical cross-section were derived. Since each cross-section was used with more than one TR-20 section, enough runs were made for each typical section so that the whole range of tabulated channel slopes was analyzed.

Using a similar procedure, X and M values were generated for each typical cross-section and its corresponding range of channel slopes. TR-20 models were used to generate X and M values for each of the rating tables for each typical section. Thus X and M values covering a range of channel slopes were derived for each typical cross-section. Plots were constructed displaying X and M values versus slope for each cross-section.

The above procedure employing HEC-2 and TR-20 to generate X and M values was used for four of the 15 sub-watersheds. Using the X and M versus slope plots resulting from these tests, the X and M values for the remaining 11 sub-watersheds were selected. Each of the cross-sections in these 11 sub-watersheds was matched as nearly as possible to a section having computer generated X and M values. Upon finding a cross-section of similar shape, the appropriate X and M values were read from the corresponding plot of X and M versus channel slope. In cases where a matching section could not be found, HEC-2 and TR-20 were utilized to generate the needed X and M values.

4. Calibration and Verification of TR-20 Models

a. General

Calibration of the TR-20 models for the Gunpowder Falls watershed was accomplished using three stream gages located within the watershed. One gage is located on Little Falls in Blue Mount, Maryland. This gage includes sub-watersheds FA and BT. The second gage is located on Long Green Creek near Glen Arm and is located entirely in sub-watershed LO. The third gage is located on Western Run near Cockeysville. This gage includes all of sub-watersheds PI, BL, and most of WE (see Figure 3, Appendix A). A fourth stream gage, located on Slade Run near Glyndon, is no longer in operation. Slade Run is a part of the Western Run stream gage drainage area and, therefore, was not used for calibration of the Gunpowder Falls TR-20 models. Data recorded at the stream gages was readily available from the U.S.G.S. office in Towson.

For each of the stream gages a search was conducted of available runoff records to find suitable data for calibration purposes. The data consisted of hourly or bi-hourly stage levels at the gage which were converted to flow via gage rating tables. Base flows were removed from the plotted gage hydrographs graphically by separation procedures described in "Hydrology for Engineers" by Linsley, Kohler and Paulhus.

Individually occurring runoff hydrographs having a simple structure and preferably one peak were selected for calibration purposes. The runoff hydrographs for Tropical Storms Agnes, Eloise, and David were also obtained.

Two forms of rainfall data were obtained for the calibration process. Hourly rainfall data was obtained from the recording rain gages in Parkton, Towson, and Unionville (Pennsylvania). Daily rainfall amounts were obtained for these and several other gages, ranging in location from southern Pennsylvania to the Baltimore-Washington Airport. Thus, good coverage of the watershed with rainfall data was achieved. Storms that met the following criteria were selected for calibration:

1. Individually occurring storms, i.e., storms having a simple structure and preferably one peak rainfall period between periods of no rain.

2. Storms having a relatively uniform rainfall distribution.

In some cases, storms meeting the above criteria were supplemented with multiple peak storms and extreme events. However, these supplemental storms were used only for verifying the final calibrated models.

For each potential calibration storm, an average total rainfall volume (expressed in watershed inches) was derived for each gaged area using one of two methods. For storms having a significant geographical extent and high rainfall amounts such as Tropical Storms Agnes, David, and Eloise, average total rainfall depths were derived by constructing isohyetal maps. An isohyet is a line connecting points of equal rainfall depth and the map is made by drawing the lines similar to contour lines on a topographic map. More localized storms with smaller rainfall amounts were analyzed by constructing Thiessen diagrams. In the Thiessen method, the watershed is divided into subareas using the rain gage locations as hubs of polygons. The weighted average of the polygon is then computed to determine the average depth. Both methods used data from as many rain gages as possible.

Once an estimated average rainfall volume was derived, rainfall hyetographs (incremental rainfall graph) were developed for each storm. This task was accomplished by applying scaling factors to the actual hourly rainfall measurements from the Towson or Parkton rain gages so that the cumulative hourly rainfall equaled the derived average watershed rainfall.

Further refinement of the calibration storm candidates was accomplished through a comparison of runoff curve numbers derived using two methods. LANDSAT imagery was used to define existing condition curve numbers. A second curve number was derived by working backwards through the SCS rainfall-runoff equations using actual runoff volumes at the gage and estimated rainfall volumes. Those storms having a relatively close agreement between the LANDSAT-based and computed RCN's, as well as meeting the previous selection criteria, were considered for calibration storms.

Records of rainfall preceding the candidate storms were analyzed to determine which antecedent moisture condition (AMC) existed prior to each storm. The AMC is the method of the Soil Conservation Service for estimating the soil moisture content prior to a rainfall event.

Calibration of the TR-20 models continued with an analysis of runoff volumes. The runoff volumes measured at the stream gage were compared to runoff volumes computed by the TR-20 model. Generally, the two volumes were comparable. In those cases where a difference existed, the actual storm hydrograph volume was compared to volumes derived using TR-20 with different AMC values. Thus, it was possible to bracket the actual runoff values with volumes from two different AMC conditions. Later sections of the report will address this issue more specifically.

Given satisfactory estimates of runoff volumes for the calibration storms, parameters affecting the shape and timing of the hydrograph were adjusted. Previous studies indicated that minimal effects in hydrograph shape and timing result from modifying times of concentration. Moreover, since times of concentration were computed using accepted methods, it is not justifiable to adjust this parameter. Instead, the reach coefficients, X and M, were manipulated to produce a hydrograph of desired shape. Adjustments in these factors account for the approximate methods of estimating the channel cross-section shapes and friction factors. However, all adjustments resulted in reach coefficients that were within acceptable limits. The final calibrated hydrographs are shown in Figures D-2 through D-7 of Appendix D - Calibration Data.

A technical description of the model calibration can also be found in Appendix D of this report.

b. Calibration of Non-gaged Sub-watersheds

The TR-20 models which are contained within the gaged sub-watershed areas have been calibrated. For the Little Falls gage this included sub-watersheds FA and BT. Sub-watersheds PI, BL, and WE were part of the Western Run gage calibration. The Long Green Creek gage involved sub-watershed LO. The nine sub-watersheds remaining within the Gunpowder Falls study area were compared to the calibrated sub-watersheds for similar land use conditions, stream slopes, shapes, soils, and geological conditions. It was determined that sub-watersheds GR, SG, MU, CA, and SB were similar to sub-watershed FA and BT. These were given the same adjustments to their TR-20 models as the Little Falls gage TR-20 calibration model. Sub-watersheds BE, BU, and LG were similar to the Western Run gage sub-watersheds PI, BL, and WE. Hence, they were given the same calibration adjustments to their TR-20 models. Lastly, sub-watershed LC compared well to Long Green Creek gage sub-watershed LO. The TR-20 model for sub-watershed LC was given similar calibration adjustments as the TR-20 model for sub-watershed LO.

c. Comparison of TR-20 and Stream Gage Derived Flood Flow

The resulting calibrated TR-20 models were used to derive the 2, 10, and 100-year frequency stream flows at the Little Falls (STA-01582000), Western Run (STA-01583500), and Long Green Creek (STA-01584050) gages. These values and the gage derived flood flow frequencies were plotted on probability graphs shown in Appendix D, Figures D-8, D-9, and D-10. These were the three gages used for TR-20 model calibration. The plot of TR-20 derived flow frequencies versus gage statistical data for the Slade Run gage (STA-01583000) is shown in Appendix D as Figure D-11. The reference data for all four gages are listed in Chapter 3 of the Phase I report.

It can be seen from these flood frequency figures that, with the exception of the Slade Run gage, all calibrated TR-20 derived 100-year frequency flow rates agree quite well with those calculated using the Log-Pearson Type III probability analysis. The higher 2 and 10-year values derived from the TR-20 models as compared to the gage data frequency plot may be attributed to the times of concentration. The TR-20 models use 1983 land cover whereas the gage frequency data represents variable land use during the period of record listed below:

Gage	Period of Record
Slade Run	34 years, 1947 to 1981
Western Run	40 years, 1944 to present
Long Green Creek	9 years, 1975 to present
Little Falls	40 years, 1944 to present

d. Derivation of Flood Flow Rates for the Detailed Study Areas

For the six detailed hydraulic study areas, calibrated TR-20 runs were made for the 2, 10, and 100-year frequency storms for existing land use (1983) conditions and ultimate land use conditions based on current zoning maps.

The upper two-thirds of the Gunpowder Falls watershed is zoned predominantly agricultural or conservation land. Prior to assigning runoff curve numbers in these two zones, the existing land use was overlayed in these zones and used in lieu of the zoned land use. Under existing land use conditions, the conservation zones consist entirely of wooded or forest land, and the agricultural zone consists mostly of farm land with some wooded land. In both instances, the existing land use is nearly identical to the zoning land use. Little change will occur in the existing land use in the future because the area is basically stable and developed to permissible zoned levels.

The flows for the Piney Creek and Lower Piney Creek were obtained by running the TR-20 model for sub-watershed BU which has a drainage area of 12.17 square miles. Based on the area-depth adjustment curves in TP-40, shown in Appendix D, Figure D-12, the percent of point rainfall is 98 percent of the base value. Therefore, rainfall depths of 3.14, 5.00, and 6.96 inches were used for modeling the 2, 10, and 100-year frequency storms, respectively. The resulting peak flows at each cross-section in the detailed study area are shown in the Appendix E.

The flows for the Long Green Creek study area were computed by the TR-20 model for sub-watershed LO. Sub-watershed LO is 14.35 square miles in area and also has a 98 percent point rainfall adjustment value. The same rainfall depths as for sub- watershed BU were used. The peak flows computed are shown in Appendix E.

The TR-20 model for sub-watershed FA was run to obtain the peak flows for the Beetree Run study area. The sub-watershed area is 24.72 square miles. This size area yields a 96 percent point rainfall value. Point rainfall values of 3.07, 4.90, and 6,82 inches were thus used for the 2, 10, and 100-year frequency storms, respectively. Resulting peak flows are also listed in Appendix E.

The last two detailed study areas are on the Gunpowder Falls. In order to obtain the peak flow rates for these areas, eight TR-20 models were run. Sub-watershed FA TR-20 model was run with the resulting final hydrographs being punched to a file. This file was then retrieved and used as input to the TR-20 model for sub-watershed BT to continue the flow down Little Falls to the confluence with the Gunpowder Falls. Similarly, sub-watersheds SC, GR, MU, and CA were run in series with the resulting hydrograph from one model being inputted to the model immediately downstream. Lastly, the hydrographs from sub-watersheds BT, CA, and BU were inputted into sub-watershed SB to obtain the peak flows for the detailed study areas along the Gunpowder Falls (see Figure 4 in Appendix A). The total drainage area for these eight sub-watersheds is 181.66 square miles. The percent of point rainfall is 93 percent for area-depth curves from TP-40. This resulted in rainfall depths of 2.98, 4.74, and 6.60 inches for the 2, 10, and 100-year frequency storms, respectively. Resultant peak flows for the study area are shown in Appendix E.

e. TR-20 for Non-Detailed Study Areas

There are six sub-watersheds (PI, BL, WE, BE, LC, and LG) in which no detailed hydraulic study areas exist. For these subwatershed's working TR-20 models were developed for future use.

F. HYDRAULICS

1. Description and Input Data Requirements

The HEC-2 program is designed to model the stream hydraulics. The program will compute the water surface profile, flow velocities, energy gradient, and friction losses. Additionally, it will accommodate hydraulic structures such as bridges, culverts, weirs, and any combination of flow through or over these structures. Input information used in programming HEC-2 includes cross-section geometry, Manning's roughness coefficients, stream flow rate, and minor losses due to expansion and contraction of the cross-sectional areas.

Peak discharges for the 2, 10, and 100-year frequency storms for both existing and ultimate land use developed by the TR-20 models were programmed into HEC-2, and water surface profiles were calculated for the stream in each study area. Five HEC-2 models were developed, one for each of the following streams: Beetree Run, Long Green Creek, Gunpowder Falls, Piney Creek at Ensor Mill Road, and Piney Creek confluence with the Gunpowder Falls.

2. Accuracy of HEC-2

The accuracy of any computer model is, in part, dependent on the basic assumptions inherent in the modeling technique. The HEC-2 computer program is a one-dimensional model based on the assumption of steady, gradually varied flow. Therefore, the accuracy of the model is partially dependent on how closely the prototype conforms to these basic assumptions. As a general rule, the steady gradually varied flow assumption yields good results for streams with gentle slopes (10% or less) and relatively constant cross-sections. The streams studied in this report meet both of these requirements.

The other factors affecting the accuracy of the HEC-2 model are as follows:

(a) Stream flow rate and variation along length of reach.

(b) Manning's roughness coefficient for determining resistances to flow from channel and overbank surfaces.

(c) Stream geometry - such as cross-sectional form and channel slopes.

The first factor is the flow rate which is computed by using the Soil Conservation Service computerized hydrograph method for runoff determination (TR-20) as described previously. Flow rate errors are minimized by calibrating the model using stream gage records as previously discussed.

The second factor is the assignment of Manning's roughness coefficients which were chosen by applying data from careful field observation to the techniques presented in SCS publication TR-24. Several roughness coefficients were chosen for each cross-section in the study areas.

The third factor required to model the hydraulic performance of a stream is the cross-section geometry. The impact each cross-section has on the model is dependent on the distance between cross-sections. Lengths between the 136 cross-sections for the study areas varied from 10 feet to 800 feet. Sections were chosen wherever necessary to describe changes in cross-section shape, channel or overbank roughness coefficients, channel slope, or locations of stepped increase in flow. Cross-section information was obtained from aerial photogrammetry in 1982 by Aerial Data Reduction (ADR) of New Jersey. The variations in ground surface elevations between cross-sections produce random errors which are compensating in nature and do not significantly influence the results.

3. Development of HEC-2 Models

The HEC-2 models were developed in two steps. First, all bridges were analyzed individually to determine the best HEC-2 modeling application. Second, each reach between the structures was analyzed to determine general stage-discharge and flow regime characteristics which aided in development of the final stream model.

4. Structures

There are 14 existing structures within the study areas. Five of these are railroad bridges, and the rest are road bridges. Each of the 14 structures appears on 1" = 200' scale strip maps depicting the extent of flooding (see Appendix F). Also, each of the 14 structures was analyzed separately to determine which of the following two techniques would provide the most accurate model for use in the final HEC-2 programs.

a. Calculating the energy loss using the HEC-2 normal bridge routine.

   The normal bridge routine handles a bridge cross-section in the same manner as a natural river cross-section with the following exception. The area of the bridge structure that is below the water surface is subtracted from the total area, and the wetted perimeter is increased where the water is in contact with the bridge structure. This routine is most applicable when friction losses are the predominant consideration.

b. Calculating the energy loss using the HEC-2 special bridge routine.

   The special bridge routine computes losses through the structure for either low flow (water surface below low chord of structure), pressure flow (water surface above low chord of structure), weir flow (flow around bridge and/or over bridge deck), or for a combination of these. The profile through the bridge is calculated by using hydraulic formulas to determine the change in energy and water surface elevation through the bridge. Although this technique is capable of solving a wide range of flow problems, it is most applicable for structures operating under pressure flow conditions with road embankments having well-defined weir surfaces.

The following discussion consists of a short description of the physical characteristics of each structure including the type of road it serves (i.e., arterial, collector, etc.), the modeling technique chosen for each structure, and a short description of the hydraulic performance of each structure during the 10 and 100-year frequency storms as predicted by the HEC-2 modeling.

Upper Piney Creek Study Area

Structure No. 1 - Belfast Road (Appendix G, Sheet 1)

Structure No. 1 is a twin-cell concrete box culvert for Belfast Road which is classified as a major collector. Each cell is 21 feet by 10.5 feet. The 10-year frequency storm for Piney Creek is passed as a low flow condition. The 100-year frequency storm flow results in a combination of pressure through the culverts and weir flow over the roadway. Weir flow occurs over Belfast Road to the west of the culvert. This structure was handled by the special bridge routine.

Structure No. 2 - Ensor Mill Road (Appendix G, Sheet 2)

Structure No. 2 is a 78-foot by 7-foot steel girder bridge with concrete deck. The roadway passing over this structure is a local, residential road. The 10-year frequency storm for Piney Creek passes through this opening as low flow. Half of the 100-year frequency storm passes through the bridge as pressure flow. This structure was modeled using the special bridge routine.

Lower Piney Creek Study Area

Structure No. 3 - York Road (Appendix G, Sheet 5)

Structure No. 3 is a triple-cell concrete box culvert which carries York Road over Lower Piney Creek. Each cell is 15 feet wide by 7.8 feet high. York Road is a major collector. This structure operates under pressure flow during the 10-year frequency storm. Pressure flow and weir flow exist during the 100-year frequency storm. The special bridge routine is the best selection for modeling this structure.

Gunpowder Falls Study Area

Structure No. 4 - Sparks Road (Appendix G, Sheet 6)

Structure No. 4 is a steel bridge and deck with stone abutments that carries Sparks Road over the Gunpowder Falls below the confluence with Lower Piney Creek. Sparks Road is a major collector. The bridge opening is 176 feet wide and 10 feet high. The bridge deck, guardrails, and framing are all open and offer little resistance to flow. This structure was modeled by the normal bridge routine.

Structure No. 5 - Glencoe Road (Appendix G, Sheet 8)

Structure No. 5 is a steel bridge with wood deck and stone abutments. It carries Glencoe Road over the Gunpowder Falls. The bridge opening is 93.3 feet wide and 11 feet high. The bridge and guardrails are open structures and offer little resistance to flow which made it suited for normal bridge modeling.

Structure No. 6 - Pennsylvania Railroad (Appendix G, Sheet 11)

Structure No. 6 is the Pennsylvania Railroad Bridge over the Gunpowder Falls below Corbett Road. The bridge is a metal structure with stone abutments. The railroad right-of-way has been converted to a hiking trail. The surface of the bridge is now gravel with the railroad ties having been removed. The bridge has a stone pier, 5.5 feet wide, with a total opening of 149.5 feet in width and 30 feet in height. Both the 10 and 100-year frequency storms behave in a low flow situation. The special bridge routine was used to account for the pier losses.

Structure No. 7 - Corbett Road (Appendix G, Sheet 13)

Structure No. 7 is a steel bridge with concrete deck, stone abutments, and a single stone pier. The bridge carries Corbett Road over the Gunpowder Falls to Falls Road. The bridge opening is 115.5 feet wide and 17 feet high. The road approaching the bridge from the north is lower than bridge surface. For the 100-year frequency storm there is weir flow over this point while low flow occurs through the bridge. Only low flow occurs for the 10-year frequency storm. This bridge was modeled with the special bridge routine.

Structure No. 8 - Pennsylvania Railroad (Appendix G, Sheet 14)

Structure No. 8 is similar to the lower railroad bridge over the Gunpowder Falls. This railroad bridge has also been abandoned and converted as part of the hiking trail. This is a metal bridge with gravel deck surface, stone abutments, and a single stone pier. The bridge opening is 123 feet wide and 30 feet high. The pier is 5.5 feet wide. The 10-year and 100-year frequency storms are both low flow cases. The special bridge routine was used to better model pier losses.

Long Green Creek Study Area

Structure No. 9 - Long Green Pike (Appendix G, Sheet 15)

Structure No. 9 is a twin-cell, concrete box culvert which passes Long Green Pike over Long Green Creek. The cells are 13.7 feet wide by 5 feet high. Both the 10 and 100-year frequency storms exhibit pressure and weir flow conditions. Since the weir surface is well defined, the special bridge routine was used.

Structure No. 10 - Long Green Road (Appendix G, Sheet 15)

Structure No. 10 is a steel bridge with asphalt deck and concrete abutments. It passes Long Green Road over Long Green Creek 200 feet above the Long Green Pike Bridge. The bridge opening is 26 feet wide and 7.5 feet high. Both the 10 and 100-year frequency storms exhibit pressure and weir flow conditions. This structure was also modeled by the special bridge routine.

Beetree Run Study Area

Structure No. 11 - Pennsylvania Railroad (Appendix G, Sheet 16)

Structure No. 11 is the furthest downstream of the three railroad bridges below Freeland Road. The structure is a steel girder bridge with stone abutments. It has an opening 20 feet wide and 12 feet high. The railroad track define the weir surface in this case. The 10-year frequency storm exhibited a low flow condition. The 100-year frequency storm occurs under a pressure flow situation. The special bridge routine was best suited for this structure.

Structure No. 12 - Pennsylvania Railroad (Appendix G, Sheet 17)

Structure No. 12 is the middle railroad bridge in series below Freeland Road. It consists of a steel girder bridge with stone abutments presenting a 19.8-foot by 7-foot opening. The elevation of the Pennsylvania Railroad tracks defines the weir surface for this structure. The 10-year frequency storm was passed by a low flow condition. The 100-year exhibit pressure and weir flow condition. The special bridge routine was used for modeling purposes.

Structure No. 13 - Pennsylvania Railroad (Appendix G, Sheet 17)

Structure No. 13 is the first railroad bridge below Freeland Road. The bridge consists of a steel girder and stone abutments design. The opening is 30.8 feet wide and 4.5 feet high with the railroad track defining the weir surface. The 10-year frequency storm is a pressure flow condition with the 100-year exhibiting pressure and weir flow. The special bridge routine was used.

Structure No. 14 - Freeland Road (Appendix G, Sheet 18)

Structure No. 14 is a concrete bridge having an opening 16 feet wide and 5.5 feet high. It carries Freeland Road over Beetree Run. Both the 10-year and 100-year frequency storms exhibit pressure and weir flow conditions. Freeland Road defines a good weir surface for the special bridge modeling.

VI. DETAILED STUDY AREAS

A. UPPER PINEY CREEK NEAR ENSOR MILL ROAD

1. Description of Study Area

This reach of Piney Creek is parallel to Ensor Mill Road. The study area begins 250 feet above where Ensor Mill Road crosses the stream to a point 500 feet below Belfast Road as shown in Appendix F, Drawing No 1. The stream averages 20 feet in width, with a depth ranging from one-half to one foot. The stream slope for this 3,510-foot stretch is 0.8 percent. The Belfast Road Bridge is a twin-cell concrete box culvert. The Ensor Mill Road Bridge is a single-span bridge. The east bank of the stream near Ensor Mill Road is occupied by three sets of tennis courts and a small pond. The overbank areas consist of lawns and grasses in the upper and middle reaches of the study area, while the southern end is entirely wooded.

Manning's roughness "n" coefficients for the channel average 0.045; overbank roughness varies from 0.015 for paved areas to 0.15 for heavily wooded areas with dense undergrowth.

There are five structures adjacent to Piney Creek which were studied for potential flooding. Four houses are located along Ensor Mill Road and a tennis club is situated near the Ensor Mill Road Bridge.

2. Identification of Flood Hazards

The water surface profile for upper Piney Creek was plotted for the 10 and 100-year frequency storms for existing development conditions as shown in Appendix G. The water surface profile for ultimate development conditions showed negligible (less than 0.1 foot) increase over the water surface profiles for existing development conditions (see Appendix E). This is due to the nearly identical conditions of the existing land use and zoning maps. The analysis of ultimate runoff conditions produced substantially the same flood hazards as identified in the analysis of existing runoff conditions. Therefore, only the ultimate flood hazard areas were delineated as shown in Appendix G. Drawing No. 1 depicts the 100-year flood delineation for Upper Piney Creek.

The Ensor Mill Road Bridge does not flood, but Ensor Mill Road floods from Cross-section 5 to the bridge. Belfast Road is overtopped at the low point in the road, west of the Belfast Road Bridge. The three tennis courts and the pond are all under water. Four of the five houses examined will be located within the 100-year flood zone. Two will have their first floors flooded, one will have its basement flood, and the tennis club will have its foundation (crawl space) flooded. The fifth house is beyond the flood zone.

B. LOWER PINEY CREEK NEAR GUNPOWDER FALLS

1. Description of Study Area

This is a second reach of Piney Creek under detailed study. The limits of study go from the confluence with the Gunpowder Falls at Sparks Station upstream to the point 1,350 feet above York Road as shown in Appendix F, Drawing No. 2. The stream has an average slope of 0.3 percent in this 6,720 foot stretch. The stream width ranges from 10 to 40 feet, while the depth ranges from one to four feet.

The York Road Bridge is a triple cell concrete box culvert structure.

The overbanks are mostly wooded in the lower part of this study area. Two ballfields and some tennis courts exist in the south overbank in the middle of this reach. Lawns and grasses cover the overbank in the upper part of the study reach.

Manning's "n" coefficients average 0.045 for the channel; overbank values range from 0.015 for paved areas to 0.15 for wooded areas.

Three houses were examined in detail in this study reach. They are located on the north bank of Piney Creek adjacent to York Road.

2. Identification of Flood Hazards

The water surface profiles for ultimate development conditions showed increases of less than 0.10 foot over the water surface profiles for existing development conditions. The water surface profiles were plotted for the 10 and 100-year frequency storms, existing land use conditions, and are presented in Appendix F. The flood hazard areas was delineated for the 100-year frequency storm, ultimate development conditions, and is shown as Drawing No. 2 in Appendix G. York Road is overtopped by this flood. Three house are located within the floodplain. One is flooded above the first floor, and the other two have basement flooding.

C. GUNPOWDER FALLS FROM SPARKS ROAD BRIDGE TO THE CORBETT RAILROAD BRIDGE

1. Description of Study Area

This reach of stream comprises two of the detailed study areas. The first being the Sparks Station to Glencoe study area. The second is the Corbett study area. The study begins 1,750 feet below the Sparks Road Bridge and continues upstream through Glencoe and Corbett to a point 600 feet above the second Pennsylvania Railroad Bridge crossing (see Appendix F, Drawing No. 3 through Drawing No. 10). The stream length is 25,010 feet with an average slope of 0.1 percent. The width of the Gunpowder Falls varies from 80 to 130 feet with the depth fluctuating between two to six feet.

There are five bridge structures crossing the stream in this reach.

The Sparks Road Bridge is an open steel structure. The Glencoe Road Bridge is a single-span steel bridge with concrete deck. The two railroad bridges are similar structures. Each is a masonry bridge having a single brick masonry pier. The Corbett Road Bridge is a concrete bridge with a concrete pier.

The stream overbanks below Sparks Road are lightly to heavily wooded. Cropland exists in the overbanks between the Sparks Road and Glencoe Road Bridges. From Glencoe Road Bridge upstream to the lower Pennsylvania Railroad Bridge the overbanks are lightly to heavily wooded. Cropland exists from this railroad bridge to the Corbett Road Bridge on the northern overbank area. The southern overbanks are wooded. From the Corbett Road Bridge to the upper railroad bridge woods dominate the overbanks with some cropland on the northern overbanks near the railroad bridge.

The Manning's "n" values for the channel average 0.045. The overbank values range from 0.05 for cropland to 0.15 for heavily wooded areas.

There are 13 houses within this stream reach under examination. A house is located on each side of the Sparks Road Bridge. Three homes are located on the east bank on the stream above the Glencoe Road Bridge. Another home is located below the lower Pennsylvania Railroad Bridge. Two homes are located along Corbett Road. The remaining five homes are adjacent to Falls Road which parallels the Gunpowder Falls in Corbett.

2. Identification of Flood Hazards

The water surface profiles for the 10 and 100-year frequency storms were plotted for existing development conditions. The water surface elevations for ultimate development conditions increase on the average less than 0.10 foot over existing development conditions (see Appendix E). Likewise, the flood hazard areas are also similar. The flood hazard area for the Gunpowder Falls was delineated for the 100-year frequency storm and ultimate development conditions. Drawing No. 3 in Appendix F shows the Gunpowder Falls at Sparks Road. The Sparks Road Bridge and the Pennsylvania Railroad are flooded. Two houses are located within the floodplain. Drawing No. 4 shows the floodplain for the Gunpowder Falls near Glencoe. Glencoe Road and Bridge are flooded. The Pennsylvania Railroad is still under water in this region. There is one house located north of the Glencoe Road Bridge that gets flooded above the first floor. Drawing No. 5 shows the Gunpowder Falls north of Glencoe. Glencoe Road, the Pennsylvania Railroad, and Home Road are flooded by the 100-year frequency storm, ultimate development conditions. Two houses are located near the flooding boundary. Neither has its first floor flooded but both may experience basement flooding under 100-year storm conditions. Drawing No. 6 shows the Gunpowder Falls below the lower Pennsylvania Railroad Bridge in Corbett. In this stretch of the river, the railroad is no longer flooded. No houses are located in or near the flood zone on this drawing. Drawing No. 7 shows the vicinity of the lower Pennsylvania Railroad Bridge. The railroad bridge is high enough so that it is not overtopped. The one house under examination on this drawing is beyond the flooding boundaries. Drawing No. 8 is upstream of the previous railroad bridge. The one house located on Corbett Road is beyond the flood limits. Drawing No. 9 shows the Gunpowder Falls flood limits in the vicinity of the Corbett Road - Falls Road intersection. The Corbett Road Bridge doe not flood, but the road approaching the bridge from the north does flood. The house located on Corbett Road is not within the flood zone. Three other houses are located on Falls Road. Only the house between Cross-sections 70 and 71 gets flooded above the first floor. The other two are beyond the flood boundaries.

Drawing No. 10 depicts the Gunpowder Falls at the upper Pennsylvania Railroad Bridge. Like the lower railroad bridge, this one is also high enough so that it is not overtopped by the 100-year frequency storm under ultimate development conditions. One home on Falls Road is flooded above the first floor, the other is beyond the flood boundary.

D. LONG GREEN CREEK NEAR LONG GREEN ROAD

1. Description of Study Area

Long Green Creek flows in a southerly direction under Long Green Road and under Long Green Pike. The stream then flows adjacent to Long Green Pike. The study area is from 290 feet above Long Green Road to 1,630 feet below Long Green Pike as shown in Appendix F, Drawing No. 11. The study reach is 2,230 feet long with an average stream slope of 0.2 percent. The stream averages 20 feet in width and one foot in depth. The Long Green Road Bridge is a single-span bridge. The Long Green Pike Bridge is a twin-cell concrete box culvert. A side tributary joins with Long Green Creek between these two roads. The overbank areas consist mainly of lawns or grasses with some wooded sites. Croplands exist above Long Green Road.

Manning's roughness "n" coefficients for the channel average 0.045; overbank roughness varies from 0.015 for paved areas to 0.05 for crops to 0.10 for wooded areas.

Within this study reach there are eight houses which were examined for potential flooding problems. Seven are located on the west side of the creek and the other on the east side.

2. Identification of Flood Hazards

Water surface profiles were developed for the 10 and 100-year frequency storms, existing development conditions for Long Green Creek. The profiles are shown in Appendix G. Water surface elevations for ultimate development conditions show no significant increase over existing development conditions (less than 0.10 foot increase as shown in Appendix E). Drawing No. 11 in Appendix F presents the flood limits for the 100-year frequency storm, ultimate development conditions. Both the Long Green Pike and Long Green Road Bridges are overtopped by the flood. Only one of the eight houses in this study area is located in the flood zone; however, its first floor is above the flood elevation. Its basement is subject to flooding.

E. BEETREE RUN NEAR FREELAND ROAD

1. Description of Study Area

The study area for Beetree Run extends from 920 feet above Freeland Road downstream beyond three railroad crossings of the Pennsylvania Railroad as shown in Appendix F, Drawing No. 12 and Drawing No. 13. The stream has an average slope of 1.0 percent in this 6,400-foot reach with a 20-foot wide channel and a one-foot average depth.

The Freeland Road Bridge is a single-span concrete structure. The three railroad bridges below Freeland Road are all single-span steel bridges with masonry abutments.

The overbank areas consist of grasses and lawns in the vicinity of Freeland Road. Wooded overbanks dominate between the first and third railroad crossings.

The Manning's "n" coefficients for the channel average 0.045; overbank values range from 0.045 for grasses to 0.15 for the heavily wooded lands.

Ten houses were initially identified within this study area for potential flooding problems. These houses are clustered along Freeland Road.

2. Identification of Flood Hazards

The water surface elevations for ultimate development conditions were identical to existing development conditions (see Appendix E). This was due to similar flows generated by the TR-20 model and because, essentially, the existing land use is agricultural and is also zoned agricultural. Water surface profiles were plotted for existing development conditions for the 10 and 100-year frequency storms (see Appendix G). Flood hazard areas were plotted for the 100-year storm, ultimate development conditions as shown in Appendix F. Drawing No. 12 shows the flood boundary for Long Green Creek at the lower two Pennsylvania Railroad Bridges. The lower bridge is under a pressure flow situation. The upper bridge is overtopped by the flood. No houses are within the flood zone on this drawing. Drawing No. 13 shows the Freeland Road area of Long Green Creek. Both the railroad bridge and the Freeland Road Bridge are flooded. There are ten houses located in this study area. Four of the houses are located beyond the flood zone, four are located on the edge of the flood zone, and two are within the flood area. All have first floor elevations above the flood elevations. Except for those houses beyond the flood limits, the houses may experience basement flooding under 100-year flood conditions.

VII. FLOOD MANAGEMENT ALTERNATIVES

Flood management alternatives were evaluated for each detailed study area. Table 4 in Appendix B summarizes the recommended management alternatives for all detail areas. The following is a brief discussion of the alternatives.

A. UPPER PINEY CREEK

The following alternatives were considered to alleviate flooding of the three residential structures within this study reach:

1. Change in Existing Zoning

Projected land use according to zoning is nearly identical to present land use. The land use is currently pasture, forest, and cropland. Therefore, modifications of the current zoning could not provide a means to reduce the stormwater runoff volume rates.

2. Flood Insurance

Flood insurance is a feasible alternative for flood hazard mitigation. However, flood insurance does not address the risk of personal injury.

3. Floodproofing

Floodproofing is a feasible alternative for structures with only minor basement flooding and which are not located in the floodway.

4. Foundation Raising

Foundation raising for structures in the floodway is not practical. More than two feet of hydrostatic pressure on foundation walls will cause failure for most standard foundation construction methods and materials.

5. Flood Warning Systems

The rapid response time of the small watershed prohibits the use of stage alarms. The present weather bureau severe rainfall warning notices through the media is the only feasible warning system for this site.

6. Acquisition

The purchase of flooded structures and their removal from the floodplain eliminates future problems. Homes which are flooded above the first floor are candidate structures. In this study area House No. 1 and No. 2 fall under this condition. House No. 4 is located within the floodway, and it is also a candidate for acquisition.

7. Stormwater Management

Stormwater management alternatives, including infiltration methods, are not practical due to the size of the areas needed to infiltrate stormwater runoff.

8. Bridge and Culvert Replacement

Bridges and culverts that are undersized may produce back-water flooding. This condition does not exist in this study area. Both Ensor Mill Road and Belfast Road convey floodwaters without being overtopped at the bridge structure.

9. Channelization

Channelizing Upper Piney Creek would be very costly compared to the benefit received by protecting the three flood structures. The channel would have to be approximately 10 feet deep, 20 to 30 feet wide, and 2,000 feet long.

10. Floodwalls

Floodwalls are not practical. To protect the three flooded structures, a fortress-like structure is needed around the homes. There would be no ingress or egress from the structures during floods.

11. Levees

Levees for Upper Piney Creek are not practical. Ensor Mill Road is flooded, and in order to protect the structures, the levees would have to completely encircle the three structures similar to floodwalls.

12. Retention/Detention Structures

Detention structures upstream of I-83 consisting of a total of 150-acre feet are required to reduce flood levels to below first floor levels. This quantity of storage is not available without significant grading and land acquisition.

13. Stream Relocation

The flood structures are located from 40 to 90 feet from the stream. This closeness, the size of the floodplain, and the lack of available space make stream relocation impossible.

14. Stream Enclosures

Enclosing the stream in pipes is not economically justified in this study reach. This stream would have to be enclosed in similar dimensions to the channelization alternative.

B. LOWER PINEY CREEK

Flood mitigation alternatives were considered for the three residential structures within the 100-year flood zone.

1. Change to Existing Zoning

Similar to Upper Piney Creek, a change to the current zoning will not reduce stormwater runoff rates.

2. Flood Insurance

Flood insurance helps to mitigate flood damages dollarwise but does not consider the personal injury factor. House No. 3, where injury risk is minimal, is a candidate for this alternative.

3. Floodproofing

Floodproofing is feasible for structures on the edge of the flood zone which only experience basement flooding. This is the case for House No. 3 in this study area.

4. Foundation Raising

See Upper Piney Creek.

5. Flood Warning Systems

See Upper Piney Creek.

6. Acquisition

Purchase of structures is a feasible alternative where first floor flooding and possible personal injury could occur. This is the situation for House No. 2. House No. 1 receives 4.5 feet of basement flooding and is located in the floodway. Purchasing is recommended because of the depth of flooding and structure location.

7. Stormwater Management

See Upper Piney Creek.

8. Bridge and Culvert Replacement

The York Road bridge is above the flooded structures. Weir flow exists over York Road, north of the bridge in the low point of the road, causing floodwaters to reach the flooded residential structures from this direction during the 100-year storm. Replacing the fairly new York Road bridge will not alleviate this situation.

9. Channelization

Channelization of Lower Piney Creek would require a large channel which is economically impractical.

10. Floodwalls

A floodwall built parallel to York Road and adjacent to the stream and back up to high ground forming a U-shape condition is envisioned. However, this would be costly and does not seem to be a viable alternative.

11. Levees

A levee similar in shape to the above-described floodwall would be required. However, based on space limitation between road and structures and stream and structure, the levee cannot be stably built.

12. Retention/Detention Structures

The retention/detention structure would have to be even greater than that of Upper Piney Creek. It, too, is not feasible.

13. Stream Relocation

There is no feasible place to relocate the stream in this study reach.

14. Stream Enclosures

As with channelization, an attempt to enclose the stream would be too costly.

C. GUNPOWDER FALLS

Six structures experience first flood flooding and two experience basement flooding along the Gunpowder Falls study reaches.

1. Change in Existing Zoning

The total drainage area to the study reaches is approximately 185 square miles. Although this is a very large area, current land use and projected land use based on zoning are nearly identical. Therefore, stormwater runoff rates cannot be significantly reduced by a change in the current zoning maps.

2. Flood Insurance

Same as Upper Piney Creek.

3. Floodproofing

Same as Upper Piney Creek.

4. Foundation Raising

Raising the foundation for residential structures receiving minor first floor flooding and which do not have a basement is a feasible alternative. Structures No. 1 and 2 are commercial and manufacturing structures not considered in the scope of this study.

5. Flood Warning Systems

Although the drainage area is of considerable size, the flooded few (eight) structures are spaced over a five-mile stretch of stream. A warning system may reduce risk to personal injury but not to structural and contents damage.

6. Acquisition

Acquisition is feasible for those structures which receive first floor flooding. Houses No. 3, 10, 12, and 13 fall into this case. Houses No. 4 and 5 are located within the floodway of the tributary and are candidates for flooding.

7. Stormwater Management

See Upper Piney Creek.

8. Bridges and Culvert Replacement

The five bridge structures within the Gunpowder Falls study area do not produce adverse flooding conditions.

9. Channelization

Channelization of a large stream like the Gunpowder Falls is unrealistic.

10. Floodwalls

Floodwalls may be practical for the commercial and industrial structures in the study reach but not considered under this scope of study. Floodwalls for any of the residential structures in the floodplain are not economical. The wall would recreate a fortress-like effect around the structures and leave no place to egress and ingress.

11. Levees

Levees are not feasible.

12. Retention/Detention Structures

Any retention or detention structure would have to be of enormous size to significantly reduce runoff rates. They would also be uneconomical from the point of reducing flood losses.

13. Stream Relocation

Stream relocation for such a large stream as the Gunpowder Falls is just impracticable.

14. Stream Enclosure

As with relocation, enclosing the Gunpowder Falls is impracticable.

D. LONG GREEN CREEK

Of the eight structures initially identified for investigation, only one is subject to flooding, and it only experiences basement flooding.

1. Change in Existing Zoning

Same as Upper Piney Creek.

2. Flood Insurance

Flood insurance is a feasible alternative for the flooded structure. The risk of personal injury is not as great because only basement flooding exists.

3. Floodproofing

Floodproofing is a feasible alternative for the structure with basement flooding.

4. Foundation Raising

Foundation raising is not practical because the first floor is already above the flood elevation.

5. Flood Warning Systems

See Upper Piney Creek.

6. Acquisition

Purchasing of this structure is recommended because it experiences more than one foot of flooding around the house.

7. <u>Stormwater Management</u>

See Upper Piney Creek.

8. <u>Bridge and Culvert Replacement</u>

The flooded structure is below both Long Green Road and Long Green Pike. Even though both bridges are overtopped by the 10 and 100-year floods, replacement will not reduce flood levels at the residential structure.

9. <u>Channelization</u>

Channelization is not economically feasible to protect one structure at the edge of the flood zone.

10. <u>Floodwalls</u>

Floodwalls around the flooded structure are possible, but economically the cost is high because it must be at least 6.5 feet high on the stream size.

11. <u>Levees</u>

To enclose the single house with a levee is unreasonable.

12. <u>Retention/Detention Structure</u>

A retention or detention structure is not economically beneficial to protect one structure.

13. <u>Stream Relocation</u>

There is no feasible place to relocate the stream.

14. Stream Enclosure

A stream enclosure is not economically feasible.

E. BEETREE RUN

No structures within this study area experience first floor flooding from the 100-year frequency storm. Three structures do experience basement flooding.

1. Change in Existing Zoning

Same as Upper Piney Creek.

2. Flood Insurance

Flood insurance is a feasible alternative for flood hazard mitigation. With only basement flooding existing, the risk of personal injury is small in comparison to first floor flooding.

3. Floodproofing

Floodproofing is a feasible alternative for all three structures which are subject to basement flooding.

4. Foundation Raising

First floor elevations are already above the 100-year flood zone.

5. Flood Warning Systems

See Upper Piney Creek.

6. Acquisition

Acquisition of the two flooded houses is recommended because they are located within the floodway and experience more than one foot of flooding.

7. Stormwater Management

See Upper Piney Creek.

8. Bridge and Culvert Replacement

Freeland Road does not produce a significant backwater flooding problem.

9. Channelization

Channelization would be too costly. The side tributary would also have to be channelized to produce significant results.

10. Floodwalls

Floodwalls are not practicable.

11. Levees

Levees may be possible for Structure No. 7 on the edge of the flood zone, but floodproofing is more economical.

12. Retention/Detention Structures

Retention and detention structures are not economical.

13. Stream Relocation

There is no practical place to relocate Beetree Run.

14. Stream Enclosure

As with channelization, the side tributary would also have to be enclosed. The cost would be economically too high based on the benefits received.

F. NON-DETAILED STUDY AREAS

Other methods of analysis were employed to determine the flood elevations for structures in the non-detailed study areas. This included previous studies performed by other agencies, historical data, or approximate methods. Table 5 in Appendix B is a summary of the methods used along with the recommended improvement alternative for each structure. As with the detailed study areas, the only feasible and recommended alternatives appear either to be floodproofing or acquisition.

VIII. COST/BENEFIT ANALYSIS

To assess the economic efficiency of the recommended improvement alternatives, the cost and benefit of each alternative were computed. Benefits are felt by the reduction of flood damages and related costs. Costs are those required for construction, operation, maintenance, etc. of the alternative.

Flood damages were computed for each flooded structure. First, flood damages were computed for the 2, 10, and 100-year frequency storms. These were then plotted versus their probability of occurrence. The 2, 10, and 100-year storms have 0.50, 0.10, and 0.01 probability of occurrence. The points thus plotted formed a curve. The area under this curve was determine and is equal to the average annual flood damage. Table 4 and Table 5 list the average annual flood damage for those structures which will be flooded by 2, 10, or 100-year frequency storms.

The only cost analysis involved in this study would be in the acquisition of flooded structures. An average cost of $80,000 was used which included purchase price, relocation cost, and any other associated costs. This cost is well above the annual flood damage received by any of the flooded structures recommended for purchase. However, based on Baltimore County policy, purchase of homes will be considered where the average flood depth equals or exceeds one foot of flooding.

IX. RECOMMENDATIONS

There are only two improvement alternatives recommended in this study. They consist of either acquisition of the structure or floodproofing it. Acquisition is recommended where first floor flooding exists. A total of 23 houses fall into this group. Acquisition is also recommended where the average depth of floodwater equals or exceeds one foot based on Baltimore County policy. Seven houses are in this category. Floodproofing is recommended where only basement flooding exists and the structure is on the edge of the floodway (flood fringe). A total of 15 houses fall into this group. The remaining houses do not experience flooding from the 2, 10, or 100-year storms, although some have received historical flooding in the past from what appears to be greater than a 100-year event.

X. REFERENCES

U.S. Army Corps of Engineers, Baltimore District, Prettyboy Dam, Phase I Inspection Report, National Dam Inspection Program, Baltimore, Maryland, July 1978.

U.S. Army Corps of Engineers, Baltimore District, Loch Raven Dam, Phase I Inspection Report, National Dam Inspection Program, Baltimore, Maryland, February 1978.

Greiner Engineering, Hydrological/Hydraulic Impact Assessment of Little Falls through Parkton, State Highway Administration, April 1982.

U.S. Department of Agriculture, Soil Conservation Service, Flood Hazard Analysis, Western Run and Tributaries, Baltimore County, Maryland, College Park, Maryland, July 1975.

Wilson T. Ballard Company, Preliminary Engineering Report, Replacement of Three Bridge at White Hall, Baltimore County Department of Public Works, December 1980.

Whitman, Requardt and Associates, Flood Study, Beaverdam Run in Cockeysville, Baltimore County Department of Public Works, October 1973.

U.S. Department of the Interior, Geological Survey, Water Resources Division, A Summary of Peak Stages and Discharges in Maryland, Delaware and District of Columbia for Flood of June 1972, Open-File Report, Parkville, Maryland, 1972.

U.S. Department of the Interior, Geological Survey, Flood of August and September 1971 in Maryland and Delaware, Open-File Report, Parkville, Maryland, 1974.

U.S. Department of Agriculture, Soil Conservation Service. Guide for Selecting Roughness Coefficient 'n' Values for Channels, Technical Release No. 24, December 1963.

U.S. Department of Agriculture, Soil Conservation Service, National Engineering Handbook, Section 4, Hydrology, August 1972.

Barnes, H.H Jr., Roughness Characteristics of Natural Channels, Water Supply Paper 1849, U.S. Geological Survey, 1977.

Bonner, Vernon R., Application of the HEC-2 Bridge Routines, Training Document No. 6, U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, California, June 1974.

U.S. Department of Agriculture, Soil Conservation Service, Urban Hydrology for Watersheds, Technical Release No. 55, January 1975.

U.S. Department of Commerce, Weather Bureau, Technical Paper No. 40,

U.S. Army Corps of Engineers, Baltimore District, Cost Report on Non-Structural Flood Damage Reduction Measure for Residential Buildings within the Baltimore District, U.S. Army Institute for Water Resources, July 1977.

U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-2, Water Surface Profiles Users Manual, Davis, California, August 1979.

U.S. Department of Agriculture, Soil Conservation Service, TR-20 Project Formulation Hydrology, May 1982 Draft.

U.S. Army Corps of Engineers, Baltimore District, Flood Damage Assembly Program User's Manual, DAPROG2, March 1983.

Department of Public Works, Bureau of Engineering, Division of Storm Water Management, Howard County, Storm Drainage Design Manual, Purdum and Jeschke, October 1976.

Rainfall Data, Towson, Hereford, Fullerton, and Reisterstown Fire Stations, 1975-1979.

Baltimore County Topographic Maps, Scale 1" = 200' Reduced, 5' Contour Intervals, Maps incorporated, 1958 and 1961.

U.S. Department of the Interior, Geological Survey, 7.5 Minute Series Topographic Maps, Sale 1:24,000, Cockeysville, Edgewood, Hampstead, Hereford, Jarrettsville, Lineboro, Manchester, New Freedom, Norrisville, Phoenix, Reisterstown, Towson, White Marsh.

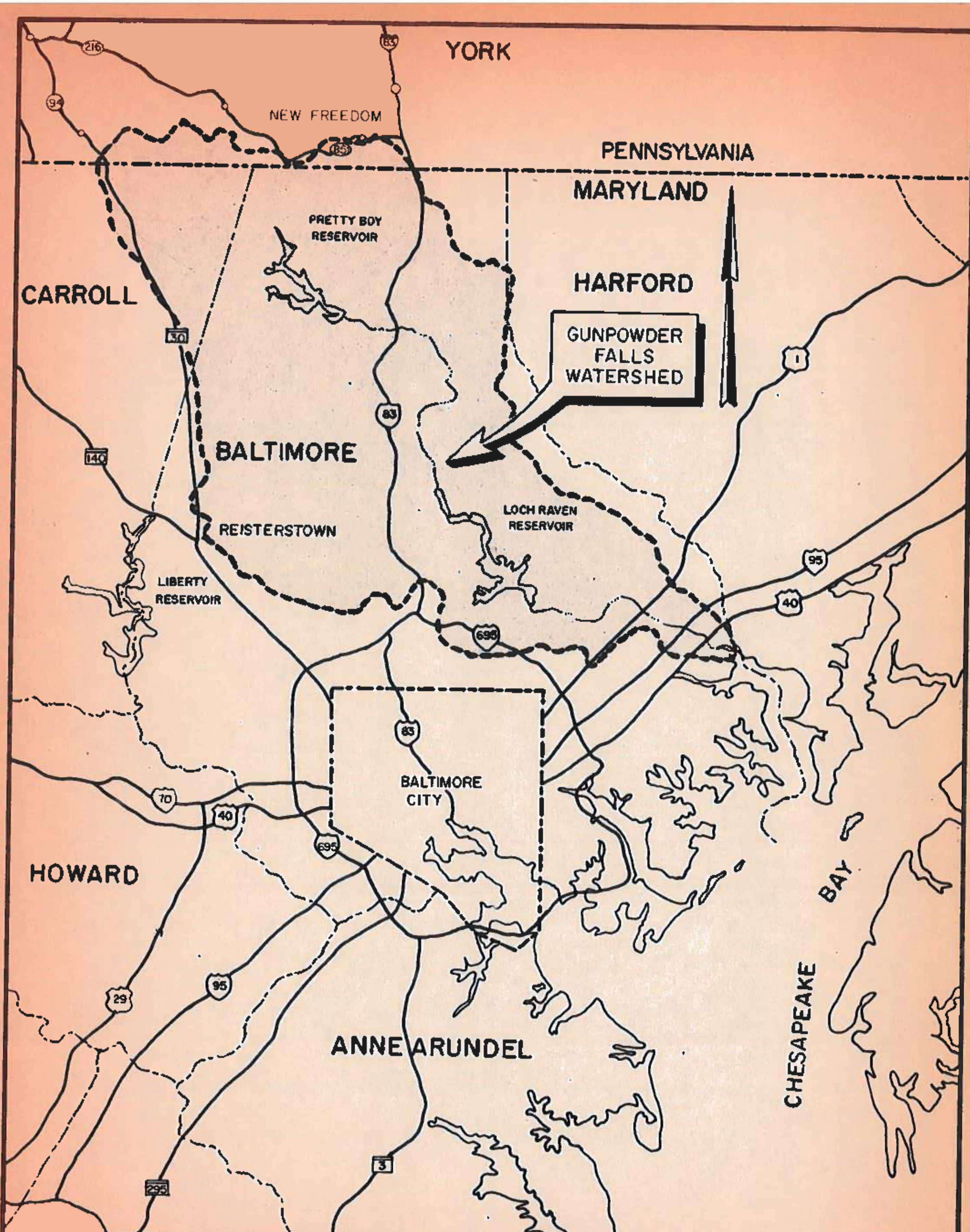
Aerial Data Reduction Associates, Inc., Aerial Photographs of Baltimore County, 1982.

Maryland Surveying and Engineering Co., Inc., Watershed Drainage Study, Spring Branch, Baltimore County Department of Public Works, October 1981.

U.S. Army Corps of Engineers, Baltimore District, Computation of Expected Annual Damage from HEC-5C, February 1981.

APPENDIX A

REPORT FIGURES



PURDUM & JESCHKE
CONSULTING ENGINEERS
1029 N. CALVERT STREET
BALTIMORE, MARYLAND 21202

GUNPOWDER FALLS WATERSHED STUDY

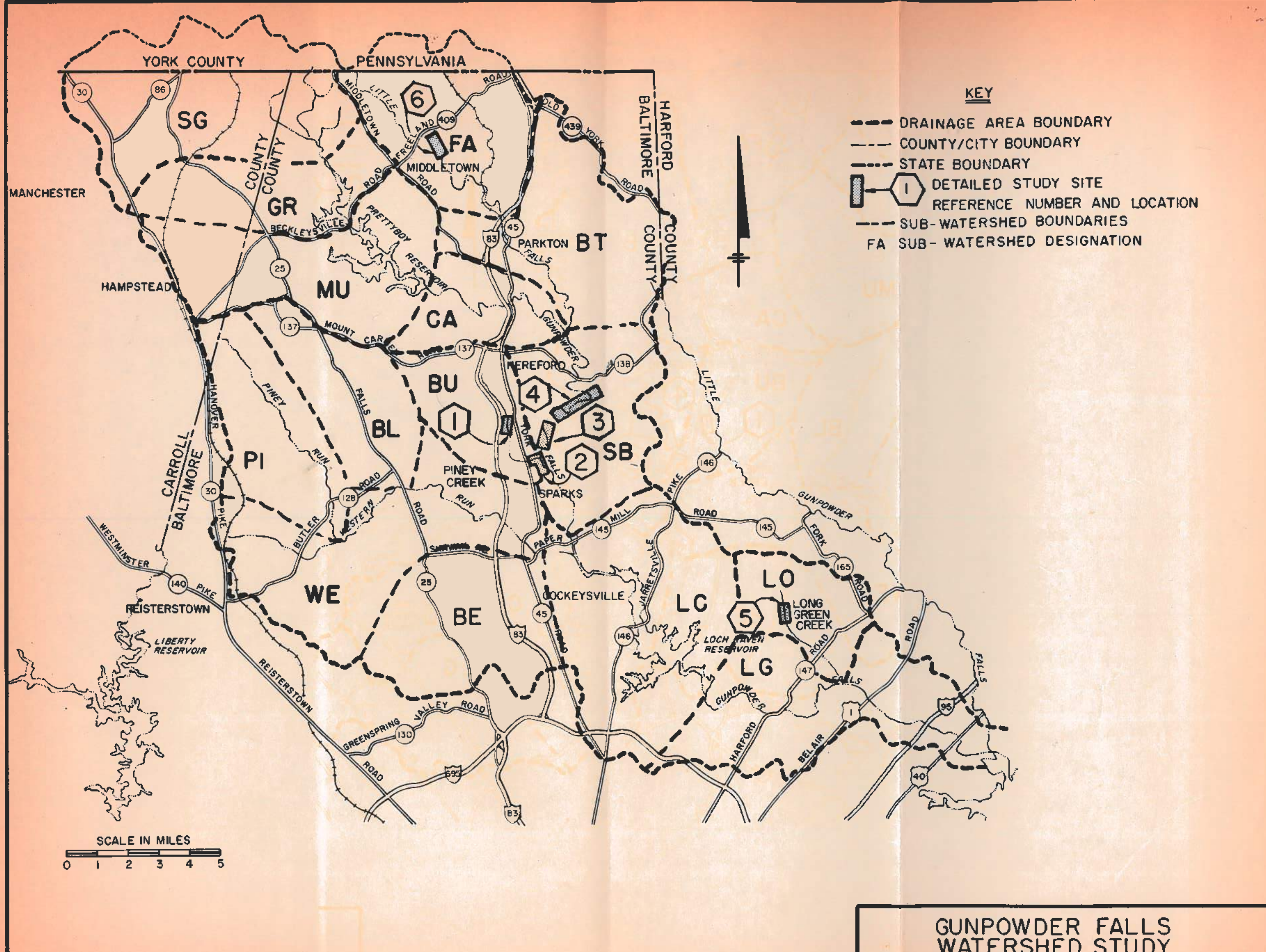
VICINITY MAP

6 3 0 6

SCALE: 1" = 6 Miles

FIGURE

1

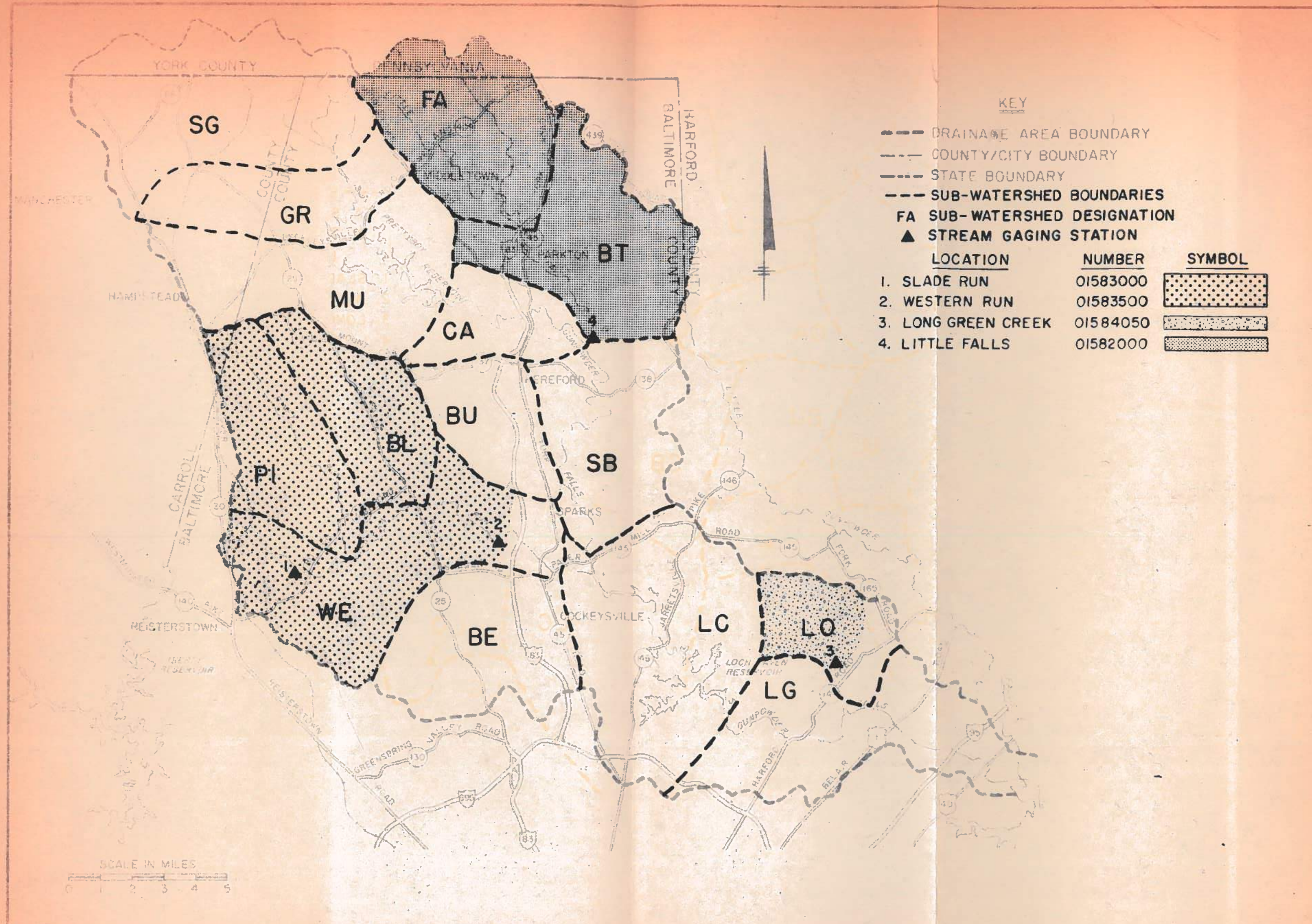


PURDUM AND JESCHKE
CONSULTING ENGINEERS
1029 N. CALVERT STREET
BALTIMORE, MARYLAND 21202

GUNPOWDER FALLS WATERSHED STUDY

TR-20 MODEL SUB-WATERSHEDS & DETAILED STUDY AREAS

FIGURE 2

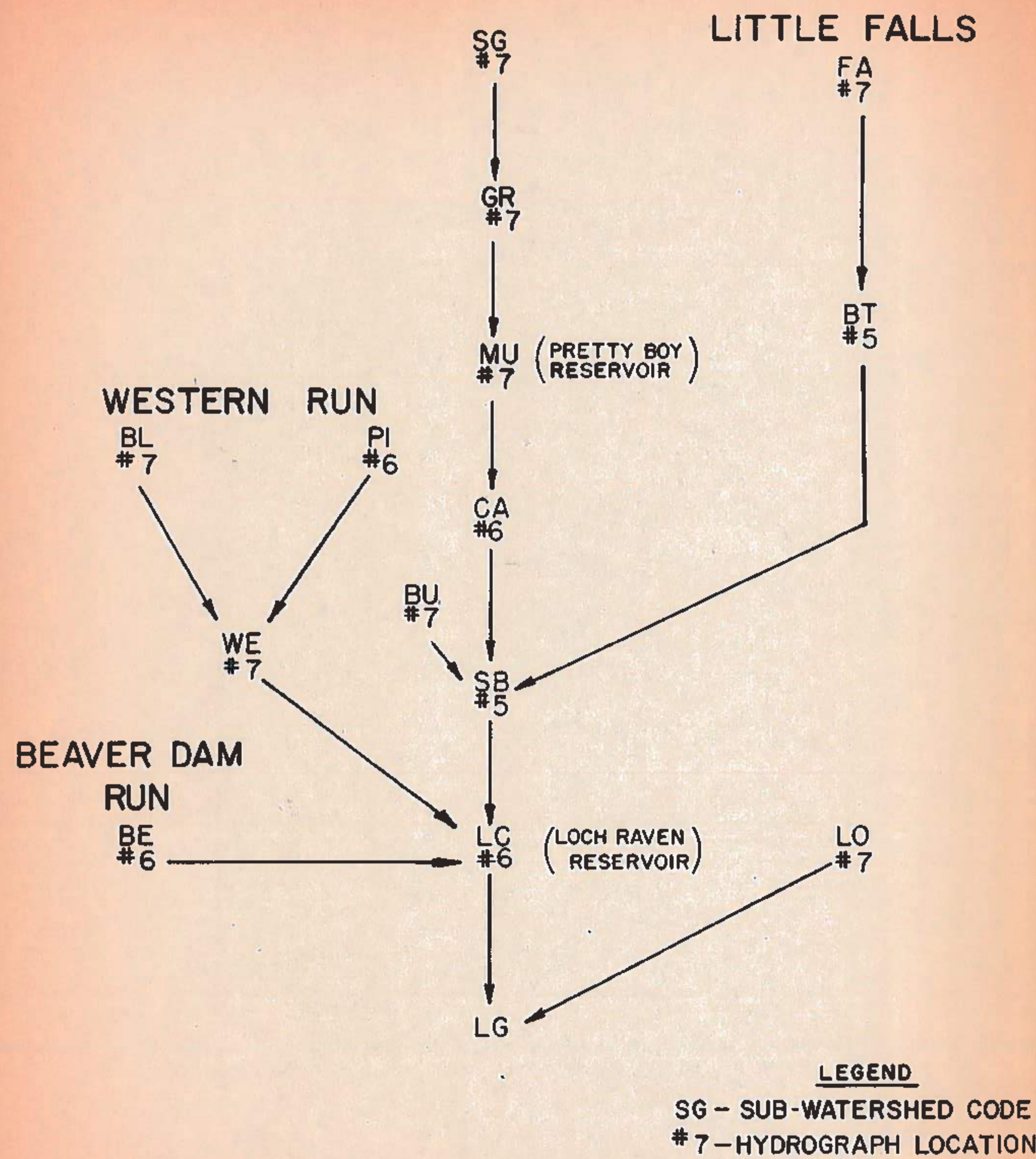


PURDUM AND JESCHKE
CONSULTING ENGINEERS
1029 N. CALVERT STREET
BALTIMORE, MARYLAND 21202

GUNPOWDER FALLS WATERSHED STUDY

GAGE DRAINAGE AREAS

FIGURE 3



PURDUM & JESCHKE
CONSULTING ENGINEERS
1029 N. CALVERT STREET
BALTIMORE, MARYLAND
21202

GUNPOWDER FALLS WATERSHED STUDY
MASTER SCHEMATIC OF WATERSHED

FIGURE 4

APPENDIX B

REPORT TABLES

Table 1

Detailed Hydraulic Study Areas

Detailed Study Site Ref. No.	Stream Name	Stream Length	Description
1	Upper Piney Creek	3,510 feet	From 500 feet below Belfast Road upstream to 250 feet above Ensor Mill Road.
2	Lower Piney Creek	6,720 feet	From the confluence with Gunpowder Falls to 1,350 feet above York Road.
3	Gunpowder Falls	9,900 feet	From 1,750 feet below the Sparks Road Bridge to 3,750 feet upstream from the Corbett Road Bridge.
4	Gunpowder Falls	15,110 feet	From 3,750 feet upstream of the Corbett Road Bridge upstream a distance of 15,110 feet.
5	Long Green Creek	2,230 feet	From 2,000 feet downstream of Long Green Road and 500 feet upstream.
6	Beetree Run (Little Falls)	6,400 feet	From 5,480 feet downstream of Freeland Road to 920 feet upstream.

Table 2

Gunpowder Falls Sub-Watersheds

Sub-watershed Designation	Sub-watershed Area (acres)	(square miles)	Sub-watershed Name
BE	13,441	21.00	Beaverdam Run
BL	9,560	14.94	Black Rock Run
BT	18,472	28.86	Beetree Run
BU	7,788	12.17	Buffalo Creek
CA	8,163	12.75	Bush Cabin Run
FA	15,821	24.72	Little Falls
GR	11,348	17.73	Grave Run
LC	24,099	37.65	Loch Raven
LG	19,962	31.19	Lower Gunpowder Falls
LO	9,181	14.35	Long Green Creek
MU	20,757	32.43	Murphy Run
PI	12,542	19.60	Piney Run
SB	14,868	22.23	Southern Beetree Run
SG	19,052	29.77	South Branch Gunpowder Falls
WE	18,559	29.00	Western Run
TOTAL	223,613	349.39	

Table 3

RCN Comparison - Previous Studies vs. GIS/LANDSAT

SCS 1973 Study Subbasin Name	Area (mi.^{2})	RCN	No. of Subbasins	GIS/LANDSAT Area (mi.^{2})	GIS/LANDSAT 1973 RCN
Piney Run					
Subbasin 8	5.38	72	20	5.374	69.1
Subbasin 12	0.53	70	1	0.545	74.5
Black Rock Run					
Subbasin 19	1.32	72	6	1.376	74.2
Subbasin 17	8.53	72	34	8.599	72.0
Beaverdam Run					
Subbasin 23	7.15	75	19	7.196	69.1
Subbasin 27	0.24	82	3	0.259	84.5
Subbasin 25	0.97	75	5	1.080	72.6
Subbasin 31	0.40	66	4	0.392	71.4
Subbasin 26	1.48	62	5	1.476	64.1

Baltimore County 1984 Parkton Study	Area (mi.^{2})	RCN	No. of Subbasins	GIS/LANDSAT Area (mi.^{2})	GIS/LANDSAT 1983 RCN
Little Falls Run					
Subbasin 1	12.55	69	24	12.478	73.7
Subbasin 2	10.10	67	22	9.936	72.0
Subbasin 3	2.55	69	6	2.549	72.0
Beetree Run					
Subbasin 4	3.52	66	12	3.620	70.5
Subbasin 6	0.06	68	1	0.075	71.2
Subbasin 5	2.54	70	9	2.461	71.8

Table 4

Detail Study Areas
Flood Mitigation Summary Analysis

Dwg No.	Stream Name	House No. on Dwg.	Data Base Number	House Address	First Floor				Basement			Recommended Improvement Alternatives	Annual Flood Damage	Comments
					Elev.	Flooded Yes	Flooded No	Depth	Yes	No	Flooded			
1	Upper Piney Creek	1	B01-03	15529 Ensor Mill Road	328.15	X		2.0		X		Purchase	$ 600	
1		2	B01-02	15531 Ensor Mill Road	329.79	X		1.5		X		Purchase	$ 400	
1		3	B01	15530 Ensor Mill Road	346.08		X		X					Out of zone
1		4	B01-01	15601 Ensor Mill Road	337.00		X		X		X	Purchase - In floodway	$ 600	
1		5	B-01	Tennis Club	343.73		X			X		Not considered under scope		Crawl space flooding
2	Lower Piney Creek	1	B03-03	15015 York Road	275.22		X		X		X	Purchase - In floodway	$ 300	
2		2	B03-02	15017 York Road	267.65	X		1.0		X		Purchase	$ 300	
2		3	B03-01	15021 York Road	277.48		X		X		X	On edge of flood zone - floodproof	$ 100	
3	Gunpowder Falls	1	B05-02	1207 Sparks Road	255.85	X		3.0		X		Not considered under scope		Old bank
3		2	B05-01	on Sparks Road	258.27	X		1.0		X		Not considered under scope		Manufacturing building
4		3	B04-03	15512 Home Road	261.70	X		1.0	X			Purchase	$ 400	
5		4	B04-02	15605 Home Road	267.37		X		X		X	Purchase	$ 200	On edge of flood zone
5		5	B04-01	15609 Home Road	264.93		X		X		X	Purchase	$ 500	On edge of flood zone
7		6	B06-01	1449 Corbett Road	280.0		X		X					Out of zone

Table 4 - Detail Study Areas - Flood Mitigation Summary Analysis (continued)

Dwg No.	Stream Name	House No. on Dwg.	Data Base Number	House Address	First Floor				Basement			Recommended Improvement Alternatives	Annual Flood Damage	Comments
					Elev.	Flooded Yes	Flooded No	Depth	Yes	No	Flooded			
8	Gunpowder Falls (cont'd)	7	B26	1717 Corbett Road	283.34		X		X					Out of zone
9		8	B26-01	1827 Corbett Road	290.19		X		X					Out of zone
9		9	B09-01	2005 Corbett Road	290.98		X		X					Out of zone
9		10	B07-04	16251 Falls Road	280.22	X		1.0		X		Purchase	$ 600	
10		11	B07-03	16339 Falls Road	290.82		X		X					Out of zone
10		12	B07-02	16351 Falls Road	284.78	X		0.5	Tri-level			Purchase	$ 300	
10		13	B07-01	16365 Falls Road	282.90	X		2.0	Semi-Basement		X	Purchase	$1400	Tri-level house. Lower level floods.
11	Long Green Creek	1	N04-01	12518 Long Green Pike	294.41		X		X		X	Purchase	$1700	
11		2	N04-02	12508 Long Green Pike	302.83		X		X					Out of zone
11		3	N11		296.22		X		X					Out of zone
11		4	N11		313.29		X		X					Out of zone
11		5	N11		302.25		X		X					Out of zone
11		6	N11		312.00		X		X					Out of zone
11		7	N11		324.07		X		X					Out of zone

Table 4 - Detail Study Areas - Flood Mitigation Summary Analysis (continued)

Dwg No.	Stream Name	House No. on Dwg.	Data Base Number	House Address	First Floor				Basement			Recommended Improvement Alternatives	Annual Flood Damage	Comments
					Elev.	Flooded Yes	Flooded No	Depth	Yes	No	Flooded			
13	Beetree Run	1	S25	Railroad Ave.	680.48		X		X					Out of zone
13		2	S25	Railroad Ave.	680.26		X		X					Out of zone
13		3	S25	21146 Railroad Ave.	680.19		X		X					Out of zone
13		4	S25	Railroad Ave.	680.58		X		X					Out of zone
13		5	S25-03	1053 Freeland Road	677.70		X		X		X	Purchase	$ 800	In floodway
13		6	S25-02	1059 Railroad Ave.	676.92		X		X		X	Purchase	$1100	In floodway
13		7	S25-01	Freeland Rd.	682.09		X		X		X	Not considered under scope		Gun shop
13		8	S25	Maple Ave.	683.67		X		X					Out of zone
13		9	S25	Maple Ave.	682.66		X		X					Out of zone
13		10	S25	Maple Ave.	682.68		X		X					Out of zone

Table 5

Flood Mitigation Summary Analysis
Non-Detailed Study Areas

Structure Report No.	Flood Elevation Determination Method	First Floor Flooded		Water Depth Above F.F. (ft.)	Basement		Recommended Improvement Alternative	Annual Flood Damage	Historical Flooding Above F.F.		Comments
		Yes	No		Yes	No			Yes	No	
B17-01	Western	X		4.0	X		Purchase	$1400	X		Tropical Storm Agnes appears to have been greater than a 100-year event in this area. In 1982, railroad, bridge, and embankment removed structures S33-04 and S33-05 reducing damage to basement damage only. 100-year flood reduced by 7 feet in this area. Commercial/industrial areas of Cockeysville still experience severe flooding.
S05-01	Run Study		X			X	Out of flood zone			X	
S05-02	plus		X			X	Out of flood zone		X		
S06-01	Baltimore		X			X	Out of flood zone		NK		
S07-01	County		X		X		Out of flood zone			X	
S09-01	Study of	X		3.0		X	Purchase	$ 600	X		
S09-02	Railroad		X		X		Out of flood zone			X	
S11-01	Bridge and		X		X		Out of flood zone			X	
S11-02	Embankment		X		X		Out of flood zone		X		
S11-03	Removal		X			X	Out of flood zone		X		
S13-01		X		2.0	X		Purchase	$4000	X		
S33-01			X		X		Out of flood zone			X	
S33-02			X			X	Out of flood zone		X		
S33-03			X			X	Out of flood zone		X		
S33-04			X		X		Purchase	$4400	X		Flood depth greater than one foot.
S33-05			X		X		Purchase	$ 600	X		Flood depth greater than one foot.
S17-01	Spring		X		X		See		X		Inadequate road culvert caused nuisance flooding. Baltimore County plans to implement construction of supplemental box culvert and channel erosion protection improvements to alleviate problems.
S17-03	Branch		X			X	Comments		NK		
S17-04	Study		X			X				X	
S17-05			X			X			NK		
S17-06			X			X			X		
S17-07			X			X			NK		
S17-08			X			X			NK		
N05-01	White		X			X	Floodproof		X		Edge of flood zone
N05-02	Hall	X		1.0		X	Purchase		X		
N05-03	Study	X		1.0	X		Purchase		X		
N06-01			X		X		Floodproof		NK		Edge of flood zone
N06-04		X				X	Purchase		NK		
N06-05		X			X		Purchase		NK		
N01-01	Historical	X		3.0	X		Purchase	$1500	X		
N01-02	Data	X		3.0	X		Purchase	$1300	NK		
B28-01	and	X		2.0		X	Purchase	$ 400	X		
S02-02	Approxi-		X			X			X		
S02-01	mate		X			X			X		
S02-06	Methods		X			X			X		
S28-01			X		X		Floodproof	$ 100	X		Edge of flood zone

NK = Not known

Table 5 - Flood Mitigation Summary Analysis - Non-Detail Study Areas

Structure Report No.	Flood Elevation Determination Method	First Floor Flooded		Water Depth Above F.F. (ft.)	Basement		Recommended Improvement Alternative	Annual Flood Damage	Historical Flooding Above F.F.		Comments
		Yes	No		Yes	No			Yes	No	
N02-01	Approximate Methods		X		X		Floodproof	$ 50	NK		Basement flooding
N02-02			X		X		Floodproof	$ 50	NK		Basement flooding
B02-02			X			X				X	Out of flood zone
B08-01			X		X		Floodproof	$ 400		X	Basement flooding
B14-01			X		X		Floodproof	$ 500	NK		Basement flooding
B18-01		X		2.0		X	Purchase	$ 900	NK		
B19-02			X		X		Floodproof	$ 50		X	Basement flooding
B25-02			X		X		Floodproof	$ 200	NK		Basement flooding
B25-03			X		X		Floodproof	$ 100		X	Basement flooding
B27-02			X		X				NK		Out of flood zone
B29-01			X		X					X	Out of flood zone
S01-01			X		X					X	Out of flood zone
S01-02			X			X			NK		Out of flood zone
S02-03		X		1.0		X	Purchase	$ 500		X	
S02-04		X		1.0		X	Purchase	$ 500	X		
S03-01			X		X				NK		Out of flood zone
S04-01			X		X					X	Out of flood zone
S10-01			X		X		Floodproof	$ 100	NK		Basement flooding
S10-02		X		2.0	X		Purchase	$ 600	NK		
S15-01			X		X		Floodproof	$ 100		X	Basement flooding
S15-02			X		X					X	Out of flood zone
S21-03			X		X		Floodproof	$ 100	X		Basement flooding
S26-01			X		X		Floodproof	$ 100	NK		Basement flooding
S32-01			X		X				NK		Out of flood zone
S32-02			X		X				NK		Out of flood zone
S32-03			X		X					X	Out of flood zone
S36-01			X			X			NK		Out of flood zone

NK = Not known

APPENDIX C

TR-20 MODELS

DRAINAGE AREA SUMMARY

DRAINAGE AREA SUMMARY

Sub-watershed BE

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	333.23	69.5	69.5	0.57
2	210.22	65.6	65.6	0.64
3	315.79	67.4	67.4	0.79
4	215.73	64.3	64.3	0.82
5	148.72	66.5	66.5	0.49
6	305.69	65.6	65.6	0.74
7	343.33	64.7	64.7	0.60
8	444.31	64.7	64.7	0.43
9	274.48	67.2	67.2	0.95
10	235.01	64.0	64.0	0.32
11	205.63	69.9	69.9	0.81
12	98.23	75.5	75.5	0.53
13	356.18	67.2	67.2	1.06
14	38.56	73.3	73.4	0.18
15	100.06	66.0	66.0	0.29
16	353.43	65.8	65.8	1.43
17	280.91	70.4	70.4	0.71
18	100.06	63.3	63.3	0.24
19	286.42	62.9	62.9	0.50
20	115.67	62.6	62.6	0.43
21	168.91	65.1	65.1	0.40
22	305.69	65.2	65.2	0.63
23	196.45	60.5	60.5	0.55
24	125.77	61.7	61.7	0.35
26	165.24	57.5	73.3	0.92
28	281.83	58.4	70.6	0.43
29	126.68	72.2	72.9	0.43
30	82.62	68.4	68.4	0.31
31	240.52	59.8	59.8	0.58
32	132.19	58.0	58.0	0.47
33	124.85	64.1	64.1	0.29
34	256.12	72.1	72.1	0.22
35	257.96	70.6	70.6	0.51
36	193.70	65.4	65.4	0.67
37	228.58	66.7	66.7	0.40
38	205.63	68.7	68.7	0.67

DRAINAGE AREA SUMMARY

Sub-watershed BE (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
39	155.14	74.3	74.4	0.69
40	68.85	69.5	69.5	0.37
41	30.29	66.0	66.0	0.34
42	47.74	72.8	73.0	0.84
45	99.14	71.8	71.9	0.32
46	135.86	61.3	61.3	0.67
47	73.44	61.2	61.2	0.47
50	200.12	73.2	74.5	1.15
51	166.16	76.1	77.0	0.38
52	61.51	77.6	88.0	0.28
53	127.60	80.8	89.4	0.44
55	132.19	84.3	89.4	0.26
57	13.77	83.2	91.0	0.11
58	176.26	81.1	90.1	0.74
59	49.57	75.3	79.3	0.27
60	47.74	64.0	72.8	0.24
61	94.55	65.8	75.0	0.32
62	58.75	58.1	70.7	0.23
63	132.19	80.0	89.7	0.71
64	42.23	84.7	90.1	0.24
65	78.95	85.4	90.3	0.39
66	40.39	82.1	91.2	0.28
67	74.36	83.9	89.7	0.33
68	47.74	68.4	76.4	0.27
69	90.88	65.3	75.1	0.20
70	55.08	58.3	70.1	0.26
71	78.95	65.9	73.5	0.42
73	27.54	80.4	88.7	0.10
74	67.93	74.9	89.9	0.31
75	44.98	81.3	90.0	0.32
76	100.06	75.8	88.6	0.26
77	341.50	89.5	91.3	0.64
78	88.13	83.5	90.7	0.23
79	46.82	84.9	90.0	0.19
80	88.13	83.5	90.8	0.36
81	30.29	78.2	86.8	0.14

DRAINAGE AREA SUMMARY

Sub-watershed BE (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
82	100.98	82.3	85.1	0.22
83	246.94	74.4	82.1	0.26
84	15.61	84.9	84.9	0.06
85	45.90	80.0	86.0	0.07
86	67.01	72.3	80.7	0.12
87	71.60	68.1	75.0	0.17
88	63.34	69.1	75.7	0.19
89	58.75	73.0	81.7	0.12
90	67.93	83.6	91.2	0.27
91	98.23	85.3	91.0	0.20
92	50.49	71.2	90.1	0.36
93	55.08	81.1	88.1	0.23
94	28.46	87.7	89.3	0.15
95	75.28	78.5	79.2	0.27
96	58.75	77.4	88.8	0.38
97	70.69	78.1	87.2	0.31
98	179.01	70.6	78.2	0.45
99	72.52	83.9	87.8	0.26
100	333.23	64.7	76.6	0.38
101	109.24	71.2	79.6	0.35
102	128.52	71.1	72.4	0.20
103	41.31	73.0	77.8	0.22
104	112.00	76.2	78.4	1.09
105	173.50	72.5	78.1	0.20
106	47.74	71.8	88.0	0.18
	Weighted	69.7	72.7	

DRAINAGE AREA SUMMARY

Sub-watershed BL

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	61.51	71.7	71.7	0.20
2	347.92	65.4	65.4	0.24
3	41.31	69.3	69.3	0.18
4	238.68	69.5	69.6	0.32
5	384.64	67.8	67.8	0.44
6	261.63	65.7	65.7	0.37
7	152.39	63.6	63.6	0.32
8	97.31	72.9	72.9	0.20
9	119.34	70.4	70.4	0.16
10	65.18	66.1	66.1	0.16
11	210.22	65.7	65.7	0.30
12	319.46	70.3	70.3	0.46
13	292.84	65.0	65.0	0.36
14	180.85	67.9	67.9	0.35
15	288.25	65.3	65.3	0.54
16	458.08	67.8	67.8	0.61
17	104.65	73.6	73.6	0.22
18	130.36	71.1	71.1	0.22
19	260.71	69.3	69.3	0.48
20	28.46	74.7	74.7	0.14
21	58.75	71.1	71.1	0.12
22	68.85	71.4	71.4	0.20
23	106.49	65.9	65.9	0.39
24	150.55	69.4	69.4	0.30
25	65.18	73.0	73.0	0.30
26	215.73	70.1	70.1	0.41
27	116.59	71.4	71.4	0.38
28	37.64	66.0	66.0	0.16
29	117.50	70.8	70.8	0.23
30	226.75	70.0	70.0	0.23
31	255.20	68.4	68.8	0.28
32	137.70	72.9	72.9	0.42
33	167.08	71.7	71.8	0.41
34	76.19	70.7	70.7	0.21
35	106.49	68.1	68.1	0.34
36	64.26	61.9	61.9	0.10

DRAINAGE AREA SUMMARY

Sub-watershed BL (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
37	110.16	60.7	60.7	0.21
38	151.47	69.8	69.8	0.22
39	206.55	70.9	71.9	0.35
40	51.41	71.8	71.9	0.07
41	264.38	70.7	70.8	0.35
42	89.05	65.3	65.3	0.26
43	140.45	72.1	72.1	0.26
44	212.98	68.8	68.8	0.17
45	100.06	68.4	68.4	0.17
46	166.16	69.8	69.8	0.21
47	188.19	68.0	68.0	0.34
48	142.29	70.7	70.7	0.26
49	221.24	70.3	70.3	0.28
50	128.52	69.1	69.1	0.16
51	49.57	67.5	67.5	0.19
52	69.77	70.3	70.3	0.42
53	211.14	73.5	73.6	0.36
54	179.93	72.6	72.6	0.49
55	120.26	72.6	72.6	0.19
56	56.92	71.2	71.3	0.16
57	134.95	72.6	72.6	0.33
58	96.39	72.4	72.4	0.26
59	103.73	76.2	76.4	0.25
60	114.75	69.7	69.8	0.21
61	235.01	70.8	70.8	0.34
	Weighted	69.1	69.1	

DRAINAGE AREA SUMMARY

Sub-watershed BT

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	192.78	68.3	68.7	0.34
2	273.56	64.6	64.6	0.59
3	154.22	65.0	65.0	0.55
4	239.60	68.8	68.8	0.41
5	160.65	67.7	67.8	0.77
6	179.93	68.3	69.1	0.49
7	163.40	67.4	67.4	0.53
8	281.83	70.3	70.4	0.50
9	128.52	66.8	66.8	0.32
10	174.42	63.8	63.8	0.63
11	149.63	64.6	64.6	0.32
12	258.88	68.4	68.4	0.39
13	197.37	65.9	65.9	0.53
14	168.91	68.2	68.2	0.48
15	159.73	68.1	68.1	0.47
16	167.99	70.4	70.4	0.32
17	268.97	69.7	69.7	0.49
18	235.93	68.7	68.7	0.62
19	300.19	70.5	70.5	0.54
20	275.40	67.4	67.4	0.40
21	498.47	67.2	67.6	0.50
22	333.23	73.2	73.3	0.47
23	109.24	70.3	70.3	0.44
25	408.51	71.0	71.0	0.53
26	112.00	69.8	69.8	0.56
27	387.40	70.5	70.5	0.72
28	128.52	72.8	72.9	0.38
29	184.52	73.7	73.7	0.31
30	151.47	68.1	68.1	0.31
31	231.34	65.2	65.4	0.31
32	182.68	67.4	68.8	0.45
33	264.38	68.1	68.1	0.33
34	43.15	68.7	68.7	0.12
35	223.07	69.0	69.2	0.40
36	197.37	64.2	64.2	0.39
37	272.65	66.2	66.2	0.60

DRAINAGE AREA SUMMARY

Sub-watershed BT (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
38	316.71	70.8	70.8	0.35
39	270.81	68.5	68.5	0.53
40	223.99	63.5	63.5	0.42
41	182.68	67.1	67.1	0.54
42	336.91	68.8	68.8	0.45
43	420.44	69.5	69.5	0.69
44	102.82	69.4	69.4	0.32
45	357.10	64.9	64.9	0.65
46	103.73	71.3	71.3	0.40
48	165.24	68.1	68.1	0.53
49	257.04	67.8	67.8	0.28
50	174.42	67.4	67.4	0.36
51	412.18	67.6	67.6	0.83
52	196.45	70.0	70.0	0.34
53	214.81	66.4	66.4	0.47
54	137.70	72.9	75.0	0.66
55	97.31	67.9	67.9	0.38
56	47.74	67.8	70.1	0.31
57	17.44	72.6	79.1	0.24
58	143.21	63.5	63.5	0.38
59	291.01	67.0	67.0	0.31
60	282.74	68.9	68.9	0.50
61	216.65	64.7	64.7	0.34
62	369.95	65.6	65.6	0.70
63	139.54	66.0	66.0	0.29
64	159.73	62.2	62.2	0.43
65	289.17	63.9	63.9	0.45
66	246.94	69.9	70.2	0.44
67	235.93	65.3	65.3	0.26
68	160.65	66.8	66.8	0.38
69	100.98	68.3	68.3	0.40
70	86.29	64.0	64.0	0.37
71	343.33	65.2	65.2	0.63
72	109.24	67.9	69.6	0.25
73	170.75	67.4	67.4	0.77
74	185.44	68.5	70.5	0.52

DRAINAGE AREA SUMMARY

Sub-watershed BT (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
75	190.03	66.3	66.3	0.69
76	309.37	64.0	64.0	0.43
77	328.64	60.2	60.2	0.40
78	226.75	68.4	68.4	0.51
79	234.09	63.4	63.4	0.35
80	423.09	67.8	67.8	0.56
81	273.56	63.0	63.0	0.37
82	187.27	66.8	66.8	0.50
83	84.46	67.8	67.8	0.24
84	135.86	67.3	67.3	0.40
85	63.34	67.7	67.7	0.34
86	120.26	70.1	73.8	0.34
87	94.55	70.8	70.9	0.25
88	96.39	72.1	72.1	0.35
89	111.08	69.6	69.6	0.29
90	110.16	73.1	73.5	0.34
91	56.00	68.7	68.7	0.21
	Weighted	67.6	67.6	

DRAINAGE AREA SUMMARY

Sub-watershed BU

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	380.05	70.5	70.5	0.39
2	351.59	67.1	67.1	0.53
3	201.96	63.5	63.5	0.52
4	180.85	68.9	68.9	0.53
5	107.41	68.8	68.9	0.25
6	137.70	63.1	63.1	0.50
7	294.68	70.4	70.4	0.44
8	404.84	70.7	70.7	0.42
9	197.37	65.3	65.3	0.42
10	276.32	70.8	70.9	0.30
11	323.14	68.1	68.1	0.65
12	124.85	71.9	72.0	0.27
13	229.50	70.9	71.0	0.32
14	231.34	68.3	68.7	0.31
15	233.17	62.9	62.9	0.65
16	102.82	67.2	67.2	0.27
17	255.83	65.9	67.4	0.30
18	231.34	66.1	66.8	0.22
19	78.95	64.2	64.3	0.23
20	104.65	67.1	67.1	0.34
21	173.50	72.6	73.8	0.55
22	364.45	70.2	70.2	0.38
23	164.32	71.2	71.3	0.18
24	94.55	70.6	70.6	0.21
25	122.09	71.8	71.8	0.21
26	301.10	70.0	70.0	0.40
27	123.01	66.3	66.3	0.59
28	127.60	69.1	70.0	0.80
29	138.62	69.7	70.2	0.25
30	194.62	72.5	72.5	0.37
31	299.27	66.3	71.8	0.26
32	105.57	71.9	72.0	0.26
33	108.32	71.7	71.7	0.5
34	33.05	75.4	75.4	0.33
35	258.88	66.3	66.3	0.53
36	30.29	68.0	68.0	0.17

DRAINAGE AREA SUMMARY

Sub-watershed BU (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
37	71.60	70.3	70.3	0.18
38	78.03	73.0	73.1	0.16
39	285.50	69.2	69.2	0.28
40	295.60	69.9	69.9	0.37
	Weighted	68.8	69.1	

DRAINAGE AREA SUMMARY

Sub-watershed CA

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	173.50	69.3	69.3	0.32
2	229.50	68.9	68.9	0.36
3	318.55	70.0	70.0	0.35
4	309.37	61.9	61.9	0.38
5	167.99	61.2	61.2	0.38
6	337.82	67.8	67.8	0.37
7	137.70	53.8	53.8	0.21
8	289.17	58.6	58.6	0.61
9	253.37	62.8	62.8	0.53
10	172.58	65.2	65.2	0.67
11	97.31	59.9	59.9	0.50
12	394.74	67.4	67.8	0.34
13	131.27	65.9	65.9	0.24
14	93.64	68.8	68.8	0.34
15	257.04	64.3	64.3	0.91
16	116.59	67.2	67.2	0.41
17	371.79	66.1	66.1	0.67
18	154.22	59.9	59.9	0.56
19	71.60	61.8	61.8	0.27
20	199.21	61.4	61.4	0.51
23	108.32	71.0	71.0	0.17
24	167.08	66.9	66.9	0.41
25	242.35	65.8	65.8	0.53
26	202.88	65.4	65.4	0.29
27	33.97	75.7	75.7	0.20
28	272.65	66.6	66.6	0.33
29	376.38	68.1	68.8	0.35
30	402.08	64.5	64.5	0.38
31	225.83	67.1	67.1	0.36
32	285.50	66.4	66.4	0.17
33	162.49	70.7	70.7	0.27
34	297.43	66.4	66.4	0.40
35	258.88	65.0	65.0	0.57
36	100.98	68.3	68.3	0.56
37	167.08	69.3	70.5	0.36
38	214.81	61.6	61.6	0.41

DRAINAGE AREA SUMMARY

Sub-watershed CA (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
39	178.09	59.5	59.5	0.55
40	189.11	67.3	67.3	0.34
	Weighted	65.4	65.4	

DRAINAGE AREA SUMMARY

Sub-watershed FA

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	156.98	70.8	71.0	0.38
2	319.46	70.7	70.7	0.36
3	481.95	63.6	63.6	0.75
4	231.34	67.7	67.7	0.61
5	304.78	68.0	68.0	0.80
6	428.71	66.7	66.7	0.93
7	444.31	68.7	68.7	0.57
8	243.27	65.2	65.2	0.32
9	136.78	64.2	64.2	0.53
10	515.92	64.8	64.8	0.59
11	233.17	63.3	63.3	0.60
12	169.83	60.9	60.9	0.71
13	346.09	70.1	70.1	0.54
14	297.43	64.6	64.6	0.81
15	369.95	67.0	67.0	0.41
16	139.54	64.8	64.8	0.54
17	323.14	72.9	73.0	0.59
18	261.63	70.8	70.8	0.43
19	343.33	69.0	69.2	0.59
20	443.39	68.3	68.3	0.50
21	340.58	65.4	65.6	1.26
22	321.30	66.5	66.5	0.47
23	313.96	69.4	69.7	0.38
24	289.17	71.0	73.8	0.52
25	243.27	66.7	66.7	1.18
26	313.96	71.3	71.4	0.65
27	392.90	70.4	70.4	0.86
28	380.05	69.5	69.5	0.62
29	535.19	69.7	69.7	0.81
30	218.48	72.1	72.1	0.34
31	222.16	67.0	67.0	0.84
32	494.80	67.4	67.4	0.81
33	446.15	73.3	73.4	0.77
34	537.95	71.6	71.6	0.63
35	193.70	69.0	69.0	0.46
36	351.59	66.4	66.4	0.54

DRAINAGE AREA SUMMARY

Sub-watershed FA (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
37	488.38	69.3	69.3	0.89
38	352.51	69.5	69.5	0.41
39	563.65	72.3	72.4	0.71
40	240.52	70.6	70.6	0.46
41	323.14	69.3	69.3	0.55
42	245.11	70.0	70.0	0.37
43	232.25	69.6	69.6	0.45
44	388.31	65.8	65.8	0.43
45	417.69	67.5	67.5	0.72
46	293.76	72.9	73.0	0.54
47	83.54	71.0	71.0	0.58
48	75.28	61.2	61.2	0.34
49	126.68	62.0	62.0	0.44
50	74.36	65.0	65.0	0.38
51	129.44	67.3	67.3	0.50
	Weighted	68.5	68.5	

DRAINAGE AREA SUMMARY

Sub-watershed GR

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	372.71	60.0	62.6	0.38
2	279.07	70.5	71.9	0.30
3	114.75	56.2	56.2	0.20
4	201.96	60.1	60.1	0.60
5	239.60	60.5	60.5	0.33
6	91.80	59.7	59.7	0.33
7	193.70	70.3	70.3	0.39
8	126.68	60.7	60.7	0.44
9	197.37	71.9	71.9	0.30
10	244.19	63.8	63.8	0.37
11	363.53	64.2	64.2	0.42
12	164.32	71.8	71.8	0.38
13	235.01	72.8	72.8	0.44
14	220.32	70.7	71.2	0.41
15	120.26	59.5	59.5	0.36
16	29.38	57.0	57.0	0.35
17	226.75	65.1	65.1	0.46
18	184.52	55.3	55.3	0.34
19	123.93	66.6	66.6	0.73
20	29.38	69.9	69.9	0.27
21	176.26	59.5	59.5	0.28
22	117.50	66.3	66.3	0.37
23	231.34	62.3	62.3	0.28
24	341.50	63.6	63.6	0.46
25	185.44	64.6	64.6	0.41
26	122.09	68.4	68.4	0.28
27	361.69	57.7	57.7	0.40
28	269.89	62.2	62.2	0.64
29	413.10	65.6	65.6	0.44
30	229.50	67.5	67.5	0.39
31	152.39	66.6	66.6	0.50
32	110.16	57.5	57.5	0.45
33	190.03	55.0	56.1	0.28
34	103.73	58.0	58.4	0.18
35	90.88	58.2	66.8	0.09
36	158.81	68.3	68.9	0.15

DRAINAGE AREA SUMMARY

Sub-watershed GR (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
37	86.29	73.5	77.8	0.30
38	174.42	62.2	70.4	0.16
39	125.77	67.9	74.2	0.14
40	299.27	61.6	61.6	0.43
41	150.55	57.0	57.0	0.31
42	217.57	66.3	66.3	0.30
43	290.09	66.5	68.3	0.28
44	142.29	61.3	63.3	0.22
45	56.00	78.9	82.2	0.30
46	62.42	86.2	89.2	0.11
47	80.78	59.1	66.2	0.09
48	201.04	78.6	79.0	0.18
49	156.98	54.8	54.8	0.35
50	211.14	52.8	52.8	0.30
51	335.99	60.5	60.5	0.40
52	338.74	67.2	67.2	0.38
53	201.04	60.4	60.4	0.38
54	338.74	69.1	69.1	0.39
55	343.33	65.5	65.5	0.36
56	223.07	67.2	67.2	0.38
57	299.27	58.8	58.8	0.43
	Weighted	64.0	64.6	

DRAINAGE AREA SUMMARY

Sub-watershed LC

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	404.84	72.2	79.1	0.57
2	89.96	67.8	74.7	0.19
3	202.88	61.4	66.3	0.23
4	183.60	65.0	66.5	0.20
5	228.58	64.0	68.3	0.30
6	257.04	63.0	68.7	0.34
7	207.47	69.2	69.2	0.60
8	158.81	68.9	73.4	0.18
9	205.63	65.9	75.7	0.37
10	309.37	55.0	67.7	0.63
11	364.45	66.4	68.5	0.69
12	189.11	69.2	72.7	0.44
13	57.83	67.8	69.9	0.55
14	85.37	61.8	71.1	0.16
15	206.55	63.8	70.2	0.21
16	208.39	61.4	68.3	0.29
17	99.14	69.5	73.9	0.17
18	179.01	68.7	68.7	0.36
19	99.14	87.3	87.5	0.33
20	350.02	70.5	76.4	0.59
21	212.14	59.1	66.2	0.53
22	476.44	80.5	83.1	0.65
23	200.12	68.5	70.8	0.56
24	419.53	72.5	75.4	0.54
25	50.49	65.0	65.0	0.47
26	67.93	63.4	63.4	0.45
27	22.95	68.8	70.2	0.07
28	328.64	65.8	68.0	0.47
29	407.59	56.7	66.6	0.52
30	302.02	70.6	74.4	0.32
31	394.74	71.1	74.9	0.33
32	227.66	67.0	70.6	0.26
33	239.60	66.0	67.0	0.39
34	643.52	88.1	90.6	0.30
36	239.60	78.2	78.4	0.64
37	249.70	64.5	64.8	0.52

DRAINAGE AREA SUMMARY

Sub-watershed LC (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
38	184.52	69.0	69.5	0.45
39	355.27	72.5	73.2	0.53
40	304.78	72.2	77.6	0.38
42	90.88	64.0	64.0	0.38
43	269.89	70.2	71.2	0.61
44	212.98	83.9	86.9	0.31
45	104.65	81.5	87.4	0.48
46	169.83	66.1	66.4	0.45
47	123.01	71.4	71.5	0.47
48	335.07	75.3	78.9	0.28
49	391.07	67.2	73.6	0.72
50	102.82	73.7	75.2	0.19
51	220.32	75.9	78.3	0.60
52	211.14	72.2	74.0	0.64
53	219.40	70.4	70.5	0.47
54	386.48	73.9	79.9	0.37
55	345.17	82.8	82.8	0.39
56	321.30	64.9	64.9	0.68
57	342.41	68.9	68.9	0.29
58	197.37	63.2	63.2	0.63
59	366.28	61.5	61.5	0.54
60	207.47	67.2	67.2	0.48
61	417.69	67.8	67.8	0.53
62	394.74	65.7	65.7	0.30
63	333.23	65.0	65.0	0.34
64	461.77	70.2	70.2	0.41
65	272.65	68.5	68.5	0.64
66	169.83	78.3	79.5	0.66
67	173.50	72.2	74.6	0.64
68	298.35	67.9	70.1	0.67
69	183.60	67.3	69.6	0.59
70	262.55	63.5	63.6	0.65
71	310.28	67.8	69.1	0.83
72	134.95	77.6	79.7	0.68
73	412.18	67.7	67.7	0.36
74	247.86	60.1	60.1	0.53

DRAINAGE AREA SUMMARY

Sub-watershed LC (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
75	376.38	70.7	71.9	0.56
76	616.90	64.6	64.8	0.69
77	131.27	67.7	67.7	0.39
78	113.83	70.2	70.2	0.31
79	213.89	66.3	66.3	0.34
80	237.76	68.7	68.7	0.30
81	309.37	67.4	67.4	0.31
82	242.35	66.7	66.7	0.39
83	299.27	67.5	72.3	0.62
84	121.18	69.3	73.5	0.60
86	414.94	64.6	64.6	0.38
87	289.17	62.1	62.1	0.33
88	362.61	64.3	66.4	0.41
89	195.53	67.2	67.2	0.33
90	353.43	66.5	66.5	0.31
91	85.37	69.9	69.9	0.14
92	308.45	67.7	67.7	0.26
93	257.96	64.5	64.5	0.30
94	360.77	68.7	68.7	0.43
95	369.95	69.2	69.2	0.40
97	179.01	62.8	62.8	0.46
98	202.88	74.9	78.3	0.64
	Weighted	68.8	71.0	

DRAINAGE AREA SUMMARY

Sub-watershed LG

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	244.19	72.6	75.8	0.41
2	453.49	68.8	73.8	0.42
3	117.50	70.8	71.4	0.49
4	227.66	65.8	71.5	0.37
5	340.58	65.6	69.2	0.48
6	167.08	69.7	70.1	0.20
7	68.85	73.5	85.8	0.10
8	147.80	82.5	85.6	0.33
9	216.65	77.5	82.0	0.18
10	237.76	61.8	71.9	0.43
11	314.87	82.0	86.3	0.32
12	223.99	72.4	77.9	0.44
13	426.87	67.2	72.7	0.62
14	416.77	72.8	81.3	0.52
15	212.98	63.3	77.6	0.40
16	250.61	63.5	71.3	0.51
17	349.76	68.7	75.3	0.31
18	406.67	67.7	73.1	0.36
19	315.79	64.4	78.7	0.36
20	65.18	75.0	77.5	0.29
21	102.82	70.1	70.8	0.24
22	134.03	66.9	67.4	0.30
23	421.36	68.5	70.2	0.60
24	144.13	74.5	76.1	0.37
25	445.23	70.5	70.5	0.52
26	323.14	62.7	62.7	0.41
27	300.19	67.0	67.0	0.36
28	346.09	70.1	70.1	0.58
29	265.30	68.2	68.1	0.49
30	262.55	67.8	67.8	0.52
33	689.42	72.1	74.2	0.89
34	187.27	73.9	77.8	0.30
35	289.17	73.5	81.2	0.73

DRAINAGE AREA SUMMARY

Sub-watershed LG (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
36	189.11	77.0	82.1	0.24
37	155.14	78.3	82.9	0.35
38	358.02	74.3	80.4	0.50
39	140.45	70.5	76.2	0.32
40	217.57	75.4	81.0	0.23
41	150.55	66.2	71.6	0.22
42	191.86	74.8	82.7	0.55
43	521.42	71.1	71.2	0.54
44	615.98	67.0	67.0	0.42
45	593.03	73.1	73.1	0.65
46	634.34	70.6	70.7	0.72
49	204.71	74.2	77.8	0.61
50	313.96	73.1	74.9	0.40
51	153.31	73.8	82.4	0.32
52	211.14	69.0	69.5	0.36
53	442.48	69.6	69.6	0.46
54	463.59	74.7	74.8	0.51
55	365.36	71.1	71.1	0.47
56	255.20	72.0	74.7	0.56
57	156.98	76.1	80.2	0.35
59	132.19	70.5	70.5	0.33
60	411.26	73.5	73.5	0.45
61	118.42	77.2	79.3	0.26
62	246.94	75.3	77.1	0.79
63	375.46	77.9	80.6	0.57
64	94.55	75.4	79.9	0.23
65	126.68	78.7	79.8	0.31
66	582.01	69.7	69.7	0.86
67	112.91	77.6	77.7	0.28
68	58.75	77.8	78.7	0.40
69	280.91	72.8	82.0	0.41
70	94.55	68.7	68.7	0.28
71	250.61	64.7	66.7	0.29

DRAINAGE AREA SUMMARY

Sub-watershed LG (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
72	151.47	72.2	75.2	0.47
73	171.67	75.4	81.6	0.57
74	224.91	73.6	79.8	0.71
75	279.07	79.2	83.1	0.42
76	199.21	79.2	79.2	1.06
77	239.60	74.8	74.8	0.64
78	360.77	68.8	68.8	0.33
	Weighted	71.2	74.2	

DRAINAGE AREA SUMMARY

Sub-watershed LO

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	201.96	62.6	62.6	0.45
2	145.04	68.8	68.9	0.72
3	90.88	60.7	60.7	0.72
4	112.91	66.1	66.1	0.39
5	218.48	70.9	70.9	0.35
6	138.62	68.0	68.0	0.27
7	231.34	70.7	70.8	0.41
8	167.08	76.0	76.0	0.33
9	143.21	76.7	76.7	0.95
10	223.99	70.6	70.6	0.49
11	102.82	62.2	62.2	0.32
12	196.45	64.6	64.6	0.36
13	227.66	72.7	72.9	0.57
14	264.38	71.8	73.5	0.60
15	99.14	80.1	83.4	0.40
16	220.32	68.9	72.4	0.39
17	313.96	65.4	65.4	0.51
18	193.70	68.7	68.8	0.63
19	112.00	66.1	66.1	0.46
20	119.34	69.5	69.5	0.55
21	379.13	69.6	69.6	0.76
22	117.50	66.7	66.7	0.38
23	106.49	67.0	67.0	0.21
24	358.02	65.7	65.7	0.54
25	191.86	64.2	64.3	0.64
26	53.24	66.1	66.1	0.16
27	85.37	67.9	67.9	0.32
28	111.08	66.0	66.0	0.24
29	65.18	75.5	75.5	0.27
30	144.13	76.6	76.8	0.45
31	186.35	72.1	72.2	0.39
32	93.64	72.2	72.3	0.48
33	90.88	72.2	72.2	0.73
34	113.83	78.7	78.7	0.29
35	182.68	82.8	83.1	0.38
36	84.46	79.9	80.0	0.48

DRAINAGE AREA SUMMARY

Sub-watershed LO (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
38	447.98	66.8	66.8	0.53
39	98.23	72.0	72.0	0.21
40	83.54	65.4	65.4	0.20
41	93.64	63.5	63.5	0.24
42	128.52	68.8	68.8	0.35
43	133.11	70.6	70.6	0.32
44	290.09	72.6	72.6	0.42
45	299.27	69.3	69.3	0.27
46	109.24	67.0	67.0	0.36
47	302.94	69.3	69.3	0.34
48	200.12	72.0	72.0	0.43
49	357.10	75.2	75.3	0.49
50	96.39	69.8	69.8	0.24
51	211.14	71.6	71.6	0.37
52	399.33	68.7	68.7	0.52
53	43.15	65.1	65.1	0.11
	Weighted	69.8	70.0	

DRAINAGE AREA SUMMARY

Sub-watershed MU

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	343.33	71.0	71.0	0.33
2	342.41	69.0	69.0	0.43
3	243.27	69.4	69.4	0.46
4	293.76	72.0	72.0	0.38
5	335.99	70.8	70.8	0.41
6	458.08	72.5	72.7	0.40
7	173.50	66.1	70.0	0.27
8	176.26	72.2	74.3	0.31
9	132.19	69.7	70.7	0.26
10	224.91	66.1	66.1	0.32
11	70.69	60.5	60.5	0.20
12	378.22	66.3	66.3	0.44
13	237.76	68.0	68.0	0.43
14	170.75	65.5	65.5	0.40
15	127.60	69.7	69.7	0.27
16	164.32	68.3	68.3	0.30
17	211.14	71.1	71.5	0.20
18	213.89	70.6	71.8	0.34
19	466.34	68.5	71.5	0.41
20	144.13	67.7	68.0	0.14
21	116.59	69.9	70.6	0.31
22	371.79	69.3	76.9	0.38
23	42.23	68.5	73.3	0.26
24	183.60	69.8	69.8	0.42
25	116.59	64.0	64.0	0.25
27	158.81	66.6	66.6	0.37
28	159.73	64.2	64.2	0.39
29	26.62	68.6	68.6	0.12
30	231.34	71.6	71.6	0.23
31	666.47	61.7	62.2	0.35
32	155.14	62.3	62.3	0.32
33	155.14	69.6	69.6	0.47
34	183.60	53.8	53.8	0.18
35	298.35	67.5	68.9	0.15
36	182.68	65.1	65.8	0.25
37	183.60	72.9	73.0	0.36

DRAINAGE AREA SUMMARY

Sub-watershed MU (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
38	93.64	70.3	70.3	0.31
39	165.24	73.7	73.7	0.33
40	381.89	69.1	69.1	0.35
41	442.42	74.0	81.6	0.48
42	444.31	71.0	76.3	0.62
43	392.90	70.3	74.9	0.34
44	202.88	64.4	66.0	0.50
45	307.53	66.4	68.2	0.31
46	95.47	67.3	67.4	0.26
47	277.24	65.7	65.8	0.29
48	177.17	62.5	62.5	0.51
49	183.60	59.3	59.3	0.30
50	206.55	69.3	69.3	0.37
51	73.44	70.5	70.5	0.29
52	219.40	65.8	65.8	0.33
53	109.24	77.3	77.4	0.29
54	149.63	70.9	70.9	0.14
55	531.52	65.5	65.5	0.43
56	190.94	69.8	69.8	0.27
57	52.33	67.3	67.4	0.09
58	53.24	52.7	52.7	0.13
59	139.54	56.6	60.0	0.13
60	255.20	57.2	59.9	0.16
61	142.29	52.3	52.6	0.18
62	201.04	60.4	60.9	0.28
63	178.09	57.5	66.9	0.18
64	88.13	50.6	50.6	0.17
65	477.36	68.3	68.3	0.62
66	233.17	60.7	63.3	0.24
67	175.34	71.5	71.6	0.33
73	179.01	68.3	68.8	0.25
74	246.94	59.5	59.5	0.10
75	141.37	69.0	70.2	0.16
76	67.93	70.0	70.0	0.18
77	235.93	70.2	70.2	0.39
78	389.23	69.0	69.2	0.31

DRAINAGE AREA SUMMARY

Sub-watershed MU (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
79	226.75	61.5	61.5	0.29
80	367.20	60.8	60.8	0.54
81	156.98	65.5	65.5	0.36
82	563.65	68.0	68.0	0.35
83	275.40	66.4	66.7	0.27
84	249.70	64.3	65.4	0.33
85	222.16	61.2	61.2	0.31
86	110.16	66.0	67.1	0.29
87	179.93	63.7	67.9	0.13
88	79.88	53.2	55.9	0.25
89	126.68	65.7	65.7	0.40
90	237.76	73.8	75.1	0.29
91	213.89	75.4	80.1	0.26
92	167.08	79.7	86.1	0.14
93	166.16	75.8	77.0	0.16
94	227.66	69.8	72.2	0.27
95	246.94	73.1	77.1	0.23
96	276.32	59.6	59.6	0.31
97	244.19	64.7	65.0	0.41
98	167.99	75.8	79.6	0.22
99	62.42	53.4	53.9	0.11
100	145.96	63.8	66.4	0.19
	Weighted	67.2	68.4	

DRAINAGE AREA SUMMARY

Sub-watershed PI

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	284.58	73.5	74.1	0.23
2	95.47	73.3	75.2	0.22
3	97.31	71.6	72.3	0.26
4	143.21	72.3	72.3	0.35
5	117.50	66.3	66.8	0.27
6	146.88	75.2	75.5	0.35
7	166.16	69.6	69.6	0.49
8	165.24	69.8	69.8	0.25
9	273.56	70.3	70.3	0.40
10	69.77	73.9	73.9	0.21
11	123.01	76.6	77.7	0.41
12	154.22	78.4	79.6	0.31
13	110.16	72.8	72.8	0.20
14	136.78	70.3	70.3	0.29
15	205.63	71.5	71.5	0.31
16	161.57	67.2	67.2	0.28
17	169.83	74.0	74.0	0.62
18	136.78	67.2	67.2	0.36
19	314.87	68.8	68.8	0.38
20	162.49	70.3	70.3	0.31
21	151.47	70.0	70.0	0.28
22	248.78	69.9	69.9	0.26
23	101.90	66.6	66.6	0.57
24	31.21	62.7	62.7	0.20
25	106.49	67.3	67.3	0.24
26	212.06	66.6	66.6	0.54
27	291.92	65.4	65.4	0.35
28	150.55	66.6	66.6	0.28
29	447.98	70.3	70.3	0.47
30	215.73	67.4	67.4	0.32
31	254.29	69.9	70.0	0.32
32	304.78	68.4	68.4	0.38
33	105.57	69.8	69.9	0.29
34	313.96	69.8	69.8	0.49
35	243.27	65.5	65.5	0.35
36	145.96	63.3	63.3	0.31

DRAINAGE AREA SUMMARY

Sub-watershed PI (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
37	157.90	65.3	65.3	0.52
38	186.35	73.9	74.4	0.33
39	87.21	74.4	74.4	0.33
40	104.65	68.1	68.1	0.50
41	40.39	71.9	71.9	0.25
42	115.67	71.1	71.2	0.29
43	117.50	70.6	70.6	0.36
44	158.81	70.3	70.3	0.28
45	171.67	69.1	69.1	0.35
46	248.78	70.2	70.2	0.57
47	87.21	66.9	66.9	0.20
48	145.96	73.6	73.6	0.26
49	330.48	67.0	67.0	0.52
50	130.36	69.1	69.1	0.30
51	110.16	66.9	66.9	0.15
52	341.50	67.4	67.4	0.51
53	110.16	68.1	68.1	0.39
54	219.40	64.9	64.9	0.48
55	201.04	65.7	65.7	0.26
56	57.83	66.2	66.2	0.21
57	94.55	60.2	60.2	0.43
58	226.75	67.9	67.9	0.49
59	206.55	61.3	61.3	0.64
60	105.57	69.5	69.5	0.29
61	226.75	70.8	70.8	0.36
62	348.84	71.9	71.9	0.50
63	186.35	73.7	73.7	0.51
64	117.50	63.9	63.9	0.23
65	194.62	65.2	65.2	0.38
66	79.87	69.1	69.2	0.32
67	132.19	62.3	62.3	0.16
68	450.74	65.4	65.4	0.44
69	279.07	71.2	71.2	0.35
70	208.39	64.9	64.9	0.29
	Weighted	69.0	69.0	

DRAINAGE AREA SUMMARY

Sub-watershed SB

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	493.88	69.6	69.6	0.71
2	23.87	74.0	74.0	0.15
3	190.03	66.8	66.8	0.34
4	80.78	68.8	68.8	0.11
5	390.15	70.7	70.7	0.48
6	195.53	70.3	70.3	0.35
7	49.57	71.5	71.5	0.15
8	160.65	69.3	69.3	0.39
9	190.94	69.0	69.0	0.28
10	210.22	75.0	75.1	0.29
11	347.92	71.6	71.6	0.50
12	228.58	67.4	67.4	0.28
13	228.58	64.5	64.5	0.53
14	169.83	63.2	63.2	0.37
15	85.37	64.7	64.7	0.43
16	158.81	64.6	64.6	0.30
17	248.78	63.1	63.1	0.33
18	111.08	66.4	66.4	0.32
19	65.18	64.3	64.3	0.15
20	309.37	65.5	66.6	0.86
21	313.04	63.8	65.6	0.63
22	100.98	66.0	66.0	0.26
23	324.05	73.0	73.0	0.67
24	178.09	62.3	62.3	0.26
25	250.61	68.3	68.3	0.37
26	207.47	70.3	70.3	0.36
27	243.27	67.6	67.6	0.28
28	346.09	66.8	66.8	0.85
29	192.78	68.7	68.7	0.49
30	86.29	65.1	65.1	0.21
31	90.88	64.9	64.9	0.32
32	54.16	67.1	67.6	0.09
33	245.11	62.6	62.6	0.28
34	187.27	63.4	63.4	0.40
35	370.87	65.4	65.4	0.31
36	325.89	70.8	70.8	0.46

DRAINAGE AREA SUMMARY

Sub-watershed SB (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
37	266.22	69.8	69.8	0.28
38	87.21	63.3	63.3	0.14
39	231.34	65.5	65.5	0.35
40	92.72	69.7	71.2	0.33
41	82.62	60.7	60.7	0.28
42	148.72	65.4	65.4	0.93
43	174.42	67.5	67.5	0.31
44	35.80	65.7	65.7	0.41
45	134.03	67.6	67.6	0.40
46	324.05	68.6	68.6	0.37
47	313.04	66.0	66.0	0.59
48	387.40	60.9	60.9	0.60
49	307.53	61.0	60.8	0.57
50	238.68	61.1	61.1	0.54
51	134.03	60.3	60.3	0.40
52	191.86	63.2	63.2	0.49
53	239.60	64.7	65.2	0.53
54	213.89	70.7	81.9	0.28
55	285.50	67.4	68.9	0.43
56	268.97	67.3	67.3	0.53
57	108.32	62.1	62.1	0.26
58	263.47	65.1	65.1	0.58
59	70.60	66.5	66.5	0.15
60	90.88	61.8	61.8	0.38
61	272.65	63.4	63.4	0.31
62	179.93	64.7	64.7	0.38
63	278.15	67.7	67.7	0.42
64	122.09	68.9	68.9	0.55
65	201.04	69.2	69.2	0.41
66	189.11	67.6	67.6	0.33
67	156.98	65.6	65.6	0.20
68	401.17	63.5	63.5	0.35
69	291.01	63.3	63.3	0.30
70	87.21	67.4	67.4	0.18
71	53.24	66.2	66.2	0.29
72	175.34	66.5	66.5	0.26

DRAINAGE AREA SUMMARY

Sub-watershed SB (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
73	140.45	68.6	68.6	0.55
74	76.19	69.9	69.9	0.27
75	96.39	71.9	71.9	0.47
	Weighted	66.6	66.7	

DRAINAGE AREA SUMMARY

Sub-watershed SG

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	329.56	64.4	64.4	0.77
2	55.08	64.4	64.4	0.34
3	36.72	62.0	62.0	0.22
4	217.57	64.8	64.8	0.28
5	163.40	67.3	67.3	0.30
6	217.57	64.9	64.9	0.56
7	268.97	65.0	65.0	0.57
8	485.62	67.6	67.6	0.60
9	202.88	57.7	57.7	0.28
10	291.01	63.8	63.8	0.34
11	161.57	59.5	59.5	0.33
12	182.68	64.9	64.9	0.47
13	112.91	68.9	68.9	0.25
14	318.55	67.9	67.9	0.49
15	178.09	72.2	72.2	0.23
16	212.98	67.1	67.1	0.44
17	282.74	58.7	58.7	0.36
18	273.56	62.6	62.6	0.68
19	282.74	58.3	58.3	0.35
20	197.37	46.0	46.0	0.54
21	344.25	51.2	51.2	0.48
22	311.20	64.1	64.1	0.45
23	388.31	68.4	68.4	0.49
24	319.46	63.4	63.4	0.28
25	344.25	60.7	60.7	0.56
26	218.48	58.5	58.5	0.49
27	483.79	58.2	58.5	0.38
28	292.84	65.3	65.3	0.30
29	311.20	71.9	72.1	0.26
30	257.04	66.5	66.5	0.37
31	254.29	65.2	65.2	0.48
32	167.08	64.2	64.5	0.27
33	278.15	63.0	65.1	0.34
34	324.05	63.0	68.2	0.28
35	241.43	63.8	64.2	0.30
36	183.60	60.8	60.8	0.46

DRAINAGE AREA SUMMARY

Sub-watershed SG (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
37	143.21	58.5	58.5	0.39
38	226.75	66.3	66.3	0.40
39	283.66	58.3	58.3	0.30
40	268.06	63.9	63.9	0.52
41	269.89	60.6	60.6	0.46
42	203.80	63.3	67.8	0.48
43	295.60	55.6	55.6	0.58
44	353.43	61.6	61.6	0.46
45	293.76	66.9	66.9	0.47
46	301.10	58.4	58.4	0.46
47	178.09	63.4	63.4	0.48
48	116.59	60.4	60.5	0.49
49	182.68	64.8	64.8	0.43
50	204.71	61.1	61.1	0.41
51	461.75	64.2	64.2	0.61
52	270.81	66.2	66.2	0.26
53	298.35	62.0	62.1	0.49
54	108.32	71.8	73.0	0.27
55	147.80	71.5	71.5	0.25
56	105.57	69.1	69.4	0.27
57	100.98	56.1	56.4	0.28
58	267.14	67.0	67.0	0.38
59	449.82	65.4	65.4	0.40
60	157.90	67.0	67.0	0.22
61	303.86	69.6	69.6	0.48
62	511.33	67.1	67.1	0.38
63	209.30	66.3	66.3	0.30
64	287.33	61.3	61.3	0.45
65	211.14	62.6	62.6	0.42
66	222.16	66.8	66.8	0.42
67	173.50	71.8	71.8	0.34
68	243.27	69.9	73.0	0.50
69	352.51	57.8	59.1	0.39
70	218.48	53.2	53.2	0.30
71	404.84	56.6	56.6	0.36
72	220.32	56.9	56.9	0.35

DRAINAGE AREA SUMMARY

Sub-watershed SG (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
73	173.50	58.8	58.8	0.31
74	409.43	63.9	63.9	0.37
75	230.42	60.8	60.7	0.18
	Weighted	63.1	63.3	

DRAINAGE AREA SUMMARY

Sub-watershed WE

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
1	466.34	66.3	66.3	0.63
2	274.48	71.1	71.1	0.39
3	320.38	67.8	67.8	0.61
4	69.77	66.2	66.2	0.24
5	177.17	68.3	68.3	0.46
6	332.32	69.9	69.9	0.41
7	92.72	65.9	65.9	0.29
8	36.72	56.0	56.0	0.45
9	113.83	69.2	69.3	0.30
10	206.55	69.9	69.9	0.31
11	73.44	68.9	68.9	0.56
12	36.72	75.3	75.6	0.17
13	126.68	68.4	68.5	0.32
14	301.10	69.7	69.7	0.47
15	169.83	66.2	66.2	0.55
16	211.14	66.8	66.8	0.33
17	89.96	71.4	71.4	0.50
18	100.98	70.8	70.8	0.40
19	10.10	75.3	75.3	0.30
20	145.04	74.1	74.1	0.32
21	123.93	70.9	70.9	0.31
22	37.64	70.5	70.5	0.34
23	47.74	68.5	68.5	0.13
24	151.47	72.2	72.2	0.33
25	107.41	76.3	76.3	0.52
26	18.36	71.7	71.7	0.15
27	68.85	71.6	71.7	0.36
28	135.86	70.7	70.7	0.26
29	221.24	66.7	66.7	0.49
30	207.47	68.3	68.3	0.49
31	278.15	73.4	73.4	0.70
32	352.51	71.2	71.2	0.39
33	347.92	70.1	70.1	0.77
34	252.45	70.1	70.1	0.24
35	201.04	68.8	68.8	0.30
36	125.77	63.2	63.2	0.36

DRAINAGE AREA SUMMARY

Sub-watershed WE (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
37	168.91	64.6	64.6	0.44
38	94.55	72.0	72.0	0.47
39	215.73	66.4	66.4	0.51
40	238.68	63.3	63.3	0.34
41	172.58	69.0	69.0	0.27
42	166.16	63.7	63.7	0.44
43	73.44	64.5	64.5	0.22
44	114.75	63.7	63.7	0.38
45	176.26	65.8	65.8	0.40
46	279.07	72.9	72.9	0.46
47	103.73	69.9	69.9	0.26
48	283.66	67.0	67.0	0.63
49	305.69	72.0	72.1	0.67
50	265.30	70.7	70.7	0.61
51	90.88	72.1	72.1	0.33
52	197.37	66.9	66.9	0.46
53	323.14	66.7	66.7	0.49
54	233.17	69.4	69.4	0.45
55	192.78	66.2	66.2	0.64
56	248.78	68.0	68.0	0.46
57	157.90	67.4	67.4	0.53
58	265.30	69.3	69.3	0.43
59	132.19	68.1	68.1	0.50
60	88.13	65.6	68.1	0.30
61	328.64	66.5	81.3	0.27
62	171.67	63.5	72.7	0.62
63	144.13	63.2	64.6	0.32
64	212.06	64.6	70.4	0.38
65	283.66	77.3	83.7	0.53
66	119.34	70.4	79.3	0.40
67	59.67	62.8	67.1	0.62
68	49.57	64.1	70.5	0.36
69	69.77	68.8	68.8	0.26
70	279.99	65.7	65.7	0.40
71	95.47	63.4	63.4	0.41
72	24.79	73.5	73.5	0.16

DRAINAGE AREA SUMMARY

Sub-watershed WE (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
73	12.85	73.6	73.6	0.11
74	98.23	70.8	70.8	0.50
75	99.14	72.9	73.0	0.40
76	73.44	71.9	71.9	0.34
77	171.67	68.8	68.8	0.52
78	272.65	68.9	68.9	0.56
79	169.83	70.9	70.9	0.55
80	210.22	63.2	68.4	0.38
81	145.04	66.2	67.8	0.45
82	93.64	69.7	69.7	0.22
83	93.64	66.8	66.8	0.28
84	32.13	66.8	66.8	0.19
85	175.34	75.5	75.5	0.42
86	110.16	67.6	67.7	0.59
87	46.82	67.3	67.5	0.27
88	92.72	73.3	73.3	0.50
89	53.24	78.0	78.0	0.25
90	110.16	74.0	74.0	0.28
91	281.83	70.1	70.1	0.62
92	73.44	73.9	73.9	0.18
93	203.80	66.9	66.9	0.42
94	185.44	60.2	60.2	0.54
95	287.33	60.5	60.5	0.61
96	77.11	67.3	67.3	0.41
97	183.60	64.1	64.1	0.51
98	95.47	66.9	66.9	0.31
99	182.68	70.4	70.4	0.46
100	125.77	60.0	60.0	0.34
101	39.47	68.9	68.9	0.31
102	162.49	60.2	60.4	0.50
103	51.41	75.0	75.1	0.33
104	156.06	80.0	80.3	0.53
105	35.80	71.9	71.9	0.33
106	156.06	59.8	60.2	0.44
107	77.11	71.7	71.7	0.50
108	19.28	69.9	70.1	0.18

DRAINAGE AREA SUMMARY

Sub-watershed WE (continued)

Area	Acreage	Existing CN	Ultimate CN	t_c (hrs.)
109	22.95	71.4	71.4	0.15
110	176.26	57.4	57.5	0.52
111	22.95	57.6	57.6	0.25
113	175.34	66.1	66.1	0.60
114	116.59	59.6	59.6	0.40
115	226.75	59.6	59.6	0.61
116	76.19	60.6	60.7	0.42
117	156.98	62.3	68.2	0.37
118	260.71	69.8	69.8	0.75
119	122.09	66.4	66.4	0.56
120	37.64	64.4	64.4	0.29
121	112.91	58.6	58.6	0.34
122	136.78	69.8	69.8	0.79
	Weighted	67.9	68.6	

APPENDIX D

CALIBRATION DATA

STREAM GAGE CALIBRATION DISCUSSION

Little Falls Gage

Five storms were selected as possible candidates for calibrating the Little Falls gage which consisted of sub-watersheds FA and BT. Three of these storms were single peak runoff events, while the remaining two storms were multiple peak runoff events lasting several days. The latter storms were used only to verify the calibration adjustments. The single peak storm events were September 21, 1979; October 1, 1979; and June 21 and 22, 1972 (Agnes). The multiple peak storms were August 1 to 5, 1971, and September 22 to 26, 1975 (Eloise).

Calibration of the Little Falls gage was enhanced by the presence of an hourly rainfall recording gage in Parkton, a town almost in the center of the two sub-watersheds. With this recording station data available and with daily total rainfall amounts from surrounding rainfall gage stations, accurate estimated rainfall amounts were determined for the gaged watershed.

Isohyetal diagrams were constructed and total rainfall volumes for the five selected storms were derived. These total volumes were then used to adjust the hourly rainfall for the Parkton gage for each storm.

Initial screening of the five candidate storms was accomplished by computing a weighted average runoff curve number (RCN) for each storm based on the stream gage runoff volume without base flow and the total computed rainfall volume. This was computed by the SCS rainfall-runoff equation. The total rainfall five day prior to the storm was computed to determine the antecedent moisture condition (AMC) for the storms based on the SCS limits (see Table D-1). The computed RCN and AMC were used to determine the RCN and AMC for a Type II Storm based on Figure D-1.

A second RCN was computed based on existing land use conditions at the time of the storms. The LANDSAT scene from 1984 was used to compute RCN via the HYDPAR computer program. This method is already based on AMC II condition and yielded a RCN of 68.

The RCN's from the two methods were compared and similar values indicated good calibration storm potentials.

Of the five storms selected, two appeared to be adequate as potential calibration storms. The first storm, September 21 and 22, 1979, produced a watershed RCN of 56 using the SCS criteria, the AMC for this storm is 1. Converting this to AMC II conditions produces a RCN of 74, which compares favorably to the LANDSAT RCN. The storm of October 1, 1979 yielded a RCN of 78, which is somewhat comparable to the LANDSAT RCN.

Although the two derived curve numbers are higher than the LANDSAT RCN, they are not unreasonable considering the amount of rainfall for that month. Tropical Storm David dropped 5.5 inches early in the month, while 3.9 inches fell on September 21 and 22. The total rainfall for September 1979 was 11.0 inches. Given the heavy rainfall and recognizing that the SCS AMC is only an approximate method of estimating the initial moisture content, it was decided to use these storms for calibration.

Uncalibrated TR-20 runs confirmed that the storms selected would be suitable for calibration. The peak and volume of the gaged runoff hydrograph for the September 21 and 22, 1979 storm was bracketed by TR-20 hydrographs for AMC I and II conditions. In a similar fashion, the peak and volume of the gaged runoff hydrograph for the October 1, 1979 were bracketed by TR-20 hydrographs using AMC II and III conditions.

This bracketing effect indicates that the initial moisture content could not be accurately described by a whole number AMC. Although the strict interpretation of the SCS AMC criteria requires an AMC of one for the September 21 and 22, 1979 storm, the TR-20 volume using AMC I is below the actual storm runoff volume. Thus, a more accurate estimate of the runoff volume would be achieved using an AMC between II and III. The 5.5 inches of rainfall on September 6 and 7 may have created an initial moisture content that was higher than that indicated by the rainfall amount five days previous to the September 21 and 22 storm. A similar situation existed for the storm of October 1, 1979. Using the SCS criteria, an AMC of one should be used. However, TR-20 hydrographs for AMC II and III bracket the runoff volume, indicating that the true initial moisture condition for this storm was probably between II and III. Most likely the 3.9 inches of rainfall on September 21 and 22, 1979 still affected the initial moisture conditions for the October 1, 1979 storm, even though the five-day criteria specified by SCS showed no rainfall.

The apparent discrepancy between the TR-20 runoff volume (based on the required AMC) and the actual gaged storm runoff is not unreasonable in light of the approximate methods used to estimate the soil moisture conditions prior to storms. Since direct measurement of soil moisture is impractical, approximate methods have arisen. Measurements of ground water flow and pan-evaporation measurements have been used. Antecedent precipitation indices probably have seen more use because precipitation is readily measurable (Linsley, Kohler, and Paulus, page 242). The SCS method requires a total precipitation depth for the five days prior to the storm, while in theory, an infinite amount of time prior to a storm should be examined. These indices are derived from rainfall occurring from five to 30 days prior to a storm. Given that precipitation, indices do not account for the effects of evapotranspiration and infiltration on watershed moisture content. SCS recognizes that great accuracy in determining the antecedent moisture condition is not required. (See NEH 4.)

Having achieved a reasonable approximation of the runoff volumes, parameters affecting the hydrograph shape and timing were adjusted. Uncalibrated TR-20 runs consistently produced hydrographs that peaked several hours before the gaged hydrographs. To alleviate this, adjustments were made to the X and M coefficients in the TR-20 input. After several trials, X and M adjustments were found that yielded reasonable hydrographs for the storms on September 21 and 22 and October 1, 1979. These adjustments to the initial estimates of X and M for each reach were submitted under separate cover. Table D-2 is a calibration summary which includes the Little Falls gage.

Long Green Creek Gage

Four storms were investigated for calibrating the Long Green Creek Gage, located within the LO sub-watershed. All were single peak events dated September 16, 1976, September 21, 1979, June 21, 1978, and August 27, 1978.

Since there were no hourly rainfall gages within sub-watershed LO, other records had to be used. The recording rain gage at Towson was thus used as a source of hourly rainfall data.

Average total rainfall depths for each storm were derived by constructing isohyetal or Thiessen diagrams. These volumes were then used to generate runoff curve numbers (RCN) for each storm using the SCS equation which were then compared to the LANDSAT derived RCN of 70.6.

The Towson hourly rainfall patterns were scaled up or down so that the cumulative rainfall for each storm equaled the amount derived by using the isohyetal or Thiessen diagrams.

An isohyetal diagram for the September 16, 1976 storm generated a rainfall depth of 3.25 inches. The SCS equation yielded a runoff curve number of 71. The AMC prior to the storm was 1. This converts to a RCN of 86 for AMC II. The LANDSAT RCN of 70.6 does not compare favorably with this RCN. The full rainfall for the Towson rain gage was 5.5 inches for this storm. Using this value, a RCN of 50 was generated. This converts to a RCN of 69 which compared favorably with the LANDSAT RCN of 71. Therefore, the unadjusted Towson rainfall was used for the September 16, 1976 calibration storm.

Using an average precipitation volume of 1.3 watershed inches and a measured stream flow runoff volume of 0.66 watershed inches, a weighted runoff curve number of 92 resulted for the storm of June 21 to 22, 1978. This derived curve number did not compare favorably with the LANDSAT derived RCN of 71, especially when rainfall records from nearby rain gages indicated an AMC of 1 for this storm. Examination of the rainfall records reveals that most of the rainfall fell on June 22, while the stream gage recorded a runoff hydrograph on June 21. Considering the unusually high curve number and the inconsistencies in recorded data, this storm was not considered for calibration.

Difficulties also arose when a curve number was computed for the storm of August 27 and 28, 1978. Construction of a Thiessen diagram for this storm yielded a precipitation volume of 3.24 inches, while the recorded hydrograph showed 1.77 inches of runoff. Working backwards using the SCS equations produced a watershed curve number of 85 for AMC I. As with the previous storm, this computed curve number did not compare well with the LANDSAT derived RCN of 71 for AMC II. Computations were performed to determine how much rainfall should have occurred in order to derive the LANDSAT based RCN. Converting the LANDSAT RCN of 71 to AMC I conditions, a rainfall of 6.87 inches is required to produce the measured runoff volume of 1.77 inches. A rainfall of 6.87 inches for this storm is unlikely in view of the other rainfall amounts recorded around sub-watershed LO. Notes on the stream gage record for this storm indicate that the gage may have malfunctioned. Thus, the storm of August 27 and 28, 1978 was not considered as a calibration storm.

A more favorable curve number comparison was achieved for the storm dated September 21 and 22, 1979. Using the rainfall volume of 3.5 watershed inches derived from the Isohyetal Map, a curve number of 69 was computed. Since this storm occurred about two weeks after storm David, an AMC of II would not be an unreasonable estimate. Thus, the LANDSAT RCN of 71 (AMC II) agrees well with this value.

Preliminary TR-20 runs further confirmed that two of the four storms initially selected would not be adequate for calibration. These storms, dated June and August, 1978, produced runoff volumes far below those measured by the stream gage. These differences in runoff volumes occurred at every AMC value. Therefore, these storms were not considered further.

The selected storms, September 15 and 16, 1976, and September 21 and 22, 1979, both had runoff volumes that compared favorably to the gaged storm runoff. For the September 21 and 22, 1979 event, both the volume of runoff and peak runoff rate were well bracketed by hydrographs using AMC I and II. Using AMC II, the uncalibrated TR-20 model generated 1.05 watershed inches, while the actual measured runoff volume was 0.95 inches. Apparently, the AMC prior to this storm was between I and II and closer to II. This does not seen unreasonable considering the occurrence of Tropical Storm David only 14 days before.

A favorable runoff volume comparison was also achieved with the storm dated September 16, 1976. TR-20 produced runoff hydrographs for AMC I and II conditions. A close agreement between the runoff volumes of the AMC I and actual storm hydrographs indicates that the moisture conditions depicted by AMC I probably existed. Moreover, daily rainfall records for locations surrounding sub-watershed LO substantiate the choice of AMC I here.

Once favorable volume comparisons were achieved, the shape and timing of the hydrographs were adjusted. For both storms selected for calibration, the predicted hydrographs from the uncalibrated TR-20 model peaked from one to two hours early. To delay the hydrographs, the X values used in reach routing were reduced by 20 percent. This adjustment, with M held constant, forced more of the hydrograph out of bank, increasing the storage and, thus, attenuating the hydrographs. With this adjustment the predicted peaks from the calibrated TR-20 were brought within one hour of the actual runoff hydrographs. Thus, calibration of the Long Green Creek TR-20 model was accomplished by implementing a 20 percent reduction in X values.

Western Run Gage

The Western Run gage included all of sub-watersheds PI and BL and most of WE. Five storms were originally considered for calibration. The storm dates were August 3 to 5, 1971; June 29 and 30, 1972; September 26 and 27, 1975; September 5 and 6, 1979; and September 21 and 22, 1979.

Isohyetal diagrams were constructed to derive average total rainfall volumes for each storm. The hourly rainfall pattern for each rainfall event was developed using data from either the Parkton or Towson continuous rain gage. For each storm, the rainfall amounts derived from isohyetal maps was compared to the total amounts from the two recording gages to decide which hourly pattern to use. Thus, the hourly rainfall pattern having a total rainfall volume closest to the isohyetal storm rainfall volume was used. The incremental hourly amounts of the selected pattern were then modified so that the cumulative hourly rainfall equaled the total volume derived from the isohyetal maps.

Examination of the rainfall pattern derived for the June 29 and 30, 1972 events precluded further consideration of the storm. The incremental rainfall pattern for this event consisted of three separate occurrences of rainfall indicating that a multipeaked runoff hydrograph should result. However, the gaged hydrograph was only single peaked indicating that an accurate hourly rainfall pattern could not be reproduced.

Tropical Storm Eloise on September 26 and 27, 1975 was similar to the storm of June 29 and 30, 1972 in that it was multipeaked. The hydrograph for the August 3 to 5, 1971 storm was also multipeaked.

Rainfall events dated September 5 and 6, 1979 (David) and September 21, 1979 were single peak events.

Calibration runs on the previous two gages indicated that in order to match a stream runoff hydrograph more exactly, an AMC condition somewhere between I and II or II and III is required. A program was developed whereby the AMC can be adjusted to a non-integer value. Using this program, AMC's of 1.08 and 2.10 were generated and used to calibrate the September 5 and 6, 1979 and September 21, 1979 events, respectively. These AMC values produced almost matching volumes of runoff.

Given the close agreement between predicted and actual runoff volumes, adjustments were made to the X and M parameters to adjust the timing the shape of the hydrographs.

Uncalibrated TR-20 runs produced runoff hydrographs that peaked higher and earlier than the actual hydrographs (this trend existed throughout all of the sub-watersheds. To alleviate this discrepancy, M values were reduced a certain percentage uniformly over PI, WE, and BL. Even with the adjustment, however, values of M resulted that were still within acceptable limits.

Table D-1

Five-Day Antecedent Rainfall

AMC	INCHES
I	Less than 1.4
II	1.4 to 2.1
III	Over 2.1

Table D-2

STREAM GAGE CALIBRATION SUMMARY

Gage Location	Storm Date	Stream Gage (w/o base flow): Peak Discharge Q (cfs)	Stream Gage (w/o base flow): Peak Time (hrs)	Stream Gage (w/o base flow): Runoff Volume (in)	Total Computed Rainfall Volume (in)	Computed RCN Based on SCS Equation	AMC Based on Previous 5-Day Precip.	RCN Based on Conversion to AMC II	AMC II RCN Based on LANDSAT	Calibration TR-20 Runs: AMC Used	Calibration TR-20 Runs: Runoff Volume (in)	Calibration TR-20 Runs: Peak Discharge (cfs)	Calibration TR-20 Runs: Peak Time (hrs)	Comments
Long Green Creek	9-16-76*	1637	14.0	0.91	5.50	50	1	69	70.6	1.04	1.05	1442	13.3	Good simulation.
	9-21-79*	1498	17.0	0.95	3.50	69	2	69	70.6	1.88	0.96	1424	16.2	Nearly exact match.
	8-27-78	2600	7.5	1.77	3.24	85	1	94	70.6	2.0	0.90	2200	8.8	Timing and shape good. Peak close.
	6-21/ 6-22-78	2150	7.5	0.66	1.30	92	1	82	70.6	3.0	0.35	1109	8.3	Timing and shape good. Peak low.
Western Run	9-5/ * 9-6-79	8639	28.0	1.34	6.20	51	1	70	71	1.08	1.21	8692	28.0	Good simulation.
	9-21/ * 9-22-79	2879	29.0	0.61	2.70	71	1	86	71	2.10	0.51	2968	27.5	Good simulation.
	8-3-71	2370	12.0	0.51	1.00	94	3	84	71	1.70	0.69	2494	19.2	This was first peak of double peak hydrograph.
	6-29/ 6-30-72	1760	36.0	0.30	1.76	76	1	62	71	2.30	0.25	1538	30.0	Unionville rainfall used. Parkton rainfall gage not working.
Little Falls	9-21/ * 9-22-79	3004	26.5	0.59	4.1	56	1	75	68	1.40	0.58	2538	26.5	Good simulation.
	10-1-79 *	4088	12.0	0.59	2.2	78	2	78	68	2.90	0.83	3615	9.7	Good simulation.
	6-21/ 6-22/72	8000	33.0	4.04	12.2	43	1	63	68	1.00	4.93	11331 9218	28.0 35.0	Rainfall pattern produced double peak hydrograph.
	8-1 to 8-5/71	3200	72.0	1.26	4.99	60	2	60	68	2.00	1.51	5886	69.0	Triple peak hydrograph. Timing and shape good for highest peak.
	9-22 to 9-26-75	6500	111.0	2.31	2.90	86	3	94	68	3.00	3.04	7856	109.0	Time and shape good. Peak slightly high.

* Storm used for calibration and plotted; all others used for verification only.

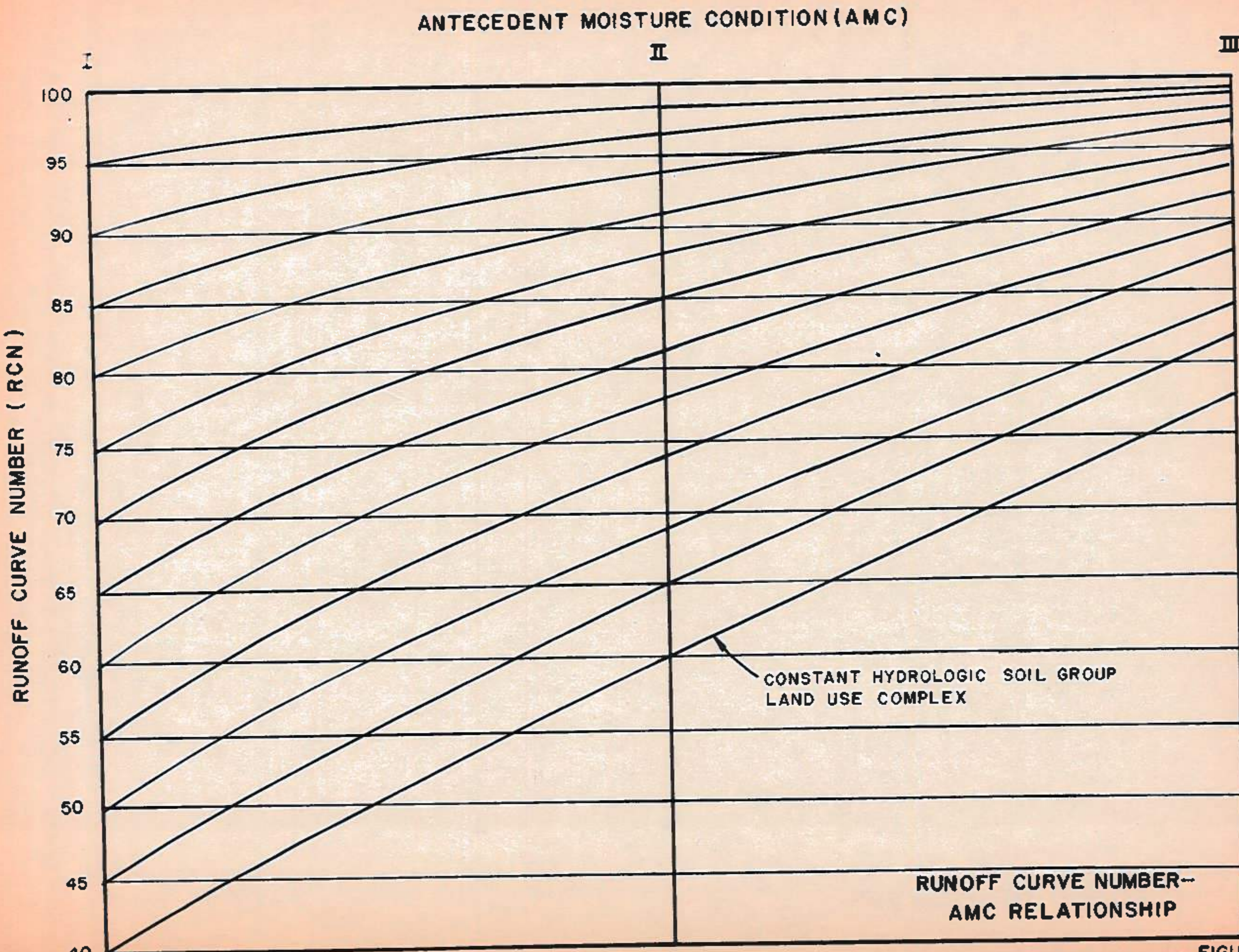
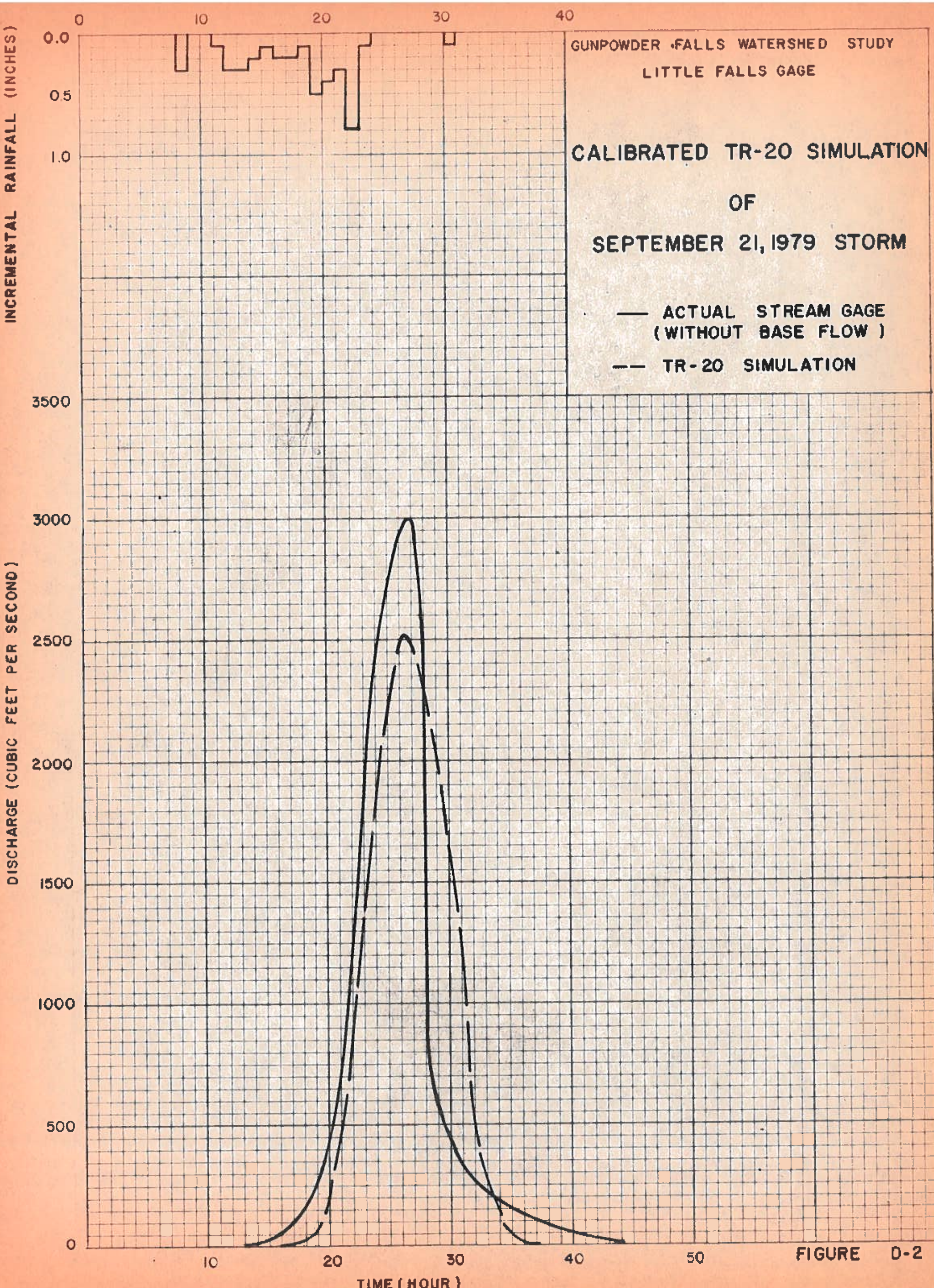

ANTECEDENT MOISTURE CONDITION (AMC)
I
II
III
RUNOFF CURVE NUMBER (RCN)
100
95
90
85
80
75
70
65
60
55
50
45
40
CONSTANT HYDROLOGIC SOIL GROUP
LAND USE COMPLEX
RUNOFF CURVE NUMBER—
AMC RELATIONSHIP

FIGURE D-1



GUNPOWDER FALLS WATERSHED STUDY
LITTLE FALLS GAGE
CALIBRATED TR-20 SIMULATION OF SEPTEMBER 21, 1979 STORM
ACTUAL STREAM GAGE (WITHOUT BASE FLOW)
TR-20 SIMULATION
INCREMENTAL RAINFALL (INCHES)
0.0
0.5
1.0
DISCHARGE (CUBIC FEET PER SECOND)
3500
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
50
TIME (HOUR)

FIGURE D-2

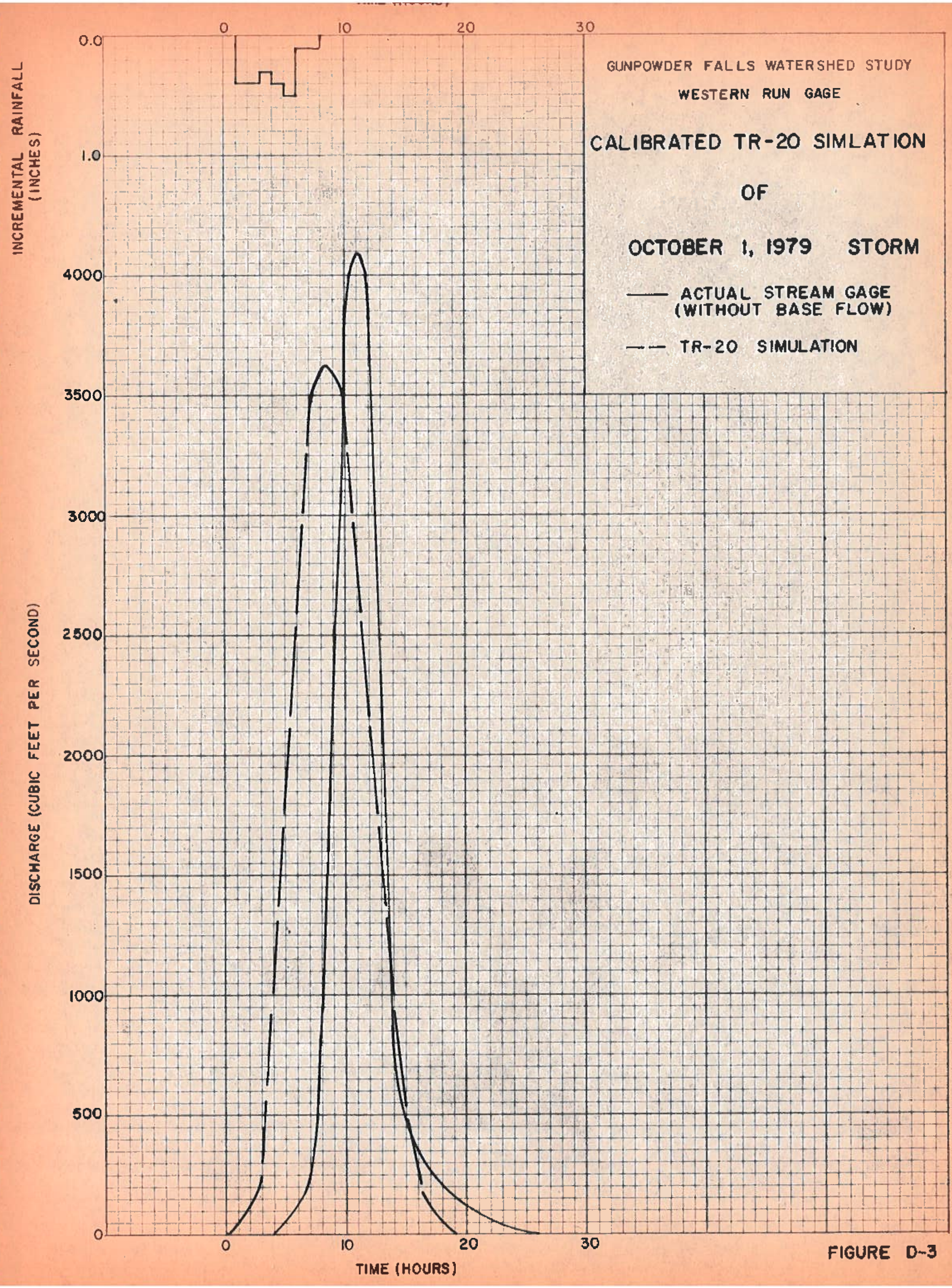
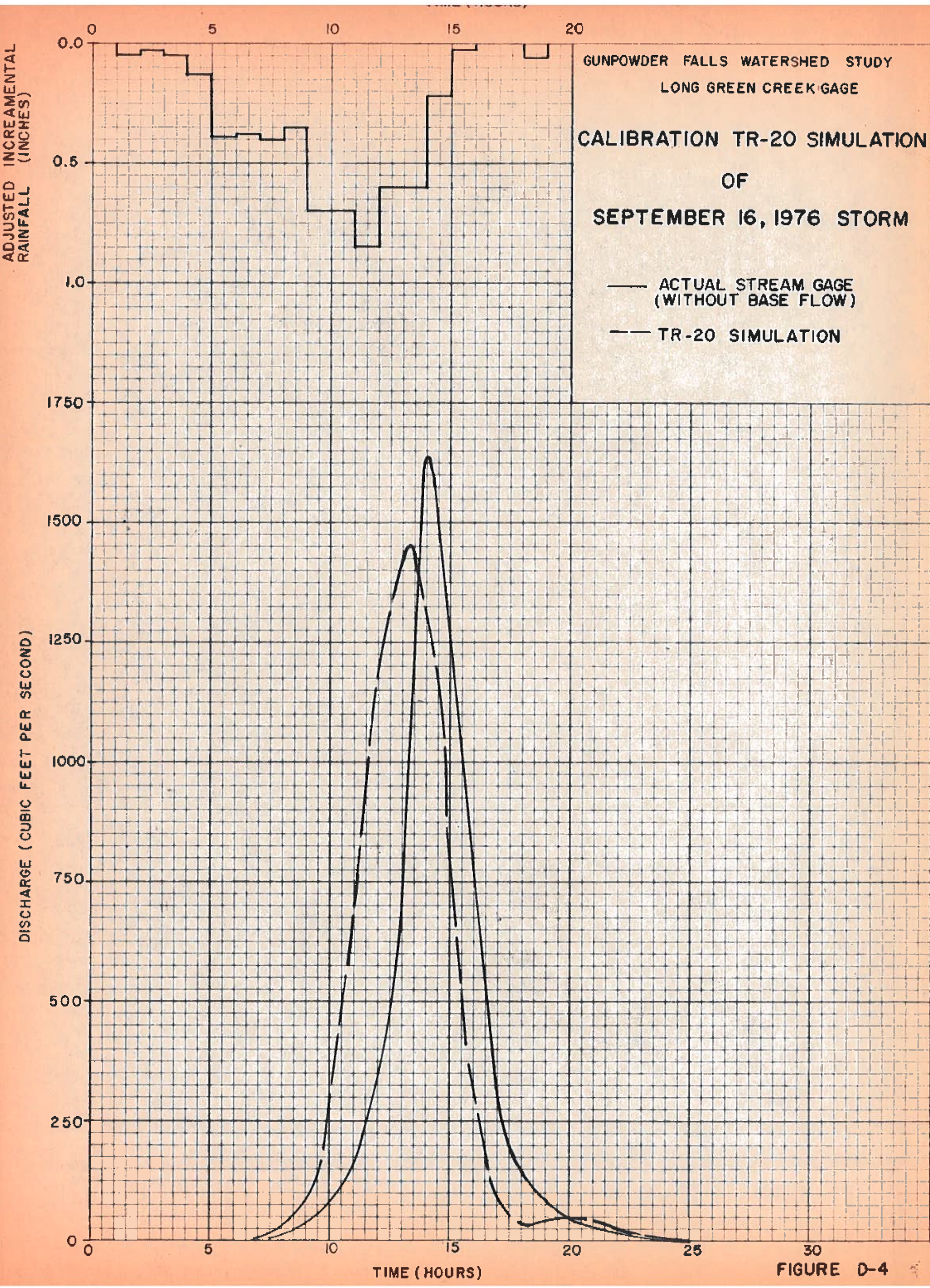

GUNPOWDER FALLS WATERSHED STUDY
WESTERN RUN GAGE
CALIBRATED TR-20 SIMLATION
OF
OCTOBER 1, 1979 STORM
ACTUAL STREAM GAGE (WITHOUT BASE FLOW)
TR-20 SIMULATION
INCREMENTAL RAINFALL (INCHES)
DISCHARGE (CUBIC FEET PER SECOND)
TIME (HOURS)
0.0
1.0
4000
3500
3000
2500
2000
1500
1000
500
0
10
20
30

FIGURE D-3



GUNPOWDER FALLS WATERSHED STUDY
LONG GREEN CREEK GAGE
CALIBRATION TR-20 SIMULATION
OF
SEPTEMBER 16, 1976 STORM
ACTUAL STREAM GAGE (WITHOUT BASE FLOW)
TR-20 SIMULATION
ADJUSTED INCREAMENTAL RAINFALL (INCHES)
DISCHARGE (CUBIC FEET PER SECOND)
TIME (HOURS)
0.0
0.5
1.0
1750
1500
1250
1000
750
500
250
0
5
10
15
20
25
30

FIGURE D-4

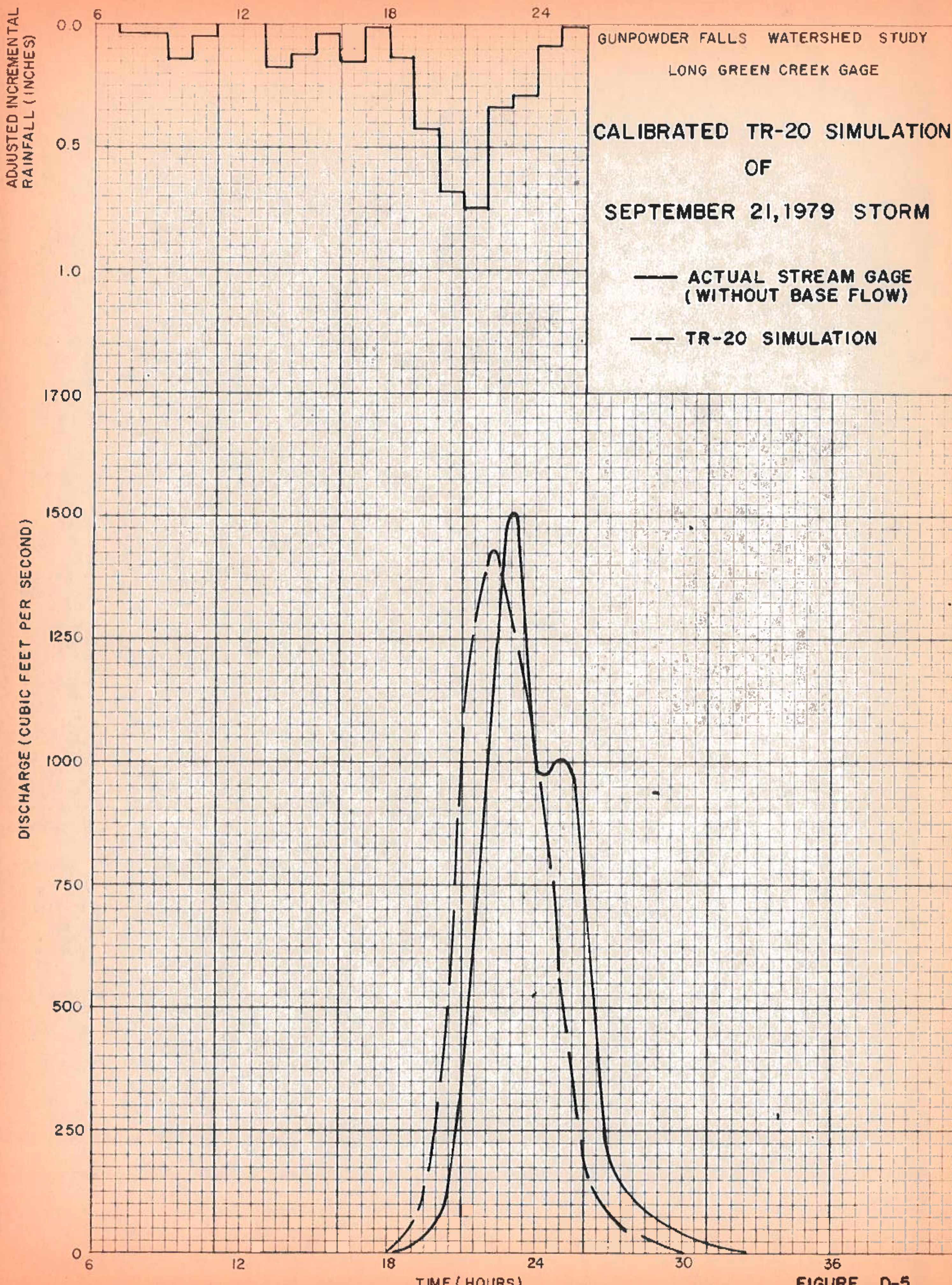
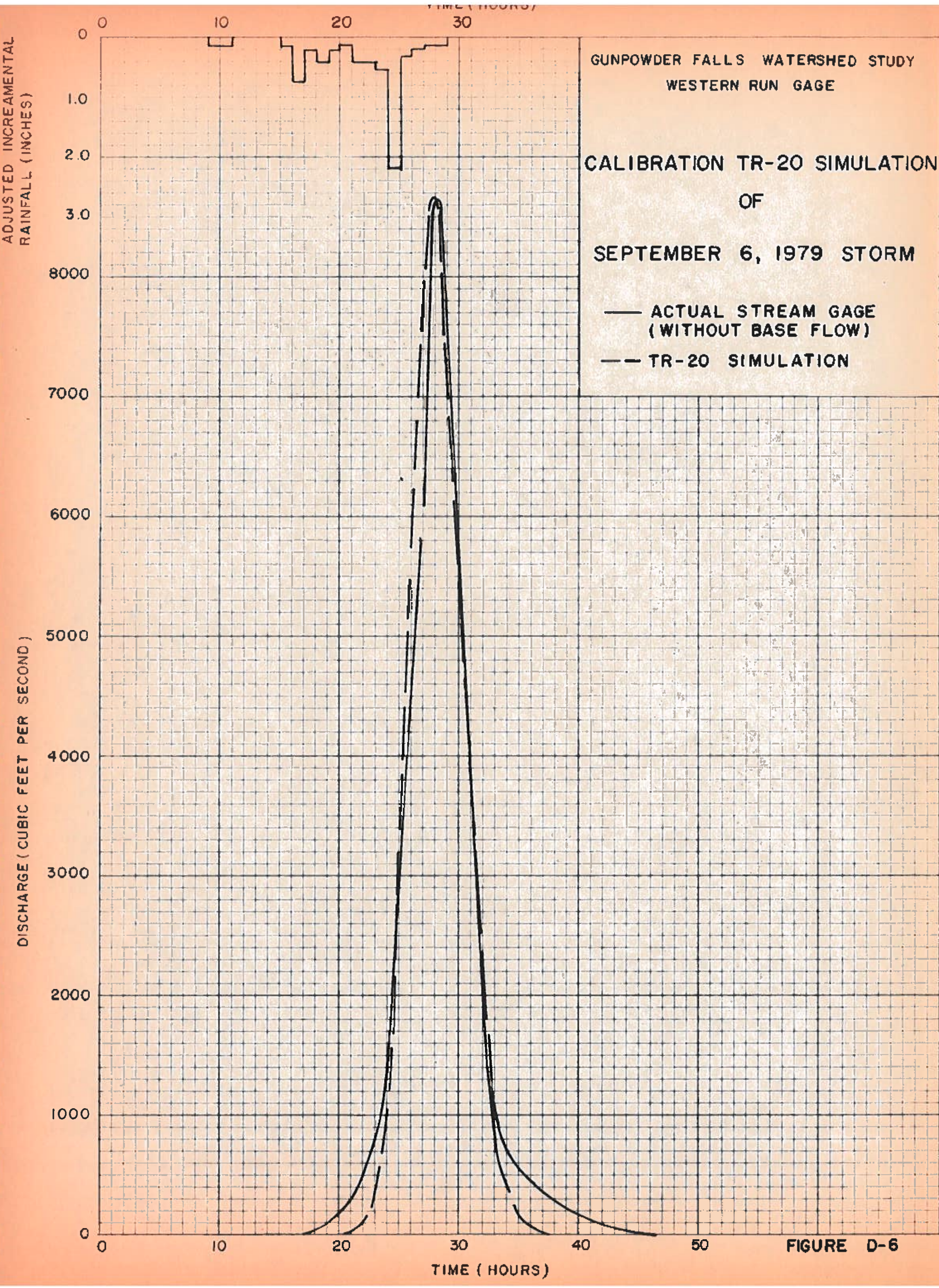
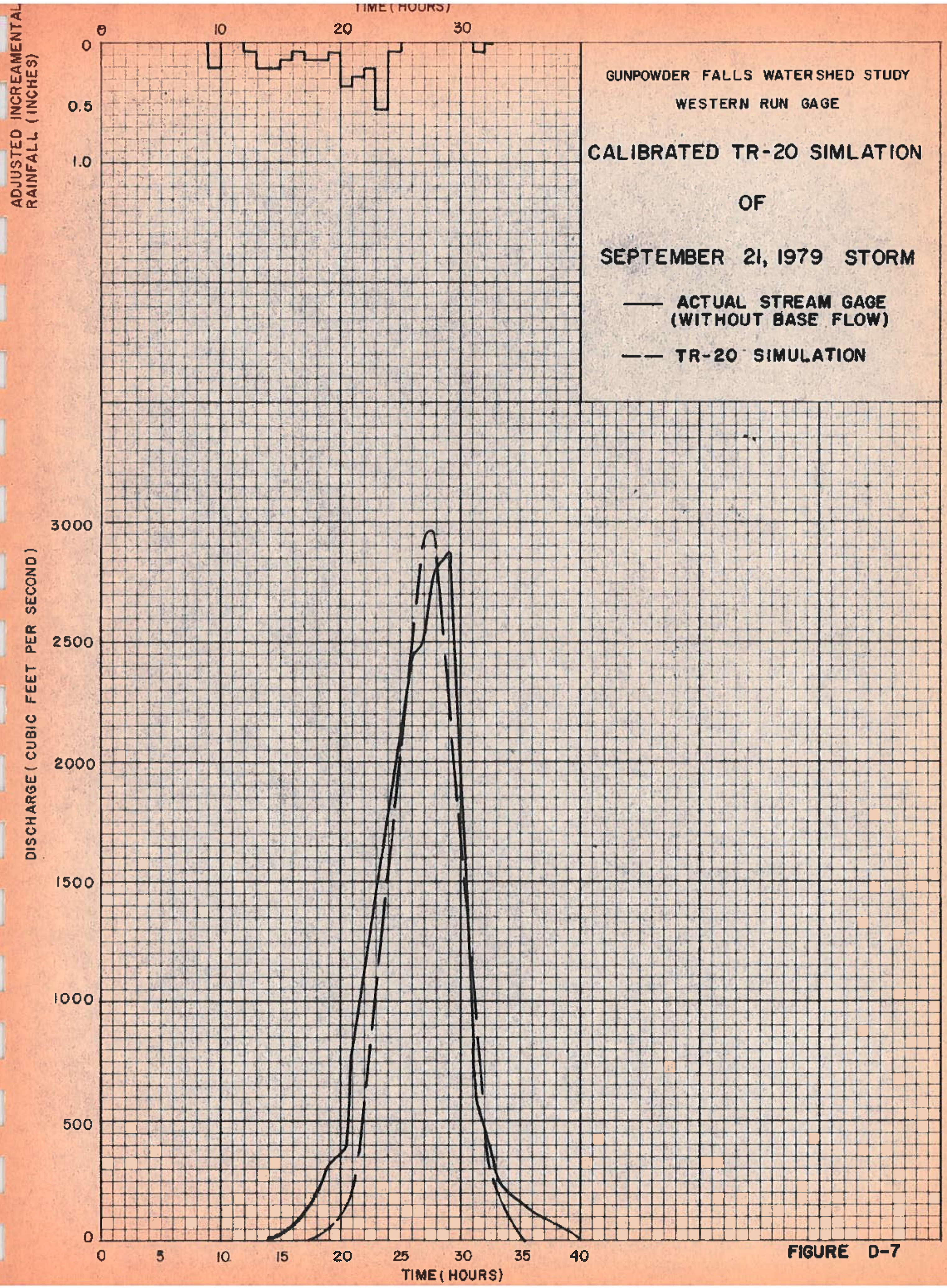

GUNPOWDER FALLS WATERSHED STUDY
LONG GREEN CREEK GAGE
CALIBRATED TR-20 SIMULATION OF SEPTEMBER 21, 1979 STORM
ACTUAL STREAM GAGE (WITHOUT BASE FLOW)
TR-20 SIMULATION
ADJUSTED INCREMENTAL RAINFALL (INCHES)
0.0
0.5
1.0
6
12
18
24
DISCHARGE (CUBIC FEET PER SECOND)
1700
1500
1250
1000
750
500
250
0
6
12
18
24
30
36
TIME (HOURS)

FIGURE D-5



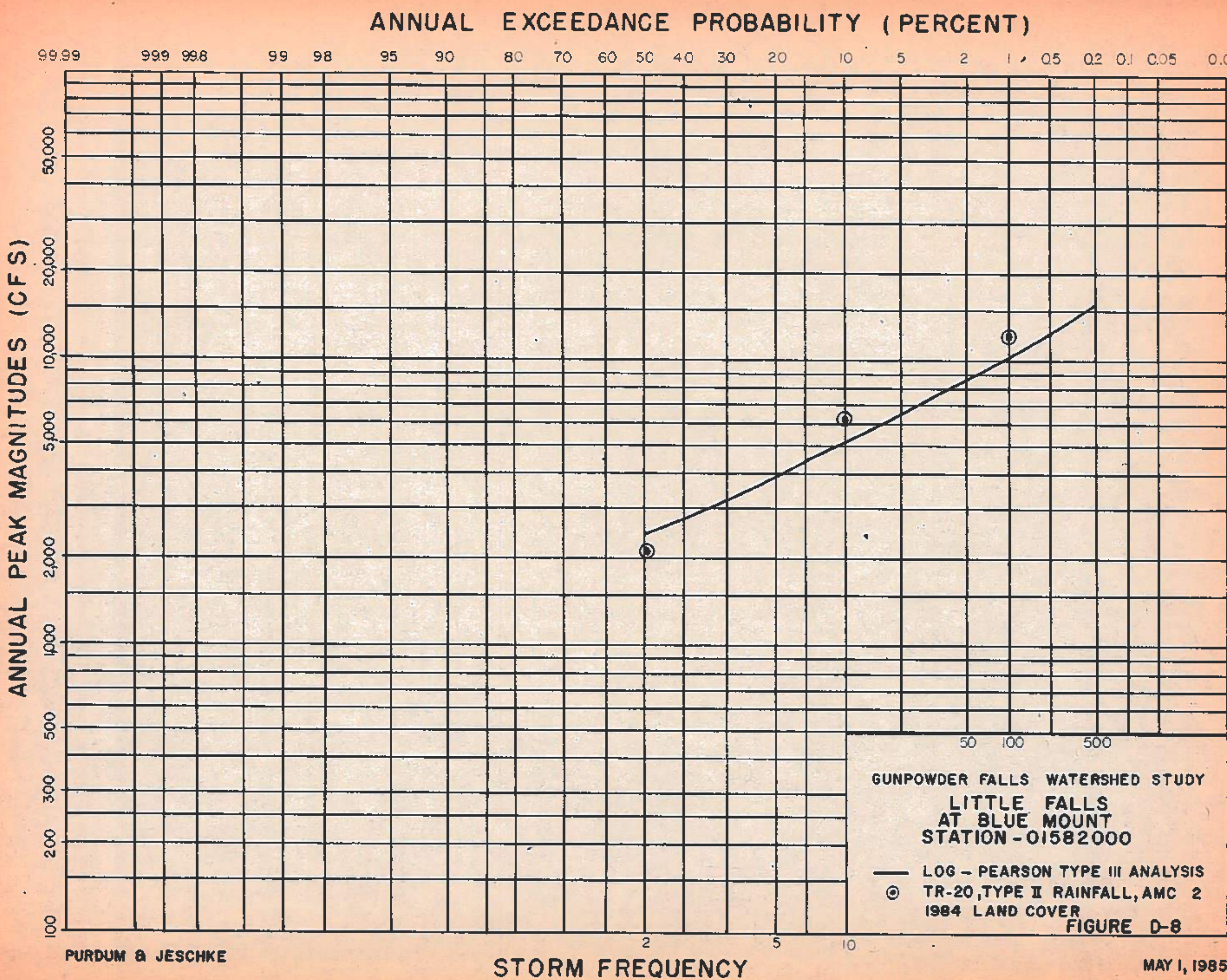
TIME (HOURS)
0
10
20
30
ADJUSTED INCREAMENTAL RAINFALL (INCHES)
0
1.0
2.0
3.0
GUNPOWDER FALLS WATERSHED STUDY
WESTERN RUN GAGE
CALIBRATION TR-20 SIMULATION
OF
SEPTEMBER 6, 1979 STORM
ACTUAL STREAM GAGE
(WITHOUT BASE FLOW)
TR-20 SIMULATION
DISCHARGE (CUBIC FEET PER SECOND)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
TIME (HOURS)

FIGURE D-6



TIME (HOURS)
ADJUSTED INCREAMENTAL RAINFALL (INCHES)
GUNPOWDER FALLS WATERSHED STUDY
WESTERN RUN GAGE
CALIBRATED TR-20 SIMLATION
OF
SEPTEMBER 21, 1979 STORM
ACTUAL STREAM GAGE (WITHOUT BASE FLOW)
TR-20 SIMULATION
DISCHARGE (CUBIC FEET PER SECOND)
TIME (HOURS)

FIGURE D-7



GUNPOWDER FALLS WATERSHED STUDY

LITTLE FALLS
AT BLUE MOUNT
STATION - 01582000

FIGURE D-8

PURDUM & JESCHKE

MAY 1, 1985

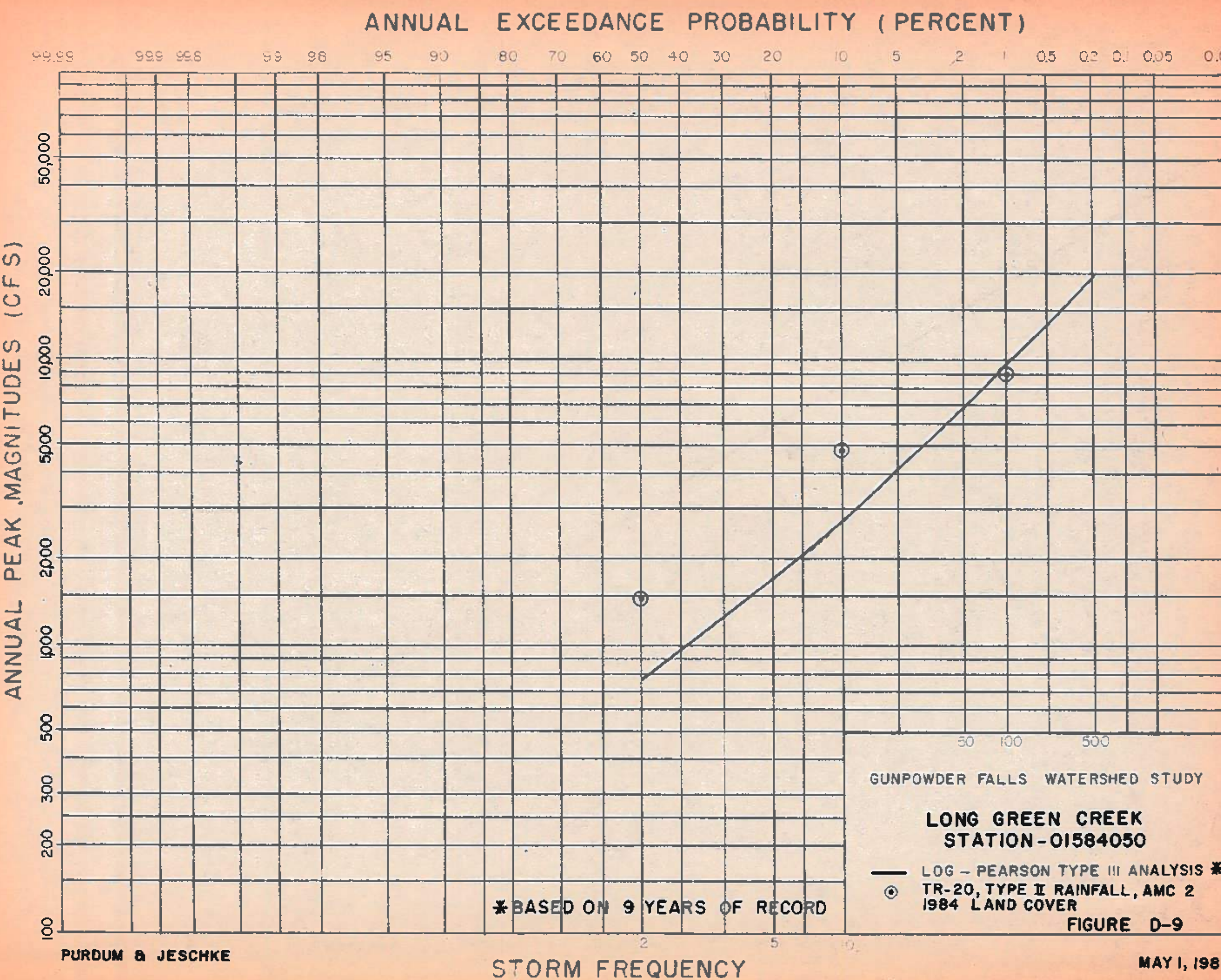


FIGURE D-9

PURDUM & JESCHKE

MAY 1, 1985

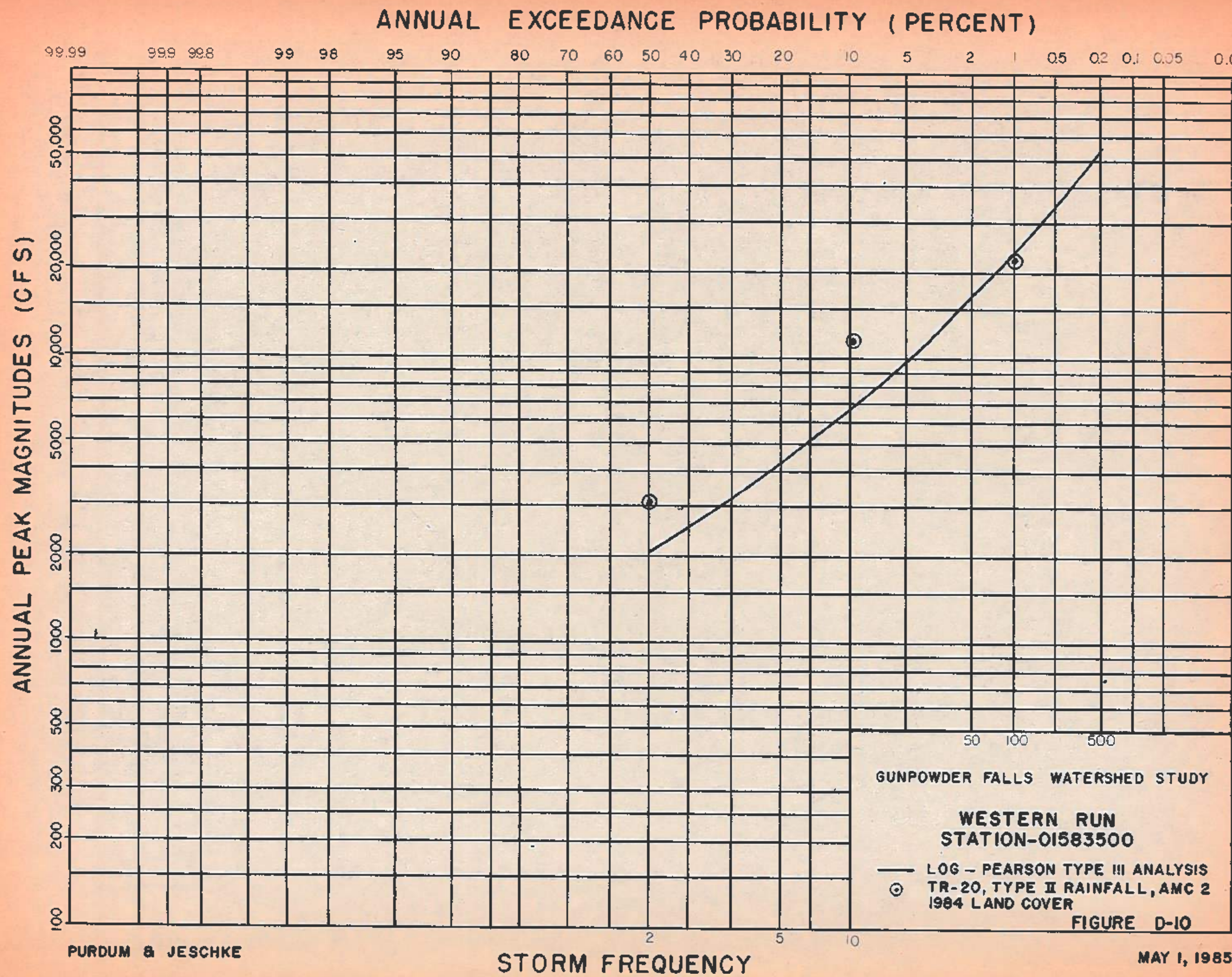
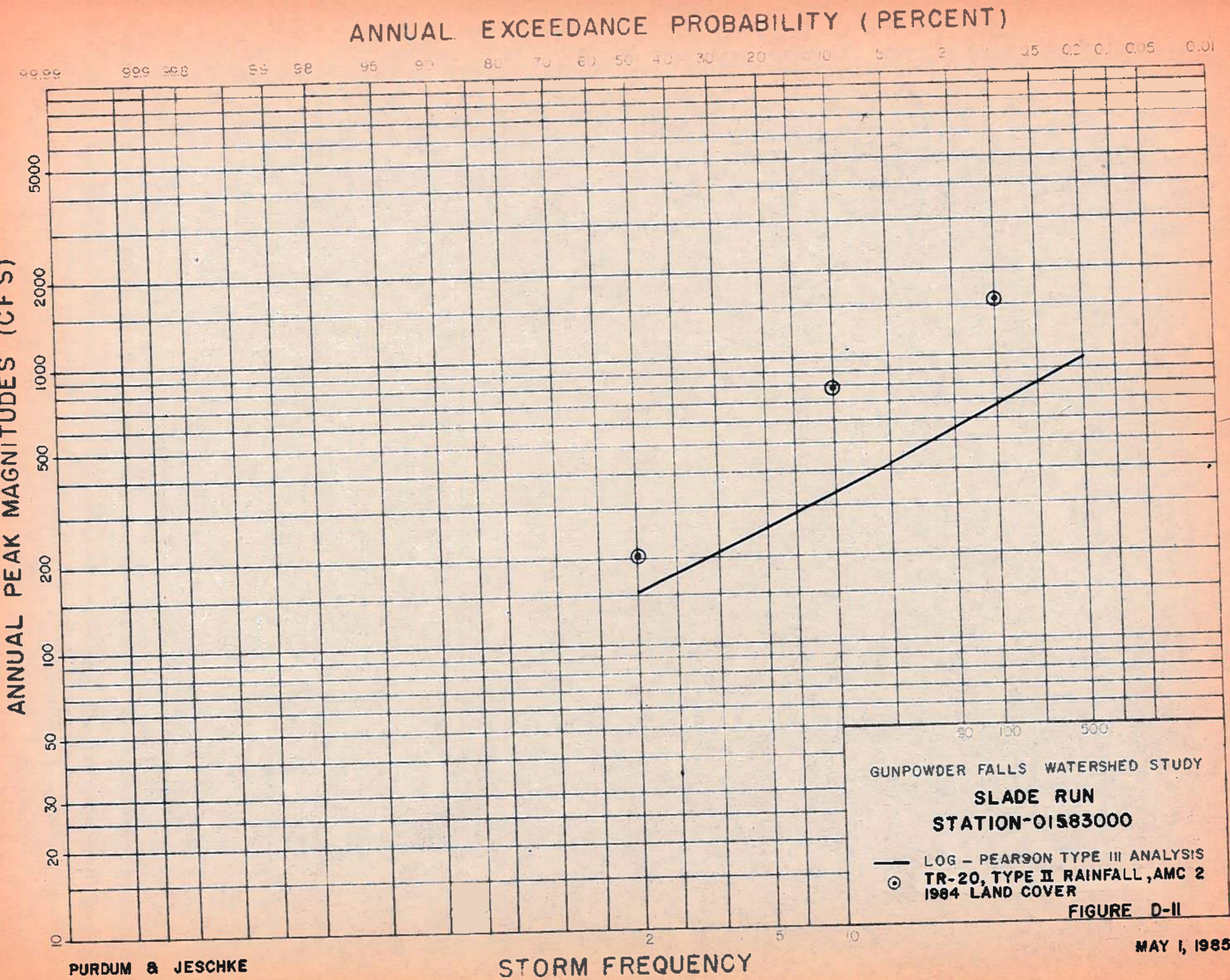


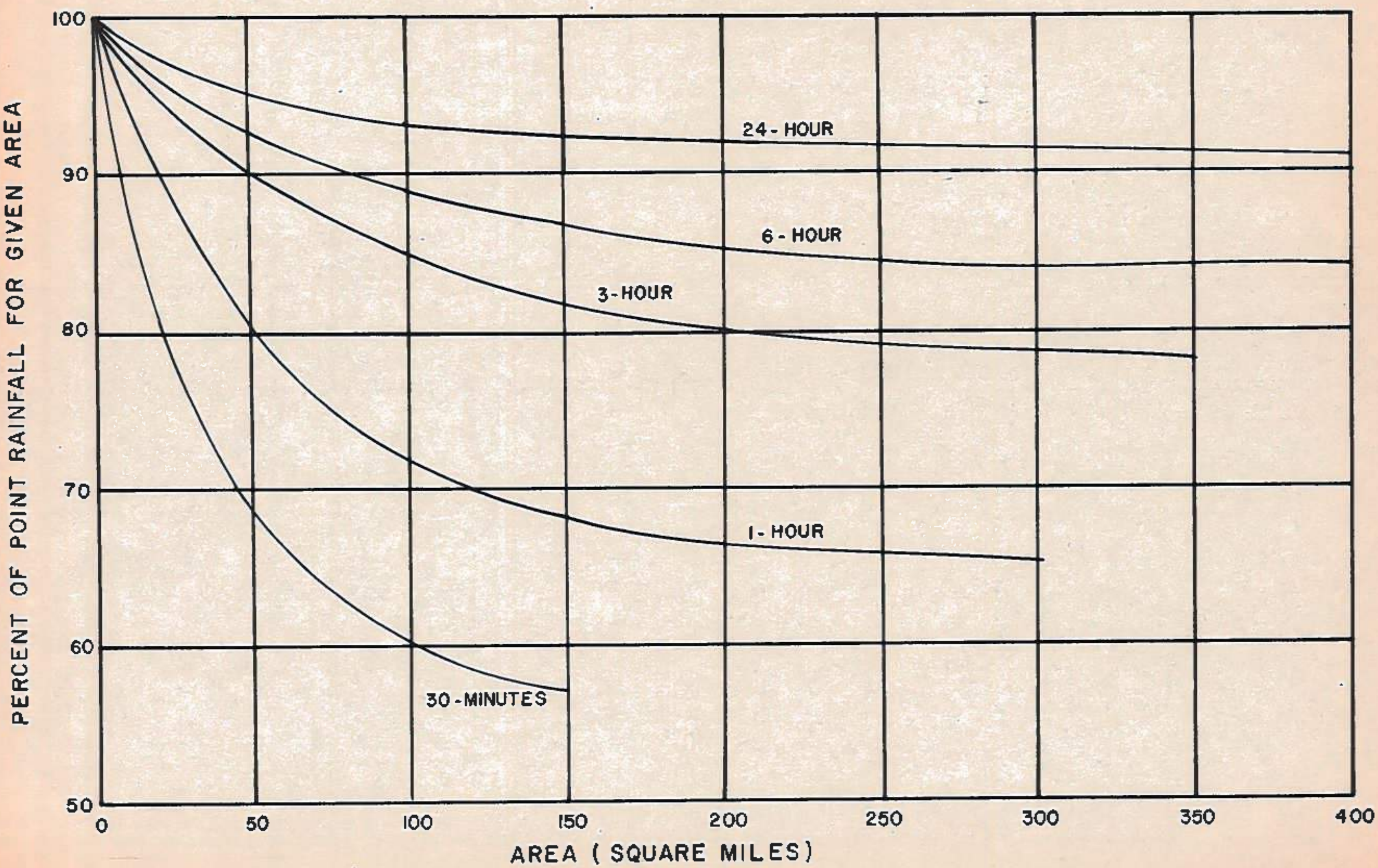
FIGURE D-10

PURDUM & JESCHKE

MAY 1, 1985



ANNUAL EXCEEDANCE PROBABILITY (PERCENT)
99.99
99.9
99.8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01
ANNUAL PEAK MAGNITUDES (CFS)
5000
2000
1000
500
200
100
50
30
20
10
2
5
10
50
100
500
STORM FREQUENCY
GUNPOWDER FALLS WATERSHED STUDY
SLADE RUN
STATION-01583000
LOG - PEARSON TYPE III ANALYSIS
TR-20, TYPE II RAINFALL, AMC 2
1984 LAND COVER
FIGURE D-11
MAY 1, 1985
PURDUM & JESCHKE



AREA - DEPTH CURVES

FIGURE D-12

APPENDIX E

COMPUTED WATER SURFACE ELEVATIONS FOR EACH CROSS-SECTION

Upper Piney Creek

Computed Water Surface Elevations for Each Cross Section

SECTION	EXISTING DEVELOPMENT CONDITIONS						ULTIMATE DEVELOPMENT CONDITIONS					
	Q_2	$WSEL_2$	Q_{10}	$WSEL_{10}$	Q_{100}	$WSEL_{100}$	Q_2	$WSEL_2$	Q_{10}	$WSEL_{10}$	Q_{100}	$WSEL_{100}$
1.0	1240	309.47	4110	311.90	7480	313.77	1260	309.49	4150	311.93	7530	313.79
1.1		309.96		312.50		314.49		309.99		312.53		314.52
1.2		310.22		312.85		314.90		310.24		312.88		314.92
2.0		312.35		315.45		318.55		312.37		315.48		318.56
2.1		313.99		318.08		320.12		314.03		318.13		320.14
2.2		314.07		318.17		323.86		314.10		318.22		323.92
4.0		314.05		320.69		325.21		314.09		320.76		325.27
5.0		319.84		322.12		325.39		319.87		322.11		325.44
6.0		323.60		326.02		327.11		323.63		326.06		327.14
7.0		325.68		328.68		331.09		325.70		328.70		331.11
8.0		329.61		333.23		335.38		329.66		333.27		335.41
9.0		332.85		335.82		337.46		332.87		335.84		337.48
10.1		335.85		338.03		339.80		335.87		338.05		339.82
10.2		336.43		338.97		340.32		336.45		338.98		340.33
10.3		336.69		339.61		341.26		336.72		339.64		341.32
12.0		336.79		340.22		343.19		336.82		340.26		343.25
13.0		337.71		340.42		343.01		337.73		340.45		343.03

Lower Piney Creek

Computed Water Surface Elevations for Each Cross Section

SECTION	EXISTING DEVELOPMENT CONDITIONS						ULTIMATE DEVELOPMENT CONDITIONS					
	Q_2	$WSEL_2$	Q_{10}	$WSEL_{10}$	Q_{100}	$WSEL_{100}$	Q_2	$WSEL_2$	Q_{10}	$WSEL_{10}$	Q_{100}	$WSEL_{100}$
32.0	1290	250.48	4190	254.64	7810	257.32	1310	251.18	4240	254.69	7870	257.36
33.0		252.80		254.89		257.56		251.04		254.94		257.59
25.0		253.61		253.61		257.10		253.28		253.75		257.05
24.0		254.54		257.25		259.80		254.52		257.31		259.87
23.0		256.12		258.09		260.57		256.16		258.12		260.62
22.0		257.69		260.31		262.06		257.72		260.34		262.09
21.0		259.86		262.02		263.83		259.88		262.05		263.86
20.0		261.21		263.09		264.52		261.23		263.11		264.54
19.0		262.00		264.95		267.15		262.04		264.98		267.19
18.0		264.10		266.65		268.49		264.15		266.68		268.52
18.1		265.04		268.39		271.56		265.07		268.44		271.61
18.2		265.99		270.55		276.61		266.03		270.72		276.65
16.0		266.61		272.11		276.48		266.66		272.25		276.52
15.0		269.01		273.47		277.37		269.06		273.58		277.41
14.0		270.28		273.76		277.49		270.32		273.85		277.52

Gunpowder Falls

Computed Water Surface
Elevations for Each Cross Section

SECTION	EXISTING DEVELOPMENT CONDITIONS						ULTIMATE DEVELOPMENT CONDITIONS					
	Q_2	$WSEL_2$	Q_{10}	$WSEL_{10}$	Q_{100}	$WSEL_{100}$	Q_2	$WSEL_2$	Q_{10}	$WSEL_{10}$	Q_{100}	$WSEL_{100}$
26.0	2540	245.96	7700	251.20	15230	255.22	2570	246.00	7760	251.24	15340	255.26
27.0		247.52		252.81		256.90		247.57		252.85		256.95
28.0		249.02		254.42		258.10		249.07		252.46		258.14
29.0		249.97		255.45		258.90		250.02		255.49		258.94
29.1		250.18		255.53		258.93		250.23		255.56		258.97
29.2		250.41		255.89		258.94		250.46		255.93		258.99
29.3		250.42		255.91		259.04		250.47		255.94		259.09
31.0		250.38		255.88		259.31		250.43		255.91		259.35
31.1		250.43		256.07		259.35		250.48		256.11		259.39
32.0		250.55		256.18		259.45		250.60		256.22		259.49
33.0	2470	251.59	7440	256.62	14740	259.86	2500	251.64	7510	256.66	14850	259.90
34.0		252.02		256.65		259.92		252.07		256.69		259.96
35.0		253.09		257.64		260.63		253.15		257.67		260.66
36.0		253.91		258.26		261.25		253.97		258.30		261.29
37.0		254.35		258.70		261.68		254.41		258.74		261.71
38.0		254.85		259.04		262.10		254.91		259.08		262.14
39.0		255.20		259.24		262.39		255.26		259.27		262.43
39.1		255.22		259.49		262.60		255.28		259.53		262.64
39.3		255.23		259.57		262.68		255.29		259.61		262.72
39.4		255.23		259.47		262.63		255.29		259.51		262.67
41.0		255.25		259.84		262.80		255.31		259.88		262.84
42.0		255.42		260.13		263.09		255.48		260.18		263.13
43.0	2480	255.88	7440	260.72	14730	263.65	2500	255.94	7500	260.76	14850	263.68
44.0		756.12		261.01		263.97		256.18		261.05		264.00
45.0		256.46		261.63		264.89		256.52		261.67		264.93
46.0		256.65		261.99		265.51		256.71		262.03		265.55
47.0		256.95		262.37		265.98		257.01		262.42		266.02
48.0		257.51		262.90		266.60		257.57		262.95		266.65
49.0		257.87		263.37		267.21		257.92		263.42		267.26
50.0		258.19		263.75		267.65		258.24		263.80		267.69

Gunpowder Falls

Computed Water Surface
Elevations for Each Cross Section

SECTION	EXISTING DEVELOPMENT CONDITIONS						ULTIMATE DEVELOPMENT CONDITIONS					
	Q_2	$WSEL_2$	Q_{10}	$WSEL_{10}$	Q_{100}	$WSEL_{100}$	Q_2	$WSEL_2$	Q_{10}	$WSEL_{10}$	Q_{100}	$WSEL_{100}$
51.0		258.73		264.61		268.96		258.78		264.65		269.01
52.0		259.54		265.31		269.83		259.59		265.36		269.89
53.0	2470	260.72	7380	266.70	14640	271.48	2500	260.77	7450	266.75	14750	271.54
54.0		261.82		267.58		272.31		261.87		267.63		272.37
55.0		262.38		267.98		272.61		262.42		268.03		272.67
55.1		262.42		267.98		272.44		262.47		268.03		272.50
55.3		262.43		267.99		272.46		262.48		268.04		272.52
55.4		262.45		268.06		272.91		262.50		268.12		272.97
58.0		262.85		268.46		273.17		262.90		268.51		273.23
59.0		263.75		269.28		273.66		263.80		269.33		273.72
60.0		264.91		270.61		274.94		264.96		270.66		274.99
61.0		265.77		271.42		275.56		265.82		271.47		275.61
62.0		267.01		272.80		277.10		267.06		272.85		277.16
63.0		267.61		273.42		277.54		267.66		273.47		277.60
64.0	2470	268.29	7380	274.01	14640	277.79	2500	268.35	7450	274.06	14750	277.84
65.0		269.36		275.02		278.84		269.41		275.06		278.88
66.0		270.10		275.70		279.45		270.15		275.75		279.50
67.0		270.63		276.09		279.88		270.68		276.14		279.93
67.1		270.69		276.12		279.89		270.74		276.16		279.94
68.0		270.70		276.14		279.76		270.75		276.18		279.80
69.0		270.65		276.05		279.95		270.70		276.10		280.00
70.0		271.68		277.18		281.15		271.73		277.23		281.19
71.0		272.86		278.42		282.15		272.92		278.47		282.19
72.0		273.84		279.49		283.29		273.89		279.54		283.33
73.0		274.94		280.76		284.55		275.00		280.81		284.60
74.0	2430	275.73	7270	281.61	14440	285.39	2460	275.49	7330	281.66	14550	285.44
75.0		276.17		282.03		285.92		276.22		282.08		285.97
76.0		276.83		282.55		286.52		276.88		282.60		286.57
76.1		276.86		282.54		286.28		276.91		282.59		286.32
76.2		276.87		282.56		286.33		276.29		282.60		286.38
78.0		276.86		282.56		287.00		276.91		282.61		287.06
79.0		277.31		283.11		287.33		277.36		283.16		287.38

Long Green Creek

Computed Water Surface
Elevations for Each Cross Section

SECTION	EXISTING DEVELOPMENT CONDITIONS						ULTIMATE DEVELOPMENT CONDITIONS					
	Q_2	$WSEL_2$	Q_{10}	$WSEL_{10}$	Q_{100}	$WSEL_{100}$	Q_2	$WSEL_2$	Q_{10}	$WSEL_{10}$	Q_{100}	$WSEL_{100}$
80.0	1430	284.79	4700	287.00	8740	288.82	1440	284.80	4710	287.00	8750	288.83
80.1		284.90		287.10		288.93		284.91		287.10		288.93
80.2		284.99		287.19		289.03		285.00		287.20		289.03
81.0		285.83		287.91		289.49		285.84		287.91		289.49
82.0		287.21		290.41		292.66		287.23		290.41		292.66
83.0		288.52		291.57		293.83		288.54		291.58		293.84
84.0		289.06		291.95		294.07		289.08		291.95		294.07
85.1		288.97		292.21		294.49		288.98		292.22		294.49
85.2		289.01		291.88		293.64		289.01		291.89		293.66
86.0		288.93		293.83		296.04		288.94		293.84		296.04
87.1	1100	290.81	3620	294.06	6740	296.33	1110	290.83	3630	294.07	6750	296.33
87.2		291.15		294.16		296.24		291.18		294.17		296.23
87.4		291.49		294.17		296.24		291.52		294.17		296.24
88.0		291.61		294.50		296.72		291.64		294.50		296.72
89.0		291.70		294.59		296.82		291.73		294.60		296.82

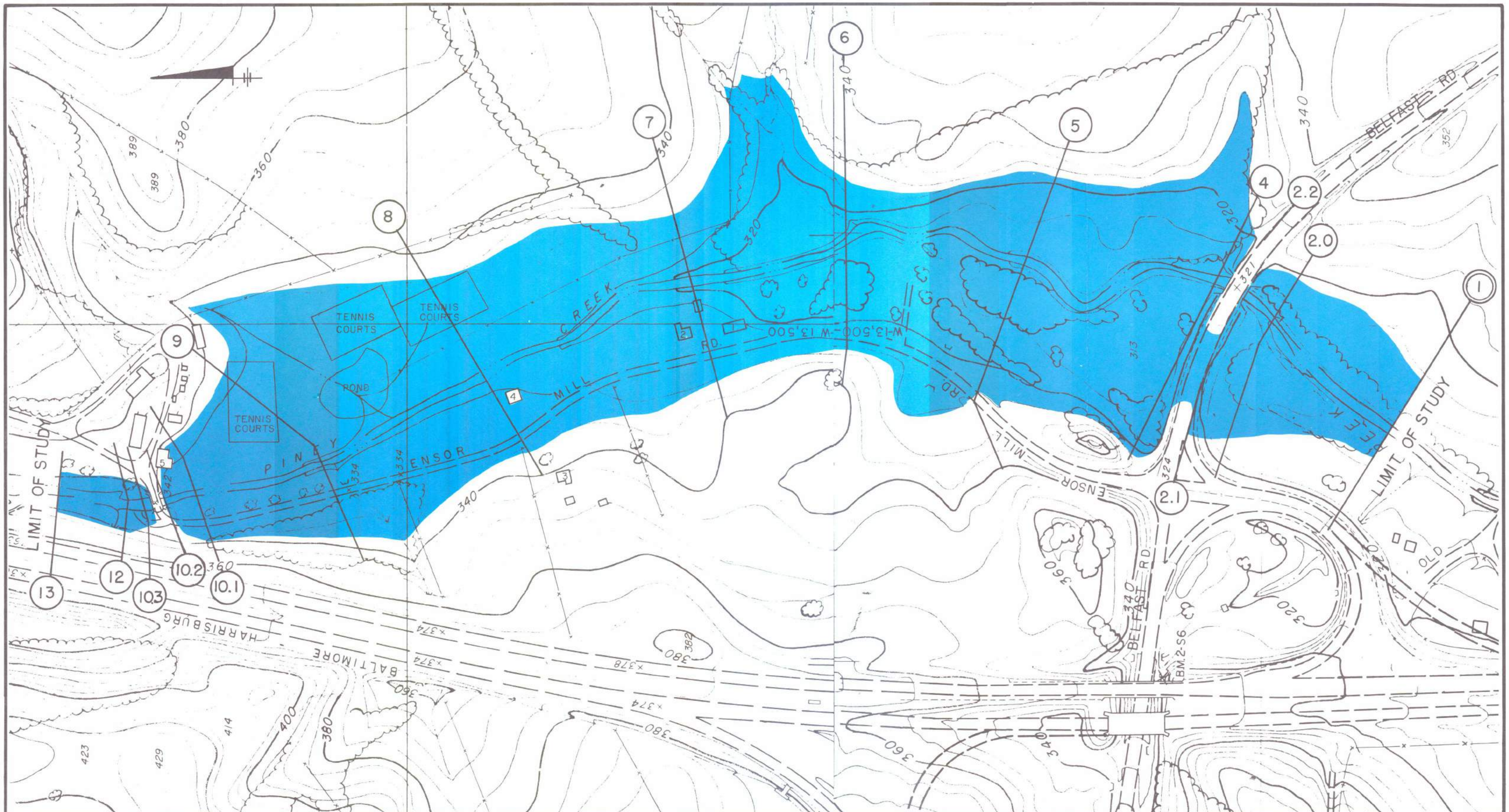
Beetree Run

Computed Water Surface
Elevations for Each Cross Section

SECTION	EXISTING DEVELOPMENT CONDITIONS						ULTIMATE DEVELOPMENT CONDITIONS					
	Q_2	$WSEL_2$	Q_{10}	$WSEL_{10}$	Q_{100}	$WSEL_{100}$	Q_2	$WSEL_2$	Q_{10}	$WSEL_{10}$	Q_{100}	$WSEL_{100}$
95.0	500	618.92	1665	620.82	3115	622.26	500	618.92	1665	620.82	3115	622.26
95.1		619.42		621.32		622.75		619.42		621.32		622.75
95.2		619.91		621.81		623.25		619.91		621.81		623.25
96.0		626.46		629.43		632.74		626.46		629.43		632.74
96.1		626.55		629.58		632.58		626.55		629.58		632.58
98.0		627.57		631.75		634.59		627.57		631.75		634.59
98.1		627.87		633.21		638.17		627.87		633.21		638.17
99.0		635.86		638.15		639.73		635.86		638.15		639.73
100.0		639.98		642.39		643.91		639.98		642.39		643.91
101.0		642.01		645.01		647.34		642.01		645.01		647.34
101.1		642.01		645.40		648.58		642.01		645.40		648.58
103.0		643.29		647.69		653.18		643.29		647.69		653.18
103.1		643.78		649.70		653.20		643.78		649.70		653.20
104.0		649.55		651.09		653.85		649.55		651.09		653.85
105.0		656.27		658.08		658.69		656.27		658.08		658.69
106.0		659.46		662.10		663.86		659.46		662.10		663.86
106.1		659.43		661.92		664.43		659.43		661.92		664.43
108.0		660.15		663.64		666.10		660.15		663.64		666.10
108.1		660.39		664.10		666.11		660.39		664.10		666.11
109.0		666.26		667.20		667.83		666.26		667.20		667.83
110.0		669.28		670.52		671.48		669.28		670.52		671.48
111.0		672.20		673.08		673.78		672.20		673.08		673.78
111.1		672.57		674.77		674.80		672.57		674.77		674.80
113.0		672.73		675.34		676.69		672.73		675.34		676.69
113.1		673.36		675.59		677.12		673.36		675.59		677.12
114.0		675.37		678.37		679.09		675.37		678.37		679.09
115.0		684.88		686.29		686.95		684.88		686.29		686.95

APPENDIX F

FLOOD DELINEATIONS



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

- 100 YEAR FLOOD
- CROSS SECTION
- (47) CROSS SECTION NUMER
- [3] STRUCTURE NUMBER
- (36) CROSS SECTION WHERE STREAM FLOW HAS CHANGED (TR-20 REACH SECTION)
- FIRST FL. ABOVE FLOOD EL.
- FIRST FL. BELOW FLOOD EL.

SCALE IN FEET
0 100 200 300

STREAM PLAN

UPPER PINEY CREEK

LIMITS OF 100 YEAR FLOOD
ULTIMATE DEVELOPMENT

DRAWING NO.
1 of 13

PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

- 100 YEAR FLOOD
- CROSS SECTION
- (47) CROSS SECTION NUMER
- (36) CROSS SECTION WHERE STREAM FLOW HAS CHANGED (TR-20 REACH SECTION)
- 3 STRUCTURE NUMBER
- FIRST FL. BELOW FLOOD EL.
- FIRST FL. ABOVE FLOOD EL.

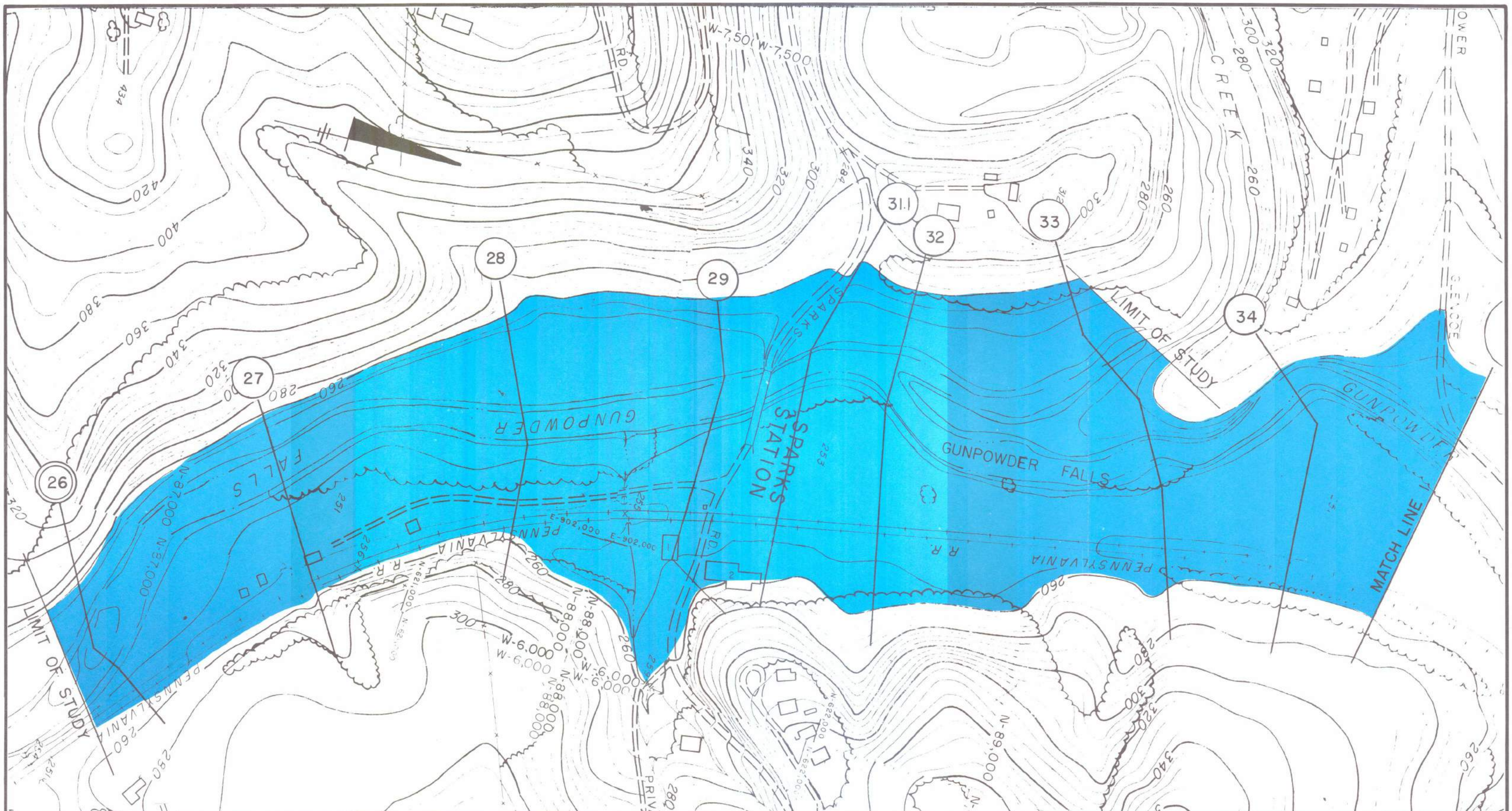
SCALE IN FEET
0 100 200 300

STREAM PLAN

LOWER PINEY CREEK

LIMIT OF 100 YEAR FLOOD
ULTIMATE DEVELOPMENT

DRAWING NO.
2 of 13



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

- 100 YEAR FLOOD
- CROSS SECTION
- (47) CROSS SECTION NUMER
- [3] STRUCTURE NUMBER
- (36) CROSS SECTION WHERE STREAM FLOW HAS CHANGED (TR-20 REACH SECTION)
- FIRST FL. ABOVE FLOOD EL.
- FIRST FL. BELOW FLOOD EL.

SCALE IN FEET
0 100 200 300

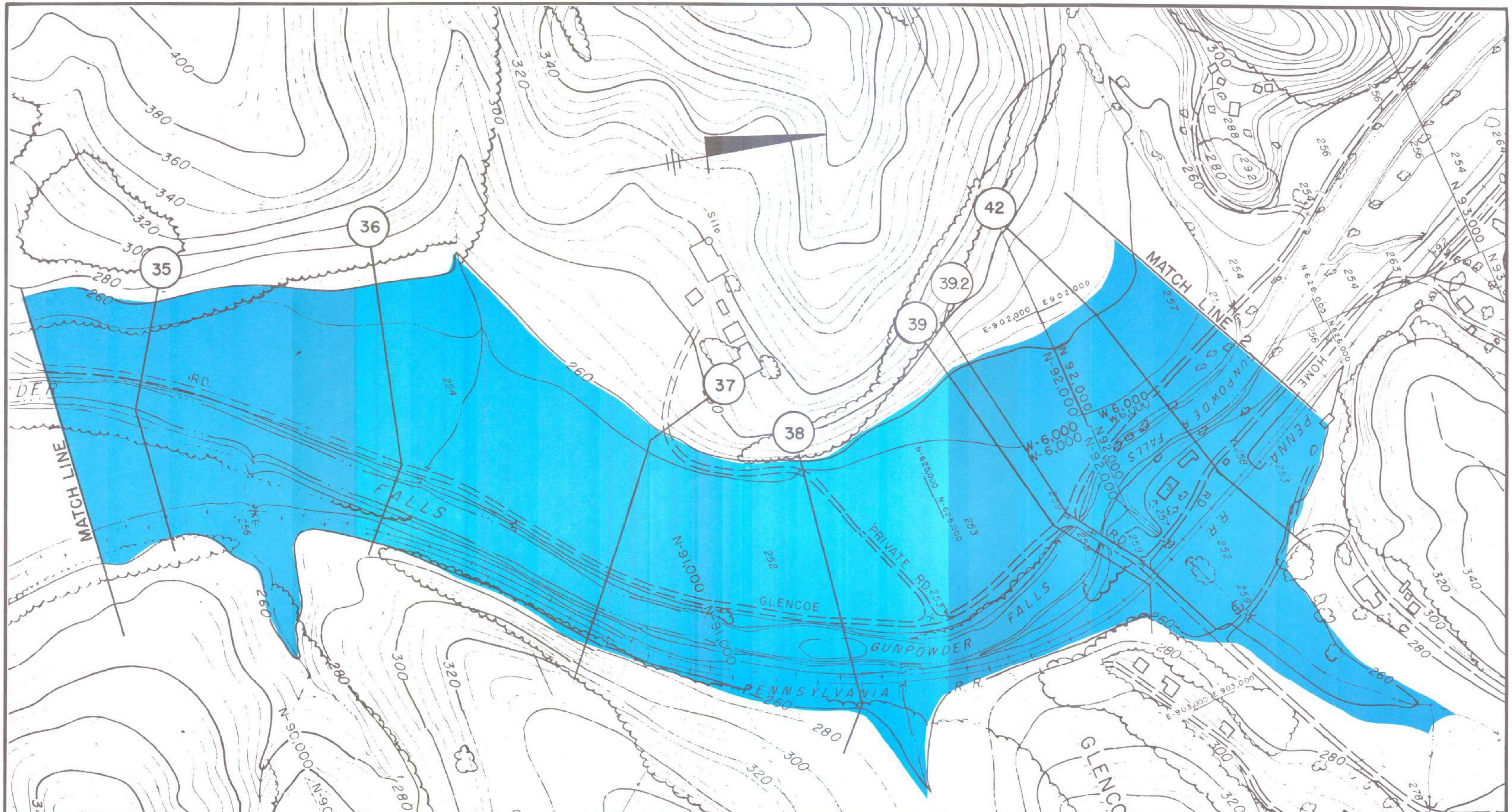
STREAM PLAN

GUNPOWDER FALLS

LIMIT OF 100 YEAR FLOOD
ULTIMATE DEVELOPMENT

DRAWING NO.

3 of 13



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

- 100 YEAR FLOOD
- CROSS SECTION
- (47) CROSS SECTION NUMER
- 3 STRUCTURE NUMBER
- (36) CROSS SECTION WHERE STREAM FLOW HAS CHANGED (TR-20 REACH SECTION)
- FIRST FL. BELOW FLOOD EL.
- FIRST FL. ABOVE FLOOD EL.

SCALE IN FEET
0 100 200 300

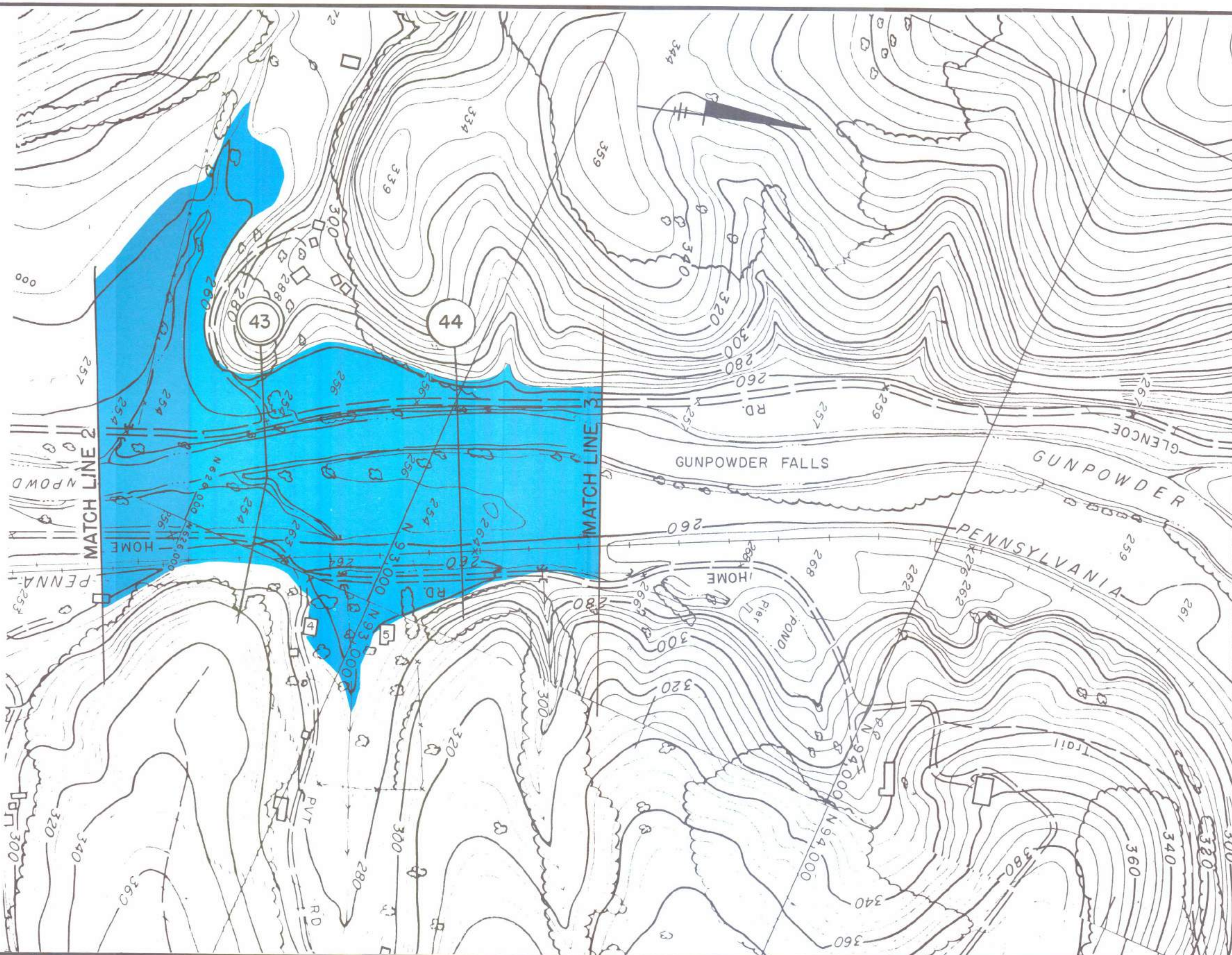
STREAM PLAN

GUNPOWDER FALLS

LIMITS OF 100 YEAR FLOOD
ULTIMATE DEVELOPMENT

DRAWING NO.

4 of 13



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

- 100 YEAR FLOOD
- CROSS SECTION
- (47) CROSS SECTION NUMER
- [3] STRUCTURE NUMBER
- (36) CROSS SECTION WHERE STREAM FLOW HAS CHANGED (TR-20 REACH SECTION)
- FIRST FL. ABOVE FLOOD EL.
- FIRST FL. BELOW FLOOD EL.

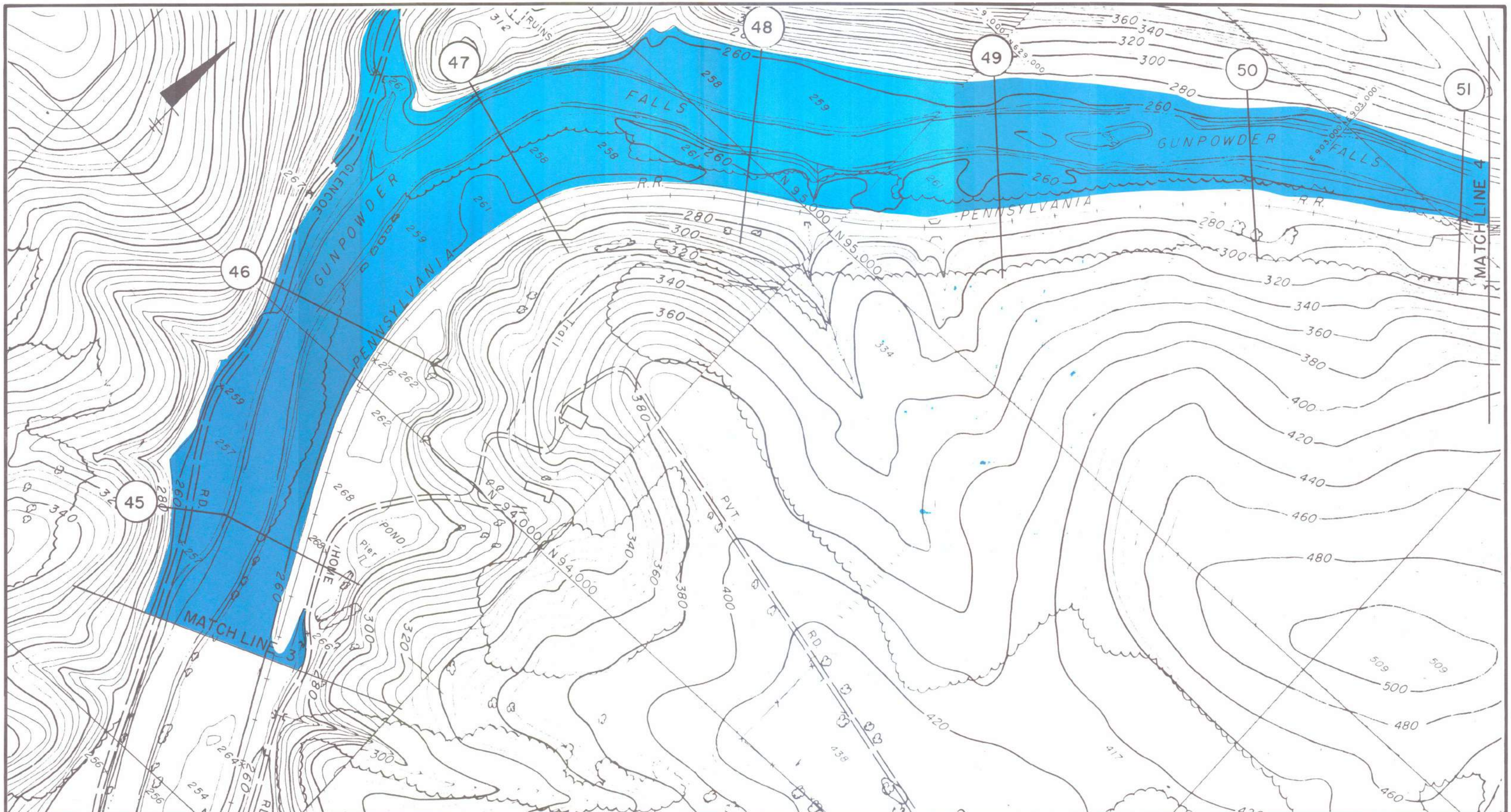
SCALE IN FEET
0 100 200 300

STREAM PLAN

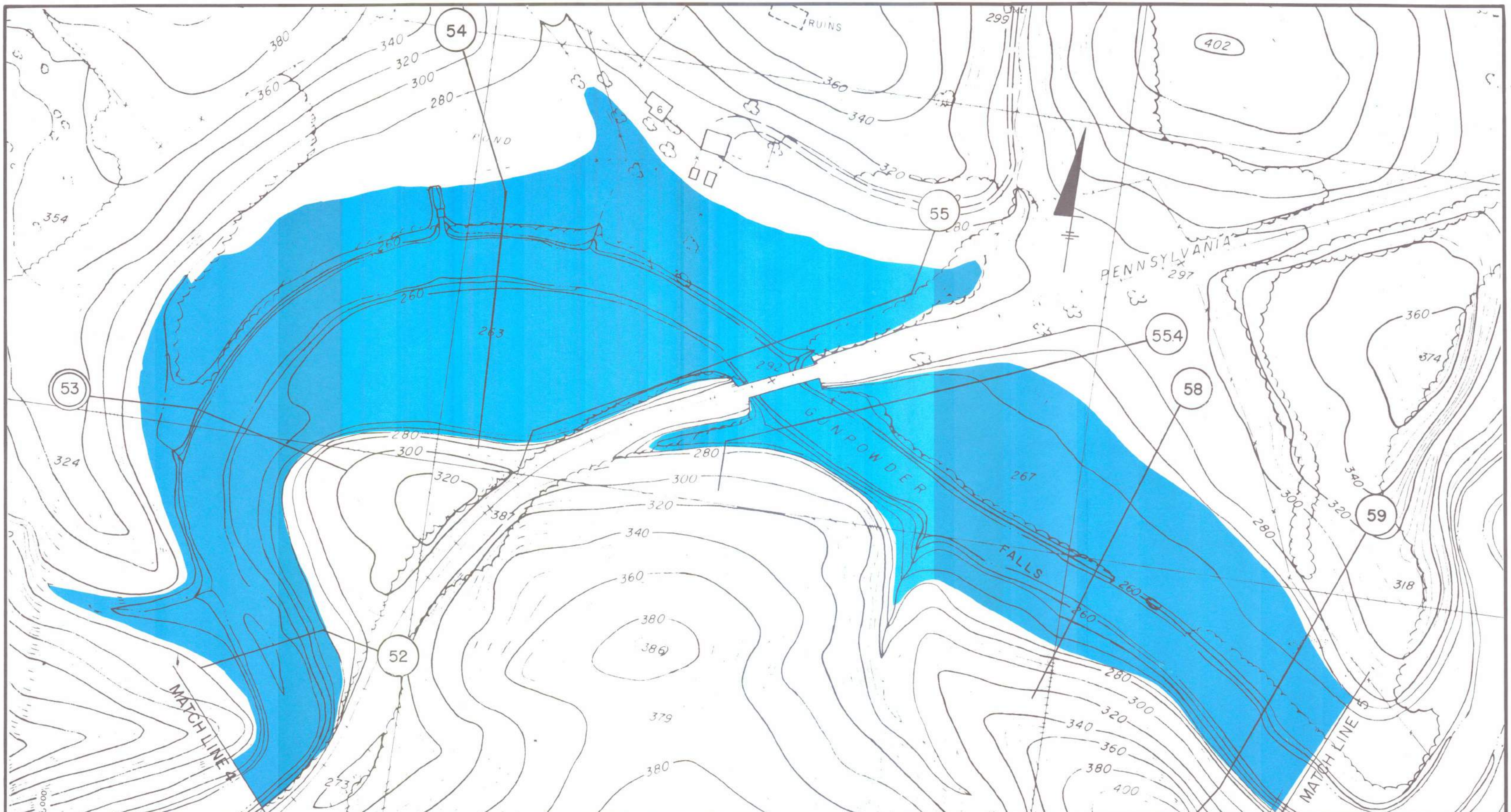
GUNPOWDER FALLS

LIMITS OF 100 YEAR FLOOD
ULTIMATE DEVELOPMENT

DRAWING NO.
5 of 13



PURDUM & JESCHKE CONSULTING ENGINEERS LAND SURVEYORS	**LEGEND** 100 YEAR FLOOD — CROSS SECTION (47) CROSS SECTION NUMER [3] STRUCTURE NUMBER (36) CROSS SECTION WHERE STREAM FLOW HAS CHANGED (TR-20 REACH SECTION) FIRST FL. ABOVE FLOOD EL. FIRST FL. BELOW FLOOD EL. SCALE IN FEET 0 100 200 300	STREAM PLAN	GUNPOWDER FALLS LIMIT OF 100 YEAR FLOOD ULTIMATE DEVELOPMENT	DRAWING NO. 6 of 13



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

- 100 YEAR FLOOD
- CROSS SECTION
- (47) CROSS SECTION NUMER
- [3] STRUCTURE NUMBER
- (36) CROSS SECTION WHERE STREAM FLOW HAS CHANGED (TR-20 REACH SECTION)
- FIRST FL. ABOVE FLOOD EL.
- FIRST FL. BELOW FLOOD EL.

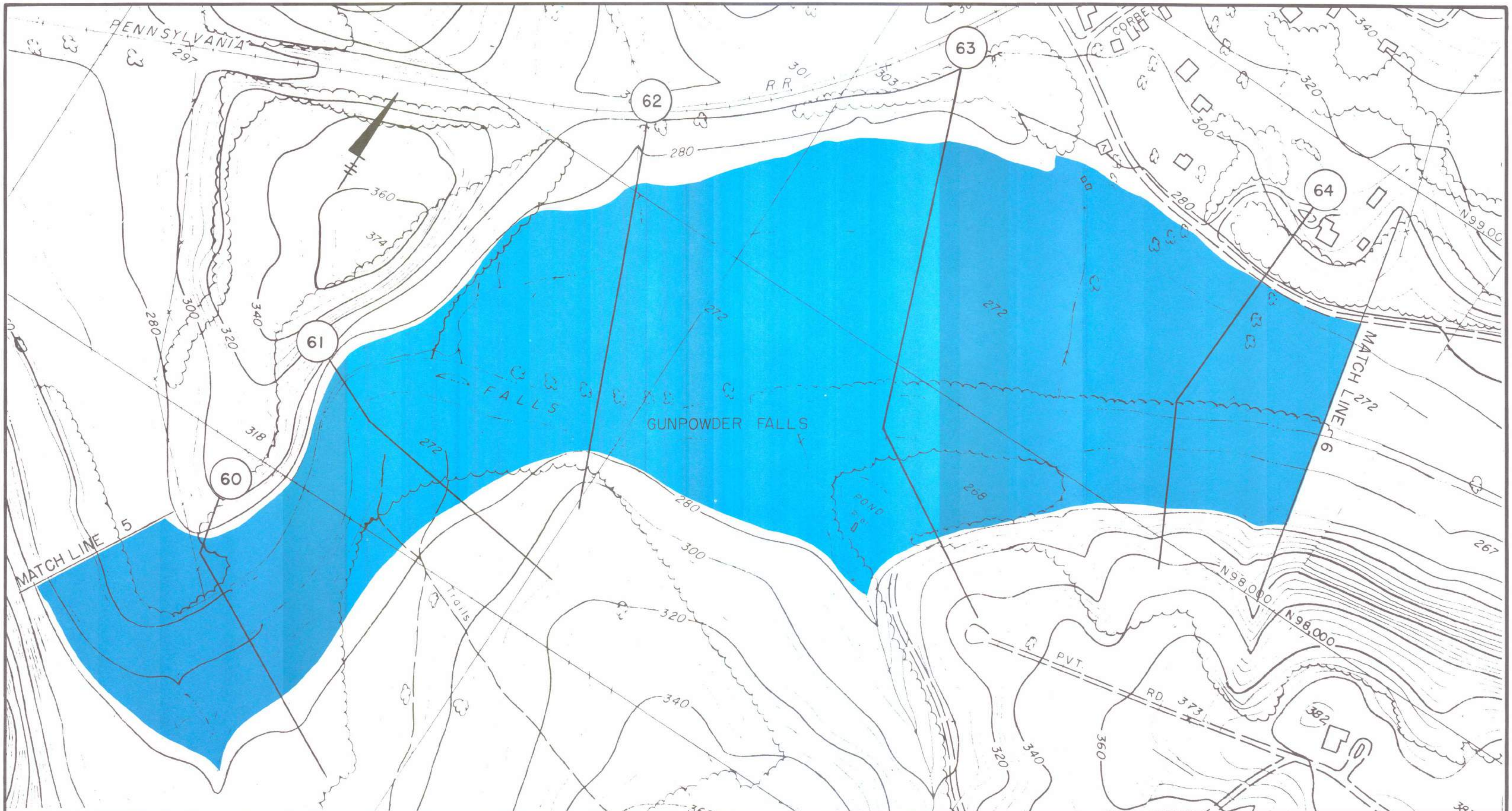
SCALE IN FEET
0 100 200 300

STREAM PLAN

GUNPOWDER FALLS

LIMIT OF 100 YEAR FLOOD
ULTIMATE DEVELOPMENT

DRAWING NO.
7 of 13



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

- 100 YEAR FLOOD
- CROSS SECTION
- (47) CROSS SECTION NUMER
- [3] STRUCTURE NUMBER
- (36) CROSS SECTION WHERE STREAM FLOW HAS CHANGED (TR-20 REACH SECTION)
- FIRST FL. ABOVE FLOOD EL.
- FIRST FL. BELOW FLOOD EL.

SCALE IN FEET
0 100 200 300

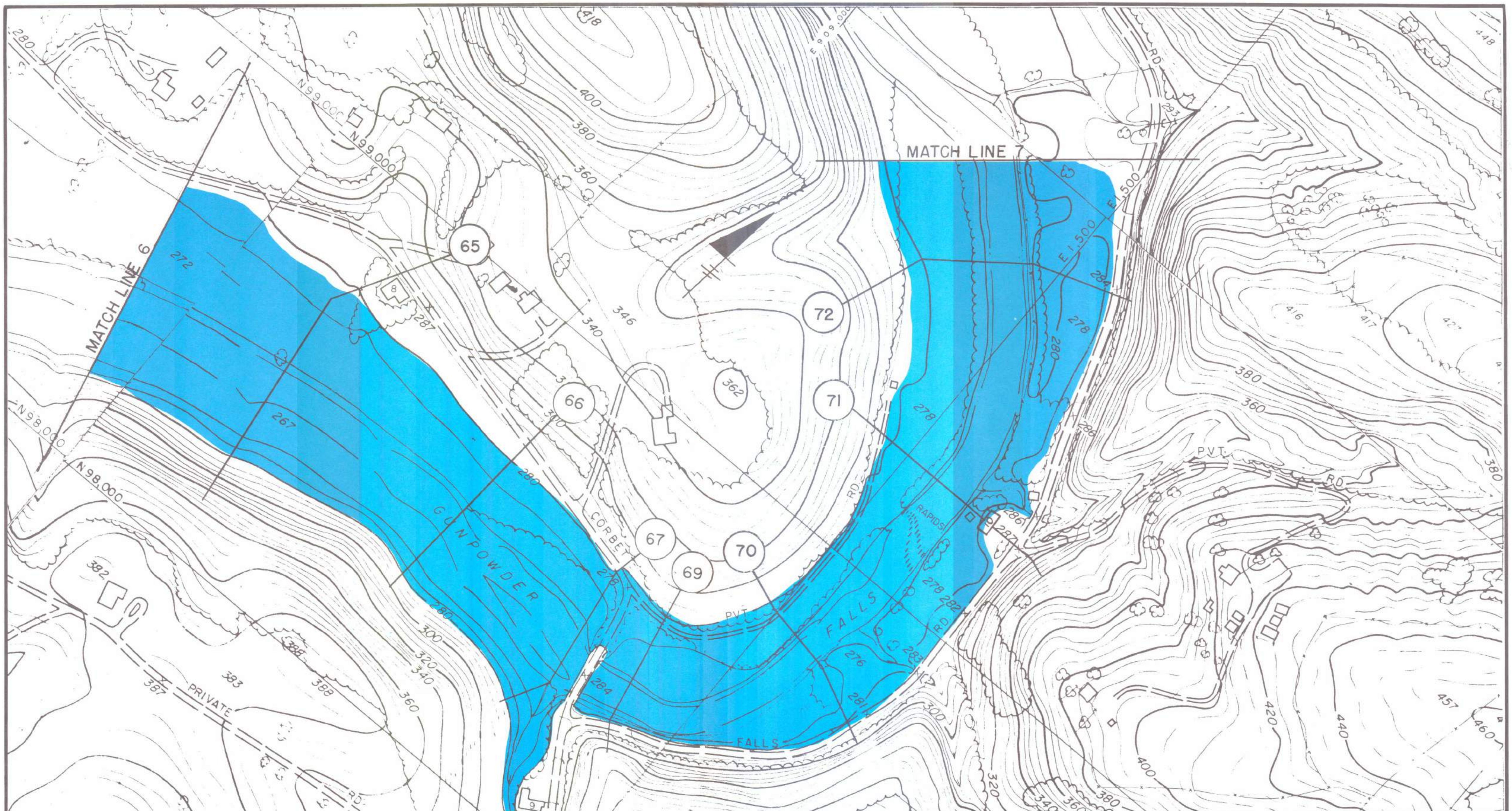
STREAM PLAN

GUNPOWDER FALLS

LIMITS OF 100 YEAR FLOOD
ULTIMATE DEVELOPMENT

DRAWING NO.

8 of 13



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

- 100 YEAR FLOOD
- CROSS SECTION
- (47) CROSS SECTION NUMER
- [3] STRUCTURE NUMBER
- (36) CROSS SECTION WHERE STREAM FLOW HAS CHANGED (TR-20 REACH SECTION)
- FIRST FL. ABOVE FLOOD EL.
- FIRST FL. BELOW FLOOD EL.

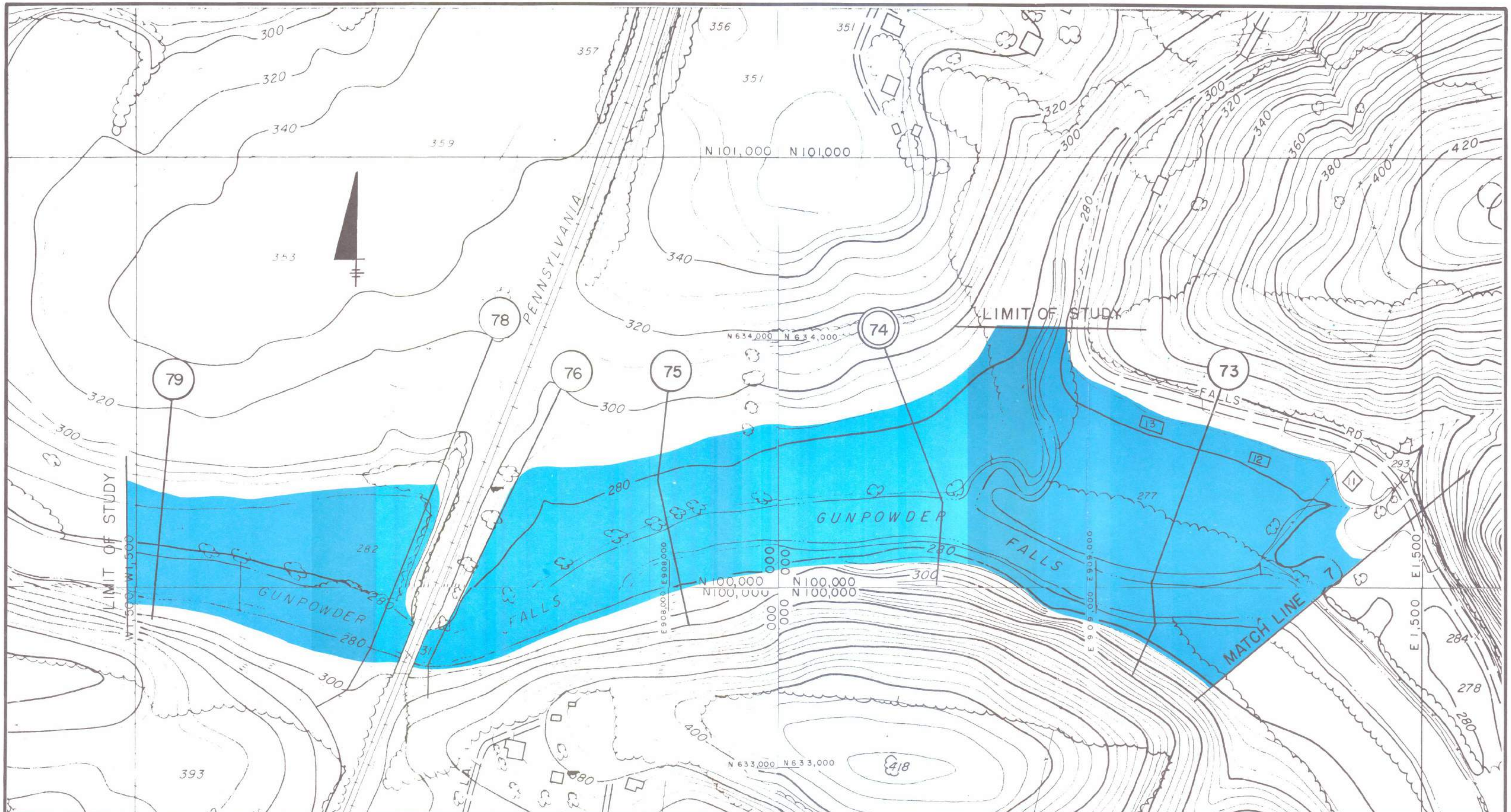
SCALE IN FEET
0 100 200 300

STREAM PLAN

GUNPOWDER FALLS

LIMITS OF 100 YEAR FLOOD
ULTIMATE DEVELOPMENT

DRAWING NO.
9 of 13



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

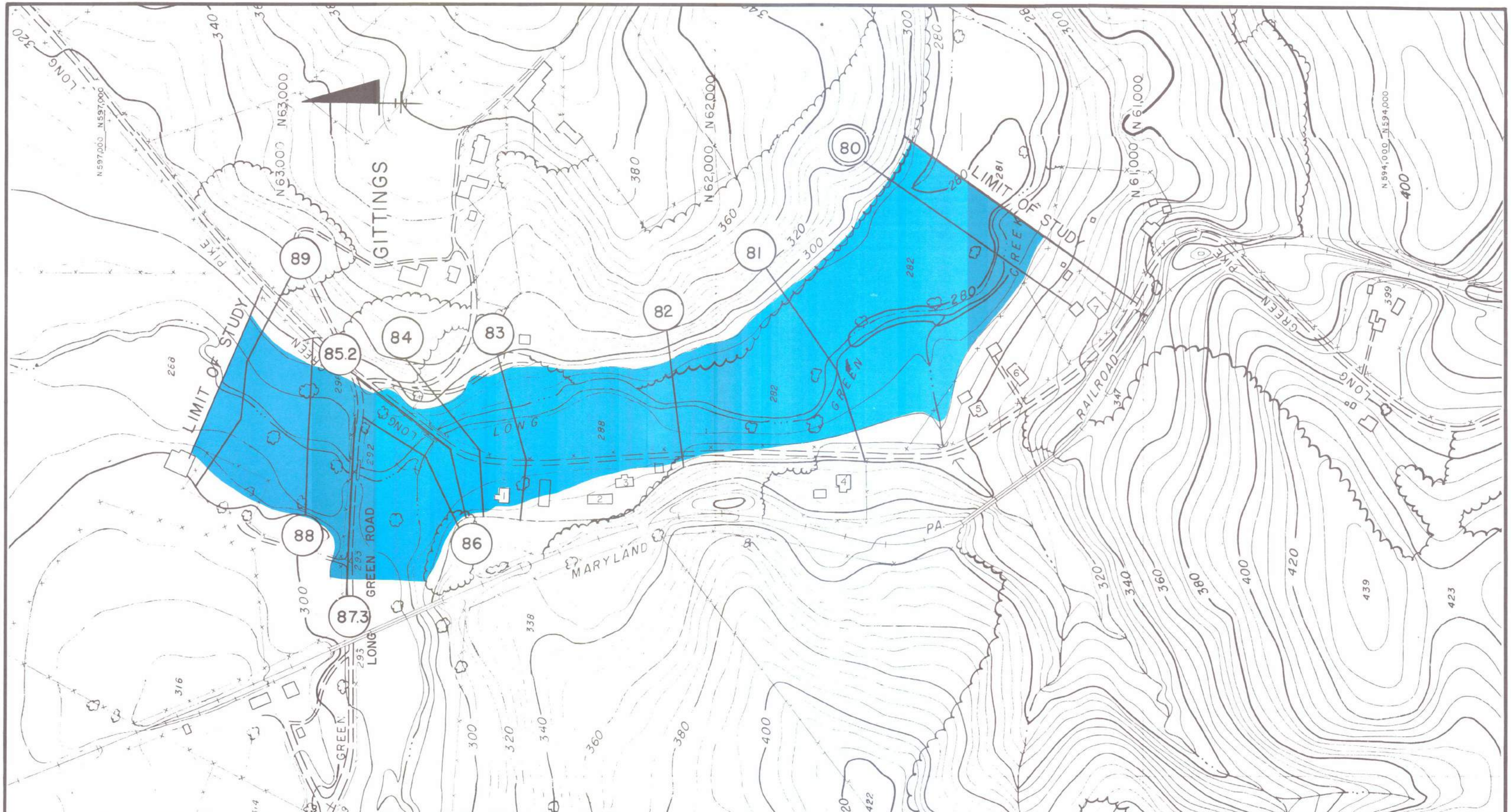
- 100 YEAR FLOOD
- CROSS SECTION
- (47) CROSS SECTION NUMER
- (36) CROSS SECTION WHERE STREAM FLOW HAS CHANGED (TR-20 REACH SECTION)
- 3 STRUCTURE NUMBER
- FIRST FL. BELOW FLOOD EL.
- FIRST FL. ABOVE FLOOD EL.

SCALE IN FEET
0 100 200 300

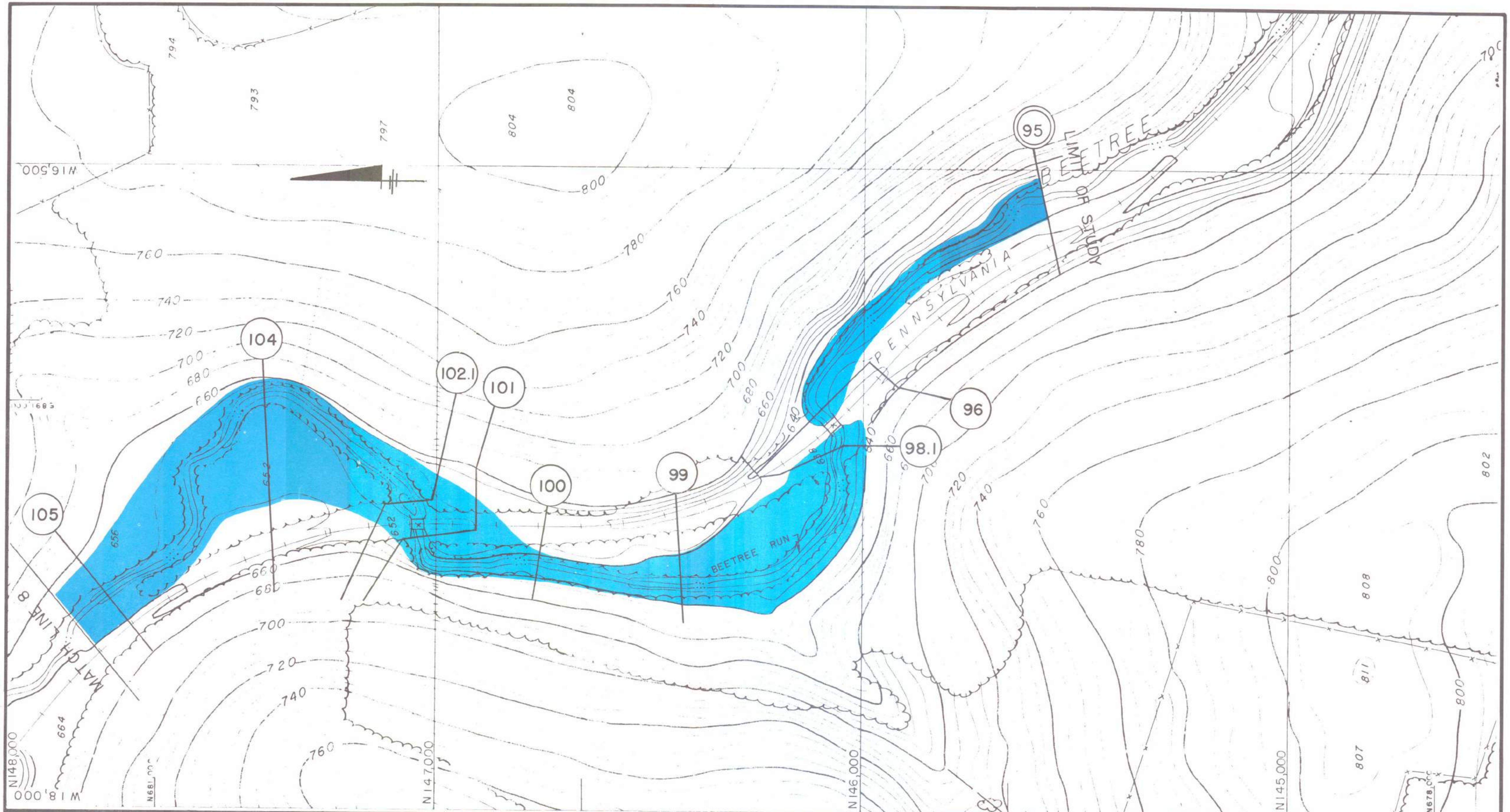
STREAM PLAN

GUNPOWDER FALLS
LIMITS OF 100 YEAR FLOOD
ULTIMATE DEVELOPMENT

DRAWING NO.
10 of 13



PURDUM & JESCHKE CONSULTING ENGINEERS LAND SURVEYORS	**LEGEND** 100 YEAR FLOOD CROSS SECTION (47) CROSS SECTION NUMER (36) CROSS SECTION WHERE STREAM FLOW HAS CHANGED (TR-20 REACH SECTION) 3 STRUCTURE NUMBER FIRST FL. ABOVE FLOOD EL. FIRST FL. BELOW FLOOD EL. SCALE IN FEET 0 100 200 300	STREAM PLAN	LONG GREEN CREEK LIMITS OF 100 YEAR FLOOD ULTIMATE DEVELOPMENT	DRAWING NO. 11 of 13



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

- 100 YEAR FLOOD
- CROSS SECTION
- (47) CROSS SECTION NUMER
- [3] STRUCTURE NUMBER
- (36) CROSS SECTION WHERE STREAM FLOW HAS CHANGED (TR-20 REACH SECTION)
- FIRST FL. BELOW FLOOD EL.
- FIRST FL. ABOVE FLOOD EL.

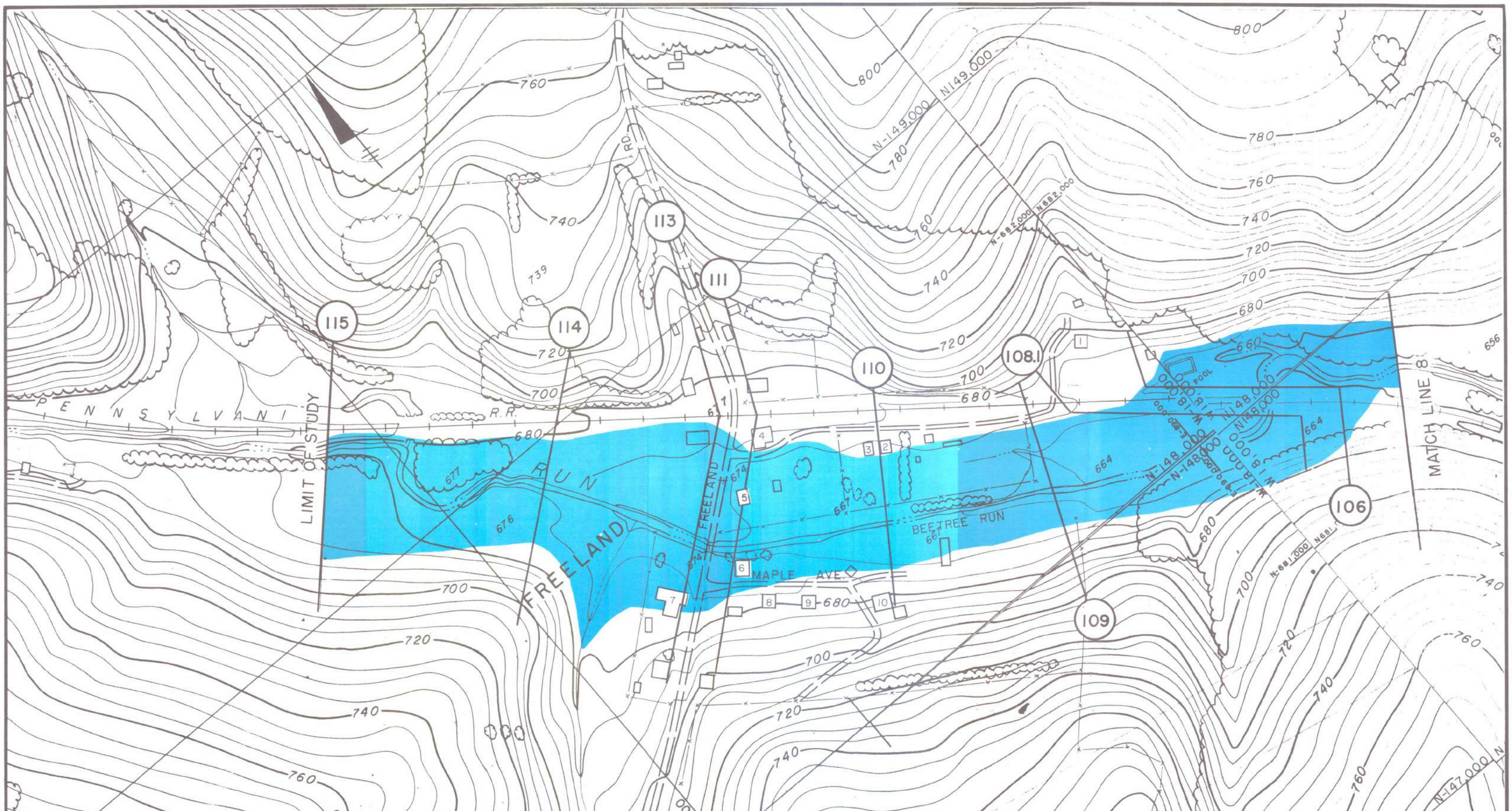
SCALE IN FEET
0 100 200 300

STREAM PLAN

BEETREE RUN

LIMIT OF 100 YEAR FLOOD
ULTIMATE DEVELOPMENT

DRAWING NO.
12 of 13



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

100 YEAR FLOOD
CROSS SECTION
47 CROSS SECTION NUMER
3 STRUCTURE NUMBER
36 CROSS SECTION WHERE STREAM FLOW HAS CHANGED (TR-20 REACH SECTION)
FIRST FL. ABOVE FLOOD EL.
FIRST FL. BELOW FLOOD EL.

SCALE IN FEET
0 100 200 300

STREAM PLAN

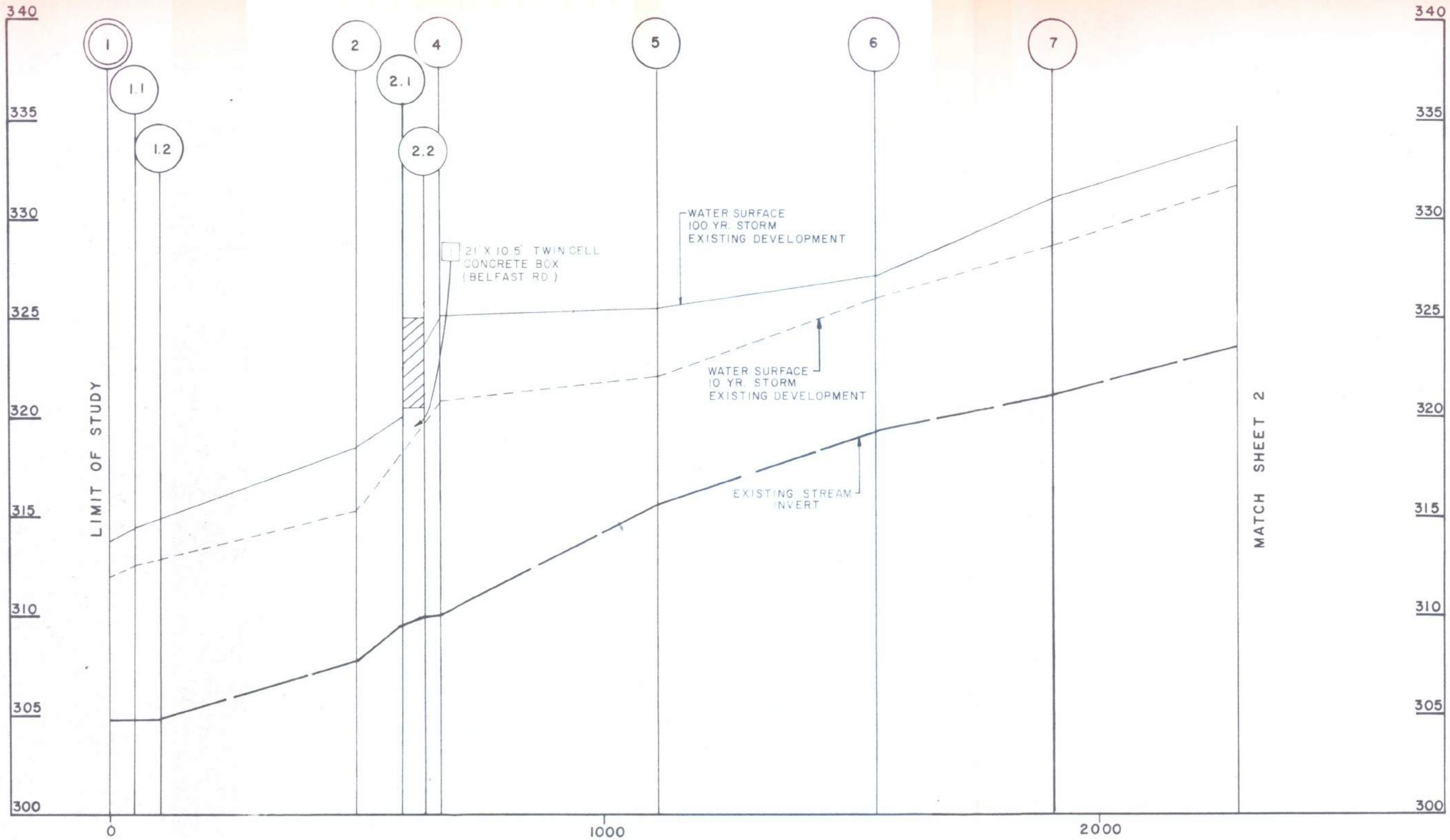
BEETREE RUN

LIMITS OF 100 YEAR FLOOD
ULTIMATE DEVELOPMENT

DRAWING NO.
13 of 13

APPENDIX G

WATER SURFACE PROFILES



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

(4.0) CROSS SECTION NUMBER & LOCATION

(4.0) CROSS SECTION WHERE STREAM FLOW HAS CHANGED

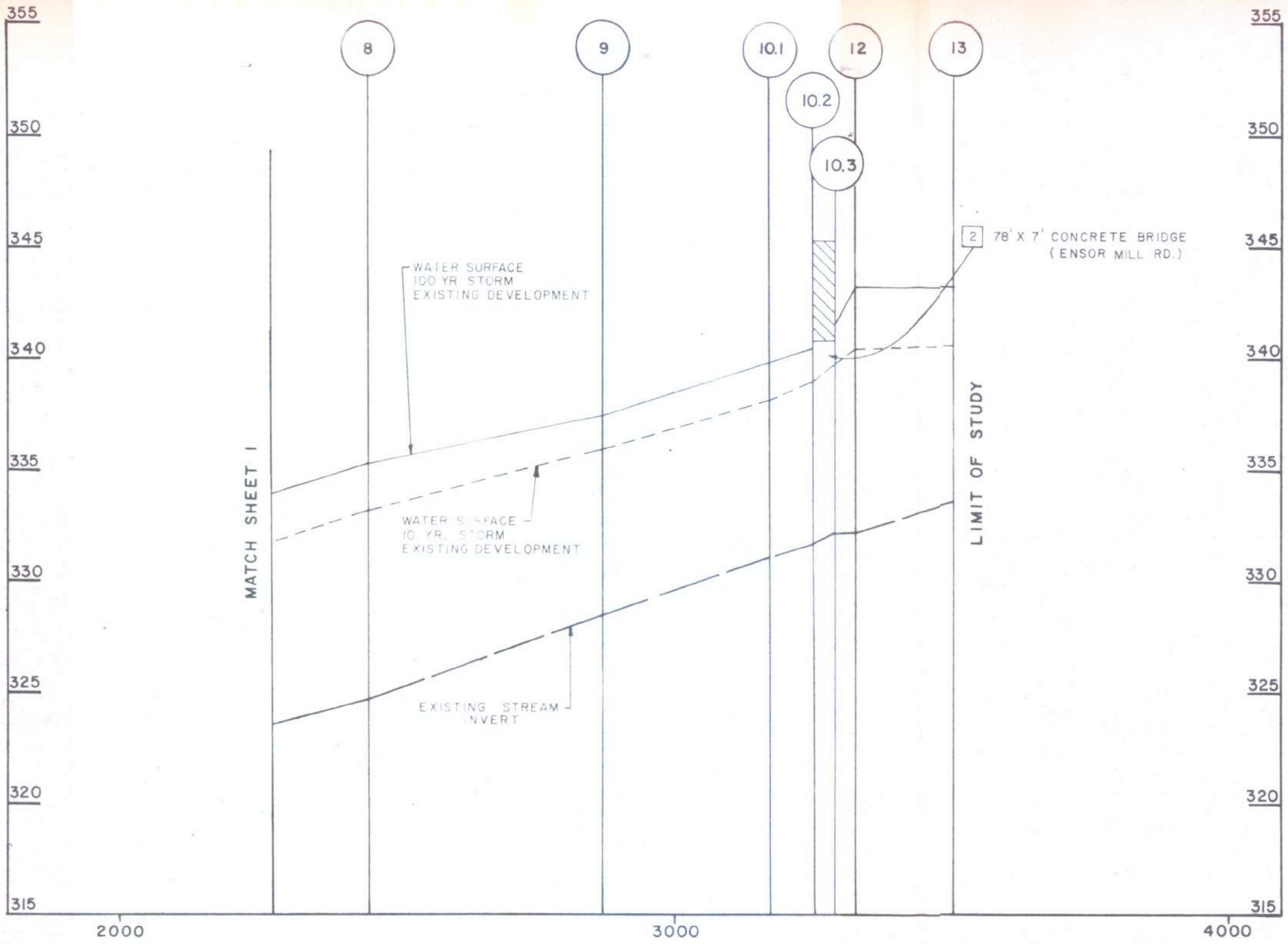
[3] STRUCTURE NUMBER

SCALE
HORIZONTAL 1" = 200'
VERTICAL 1" = 5'

STREAM PROFILE

UPPER PINEY CREEK
EXISTING
DEVELOPMENT

SHEET NO.
1 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

4.0 CROSS SECTION NUMBER & LOCATION

3 STRUCTURE NUMBER

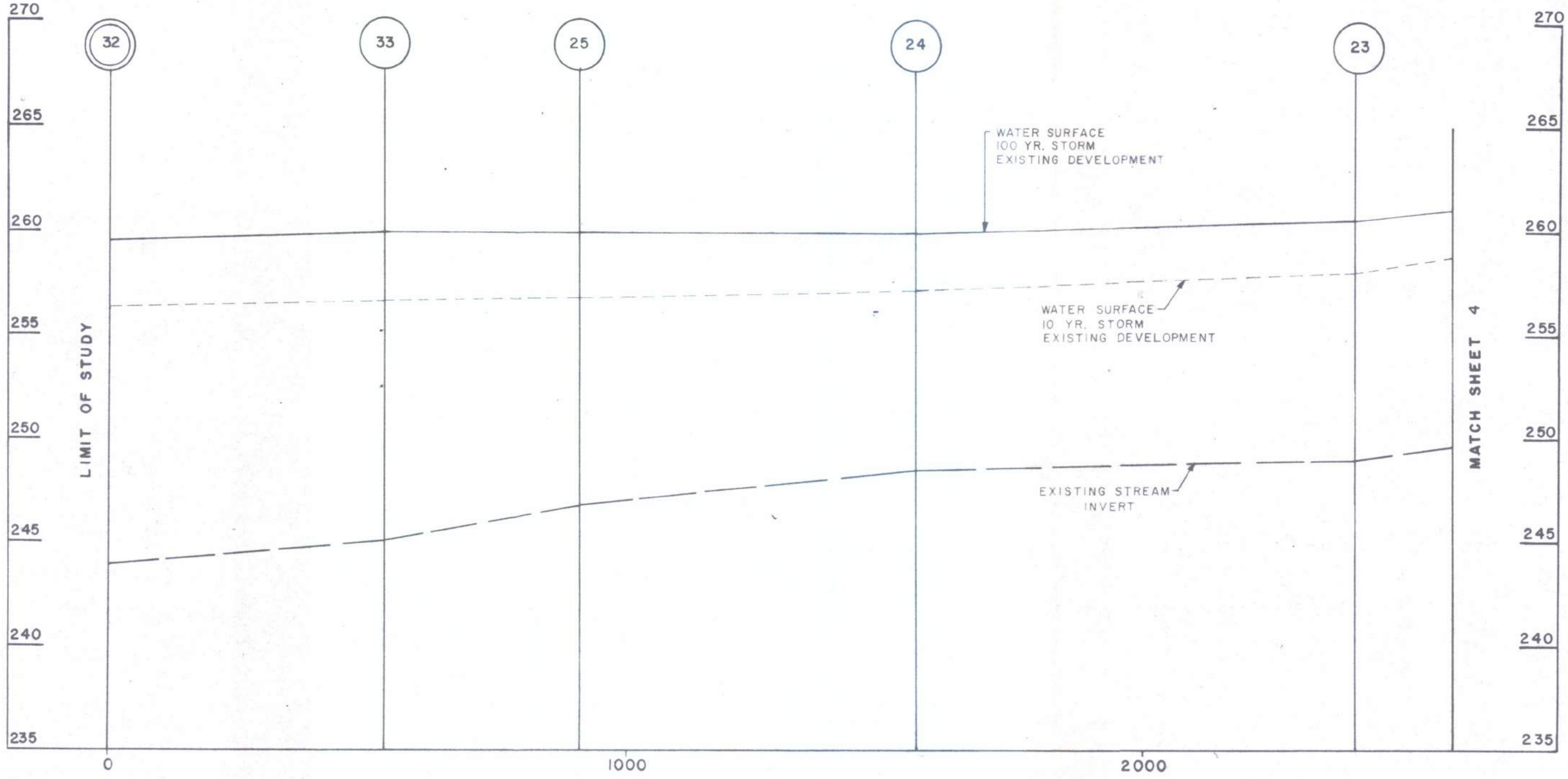
4.0 CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL 1" = 200'
VERTICAL 1" = 5'

STREAM PROFILE

UPPER PINEY CREEK EXISTING DEVELOPMENT

SHEET NO. 2 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

CROSS SECTION NUMBER & LOCATION

STRUCTURE NUMBER

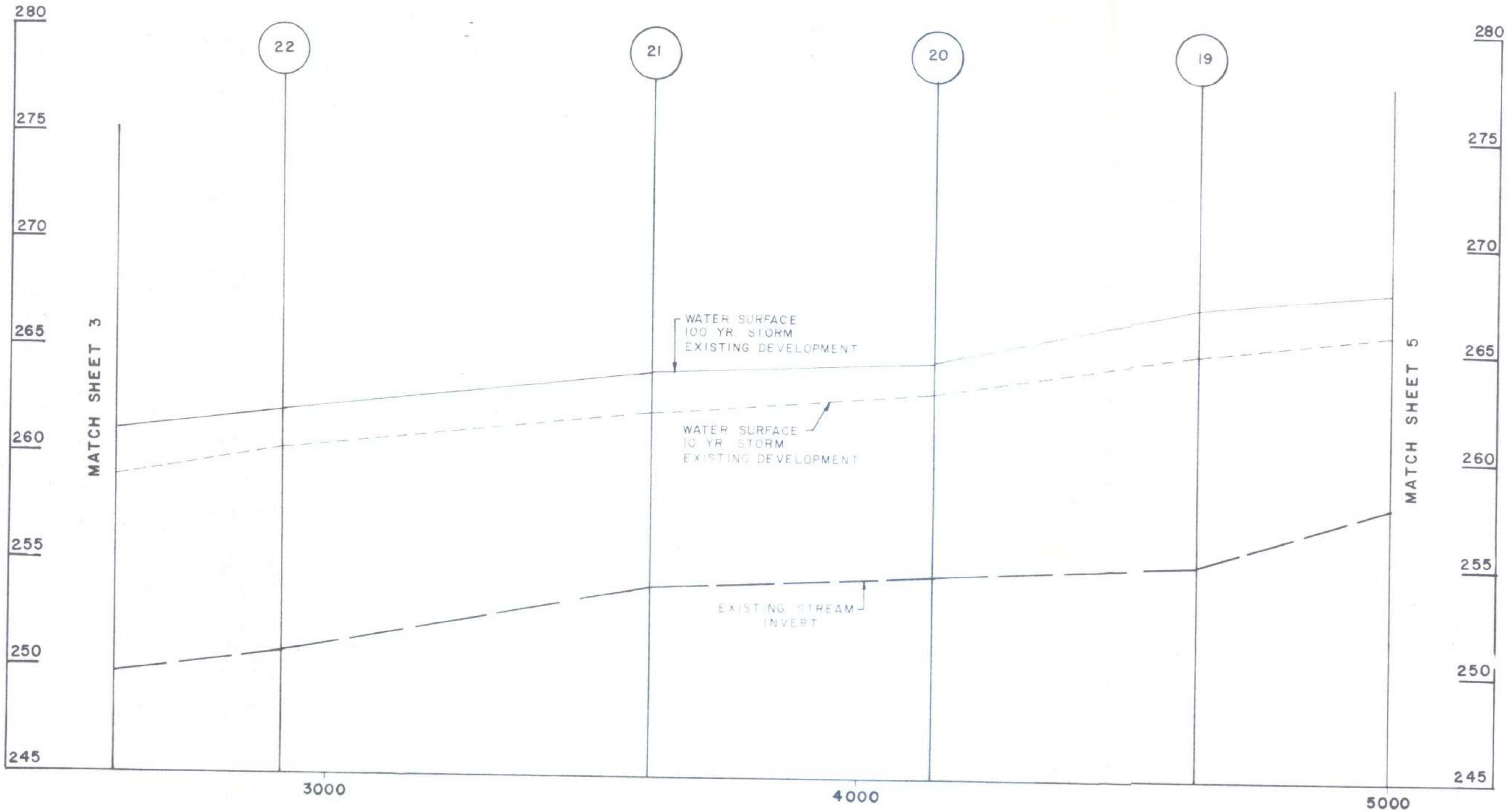
CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL 1" = 200'
VERTICAL 1" = 5'

STREAM PROFILE

LOWER PINEY CREEK EXISTING DEVELOPMENT

SHEET NO.
3 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

CROSS SECTION NUMBER & LOCATION

STRUCTURE NUMBER

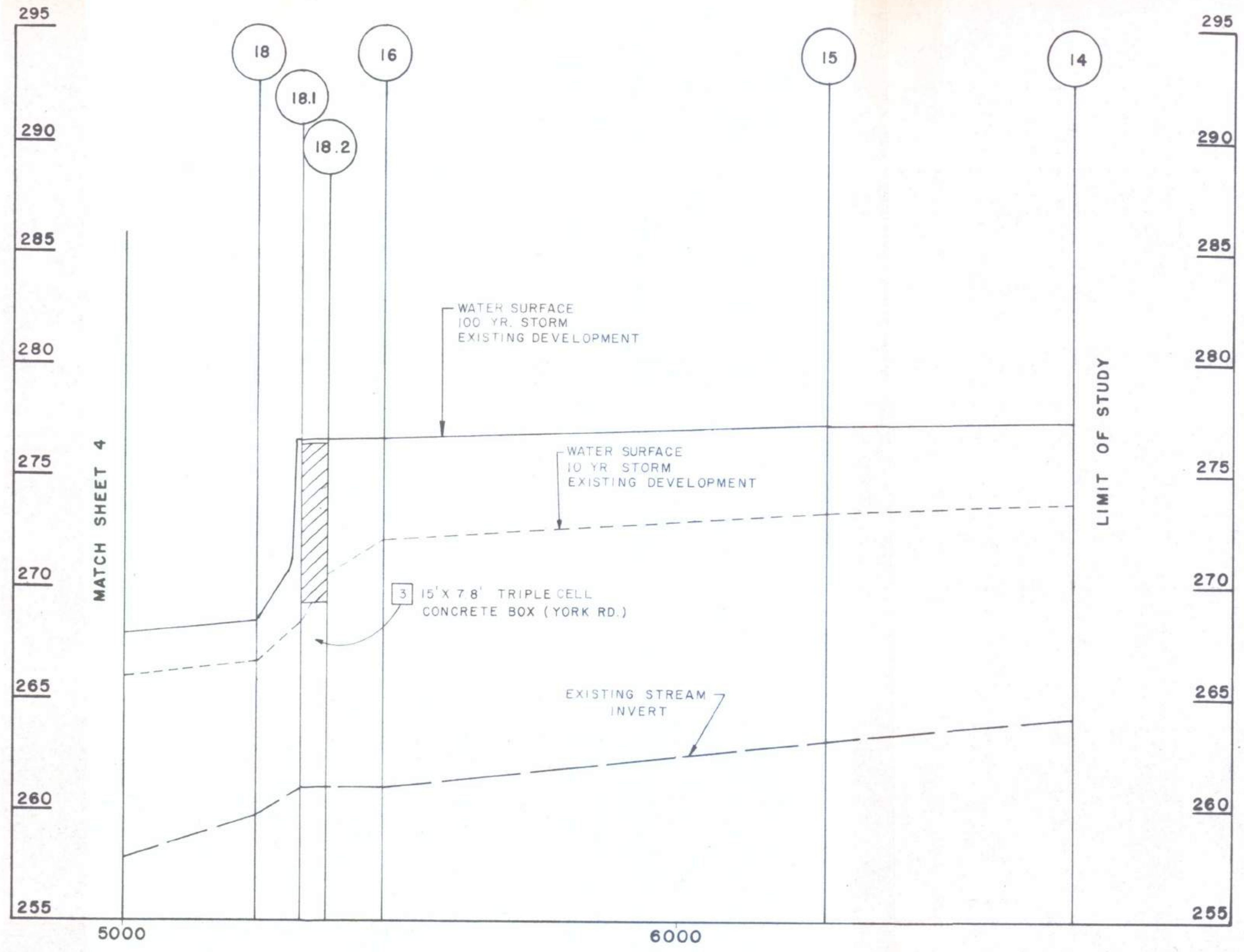
CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL 1" = 200'
VERTICAL 1" = 5'

STREAM PROFILE

LOWER PINEY CREEK
EXISTING
DEVELOPMENT

SHEET NO.
4 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

(4.0) CROSS SECTION NUMBER & LOCATION

[3] STRUCTURE NUMBER

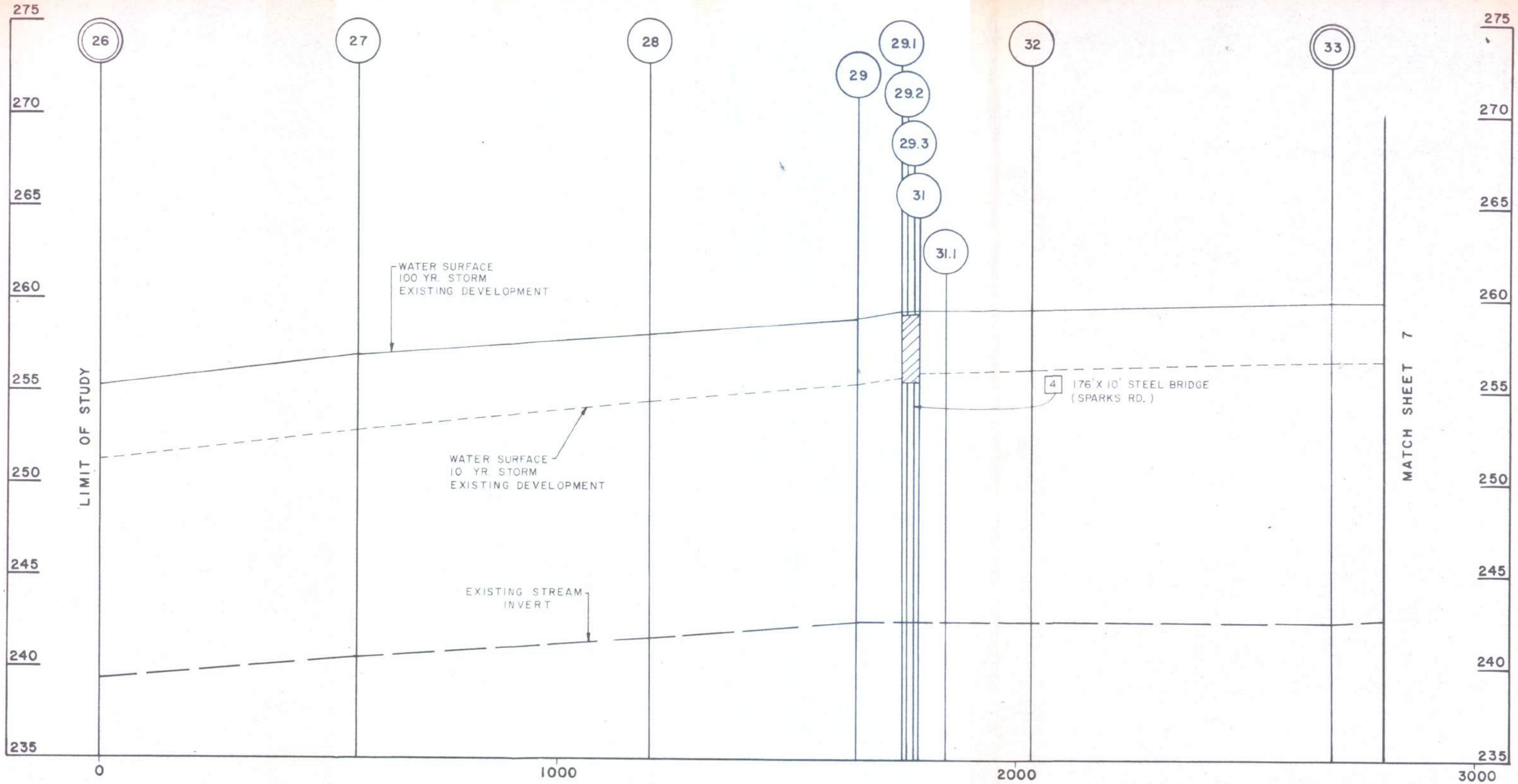
(4.0) CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL: 1" = 200'
VERTICAL: 1" = 5'

STREAM PROFILE

LOWER PINEY CREEK
EXISTING
DEVELOPMENT

SHEET NO.
5 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

(4.0) CROSS SECTION NUMBER & LOCATION

[3] STRUCTURE NUMBER

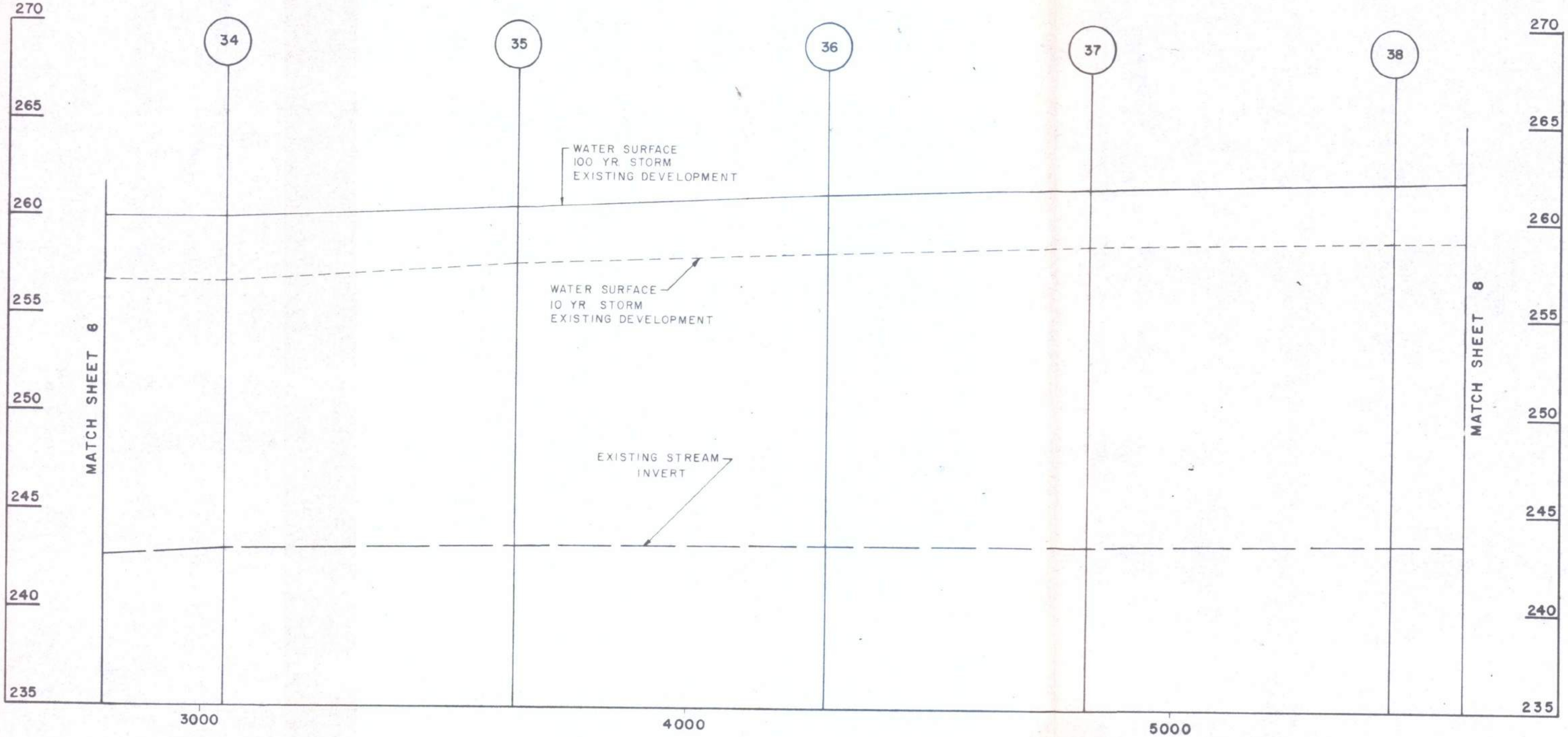
(4.0) CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL: 1" = 200'
VERTICAL: 1" = 5'

STREAM PROFILE

GUNPOWDER FALLS
EXISTING
DEVELOPMENT

SHEET NO.
6 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

(4.0) CROSS SECTION NUMBER & LOCATION

[3] STRUCTURE NUMBER

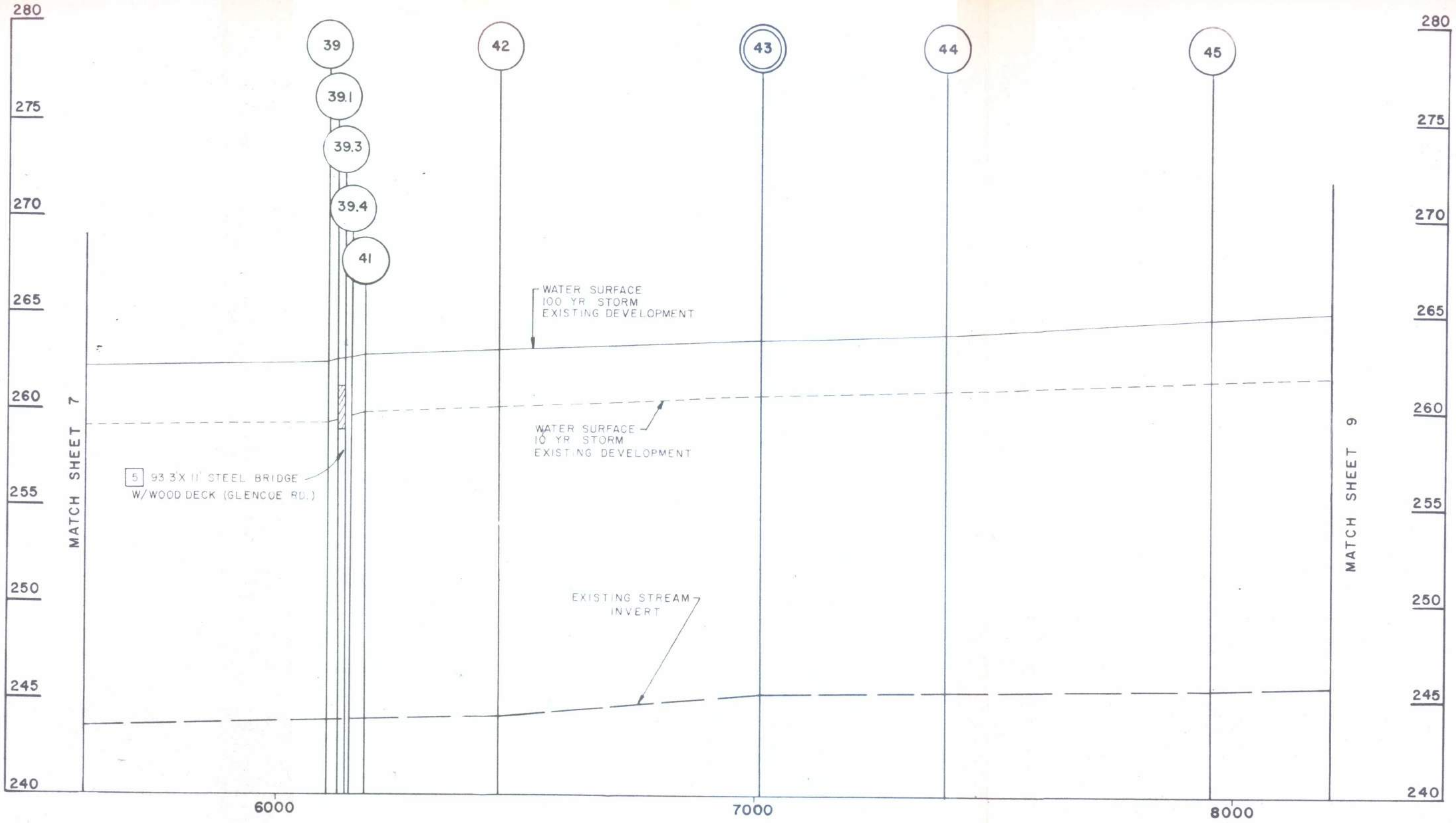
(4.0) CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL: 1" = 200'
VERTICAL: 1" = 5'

STREAM PROFILE

GUNPOWDER FALLS
EXISTING
DEVELOPMENT

SHEET NO.
7 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

4.0 CROSS SECTION NUMBER & LOCATION

3 STRUCTURE NUMBER

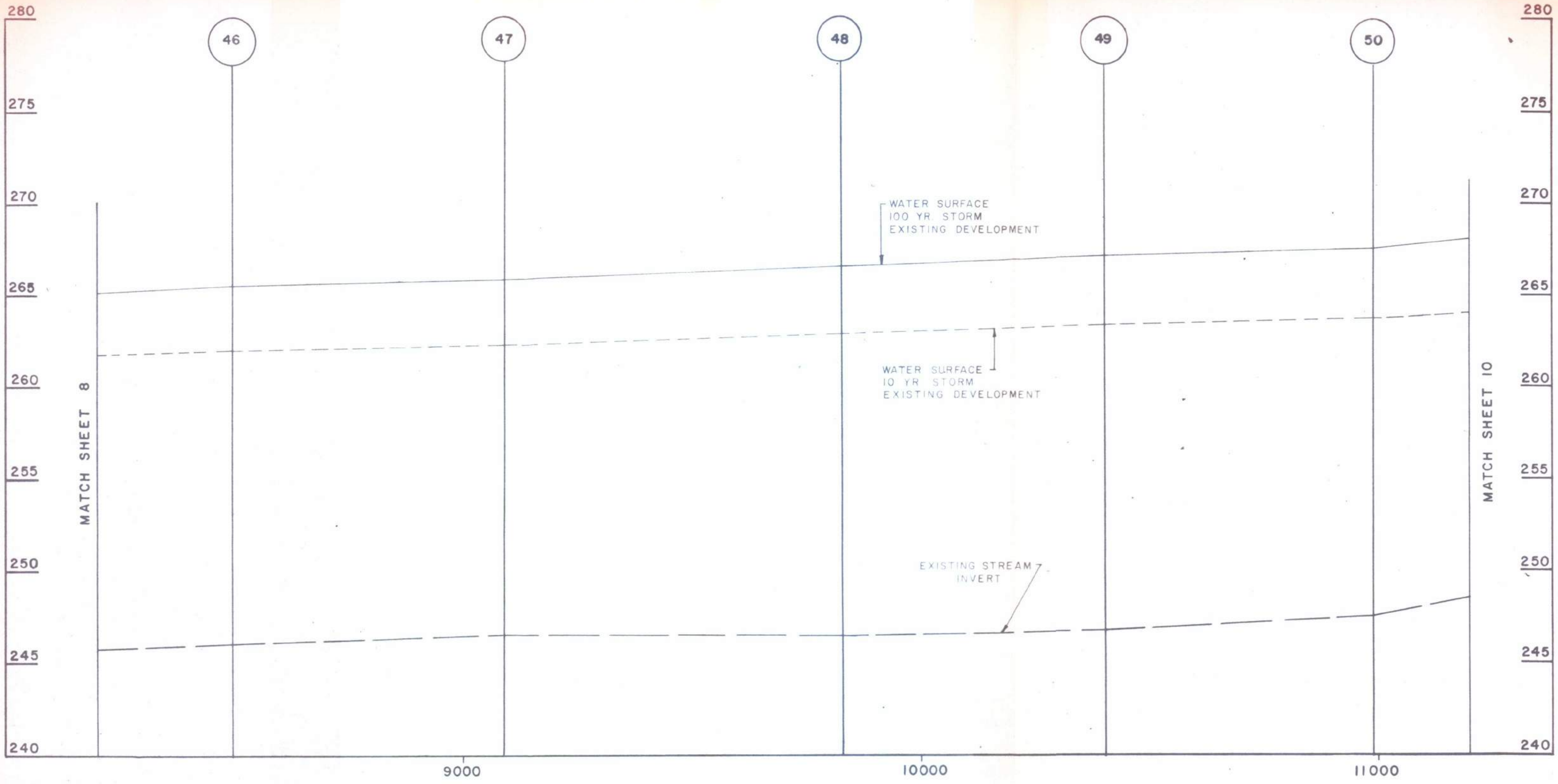
4.0 CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL 1" = 200'
VERTICAL 1" = 5'

STREAM PROFILE

GUNPOWDER FALLS
EXISTING
DEVELOPMENT

SHEET NO.
8 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

(40) CROSS SECTION NUMBER & LOCATION

[3] STRUCTURE NUMBER

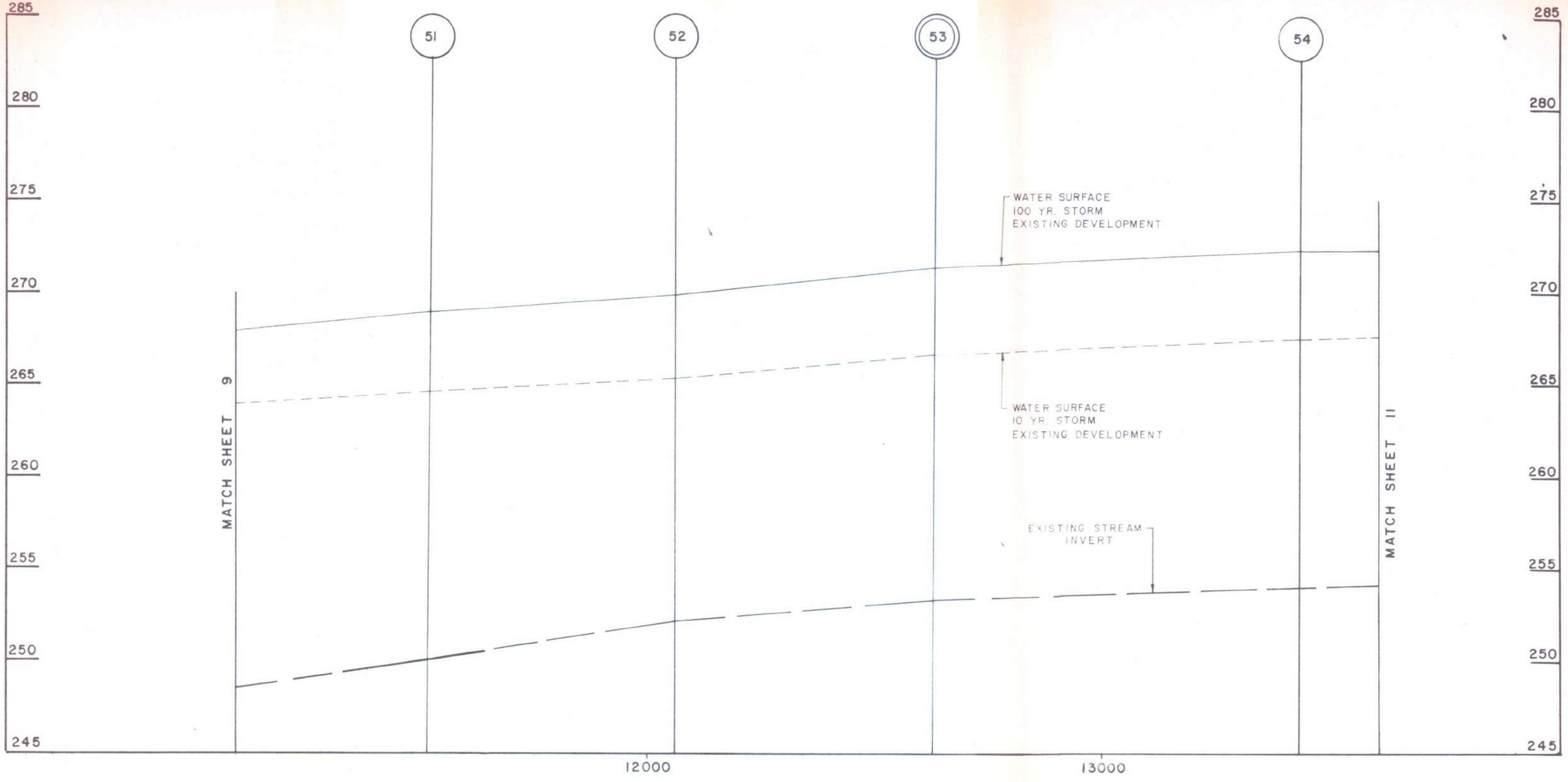
((40)) CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL 1" = 200'
VERTICAL 1" = 5'

STREAM PROFILE

GUNPOWDER FALLS
EXISTING
DEVELOPMENT

SHEET NO.
9 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

CROSS SECTION NUMBER & LOCATION

STRUCTURE NUMBER

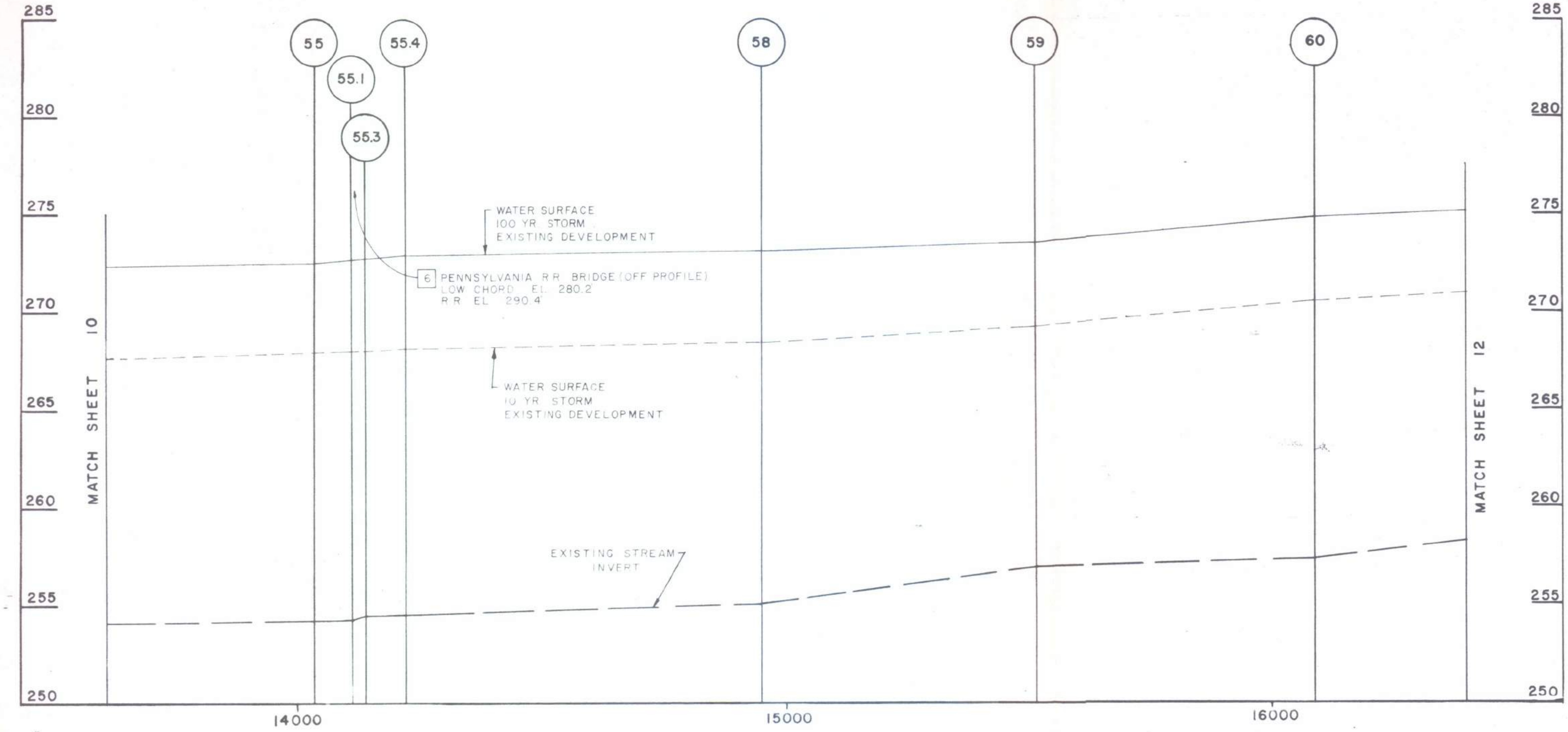
CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL 1" = 200'
VERTICAL 1" = 5'

STREAM PROFILE

GUNPOWDER FALLS
EXISTING
DEVELOPMENT

SHEET NO.
10 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

4.0 CROSS SECTION NUMBER & LOCATION

3 STRUCTURE NUMBER

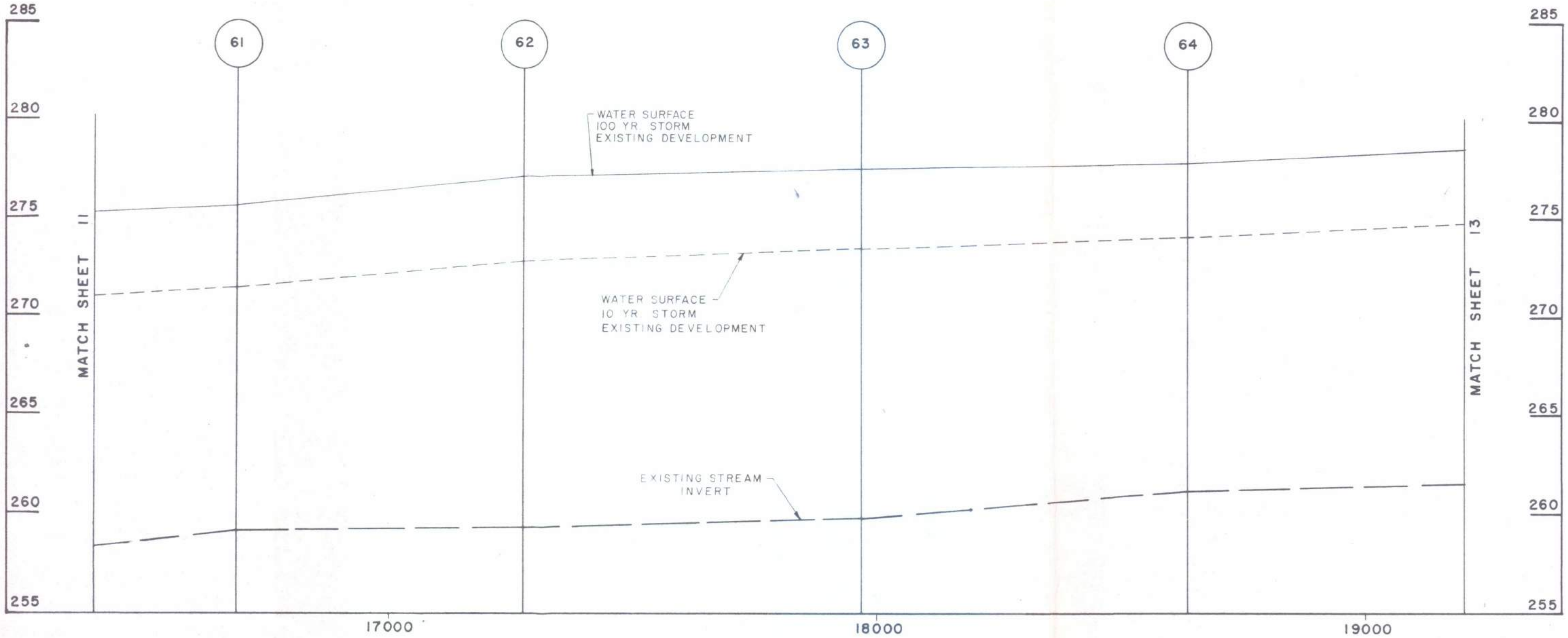
4.0 CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL: 1" = 200'
VERTICAL: 1" = 5'

STREAM PROFILE

GUNPOWDER FALLS
EXISTING
DEVELOPMENT

SHEET NO.
11 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

(4.0) CROSS SECTION NUMBER & LOCATION

[3] STRUCTURE NUMBER

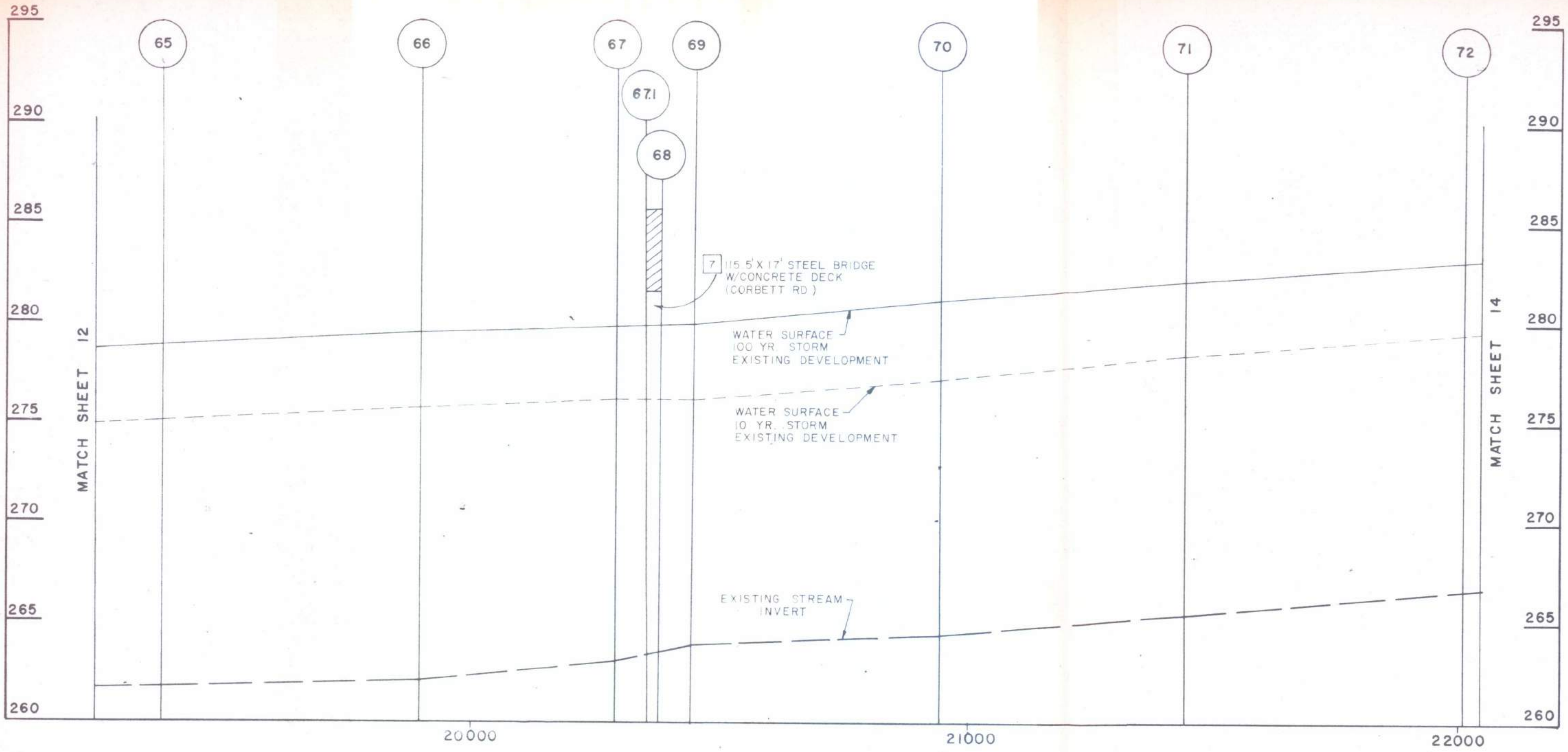
(4.0) CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL: 1" = 200'
VERTICAL: 1" = 5'

STREAM PROFILE

GUNPOWDER FALLS
EXISTING
DEVELOPMENT

SHEET NO.
12 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

(40) CROSS SECTION NUMBER & LOCATION

[3] STRUCTURE NUMBER

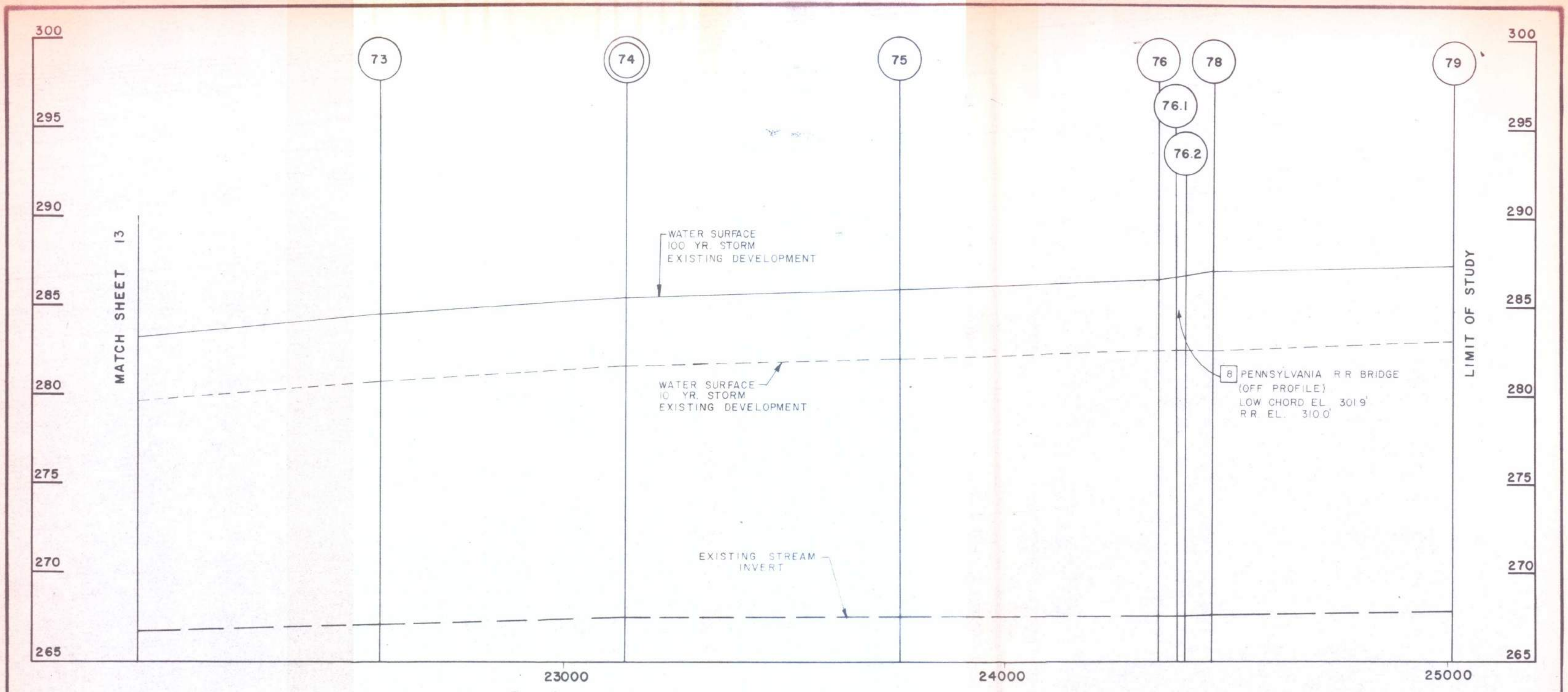
(40) CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL 1" = 200'
VERTICAL 1" = 5'

STREAM PROFILE

GUNPOWDER FALLS
EXISTING
DEVELOPMENT

SHEET NO.
13 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

(4.0) CROSS SECTION NUMBER & LOCATION

[3] STRUCTURE NUMBER

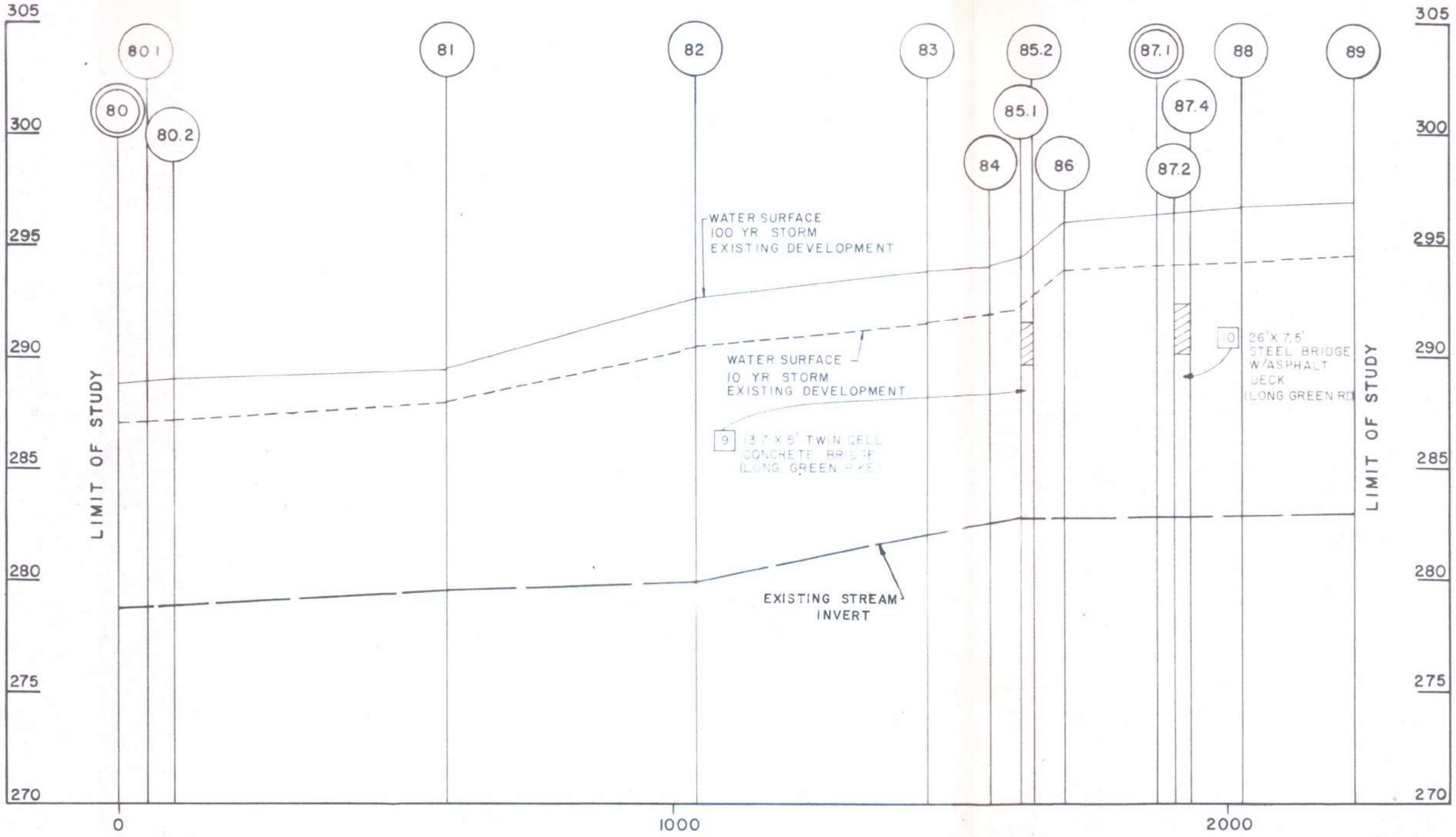
(4.0) CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL: 1" = 200'
VERTICAL: 1" = 5'

STREAM PROFILE

GUNPOWDER FALLS
EXISTING
DEVELOPMENT

SHEET NO.
14 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

CROSS SECTION NUMBER & LOCATION

STRUCTURE NUMBER

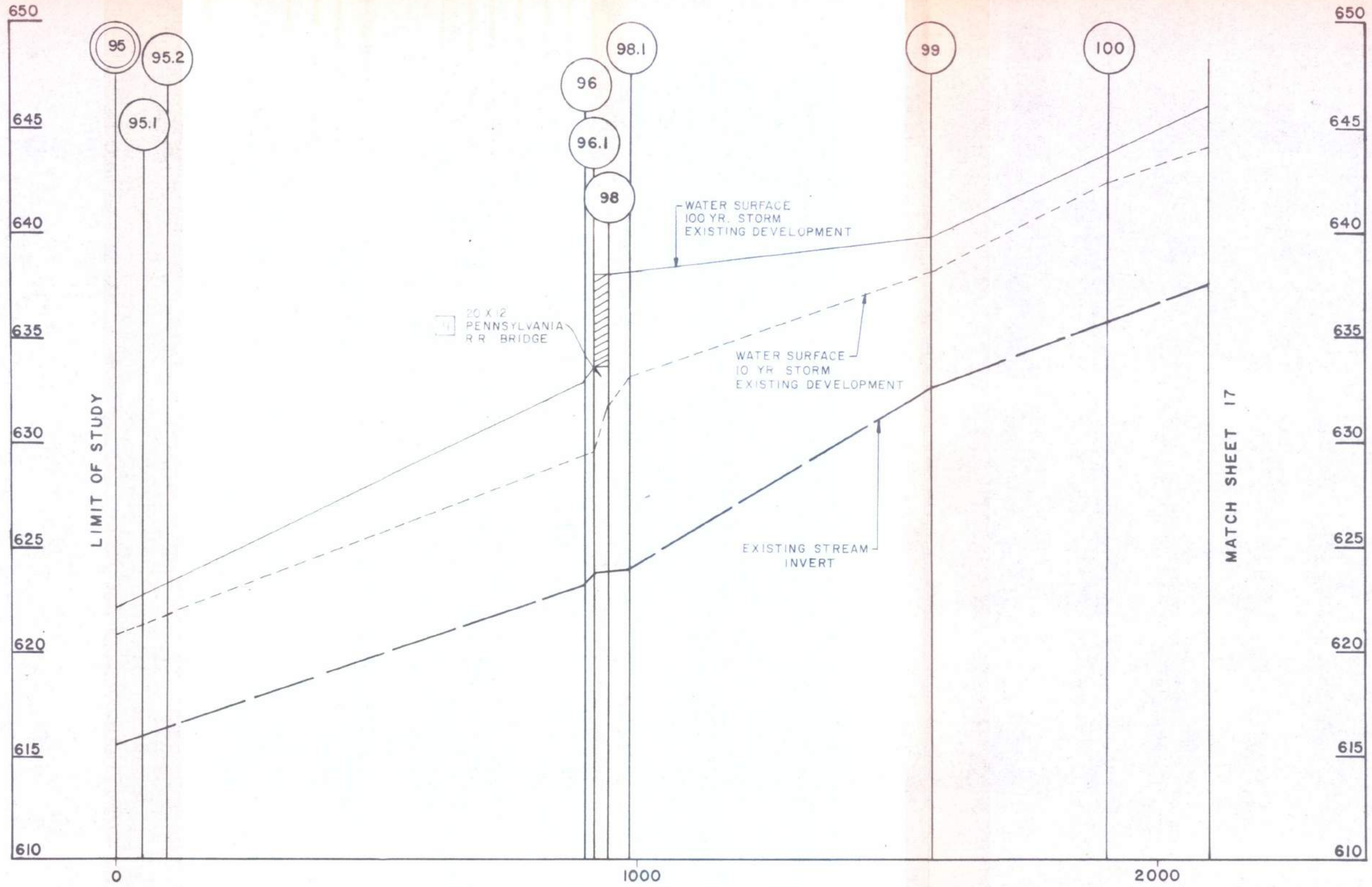
CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL 1" = 200'
VERTICAL 1" = 5'

STREAM PROFILE

LONG GREEN CREEK
EXISTING
DEVELOPMENT

SHEET NO.
15 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

(4.0) CROSS SECTION NUMBER & LOCATION

(4.0) CROSS SECTION WHERE STREAM FLOW HAS CHANGED

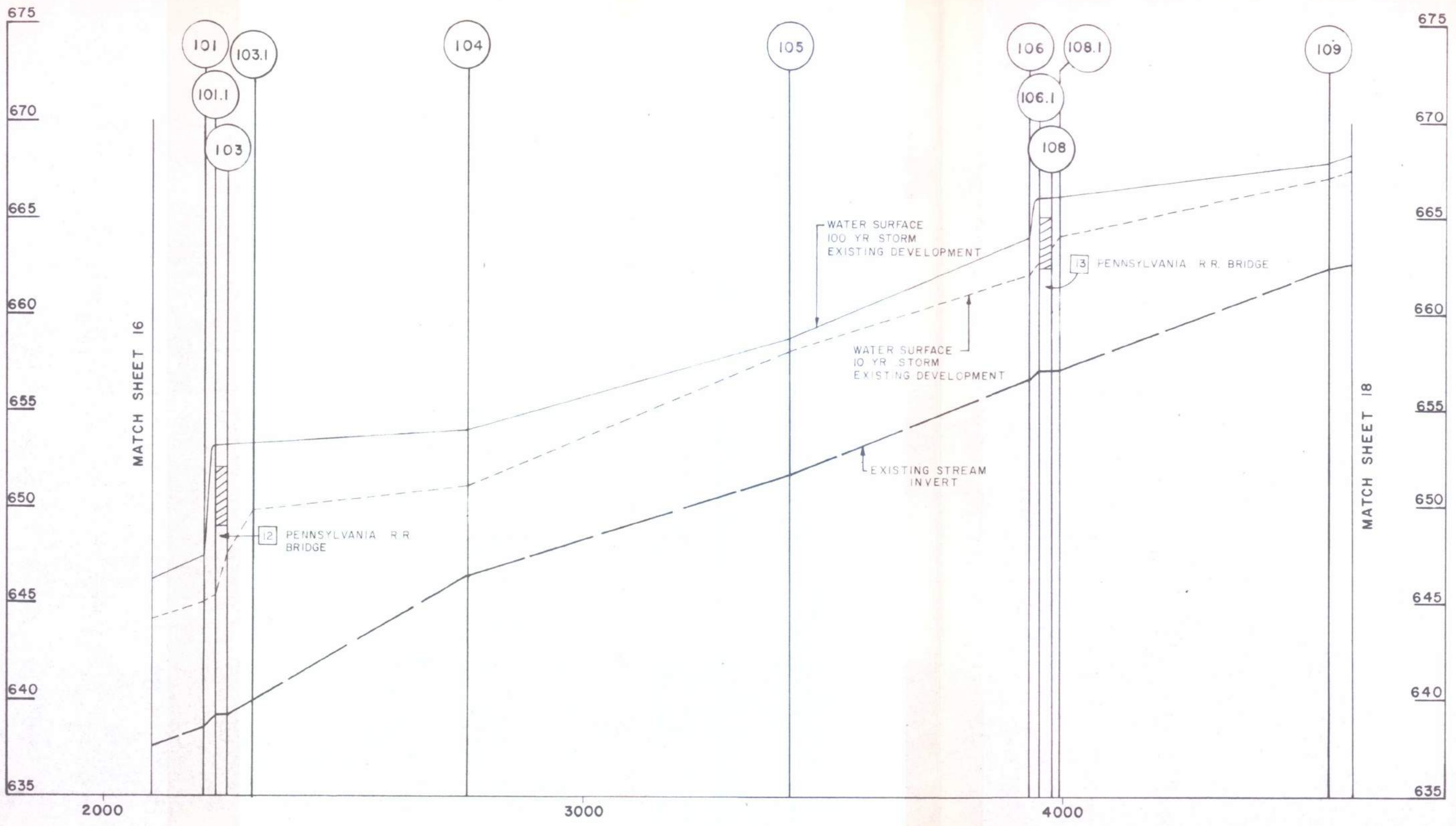
[3] STRUCTURE NUMBER

SCALE
HORIZONTAL 1" = 200'
VERTICAL 1" = 5'

STREAM PROFILE

BEETREE RUN
EXISTING
DEVELOPMENT

SHEET NO.
16 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

(4.0) CROSS SECTION NUMBER & LOCATION

[3] STRUCTURE NUMBER

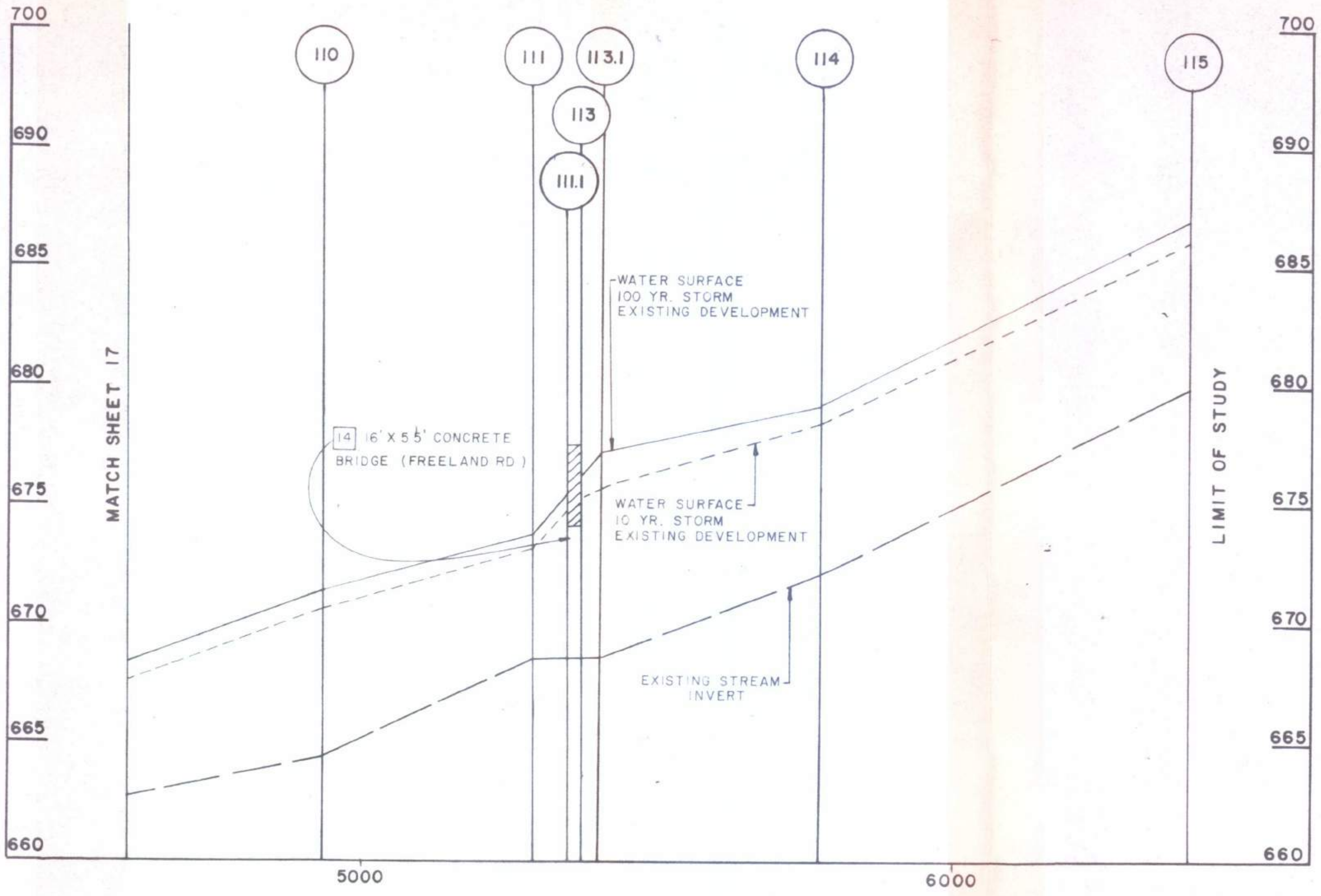
(4.0) CROSS SECTION WHERE STREAM FLOW HAS CHANGED

SCALE
HORIZONTAL 1" = 200'
VERTICAL 1" = 5'

STREAM PROFILE

BEETREE RUN
EXISTING
DEVELOPMENT

SHEET NO.
17 OF 18



PURDUM & JESCHKE
CONSULTING ENGINEERS
LAND SURVEYORS

LEGEND

(4.0) CROSS SECTION NUMBER & LOCATION

(4.0) CROSS SECTION WHERE STREAM FLOW HAS CHANGED

[3] STRUCTURE NUMBER

SCALE
HORIZONTAL: 1" = 200'
VERTICAL: 1" = 5'

STREAM PROFILE

BEETREE RUN
EXISTING
DEVELOPMENT

SHEET NO.
18 OF 18