Development and Analysis of Computer Aided Design and Drafting Software for Storm Sewers

by

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(ABSTRACT)

A software package has been developed for the IBM personal computer that aids engineers in storm sewer design and drafting.

The most unique feature of this software package is its extensive use of the AutoCAD graphics system. The software package uses AutoCAD to enter storm sewer data. Drainage areas, sewer line locations, type of structures, and all other hydrologic parameters can be entered. The software also creates plan and profile drawings of the storm sewer system through AutoCAD. There are other unique features. The software can calculate the hydraulic grade line for the system. If the user enters street centerlines and widths, the program can automatically calculate the exact coordinates for drainage inlet structures located on streets. If contour lines are entered, the program will determine the surface profile above the sewer lines, calculate the approximate elevations of the structures, and check for minimum ground cover when designing the storm sewer system.

Data can be entered two ways in AutoCAD. The first way is to simply enter the numeric values for the parameters. The second way is to enter the raw data and let the program calculate the parameters. An example of this would be, entering a drainage area polygon and letting the program calculate the drainage area, weighted runoff coefficient and the time of concentration.

This software allows the engineer to design and later make changes in the configuration of a storm sewer system quickly and easily.

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Chapter I - Introduction

When building a subdivision the construction of roads and buildings greatly increases the stormwater runoff. Stormwater runoff is the portion of the rainfall which flows over the ground surface during a storm and for a short time after a storm. Without any means to remove this excess runoff, streets and properties will be flooded. To prevent property damage and inconvenience to the public, storm sewer systems are usually built. A storm sewer system is made up of inlet structures that divert surface flow to underground conduits. These conduits then transport the water to a natural stream channel or to some type of detention and infiltration facility.

When designing storm sewer systems the calculations involved and the drafting required is very repetitious. In the past, nomographs or tables were used to speed up hydraulic calculations. With the development of personal computers several software packages have been developed that can perform hydraulic calculations for a storm sewer system. When using such software, hydrologic data (such as drainage areas and surface runoff coefficients) for each of the inlets needs to be calculated by the engineer. These packages usually design a storm sewer system line by line, and data for the system is entered for one line at a time. After the software has finished execution, drafting of the plan and profiles and survey calculations for the exact locations of the structures have to be done. Other types of software now exist that can help with survey calculations and drafting.

Several large software packages exist that perform a wide range of hydraulic and hydrologic calculations such as reservoir routing, stream routing, unit hydrograph calculations (by several different procedures) and backwater curve calculations. Some of these packages have subroutines that can analyze storm sewer pipes, but use of these routines do not save much time when designing a storm sewer system since the system is still designed one line at a time. MIDUSS (Alan A. Smith, Inc., 1986), and PCSWMM (James, Computational Hydraulics, 1986) are examples of this type of software. SDNET (Falk, 1986) is a software package that has been developed specifically to calculate backwater curves in gravity-flow pipes. SDNET can aid in designing storm sewer systems. The package will determine the hydraulic grade line through the system and determine the slopes of the storm sewer lines. All data for the system is typed in and then the software evaluates the storm sewer system. The user interprets the results, makes any desired changes and reruns the program until a satisfactory design has been achieved. The flow must be calculated by the user, and be entered for each storm line. Survey calculations and drafting of the system must then be done by some other means. Recently, two software packages have been developed that will perform some of the drafting and survey calculations for a storm sewer system. These are Dimension-II (sales literature), which uses a Data General computer, and Site Comp II (sales literature), which uses a Hewlett Packard 200 or 300 computer. Neither of these systems is compatible with the IBM personal computer. Dimension-II will take the engineer's completed design notes to produce drawings and help calculate locations of the structures. Site Comp II will do the drafting and help calculate locations of the structures as well as use Manning's equation to size storm sewer pipes. For both packages data is still entered one line at a time. Neither package will consider the ground surface profiles above a sewer line in the design nor automatically calculate a structure's location.

The above are typical examples of software packages that now exist. No software package has yet been developed that will aid the engineer in hydrologic calculations, automating survey calculations and determining ground surface profiles for the sewer lines as well as perform hydraulic calculations and drafting. Also, no software package has been developed that will automate the drafting of storm sewer systems when using an IBM personal computer and allow easy entry and manipulation of the data required to design the storm sewer system.

This study will present how the above software has been developed using an IBM personal computer and the AutoCAD graphics system. A discussion of this software's capabilities and limitations, a storm sewer system design example for a subdivision, and a user's manual for the software will also be presented.

The name that has been given to this software package is CADDSS. This stands for Computer Aided Design and Drafting for Storm Sewers.

Chapter II - Software Development

2.1 System Requirements

This software package has been developed for the IBM Personal Computer or compatible. The machine should have 640K of memory and 2 disk drives or a hard disk.

The software uses a temporary disk or RAM disk. A temporary disk can be thought of as an extra disk drive that is located in the computer's excess memory. This drive can be used to store and read files. Using a temporary disk speeds up program execution and prevents excess wear on the disk drives.

The vast majority of the programs written for this software package were written in Microsoft's Quick Basic version 2.0. Quick Basic is a compiled language, which is an advanced version of Microsoft's Basic. The main advantages of Quick Basic are that it will run about 10 times quicker than Basic, and some added commands allow for more structured programs.

2.2 *AutoCAD*

Most data that is used or produced by the software package is viewed or edited by the AutoCAD graphics system. AutoCAD is an interactive graphics system developed for the IBM PC. It is very inexpensive, compared to other graphics systems, and is easy to use.

AutoCAD works like most other graphics systems. All data is entered based on a cartesian coordinate system, with the positive X axis as the reference axis for angles. A drawing, in AutoCAD, is made up of drawing entities. Examples of drawing entities are a line, arc or circle. AutoCAD has some special drawing entities such as blocks. Blocks can be made up of a variety of other drawing entities to make an entity that is used often. For example, in architecture blocks of standard windows and doors would be very useful. Drawing entities can be stored on separate layers. Each layer can have its own line type, pen number and color, also layers can be turned on or off. This allows great manipulation of a drawing. An example would be a drawing of a subdivision, which consist of streets, storm sewer, sanitary sewer and lots. These could all be placed on different layers of a drawing, thus several different plots could be obtained from one drawing. Another great feature of AutoCAD is that once a drawing has been created, any portion of the drawing can be plotted at any scale.

An AutoCAD drawing file is stored in a very compact form. AutoCAD has a special command (dxfout) which will store a drawing in an expanded form, called a drawing interchange file (DXF). With this drawing interchange file may be changed or created outside of AutoCAD using user created programs. The drawing interchange file is made up of four sections. The first 3 sections contain information concerning status of the drawing. The 4fourth section, the entities section, contains all the drawing entities and the layer that each is stored on.

The drawing interchange file gives AutoCAD almost unlimited flexibility. Programs can be written that take information from a DXF file, can manipulate a DXF file or even create a new DXF file.

With these files, hours of monotonous tasks can be eliminated. For CADDSS, data such as location of storm sewer lines, drainage areas and contour lines are entered by means of a drawing interchange file, then the software calculates hydraulic information and produces plan and profile drawing interchange files of the storm sewer system.

2.3 Program Development

The software package has been developed by combing several programs. These programs can be broken down into three major classifications. They are data transfer programs, computing programs, and display programs. Data transfer programs take information from drawing interchange files and convert it to a form that the computing programs can use. The computing programs compute all required parameters for the storm sewer design. The display programs create drawing interchange files of the plan and profiles and print computed information in tabular form. Table 1 lists all programs included in this software package.

2.3.1 DRIVER Program

All programs are linked and used by the DRIVER program. This program is interactive with the user. Any information that is not provided by the drawing interchange files is entered here. This program also determines which other programs will be used. The program creates batch files, which execute the other programs.

Table 1. Outline of programs contained in software package.

1. DRIVER Program
2. Data Transfer Programs
   a. EL
   b. DRAREA
   c. CAREA
   d. STRDAT
   e. STMLINES
   f. INTTRAN
3. Computation Programs
   a. STFIG
   b. STMDAT
   c. SPROF
   d. SEWDES
   e. HGL
   f. MODIFY
4. Display Programs
   a. NDXF
   b. PLDRAW
   c. PRODRAW
   d. PRSEWCAL
   e. PRHGL

2.3.2 Data Transfer Programs

EL: This program takes contour lines, with their respective elevations, that have been entered through AutoCAD and breaks them up into individual line segments. The program then stores each line segment, with its elevation, in 1 to 4 data files depending on the line segments location relative to the total area being considered. These data files have the extension .CON.

DRAREA: This program takes drainage area information from a drawing interchange file. In the AutoCAD drawing file drainage areas are represented by closed polygons. A number is entered, after the polygon is entered, to indicate what structure the drainage area is associated with. The program takes these polygons and stores them in a data file called DRAREA.DAT. The program also finds the areas of the drainage area polygons by using the coordinates of the polygon's line segments. The general equation to determine the area by coordinates used in the program is

$$A = \frac{X_1(Y_2 - Y_n) + X_2(Y_3 - Y_1) + \cdots + X_{n-1}(Y_n - Y_{n-2}) + X_n(Y_1 - Y_{n-1})}{2}$$

where

X_i	= X coordinate of a point
Y_n	= Y coordinate of a point
i	= total number of coordinates

CAREA: This program takes polygons from a DXF file that represent different runoff coefficients (C factors) needed in the Rational Formula. The program works the same as the DRAREA program except that the C factor polygons can be stored in 1 to 4 different data files. Which data files the polygon is stored in depends on its location relative to the total area being considered. The names of all data files that store the C factor information begin with CAREA.

STRDAT: This program uses the center lines of streets which have been entered through AutoCAD to find the edges of pavement (EOP) and where the curb roundings intersect the edges of pavement. Edges of pavement are the same as edges of streets. There are 2 edges of pavement per centerline. A curb rounding is the curve that has as its tangents the edges of pavement of the 2 intersecting streets. The program can handle straight streets, curved (arced) streets and courts. On straight sections of street, the edges of pavement can be tapered.

The first section of the program determines the EOP lines for all sections of the streets. For straight line sections, the slope of the line is determined, and endpoints for the EOP lines are offset perpendicular to the centerline endpoints. For arcs, EOP sections are easily found by adding and subtracting half the street width from the radius of the centerline arc. For courts, the actual radius of the EOP is entered through AutoCAD so calculations are not needed.

After all the edges of pavement have been calculated, intersection points are found between the different EOP sections. When intersections are found intersection points with the curb roundings and the EOP lines are calculated.

To determine if 2 straight line sections intersect, the inverse of the slope is found (dX/dY) for each line. Then the Y coordinate of the intersection point is found by the equation

$$Y = \frac{XS \times Y1 - XXS \times YY1 - X1 + XX1}{XS - XXS}$$

The X coordinate is found by the following equation

$$X = XS(Y - Y1) + X1$$

Where

X = X coordinate of the intersection point

Y = Y coordinate of the intersection point

XS = inverse slope of the first line

XXS = inverse slope of the second line

X1 = X coordinate of the first point of the first line

Y1 = Y coordinate of the first point of the first line

XX1 = X coordinate of the first point of the second line

YY1 = Y coordinate of the first point of the second line

Lines intersect if the X and Y coordinates of the intersection point are on both lines.

To determine if a line intersects a court or curve, the equations of line and a circle were solved simultaneously to give the following equation:

$$(S^2 + 1)Y^2 + (2SC - 2SA - 2B)Y - 2AC + C^2 + B^2 + A^2 - R^2 = 0$$

where

Y = Y coordinate of an intersection point

S = inverse slope of the line

A = X coordinate of the radius point of the arc

B = Y coordinate of the radius point of the arc

C = X intercept for the equation of the line

R = radius of the arc

Y is found, in the program, by using the quadratic formula. X can then be found by using the equation of the line. Two intersection points will be found. The points must then be checked to see if they are within the boundaries of each entity.

To find intersection points for curves with other curves or curves and courts the distance is found between the two radius points. Then using this distance and the radius of the two arcs in the law of cosines the angle between the line from the radius point of one arc to the radius point of the other arc and the line from a radius point to an intersection point on the arc is found. With this angle, the X and Y coordinates of the two intersection points can be found by using trigonometric relationships. These points are then checked to see if they are within the limits of the arcs.

Where an intersection point is found to exist, the effects of the curb rounding must be found. Intersection points of the curb roundings on the various entities are found by using trigonometric relationships.

Results from this program are stored in various data files. Files beginning with ST and ending with the extension .DAT store the EOP lines. Files with the extension .MOV contain line and arc segments that are affected by curb roundings. Figure 17 in the appendix shows a flowchart of this program.

STMLINES: In AutoCAD, the storm sewer lines and the text information for the structures can be entered in any order. As a result this program has been developed to sort the storm sewer lines and determine their proper order. For the proper order each individual network in the system is grouped together. Storm sewer paths, in the network, are stored in order of the lowest number of structures to the greatest and from the upstream end of the path to the downstream end. A storm sewer line is defined as the sewer line between just 2 structures. A path is defined as a group of storm sewer lines with only 1 upstream end and 1 downstream end. This program has 3 basic sections. The first section reads storm sewer lines and text information from an AutoCAD drawing interchange file. The second section finds the end of each individual storm sewer network and all storm sewer lines and text associated with each network. The final section finds the number of structures (i.e. manholes, inlets, etc.) for each path in the network. Next, this section ranks all paths from the fewest number of structures to the greatest number for each network and stores these in the STMDAT.DAT data file in the proper order. Figure 18 in the appendix shows a flowchart of this program.

First, in the second section the end of a network is found. Then, the coordinates of the upstream structure, from the end of the network, are compared to the coordinates of the other structures until a match is found. After a match is found, the process is repeated until the upstream end of the path is reached. Once the end of a path is reached, the structures, within the path, are checked to see if any other lines intersect at the structures. If another line is found to join at a structure, its path is found to the last upstream structure. This routine is continued until all possibilities have been checked. The process is repeated for all networks in the system.

The third section of the program works on one network at a time. The section starts at the upstream end of a path and counts the number of structures to the downstream end of the path. This is done for all possible paths in the network. The sewer lines that make up the longest path are removed from consideration and the next longest route is found. Once all routes have been ranked in the network, the structures along with their respective text information are written into the STMDAT.DAT data file. The structures are written in groups of paths in order of the least number of structures, in the path, to the greatest. This process is done for all networks in the system. Paths are ranked in this manner because the SEWDES program designs the storm sewer paths from the upstream end to the downstream end.

INTTRAN: This program transfers a rainfall intensity duration frequency curve that has been entered through AutoCAD to a permanent data file. This file is stored with the extension .INT.

2.3.3 Computation Programs

STFIG: This program takes inlet structures that are located along street curbs and calculates the exact location of the structures. Structure information is taken from the STMDAT.DAT data file. Street information is taken from files with the extension .MOV and files beginning with ST and having a extension .DAT. This program has 4 basic sections. The first section reads structure information from the STMDAT.DAT data file and determines if the structures are near a street and if their coordinates need to be calculated. The second section determines the closest edge of pavement section (EOP) to each structure, and moves the structure onto this EOP section. The third section checks if the newly found structure locations are where curb roundings have an effect on the EOP sections. The final section offsets the structure the proper distance from the curb and rewrites the structure's coordinates into the STMDAT.DAT data file. Figure 19, in the appendix, shows a flowchart of this program.

The second section first finds the closest EOP line section to each structure. This is done by finding the perpendicular distance from the structure to the EOP line, for each line. The line that is closest is stored in memory. Next the distance is found from the structure to the radius point of an EOP curve section. The bearing of this line is checked to see if it is within or near the curve. If the bearing is near or within the curve the radii for the inside and outside EOP curve sections are subtracted from the distance and then these distances are compared to the previously closest EOP section to see if one of them is closer. This is done for all EOP curve sections and the closest distance is stored in memory (if it is closer than an EOP line section). The same procedure is then done for courts. When checking distances to EOP sections, this program also finds the closest point to the structure that is on the EOP section. The coordinates of this point are stored in memory.

The third section takes the structures new coordinates (placed on an EOP section) and tests if these coordinates are on a part of an EOP section where a curb rounding has an effect. This is done by taking EOP line sections which represent the effects of the curb roundings (stored in files with the extension .MOV), and test if structures lie on these lines. If a structure is located where a curb rounding has an effect, the structure is moved to the end of the curb rounding plus a proper distance along the EOP section.

The final section offsets the structure the proper distance from the curb. For example, a catch basin can be offset 4 feet to the outside of a curb and a grate inlet can be offset to the inside of the curb so that its edge will be along the curb. These newly calculated coordinates are then stored in the stmdat.dat data file. This section also determines the rotation angle needed for the structures to be tangent to the street on which they lie. This angle is perpendicular to the angle used to offset the structure. The rotation angle is stored in the STROT.DAT data file.

STMDAT: This program finds the hydrologic parameters for the structures that are required for the storm sewer design. These parameters are the structures' elevations, runoff coefficients (C factors), time of concentrations, maximum length of travels, and the high points. These parameters can be entered through AutoCAD or are found by the following procedures. Figure 20 in the appendix shows a flowchart for this program.

To find a structure's elevation, contour lines, that where sorted in the EL program, are interpolated in the X and Y direction. First, the closest North and South (Y direction) contour lines and the closest East and West contour lines to the point are found. Next the following equations are used to get the elevation of the point:

$$EVX = \frac{EVW \times XE - EVE \times XW}{XD}$$

$$EVY = \frac{EVS \times XN - EVN \times XS}{YD}$$

$$EV = \frac{EVX \times YD - EVY \times XD}{(XD + YD)}$$

where

EV	=	elevation of the point
EVX	=	interpolated elevation in the X direction
EVY	=	interpolated elevation in the Y direction
EVE	=	elevation of the closest eastern contour line
EVW	=	elevation of the closest western contour line
EVN	=	elevation of the closest northern contour line

EVS = elevation of the closest southern contour line

XD = distance between eastern and western contour lines (parallel to the X axis)

YD = distance between northern and southern contour lines (parallel to the Y axis)

XE = distance from the point to the eastern contour line

XW = distance from the point to the western contour line

YN = distance from the point to the northern contour line

YS = distance from the point to the southern contour line

The program next finds the C factors. To do this, the program uses the limits of the drainage area (maximum and minimum X and Y coordinates of the drainage area polygon) and an element with an area that is 2 percent of the total drainage area. The program increments through the limits of the drainage area element by element and test if the element is inside the drainage area polygon. The method used to test if an element is inside a polygon is as follows. A vertical line is drawn upwards from the center of the element past the upper limit. The program then checks how many times this line crosses lines that make up a polygon's area (this is done similarly to line/line intersection routine in the STRDAT program). If the line crosses the polygon's lines an odd number of times the element is inside the polygon. If an element is found to be inside the drainage area, the program then finds which C factor polygon the element is in. The C factor, for this area, is multiplied by the element's area, and it is summed with previous values. Once all elements have been tested, the sum of the individual C factors is divided by the total drainage area giving the weighted C factor. Drainage area polygons are found in the DRAREA program, and C factor polygons are found in the CAREA program.

The length of travel is found by inversing between the structures coordinates and the coordinates that make up the drainage area polygon. The greatest distance found is the length of travel.

The high point is the elevation of the coordinates that result in the length of travel. This high point along with the elevation of the structure and the length of travel are used to determine the slope for the basin.

To find the time of concentration the graph shown in figure 1 is used. The graph in figure 1 has been developed for overland flow. The graph does not consider pipe flow or gutter flow. The SEWDES program will calculate the travel time in pipes. The graph is put into equation form and these equations along with the above calculated parameters give the time of concentration.

SPROF: This program finds the ground surface profiles that are above the sewer lines. The program first reads in the storm sewer lines and determines which elevation quadrants they are in. Once this is done, contour lines are read in one line at a time and checked to see if any sewer lines, which are in the same quadrant as the contour line, cross the contour line. Intersections are tested the same way as explained for line/line intersections in the STRDAT program. If a line is found to intersect the distance from the lower structure to the contour line, the elevation of the contour line and the structures' numbers (structures that are immediately upstream and downstream of the line) are stored in a temporary data file. After all contour lines have been tested, data in the temporary file is sorted by storm sewer lines and stored in the SPROF.DAT data file. Figure 21 in the appendix shows a flowchart of this program.

SEWDES: This program does the actual designing of the storm sewer system. The program first reads in the intensity duration curve for a given frequency, the sewer pipe properties and the design requirements. The design requirements are the minimum cover, minimum slope, minimum pipe size, minimum velocity and the maximum velocity. A special data file (MINDAT.VAR) contains the design requirements for individual storm lines. The program designs the first line in the STMDAT.DAT data file and then designs the next line downstream. The program has been set up to keep the pipes as close to the surface as possible. The program will allow crowns, flow lines or center lines to be set equal for different size pipes at the junctions. If pipes are the same size the outflow pipe will be set .1 ft. lower than the inflow pipe. If the lower pipe is larger than the upper pipe, the program will raise the lower pipe, if it will still be below the minimum cover. Otherwise the upper pipe will be lowered to match the lower pipe. Any other pipes that enter at the junction

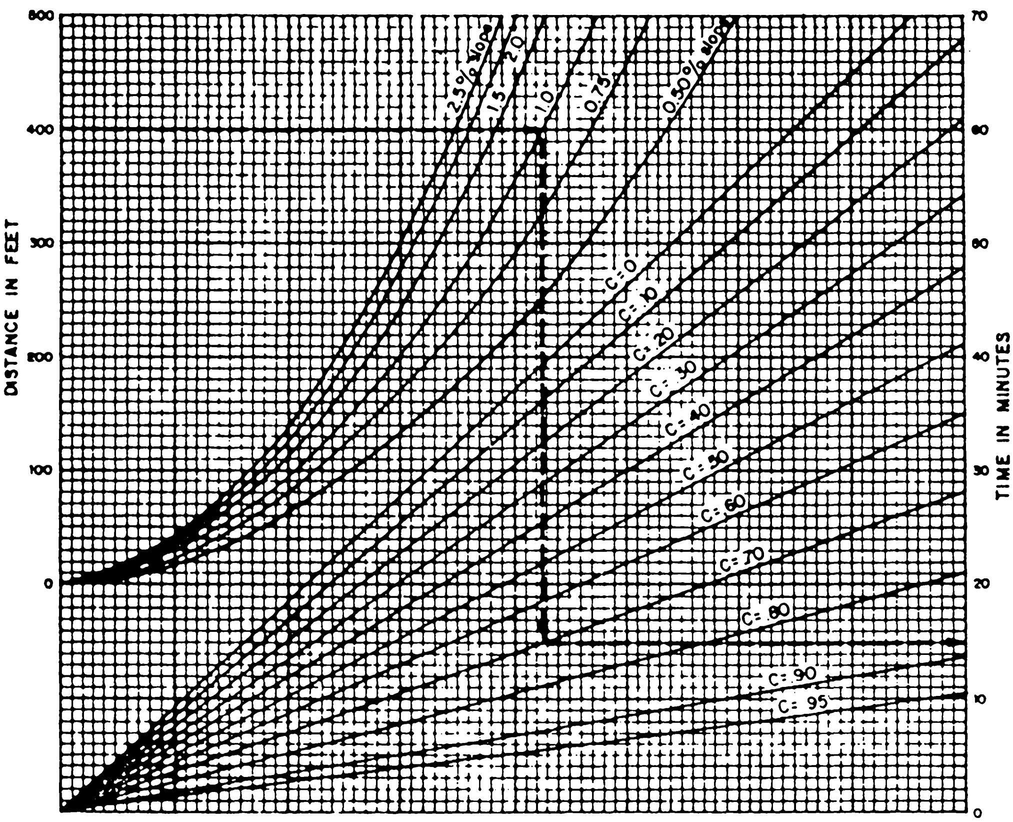

Figure 1. Overland time of concentration (Wright, 1969)

will also be adjusted accordingly. This is done only when setting the pipe centerlines or the flowlines equal. This process is continued until all lines have been designed.

Flows in the pipes are found on a cumulative bases. That is drainage areas and time of concentrations are added as you go down the system, from these combined values the flow is found using the Rational formula. The Rational formula is

$$Q = CIA$$

where

Q	= flow (cubic ft./sec)
C	= runoff coefficient
I	= rainfall intensity (in./hr.)
A	= drainage area (acres)

The drainage area and runoff coefficient are taken from the STMDAT.DAT data file. To find the intensity a parabolic interpolation is done on the intensity frequency duration curve that has been read into memory. The equation used for the interpolation is

$$I = A(TC)^2 + B(TC) + C$$

The coefficients for this equation have been derived as follows:

$$A = \frac{I_3 - \frac{I_2 - I_1}{T_2 - T_1}T_3 - I_1 + \frac{I_2 - I_1}{T_2 - T_1}T1}{T_3^2 + \frac{T_1^2 - T_2^2}{T_2 - T_1}T_3 - T_1^2 - \frac{T_1^2 - T_2^2}{T_2 - T_1}T_1}$$

$$B = \frac{I_2 - I_1 + A(T_1^2 - T_2^2)}{T_2 - T_1}$$

$$C = I_1 - AT_1^2 - BT_1$$

where

TC	=	time of concentration (min.), set to equal to the rainfall duration
I_j	=	intensity for j value
T_j	=	time for j value
j	=	three closest times to the time of concentration.

After the flow is found, Manning's equation is used to size the pipe. This means picking the smallest pipe that will handle the given amount of flow at the given slope and pipe roughness. Manning's equation is

$$Q = \frac{1.49}{n} A \left(\frac{D}{4}\right)^{\frac{2}{3}} S^{\frac{1}{2}}$$

where

n	=	Manning's roughness coefficient
A	=	area of pipe (sq. ft.)
D	=	diameter of pipe (ft.)
S	=	slope of pipe (ft./ft.)

After the pipe size is found, Manning's equation is again used to find the exact depth and velocity in the pipe, if the pipe is not flowing flow. Since the pipe is flowing partially full, the following equations are used in an iterative solution to find the depth and velocity, in the pipe:

$$A = \frac{D^2}{4}\left[\sin^{-1}\left(2\frac{d}{D} - 1\right) + \frac{\pi}{2}\right] + \left(d - \frac{D}{2}\right)\sqrt{dD - d^2}$$

$$P = D\left[\sin^{-1}\left(2\frac{d}{D} - 1\right) + \frac{\pi}{2}\right]$$

where

A	= area of the flow
P	= wetted perimeter
d	= depth of flow

Results of this program are stored in the SEWCALC.RES and COORDS.DAT data files. Figure 22 in the appendix shows a flowchart for this program.

HGL: This program finds the hydraulic grade line throughout the system. The program follows the procedure outlined in the Virginia Department of Highways and Transportation Drainage Manual (VDH&T, 1980). This procedure is listed in the appendix. The program first searches through the COORDS.DAT and SEWCALC.RES data files to find the downstream ends of the storm sewer paths. Once the ends have been found the hydraulic grade line is found from the downstream end to the upstream end for each path according to the procedure. Results are stored in the HGL.RES and STRELEV.DAT data files. Figure 23 in the appendix shows a flowchart for this program.

MODIFY: This program allows the user to make changes to the structure information. The program only uses the STMDAT.DAT data file. The program reads the information into an array. The user is then allowed to make any changes to any of the information.

2.3.4 Display Programs

NDXF: This program modifies the drawing interchange file that contains drainage areas, storm lines and structures' data. Drainage areas that have been found in the DRAREA program are written onto the ODRAREA layer, of the DXF file and any drainage areas that existed in the drawing file previous are removed. Text information that has been found in the STMDAT program is written into the DXF file to show the newly calculated data. Triangles are placed at the structures coordinates, to show if and where the structures have been moved.

For this program and the next two programs information is written into drawing interchange files. When writing information into a drawing interchange file an exact format must be followed. Figure 2 gives an example of this format.

Referring to Figure 2 notice that Entities is on the first line. This represents the start of the fourth section of the drawing interchange file. On the next line is a 0, this is used to show the start of a drawing entity. The next line is the type of drawing entity and 2 lines after this is the layer that the entity is stored on. The first X and Y coordinates of an entity follow a 10 and a 20, respectively. Notice that any number that follows a 50 is the rotation angle of an entity. Also notice that any information that is entered by the user (in AutoCAD) is left justified. For a more detailed explanation refer to AutoCAD's users manual.

PLDRAW: This program creates a drawing interchange file of the plan view for the entire storm sewer system. The program reads data in from the COORDS.DAT, STROT.DAT and SEWCALC.RES data files. The information used is the structures' rotation angles, coordinates, types, and numbers and the diameters and pipe materials of the storm sewer lines. The program calculates the distance and the bearings of the storm sewer lines using trig relationships. Structures are represented by different shapes depending on their type. These shapes are rotated so that they are parallel with the street, when appropriate. Bearings and distance are shown above and below the center of the lines, unless a line is too short then they are written in a table to the side. Pipe material and diameter is written above the center of the pipe.

PRODRAW: This program draws the profile view of the storm sewer system. The program draws one path at a time, but the whole system is placed in one DXF file. The program first reads in the X and Y scale. Next, the program reads needed information from the STRELEV.DAT data file,

```
ENTITIES
  0
SHAPE
  8
STMSTRU
 10
4851.1044
 20
5084.1256
 40
4.0
  2
BOX
 50
176.20439
  0
LINE
  8
STMLINES
 10
4851.1044
 20
5084.1256
 11
4674.1444
 21
5071.8305
  0
TEXT
  8
STMDIA
 10
4762.2778
 20
5082.9660
 40
15
  1
12" RCP
 50
3.9745
  0
ENDSEC
  0
EOF
```

Figure 2. Example of an AutoCAD drawing interchange file

one path at a time. Profiles are then drawn for the path. The program then repeats this process until all paths have been drawn.

PRSEWCAL: This program is written in Basic and it is used to display results of the storm sewer design calculation. This program has been set up so that it can be modified by the user to allow for different spacing or to omit data. Results are printed on a graphics printer in tabular form.

PRHGL: This program is written in Basic and it is used to display the results of the hydraulic grade line calculations. This program has been set up so that it can be modified by the user to allow for different spacing or to omit data. Results are printed on a graphics printer in tabular form.

Chapter III - Design Example

In order to present how this software works, this chapter will present a design example. Figure 3 shows the street and lot layout for part of a subdivision located in Arlington, Virginia that will be used for this example. Notice that the detention pond is located in the Southwest corner. Also looking at this Figure it can be seen that lots and streets take up the whole area. As a result, storm water must be transported to the detention pond via storm sewers since there are no open areas to allow for open channel flow.

3.1 AutoCAD Data Entry

3.1.1 Preliminary Data Entry

For a guide to the procedures for entering the data described below, refer to the user's manual in the appendix.

Figure 3. Lot and street layout for the subdivision

The data first entered for this example was Arlington's rainfall intensity duration curves. These curves are shown in Figure 4. The curves are digitized in AutoCAD, then the INTTRAN program is run to convert the curves into a data file. Once a graph is entered for a county or an area it can be used to design any storm sewer system in that area. The 5 year design storm was used for this example.

Next, contour lines are entered. Figure 5 shows the contour lines along with the streets in the subdivision. It can easily be seen that the text does not look all that good. When entering contour lines, the text is entered first, then the contour lines are digitized. The location of the text can be anywhere in the drawing and can be any size. The appearance of the text will not effect the operation of the programs. Contour lines are entered at 2 foot intervals, if more detail is required contour lines can be entered at odd intervals in areas where they are needed. To transfer contour lines from a drawing file to data files, the program EL is run.

Next, runoff coefficient (C factors) areas are entered (Figure 6). These are used to determine the weighted runoff coefficients for the inlet structures. When entering these, one may go into as much or as little detail as he likes. Each C-area is represented by a closed polygon. The C factor value is entered immediately after the polygon has been digitized. For this example streets and lots areas were digitized separately. Notice that some lines tend to overlap or some small areas have been missed. These gaps are a result of using the digitizer to enter the polygons. This will not significantly affect the results, since these gaps and overlaps are small compared to the areas being considered. To transfer C-areas from a drawing file to data files the CAREA program is run.

Next, street centerlines are entered. These are entered to determine the edges of pavement and curb rounding intersections. Edges of pavement and curb roundings intersections are used to calculate the location of drainage structures that which located on streets. Street centerlines are shown in Figure 7 along with the edges of pavement and the curb roundings. Once again text can be entered anywhere, but the text must be entered immediately after the entity that it affects is drawn. The STRDAT program is used to find and store the needed street information.

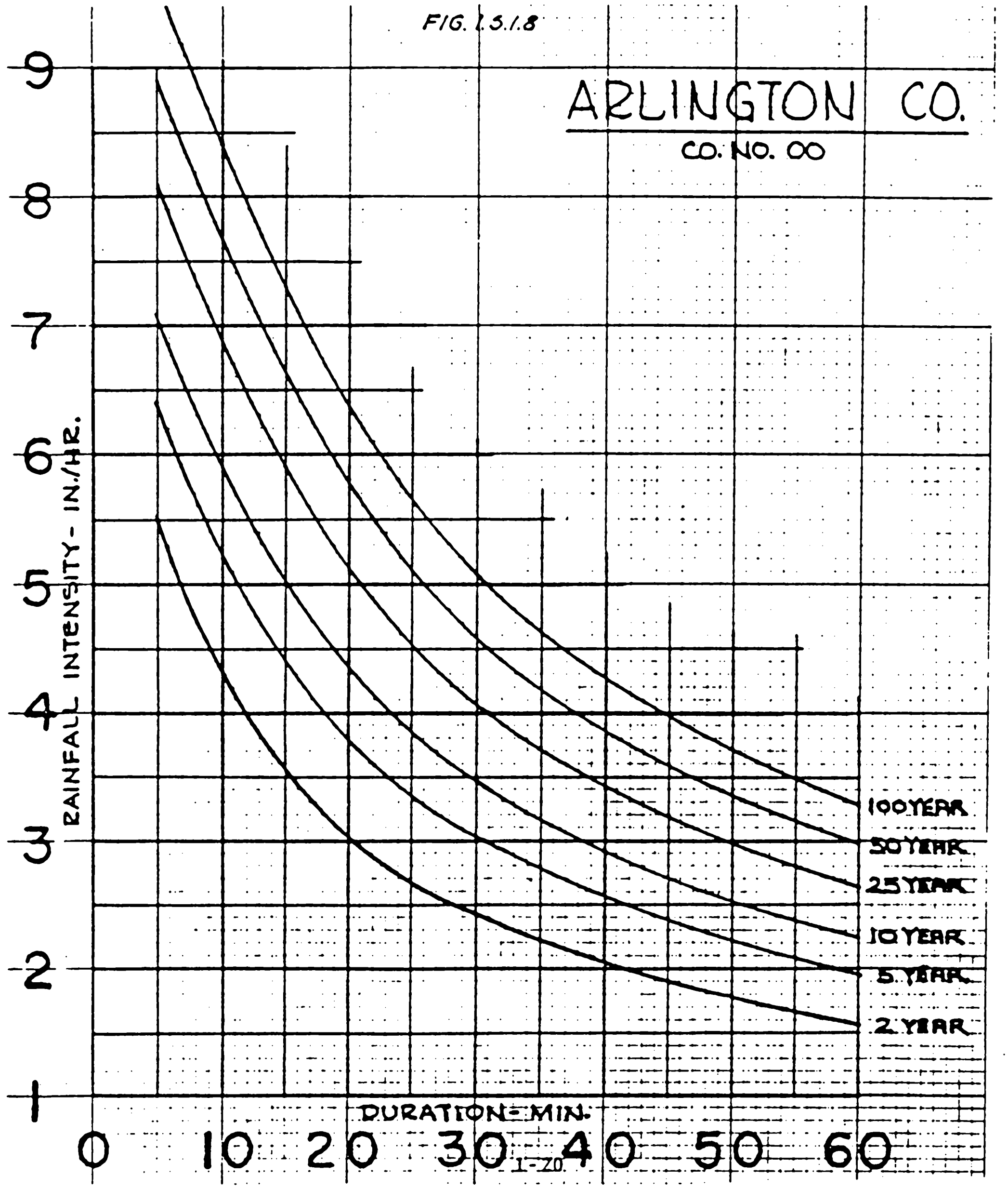

Figure 4. Intensity curves for Arlington, Virginia (VDH&T, 1980)

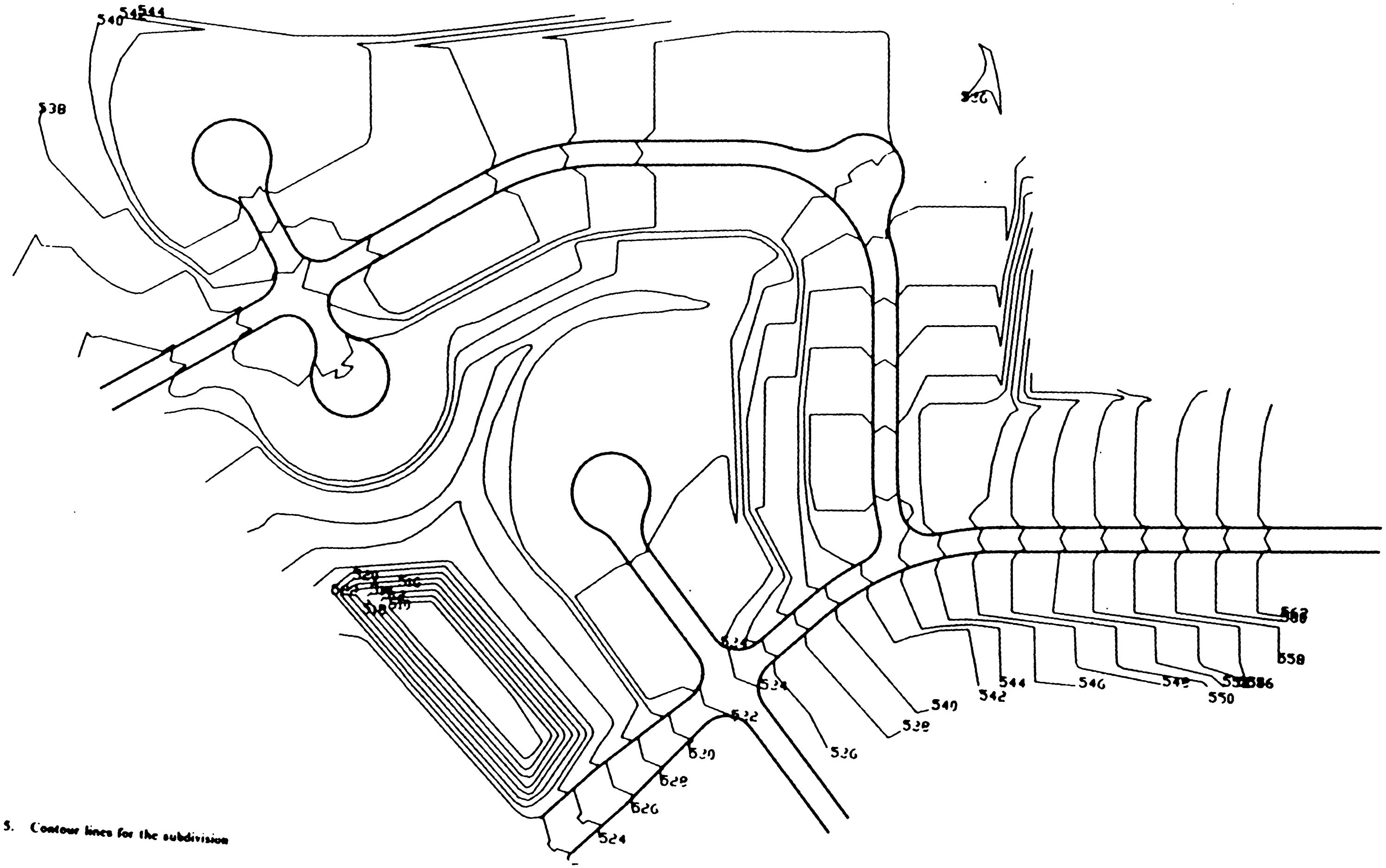

Figure 5. Contour lines for the subdivision

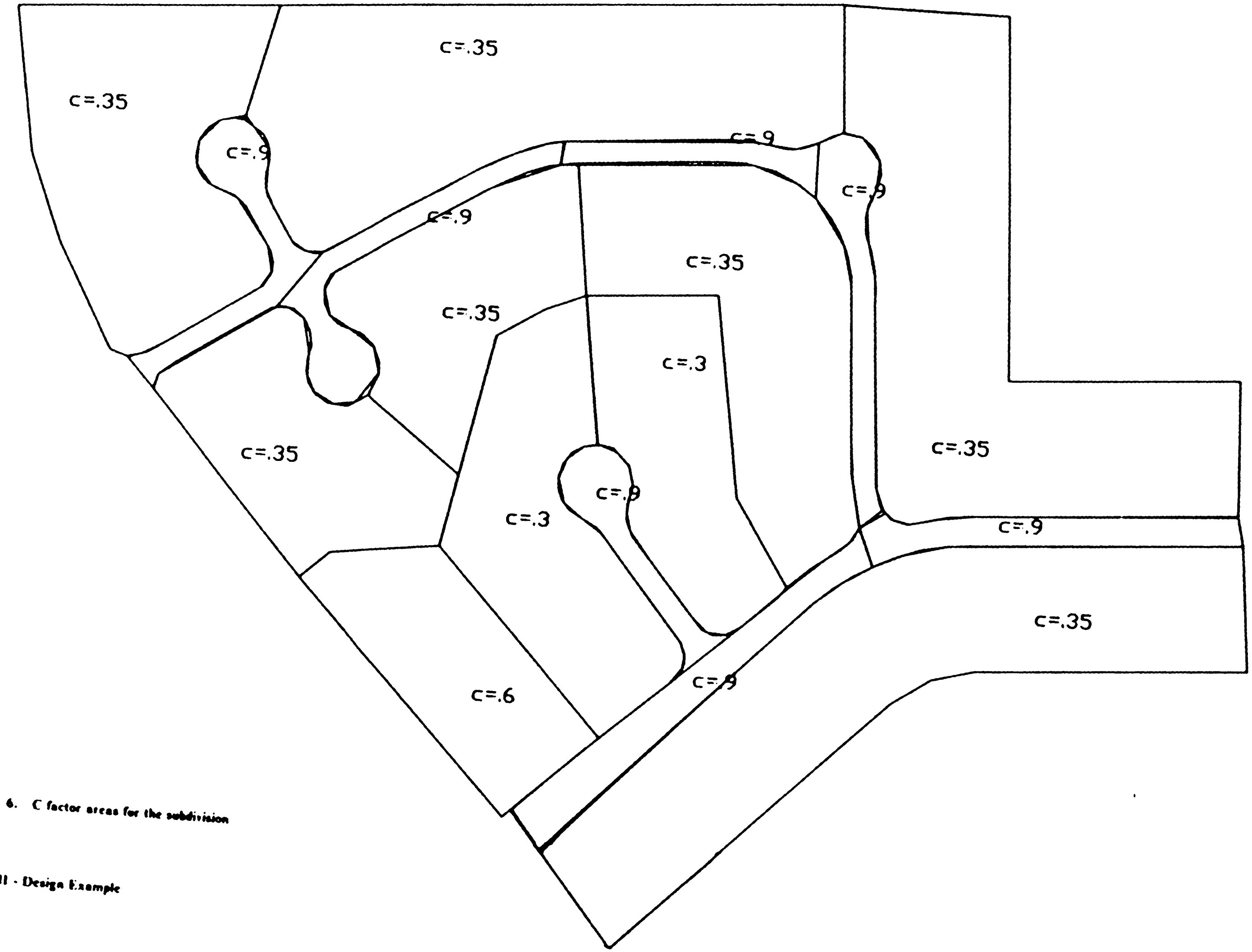

Figure 6. C factor areas for the subdivision

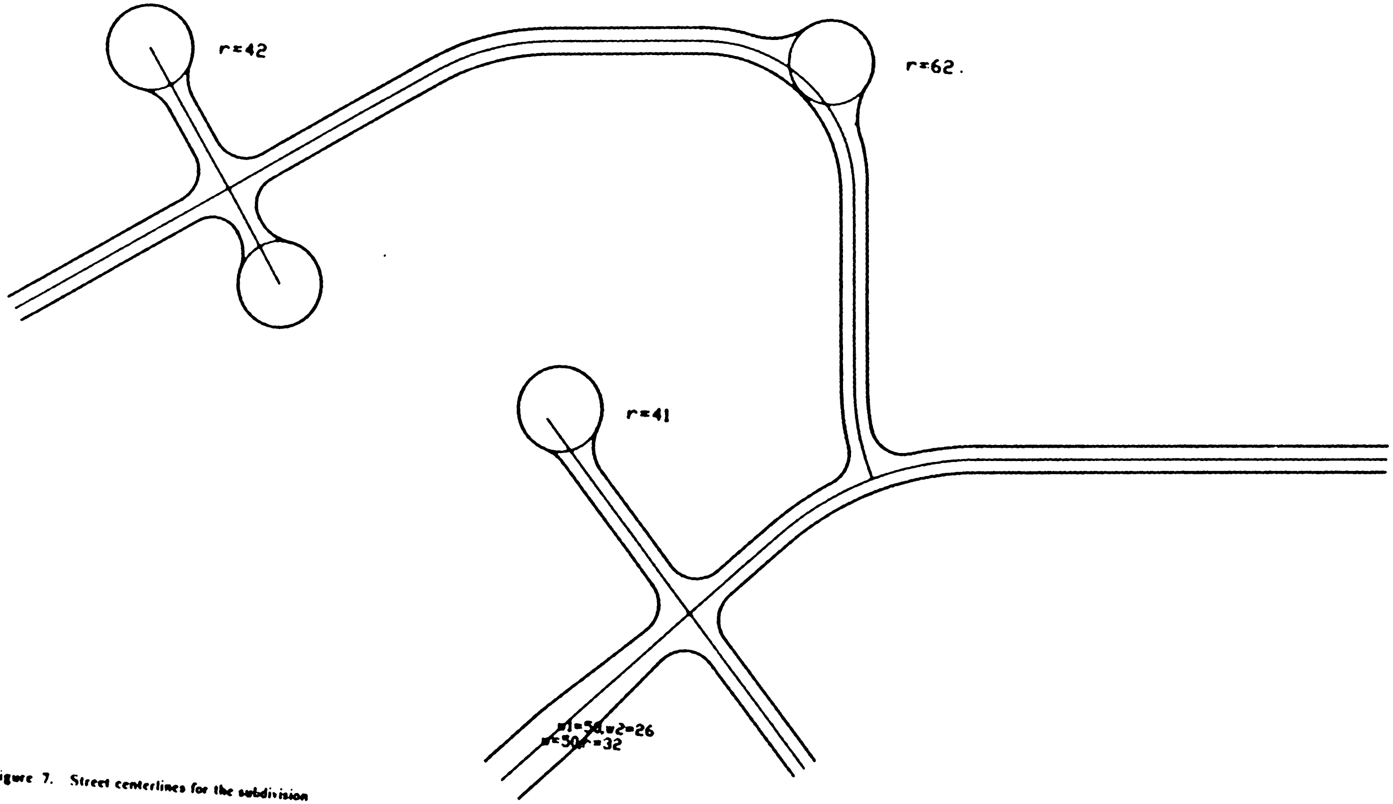

Figure 7. Street centerlines for the subdivision

3.1.2 Variable Data Entry

The preliminary data is data that once it is entered it should not need to be changed. Unless you want to add more contour lines. The following data is set up to be adjusted to allow for different configurations in the storm sewer system. This data is stored in the same AutoCAD drawing file.

Storm sewer lines entered are shown in Figure 8. The locations of the structures are represented by the end points of a line or lines. The different types of structures that can be used are in explained Table 2. For the program to work, if more than one sewer line joins at a structure the ends of the lines must meet at the exact same point. Notice that the text must be placed exactly at the location of the structures. Also notice that the structure's number and type must be included in the text. Optional data that can be entered, along with the structure number and type is the drainage area, C factor, time of concentration, rainfall intensity, elevation, length of travel and height of the most distant point. Looking at the Figure it can be seen for catch basin (CB) #2 optional data has been entered; also for CB #2 a F has been placed in front of CB. This F indicates that the structure is fixed where it is at, so the program will not calculate the coordinates for the structure. The optional data that was entered for CB #2 was the structure's elevation, the C factor, the drainage area, and the time of concentration. Refer to the user's manual for the proper order of optional data. The program used to transfer the storm sewer lines from the drawing interchange file to a data file is the STMLINES program.

Drainage areas are shown in Figure 9. Each drainage area is a closed polygon with the structure number entered after the polygon is drawn. Again the areas that represent the drainage areas tend to overlap or small gaps are left. These gaps will not affect the program since these areas are small compared to the total area being considered. The DRAREA program is used to calculate and store the drainage areas in a data file.

Table 2. Definitions of different types of structures

AI	Area inlet, collects surface flow from fields and open areas.
CB	Catch basin also referred to as a curb opening inlet, vertical opening in a curb covered by a top slab.
CI	Combination of a grate inlet and a catch basin.
EP	End of pipe, where flow is discharged from the sewer system.
FE	Flared end, functions the same as the end of pipe. The end is flared which helps to dissipate the energy of the water.
GI	Grate inlet, opening in the gutter which is covered by a grate.
MH	Manhole

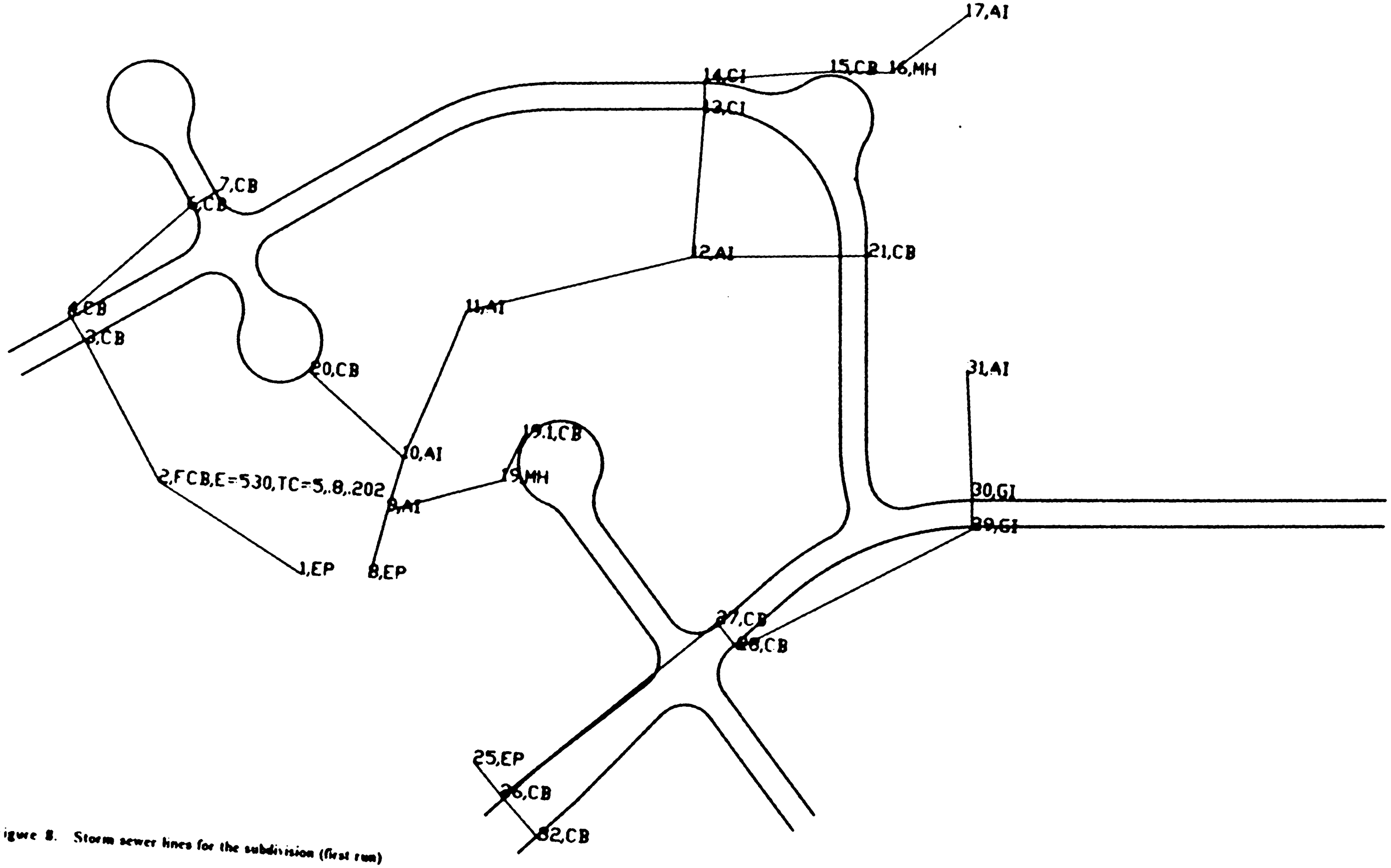

Figure 8. Storm sewer lines for the subdivision (first run)

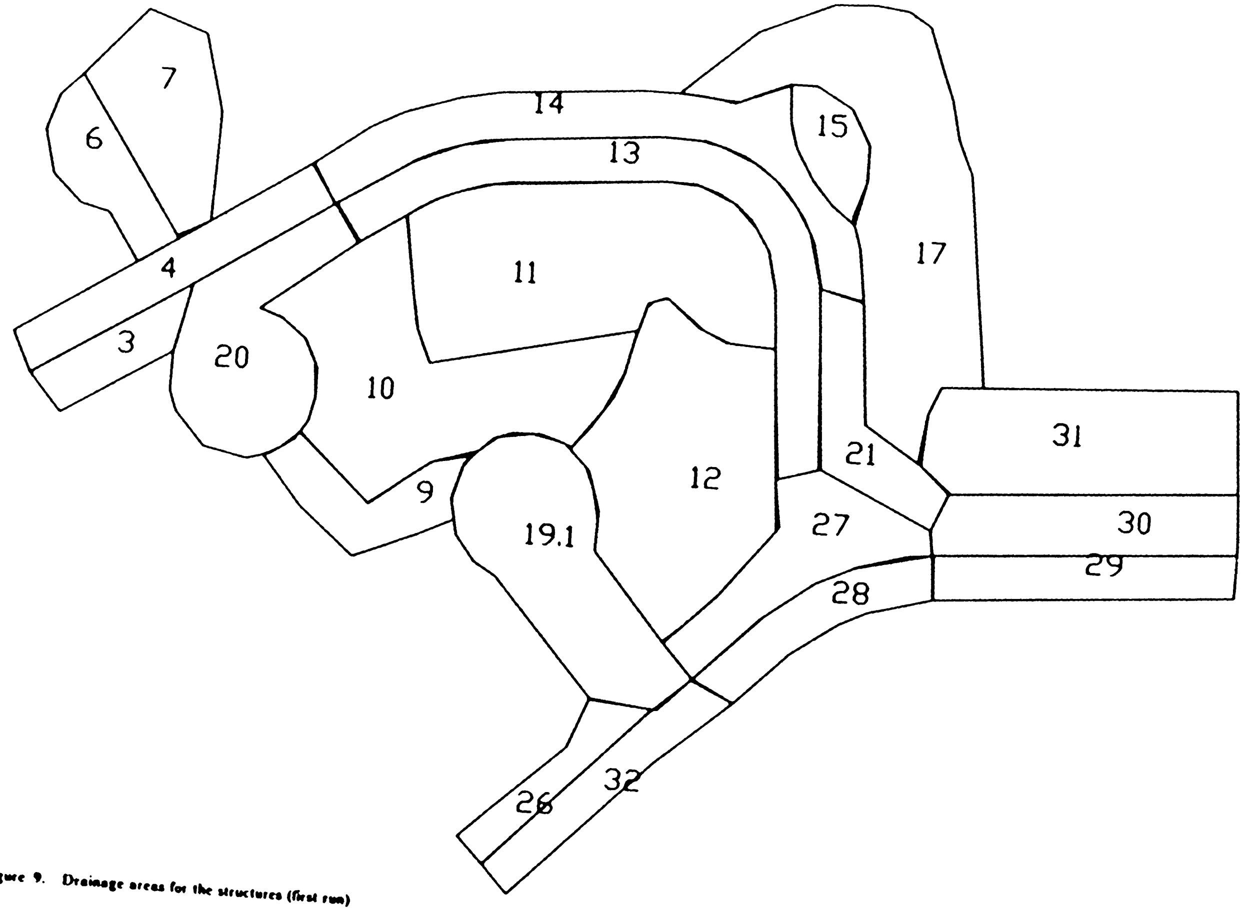

Figure 9. Drainage areas for the structures (first run)

3.2 Program Execution

3.2.1 First Run

After all data has been entered the program can be run. The purpose of this run is to check to see if the flows are adequate and if structures need to be added or moved. For the first run, all the data entry programs were run and the STMDAT and SEWDES computation programs were run. The PRSEWCAL program was run to print out the storm sewer design calculation sheet. This sheet is shown in Table 3. The NDXF program is run which modifies the STMDAT layer to show the hydrologic parameters and the structure locations (Figure 10). Looking at CB #28 in the lower right corner of Figure 10 the parameters that NDXF program displays can be seen. These parameters are the elevation in feet, the time of concentration in minutes, the C factor, and the drainage area in acres. The NDXF program also moves drainage areas to the ODRAREA layer.

3.2.2 Second Run

Looking at Table 3 it was decided that another catch basin should be added, across from CB #21. To do this, the line from CB #21 to AI #12 was erased. Then 2 lines where put in its place. The middle end points of these 2 lines is the location of the new structure. Using the text command the new structure number and type was entered (21.1,CB). Next, the drainage area for this structure was digitized on the DRAREA layer. The drainage area and the text for CB #13 also had to be re-entered. Figure 11 shows the storm sewer lines and the drainage areas. The new drainage areas are represented by thick lines and the old drainage areas are represented by thin lines.

Table 3. Preliminary sewer calculation sheet

FROM	TO	DR. AREA (ac)	TOT DR. AREA (ac)	WGT. C FAC.	TC (min)	I (in/hr)	QINC (cfs)	Q (cfs)	S	PIPE DIA. (in)	QF (cfs)	V (fps)	L (ft)	PIPE INVERT UPPER (ft)	PIPE INVERT LOWER (ft)	GROUND ELEV. UPPER (ft)	GROUND ELEV. LOWER (ft)
CB 21	AI 12	0.29	0.29	0.35	21.4	3.99	0.40	0.40	4.86	12	8.54	5.57	177.07	526.64	520.02	540.15	531.69
CB 20	AI 10	0.58	0.58	0.52	12.4	5.30	1.60	1.60	5.61	12	9.17	8.77	124.65	530.99	523.99	534.57	527.57
CB 19.1	MH 19	0.72	0.72	0.36	24.8	3.66	0.95	0.95	1.21	12	4.25	4.37	48.49	527.27	526.69	530.42	530.37
MH 19	AI 9	0.00	0.72	0.36	25.1	3.63	0.00	0.95	3.88	12	7.62	6.61	119.24	526.59	521.97	530.37	525.44
AI 17	MH 16	1.20	1.20	0.35	22.4	3.88	1.63	1.63	0.31	12	2.17	3.03	94.52	532.85	532.56	536.00	536.59
MH 16	CB 15	0.00	1.20	0.35	22.9	3.83	0.00	1.63	0.39	12	2.42	3.31	58.83	532.46	532.23	536.59	536.00
CB 15	CI 14	0.16	1.36	0.35	23.2	3.80	0.18	1.81	0.33	12	2.21	3.14	126.78	532.13	531.71	536.00	535.42
CI 14	CI 13	0.66	2.02	0.35	23.9	3.74	0.86	2.67	3.94	15	13.94	8.76	32.15	531.51	530.25	535.42	535.30
CI 13	AI 12	0.71	2.73	0.35	24.0	3.73	0.92	3.58	2.10	15	10.16	7.56	143.79	530.15	527.13	535.30	531.69
AI 12	AI 11	1.03	4.05	0.35	32.1	3.16	0.49	4.47	0.18	18	4.84	3.11	230.56	519.62	519.21	531.69	528.00
AI 11	AI 10	1.19	5.24	0.34	33.3	3.10	1.12	5.59	0.14	21	6.55	3.06	158.03	519.01	518.78	526.00	527.57
AI 10	AI 9	1.02	6.84	0.36	34.2	3.05	0.26	7.45	0.14	24	9.23	3.27	54.85	518.58	518.50	527.57	525.44
AI 9	EP 6	0.25	7.81	0.36	34.5	3.03	0.06	8.46	8.02	24	69.58	14.99	68.36	512.90	507.42	525.44	511.63
CB 7	CB 6	0.42	0.42	0.35	18.5	4.34	0.64	0.64	2.45	12	6.05	5.02	36.01	536.49	535.61	539.64	539.15
CB 6	CB 4	0.23	0.65	0.35	16.6	4.32	0.34	0.98	3.25	12	6.98	6.26	155.32	535.51	530.46	539.15	534.00
CB 4	CB 3	0.35	1.00	0.41	19.1	4.27	0.76	1.75	3.17	12	6.89	7.31	33.61	530.36	529.29	534.00	534.00
CB 3	CB 2	0.16	1.16	0.41	19.2	4.24	0.26	2.00	2.12	12	5.63	6.56	155.32	529.19	525.91	534.00	530.00
CB 2	EP 1	0.20	1.36	0.47	19.6	4.19	0.65	2.66	8.88	12	11.53	11.94	167.89	525.81	510.90	530.00	514.04
CB 32	CB 26	0.26	0.26	0.59	12.5	5.29	0.81	0.81	2.29	12	5.85	5.22	57.26	520.71	519.40	523.85	522.54
AI 31	GI 30	0.72	0.72	0.35	19.7	4.18	1.05	1.05	1.73	12	5.10	5.12	120.96	543.68	541.58	546.83	544.73
GI 30	GI 29	0.41	1.13	0.36	20.1	4.14	0.62	1.67	1.29	12	4.40	5.21	34.53	541.48	541.04	544.73	544.18
GI 29	CB 28	0.30	1.43	0.37	27.7	3.44	0.13	1.80	3.80	12	7.54	7.87	261.57	540.94	531.01	544.18	534.15
CB 28	CB 27	0.26	1.69	0.38	28.3	3.40	0.40	2.21	0.35	12	2.29	3.32	33.40	530.91	530.79	534.15	534.26
CB 27	CB 26	0.42	2.11	0.42	28.4	3.39	0.79	3.00	4.09	12	7.83	9.30	276.28	530.69	519.40	534.26	522.54
CB 26	EP 25	0.17	2.54	0.45	28.9	3.36	0.04	3.85	12.51	12	13.69	14.95	43.08	514.75	509.36	522.54	512.51

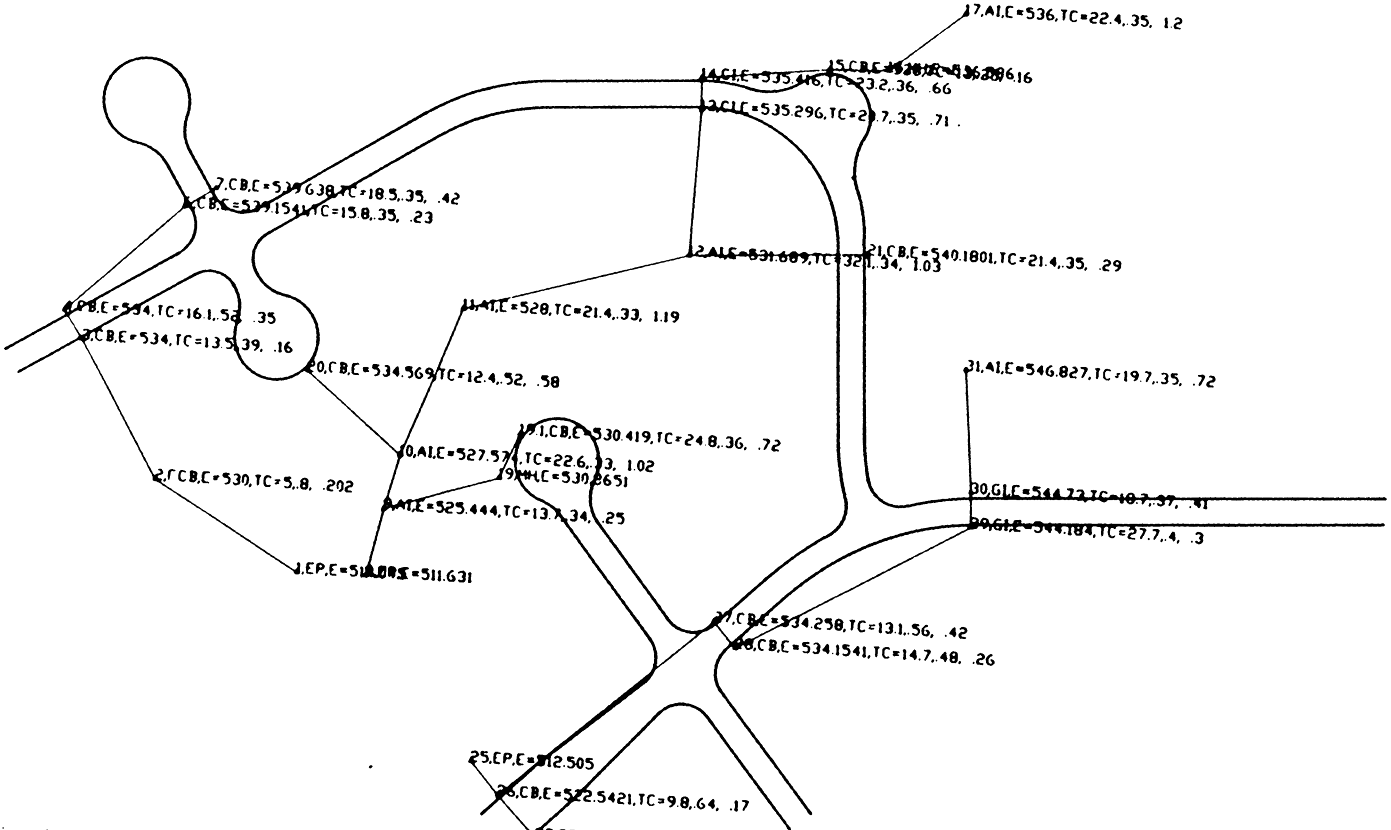

Figure 10. Storm sewer lines and calculated data for the structures (first run)

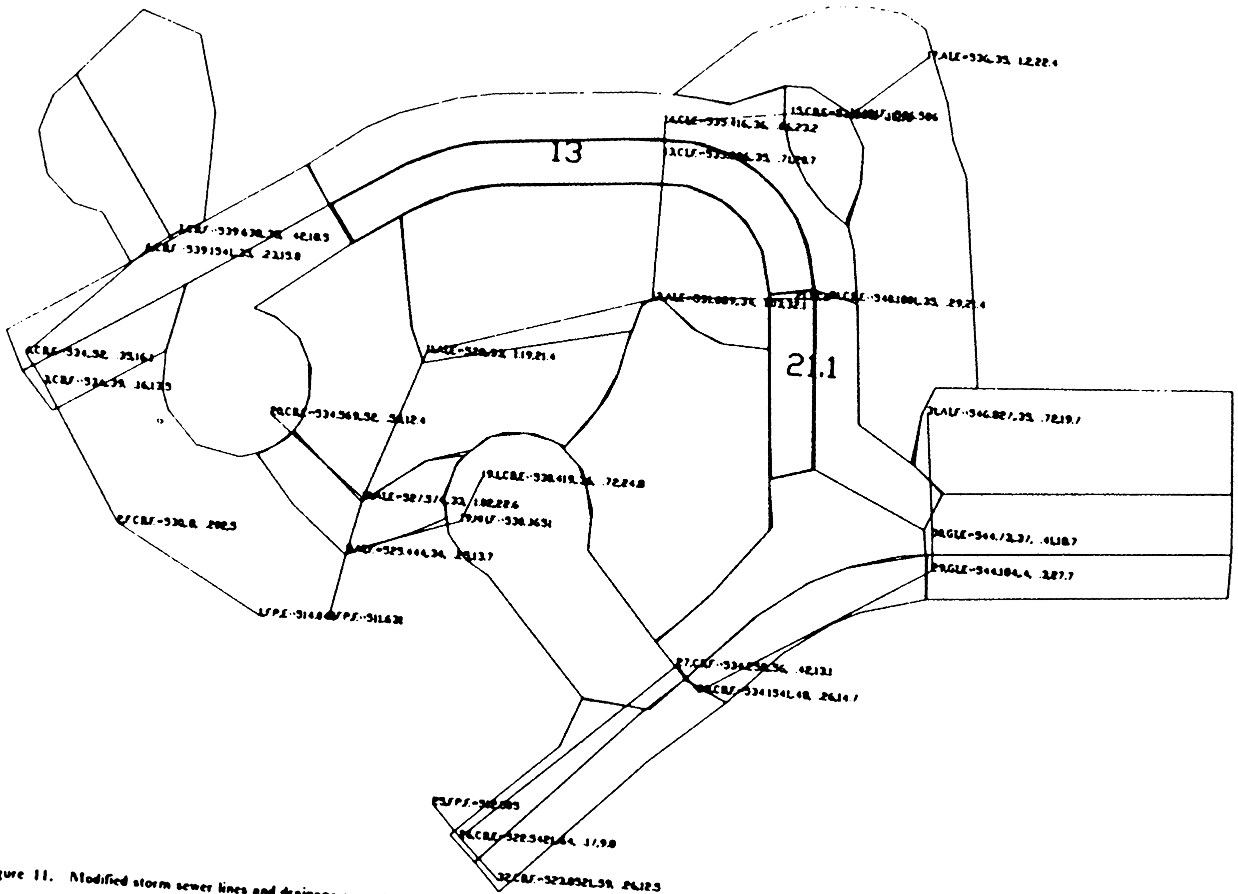

Figure 11. Modified storm sewer lines and drainage areas (second run)

For this run the DRAREA and STMLINES data entry programs were run, all computation programs where run (except MODIFY), and all display programs where run except PLDRAW. Figure 12 shows a profile of one of the paths in the storm sewer network. Table 4 shows the hydraulic grade line calculation sheet. The NDXF program was run to show how inlet structures located on streets have been moved (Figure 13). For example, looking at catch basins 6 and 7 in Figure 13 it can be seen that structures (represented by triangles) have been moved to be outside the curbs and 2 feet away from the end of the rounding. Another example is grate inlets 29 and 30. These structures have been offset to the inside of the curbs.

3.2.3 Following Runs

Looking at the profile and the hydraulic grade line calculation sheet it can be seen that the hydraulic grade line is over the rim of several structures. Also in Figure 12, notice the ground surface profile, represented by a dashed line, is above the storm sewer lines. When the hydraulic grade line is above the rims of drainage inlets (and the ground surface), potential ponding will result, and the design is not accepTable. To correct this problem, the depth of the pipes must be lowered and or velocities of the flow in the pipes must be lowered. Also to reduce head loss, it was decided to shape the structures. Shaping is a design in which the flow is directed through the structure, and pipes are bell shaped at the structure entrances. Elevations need to be taken off street profiles and re-entered if there is much difference between these and elevations calculated by the computer. Also the pipe diameters were increased to fifteen inches for all pipes except for pipes at the very upstream ends of paths.

To re-enter the elevations, the MODIFY program was run. Programs used to adjust the hydraulic grade line were the DRIVER program, SEWDES program, HGL program and the PRHGL program. While running the DRIVER program, variable data is entered that will adjust the depth of the pipe, and check the minimum and maximum velocities. To enter variable data, the number of

Table 4. Preliminary hydraulic grade line calculation sheet

INLET STATION	OUTLET ELEV. (ft)	Do (in)	Qo (cfs)	Lo (ft)	SFo	Hf (ft)	Vo (fps)	Ho (ft)	Qi (cfs)	Vi (fps)	QiVi	Hi (ft)	ang	Hd (ft)	Ht (ft)	adj. Ht (ft)	total H (ft)	WATER ELEV. (ft)	RIM ELEV. (ft)
CB 26	510.16	12	13.72	42.5	0.15	6.27	17.46	1.18	7.81	9.95	77.72	0.54	90	1.08					
									5.82	7.41	43.07	0.30	2	0.00	2.80	3.64	9.90	520.20	522.54
CB 27	520.20	12	7.81	277.1	0.05	13.26	9.95	0.38	2.27	2.89	6.55	0.05	88	0.09	0.52	0.68	13.93	534.13	534.26
CB 28	534.13	12	2.27	34.1	0.00	0.14	2.89	0.03	7.51	9.56	71.74	0.50	80	0.94	1.46	1.90	2.04	536.17	534.15
GI 29	536.17	12	7.51	264.0	0.04	11.65	9.56	0.35	5.51	7.01	38.65	0.27	61	0.42	1.04	1.35	13.01	549.18	544.18
GI 30	549.18	12	5.51	22.0	0.02	0.52	7.01	0.19	4.94	6.29	31.08	0.22	2	0.00	0.41	0.53	1.05	550.23	544.73
AI 31	550.23	12	4.94	128.7	0.02	2.46	6.29	0.15							0.41	0.20	2.66	552.89	546.83
CB 32	520.20	12	5.82	58.0	0.03	1.54	7.41	0.21							0.41	0.28	1.81	522.01	546.83
CB 2	511.70	12	11.52	167.9	0.10	17.47	14.67	0.84	5.69	7.24	41.16	0.28	29	0.23	1.35	1.75	19.23	530.92	530.00
CB 3	530.92	12	5.69	153.3	0.03	3.88	7.24	0.20	6.91	8.80	60.81	0.42	3	0.00	0.62	0.81	4.69	535.62	534.00
CB 4	535.62	12	6.91	34.0	0.04	1.27	8.80	0.30	6.96	8.87	61.75	0.43	80	0.81	1.53	1.99	3.27	538.89	534.00
CB 6	538.89	12	6.96	156.1	0.04	5.93	8.87	0.31	6.15	7.83	48.14	0.33	10	0.04	0.68	0.88	6.81	545.70	539.15
CB 7	545.70	12	6.15	34.0	0.03	1.01	7.83	0.24							0.68	0.31	1.32	547.01	539.64
AI 9	509.16	18	30.83	68.4	0.09	5.86	17.45	1.18	19.44	11.00	213.76	0.66	1	0.00					
									7.62	9.70	73.91	0.51	59	0.80	2.64	3.44	9.29	522.77	525.44
AI 10	522.77	18	19.44	54.8	0.03	1.87	11.00	0.47	10.62	6.01	63.79	0.20	6	0.00					
									9.68	12.32	119.30	0.83	65	1.44	2.73	3.55	5.42	528.19	527.57
AI 11	528.19	18	10.62	158.0	0.01	1.61	6.01	0.14	7.34	5.98	43.88	0.19	52	0.26	0.60	0.77	2.38	530.57	528.00
AI 12	530.57	15	7.34	230.6	0.01	2.96	5.98	0.14	10.19	8.31	84.69	0.38	72	0.65					
									9.57	12.19	116.64	0.81	12	0.09	1.60	2.08	5.04	535.61	531.69
CI 13	535.61	15	10.19	148.8	0.02	3.69	8.31	0.27	16.32	13.30	216.95	0.96	3	0.00	1.23	1.60	5.28	540.89	535.32
CI 14	540.89	15	16.32	22.0	0.06	1.40	13.30	0.69	2.21	2.81	6.20	0.04	82	0.08	0.81	1.05	2.45	543.34	535.42
CB 15	543.34	12	2.21	127.3	0.00	0.49	2.81	0.03	2.42	3.08	7.44	0.05	7	0.00	0.08	0.11	0.59	543.93	536.00
MH 16	543.93	12	2.42	58.8	0.00	0.27	3.08	0.04	2.17	2.76	6.00	0.04	37	0.05	0.12	0.12	0.39	544.32	536.59
AI 17	544.32	12	2.17	94.5	0.00	0.35	2.76	0.03							0.12	0.04	0.39	544.71	536.00
MH 19	522.77	12	7.62	119.2	0.05	5.42	9.70	0.37	4.25	5.41	23.00	0.16	50	0.21	0.74	0.74	6.16	528.93	530.37
CB 19.1	528.93	12	4.25	48.6	0.01	0.69	5.41	0.11							0.74	0.15	0.84	529.76	530.42
CB 21.1	535.61	12	9.57	143.4	0.07	10.29	12.19	0.58	6.09	7.75	47.20	0.33	1	0.00	0.90	1.17	11.47	547.07	540.10
CB 21	547.07	12	6.09	34.0	0.03	0.99	7.75	0.23							0.90	0.30	1.29	548.36	540.18
CB 20	528.19	12	9.68	124.5	0.07	9.14	12.32	0.59							0.90	0.77	9.91	538.10	540.18

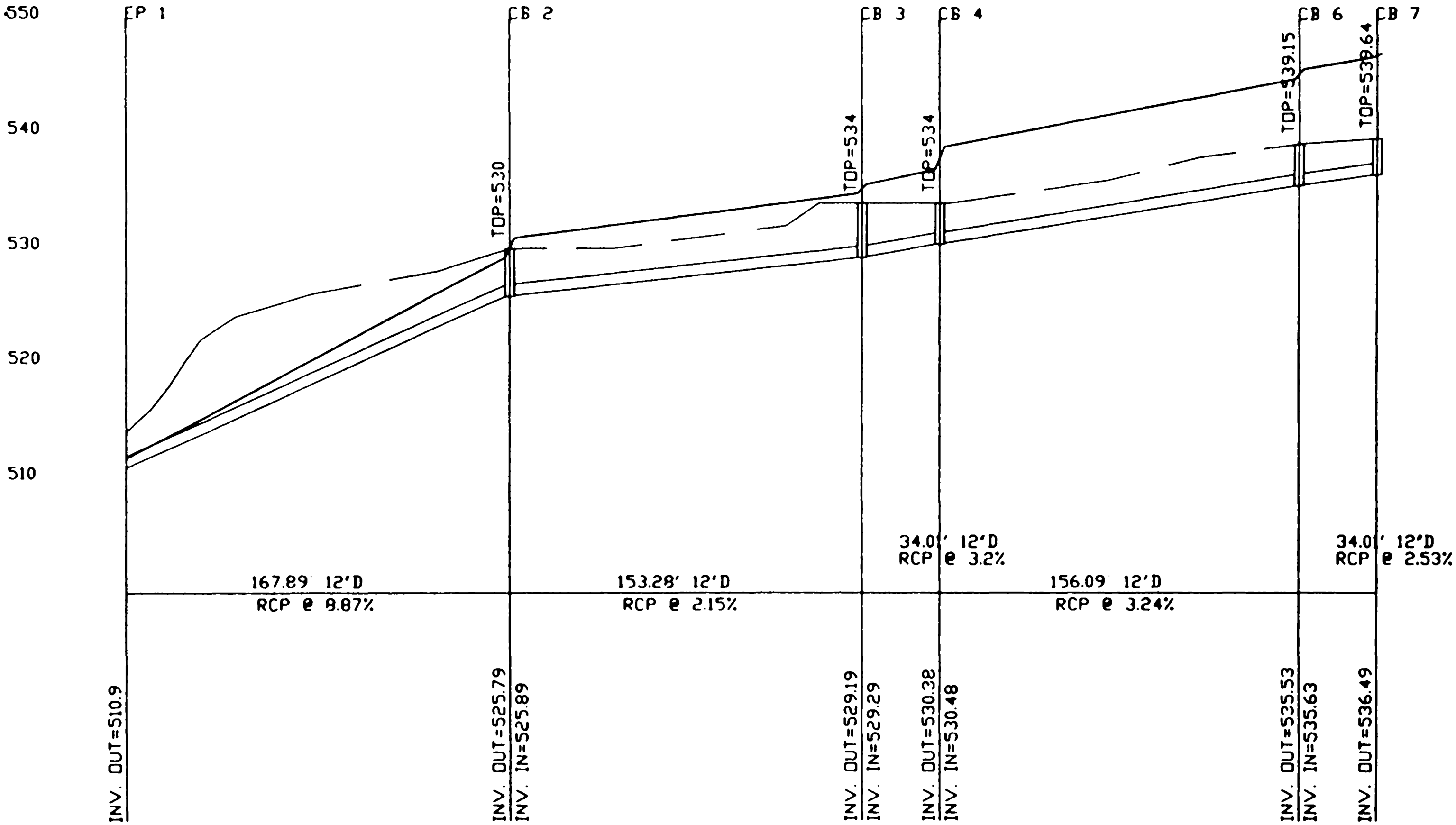

Figure 12. Preliminary profile drawing for a path in the storm sewer system

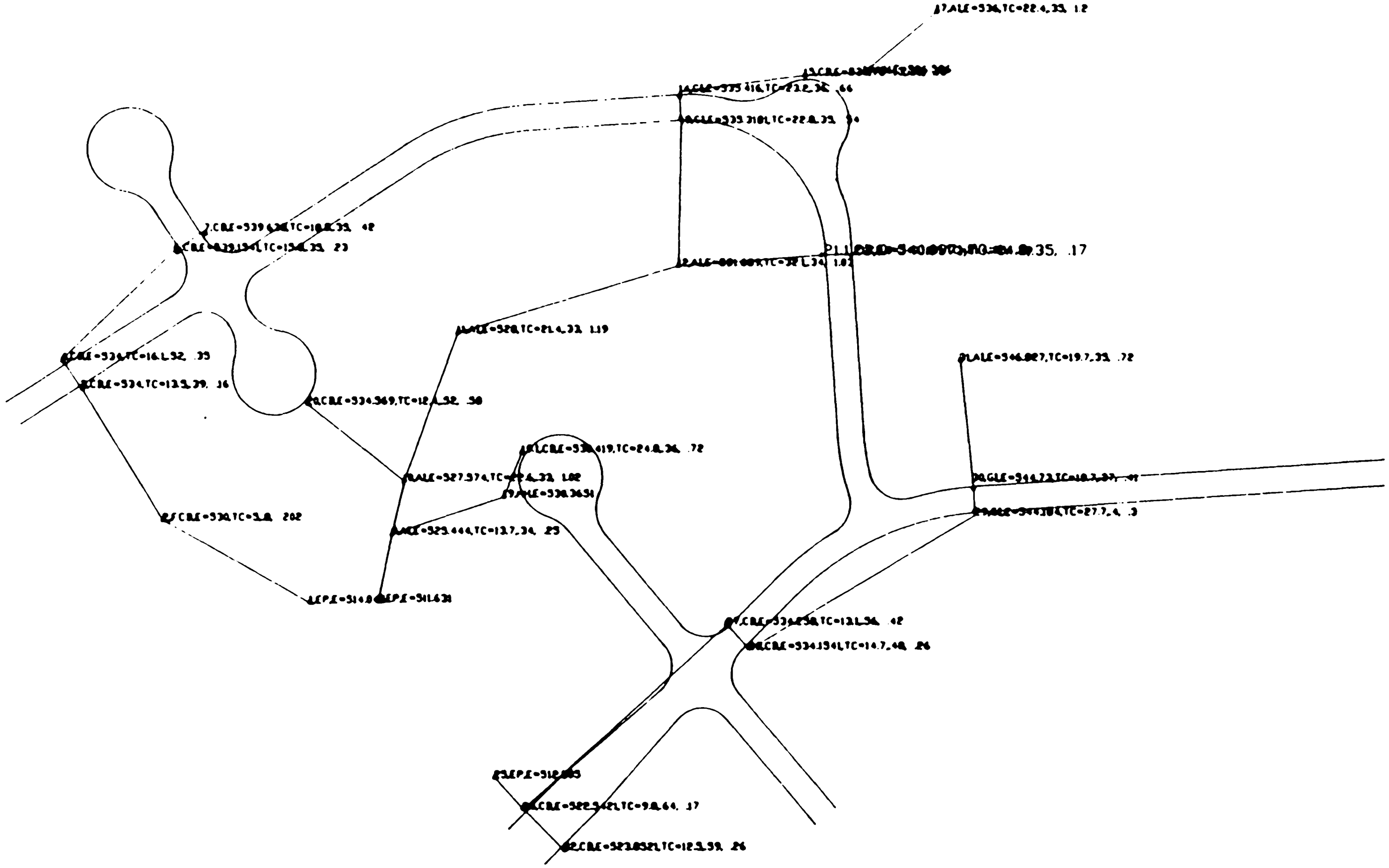

Figure 13. Adjusted structure locations with respect to the street

the upstream structure is entered and then the depth of cover for the upstream end and down stream end can be entered. Other data that can be entered is the minimum and maximum velocities, minimum pipe diameter, minimum slope, maximum slope and the pipe material. To achieve the optimum design several iterations were done using the above programs. Figure 14 shows a revised profile of the same path that was shown before. Table 5 shows the final hydraulic grade line calculation sheet.

3.2.4 Final Run

Looking at the profile and the calculation sheet it can be seen that the hydraulic grade line is below the rim of every structure.

The last step is to run the PLDRAW, the PRSEWCAL and the PRHGL programs. The PLDRAW program produces the plan views which are shown in Figure 15 and Figure 16. The final sewer calculation sheet is shown in Table 6.

Looking at Figure 15, it can be seen that all structures have been adjusted the proper distance from the edges of pavement, and the structures have been rotated so they are perpendicular to the streets. It can also be seen that all bearings and distances have been calculated for the storm sewer lines. In Figure 15, it can be seen that when a sewer line is short a number is placed on the line, and the bearing and distance are written over to the side. Figure 16 shows the same drawing except that the pipe diameter and the pipe material is displayed. Figure 15 shows the drawing exactly as the software has generated it. Notice that some of the structure names and numbers are overwritten or are written in a line. In Figure 16, structure names were moved where they were overwritten. This was done to illustrate how easy the drawing can be modified once it is in AutoCAD.

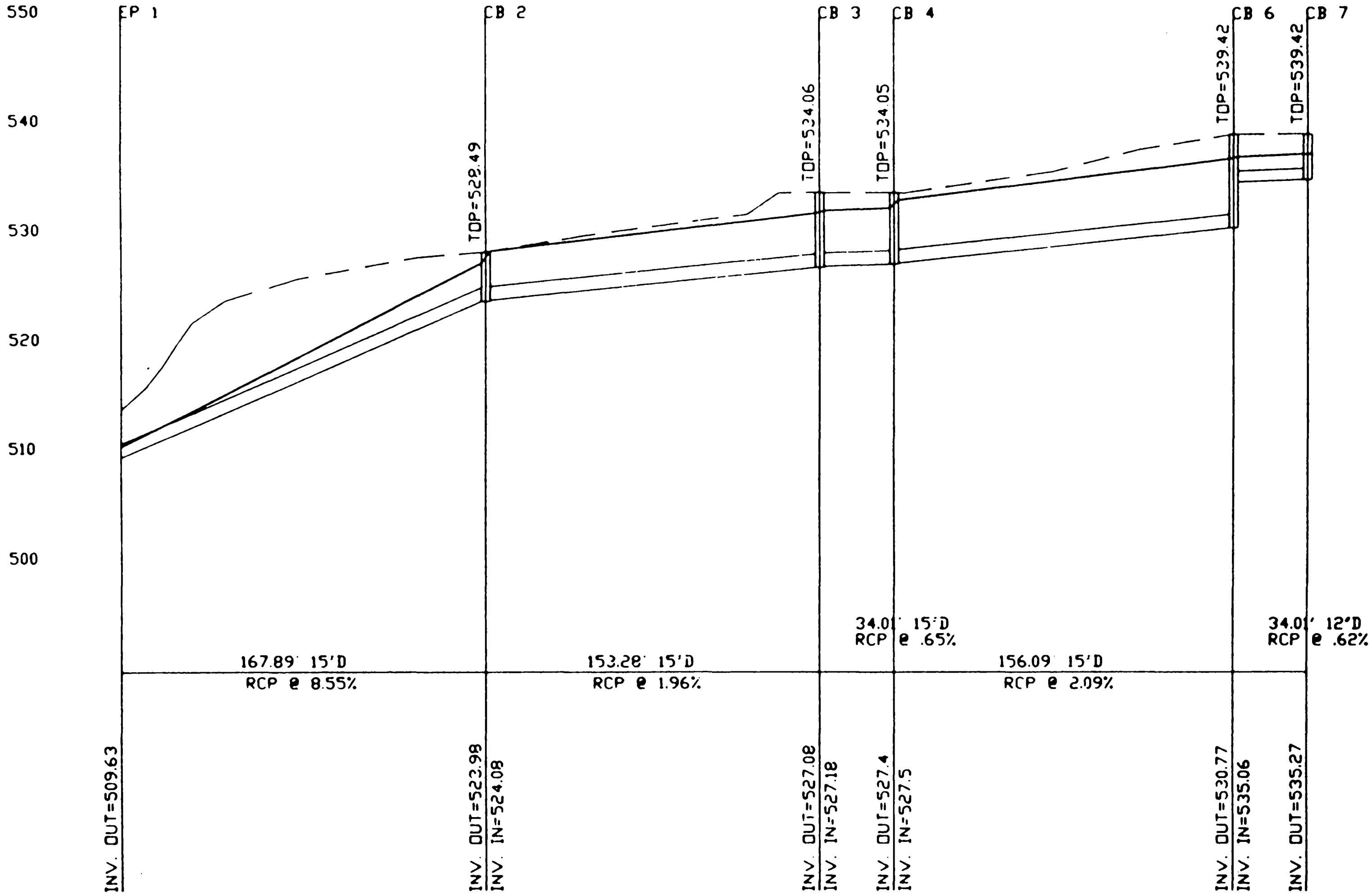

Figure 14. Final profile drawing for a path in the storm sewer system

Table 5. Final hydraulic grade line calculation sheet

INLET STATION	OUTLET ELEV. (ft)	Do (in)	Qo (cfs)	Lo (ft)	SFo	Hf (ft)	Vo (fps)	Ho (ft)	Qi (cfs)	Vi (fps)	QiVi	Hi (ft)	ang	Hd (ft)	Ht (ft)	adj. Ht (ft)	total H (ft)	WATER ELEV. (ft)	RIM ELEV. (ft)
CB 26	509.10	15	25.59	42.5	0.16	6.63	20.85	1.69	0.00	0.00	0.00	0.00	0	0.00					
									0.00	0.00	0.00	0.00	0	0.00	1.69	1.10	7.73	519.81	523.39
CB 27	519.81	15	14.84	277.1	0.05	14.55	12.09	0.57	6.64	5.41	35.95	0.16	40	0.17	0.90	0.58	15.13	534.94	536.36
CB 28	534.94	15	6.64	34.1	0.01	0.36	5.41	0.11	11.38	9.27	105.49	0.47	80	0.88	1.46	0.95	1.31	536.25	536.49
GI 29	536.25	15	11.38	264.0	0.03	8.14	9.27	0.33	4.98	4.06	20.23	0.09	61	0.14	0.56	0.37	8.51	544.76	549.49
GI 30	544.76	15	4.98	22.0	0.01	0.13	4.06	0.06	4.65	3.79	17.60	0.08	2	0.00	0.14	0.09	0.22	544.98	549.09
AI 31	544.98	15	4.65	128.7	0.01	0.66	3.79	0.06							0.00	0.04	0.70	545.68	546.43
CB 32	519.81	12	2.91	58.0	0.01	0.39	3.71	0.05							0.00	0.03	0.42	520.23	523.39
CB 2	510.63	15	20.51	167.9	0.10	16.84	16.72	1.08	9.81	7.99	78.40	0.35	29	0.28	1.71	1.11	17.95	528.59	528.49
CB 3	528.59	15	9.81	153.3	0.02	3.52	7.99	0.25	5.66	4.61	26.06	0.12	3	0.00	0.36	0.24	3.75	532.34	534.06
CB 4	532.34	15	5.66	34.0	0.01	0.26	4.61	0.08	10.16	8.28	84.05	0.37	80	0.70	1.16	0.75	1.01	533.35	534.05
CB 6	533.35	15	10.16	156.1	0.02	3.84	8.28	0.27	0.00	0.00	0.00	0.00	0	0.00	0.27	0.17	4.01	537.36	539.42
CB 7	537.36	12	3.09	34.0	0.01	0.25	3.94	0.06							0.00	0.04	0.29	537.65	539.42
AI 9	508.16	18	30.90	68.4	0.09	5.88	17.48	1.19	0.00	0.00	0.00	0.00	0	0.00					
									0.00	0.00	0.00	0.00	0	0.00	1.19	0.77	6.65	520.89	524.24
AI 10	520.89	18	20.52	54.8	0.04	2.08	11.61	0.52	12.09	6.84	82.76	0.25	25	0.16					
									16.84	13.72	231.04	1.02	82	1.93	3.48	2.26	4.34	525.24	526.20
AI 11	525.24	18	12.09	158.0	0.01	2.08	6.84	0.18	4.70	2.66	12.49	0.04	52	0.05	0.27	0.18	2.26	527.50	528.00
AI 12	527.50	18	4.70	230.6	0.00	0.46	2.66	0.03	0.00	0.00	0.00	0.00	0	0.00					
									16.88	13.76	232.24	1.03	12	0.12	1.17	0.76	1.22	528.72	529.90
CI 13	529.72	15	6.61	148.8	0.01	1.55	5.38	0.11	11.39	9.28	105.69	0.47	75	0.88	1.46	0.95	2.50	531.22	534.03
CI 14	531.22	15	11.39	22.0	0.03	0.68	9.28	0.33	0.00	0.00	0.00	0.00	0	0.00	0.33	0.22	0.90	532.11	533.98
CB 15	532.11	12	3.25	127.3	0.01	1.06	4.14	0.07	2.16	2.75	5.93	0.04	89	0.09	0.19	0.12	1.18	533.29	534.98
MH 16	533.29	12	2.16	58.8	0.00	0.21	2.75	0.03	2.17	2.76	6.00	0.04	37	0.05	0.12	0.06	0.27	533.57	537.78
AI 17	533.57	12	2.17	94.5	0.00	0.35	2.76	0.03							0.00	0.02	0.37	533.93	535.56
MH 19	520.59	12	8.71	119.2	0.06	7.09	11.09	0.48	4.58	5.83	26.70	0.18	50	0.25	0.91	0.46	7.54	528.44	530.38
CB 19.1	528.44	12	4.58	48.6	0.02	0.80	5.83	0.13							0.00	0.09	0.88	529.32	531.06
CB 21.1	529.72	15	16.88	143.4	0.07	9.74	13.76	0.73	0.00	0.00	0.00	0.00	0	0.00	0.73	0.48	19.22	538.94	540.30
CB 21	538.94	12	3.57	34.0	0.01	0.34	4.55	0.08							0.00	0.05	0.39	539.33	540.34
CB 20	525.24	15	16.34	124.5	0.07	8.41	13.72	0.73							0.00	0.48	8.89	534.12	535.37

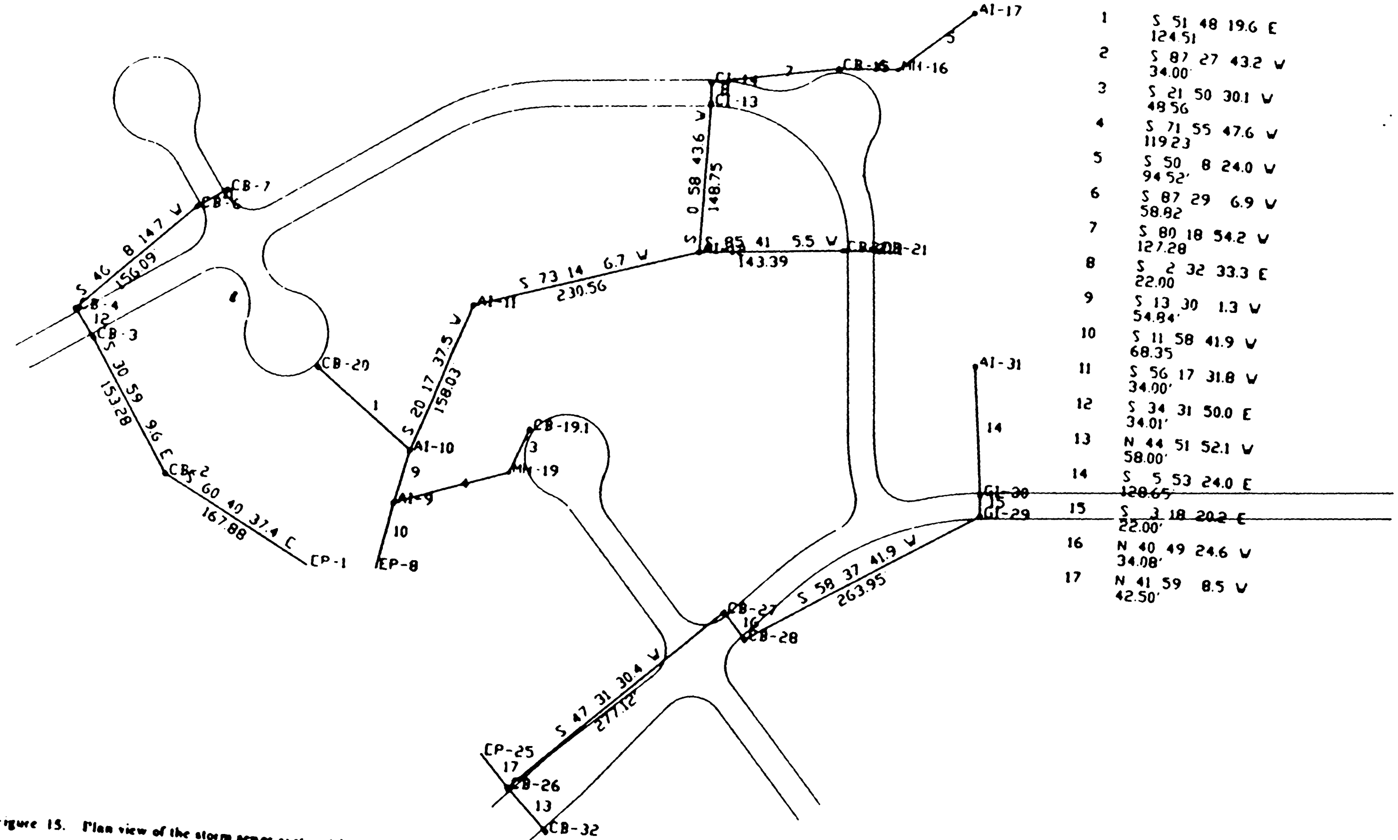

Figure 15. Plan view of the storm sewer system (showing bearings and distances)

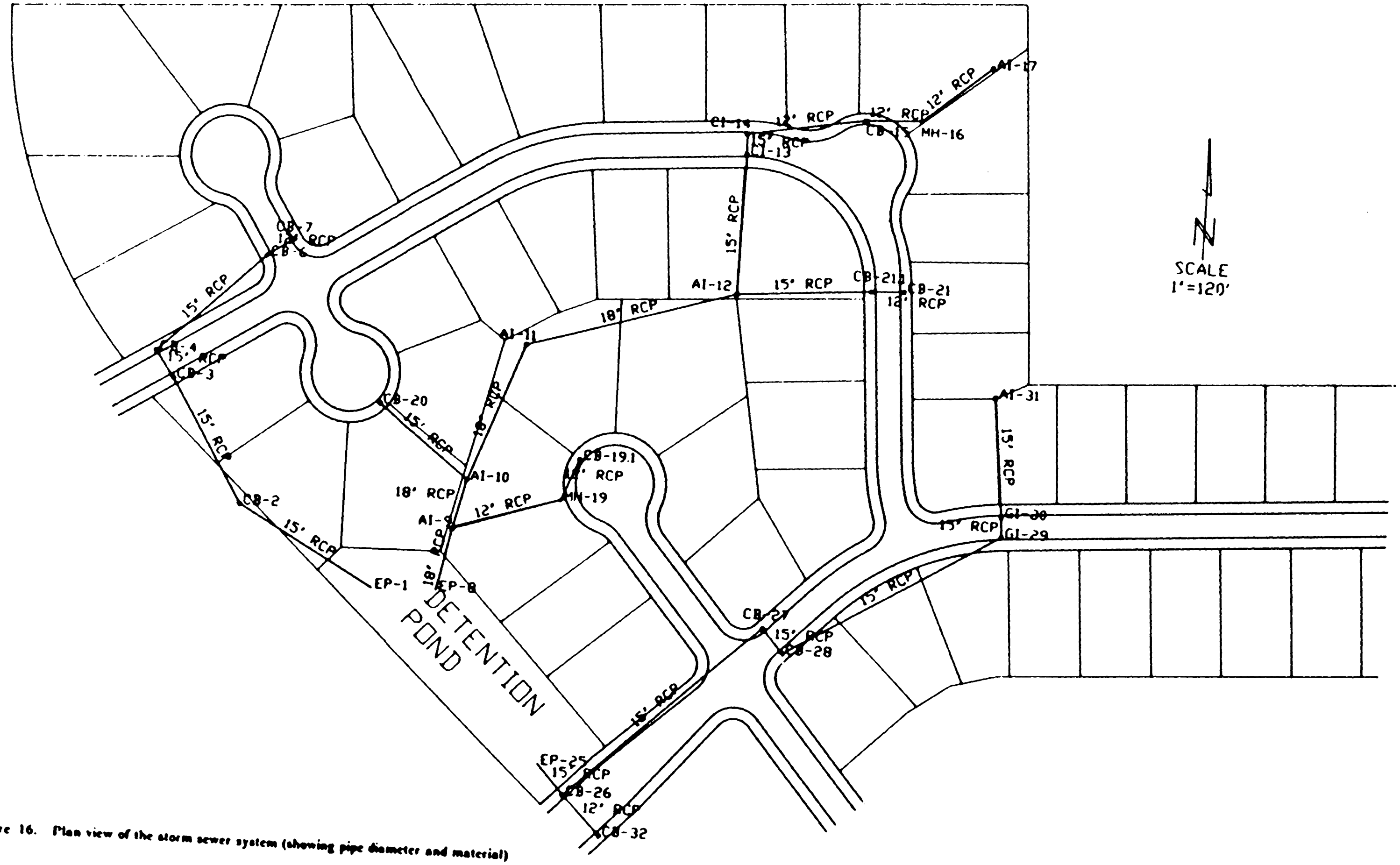

Figure 16. Plan view of the storm sewer system (showing pipe diameter and material)

Table 6. Final storm sewer calculation sheet

FROM	TO	DR. AREA (ac)	TOT DR. AREA (ac)	WGT. C FAC.	TC (min)	I (in/hr)	QINC (cfs)	Q (cfs)	S	PIPE DIA. (in)	QF (cfs)	V (fps)	L (ft)	PIPE INVERT UPPER (ft)	PIPE INVERT LOWER (ft)	GROUND ELEV. UPPER (ft)	GROUND ELEV. LOWER (ft)
CB 20	AI 10	0.58	0.58	0.52	12.4	5.30	1.60	1.60	5.76	15	16.84	8.66	124.51	528.88	521.71	535.37	526.20
CB 21	CB 21.1	0.29	0.29	0.35	21.4	3.99	0.40	0.40	0.85	12	3.57	3.03	34.01	535.89	535.60	540.34	540.30
CB 21.1	AI 12	0.17	0.46	0.35	21.6	3.97	0.23	0.64	5.79	15	16.88	6.61	143.39	533.04	524.74	540.30	529.90
CB 19.1	MH 19	0.72	0.72	0.36	24.8	3.66	0.95	0.95	1.40	12	4.58	4.60	48.56	526.91	526.23	531.06	530.38
MH 19	AI 9	0.00	0.72	0.36	25.0	3.64	0.00	0.95	5.07	12	8.71	7.27	119.24	526.13	520.09	530.38	524.24
AI 17	MH 16	1.20	1.20	0.35	22.4	3.88	1.63	1.63	0.31	12	2.17	3.03	94.52	531.41	531.12	535.56	537.78
MH 16	CB 15	0.00	1.20	0.35	22.9	3.83	0.00	1.63	0.31	12	2.16	3.03	58.82	531.02	530.83	537.78	534.98
CB 15	CI 14	0.16	1.36	0.35	23.2	3.80	0.18	1.81	0.71	12	3.25	4.25	127.28	530.73	529.83	534.98	533.98
CI 14	CI 13	0.66	2.02	0.35	23.7	3.75	0.87	2.68	2.63	15	11.39	7.58	22.00	527.97	527.39	533.98	534.03
CI 13	AI 12	0.54	2.56	0.35	23.9	3.74	0.70	3.38	0.89	15	6.61	5.41	148.75	527.29	525.98	534.03	529.90
AI 12	AI 11	1.03	4.05	0.35	32.1	3.16	0.46	4.47	0.17	18	4.70	3.03	230.56	523.71	523.32	529.90	528.00
AI 11	AI 10	1.19	5.24	0.34	33.4	3.09	1.12	5.59	1.12	18	12.09	6.71	158.03	523.22	521.45	528.00	526.20
AI 10	AI 9	1.02	6.84	0.36	33.8	3.07	0.32	7.51	3.23	18	20.52	10.72	54.85	521.35	519.57	526.20	524.24
AI 9	EP 8	0.25	7.81	0.36	33.9	3.07	0.10	8.56	7.33	18	30.90	14.94	68.36	511.97	506.96	524.24	511.63
CB 7	CB 6	0.42	0.42	0.35	18.5	4.34	0.64	0.64	0.64	12	3.09	3.09	34.01	535.27	535.06	539.42	539.42
CB 6	CB 4	0.23	0.65	0.35	18.7	4.31	0.34	0.98	2.09	15	10.16	5.24	156.09	530.77	527.50	539.42	534.05
CB 4	CB 3	0.35	1.00	0.41	19.2	4.25	0.76	1.74	0.65	15	5.66	4.06	34.01	527.40	527.18	534.05	534.06
CB 3	CB 2	0.16	1.16	0.41	19.4	4.23	0.25	2.00	1.95	15	9.81	6.28	153.28	527.08	524.08	534.06	528.49
CB 2	EP 1	0.20	1.36	0.46	19.8	4.17	0.64	2.64	8.55	15	20.51	11.49	167.59	523.98	509.63	528.49	514.04
CB 32	CB 26	0.26	0.26	0.59	12.5	5.29	0.81	0.81	0.57	12	2.91	3.17	58.00	519.24	518.92	523.39	523.39
AI 31	GI 30	0.72	0.72	0.35	19.7	4.18	1.05	1.05	0.44	15	4.65	3.06	128.65	539.52	538.96	546.43	549.09
GI 30	SI 29	0.41	1.13	0.36	20.4	4.10	0.60	1.66	0.50	15	4.98	3.66	22.01	538.86	538.75	549.09	549.49
SI 29	CB 28	0.30	1.43	0.37	27.7	3.43	0.14	1.80	2.63	15	11.38	6.77	263.95	538.65	531.71	549.49	536.49
CB 28	CB 27	0.26	1.69	0.38	28.4	3.38	0.40	2.19	0.90	15	6.64	4.86	34.09	531.61	531.30	536.49	536.36
CB 27	CB 26	0.42	2.11	0.42	28.5	3.37	0.79	2.98	4.47	15	14.84	9.46	277.13	531.20	518.81	536.36	523.39
CB 26	EP 25	0.17	2.54	0.45	29.0	3.34	0.04	3.83	13.30	15	25.59	14.99	42.51	513.76	508.10	523.39	512.51

Chapter IV - Discussion

This software operates extremely fast compared to present methods for storm sewer design such as using nomographs or tables or using part of a larger software package. Also the software has been set up so it is very easy to manipulate, add or delete data. Easy data entry and quick execution allows for several different configurations to be tried, so an efficient design can be reached. The program has been set up to do most of the tedious work, while letting the engineer make the decisions and do the design.

Some of the problems and limitations of the CADDSS software package will be presented in the following discussion.

4.1 Data Entry

Entering data through AutoCAD is very convenient. But when entering the data, an exact format must be followed. If this format is not followed a mistake will be made. The program can only tell you that a mistake has been made and what type of data the program was reading. Not when or where the mistake was made. For example, if when entering drainage areas, the user forgets to close one of the drainage area polygons, the program can not tell which polygon the mistake occurred at. Thus, correcting any data entry mistakes can be very tedious.

4.2 Program execution

When running CADDSS execution time is not extremelly quick, since a personal computer is used. All programs run reasonably fast except for the STMDAT program. This program takes a while to run mainly because of the method used to determine the C factors. When testing this software on a thirty acre subdivision the STMDAT program took three hours to run. If C areas had been entered by the user the program would of run in less than ten minutes. Therefore, it is reccommended that C factors be entered by the user.

The elevation calculations are not very accurate. This software interpolates elevations in the X and Y direction, and weights these values based on distances (refer to chapter 2). Thus, in street sections elevations tend to be somewhat off. The greatest amount of error in the elevation, for a structure located near a street, was 1.5 feet. The program gives acceptable approximations, but for final designs the elevations must be read from street profiles, and entered by the user.

When determining the ground surface profiles above the sewer lines the program test to find contour lines that intersect the sewer line locations. Testing this way will not accurately show a street section above a sewer line since street cross sections are not accurately represented by contour lines. Execution time for determining the surface profile above the sewer lines, for the thirty acre subdivision, was 5 minutes. For larger tracts of land the execution times may begin to inconvience the user.

The programs are connected by batch files. When a program finishes execution and a batch file begins the next program, the A drive is read. If the disk in the A drive, does not have the Command.com program on it CADDSS, will not work. This error is due to a fault in the Quick Basic software.

The drafting of the system is quick and convienent, but the symbols and style used are not yet of acceptable quality for professional use.

4.3 Design Limitations

CADDSS makes no allowance for curved pipes. If curved pipe is needed in a storm sewer system the system must be designed using straight pipe. Then once the design is complete the user can enter the drawing containing the plan view and use the fillet command to insert curved sections of pipe.

CADDSS makes no allowances for flow bypassing a street drainage inlet and going into another inlet. In other words, both grate inlets and curb opening inlets have 100 percent interception of the gutter flows.

Chapter V - Conclusion

The software developed has great potential to aid engineers in storm sewer design. With this software an, engineer could design a storm sewer system quickly and accurately. After the initial design has been done, changes to the system can be made even quicker.

Using this software an engineer can enter raw data needed for the storm sewer design through AutoCAD. CADDSS has programs that transfer contour lines, drainage areas, C factor areas or C factors, street locations and storm sewer line locations from AutoCAD drawing interchange files to data files. Information in these data files is then used by the computation programs. The computation programs can calculate the inlet structure locations, find hydrologic parameters, design the sewer system and calculate the hydraulic grade line. Once the system is designed, the display programs can create plan and profile drawings and display calculated information. If any of this information needs to be changed to improve the design, it can be done through AutoCAD, through the MODIFY program or through the DRIVER program. Programs are rerun and data is changed until a satisfactory design has been achieved.

Some of the more unique features of CADDSS are

1. using contour lines to determine the surface profiles above storm sewer lines

2. inputting sewer line locations through AutoCAD (which allows the user to see what he is designing)

3. calculating the coordinates of structures that are located on streets

4. creating plan and profile drawings for the storm sewer system.

This study has presented how a software package has been developed that uses an IBM personal computer and the AutoCAD graphics system that can aid engineers in storm sewer design. Refinements still need to be made to the software before it is of professional quality. Also several other items could be included or added to this software. Three of these are

1. modification of the program so as to allow for a percentage of the flow to bypass one drainage inlet and enter another

2. expansion of the software to do sanitary sewer design

3. increase the accuracy of contour line interpolations.

If these are done the software could be applied to broader functions, such as site grading.

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Appendix A. Flowcharts

The following pages will present flowcharts of the more complicated programs in the software package.

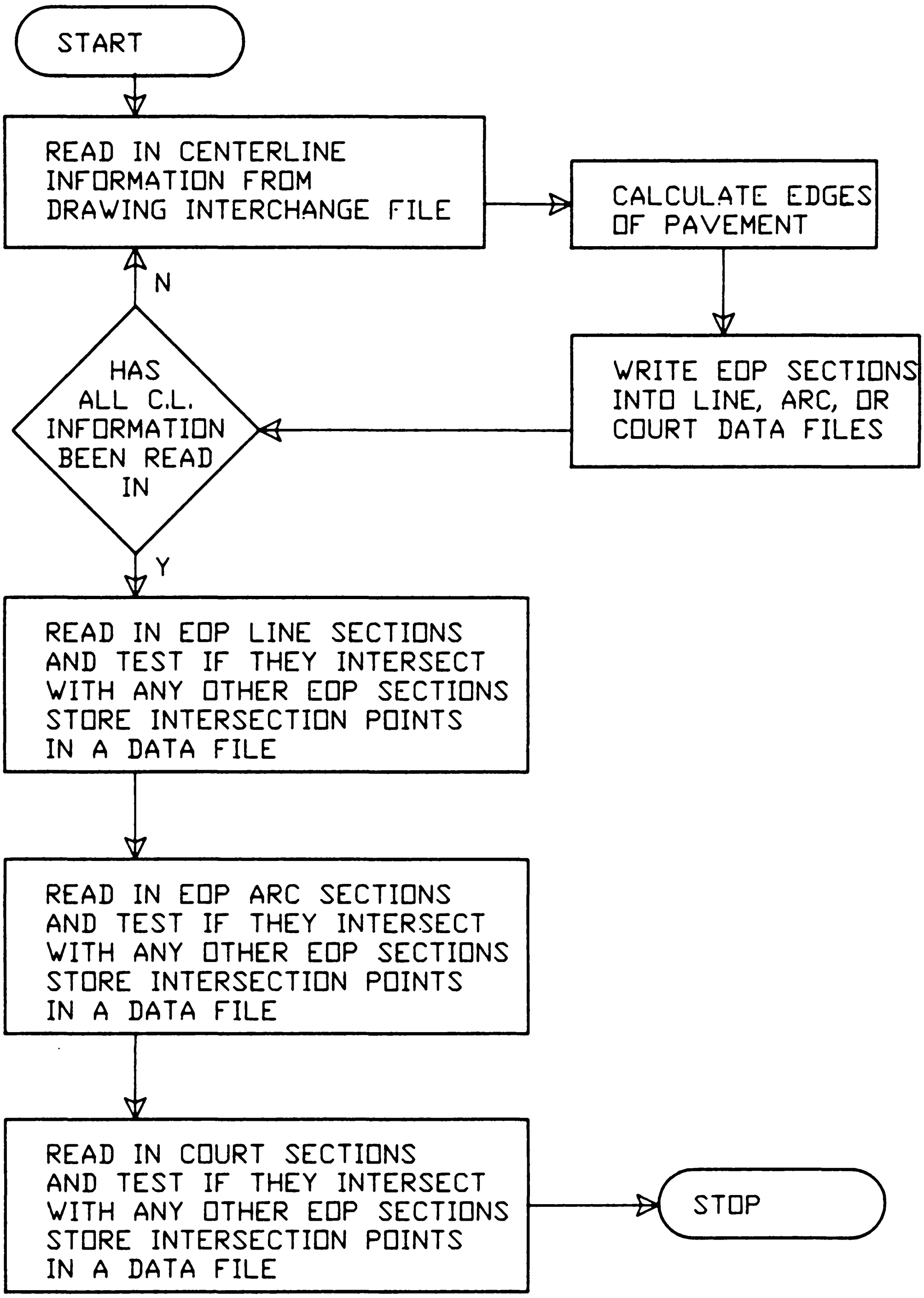

Figure 17. Flowchart of STRDAT program

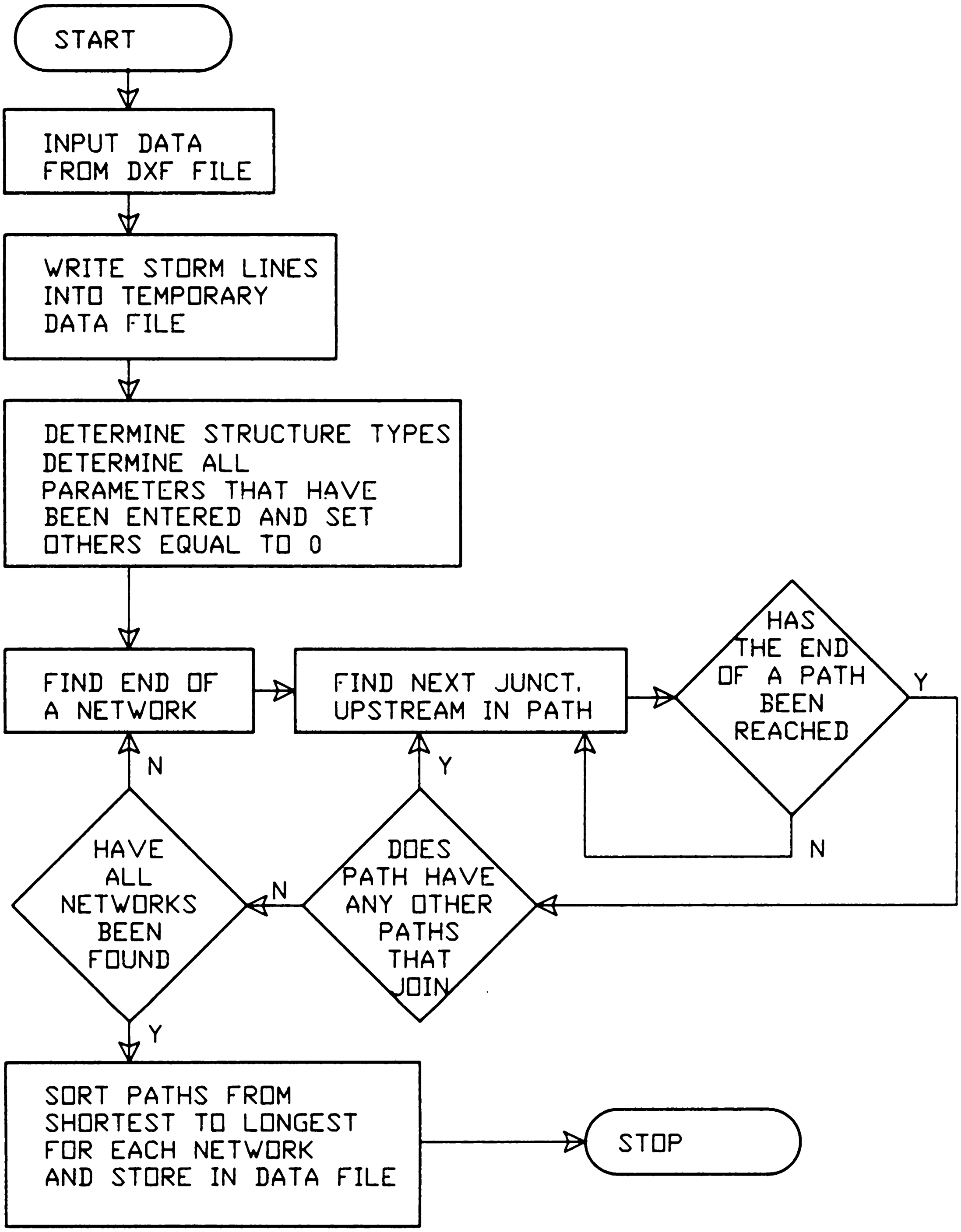

Figure 18. Flowchart of STMLINES program

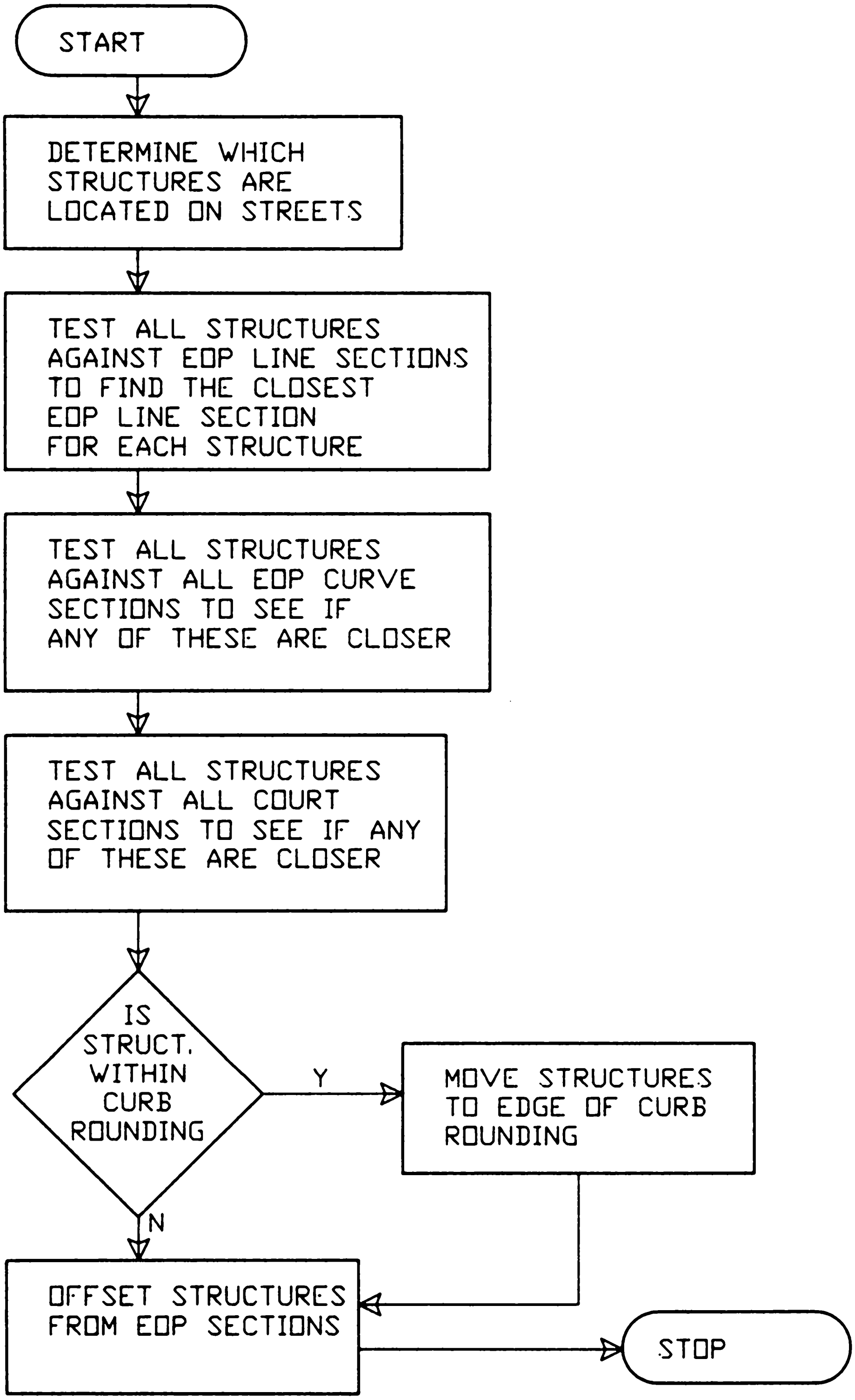

Figure 19. Flowchart of STFIG program

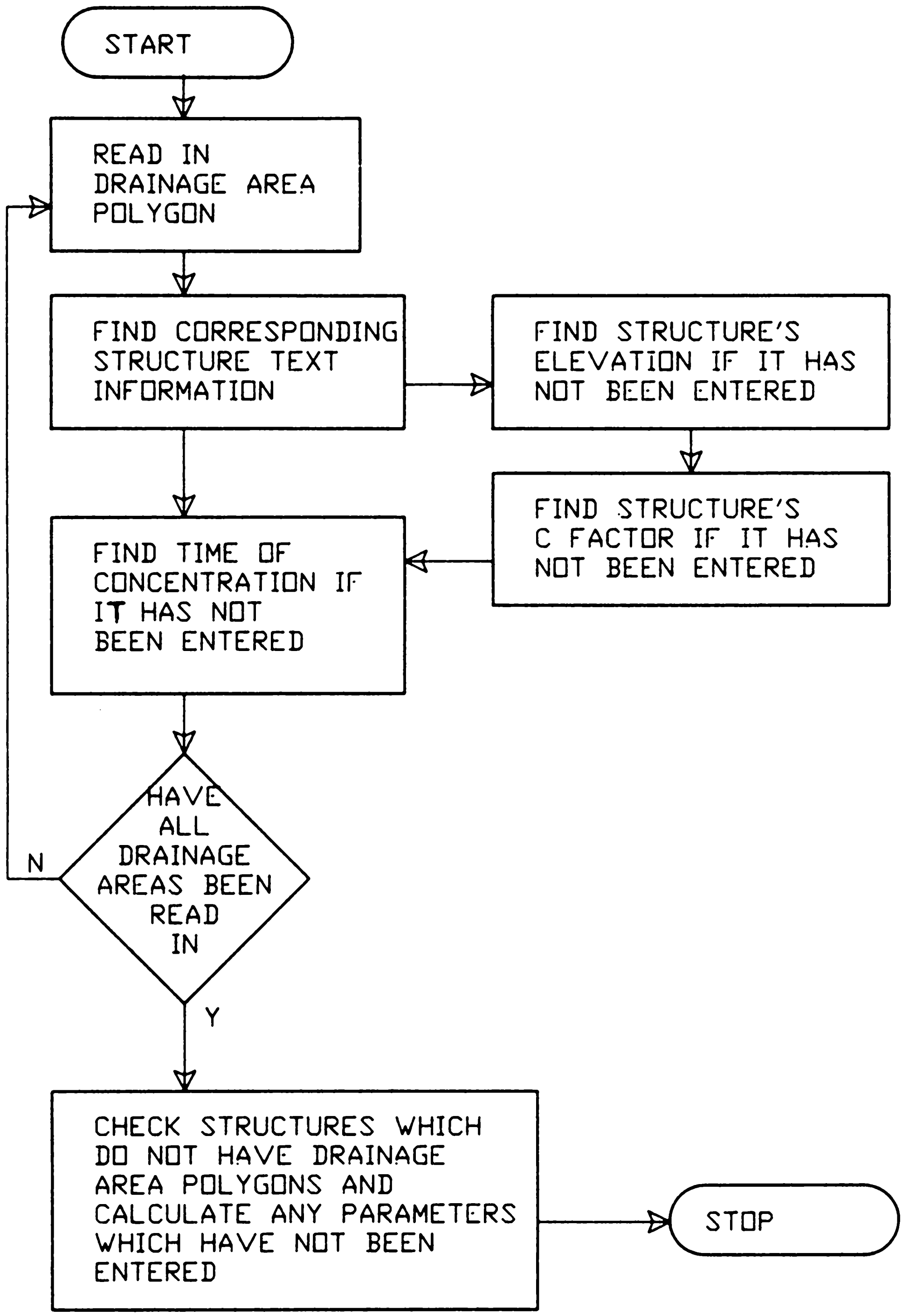

Figure 20. Flowchart of STMDAT program

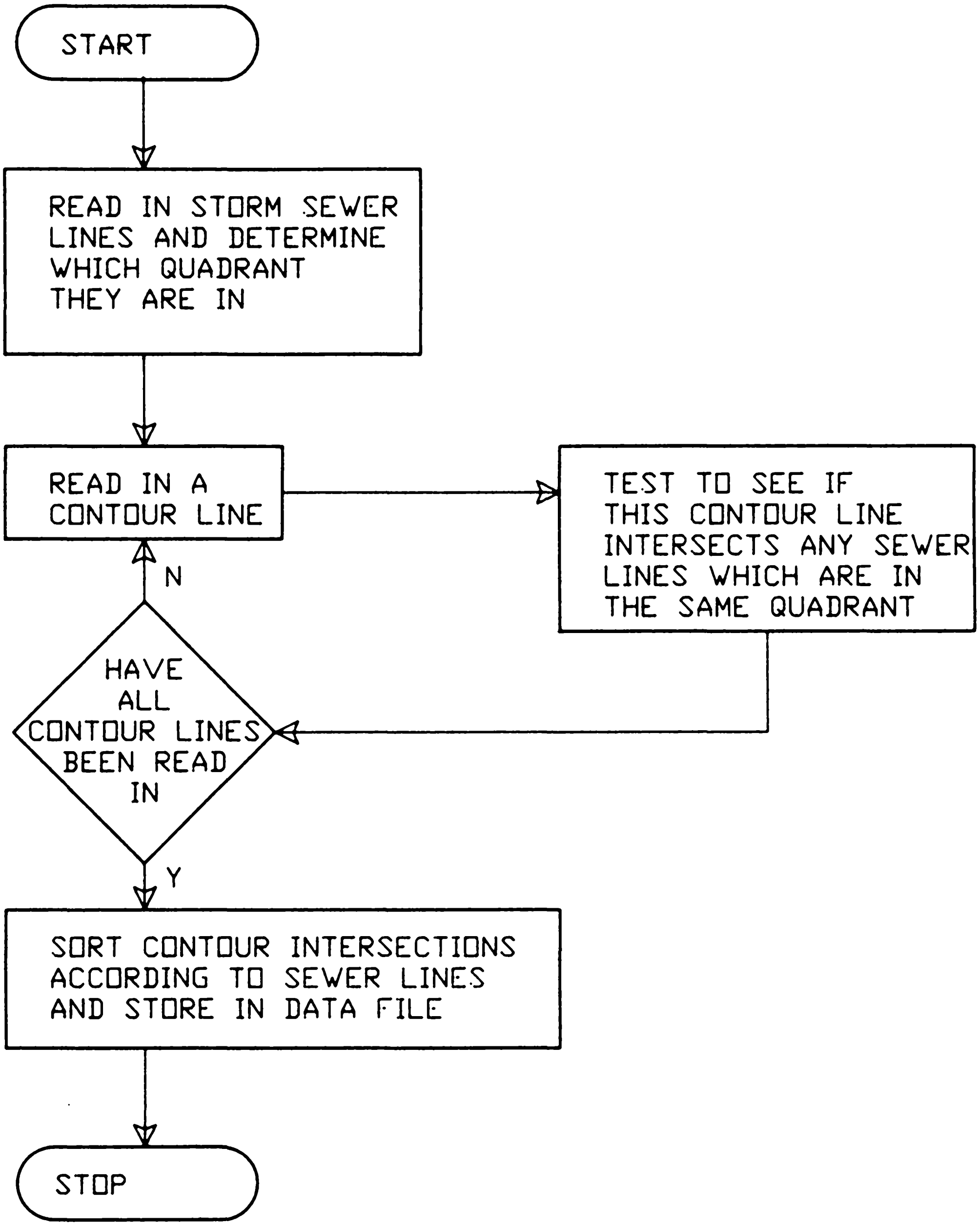

Figure 21. Flowchart of SPROF program

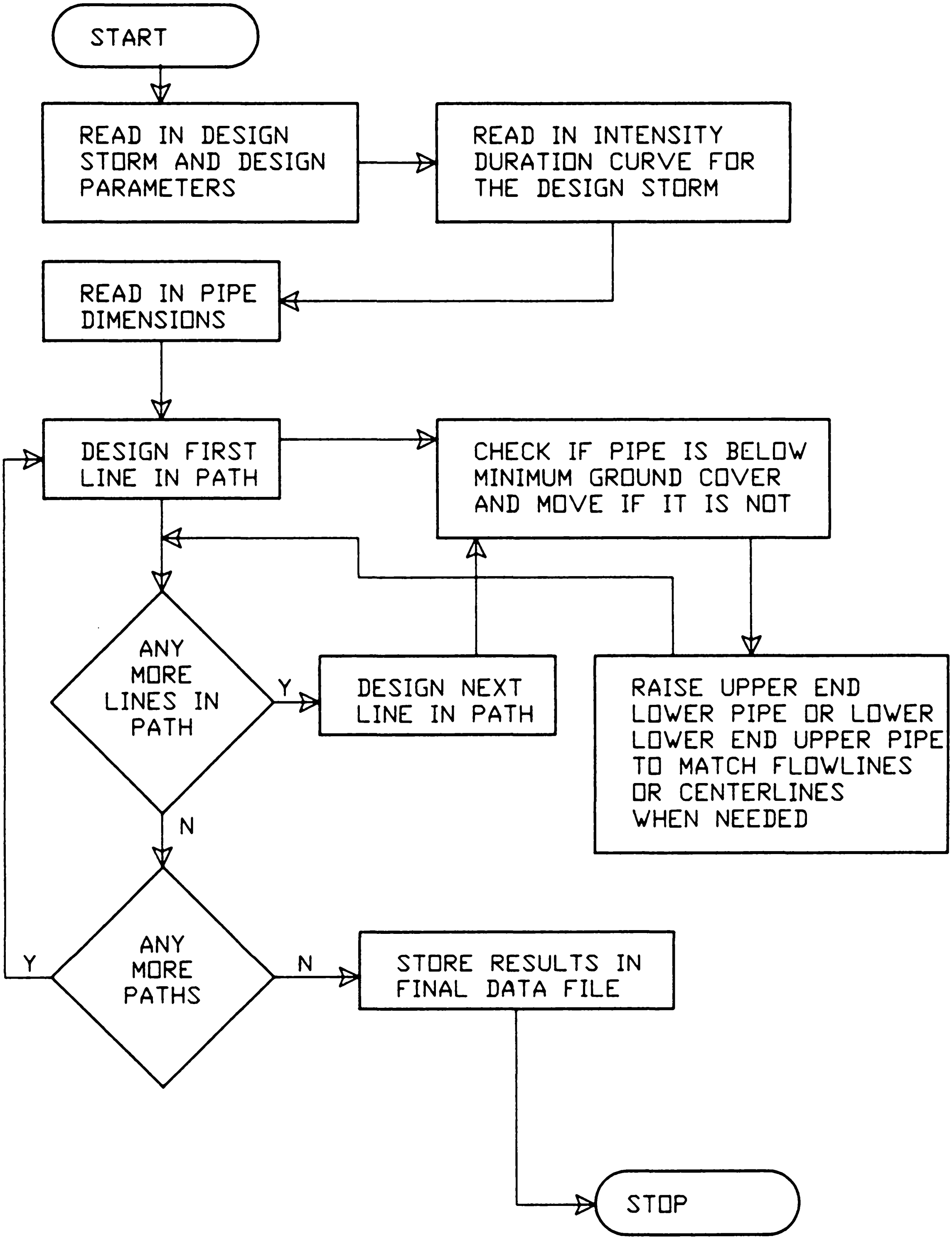

Figure 22. Flowchart of SEWDES program

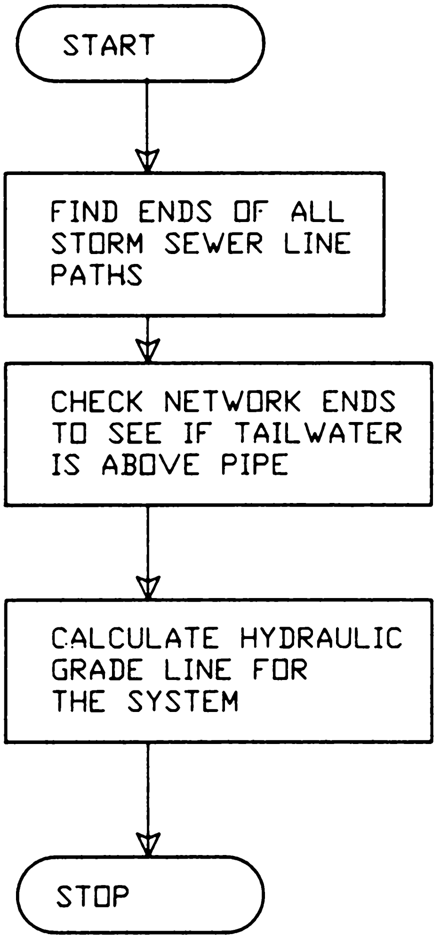

Figure 23. Flowchart of HGL program

Appendix B. Procedure For Hydraulic Grade Line Calculations

The procedure shown below is taken from the Virginia Department of Highways and Transportation Drainage Manual.

4.8 Hydraulic Grade Line

The final step in the design of a storm sewer system is to check the Hydraulic Grade Line. Computing the H.G.L. will determine the elevation, under design conditions, to which the water will rise in the various inlets, manholes, junctions, etc.

4.8.1 The Hydraulic Grade Line will be computed for all storm sewer systems and may be tabulated on Form LD-347 (page 4-74) using the following procedure:

Step 1: Enter in Col. 1 the station for the junction immediately upstream of the outflow pipe. H.G.L. computations begin at the outfall and are worked upstream taking each junction into consideration.

Step 2: Enter in Col. 2 the outlet water surface elevation if the outlet will be submerged during the design storm or .8 pipe diameter (ft) + invert out elevation of the outflow pipe whichever is greater.

Step 3: Enter in Col. 3 the diameter (D_o) of the outflow pipe

Step 4: Enter in Col. 4 the design discharge (Q_o) for the outflow pipe.

Step 5: Enter in Col. 5 the length (L_o) of the outflow pipe.

Step 6: Enter in Col. 6 the friction slope (S_{fo}) in ft/ft of the outflow pipe. This can be determined by entering the pipe flow charts or similar pipe flow calculators with the discharge (Q_o), diameter (D_o), and "n" factor (0.013) and reading the friction slope directly.

Step 7: Multiply the friction slope (S_{fo}) in Col. 6 by the length (L_o) in Col. 5 and enter the friction loss (H_f) in Col. 7.

Step 8: Enter in Col. 8 the velocity of flow (V_o) of the outflow pipe.

Step 9: Enter in Col. 9 the Contraction Loss (H_o) by using the formula

$H_o = 0.25\ (V_o^2/2g)$, where $g = 32.2$ ft/sec^2

Step 10: Enter in Col. 10 the design discharge (Q_i) for each pipe flowing into the junction. (For exception, see Sec. 4.8.2 No. 3)

Step 11: Enter in Col. 11 the velocity of flow (V_i) for each pipe flowing into the junction. (For exception, see Sec. 4.8.2 No. 3)

Step 12: Enter in Col. 12 the product of Q_iV_i for each inflowing pipe. When several pipes flow into a junction, the line producing the greatest Q_iV_i is the line which will produce the greatest Expansion Loss (H_i). (For exception, see Sec. 4.8.2 No. 3)

Step 13: Enter in Col. 13 the controlling Expansion Loss (H_i) using the formula

$H_i = 0.35\ (V_i^2/2_g)$

Step 14: Enter in Col. 14 the angle of skew of each inflowing pipe to the outflow pipe.

Step 15: Enter in Col. 15 the greatest Bend Loss (H_{Δ}) calculated by using the formula $H = K(V_i^2/2_g)$, where K = the Bend Loss coefficient corresponding to the various angles of skew of the inflow pipes.

Step 16: Enter in Col. 16 the Total Head Loss (H_t) by summing the values in Col. 9 (H_o), Col. 13 (H_i), and Col. 15 (H_{Δ}).

Step 17: If the junction incorporates surface inflow, i. e. drop inlet, increase H_t by 30% and enter the adjusted H_t in Col. 17.

Step 18: If the junction incorporates the VDH&T St'd IS-1 shaping, reduce the value of H_t by 50% and enter that adjusted value in Col. 18.

Step 19: Enter in Col. 19 the FINAL H, the sum of H_f and H_t, where H_t is the final adjusted value of H_t.

Step 20: Enter in Col. 20 the sum of the elevation in Col. 2 and the Final H in Col. 19. This elevation is the potential water surface elevation for the junction under design conditions.

Step 21: Enter in Col. 21 the rim elevation or the gutter flow line, whichever is lowest, of the junction under consideration and compare it with the potential water surface elevation in Col. 20. If the potential water surface elevation exceeds the rim elevation or the gutter flow line, adjustments are needed in the system to reduce the elevation of the H.G.L.

Step 22: Repeat the procedure starting with Step 1 for the next junction upstream.

4.8.2 The normal design of a storm sewer system will, whenever possible, incorporate the following:

1. When a trunk line passes through a junction, the pipe crown lines will be at the same elevation. An exception is that when the inflow and outflow pipes are of the same diameter, the outflow pipe invert elevation will be 0.1' lower than the inflow pipe invert.

2. The angle of an inflow trunk line pipe to the outflow trunk line pipe at a junction will not exceed 90°.

3. If a lateral pipe line enters a junction with its invert elevation above the crown line elevation of the outflow trunkline pipe, the lateral discharge will be considered as drop inlet inflow in adjusting H_t for Step 17. (4.8.1)

Appendix C. User's Manual

C-1 System Requirements

The software package uses the IBM personal computer. The software requires 215K of memory. When using CADDSS a disk must be placed in the A drive with Command.com on the disk. CADDSS uses a temporary disk that must be created by the user if one is not on a card in the computer. The temporary disk should be as large as possible. The user can refer to the computer owner's manual for the procedure to install a temporary disk. The temporary disk should be set up to have 360K. If the computer has a hard disk the programs in this software package should be stored in their own directory. CADDSS.BAT is the batch file that has been created to control this software. The batch file may have to be slightly modified in order to work on a specific system.

To use this software package, a good understanding of AutoCAD is required. When using AutoCAD, a large digitizing table is very convenient.

C-2 Data Entry

C-2.1 AutoCAD Data Entry

When entering data using AutoCAD and after a drawing file has been completed the dxfout command must be used to store the files in a format that CADDSS can understand. When entering data in AutoCAD, make sure to follow the procedures exactly as described below or errors will result. All data of the same type must be place on the same layer (the exception is when entering contour lines).

C-2.1.1 Preliminary Data

Intensity Curve: To input a rainfall intensity curve, first calibrate the digitizing tablet in inches. If you want to draw the axis of the graph it must be entered next using the line command (the axis is optional). After this the scale is set up. For this you will enter the maximum X, minimum Y and the minimum X, maximum Y coordinates. Using the text command, enter the text starting points exactly where the before mentioned points occur, then enter the scale values of these points in the form (x,y) or x,y. The line command is used to enter rainfall curves. Begin at one end of the curve and digitize to the other end, points may be put as close as you wish. Immediately after a curve has been digitized, use the text command to enter the return interval of the curve. This text may be placed anywhere, but the number of the return interval must be the first entry. Examples of acceptable formats are 5y, 5 Y, 5 and 5 year. Repeat the above process until all curves have been entered.

Contour Lines: Start a drawing file and create one or two layers for the contour lines to be entered on. The software package has been set up to take contour lines from a layer named CONTOURS and/or a layer name of your choice. To enter contour lines, the text command must first be used to enter the contour elevation. Next the line command is used to digitize the contour line. Do this for as many contour lines as you like. Contour lines do not have to be at even intervals. If you wish, even contours can be placed on one layer and odd contours can be placed on a different layer. It is a good idea to have a higher concentration of contour lines where structures and sewer lines are located. If at a later time you wish to enter more contour lines simply get back into the drawing file and enter as many as you like, following the above procedure.

C Factor Areas: When digitizing runoff coefficient areas (C-areas), all information must be placed on a layer named CAREA. C-areas should be placed in the drawing that contains the contours lines. Each C-area must be a closed polygon. The following procedure must be used. First the polygon representing the C-area is digitized using the line command. To close the polygon a C can be entered or the osnap end command must be used. The end point of the polygon must close on the first point entered, for the polygon, or the program will not function properly. After the polygon is entered the text command is used to give the value of the C-area. This value must be entered in the form C = 0.xx or c = .xx. This value can be placed anywhere within the drawing and can be any size, but must be entered immediately after the polygon is drawn.

When entering C-areas the fewer polygons entered the faster the program will run. Also, it is best to enter polygons with the fewest sides first.

Streets: Entering street centerlines and widths will in able the program to calculate the exact locations of the inlet structures. When entering these, the commands used will be line, arc, circle and text. All work must be done on the same layer (CLSTREET is the recommended layer name). The drawing file can have a name of your choice or can be a part of another drawing. The text command is used after an entity has been drawn. With it street widths and curb rounding radii will be entered. Street centerlines will be entered in segments represented by lines and arcs. Lines are used to represent straight sections of street. Arcs are used to represent curves in the street. A circle is used to represent the courts, the circle's radius is the actual distance to the edge of pavement. Streets can be tapered in straight sections. To start entering street data enter a line or arc segment (note that arc sections are usually drawn counter clockwise). Next enter the street width and curb rounding radius in the form W = xx,R = xx, for the street segment. If the street is tapered use W1 = xx,W2 = xx,R = xx. W1 being the width of the street at the first point and W2 the width at the second point. For the next centerline segment entered, the street width will be W or W2 and R will be the curb rounding radius. Text only needs to be entered when the street width or the curb rounding radius changes (always entered just after the entity that will be changed is entered). For arc and line segments make sure that the ends points join, if on a continuous section of street. If a street intersects another street the osnap near command should be used to make sure the end point of the one line is on the other line. For courts use the circle command, enter the center point at the center of the court, then enter the radius to the edge of pavement. If the circle represents the inside edge of pavement use the text command and enter inside or anything with an I in it, along with any change to the curb rounding radius (street widths are not used for courts). An example of an acceptable format for text for the inside of a court is I,r = 54.

C-2.1.2 Variable Data

The procedures listed below are for data entry of items that can be changed to provide for a more efficient design. Store the following information in the same drawing file.

Drainage Areas: When digitizing drainage areas all information must placed on a layer named DRAREA. Each drainage area must be a closed polygon. The line command is used to create these polygons. After the polygon has been entered the text command is used to enter the number of the drainage area. This number can be placed anywhere and can be any size. For the program to work the text must be entered immediately after the polygon has been entered and the polygon endpoint must close on the first point entered for the polygon.

Storm Sewer Lines: The storm sewer lines and text may be entered in any order. All information must be placed on the STMDAT layer. The main constraint is that the text representing the structure must be placed exactly at the junction or the end of a sewer line (osnap end should be used) and sewer lines must join together exactly. The line command is used to represent the storm sewer lines. Through the text command several design parameters can be entered.

Through the text command the structure number and the structure type must be entered. The different types of structures allowed are in table 2. If an F is placed in front a CB, CI or a GI the structures coordinates will not be adjusted. If END is placed in front of any structure this will indicate that the structure is an end of a network. Optional data that may be entered with the structure number and type is the structure's elevation, rainfall intensity, time of concentration, C-area, drainage area, length of travel and highest point. The elevation may be entered. If it is entered it must be in the form E=elevation. The rainfall intensity may be entered. If it is entered it must be in the form I=intensity. The time of concentration may be entered, if entered use the form TC=time of concentration. The C factor may be entered, it is entered as a single number. If the drainage area is entered, the C factor and the time of concentration or the length of travel and the high point must be entered. The drainage area is entered in as a single number. The length of travel and high point may be entered, both must be entered if they are to be entered. Both are entered as single numbers. All data must be separated by commas. Data must also be entered in the order which it was listed. Refer to table 7 for examples of different ways to parameters can be entered.

The above procedures are used when data is first entered. The following will explain how to modify this data.

Drainage Areas: When the NDXF program is run all drainage areas will be placed on a layer named ODRAREA. If you want to change a drainage area enter it on the DRAREA layer, and re-enter any drainage areas that are affected by changing this drainage area. Do not forget to enter

Table 7. Different ways text can be entered for storm structures

No,type
9,CB

No,type,C factor
8.2,CI,.65

No,type,elevation
4,MH,E = 2050.55

No,type,intensity
110,AI,I = 6.6

No,type,time of concentration
45,FCB,TC = 15

No,type,length of travel,high point
32,CB,850,2070

No,type,time of concentration,C factor,drainage area
14,GI,TC = 8,.7,.95

the structure number immediately after drawing a polygon. If you wish to delete a structure the drainage area must be eliminated. To do this enter the structure number and 'DELETE' (i.e. 9DELETE) on the DRAREA layer.

Storm Sewer Lines To change the location of a junction erase the text and all lines that come into the junction. Then redigitize the lines coming into the new location and re-enter the text. Use the osnap end command and make sure all lines and text join at the same point for the junction. If you want to add drainage structures follow the procedures outlined above. After running the NDXF program all calculated parameters will be displayed at the junctions. If you want to change any of this information erase the text (or use the change command) and re-enter the text using the new values. If a drainage area is re-entered for a structure the text may need to be changed. If text is not changed the values that are shown at the structure locations will be kept the same, except for the drainage areas.

C-2.2 MODIFY Program Data Entry

The MODIFY program lets the user give all inlet structures a constant C factor and a constant time of concentration if desired. This program also allows the user to change any of the variables that are displayed by the NDXF program. These variables are the structures' numbers, types, elevations, rainfall intensities, C factors, drainage areas, time of concentrations, length of travel and high point. The only parameters that can not be changed are the coordinates of the structures, this must be done by moving the storm sewer lines while in AutoCAD. The program will display information for 10 structures at a time and ask if you want to change anything. If the user responds with a yes, the arrow keys and the return key will be used to move around the data field. To change data simply type over the existing data. Make sure to stay between the lines. When all changes have been made press the ESC key. You will then be given a chance to modify the same data.

C-2.3 DRIVER Program Data Entry

The DRIVER program will prompt the user for any information that is needed to execute the programs. Such as the name of a drawing interchange file and where it is located. Through the DRIVER program special data is entered for the following programs.

STFIG: The DRIVER program will display the offset distances for catch basins, grate inlets, and curb inlets. The distance for curb inlets and grate inlets will usually be negative, since these are offset toward the centerlines of streets. Also displayed is the offset distance from curb roundings. This distance is measured along the curb line from the end of the curb rounding. If you want to change any of these respond with a yes to the prompt.

SEWDES: When choosing the SEWDES program the DRIVER program will first prompt you for the design parameters. These parameters are the design storm, minimum ground cover, minimum pipe slope, minimum drop in a manhole, minimum velocity, maximum velocity, minimum pipe diameter, pipe material and whether the crowns, flowlines, or center lines will be set equal for different size pipes.

After this data is entered, the program will ask you if you want to enter any variable data. The variable data will allow you to enter different parameters for individual lines. Data that can be entered is the ground cover of the upper end and lower end of the pipe, minimum and maximum velocities, minimum pipe slope, maximum pipe slope, minimum pipe diameter, and pipe material. To indicate which line the variable data is for the upper structure number is entered.

HGL: When choosing the HGL program the DRIVER program will ask if you want to enter any tailwater elevations. Tailwaters can only be entered for the ends of sewer networks and do not need to be entered if the tailwater is less than or equal to the flowline of the exit pipe. The DRIVER program also ask if you want to shape the inlets.

C-2.4 Data Entry Check List

Below is summary of the data that must be entered before you can run CADDSS. Refer to the above sections for the procedures of entering this data.

Elevations: Entering contour lines through AutoCAD is optional. If contour lines are not entered structure elevation must be entered through the MODIFY program or when entering storm sewer lines.

C factors: Entering C-area polygons through AutoCAD is optional. If C-areas are not entered the C factors must be entered through the MODIFY program or when entering storm sewer lines.

Streets: Street centerlines must be entered through AutoCAD if one wants the software to calculate the coordinates of structures that are located on streets.

Drainage areas: Drainage area polygons may be entered through AutoCAD. If drainage areas are not entered through AutoCAD they may be entered as a number while entering the storm sewer lines or through the MODIFY program. If the drainage area is entered in as a number it must be in acres.

Time of Concentration, length of travel and high point: If a drainage area is entered in as a number the time of concentration or the length or travel and the high point must be entered. These may be entered through the MODIFY program or while entering the storm sewer lines. If the user does not care for the values that the software produces for the above parameters he may enter new values. If all 3 of these parameters are entered only the time of concentration will be used.

Storm sewer lines: Storm sewer lines must be entered through AutoCAD. Text must be entered at every structure location and at the end of pipes. The text that must be entered is the structure number and type. Optional data may be entered. Any optional data entered will override any data that has been entered in raw form, except for drainage areas. An example of this is if a C factor is entered the software will not calculate the weighted C factor using the C area polygons.

C-3 Program Descriptions

This section will briefly explain the purpose of each program in the software package. All data files are stored on a drive and path that is specified by the user. Provisions have been made so drawing interchange files can be stored in different drives and paths.

C-3.1 DRIVER Program

This program controls all the other programs. Thru it all data is entered and the user specifies which programs will be run. This programs use will be explained later.

C-3.2 Data Transfer Programs

Data transfer programs are only run when the data that they convert has been entered or changed. The user is allowed to use any name for the drawing interchange files, which these programs read, and place them on any drive and path.

INTTRAN: This program transfers a rainfall intensity curve that has been entered through AutoCAD into a data file. This file will have the extension determining the flows. This program only needs to be used when designing a storm sewer system in an area for the first time.

EL: This program transfers contour lines from a drawing interchange file that was created in AutoCAD into contour data files. These data files have the extension .CON. This data is used to determine the elevation of structures and surface profiles above sewer lines. The data is also used to see if sewer lines are below minimum cover.

CAREA: This program transfers C factor polygons from an AutoCAD drawing interchange file into C-area data files. These data files begin with CAREA. The C factor polygons can be used to determine weighted C factors.

DRAREA: This program transfers drainage area polygons from an AutoCAD drawing interchange file into a data file. This data file has the name DRAREA.DAT. This data is used to determine the flows into an inlet and other hydrologic parameters.

STRDAT: This program takes street centerlines and text information, which is entered through AutoCAD, and calculates the edges of pavement and the curb roundings. Curb rounding data is stored in files with the extension .MOV. Edges of pavement are stored in various files. These data files will be used to calculate the locations of the structures.

STMLINES: This program takes storm sewer lines and text information that has been entered in AutoCAD and stores it in the STMDAT.DAT data file.

C-3.3 Computation Programs

STFIG: This program is used to figure the exact locations of the structures. The results of this program are re-written into the STMDAT.DAT data file. It must be run before the STMDAT program is run. This program only needs to be run when new structures have been entered or when structures have been moved. The program does not need to run in the early stages of the design

STMDAT: This program finds all parameters needed for the storm sewer design that have not been entered as optional data when the storm sewer lines were entered or through the MODIFY program. All data is re-written into the STMDAT.DAT data file. The program only needs to be run when raw data has been changed or entered. Raw data is data that has not been calculated. an example of raw data would be entering a drainage area polygon.

SPROF: This program finds the surface profile above the sewer lines. Results are stored in the SPROF.DAT data file. This program only needs to be run when new contour lines have been entered or new storm lines have been entered or moved.

SEWDES: This program does the actual designing of the storm sewer system. Special variation to the design can be put in through the DRIVER program. Special variations is data entered for individual lines, such as minimum cover at the upstream end and minimum cover at the downstream end. Results of this program are stored in the SEWCALC.RES and COORDS.DAT data files. This program should be run anytime special variations for the individual sewer lines have been entered or the data entered through AutoCAD has been changed.

HGL: This program determines the hydraulic grade line for the system. Results are stored in HGL.RES and STRELEV.DAT data files. Tailwater elevations which are higher than the flow lines of outlet pipes can be entered within the DRIVER program. This program can be run anytime after the SEWDES program has been run.

MODIFY: This program lets you change any structure data that you want to. This program can be run at anytime. The program modifies the STMDAT.DAT data file.

C-3.4 Display Programs

PRSEWCAL: This program will print the sewer design calculation sheet. The file that it prints is the SEWCALC.RES data file.

PRHGL: This program will print the hydraulic grade line calculations. Information is taken from the HGL.RES data file.

NDXF: This program takes the drawing interchange file which contains the storm sewer lines, structure information and drainage areas and rewrites this file to show the text structure information that was calculated and the locations of the structures. This program also moves drainage areas from the DRAREA layer to the ODRAREA layer.

PLDRAW: This program draws the plan view of the storm sewer system. Where the drawing interchange file is stored and its name is up to you.

PRODRAW: This program draws the profiles of the storm sewer system. Where the drawing interchange file is stored and its name is up to you.

C-4 Program Operation

After all data has been entered through AutoCAD you are set to run CADDSS. To run, type CADDSS. This will bring up the DRIVER program where you can specify what programs you want to run. The driver program has been set up to be "user friendly" and will prompt you for any data that it needs. First specify the drive (and path) which contains the data disk. Only one storm sewer system can be contained on one data disk, since the same data file names are used all the time. While in the driver program anything that appears between arrows is the default value (i.e. < default value >).

After the drive and path has been specified the main menu will appear. This menu gives you 3 sections to choose from. They are data entry programs, computation programs and display programs. Each of these has a sub menu which shows all programs included in the section. When you select a program to be run the DRIVER program will prompt you for information when it is needed. If a mistake is made in choosing a program or entering program constraints return to the main menu and then go back to the sub menu. This will clear all programs that have been entered for that particular section.

C-4.1 Data Entry Programs

When the data entry menu is entered you can run any of the data entry programs in any order. Programs only need to be run when the data that they are concerned with has been entered or changed. An error will result if a program is specified and no data exists for the program. For each program that can be chosen the DRIVER program will ask you the drive (and path) and the name of the drawing interchange file that the program will be taking data from. Data for the DRAREA program and the STMLINES program must be in the same drawing interchange file.

C-4.2 Computation Programs

When the computation programs menu is chosen the DRIVER program will first ask you if you want to consider contours. Choose yes only if contour lines have been entered. After this, the computation menu will appear. When choosing these program not all programs need to be run, but programs that are going to be chose must be chosen in order. For example if the STFIG program is going to be run it must be run first, since it is the first program on the menu. This is true for all programs except the MODIFY program this program can be run at any time and can be run more than once. When wanting to run the STFIG program the DRIVER program will ask you if you want to change the offset distances for the different types of structures and how far you want structures to be placed from the curb roundings. When the SEWDES program is chosen the DRIVER program will first ask you what intensity curve data file you want to use. Next the design parameters for the storm sewer system will appear. You can modify these if you wish. Next the variable design parameters will appear. These can be set for any desired lines. To enter these first enter the upstream structure then change any of the values that you wish to change. If you choose the HGL program the DRIVER program will ask you to enter any tailwater elevations. These can only be entered for outlet structures, and only if the tailwater elevation is greater than the flowline of the exit pipe.

C-4.3 Display Programs

When entering the display programs menu you can choose the programs in any order. The DRIVER program will ask you the file name and drive (and path) where you want the drawing interchange files stored for the PLDRAW and PRODRAW programs. For the PRODRAW program you need to make sure whether you are considering contour lines or not. This was entered in the computation section.

As soon as you exit the DRIVER program the software will begin execution. Once execution is complete you can view results that were produced for AutoCAD or you can look at calculation tables that were printed out. If any data needs to changed it can be so done through AutoCAD or the MODIFY program. This program can be rerun as often as you like.

Appendix D. Computer Programs

All computer programs are included on the floppy disk in the back flap. Quick Basic programs are stored in their listed form. These files have the the extension .QBA. Also included on this disk are two Basic programs which are used to print the calculation sheets and two DXF files which are needed to create plan and profile drawings. Three data files are included they are FLNAMES, SEWER.PIP and MINDAT.DAT. These data files are needed for CADDSS to run. Also on the disk are DXF files that where used in the design example in chapter three.

If one wants to run this software all programs with the QBA extension must be compiled using Quick Basic. The batch file included on the disk should be used to execute the software. The example drawing interchange files can be used and then manipulated until one is familar with the software. Refer to the user's manual for instruction on program operation.

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