4. COMPUTER MODELING

PCSWMM 2002 software was used to complete the SWMM modeling. Although this software has some GIS capabilities, it was decided to maintain the modeling data in the PCSWMM 2002 environment, and to maintain the drainage modeling infrastructure in an ArcMap GIS environment. This approach avoids redundancy, while making the best use of the modeling and GIS tools.

In Chesapeake, as in many localities, GIS and planimetric data sets have been collected to the point that a large library of data is available to use as the basis for storm water modeling. However, there is so much data to wade through, that for large-scale modeling, a majority of the project budget is consumed merely collecting, processing and rectifying the data. All data sets are temporal snap shots of watershed conditions, and no data sets are truly current or complete. Delineating subcatchments for this study involved considerable patchwork, stitching together the available planimetric, pipe, easement, topographic, aerial, land use, soils and parcel coverages, then estimating the drainage patterns. One of the most common problems was that the topographic data pre-dates the aerial imagery. Where the topo lines may indicate that ditches flow one way, the planimetrics may indicate a completely different drainage pattern. Although the City has collected a great deal of drainage inventory information, much of this information has yet to be processed into its GIS.

As in 1986, it is not feasible to survey the watershed to collect all the missing information. Although there is more data available than ever before, in a very real sense there is also more data that is missing. To successfully assemble large-scale models, protocols had to be developed to accomplish the data reductions. There are a number of physical factors that complicate the process, as these watersheds are very flat, with low-lying topography.

4.1 Data Sources & Processing

GIS data was obtained from several sources, including:

City of Chesapeake

- Easements
- Streets
- Parcels
- Land use
- Topographic spot elevations and contours
- Selected site plans, both past and current
- Storm water items (incomplete)
- City features
- Wetlands
- Zoning

Hampton Roads Planning District Commission

- 1999 Land use analysis
- Table of local land use imperviousness

U.S. Department of Agriculture, Natural Resources Conservation Service

- SSURGO soils map of Milldam Creek watershed (advanced copy, sketched by hand, subject to change)

As the work progressed, it was necessary to put the pieces together in different combinations—a process greatly simplified through the use of desktop GIS. Given the quantity of data involved, priorities were established for the amount of analytical effort that was used to reduce subcatchment-modeling parameters. For example, the determination of imperviousness was considered critical to the effort and was analyzed using GIS frequency procedures. Soils parameters, on the other hand, were derived by visually estimating

the predominant soil texture within each subcatchment using the advanced copy of the SSURGO soils data provided by NRCS.

The 2002 aerial imagery files comprise the most up-to-date data on this watershed. These files were updated with scans of site plans, as described in Section 5 of this document. URS created several GIS coverages to support this modeling effort, including pond bottom areas, pond top areas, links (i.e. channels and pipes), nodes, and subcatchments for both the current (2003) and future watershed configuration.

4.2 Methodology

The SWMM model was developed through the U.S. Environmental Protection Agency, over a period of decades. SWMM methodology, now over 30 years old, is sustained and enhanced through independent software developers and user groups. The methodology has been widely used and is essentially universally accepted. Readers interested in the development of formulations used in SWMM modeling are referred to the Computational Hydraulics web site at http://www.computationalhydraulics.com/swmm.html for details. Of particular interest is the tutorial on the SWMM RUNOFF block at http://www.computationalhydraulics.com/tutorial4.html.

The most important concept to understand is the fundamental premise of the modeling. The computer models constructed in support of this watershed management plan are intended to be numerical abstractions of the actual watershed, not numerical replicas. In other words, it is very important to understand the limits of the underlying methodology, and to appreciate the assumptions and lumping of parameters that are required to construct SWMM models. The size and complexity of the watershed has a direct bearing on how the modeling is executed. The updated models completed in connection with this master drainage plan are considerably finer in detail than the original (1986) models. The Milldam Creek watershed covers over 2,200 acres, discretized into more than 90 subcatchments. It is neither desirable nor possible to construct a true mathematical representation of this watershed. The overall purpose of this modeling is to compute flows and hydraulic grade line elevations in the major channels under a variety of design-storm scenarios. With that goal in mind, the models are constructed following standard SWMM precepts.

A general appreciation for SWMM hydrology can be developed by considering its "RUNOFF block" (the computer program that computes subcatchment runoff hydrographs for the watershed). As shown in Figure 4-1, each subcatchment is considered to be a uniformly sloped planar surface consisting of three surface components, A1, A2 and A3. Runoff is computed from each planar surface (also known as a subcatchment) using the RUNOFF block. The resultant runoff hydrographs are then routed through the drainage network using the EXTRAN block of SWMM.

In reality, there is no such planar surface that describes each subcatchment. Yet in order to compute runoff hydrographs, each subcatchment is approximated as a three-part planar surface. In this case the average planar surface in the watershed model is approximately 24 acres in size (2,272 acres divided by 94 subcatchments). If we consider a typical 24-acre plot in this watershed, we know that it will have constantly varying overland slopes, and in many locations the slope will be uphill rather than uniformly graded towards the lower 'edge' of a planar surface. Likewise, this hypothetical 24-acre plot will have drainage elements such as curbs, ditches, pipes and ponds that are not directly considered in the runoff schematic. Yet even with this simplified conceptual approach, the mathematics required to compute the runoff hydrographs are very complicated, as are the numerical routines required for the computation of the hydraulic response of the drainage network.

Again, the most important concept is to understand that SWMM modeling is an abstraction. As demonstrated over the past several decades, with good judgment and careful selection of the modeling parameters, the models can produce useful and reasonably accurate results.

It is also important to appreciate the purpose of the study in terms of level of detail. The ultimate general purpose of this modeling is to develop hydraulic grade line elevations in the major channels in the watershed. To do so, the watershed has been discretized to a high level of detail, but not to the extent that

any one parcel is favored over another. In other words, the overall purpose of the study is borne in mind as the modeling data is being prepared. Discretion and engineering judgment are used to develop a model that 'fairly' depicts all of the subcatchments. It would be inappropriate for the purposes of this study to model

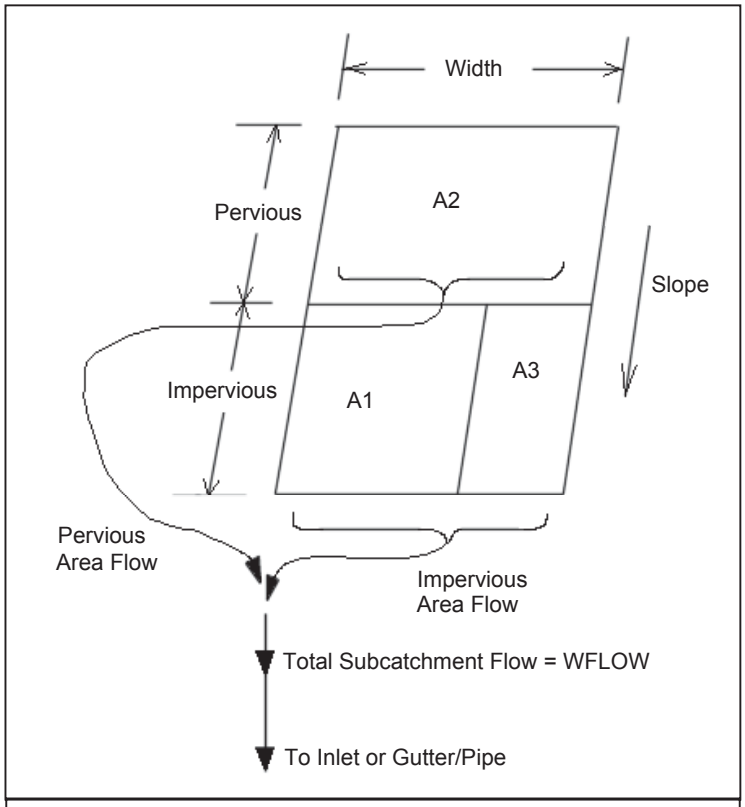


Figure 4-1. SWMM RUNOFF Block Flow Schematic

one area in extraordinarily high detail compared to the rest of the watershed. Invariably, engineers will take this model as a starting point, focus on a much smaller plot within the watershed, and then model that plot in very fine detail. There is nothing wrong with that approach, but the level of discretization that is appropriate for a 10-acre parcel cannot be applied to a 2,272-acre watershed. In such a case, the purpose of the modelers interested in the 10-acre parcel is much different than the modelers of the regional watershed.

4.3 Model Development & Selection of Parameters

There are several critical decisions and modeling options that must be addressed in order to prepare a SWMM model. Likewise, there are several parameters that must be estimated to compute the runoff from the planar surface shown in Figure 4-1. Some of these parameters are physically based and relatively easy to estimate, such as subcatchment area, and others are much more complex, such as soil infiltration parameters. A typical modeling approach is to estimate the modeling parameters, then compare the predicted results (runoff hydrographs) against some measured data in a calibration exercise. Although this procedure works well, typically there is little or no data available to calibrate these models. In most studies, the validity of the output is established by general observations over time.

4.3.1 SWMM RUNOFF & EXTRAN Blocks

Only the RUNOFF and EXTRAN computational blocks of SWMM were used in this study. The RUNOFF block was used only to compute the subcatchment runoff hydrographs for input into the EXTRAN block,

which was used to compute all of the hydraulic profiles. Channel or gutter routing was avoided in the RUNOFF block, because EXTRAN has better, more physically based routing capabilities.

The hydraulic routing routines in EXTRAN are ideally suited for the type of drainage network and system components that exist in this watershed.

4.3.2 SWMM Engine, Numerical Solutions, Time Steps

The SWMM Version 4.4h engine was used for all of the computations. Version 4.4h comprised the latest version of the model at the time this study was conducted. For the EXTRAN computations, the enhanced explicit solution (ISOL = 1) typically yielded the best numerical results.

In the RUNOFF computations, a 60-second time step was used to compute the subcatchment hydrographs. In EXTRAN, all routing was performed using a one-second time step. In older EXTRAN models, where computer processing power was more limited, modelers would often use an "equivalent pipe" to avoid violating the Courant condition without having to decrease the time step. Now, desktop computers can easily complete EXTRAN runs having a one-second time step, which effectively eliminates the need to use equivalent pipes.

4.3.3 Rainfall Hyetographs

For single-event rainfall modeling, the selection of the rainfall hyetograph is the single most important factor influencing the results. The City of Chesapeake has used a U.S. Department of Agriculture Soil Conservation Service (SCS) Type I 24-hour hyetograph for runoff computations, as stipulated in the 2001 edition of the Public Facilities Manual. The Type I hyetograph was developed for the Pacific maritime climate. The Natural Resource Conservation Service (the agency that took over the SCS) stipulates either a Type II or Type III hyetograph for use in Chesapeake. After some discussion with Public Works staff, as part of this Master Drainage Plan update, URS recommend switching to a Type II rainfall hyetograph. The Type II hyetograph was used in all the modeling associated with this study.

The SCS methodology is recommended by the State of Virginia for use in analyzing watershed over 20 acres in size, and is consistent with the City's Storm Water Management ordinance and policies.

It is important to note that the use of the Type II hyetograph does not alter the volume of rainfall applied in the models—it merely alters the shape of the design rainfall to be more consistent with the types of storms encountered in the eastern United States. This rainfall hyetograph has been used for over 20 years nationwide for runoff modeling, and tends to be inherently conservative in that the rainfall intensity is nested to produce a sharp spike in the middle of the storm, after a 12-hour slow buildup that saturates the ground.

Statistically, the SCS Type II hyetograph contains the most intense 5-minute expected rainfall nested inside the most intense 10-minute expected rainfall, nested inside the most intense 20-minute expected rainfall, and so forth. For relatively small watersheds in eastern Virginia, where frontal storms are common, and it can be assumed that rainfall intensity does not vary with location in the watershed, the Type II hyetograph has proven to be a good choice for SWMM modeling.

Table 4-1 lists the rainfall depths and return periods used in Chesapeake based on an analysis of rainfall historical records. For the purposes of this study, the 2-, 5-, 10-, 25- and 50-year rainfall events were modeled (i.e. 100-year events were not modeled). Due to temporal discretization and the sharp peak of the design hyetographs, the rainfall volumes used in the models may differ very slightly from these values.

Table 4-1. 24-Hour Rainfall Depths	
Return Period (years)	24-Hour Rainfall Depth (inches)
2	3.4
5	5.0
10	5.9
25	6.9
50	8.0

4.3.4 Subarea Delineation

The subcatchment areas, also referred to as 'subareas', were delineated entirely using ArcView GIS software. The new subarea delineation deviated somewhat from the old, as new grading and development drainage was considered. The difference between the old and new delineations is shown in Figure 4-2—the green shading represents the old delineation, and the new subareas are outlined in yellow.

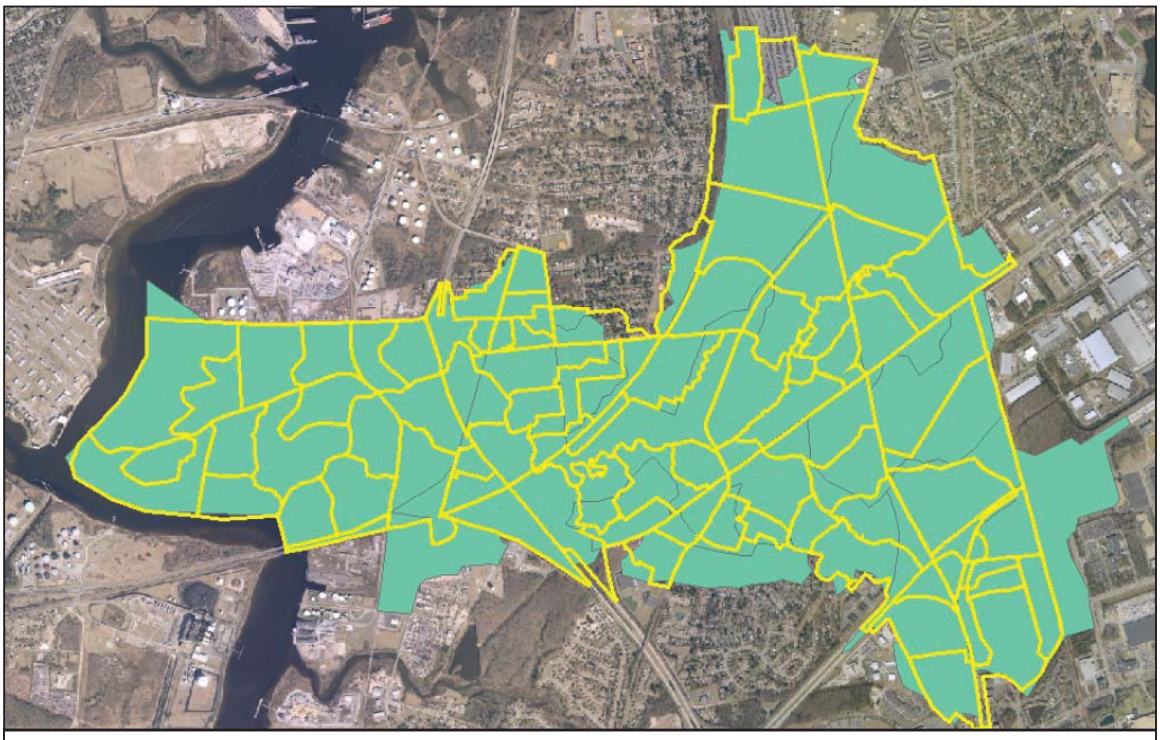


Figure 4-2. 1986 Delineation (Green) and 2003 Delineation (Yellow Outline)

The data described in Section 4.1 was used to piece together the available watershed information, and resulted in an existing (2003) conditions model that has 94 subcatchments, as shown in Figure 4-3. Figure 4-4 shows the delineation for the future conditions model, which has 96 subcatchments. (These figures can be zoomed and printed to very large formats using Adobe Acrobat Reader software.) This is a very fine level of detail for this type of modeling. Heavy weight was given to site plan drawings and aerial imagery in performing the digitizing, as these data sources represented the most up-to-date information on the watersheds.

This process was time consuming, due to the size of the data files involved, and the need to constantly re-order the themes in the GIS to see critical information in different combinations of overlays. An extraordinary amount of computer processing time was consumed regenerating the screen images during zooming to perform the required snap digitizing that defines the subcatchments.

Figure 4-3. Existing (2003) Conditions Subcatchment Delineation

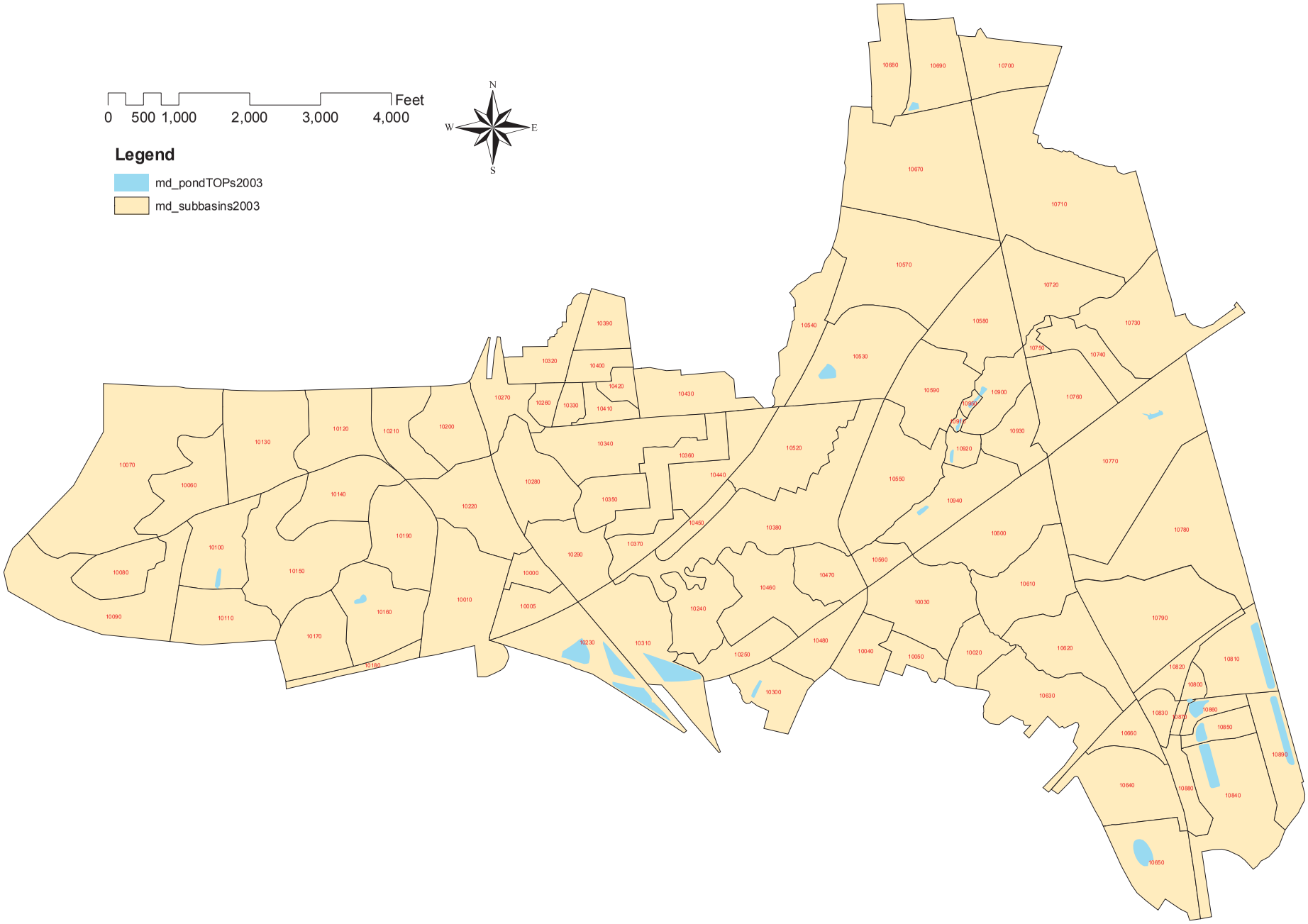
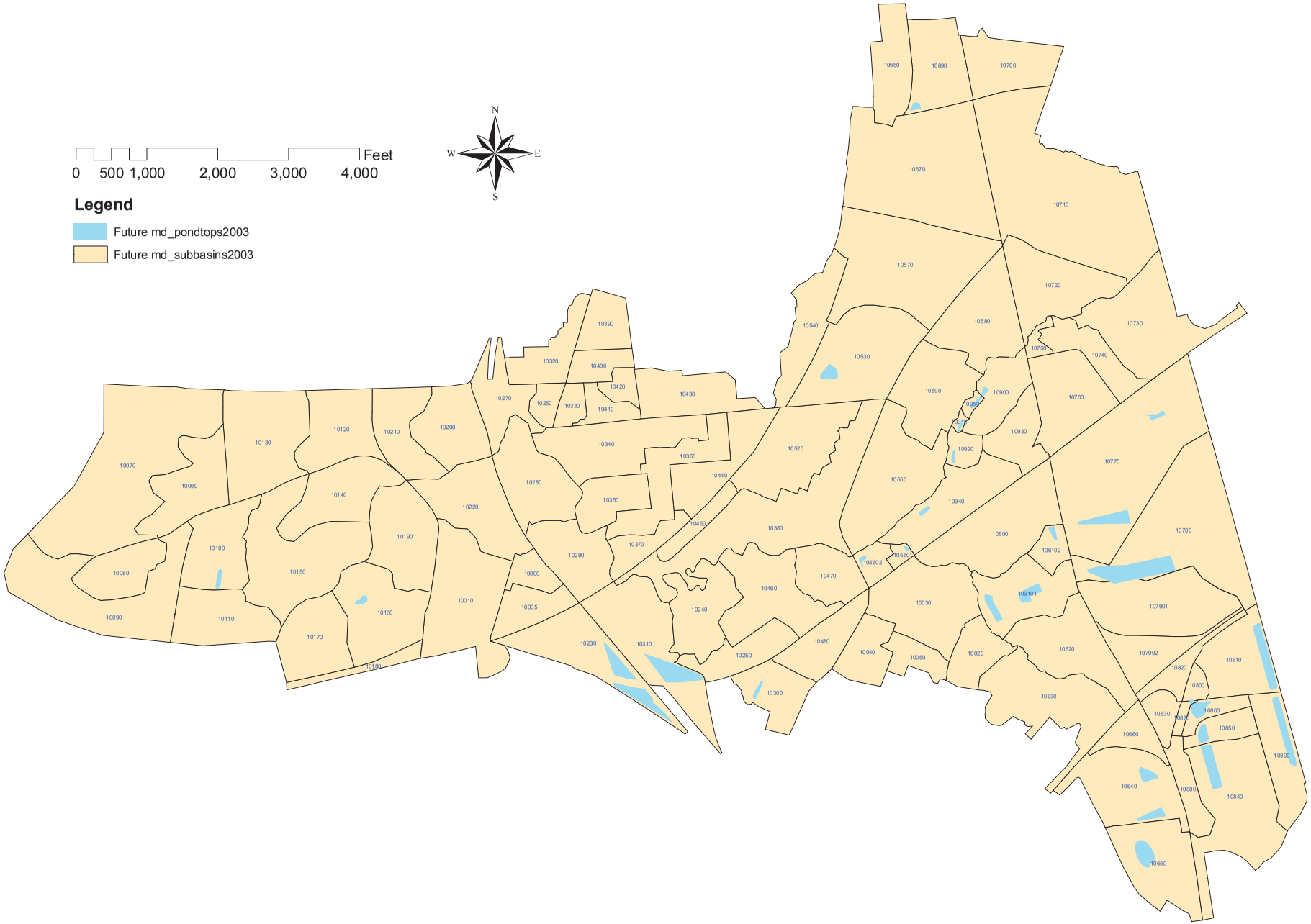


Figure 4-4. Future Conditions Subcatchment Delineation



4.3.5 Subcatchment Width

Subcatchment 'width', as depicted in Figure 4-1, is a model calibration parameter. For a given measured subcatchment area, as subcatchment width is decreased, the overland flow lengths become longer, which produces a delayed runoff hydrograph effect. Conversely, the wider the width, the shorter the overland flow path, and the faster runoff is delivered from the subcatchment.

In the absence of calibration data, subcatchment width can be estimated by envisioning the subcatchment as a rectangle—as it will be modeled according to Figure 4-1 in SWMM—and scaling the subcatchment width off a drawing or within a GIS. The modeler has to envision the effect of the width parameter on the subcatchment, considering that increasing width increases the peak rate of runoff for a given subcatchment. If for example the conceptual rectangle is adjacent to a major channel, the length of the rectangle bounded by the channel becomes the subcatchment width. Another common example involves a conceptual rectangle that is split in half by a drainage channel. In such a case the width can be estimated as twice the length of this central channel, because the channel will receive runoff from both sides in this type of subcatchment.

4.3.6 Subcatchment Slope

Subcatchment slope is also a calibration parameter. In SWMM models of very small watersheds, the overland slope can be computed directly from the topographic spot elevations of the site. However, as subcatchments become larger—as they are in this model where the average subcatchment size exceeds 24 acres—the concept of slope is less physically based and more parametric, for reasons noted in Section 4.2. As the subcatchment slopes become comparatively flat, such as they are in this watershed, this effect is even more pronounced.

The parameterization of slope becomes even more problematic when the age of the topographic data is considered. The latest topographic data available for this model predates the 2002 aerial imagery. In subcatchment areas where development has occurred since the contour mapping was completed, this topographic data cannot be used to compute the watershed slope.

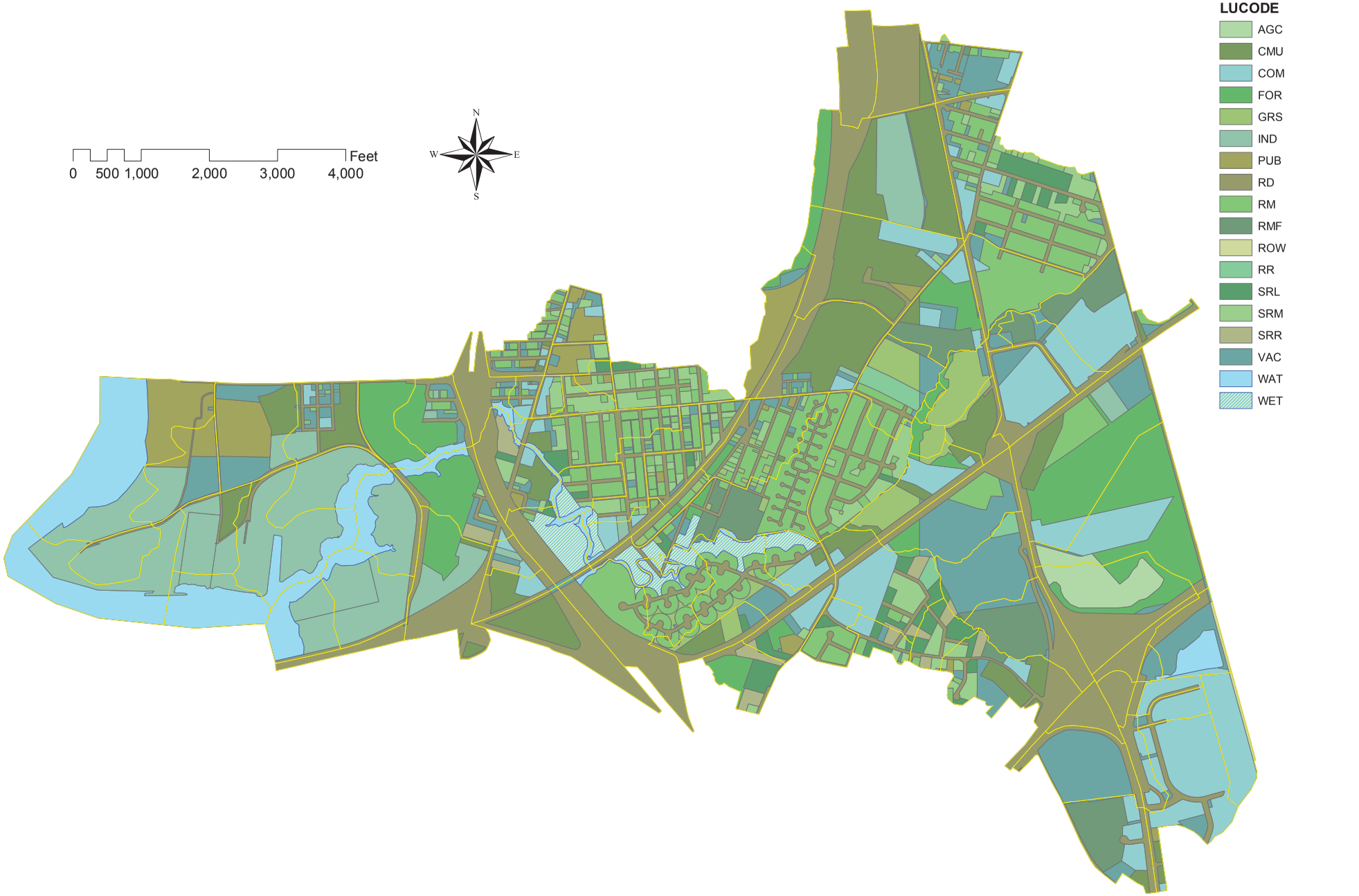
Taking the above into consideration, a general subcatchment slope of 0.001 feet per foot was used for subcatchment slope values, except where there was a clear reason to use a slope value computed from spot elevations.

4.3.7 Subcatchment Imperviousness, Roughness & Depression Storage

Subcatchment imperviousness is an important watershed parameter, because new development typically increases imperviousness, which in turn increases runoff volumes and flow rates. One of the most common approaches to mitigate the effects of increased storm water flows from developments is to incorporate storm water management basins into site designs. This approach is expensive for developers because it reduces their useful land yields, and is therefore carefully scrutinized by all parties involved in preparing and reviewing site plans.

A very detailed approach was used in this modeling effort to determine the imperviousness of each subcatchment. After the subcatchments were delineated and digitized, a GIS frequency analysis was performed to categorize and measure the land use in each subcatchment. The land use coverage employed was obtained directly from the 1999 Regional Stormwater Loading Study prepared by CH2M-Hill consultants for the Hampton Roads Planning District Commission (HRPDC). By overlaying this land use data on the newly delineated subcatchments, the actual area of each land use category within each subcatchment was directly measured in the GIS. These areas were then entered into a spreadsheet to compute the percentage imperviousness of each subcatchment using Chesapeake-specific values of imperviousness for each land use category provided by HRPDC, as shown in Appendix A. The GIS land use coverage was provided by the City of Chesapeake, as showin in Figure 4-5.

Figure 4-5. Existing (2003) Conditions Land Use



The Manning overland roughness coefficients for impervious and pervious land cover were taken from tables that are widely available in engineering literature, as were the depression storage depths. These are normally calibration parameters, but provisional values are widely published for applications where there is no calibration data that can be used. For the future conditions models, future imperviousness was based on estimates of future development, as described in Section 5.3 of this document. Tables depicting the imperviousness and soils parameters for each subcatchment are also presented in Appendix A.

4.3.8 Subcatchment Basins

As noted in Section 4.1, URS digitized storm water management basins and ponds into new polygon coverages from the aerial imagery and site data in the GIS. The Milldam Creek watershed generally has not been subjected to a proliferation of storm water management basins, however the Virginia Storm Water Management Act now stipulates that detention BMPs must be used if the downstream channel from a proposed development is inadequate.

To account for the storage effects of these facilities without having to survey all of the basins and outfall structures, an aggregated approach was used within each subcatchment, where the surface areas of all basins in the subcatchment were summed and represented using an EXTRAN storage junction. The bottom area and top area of all identifiable ponds was digitized and measured in the GIS, and modeled carefully with SWMM. This approach should adequately account for the storage effects within each subcatchment, without making the model overly complex.

4.3.9 Green-Ampt Soils Parameters

The effects of soil properties on overland runoff are quite complicated—and critically important. In a typical eastern Virginia watershed model most of the rainfall that is applied to the watershed infiltrates into the ground, and does not flow as surface runoff. For this reason, the estimation of soil parameters has a direct influence on the computed runoff volume.

For this watershed model, the Green-Ampt soil equations were used to compute runoff from pervious subareas. The Green-Ampt equations are physically based, and parameters can be estimated from agricultural research data.

For SWMM modeling, the RUNOFF block requires three input variables: SUCT, HYDCON and SMDMAX. Values for these variables can be determined from field tests, however the provisional values listed in Table 4-2 can be used where field test results are not available.

The city of Chesapeake does not have a detailed soil texture map available, however the NRCS has been working to develop such a map for more than two years. Greg Hammer of the USDA-NRCS Chesapeake Service Center kindly provided a hand drawing of soils textures in the region that will eventually be used to create GIS SSURGO soils data. URS scanned and geo-referenced this map in the GIS as shown in Figure 4-6, and used the indicated textures with Table 4-2 to obtain the Green-Ampt parameters. The used values for SUCT, HYDCON and SMDMAX were tabulated in a spreadsheet as presented in Table A-3 in Appendix A.

Figure 4-6. Soil Texture Mapping

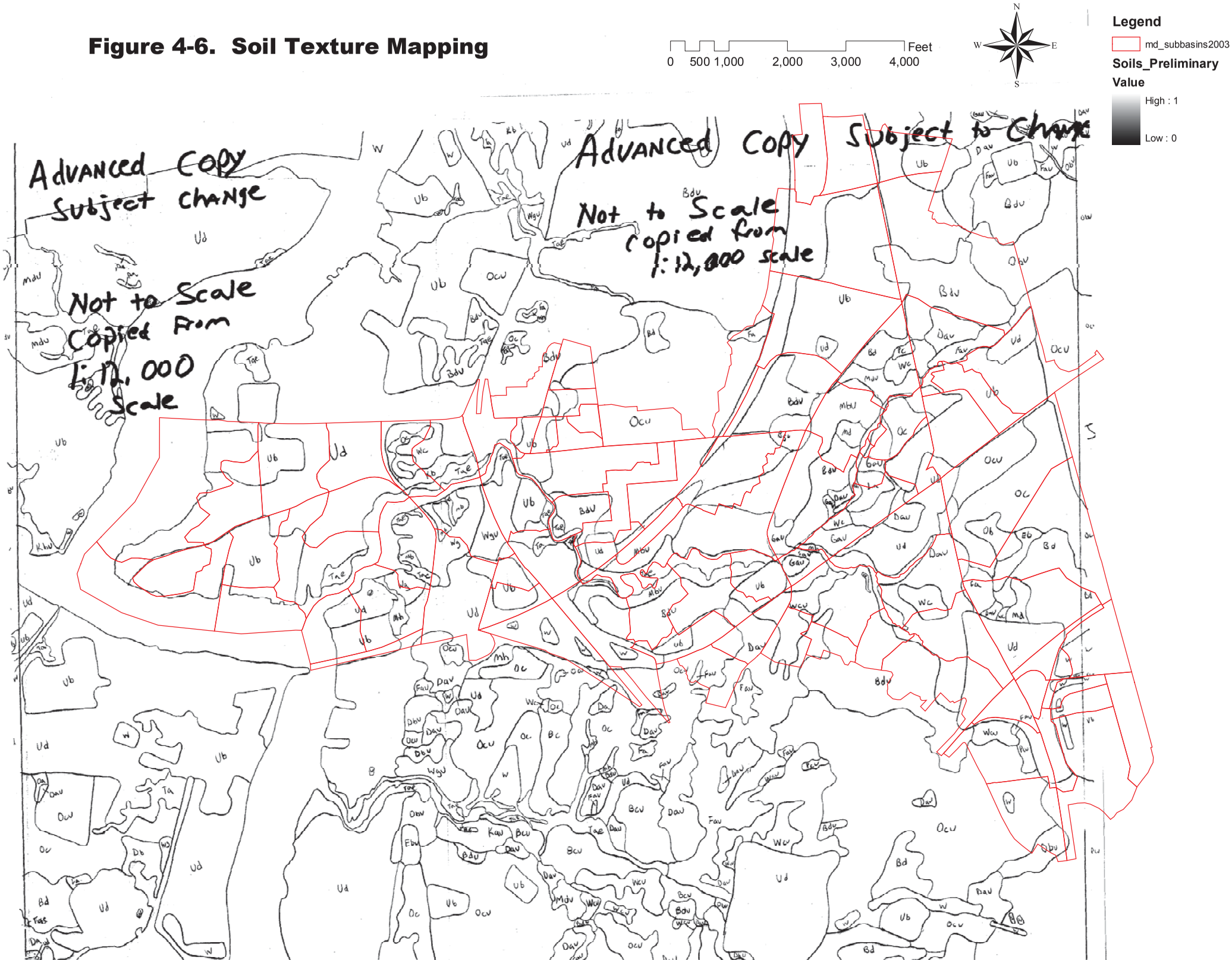


Table 4-2. Provisional SWMM Green-Ampt Parameter Values

USDA Soil Texture Classification	SUCT Avg. Capillary Suction		HYDCON Saturated Hydraulic Conductivity		SMDMAX Initial Moisture Deficit for Soil (Vol. of Air / Vol. of Voids, expressed as a fraction)	
	(in)	(mm)	(in/hr)	(mm/hr)	Moist Soil Climates (Eastern US)	Dry Soil Climates (Western US)
Sand	1.95	49.5	9.27	235.6	.346	.404
Loamy Sand	2.41	61.3	2.35	59.8	.312	.382
Sandy Loam	4.33	110.1	0.86	21.8	.246	.358
Loam	3.50	88.9	0.52	13.2	.193	.346
Silt Loam	6.57	166.8	0.27	6.8	.171	.368
Sandy Clay Loam	8.60	218.5	0.12	3.0	.143	.250
Clay Loam	8.22	208.8	0.08	2.0	.146	.267
Silty Clay Loam	10.75	273.0	0.08	2.0	.105	.263
Sandy Clay	9.41	239.0	0.05	1.2	.091	.191
Silty Clay	11.50	292.2	0.04	1.0	.092	.229
Clay	12.45	316.3	0.02	0.6	.079	.203

Notes:
1. These values are provisional, and are offered as reasonable parameter estimates for SWMM applications where more detailed soil information is not available. There is significant variance in these values; laboratory and field testing, sensitivity analysis, and calibration may be employed to improve upon these estimates.
2. Typically use the USDA SCS (now NRCS) Soil Survey to determine Soil Texture. In these surveys, 'Saturated Hydraulic Conductivity' is reported as 'Permeability'. Use the values reported in the soil survey for permeability for HYDCON, rather than the HYDCON values listed in the table above. In the absence of a soil survey or more reliable information, the values listed above may be used.
3. Synthesized from *Handbook of Hydrology*, D.R. Maidment, Editor in Chief, McGraw-Hill, Inc., 1993, pp. 5.1 - 5.39.

4.3.10 Drainage Network Discretization (Links and Nodes)

The model links and nodes were discretized after the subarea delineation task was completed (see Section 4.3.4). The drainage network information was input for the major channels and culvert crossings, with drainage pipes modeled down to approximately a 30-inch diameter minimum. Pipes with diameters smaller than 30 inches modeled where necessary. For example, where a significant pond had an outfall pipe less than 30 inches in diameter, the outfall pipe would be modeled regardless of size. On the other hand, where multiple ponds were aggregated into a single pond for modeling purposes, the interconnecting pipes were not modeled within the subcatchment. Generally the drainage network was discretized so that there was a clear drainage conveyance from each subcatchment. The existing (2003) conditions and future conditions link-node diagrams are presented in Figures 4-7 and 4-8 respectively. These figures can be zoomed and printed in large formats using the Adobe Acrobat Reader software.

Figure 4-7. Existing (2003) Conditions Link-Node Diagram

Figure 4-8. Future Conditions Link-Node Diagram

As in all storm water models, there is some missing pipe and channel configuration data that had to be guessed. The pipe configurations and dimensions in this area should be field-verified before constructing any improvements based on these models.

4.3.11 Missing Pipe & Channel Data

In every large-scale model there is missing data. Even though this model benefits from large quantities of GIS and CAD data, and although there is link-node data that can be adapted from previous modeling efforts, there is still quite a bit of information that is simply not available. Where pipe locations and sizes, pond outfall structure details and dimensions, and ditch cross sections were missing, the modelers made educated guesses. If the models need to be adjusted as additional information is collected or certain areas receive detailed attention, the intent is to adapt the better information when appropriate.

4.3.12 Treatment of EXTRAN Flooding

The EXTRAN block of SWMM is capable of solving very complex hydraulic equations over the course of the storm event. However there is a fundamental issue to be dealt with in terms of nodal flooding in every EXTRAN model.

When the computed hydraulic grade line exceeds the ground elevation at a node, EXTRAN computes the quantity that is lost from the system as "nodal flooding," but does not allow the lost water to re-enter the drainage network.

In low-lying flood-prone drainage systems, backups and street flooding are commonplace. If the SWMM modeling is accurate, the model will compute and report nodal flooding. The problem is that the complexities of re-introducing flows from nodal flooding back into the drainage network are too great for EXTRAN (and all other operational models) to handle. So the modeler must decide how to deal with nodal flooding. As long as the quantities are relatively small compared to the total flow volume through the drainage system, there is no problem. However as the nodal flooding volume increases—as it typically does with heavier storms—the hydraulic results are less 'accurate'. This loss of accuracy stems from the fact that in reality, these flows will re-enter the drainage network, and be carried downstream. In an inadequately sized system, flooding can occur at one node after another, and all the hydraulic grade line calculations are affected.

In an existing drainage system the modeler has essentially two choices to treat nodal flooding. First, the system can be enlarged in the model to contain the flow within the sewer network. Typically this means increasing channel and pipe sizes, or (more frequently) raising the ground elevation in the model to keep the hydraulic grade line below ground (in which case no nodal flooding is computed).

A second approach is to model the flood-prone area as a storage node, where the flow will be contained within the system over time (assuming the storage node is big enough). The disadvantage here is that the hydraulic conceptualization of the pipes and channels is totally lost, and the model loses its resolution and flow characteristics.

The main problem with adjusting the model to reduce nodal flooding is that the model can become a departure from reality, and false conclusions can be drawn. There is no 'best' answer to this problem, and in the end the modeler must rely on judgment. In our case the Milldam Creek watershed is highly flood-prone, and nodal flooding is commonplace. The preferred modeling approach has been to minimize the distortion of the model in the presence of nodal flooding.

4.3.13 Channel Roughness

Manning roughness coefficients for prismatic and natural channels modeled in this study are based on engineering judgment, and take into consideration the likelihood that the channels can be maintained in the condition represented in the models. Generally the models reflect the performance of the drainage system

under well-maintained conditions. Maintenance has a significant effect in minimizing flood elevations, particularly in those locations that have dense growth or sediment in the main channel.

4.3.14 Outfall Boundary Conditions

Boundary conditions (water surface elevations) at the downstream outfall (Node 100 in the Elizabeth River) were set in accordance with Chapter 5, Section Q of the City of Chesapeake Public Facilities Manual (July 2001 Edition). In all cases, for all return periods, the hydraulic boundary condition was modeled as a constant water surface elevation of 3.55 feet (NAVD88).

4.3.15 Important Considerations and Implications Regarding Boundary Conditions and Return Periods

Hydraulic modeling in low-lying, coastal, flat topography is highly sensitive to the water surface elevations modeled at the downstream boundaries. It has been the City's policy to use an elevation of 3.55 feet at these boundaries for several years for storm water computations. If the City were to raise or lower the starting water surface elevations used in its SWMM models, the result would be a corresponding rise or drop in the water surface elevations computed throughout the watershed. The City began using an elevation of 3.55 feet in the past because this elevation is believed to equate to an annual high tide. In order to avoid problems associated with joint probability analysis, the annual high tide was selected as the boundary condition for SWMM modeling for all modeling scenarios and rainfall events.

Flood Insurance studies performed for the Federal Emergency Management Agency (FEMA) in this area use significantly higher water surface elevations at their model boundary locations to compute the 100-year floodplain elevations and flood zone limits. FEMA has policy requirements that involve a somewhat elaborate consideration of high tides and storm surges to obtain their boundary hydraulics. Primarily for this reason FEMA flood models in this watershed list significantly higher flood elevations than those shown in the City's SWMM models. It should be recognized that a primary intent of the FEMA studies is to provide protection against structural damage to facilities, while the primary use of the City's Master Drainage Plan models is to provide tailwater elevations for the planning, evaluation, and design of secondary drainage systems.

According to National Flood Insurance Rate Map Panel 5100340015C, Revised 2 May 1999, the 100-year flood elevation in Milldam Creek is 7.7 feet (NAVD88).

The FEMA flood insurance models are the definitive source of floodplain limits and elevations in all cases. The City's SWMM models are design scenarios based on 2-, 5-, 10-, 25-, and 50-year rainfall events—THEY ARE NOT TO BE CONSTRUED AS INDICATIVE OF THE EXPECTED WATER SURFACE ELEVATIONS FOR THE PURPOSE OF FLOODPLAIN MANAGEMENT AND/OR INSURANCE REQUIREMENTS.