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DATA COLLECTION FOR THE HAZARDOUS WASTE IDENTIFICATION RULE

SECTION 7.0 SOIL DATA

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7.0 Soil Data

The Hazardous Waste Identification Rule (HWIR) risk assessment uses a site-based data collection strategy centered around 201 sites randomly selected from the 1985 Industrial D Screening Survey. Site-specific soil data were collected for all 201 sites, largely using automated methods. Geographic information system (GIS) programs were used to identify and extract, for each Industrial D site modeled for the HWIR, soil map units and map unit areas by watershed subbasin and by waste management unit (WMU). Database programs were used to extract soil data from the underlying databases by these map units and process them to generate soil properties by watershed for surface soil and by the WMU for the entire soil column (vadose zone or subsoil). Surface soil is defined as the top 20 cm within the HWIR modeling system. Vadose zone soil extends from the ground surface to the water table. Depending on the property, average (area- and depth-weighted) or predominant soil properties were derived for the soil depth zone of interest across each watershed subbasin or WMU.

Section 5 describes the GIS and database processing used to delineate the watershed subbasins and local watersheds (which include the WMU) for which soil data were collected. This section describes the collection and processing of soil data for these entities, including the parameters collected (Section 7.1), the data sources (Section 7.2), the overall data collection methodology (Section 7.3), and the data collection results by parameter (Section 7.4). Section 7.5 describes quality assurance and quality control (QA/QC) measures. Significant uncertainties are discussed by parameter in Section 7.4 and summarized in Section 7.5.

7.1 Parameters Collected

Table 7-1 lists the soil and universal soil loss equation (USLE) soil erosion input parameters required by the various HWIR model components. Soil data are primarily used by the source, watershed, and vadose zone models, but fraction organic carbon is used by the farm food chain, terrestrial food web, human exposure, and ecorisk models. Additionally, the farm food chain model uses soil pH. This section also includes the land use-based water erosion inputs, the USLE cover factor (C), and the USLE erosion control factor (P). Collection of the USLE rainfall erosivity factor (R) and the USLE length/slope factor (LS) are described in Section 4 and Section 5, respectively.

In terms of collection scale, all soil parameters can be considered to be site-based in that they are either site-specific or derived from site-specific data using national relationships. The latter category includes soil hydrologic properties derived from site-specific soil texture or hydrologic class and other properties derived from a combination of soil texture or class and site-specific land use.

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Table 7-1. Soil Inputs by Model Component

	Source Models				Media Models		Food Chain & Exp. Models[a]			
Model Input	**LF**	**LAU**	**SI**	**WP**	**WS**	**Vadose Zone**	**Farm Food Chain**	**TFW**	**Human Exp.**	**Eco Exp.**
depth of root zone		!		!	!					
dry bulk density (subsoil)						!				
field capacity		!		!	!					
fraction organic carbon (cover soil)	!									
fraction organic carbon (surface soil)		!		!	!		!	!	!	!
fraction organic carbon (subsoil)	!									
hydrologic soil group		![1]		![1]	![1]					
percentage organic matter (subsoil)						!				
pH (subsoil)						!	!			
residual water content (subsoil)						!				
saturated hydraulic conductivity (cover soil)	!									
saturated hydraulic conductivity (surf. soil)		!		!	!					
saturated hydraulic conductivity (subsoil)	!		!			!				
saturated water content (cover soil)	!									
saturated water content (surface soil)		!		!	!					
saturated water content (subsoil)	!					!				
SCS curve number		!		!	!					
silt content (surface soil at LAU)		!								
soil column temperature (annual average)	!					!				
soil moisture coefficient *b* (cover soil)	!									
soil moisture coefficient *b* (surface soil)		!		!	!					
soil moisture coefficient *b* (subsoil)	!									
soil parameter, alpha (subsoil)			!			!				
soil parameter, beta (subsoil)			!			!				
soil type/texture (subsoil)						![1]				
USLE cover factor (C)		!		!	!					
USLE erodibility factor (K)		!		!	!					
USLE erosion control factor (P)		!		!	!					
wilting point		!		!	!					

[a] Parameter used to determine correct cross-correlation for soil properties.
LF = landfill; LAU = land application unit; SI = surface impoundment; WP = waste pile; WS = watershed; TFW = terrestrial food web; Hum Exp = human exposure; Eco Exp = ecological exposure

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7.2 Data Sources

Table 7-2 shows the data sources used for soil properties and erosion factors. The primary sources for site-specific soil properties were the State Soil Geographic (STATSGO) database maintained by the U.S. Department of Agriculture (USDA, 1994a) and two GIS-based compilations of STATSGO data, USSOILS (Schwarz and Alexander, 1995) and the Conterminous United States Multi-Layer Soil Characteristics (CONUS) data set (Miller and White, 1998). USSOILS, maintained by the U.S. Geological Survey (USGS), averages STATSGO data by map unit, with depth-weighted averages to the water table. CONUS, created by Pennsylvania State University, averages by STATSGO map unit and converts STATSGO soil layers into a set of 11 standardized soil layers extending to a depth of 2.5 m (60 in).

Various lookup tables based on STATSGO soil texture and hydrologic soil group were used for parameters not readily available using STATSGO-based data sources alone. Only one soil parameter, soil column temperature, was not derived using STATSGO-based sources. The land use-based USLE factors were obtained using lookup tables by Anderson land use codes obtained for each site from the Geographic Retrieval and Analysis System (GIRAS) land use database.

7.2.1 STATSGO Data

STATSGO (USDA, 1994a) is a GIS database designed primarily for regional, multistate, river basin, State, and multicounty planning, managing, and monitoring resources. Soil maps for STATSGO are compiled from more detailed county soil survey maps. When county soil survey maps are not available, data on geology, topography, vegetation, and climate are assembled, together with Land Remote Sensing Satellite (LANDSAT) images. Soils of like areas are studied, and the probable classification and extent of the soils are determined.

Using the USGS 1:250,000 scale, 1- by 2-degree quadrangle series as a map base, the soil data are digitized by vector method to comply with national guidelines and standards. Data for the STATSGO database are collected in 1- by 2-degree topographic quadrangle units and merged and distributed as statewide coverages. Features are edge-matched between states. The STATSGO data provide national coverage at a scale of 1:250,000, except for Alaska, which is at a scale of 1:200,000.

The approximate minimum area delineated is 625 ha (1,544 acres), which is represented on a 1:250,000-scale map by an area approximately 1 cm by 1 cm (0.4 in by 0.4 in). Linear delineations are no less than 0.5 cm (0.2 in) in width. The number of delineations per 1:250,000 quadrangle typically is 100 to 200 but may range up to 400. Delineations depict the dominant soils making up the landscape. Other dissimilar soils, too small to be delineated, are present within a delineation.

Attribute accuracy is tested by manual comparison of the source with hardcopy plots and/or symbolized display of the map data on an interactive computer graphic system. Selected attributes that cannot be visually verified on plots or on screen are interactively queried and verified on screen. In addition, the attributes are tested against a master set of valid attributes.

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Table 7-2. Soil Property Data Sources

Parameter	Code	Source	Description
depth (root zone)	DRZ	Dunne and Leopold (1978)	lookup table by soil texture and land use
dry bulk density (subsoil)	RHOB	U.S. EPA (1996)	calculated from saturated water content
field capacity	SMFC	Carsel et al. (1988)	lookup table by hydrologic soil group
fraction organic carbon (cover soil)	focC	U.S. EPA (1996)	calculated from USSOILS POM
fraction organic carbon (surface soil)	focS	U.S. EPA (1996)	calculated from STATSGO POM
fraction organic carbon (subsoil)	focS_lf	U.S. EPA (1996)	calculated from USSOILS POM
hydrologic soil group	HydroGroup	USDA (1994a)	derived from STATSGO data
percentage organic matter (subsoil)	POM	Schwarz and Alexander (1995)	USSOILS
pH (subsoil)	FarmPh, VadPh, WSPh	USDA (1994b)	derived from STATSGO data
residual water content (subsoil)	VadWCR	Carsel and Parrish (1988)	lookup table by soil texture
saturated hydraulic conductivity (cover soil)	KsatC	Carsel and Parrish (1988)	lookup table by soil texture
saturated hydraulic conductivity (surf. soil)	Ksat	Carsel and Parrish (1988)	lookup table by soil texture
saturated hydraulic conductivity (subsoil)	VadSATK	Carsel and Parrish (1988)	lookup table by soil texture
saturated water content (cover soil)	WCS_C	Carsel and Parrish (1988)	lookup table by soil texture
saturated water content (surface soil)	WCS	Carsel and Parrish (1988)	lookup table by soil texture
saturated water content (subsoil)	VadWCS	Carsel and Parrish (1988)	lookup table by soil texture
SCS curve number	CN	USDA (1986)	lookup table by hydrologic soil group and land use
silt content (soil at lau)	Ss	Miller and White (1998)	derived from CONUS data
soil column temperature (annual average)	VadTemp	Collins (1925)	same as groundwater temp.
soil moisture coefficient *b* (cover soil)	SMbC	Clapp and Hornberger (1978)	lookup table by soil texture
soil moisture coefficient *b* (surface soil)	SMb	Clapp and Hornberger (1978)	lookup table by soil texture
soil moisture coefficient *b* (subsoil)	SMbS	Clapp and Hornberger (1978)	lookup table by soil texture
soil parameter, alpha (subsoil)	VadALPHA	Carsel and Parrish (1988)	lookup table by soil texture
soil parameter, beta (subsoil)	VadBETA	Carsel and Parrish (1988)	lookup table by soil texture
soil type/texture (subsoil)	VadSoilType, SoilType	Miller and White (1998)	derived from CONUS
USLE cover factor	C	Wanielista and Yousef (1993)	lookup table by land use
USLE erodibility factor	K	Schwarze and Alexander (1995)	USSOILS
USLE erosion control factor	P	Wanielista and Yousef (1993)	lookup table by land use
wilting point	SMWP	Carsel and Parrish (1988)	lookup table by hydrologic soil group

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All attribute data conform to the attribute codes in the signed classification and correlation document and amendments and are current as of the date of digitalizing.

A map unit is a collection of areas defined and named the same in terms of their soil and/or nonsoil areas. Each map unit differs in some respect from all others in a survey area and is uniquely identified. Each individual area is a delineation. Each map unit consists of 1 to 21 components.

In those few areas where detailed maps do not exist, reconnaissance soil surveys were combined with data on geology, topography, vegetation, climate, and remote sensing images to delineate map units and estimate the percentages of the components. The STATSGO map unit components are soil series phases, and their percentage composition represents the estimated area proportion of each within the STATSGO map unit. The composition for a map unit is generalized to represent the statewide extent of that map unit and not the extent of any single map unit delineation. These specifications provide a nationally consistent representation of STATSGO attribute data.

Refer to metadata available on the Internet at http://www.ftw.nrcs.usda.gov/stat2.html (USDA, 1994a) for more information on STATSGO. The STATSGO User's Guide (USDA, 1994b) provides details on STATSGO database structures and definitions.

USSOILS (Schwarz and Alexander, 1995) and CONUS (Miller and White, 1998) are simplified compilations of STATSGO data. They were used in this HWIR risk assessment to reduce data processing requirements for certain soil parameters. The USSOILS coverage was originally compiled to support a national model of water quality. USSOILS aggregates the STATSGO layer and component information up to the level of a map unit by depth-averaging, over the entire soil column, median properties within a component and then area-averaging component values across a map unit. Metadata on USSOILS can be found at: http://water.usgs.gov/lookup/getspatial?ussoils.

The CONUS soil data set was compiled by the Earth System Science Center in the College of Earth and Mineral Sciences at Pennsylvania State University for application to a wide range of climate, hydrology, and other environmental models (Miller and White, 1998). CONUS contains STATSGO soil properties averaged to 11 standard layer depths from the STATSGO layers to a depth of 2.5 m. Within each STATSGO map unit and CONUS standard layer, soil properties either represent the predominant property (as with soil texture) or are area-weighted averages of STATSGO component values. Additional information on CONUS can be found at: http://www.essc.psu.edu/soil_info/index.cgi?soil_data&conus.

7.2.2 GIRAS Data

GIRAS (U.S. Environmental Protection Agency [EPA], 1994) provides comprehensive land use data, in digital GIS format, for the conterminous United States. This spatial data set represents digital data originally collected by the USGS (USGS, 1990) and then converted into the ARC/INFO GIS format by EPA. These digital coverages are available from EPA by 1-degree quadrangles (1:250,000 scale). This information was extracted from metadata available on

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GIRAS. The full metadata record may be found at http://www.epa.gov/ngispgm3/nsdi/projects/giras.htm (U.S. EPA, 1994).

GIRAS land use/land cover (LU/LC) data are useful for environmental assessment of land use patterns based on water quality analysis, growth management, and other types of environmental impact assessment. Data are meant to be used by quadrangle, or among adjacent quadrangles where they are temporally contiguous. The data can be used in any geographic application where intermediate scale land use data are appropriate and the dates are representative of the need. Each quadrangle of land use data has a different representative date. Date ranges from mid-1970s to early 1980s are common. Because the data are about 15 to 25 years old, their use may be limited.

When joined together, quadrangles will not likely match along edges due to differences in interpretation and time coverage. Edges of each map file were manually digitized and may not join neighboring maps. For some quadrangles, edges have been mathematically recalculated (using a GIRASNEAT Arc Macro Language [AML] program) to join without overlap or gaps in coverage with adjacent maps.

The GIRAS series includes several themes of spatial data. The LU/LC data were used in HWIR. LU/LC in GIRAS was mapped and coded using the Anderson classification system (Anderson et al.,1976), which is a hierarchical system of general (one-digit, level 1) to more specific (two-digit, level 2) characterizations (see Table 7-3).

7.2.3 National Data Sources

Nationwide relationships from various sources were used as lookup tables in conjunction with STATSGO and GIRAS site-specific data. Carsel and Parrish (1988) provide transformed distributions by soil texture for saturated hydraulic conductivity, residual water content, and water retention parameters alpha and beta. Clapp and Hornberger (1978) provide values for the soil moisture coefficient *b* by soil texture. Carsel et al. (1988) have values for field capacity and wilting point by hydrologic soil group and layer. A lookup table for root zone depth by Anderson land use code and soil texture was developed using a Dunne and Leopold (1978) table of rooting depth by vegetative cover and soil texture. Similarly, a lookup table for Soil Conservation Service (SCS) curve number by Anderson land use code and hydrologic soil group was developed using tables of curve number by ground cover and hydrologic soil group from *Urban Hydrology for Small Watersheds* (USDA, 1986). As with the soil properties, lookup tables for USLE factors C and P by land use were developed using Wanielista and Yousef's (1993) tables of C and P factors by land use.

7.3 Methodology

A largely automated methodology was employed to collect soil data for HWIR. Figure 7-1 shows an overview of this methodology, which employs both GIS and conventional database processing to collect soil property data by map unit for watershed subbasin or WMU. Because GIS spatial soil data coverages were available for the entire United States, site-specific data were collected for all 201 HWIR sites. For a particular spatial area of concern (e.g., watershed subbasin or WMU), STATSGO map units were obtained using GIS. Map unit data

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Table 7-3. Anderson Land Use Codes

1 Urban or builtup land	**5 Water**
11 Residential	51 Streams and canals
12 Commercial and services	52 Lakes
13 Industrial	53 Reservoirs
14 Transportation, communication, utilities	54 Bays and estuaries
15 Industrial and commercial complexes	**6 Wetland**
16 Mixed urban or builtup land	61 Forested wetland
17 Other urban or builtup land	62 Nonforested wetland
2 Agricultural land	**7 Barren land**
21 Cropland and pasture	71 Dry salt flats
22 Orchards, groves, vineyards, nurseries, and ornamental horticultural land	72 Beaches
	73 Sandy areas not beaches
23 Confined feeding operations	74 Bare exposed rock
24 Other agricultural land	75 Strip mines, quarries, gravel pits
3 Rangeland	76 Transitional areas
31 Herbaceous rangeland	**8 Tundra**
32 Shrub and brush rangeland	81 Shrub and brush tundra
33 Mixed rangeland	82 Herbaceous tundra
4 Forest land	83 Bare ground
41 Deciduous forest land	84 Wet tundra
42 Evergreen forest land	85 Mixed tundra
43 Mixed forest land	**9 Perennial snow or ice**
	91 Perennial snowfields
	92 Glaciers

Source: Anderson et al. (1976)

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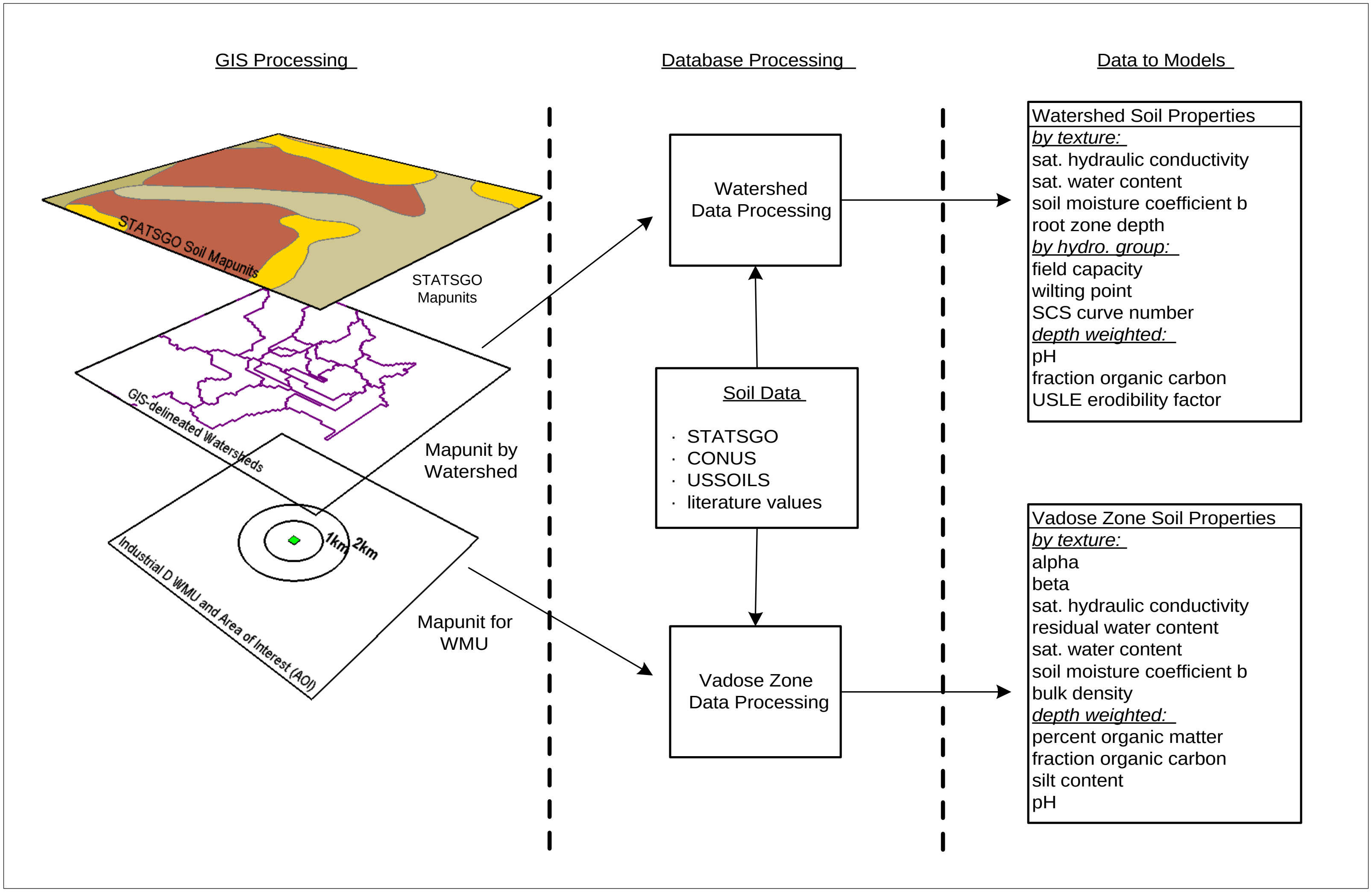

Figure 7-1. HWIR soil data collection overview.

were then passed to a Microsoft Access database containing soil data by map unit from STATSGO, USSOILS, and CONUS, along with lookup tables for the nationwide relationships. Similarly, GIRAS coverages for the areas surrounding each site were used to obtain site-specific land use data, which were passed to the data processor to generate land use-based inputs.

Database query programs processed the soil data by watershed or WMU to generate the HWIR model inputs shown in Figure 7-1. Parameters collected by the watershed map units included soil properties for the watershed model as well as those collected for the local watersheds in the land application unit (LAU) and waste pile (WP) models. Although the LAU and WP soil parameters were indexed by local watershed and subarea, they are the values for the watershed subbasin in which the local watershed resides. Soil parameters collected by the WMU map units were used to provide subsoil data for the vadose zone model and subsoil and cover soil data for the landfill model.

7.3.1 STATSGO GIS Processing

Soil map unit data contained in STATSGO were downloaded as a single national ARC/INFO coverage from a University of Pennsylvania Web site. A soil polygon coverage was overlaid with the regional watershed subbasin coverage to identify map units within the subbasins; it was also overlaid with the WMU to identify map units within the WMU (Figure 7-2). For each watershed subbasin and WMU, GIS was used to calculate the area of the subbasin or WMU that was covered by the map unit. Map unit assignments were exported for data processing in two GIS tables (w_all and o_all in Figure 7-3) The o_all table includes map units by watershed subbasin and site, and the w_all table includes map units by WMU type and site.

7.3.2 GIRAS GIS Processing

The GIRAS coverages were downloaded from an EPA Web site as ARC/INFO coverages. GIS was used to overlay the regional watershed coverage with a nationwide coverage of all the GIRAS quadrangle names. Each quadrangle that touched a watershed subbasin was then combined to create one coverage (Figure 7-2). The GIRAS coverage was then clipped to the regional watershed boundaries. The Anderson land use classification code in GIRAS is contained in the two-digit lucode attribute in the polygon attribute table. The first digit is the Anderson level 1 value, and the second digit is the level 2 value (U.S. EPA, 1994). GIS identified all land use types (lucode) within the watershed subbasin and calculated their areas. A GIS land use data table (u_all in Figure 7-3) contains land use data by watershed and site.

7.3.3 Database Processing

GIS soil map unit and land use tables were used along with various compilations of STATSGO data and static lookup tables to provide the soil and land use data required by the

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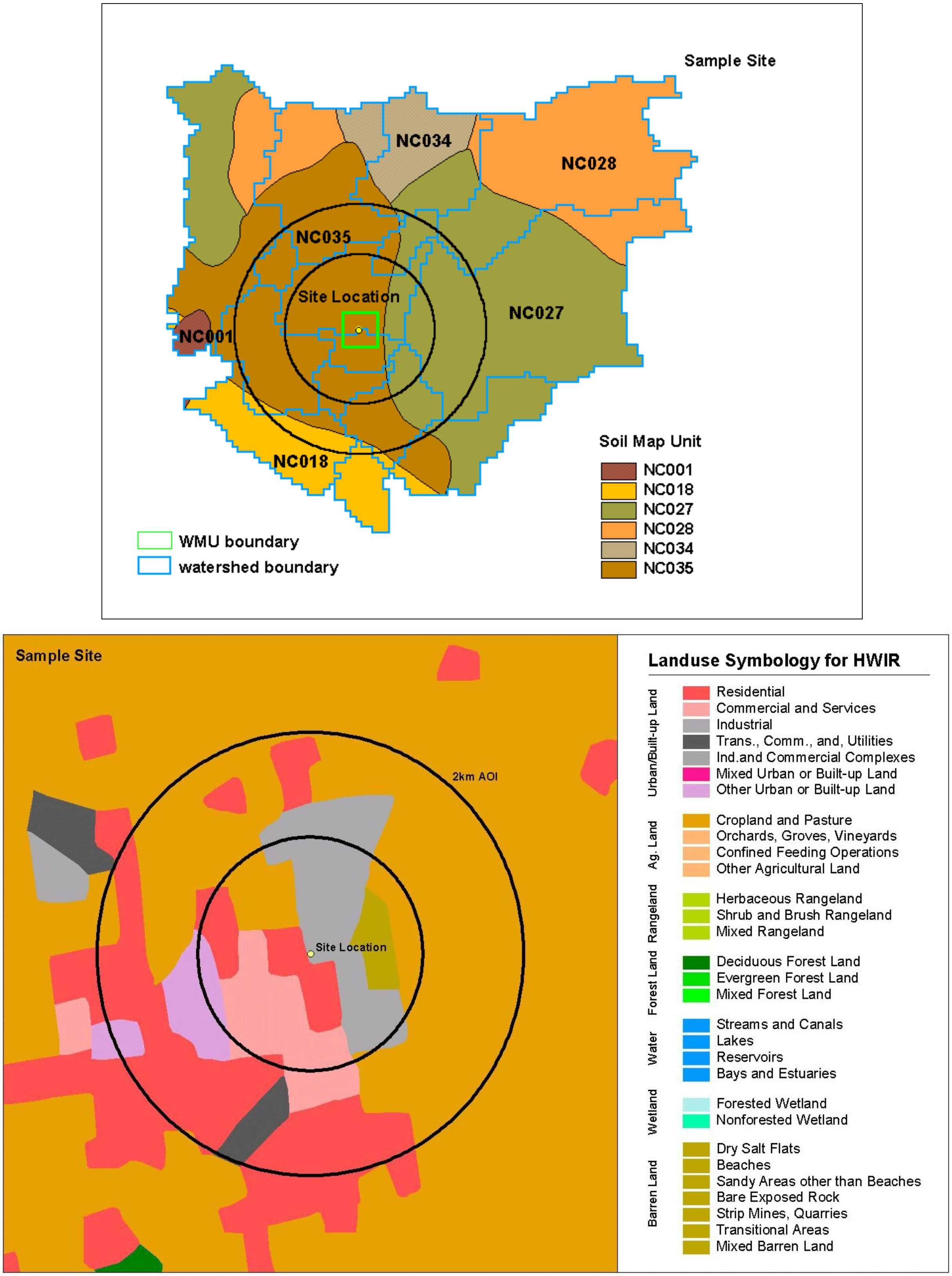

Figure 7-2. Sample soil and land use coverages.

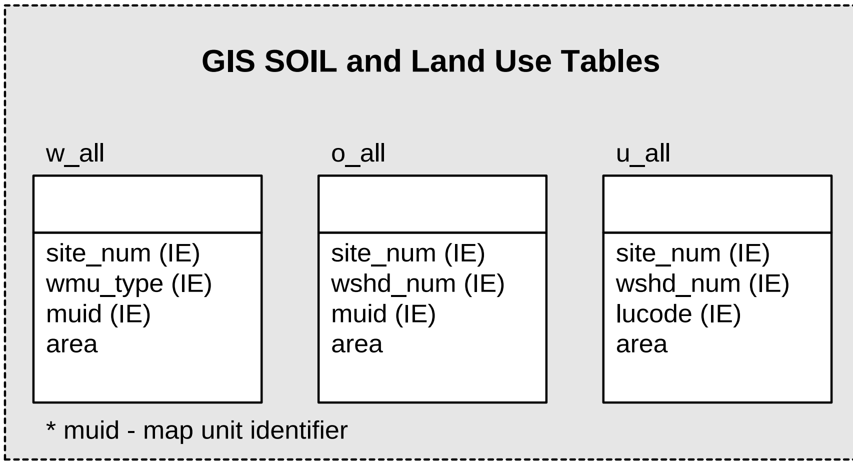

Figure 7-3. GIS soil and land use data tables.

models. The flow chart in Figure 7-4 provides an overview of the soil database processing. Using the GIS map unit assignments, site-specific data for soil parameters were queried from a soil database composed of STATSGO, USSOILS, and CONUS data tables. Other inputs (e.g., soil hydrologic properties) were derived from lookup data tables using the site-specific STATSGO USDA soil texture class or hydrologic soil group. A couple of the soil parameters, depth of root zone and SCS curve number, along with the USLE cover factor and erosion control factor, required site-specific land use information by watershed, obtained using the GIS GIRAS data. As with soil hydrologic properties, this land use data was related to the parameters of interest using lookup tables.

7.4 Results by Parameter

The following sections describe the data collection process and results by each soil-related input parameter. Significant assumptions and uncertainties are also provided by parameter.

7.4.1 Soil Texture

USDA soil texture was derived from CONUS data by layer and map unit for the top 20 cm of soil (soil) and for the entire soil column (subsoil). Even though only the soil texture for the entire soil column was passed explicitly in the data, many of the other parameters came from lookup tables based on the predominant texture in either surface soil or the entire soil column.

7.4.1.1 <u>Database Compilation for Soil Texture</u>. CONUS texture data are given by 11 standard layers with bottom depths of 5, 10, 20, 30, 40, 60, 80, 100, 150, 200, and 250 cm. The CONUS data were used to create tables of soil texture by map unit for the entire soil column and for the top 20 cm of soil. Possible values in CONUS for the texture are shown in Table 7-4.

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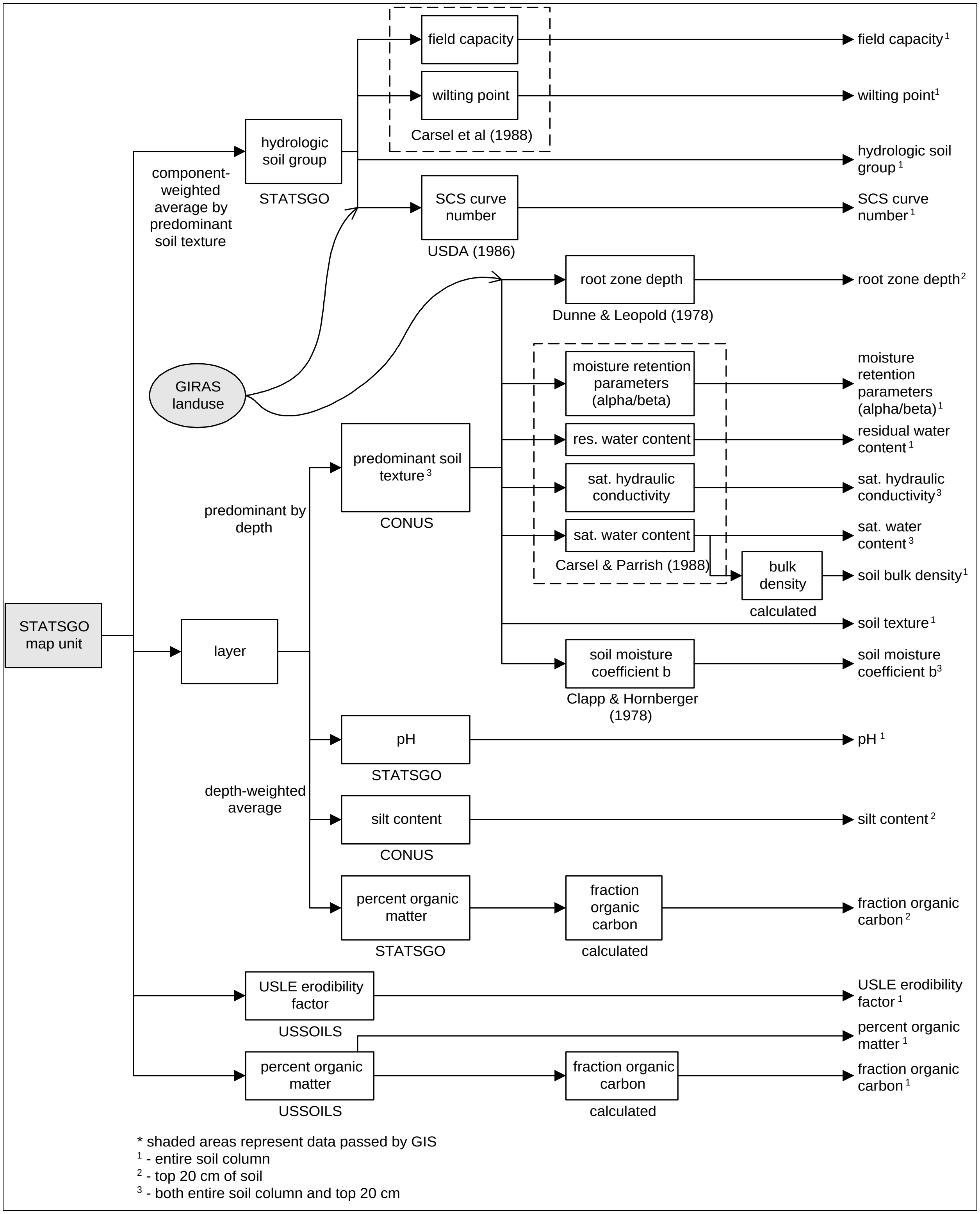

Figure 7-4. HWIR soil data processing.

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Table 7-4. Soil Textures in CONUS

CONUS Abbreviation	Soil Texture
ND	no data
S	sand
LS	loamy sand
SL	sandy loam
SIL	silt loam
SI	silt
L	loam
SCL	sandy clay loam
SICL	silty clay loam
CL	clay loam
SC	sandy clay
SIC	silty clay
C	clay
OM	organic materials
W	water
BR	bedrock
O	other

- Soil texture for the entire soil column was defined for each map unit as the predominant soil texture weighted by layer depth for all 11 CONUS layers, excluding layers with textures of no data, bedrock, and other. When two soil textures had equal predominance (a tie), the texture that occurs most commonly across the United States was used.

- Soil texture for the top 20 cm of soil was defined for each map unit as the predominant soil texture weighted by layer depth for the top three CONUS layers, excluding layers with textures of no data, bedrock, and other. When there was a tie between textures, the texture that occurs most commonly across the United States was used.

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7.4.1.2 Database Processing for Soil Texture. GIS programs were used to obtain the map units and portions of each map unit in the area concerned (e.g., watershed or WMU) for each site or site/WMU combination. The map unit with the largest area (that did not have a texture of water) in the area of concern was then used to assign a soil texture from the pre-existing tables prepared as described earlier.

7.4.1.3 Assumptions and Uncertainty for Soil Texture. To simplify data processing, CONUS, which contains a limited number of basic soil textures by standard layers, was chosen over the STATSGO raw data, which contain a greater number of textures by component-specific layer thickness (i.e., STATSGO lay_thick varies by component). Further processing was then done to simplify and compile CONUS data to a level of resolution appropriate for the HWIR models (i.e., the watershed model requires homogeneous soil properties with depth and across a watershed subbasin; the vadose zone model requires a homogeneous soil column). Because of this processing, soil textures are assumed to be homogeneous when they actually may vary by layer and component.

7.4.2 Hydrologic Soil Group

STATSGO, which contains hydrologic soil groups by component, was used as the data source for this parameter. To ensure that the hydrologic soil group reflected the predominant soil texture used to derive other soil properties for a particular map unit, only the components with the same predominant texture as determined from CONUS data were used to determine the hydrologic soil group. The hydrologic soil group was passed explicitly to provide the values on which the cross-correlation for field capacity and wilting point are based and also was used to derive other parameters (i.e., curve number, wilting point, and field capacity) from lookup tables.

7.4.2.1 Database Compilation for Hydrologic Soil Group. Although STATSGO contains hydrologic soil groups by components, independent of layer, soil texture is given by layer and not limited to the 17 textures possible in CONUS. The first step in the risk assessment process was to derive textures by component from STATSGO layer data. The process used to do this closely matches the CONUS methodology for deriving texture for the standardized CONUS layers. Descriptors were first stripped from textures in STATSGO. The descriptors are adjectives such as cherty, gravelly, peaty, and stony, that are commonly followed by a dash before the actual texture. Because STATSGO may contain more than one texture per layer, the first texture after the descriptors was chosen to be the representative texture for that layer. This usage is consistent with CONUS documentation. The final stripped texture was then matched to the CONUS textures using a crosswalk table (Table 7-5). The predominant texture for the entire STATSGO component was determined by summing the layer depths by soil texture, excluding bedrock and other textures, and using the soil texture with the greatest depth. To be consistent with CONUS, if the lowest layer did not extend to bedrock, then the layer was extended to bedrock or to 2.5 m (60 in, the bottom of the lowest CONUS layer), whichever was encountered first.

The second part of the process required obtaining an "average" hydrologic soil group for all of the components within each map unit that had the same predominant texture as the predominant CONUS texture for the entire soil column. After using the texture to obtain only the hydrologic soil groups for the components with the same texture as the predominant texture

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Table 7-5. Crosswalk between STATSGO and CONUS Soil Textures

STATSGO	CONUS	Description	STATSGO	CONUS	Description
IND	BR	bedrock	FRAG	O	other
MARL	BR	bedrock	GYP	O	other
UWB	BR	bedrock	ICE	O	other
VAR WB	BR	bedrock	VAR	O	other
WB	BR	bedrock	CIND GRX-S	S	sand
C	C	clay	CIND S	S	sand
CL	CL	clay loam	COS	S	sand
G	G[1]	gravel	FS	S	sand
L	L	loam	S	S	sand
LCOS	LS	loamy sand	SG	S	sand
LFS	LS	loamy sand	VFS	S	sand
LS	LS	loamy sand	SC	SC	sandy clay
LVFS	LS	oamy sand	SCL	SCL	sandy clay loam
CE	OM	organic materials	DE SI SIL	SI	silt
FB	OM	organic materials	SI	SI	silt
HM	OM	organic materials	SIC	SIC	silty clay
MPT	OM	organic materials	CEM SICL	SICL	silty clay loam
MUCK	OM	organic materials	SICL	SICL	silty clay loam
PEAT	OM	organic materials	SIL	SIL	silt loam
SP	OM	organic materials	COSL	SL	sandy loam
CEM	O	other	FSL	SL	sandy loam
CIND	O	other	SL	SL	sandy loam
DE	O	other	VFSL	SL	sandy loam

[1] G (gravel) is not one of the CONUS textures but was retained because it does not match well to a CONUS texture.

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for the entire map unit, the hydrologic soil groups were averaged. Using a conversion similar to the one in USSOILS, hydrologic soil groups were assigned numbers to allow numeric averaging (Table 7-6).

The new numeric-equivalent hydrologic soil groups were then averaged, weighted by the percent area of the map unit occupied by that component. The average numeric hydrologic soil groups were then converted back to letters using the following criteria:

Average	Letter
≤ 1.5	A
> 1.5 and ≤ 2.5	B
> 2.5 and ≤ 3.5	C
> 3.5	D

The final result was a table of hydrologic soil groups by map unit based on soil texture. Even though every attempt was made to mimic CONUS processing, occasionally no component within a map unit had the same predominant texture as that map unit (this occurred in 370 out of the 10,388 map units that had texture data derived from CONUS). These map units were filled in with the hydrologic soil type most common nationally (B) and marked as infilled in the database.

7.4.2.2 <u>Database Processing for Hydrologic Soil Group</u>. As with soil texture, the map unit with the largest area (that did not have a texture of water) in the area concerned was used to derive the hydrologic soil group from the pre-existing table described earlier.

7.4.2.3 <u>Assumptions and Uncertainty for Hydrologic Soil Group</u>. The process by which the predominant texture was derived for each STATSGO component resulted in 370 out of 10,388 map units that did not have any components of the same texture as the predominant CONUS texture. This indicates that, although a process similar to that of CONUS was employed, there may be some differences in the results due to the processing to standard layers in CONUS versus processing to STATSGO component. The use of the average soil hydrologic group, however, should minimize any potential bias for these few map units.

7.4.3 Field Capacity

Field capacity was obtained using a lookup table from Carsel et al. (1988) of field capacity by hydrologic soil group and layer. Median values were used because field capacity is correlated with saturated water content (i.e., total porosity), yet Carsel et al. (1988) do not provide correlation parameters.

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Table 7-6. Hydrologic Soil Groups

Hydrologic Group	Number	Description
A	1	well- to excessively drained sands and gravels (high infiltration rates)
B	2	moderately well- to well-drained soils with moderate textures (moderate infiltration rates)
C	3	moderately to poorly drained soils with moderately fine to fine textures (slow infiltration rates)
D, A/D, B/D, C/D	4	poorly drained soils with very fine texture (very slow infiltration rates)
A/C, B/C, 2, VAR	----	

7.4.3.1 Database Compilation for Field Capacity. A table for field capacity from Carsel et al. (1988) was entered into the database as a lookup table, including hydrologic soil group, layer, distribution type (constant), and median value (Table 7-7).

7.4.3.2 Database Processing for Field Capacity. The map unit with the largest area in the area concerned was used to obtain the hydrologic soil group that was then used with the lookup table to obtain the value for the field capacity by layer. Field capacities derived from the infilled hydrologic soil groups were also marked as infilled in the database.

7.4.3.3 Assumptions and Uncertainty for Field Capacity. Field capacity is specified as a national median value based on site-specific hydrologic soil groups. Any uncertainty associated with the hydrologic soil group would be translated into the associated field capacity.

7.4.4 Wilting Point

Wilting point was obtained similarly to field capacity using a Carsel et al. (1988) lookup table of wilting point by hydrologic soil group and layer. Median values were used because wilting point is correlated with saturated water content, yet Carsel et al. (1988) do not provide correlation parameters.

7.4.4.1 Database Compilation for Wilting Point. A table for wilting point from Carsel et al. (1988) was entered into the database as a lookup table, including hydrologic soil group, layer, distribution type (constant), and median value (Table 7-8).

7.4.4.2 Database Processing for Wilting Point. The map unit with the largest area (that did not have a texture of water) in the area concerned was used to obtain the hydrologic soil group that was then used with the lookup table to obtain the value for the wilting point by layer. Wilting points derived from the infilled hydrologic soil groups were also marked as infilled in the database.

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Table 7-7. Field Capacity Values

Hydrologic Group	Layer	Median
A	1	9.4
A	2	8.1
A	3	5.9
A	4	5.8
B	1	19.1
B	2	18.8
B	3	18.7
B	4	17.5
C	1	22.5
C	2	23.2
C	3	22.9
C	4	21.3
D	1	24.2
D	2	26.3
D	3	25.6
D	4	24.4

Source: Carsel et al. (1988).

Table 7-8. Wilting Point Values

Hydrologic Group	Layer	Median
A	1	3.1
A	2	2.3
A	3	2.1
A	4	1.9
B	1	8.7
B	2	9.3
B	3	8.9
B	4	8.4
C	1	10.4
C	2	12.1
C	3	11.9
C	4	11.5
D	1	13.8
D	2	17.0
D	3	16.3
D	4	15.1

Source: Carsel et al. (1988).

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7.4.4.3 Assumptions and Uncertainty for Wilting Point. Wilting point is specified as a national median value based on site-specific hydrologic soil groups. Any uncertainty associated with the hydrologic soil group would be translated into the associated wilting point.

7.4.5 SCS Curve Number

The SCS curve number was obtained using a lookup table based on a USDA (1986) table of curve numbers by cover type and hydrologic soil group. The curve number was passed to the LAU and WP source models by local watershed and subarea. The curve number was also passed for the watershed model by watershed subbasin.

7.4.5.1 Database Compilation for SCS Curve Number. Using the cover type descriptions from the USDA (1986) table for curve numbers, a comparison was made to the Anderson land use descriptions (Table 7-3) to match a cover type to each Anderson land use code. The resulting table (Table 7-9) consists of SCS curve numbers by Anderson land use code and hydrologic soil group.

7.4.5.2 Database Processing for SCS Curve Number. Using the soil map unit with the largest area in the watershed subbasin, the hydrologic soil group was obtained as described in Section 7.3.2. A GIS table of Anderson land use codes by watershed subbasin was used along with the hydrologic soil group for the map unit to obtain the corresponding SCS curve number from Table 7-9. Because there could be multiple land use codes per watershed subbasin, a land use area-weighted average of the curve number was calculated, resulting in one SCS curve number for each watershed subbasin. A GIS table matching the site and WMU type to the regional watershed in which the local watershed resides was used to apply the regional watershed SCS curve number to the local watershed. The result was indexed by local watershed and subarea, but because soil and land use data were not available on the subarea scale, the same SCS curve number was passed for all of the subareas in a given local watershed.

7.4.5.3 Assumptions and Uncertainty for SCS Curve Number. As mentioned previously, the map unit and land use data were only available on the watershed subbasin scale, resulting in the same curve number being used for the local watershed as the watershed subbasin in which it lies. The same curve number was repeated for each of the subareas in each local watershed. Also, any uncertainties associated with the hydrologic soil group would be translated into the associated curve number.

7.4.6 Root Zone Depth

The depth to the root zone was obtained using a Dunne and Leopold (1978) table of rooting depth by vegetation type and soil texture. Like SCS curve numbers this parameter was indexed by regional watershed subbasin for the watershed model and by local watershed and subarea for the LAU and WP source models.

7.4.6.1 Database Compilation for Root Zone Depth. Anderson land use descriptions were used to match a vegetation type from Dunne and Leopold (1978) to an Anderson land use code. Also, because Dunne and Leopold included only five soil textures and there are 13 basic

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Table 7-9. SCS Curve Number Values

Anderson Code (GIRAS Land Use)	Assumed Cover Type (USDA, 1986)	SCS Curve Number[a]			
		A	B	C	D
11- residential	residential (averaged over different lot sizes)	58	73	82	86
12 - commercial and services	commercial and business	89	92	94	95
13, 15 - industrial/commercial services	industrial	81	88	91	93
14 -transportation, communication, utilities	paved roads, open ditches (with right of way)	83	89	92	93
16 -mixed urban or builtup land	commercial and business, industrial, residential – one-fourth acre or less (average)	80	87	91	93
17 - other urban or builtup land	urban open space (fair)	49	69	79	84
21 - cropland and pasture	mean cropland and pasture – fair (average)	57	72	80	85
22 - orchards, groves, vineyards, nurseries, and ornamental horticultural land	woods – grass combination (fair)	43	65	76	82
23, 24 - confined feeding operations/ other agricultural land	farmsteads	59	74	82	86
31 - herbaceous rangeland	herbaceous and pasture/grassland/range (average)	49	70	80	87
32 - shrub and brush rangeland	oak-aspen, desert shrub, sagebrush, brush – fair (average)	45	57	68	74
33 - mixed rangeland	31, 32 (average)	47	64	74	81
41, 42, 43 - deciduous/evergreen/ mixed forestland	woods (fair)	36	60	73	79
71, 72, 73, 76 - barren land	bare ground/newly graded areas	77	86	91	94
74 - bare exposed rock	paved parking lots/bare rock	98	98	98	98
75 - strip mines, quarries, gravel pits	gravel roads	76	85	89	91

[a] Extracted or calculated from USDA (1986) using assumed cover type. A, B, C, D are hydrologic soil groups.

CONUS textures, the five textures were mapped across the CONUS textures. Table 7-10 shows the crosswalk between Dunne and Leopold vegetation types and soil textures and the Anderson land use codes and CONUS soil textures collected for the HWIR sites.

7.4.6.2 <u>Database Processing for Root Zone Depth</u>. The data processing program for root zone depth was similar to that used for SCS curve numbers except that soil texture was used in place of the hydrologic soil group. Using the map unit with the maximum area in each

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Table 7-10. Depth to Root Zone Values

Anderson Code (GIRAS)	Vegetation (Dunne & Leopold, 1978)	Depth to Root Zone [a]				
		Fine Sand (S)	Fine Sandy Loam (LS, SL)	Silt Loam (L, OM, SI, SIL)	Clay Loam (CL, SCL, SICL)	Clay (C, SC, SIC)
11, 12, 13, 14, 15, 16, 17, 22	orchards	1.5	1.67	1.5	1	0.67
21, 24	moderately deep-rooted crops	0.75	1	1	0.8	0.5
23	shallow-rooted crops	0.5	0.5	0.62	0.4	0.25
31, 32, 33, 81, 82, 84, 85	deep-rooted crops	1	1	1.25	1	0.67
41, 42, 43, 61	mature forest	2.5	2	2	1.6	1.17
71, 72, 73, 74, 75, 76	none - no vegetation	0	0	0	0	0

[a] Extracted from Dunne and Leopold (1978); assignment to HWIR soil textures shown in parentheses.

watershed subbasin, the soil texture for the top 20 cm was used with a GIS table of Anderson land use codes by watershed to obtain the corresponding rooting depth from the lookup table shown in Table 7-10. Because there are multiple land uses per watershed, an area-weighted average root zone depth was calculated across all land uses for each watershed. The root zone depth by local watershed was obtained by taking the same value for the local watershed as the regional watershed in which it resides. This value was repeated for all subareas in each local watershed.

7.4.6.3 Assumptions and Uncertainty for Root Zone Depth. Similar to the SCS curve number, the map unit and land use data were only available on the watershed subbasin scale, resulting in the same rooting depth being used for the local watershed as the regional watershed in which it lies. Also, this same value was repeated for each of the subareas in each local watershed. Any uncertainties associated with the soil texture will be somewhat inherent in the root zone depth.

7.4.7 Alpha, Beta, Residual Water Content, and Saturated Hydraulic Conductivity

Distributions for the unsaturated zone hydrological parameters alpha, beta, residual water content (WCR), and saturated hydraulic conductivity (SatK) were taken from national distributions developed by Carsel and Parrish (1988) for different USDA soil textures. Distributions for all four variables were collected for the vadose zone model based on the predominant soil texture for the entire soil column under the WMU (see Section 7.4.1). A cross-correlation table provided by Carsel and Parrish (1988, Table 9) for these four variables also was included in the database. SatK also was provided for the LAU, WP and watershed models, but it was based on the predominant soil texture for the top 20 cm of soil.

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SatK was provided for the landfill cover soil based on the predominant soil texture for the entire soil column under the WMU. This value is based on the assumption that the soil used for covering the landfill is obtained from soil at or very nearby the facility and, in many cases, could be soil excavated to construct the landfill itself.

7.4.7.1 Database Compilation for Alpha, Beta, WCR, and SatK. The table from Carsel and Parrish (1988) was hand-entered into a database table, including soil texture, lower and upper limits, transformation type, transformed mean, and transformed standard deviation (Table 7-11). The lower limit for SatK was raised from 0 to 1x10-8 m/yr to accommodate the models that cannot handle a 0 value for this variable.

7.4.7.2 Database Processing for Alpha, Beta, WCR, and SatK. The map unit with the maximum area in the area of concern (WMU or watershed subbasin) was used to determine the predominant soil texture for either the top 20 cm of soil or the entire soil column. This texture was then used to query the distribution statistics (type, mean, standard deviation, minimum, and maximum) for each variable needed from the lookup table in the database. For a small number of map units, the predominant texture was organic materials. Because Carsel and Parrish (1988) do not provide distributions for organic materials, in these cases distribution data corresponding to the most commonly occurring texture in the United States, loam, were entered into the database as the default, with the infill flag set to true.

7.4.7.3 Assumptions and Uncertainty for Alpha, Beta, WCR, and SatK. Along with any uncertainty associated with the soil texture (see Section 7.4.1) and its effect on these properties, four sites had organic materials as the predominant texture for a few watersheds. Although a nationally typical soil type (loam) was selected in these cases, it is uncertain whether this selection presents a bias because typical hydrologic properties for organic soils were not available for this analysis. Because the number of these cases is sufficiently small, there was probably little impact on the overall analysis.

7.4.8 Saturated Water Content and Dry Bulk Density

The values for saturated water content (WCS; total porosity) were taken from a Carsel and Parrish (1988) table of mean WCS by soil texture. WCS values for the vadose zone model were taken from the soil texture for the entire soil column under the WMU. Values for the LAU, WP, and watershed models were taken from the soil texture for the top 20 cm of soil, and similar to the saturated hydraulic conductivity (see Section 7.4.7), the landfill cover soil WCS was based on the soil texture for the entire soil column under the WMU.

Dry soil bulk density (RHOB) was calculated from the WCS using an equation from U.S. EPA (1996), and it was provided for the vadose zone model based on the soil texture for the entire soil column.

7.4.8.1 Database Compilation for WCS and RHOB. WCS values from Carsel and Parrish (1988) were hand-entered into a database table, including soil texture and mean WCS (Table 7-12). RHOB was then calculated from WCS using the following equation (U.S. EPA, 1996):

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Table 7-11. Unsaturated Zone Hydrologic Parameters: Moisture Retention Parameters (Alpha, Beta), Saturated Hydraulic Conductivity (SatK), and Residual Water Content (WCR)

Variable	Soil Texture	Min	Max	Transformation	Transformed Mean	Transformed Std. Devation
Alpha	C	0	0.15	TrnJohnsonSB	-4.145	1.293
Alpha	CL	0	0.15	TrnLogNormal	-4.22	0.72
Alpha	L	0	0.15	TrnJohnsonSB	-1.27	0.786
Alpha	LS	0	0.25	Normal	0.124	0.043
Alpha	S	0	0.25	TrnJohnsonSB	0.378	0.439
Alpha	SC	0	0.15	TrnLogNormal	-3.77	0.563
Alpha	SCL	0	0.25	TrnJohnsonSB	-1.38	0.823
Alpha	SI	0	0.1	Normal	0.017	0.006
Alpha	SIC	0	0.15	TrnLogNormal	-5.66	0.584
Alpha	SICL	0	0.15	TrnJohnsonSB	-2.75	0.605
Alpha	SIL	0	0.15	TrnLogNormal	-4.1	0.555
Alpha	SL	0	0.25	TrnJohnsonSB	-0.937	0.764
Beta	C	0.9	1.4	TrnLogNormal	0.0002	0.118
Beta	CL	1	1.6	TrnJohnsonSB	0.132	0.725
Beta	L	1	2	TrnJohnsonSU	0.532	0.099
Beta	LS	1.35	5	TrnJohnsonSB	-1.11	0.307
Beta	S	1.5	4	TrnLogNormal	0.978	0.1
Beta	SC	1	1.5	TrnLogNormal	0.202	0.078
Beta	SCL	1	2	TrnLogNormal	0.388	0.086
Beta	SI	1.2	1.6	Normal	1.38	0.037
Beta	SIC	1	1.4	TrnJohnsonSB	-1.28	0.821
Beta	SICL	1	1.5	Normal	1.23	0.061
Beta	SIL	1	2	TrnJohnsonSB	-0.37	0.526
Beta	SL	1.35	3	TrnLogNormal	0.634	0.082
SatK	C	1E-08	5	TrnJohnsonSB	-5.75	2.33

(continued)

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Table 7-11. (continued)

Variable	Soil Texture	Min	Max	Transformation	Transformed Mean	Transformed Std. Devation
SatK	CL	1E-08	7.5	TrnJohnsonSB	-5.87	2.92
SatK	L	1E-08	15	TrnJohnsonSB	-3.71	1.78
SatK	LS	1E-08	51	TrnJohnsonSB	-1.27	1.4
SatK	S	1E-08	70	TrnJohnsonSB	-0.394	1.15
SatK	SC	1E-08	1.5	TrnLogNormal	-4.04	2.02
SatK	SCL	1E-08	20	TrnJohnsonSB	-4.04	1.85
SatK	SI	1E-08	2	TrnLogNormal	-2.2	0.7
SatK	SIC	1E-08	1	TrnLogNormal	-5.69	1.31
SatK	SICL	1E-08	3.5	TrnJohnsonSB	-5.31	1.62
SatK	SIL	1E-08	15	TrnLogNormal	-2.19	1.49
SatK	SL	1E-08	30	TrnJohnsonSB	-2.49	1.53
WCR	C	0	0.15	TrnJohnsonSU	0.445	0.282
WCR	CL	0	0.13	TrnJohnsonSU	0.679	0.06
WCR	L	0	0.12	TrnJohnsonSB	0.639	0.487
WCR	LS	0	0.11	TrnJohnsonSB	0.075	0.567
WCR	S	0	0.1	TrnLogNormal	-3.12	0.224
WCR	SC	0	0.12	TrnJohnsonSB	1.72	0.7
WCR	SCL	0	0.12	TrnJohnsonSB	1.65	0.439
WCR	SI	0	0.09	Normal	0.042	0.015
WCR	SIC	0	0.14	Normal	0.07	0.023
WCR	SICL	0	0.115	Normal	0.088	0.009
WCR	SIL	0	0.11	TrnJohnsonSB	0.478	0.582
WCR	SL	0	0.11	TrnJohnsonSB	0.384	0.7

Source: Carsel and Parrish (1988).

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Table 7-12. Saturated Water Content and Dry Bulk Density

Soil Texture	Saturated Water Content (WCS)	Dry Bulk Density (RHOB)
C	0.38	1.643
CL	0.41	1.5635
L	0.43	1.5105
LS	0.41	1.5635
SI	0.46	1.431
SIL	0.45	1.4575
SIC	0.36	1.696
SICL	0.43	1.5105
S	0.43	1.5105
SC	0.38	1.643
SCL	0.39	1.6165
SL	0.41	1.5635

Sources: Carsel and Parrish (1988), U.S. EPA (1996).

$$\text{RHOB} = 2.65\,(1 - \text{WCS}) \tag{7-1}$$

where

2.65 = soil particle density in g/cm^3.

RHOB values were then added to the table of mean WCS by soil texture.

7.4.8.2 <u>Database Processing for WCS and RHOB</u>. The map unit with the maximum area in the area of concern (WMU or watershed subbasin) was used to determine the predominant soil texture for either the top 20 cm of soil or the entire soil column. This texture was then used to query the corresponding values for WCS and bulk density from the lookup tables in the database. Because a small number of map units have organic materials as the predominant texture and Carsel and Parrish (1988) does not provide a value for this texture, infill values corresponding to the most commonly occurring texture in the United States, loam, were entered as the default, with the infill flag set to true.

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7.4.8.3 <u>Assumptions and Uncertainty for WCS and RHOB</u>. Like any uncertainties associated with the soil texture, a small number of map units with organic materials as the predominant texture affected some watershed values at four of the sites. Although a nationally typical soil type (loam) was selected in these cases, it is uncertain whether this selection presents a bias because typical hydrologic properties for organic soils were not available for this analysis. Because the number of these cases is sufficiently small, there was probably little impact on the overall analysis.

7.4.9 Soil Moisture Coefficient *b*

Mean values for soil moisture coefficient *b* were obtained from a Clapp and Hornberger (1978) table of *b* values by USDA soil texture class (Table 7-13). Soil moisture coefficient *b* values were collected for the landfill model, cover soil and subsoil, using the soil texture for the entire soil column under the WMU. The *b* values for the LAU, WP, and watershed models were collected using the soil texture for the top 20 cm of soil.

7.4.9.1 <u>Database Compilation for Soil Moisture Coefficient *b*</u>. The Clapp and Hornberger (1978) table for soil moisture coefficient *b* was hand-entered into a table in the database to create a lookup table for *b* values based on soil texture.

7.4.9.2 <u>Database Processing for Soil Moisture Coefficient *b*</u>. The map unit with the maximum area in the area of concern (WMU or watershed subbasin) was used to determine the predominant soil texture that was, in turn, used to query the corresponding *b* value from the lookup table in the database. Note that in Table 7-13 there is no *b* value for silt or organic materials, so an infill value corresponding to the predominant soil texture in the United States, loam, was used and designated as infilled in the data. Silt was never a predominant soil texture for a watershed or WMU, however, so this infill was not exercised for the HWIR data collection effort.

7.4.9.3 <u>Assumptions and Uncertainty for Soil Moisture Coefficient *b*</u>. Any uncertainty for soil texture (see Section 7.4.1) would also be translated into the soil moisture coefficient.

7.4.10 Fraction Organic Carbon and Percent Organic Matter

The percent organic matter (POM), available in STATSGO and USSOILS, was converted to fraction organic carbon (FOC) using an equation from U.S. EPA (1996). Like other parameters, fraction organic carbon was collected for both the top 20 cm of soil and the entire soil column. Unlike the other parameters, two different sources were used based on the depth required. Because USSOILS had already compiled the percent organic matter for the entire soil column, USSOILS was used as the source for the fraction organic carbon for the entire soil column as well as the percent organic matter required by the vadose zone model. Because a value was needed for the top 20 cm and the organic matter content is extremely sensitive to depth in the soil column, the percent organic matter data from STATSGO, by component and layer, were used to calculate values for the top 20 cm of soil.

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Table 7-13. Soil Moisture Coefficient *b* Values

Soil Texture	Soil Moisture Coefficient *b* Values
sand	4.05
loamy sand	4.38
sandy loam	4.90
silt loam	5.30
loam	5.39
sandy clay loam	7.12
silty clay loam	7.75
clay loam	8.52
sandy clay	10.4
silty clay	10.4
clay	11.4

Source: Clapp and Hornberger (1978).

7.4.10.1 <u>Database Compilation for Fraction Organic Carbon and Percent Organic Matter</u>. The USSOILS data table containing the percent organic matter for the entire soil column needed no further processing. The percent organic matter (oml and omh) contained in STATSGO by layer and component needed to be compiled to obtain the percent organic matter for the top 20 cm of soil. As shown in Equation 7-2, a depth-weighted average of average (oml and omh) percent organic matter by STATSGO layer within the standard CONUS layers was taken and then averaged (area-weighted) further across all components to obtain the percent organic matter by map unit and standard CONUS layer as follows:

$$\frac{\sum_j \left[\text{comppct}_{jk} * \left(\frac{\sum_i \text{AveOM}_{ij} * h_{ijk}}{\sum_i h_{jk}} \right) \right]}{\sum_j \text{comppct}_{jk}} \tag{7-2}$$

where

i	=	STATSGO layer
j	=	STATSGO component
k	=	CONUS layer
AveOM	=	average percent organic matter by STATSGO layer and component

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h	=	height of STATSGO layer in CONUS layer
compact	=	percentage of component in map unit.

A simple depth-weighted average over the top three CONUS layers (20 cm) was then taken to obtain the average percent organic matter for the top 20 cm of soil.

7.4.10.2 <u>Database Processing for Fraction Organic Carbon and Percent Organic Matter</u>. The percent organic matter was obtained directly from USSOILS using the map unit with the largest area in the WMU area. The map unit with the largest area in the area of concern (WMU or watershed subbasin) also was used to obtain the fraction organic carbon. Both the fraction organic carbon for the entire soil column and for the top 20 cm of soil were calculated from the percent organic matter using the following equation (U.S. EPA, 1996):

$$foc = \frac{\%OM}{174} \tag{7-3}$$

where

foc	=	fraction organic carbon
%OM	=	percent organic matter
174	=	conversion factor.

The value for the entire soil column (WMU) was calculated from the percent organic matter from USSOILS, and the value for the top 20 cm was calculated from the percent organic matter derived from STATSGO data.

7.4.11 Soil pH

The soil pH was derived from STATSGO pH data by layer (phl and phh) and determined for the entire soil column.

7.4.11.1 <u>Database Compilation for pH</u>. The soil pH for the entire soil column by map unit was calculated as the depth- and area-weighted averages of the average pH by layer and component as follows:

$$\frac{\sum_j comppct_j * \left(\frac{\sum_i \frac{(pHh_i + pHl_i)}{2} * (laydepthh_i - laydepthl_i)}{\sum_i (laydepthh_{ij} - laydepthl_{ij})} \right)}{\sum_j comppct_j} \tag{7-4}$$

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where

i	=	STATSGO layer
j	=	STATSGO component
laydepth	=	depth of the STATSGO layer (high and low).

7.4.11.2 <u>Database Processing for pH</u>. Using the map unit with the largest area in the area concerned (WMU or watershed subbasin), the pH value was obtained from the table of pH by map unit discussed in the previous section. For the farm and watershed pH, the value was further averaged across all watershed subbasins at the site.

7.4.12 Silt Content

Silt content was obtained from CONUS layer data for the percentage of silt and was obtained for the top 20 cm of soil only. CONUS was taken as the most reliable source for this parameter because CONUS values are based directly on the CONUS/STATSGO soil texture and the USDA soil textural triangle. According to Miller and White (1998), the percentages of sand, silt, and clay content values are suspect because they often do not add up to 100 percent.

7.4.12.1 <u>Database Compilation for Silt Content</u>. Silt content by map unit for the top 20 cm of soil was obtained using the following equation :

$$\frac{\Sigma_i \left(\%silt_i \, * \, layerdepth_i\right)}{\Sigma_i \; layerdepth_i} \qquad (7\text{-}5)$$

where

i	=	CONUS layer (top three only)
layerdepth	=	depth of CONUS layer.

CONUS layers with textures of other, no data, and bedrock were excluded from the averaging.

7.4.12.2 <u>Database Processing for Silt Content</u>. The map unit with the largest area in the WMU was used to obtain the percentage of silt from the table discussed in the previous section.

7.4.13 USLE Erodibility Factor (K)

The USLE erodibility factor (K) was obtained directly from USSOILS, which provides depth- and area-weighted averages by map unit. The map unit with the largest area in the watershed subbasin was used to obtain the K value from the USSOILS data table.

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7.4.14 USLE Cover Factor (C)

The USLE cover factor (C) was obtained using a Wanielista and Yousef (1993) table of C factors by land use. Values for C were collected by watershed subbasin for the watershed model and by subarea for the LAU and WP models.

7.4.14.1 **Database Compilation for USLE Cover Factor (C)**. Land use descriptions in the Wanielista and Yousef (1993) table were matched to Anderson land use codes to provide a database lookup table of C values by Anderson land use code (Table 7-14).

7.4.14.2 **Database Processing for USLE Cover Factor (C)**. A GIS table of Anderson land use codes by watershed was used to obtain the corresponding C values from the database lookup table. A land use area-weighted average C value was calculated by watershed. As with the soil properties, the C value for the regional watershed was used for all subareas of the local watershed.

7.4.15 USLE Erosion Control Factor (P)

Similar to the USLE cover factor (C), the USLE erosion control practice factor (P) was obtained using a Wanielista and Yousef (1993) table of P values by land use. Values for P were indexed by watershed subbasin for the watershed model and by local watershed subarea for the LAU and WP models.

7.4.15.1 **Database Compilation for USLE Erosion Control Factor (P)**. Land use descriptions from the Wanielista and Yousef (1993) table of P values also were matched to Anderson land use codes to create a lookup table of P values by Anderson land use code (Table 7-15).

Table 7-14. USLE Cover Factor C

Land Use	Anderson Code[a]	C
Crop land	21, 24	0.08
Forest land	41, 42, 43	0.005
Pasture land	22, 31, 32, 33, 81, 82, 84, 85	0.01
Urban land	11, 12, 13, 14, 15, 16, 17	0.01
No cover	23, 71, 72, 73, 75, 76, 83	1
No erosion	74, 91, 92	0
Water	51, 52, 53, 54, 61, 62	0

[a] See Table 7-3 for a description of Anderson land use codes.
Source: Wanielista and Yousef (1993).

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Table 7-15. USLE Erosion Control Factor

Land Use	Anderson Code[a]	P
Cropland	21	0.5
Forest land	41, 42, 43	1
Pasture land	22, 23, 24, 31, 32, 33, 81, 82	1
Urban land	11, 12, 13, 14, 15, 16, 17	1
No erosion control	51, 52, 53, 54, 61, 62, 71, 72, 73, 74, 75, 76, 83, 84, 85, 91, 92	1

[a] See Table 7-3 for a description of Anderson land use codes.
Source: Wanielista and Yousef (1993).

7.4.15.2 <u>Database Processing for USLE Erosion Control Factor (P)</u>. The processing for the P value was the same as that for the USLE cover factor. A GIS table of Anderson land use codes by watershed was used to obtain the P value from the database table. A land use area-weighted average was taken to calculate an average P value by watershed. The P value for the regional watershed in which the local watershed lies was used as the P value by the local watershed subarea.

7.4.16 Soil Column Temperature

The soil column temperature for the entire site was assumed to be the same as the groundwater temperature and was extracted from a Collins (1925) geographical distribution of groundwater temperatures for the continental United States.

7.5 Quality Assurance and Quality Control

7.5.1 Quality Control of Data Compilation

Two main types of QC were performed during database compilation: 100 percent checks of manual data entry and manual checks of automated calculations done on processed data. Manual data entry was checked by comparing the original paper copy of the table (in the original reference) to the entries in the database. Automated data transfer from the database tables into the final deliverable database also was checked against the original data sources as a QC check of both data processing and database values. To check data compilation from STATSGO and CONUS tables within the soil database, all data processing operations were checked using hand calculations for soil map units randomly selected from the database. When special processing rules applied to certain data categories, at least one of each type was chosen and checked.

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7.5.2 Quality Control of Data Transfer

To ensure that data were correctly obtained from the database tables and transferred to the final deliverable, soil data for a few sites were hand-checked to ensure that they corresponded to the correct map unit, land use code, and soil type or hydrologic soil group. Any averaging was checked by hand calculations as well. All of the final system-ready data were checked automatically using database queries to ensure that the variable name, data group, dimensions, data type, and units agreed with those in the model specifications and that the minimum and maximum limits in the model specifications had not been violated. The soil variable indices also were checked automatically to ensure that for each site the largest index was equal to the correct number of watersheds, local watersheds, or local watershed subareas on which the variable was indexed.

7.5.3 Quality Assurance

Quality assurance was conducted to ensure that an adequate QC methodology was in place and correctly implemented and recorded. QA/QC records for soil data processing can be provided on request.

7.6 Assumptions and Uncertainties

In general, the site-specific soil data readily available from STATSGO and its associated databases are more than adequate for a national screening analysis like HWIR. Although soil properties do vary significantly on a much smaller spatial scale than the nationwide soil data in STATSGO, the HWIR models, which assume average soil properties across a watershed or vadose zone, could not take advantage of such variability if the data were available. Given the demonstrated quality of the soil data in STATSGO, the QA/QC measures designed to ensure effective data processing and transfer, and the national scale of the HWIR analysis, we do not believe soil data are a significant source of overall uncertainty in this analysis. The uncertainties associated with the soil data, however, are summarized here.

One of the assumptions associated with the soil data was that soil properties are homogeneous over an area represented by a map unit. Based on STATSGO layer and component data, many of the soil properties vary on a much smaller scale than the map unit level. The representation of this complexity was not possible, however, nor could it be taken advantage of by the models, so the predominant or average values were used to characterize the soil for this national HWIR risk assessment.

A few more minor uncertainties are associated with the soil data. First, in the few cases when data were missing, an infill value, representing the most common value nationally, was substituted. Infill values for soil properties were required for 25 sites. In most cases, infill values were only necessary for a couple of the watersheds at each site and there were no sites completely missing soil data. Infill values resulted from two problems: missing hydrologic soil groups (see Section 7.4.2) and a soil type of organic materials (four sites, see Section 7.4.7).

A second uncertainty is the scale at which data were available for the local watershed. Because the scale of the STATSGO data (1:250,000) was much larger than that required to

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delineate the local watersheds, the soil properties for the local watershed and subareas were assumed to be the same as the regional watershed subbasin.

Two uncertainties associated with the land use data are lack of data currency and the scale of the data. The GIRAS land use coverages are from the mid-1970s to the early 1980s and may not accurately reflect current conditions at all sites; however they are roughly contemponaeous with the 1985 Industrial D Screening Survey used to define the sites used in this analysis. The 1:250,000-scale GIRAS land use coverages also limit the spatial resolution of the land use data. However, GIRAS data are the same scale as the digital elevation model (DEM) and STATSGO coverages. Thus, although some resolution may be lost, the level-of-detail is fairly consistent across these data sources.

7.7 References

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