Cumulative Hydrologic Impact Assessments of Surface Coal Mining Using WCMS-HSPF[1]

Samuel J. Lamont[2], Robert N. Eli, Jerald J. Fletcher, Thomas A. Galya

Abstract. As defined by the Surface Mining Control and Reclamation Act (SMCRA), a Cumulative Hydrologic Impact Assessment (CHIA) is required for all proposed coal mine permits. The Natural Resource Analysis Center (NRAC) at West Virginia University, with support from the West Virginia Department of Environmental Protection (WVDEP) and the U.S. Office of Surface Mining, Reclamation and Enforcement (OSMRE), has developed a suite of tools based on ERSI ArcGIS software to assist in this process. The EPA watershed model Hydrologic Simulation Program-Fortran (HSPF) has been added to NRAC's Watershed Characterization and Modeling System (WCMS) to predict changes in water quality and quantity caused by surface mining. HSPF is a comprehensive watershed model containing over 20 parameters. A joint calibration approach was adopted using historical stream flow records from five calibration watersheds and four additional verification watersheds throughout West Virginia. This resulted in one parameter set representative of the entire coal mining region. Because of the lack of available stream flow data from active mine sites, a link between the NRCS Curve Number (CN) and HSPF parameters was developed based on an established empirical method. Segmentation of the study site watersheds is based on the 1:24,000 NHD stream maps. The area draining to each individual reach was delineated for the entire state by NRAC. A table defining the flow connectivity between each "reachshed" was also created. The input control file for HSPF is automatically created using the reachshed physical attribute and flow connectivity tables. This results in a faster, more efficient method of creating HSPF input files than traditional raster-based methods.

Additional Key Words: HSPF, Curve Number, GIS

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Introduction

The Natural Resource Analysis Center (NRAC) at West Virginia University (WVU) with support from the West Virginia Department of Environmental Protection (WVDEP) and the U.S. Office of Surface Mining, Reclamation and Enforcement (OSMRE) has developed a suite of tools based on ESRI's ArcGIS 9.x software to support Cumulative Hydrologic Impact Assessments of proposed surface coal mining activities in West Virginia. The continuous watershed simulation model Hydrologic Simulation Program-Fortran (HSPF) has been incorporated into NRAC's Watershed Characterization and Modeling System (WCMS) in a user-friendly environment to facilitate model simulation and output analysis by WVDEP permit writers. WCMS-HSPF includes an ACIDPH subroutine which was designed at NRAC specifically for the simulation of acid mine drainage (AMD). To establish existing or baseline hydrologic conditions, WCMS-HSPF was calibrated to historical streamflow records from ten calibration and verification watersheds throughout the coal mining region of the state. This resulted in one HSPF parameter set for each landuse/cover type for the entire region. To simulate the hydrology of a proposed mine site, information available in a typical WVDEP-DMR surface mine permit is used, such as Curve Number (CN), watershed drainage area, design storm frequency, NPDES (National Pollutant Discharge Elimination System) peak discharge, and mine outflow water chemistry in mg/L. A relationship between the CN and several HSPF model parameters has been developed based on a soil physics model. The fundamental spatial unit of analysis is the segment-level watershed (SLW) or the area draining to each 1:24,000 NHD (National Hydrography Dataset) stream segment, which affords more efficient run-times for procedures such as watershed delineation when compared to traditional grid-based methods. WCMS-HSPF allows non-experts to perform spatial and hydrologic analysis (water quantity and quality) of proposed surface mine sites in a user-friendly environment.

The Watershed Characterization and Modeling System (WCMS)

WCMS is an ArcGIS 9.x extension toolbar (Figure 1) developed to bring spatial data and water quality modeling to the desktop of WVDEP personnel. It combines a variety of spatial

data layers with hydrologic and water quality modeling tools to aid in decision making and management of water resources for the state of West Virginia.

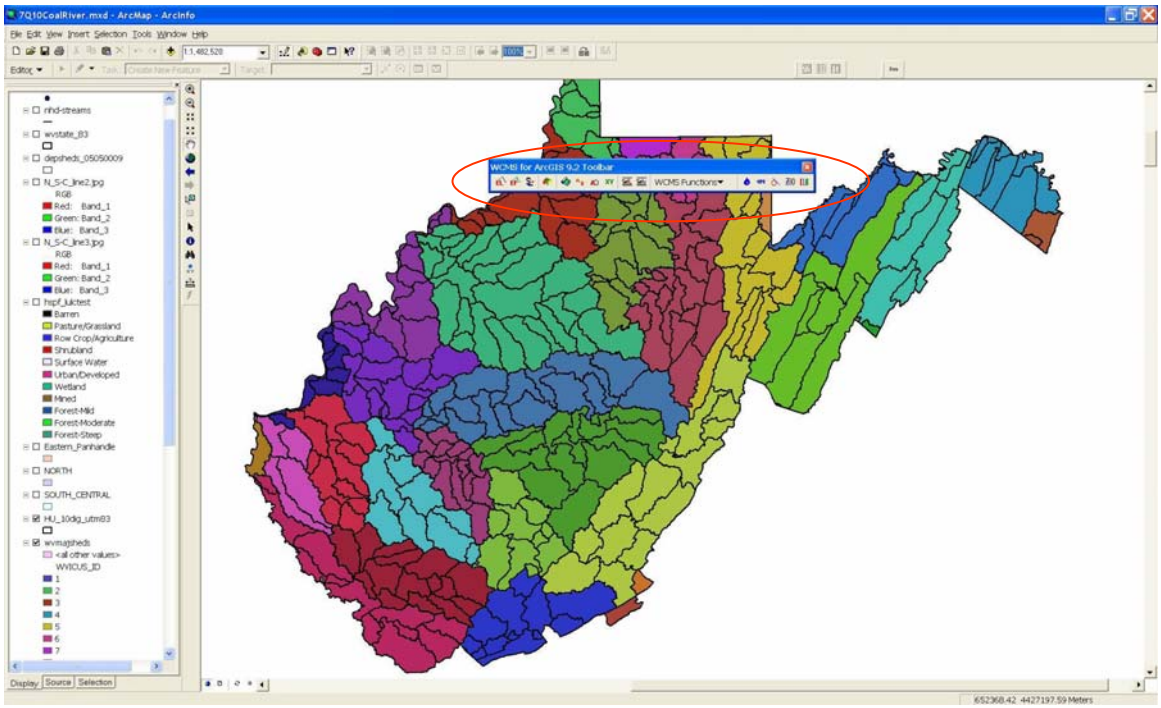

Figure 1. WCMS ArcGIS 9.x Toolbar

WCMS supports watershed analyses such as watershed delineation, drainage area calculations, and surface runoff tracking. It also includes streamflow modeling capabilities such as 7Q10 low flow (7 day low flow at a 10 year recurrence interval) for any point along a stream in the entire state. Water quality modeling capabilities are also possible, e.g., the expected mean concentration calculations of nitrogen, phosphorus, and total suspended solids. WCMS is a continually evolving tool and spatial data repository that is refined and improved as new data requirements or toolbar functionality becomes apparent to the user.

HSPF Model Summary

HSPF is a comprehensive, continuous model designed to simulate surface and subsurface water quantity and quality processes occurring in a watershed. Its origins can be traced to the Stanford Watershed Model which was developed in the 1970's. Today, HSPF is supported by the EPA (2000). It has over twenty parameters defined in its User's Control Input (UCI) file (Bicknell 2001), many of which must be determined through calibration. Surface and sub-

surface flow drains from pervious land use/cover categories, (PERLND's), which are assigned unique sets of model parameters, into the appropriate stream segments (RCHRES's). Figure 1 is a schematic of the PERLND module describing its various storages and parameters.

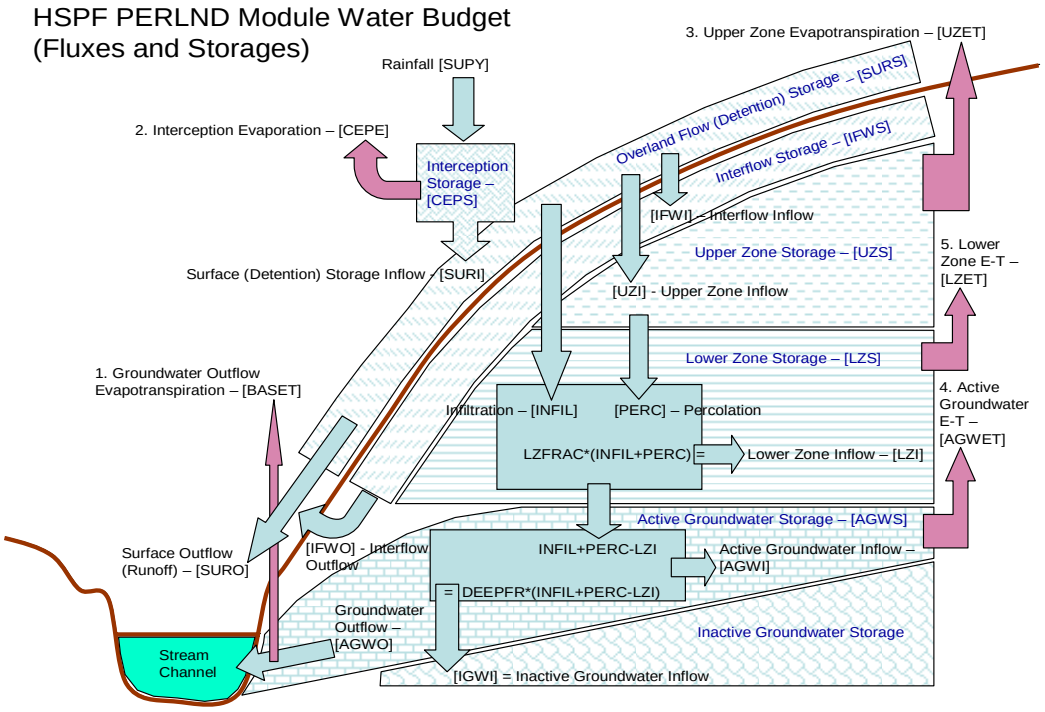

Figure 2. Flow Schematic and Storage Components within the HSPF PERLND Module

The minimum model inputs are precipitation and potential evapotranspiration (PET) time series while each of the computed storages and fluxes can be output in time series format. HSPF has been applied to a large number of watershed studies in a wide variety of locations. Forty-five studies using the model in the United States have been summarized in a user-friendly software package called HSPFParm (Donigian et al., 1999). Sams and Witt (1995) calibrated HSPF to two surface mined watersheds in Fayette County, PA, providing local relevance to this study. Because of its official support by the EPA, its long history of use in a variety of applications, and its wide ranging acceptance in the scientific community, HSPF was selected as the hydrologic model to be incorporated into WCMS to support CHIA analyses.

Baseline HSPF Calibration Summary

The area of concern for potential mine impact analyses was selected by the WVDEP and consists of 235 watersheds throughout the state defined by the water quality sampling points, or

trend stations, at their outlets (Figures 3 and 4). The WVDEP Trend Station Watershed water quality sampling points rarely coincided with USGS stream gaging stations required for model calibration. This fact, along with the obvious impracticality of individually calibrating to 235 watersheds, led to the adoption of a joint-calibration strategy following the work of Donigian (2002) and Dinacola (1990, 2001). Five calibration watersheds scattered throughout the area were selected with the intent of finding one parameter set for all of the trend station watersheds (Figure 3). Five additional verification watersheds were used to test the validity of transferring the resulting parameters (Figure 4) to ungaged locations. The Big Sandy watershed was used for both calibration and verification by using different simulation time periods. This resulted in one parameter set for each of nine land use categories for the entire trend station region. The land use categories (Forest, Pasture/Grassland, Urban/Developed, Existing Mine Land, Barren Land, Shrubland, Row Crop Agriculture, Surface Water, and Wetland) were based on 1993 GAP data (Strager and Yuill, 2002).

Figure 3. West Virginia CHIA Trend Stations and Calibration Watersheds.

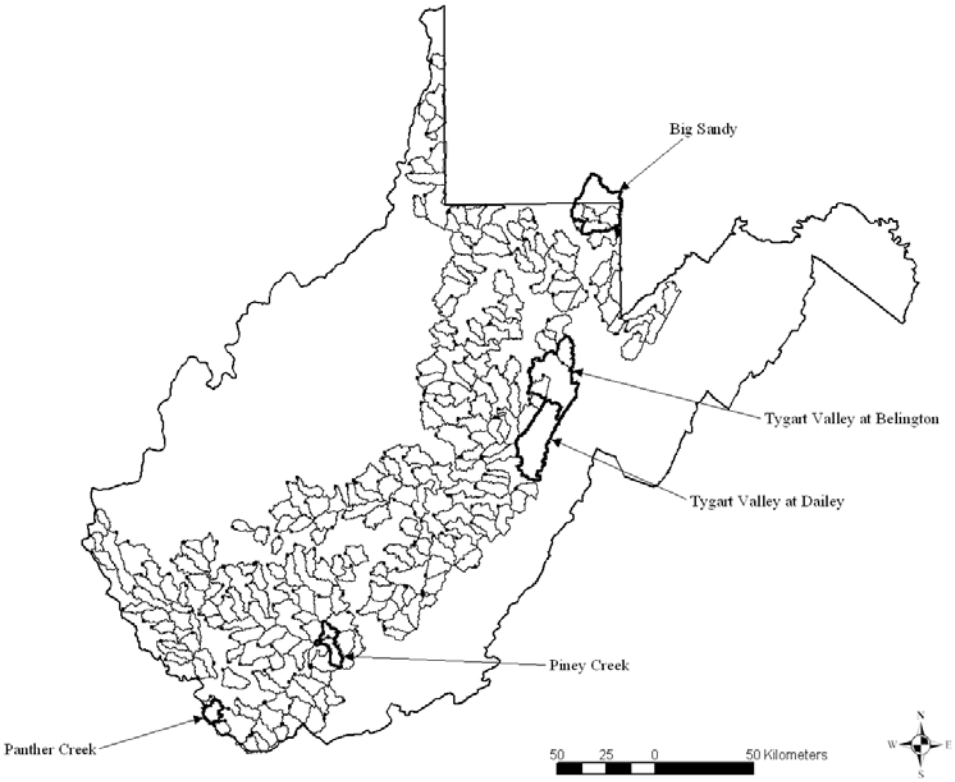

Figure 4. West Virginia CHIA Trend Stations and Verification Watersheds

The joint-calibration procedure involved two approaches. The first used the USGS semi-automated software HSPEXP (1994) which provides statistical and graphical error measures as well as parameter adjustment advice. A second calibration study was conducted using the independent parameter optimization package, PEST (Doherty, 2002). The final parameter set was selected through comparison of seven performance evaluating indices including the Coefficient of Determination (r^2), the Coefficient of Efficiency (*E*), and the Root Mean Square Error (*RMSE*). The simulated mean error is less than 12% for calibration watersheds and less than 15 % for four of the verification watersheds.

Relating HSPF Parameters to NRCS CN using a Soil Water Physics Model

Because of the lack of available historical runoff data from mine sites in West Virginia, traditional HSPF calibration methods were impossible. Because the NRCS CN is provided on the permit for each proposed mine site, a relationship between the CN and several HSPF parameters was developed based on a soil physics model. First, an analytical link was

established between HSPF soil moisture parameters and physical soil attributes by adopting a soil water physics model based on the Green-Ampt (Green and Ampt, 1911) and the Brooks-Corey (Brooks and Corey, 1964) equations. The soil model is described in terms of the soil pore size distribution index (λ_{ps}), soil porosity (η), soil water suction head (ψ), and soil moisture content (θ) shown in Figure 5.

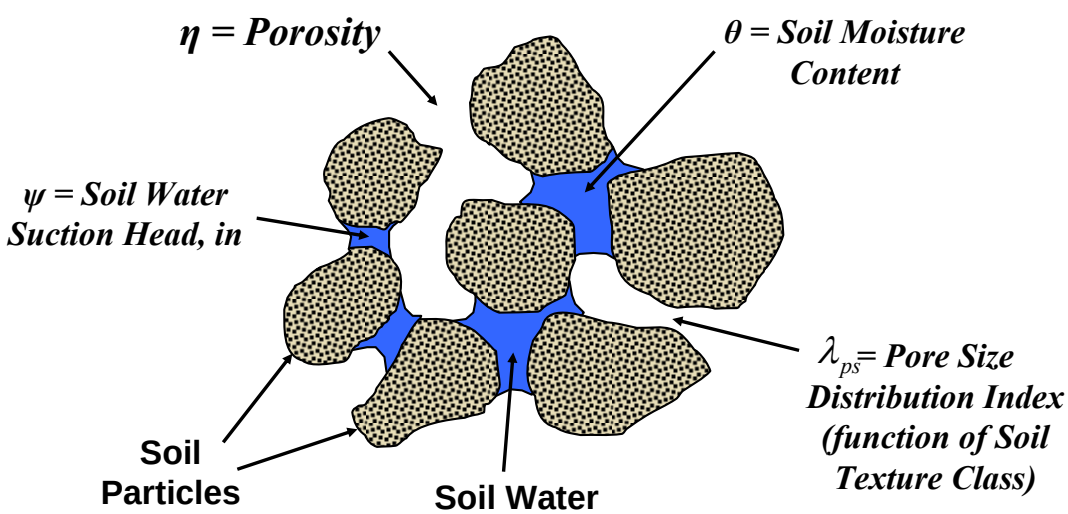

Figure 5. Soil Microstructure and Soil Water Variables (Soil Physics Model)

Brooks and Corey (1964) developed an empirical relationship between soil water suction head ψ (cm of water) and effective saturation s_e, as a function of soil texture. The Brooks-Corey equation is

$$s_e = \left[\frac{\psi_b}{\psi} \right]^{\lambda_{ps}} \qquad (1)$$

where ψ_b is the soil water suction head at which air first enters the soil (called the bubbling pressure) and λ_{ps} is pore size distribution index (a function of soil texture). The effective saturation is defined by

$$s_e = \frac{\theta - \theta_r}{\eta - \theta_r} \qquad (2)$$

where θ is the moisture content of the soil (cm^3/cm^3), θ_r is the residual moisture content of the soil (equivalent to the wilting point), and η is the soil porosity (see Figure 6 below).

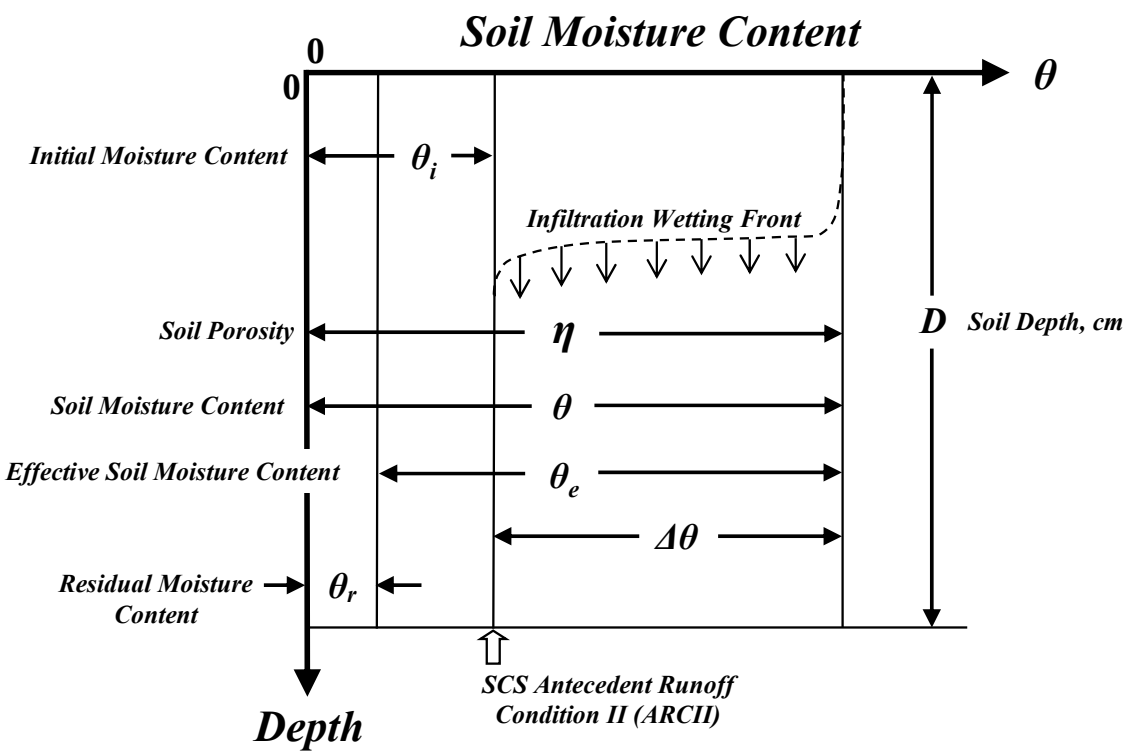

Figure 6. Soil Moisture Content as a Function of Soil Depth (Soil Physics Model)

Referring to Figure 6, the idealized soil water physics model assumes that the soil has homogeneous characteristics over the soil depth *D*. Neither the HSPF PERLND nor the CN method assumes that the soil has an explicit depth. In the soil water physics model, depth is required in order to compute soil water storage depth; and therefore, the soil depth is considered

to be the "equivalent soil depth" that produces the desired storage capacity of the soil. It should be noted that the maximum possible soil moisture content is equal to the porosity η. The actual maximum soil moisture content is actually slightly less than the porosity since a small amount of trapped air remains in the soil when fully saturated. In the development that follows, the moisture content at saturation is assumed to be equal to the porosity since the simplification introduces a negligible error. The effective moisture content, θ_e , is the amount of moisture that can be removed by gravity drainage and plant transpiration, assuming that the soil is initially saturated. The NRCS antecedent runoff condition (ARC I, ARC II, ARC III, or an intermediate value) is determined by initial moisture content, θ_i , present in the soil prior to a storm event. To simplify the model description, the moisture content is assumed to be constant over the soil depth at any given point in time.

Brakensiek, Engleman, and Rawls (1981) used the Brooks-Corey equation (1) to develop a method to determine parameters for the Green-Ampt infiltration equation (1911). The Green-Ampt equation is

$$f(t) = K\left[\frac{\psi \Delta\theta}{F(t)} + 1\right] \qquad (3)$$

where *f(t)* is the infiltration capacity at time *t*, *K* is the unsaturated hydraulic conductivity, ψ is the wetting front capillary pressure head, $\Delta\theta$ is the change in soil moisture content across the wetting front (Figure 6), and *F(t)* is the accumulated infiltration at time *t*. Rawls, Brakensiek, and Miller (1983) used this same method to analyze approximately 5000 soil horizons across the United States to determine average values of the Green-Ampt parameters for different soil texture classifications. Table 1 lists 11 soil texture classifications used in this latter study, ranging from Sand (coarse particles) to Clay (very fine particles). Combining equations 1 and 2, and solving for θ yields

$$\theta = \theta_r + \left(\eta - \theta_r\right)\left[\frac{\psi_b}{\psi}\right]^{\lambda_{ps}} \qquad (4)$$

which relates soil moisture content θ to soil water suction head ψ for a particular soil texture classification (for constant values of η, θ_r , ψ_b , and λ_{ps}). Equation 4 permits computation of the initial moisture content of the soil, θ_i , for any desired antecedent runoff condition (ARC) prior to a given storm event.

Computation of Equivalent HSPF Parameters for NRCS Curve Numbers

Examination of the HSPF PERLND module algorithms identifies six of the 20 parameters that have principal influence on the infiltration and soil moisture storage processes and the shape of the direct runoff hydrograph:

UZSN = Upper zone nominal soil moisture storage (mm).

LZSN = Lower zone nominal soil moisture storage (mm).

INFILT = Index to the mean infiltration rate (mm/hr).

INFEXP = Infiltration exponent parameter.

INTFW = Interflow inflow parameter.

IRC = Interflow recession parameter (1/day).

The first four parameters predominate in the control of the infiltration and soil moisture storage processes, and the last two parameters predominate in the control of the shape of the direct runoff hydrograph. The HSPF model has two soil water storage variables, the upper zone storage *UZS* (mm) and the lower zone storage *LZS* (mm) (see Figure 2). The corresponding nominal storage capacities, *UZSN* and *LZSN* (mm) are user adjustable model fitting parameters that are a function of "precipitation patterns and soil characteristics", according to BASINS Technical Note 6 (2000). The application of these nominal storage capacities in HSPF algorithms (Bicknell, et al., 2001) implies the following relationship between the nominal storages and the effective maximum storage capacities:

$$\begin{aligned} UZS_{\max} &= 3.0\left(UZSN\right) \\ LZS_{\max} &= 2.5\left(LZSN\right) \end{aligned} \qquad (5)$$

In view of the PERLND model component design, as shown in Figure 2, there is no defined soil depth and the combined values of *UZS* and *LZS* are the total of all storage in the subsurface between the soil surface and the ground water table (neglecting the short term interflow storage). The description of the function of the upper zone storage *UZS*, as stated in Hydrocomp (1969) (original source of the PERLND algorithm), is to provide for "depression storage and storage in highly permeable surface soils". It is further stated that "the upper zone storage prevents overland flow from a portion of the watershed depending on the value of the ratio *UZS/UZSN*, but since the nominal capacity *UZSN* is small, the upper zone retention percentage decreases rapidly with early increments of (rainfall) accretion". Inflow to the upper zone is governed by the storage ratio *UZS/UZSN* alone and is not considered to be part of the

infiltration process (Bicknell, et al., 2001). In view of these latter interpretations, the equivalent soil depth D is assumed to be defined by the maximum effective storage capacity of the lower zone storage, LZS_{max}:

$$D = \frac{LZS_{\max}}{\eta - \theta_r} \qquad (6)$$

As already noted above, η is the soil porosity and θ_r is the residual moisture content. Combining equations 5 and 6 produces:

$$LZSN = \frac{(\eta - \theta_r) D}{2.5} \qquad (7)$$

Donigian and Davis (1978) presented guidelines on the ratio of the nominal capacities of the two storages, *UZSN/LZSN*. They recommended that the nominal storage capacity of the upper zone *UZSN* be from 0.06 to 0.14 of that for the lower zone *LZSN*. Therefore, an average ratio of 0.10 was selected:

$$\frac{UZSN}{LZSN} = 0.1 \qquad (8)$$

Combining equations 7 and 8, and solving for *UZSN*, yields:

$$UZSN = \frac{(\eta - \theta_r) D}{25} \qquad (9)$$

The antecedent soil water depth of the lower zone storage, LZS_i, corresponding to the NRCS type II antecedent runoff condition (ARC II) (SCS, 1986) can be computed for the effective soil depth D if the corresponding soil moisture content θ_i is known:

$$LZS_i = (\theta_i - \theta_r) D \qquad (10)$$

Rawls and Brakensiek (1986) conducted studies comparing the runoff volume predictions of the Green-Ampt infiltration model to the CN model. They concluded that ψ = 340 cm was equivalent to the NRCS antecedent runoff condition II (ARC II). Using this value in equation 4 for each soil texture class results in the initial soil moisture content value θ_i, which in turn can be used to compute the antecedent soil water depth using equation 10. Table 1 lists values of θ_r , η, λ_{ps} , ψ_b , and θ_i , for each soil texture class.

The remaining parameters required to establish the HSPF and CN relationship for the design storm direct runoff volume are the infiltration parameter *INFILT* (mm/hr) and the

infiltration exponent parameter *INFEXP*. The HSPF infiltration capacity *IBAR* (mm/hr) is computed by (Bicknell, et al., 2001)

$$IBAR = \left[\frac{INFILT}{\left(\frac{LZS}{LZSN} \right)^{INFEXP}} \right] INFFAC \qquad (11)$$

where *INFFAC* is the frozen ground adjustment factor (set to 1 for unfrozen ground) and *INFEXP* is set equal to 2, consistent with typical applications of HSPF (U.S. EPA, 2000), and as recommended by Hydrocomp (1969). The values of *INFILT* for each of the soil texture classes listed in Table 2 are consistent with those values of *INFILT* recommended by BASINS Technical Note 6 (U.S. EPA, 2000) for NRCS Hydrologic Soil Groups A, B, C, and D, as listed in Table 2. The soil texture classes in Table 1 were first classified by hydrologic soil group using the soils data published by Nearing, et al., (1996). They compared NRCS Curve Numbers and hydrologic soil group classification to Green-Ampt hydraulic conductivities for a large number of soils covering a complete range of soil texture classes; therefore, it was possible to assign the proper hydrologic soil group to the soil texture classes in Table 1, according to soil texture class description and Green-Ampt hydraulic conductivity. After the appropriate hydrologic soil group classifications were determined, values of *INFILT* from Table 2 were assigned to each soil texture class so that the values varied smoothly from sand to clay, and so that the boundaries between hydrologic soil group classifications reflected the limits on the range of *INFILT* values listed in Table 1. In practice, this was accomplished by plotting estimated values of *INFILT* versus Green-Ampt infiltration capacity (at F(t) = 1 cm), and then adjusting the *INFILT* values by trial until a smooth curve fit was achieved (see Figure 7). The remaining less critical HSPF parameters were fixed at the values determined by the calibration process and with guidance from Sams and Witt (1995) for the surface mine land cover condition. Therefore, each soil texture class (Table 1) represents a surface mine site land cover condition with a unique infiltration capacity.

Curve Numbers were determined through an iterative process using HSPF as a theoretical watershed and synthetic rainfall and potential evapotranspiration input in hourly increments. The HSPF runoff parameters (LZSN, UZSN, and INFILT) and the simulated soil moisture content corresponding to ARC II (LZS_i) were calculated for each equivalent soil depth using

equations 7, 8, and 9 and Table 1. Therefore, each soil depth corresponds to a theoretical watershed (parameter set) with unique hydrologic characteristics. As noted, the remaining HSPF parameter values were determined through the calibration procedure for the existing mine land cover type and were fixed throughout the analysis. The input rainfall time series consisted of repetitive, regularly-spaced, SCS Type II twenty-four hour storm events (a cyclic storm input). The potential evapotranspiration (PET) time series consisted of a uniform rate maintained at a fixed value for all simulations consistent with a typical dry day rate (mm/hr) observed during the growing season. The PET was set to zero during the storm event. No diurnal fluctuation was used since the only purpose of the PET was to draw the soil moisture level down to the ARC II condition prior to the next cyclic storm event, and it was desirable not to introduce any unnecessary fluctuations into the simulation. Each simulation run was conducted over a sufficient number of storm cycles to ensure that cyclic equilibrium was reached in all of the HSPF PERLND output time series variables. The time between storm events was varied by trial and error until the lower zone storage, *LZS*, matched the initial ARC II condition computed using equation 10. The CN was then computed using equations 1-3 with the known value of P (corresponding to a specific storm distribution) and the numerically determined value of Q (the sum of *SURO* and *IFWO* HSPF output components between storm events). A check was included to ensure the rainfall depth satisfied the condition of equation 1. The SCS relationship (Soil Conservation Service, 1986) between the design storm direct runoff depth Q (cm) and the storm rainfall depth P (cm), as a function of curve number CN is

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

where: (1)

$$S = 2.54\left(\frac{1000}{CN} - 10\right)$$

which can be solved for CN for known values of P and numerically determined values of Q. This latter procedure can be used to produce a functional relationship between equivalent soil depth D and CN for a given design storm depth P.

The appropriate soil texture class is pre-selected (silty clay loam is programmed as the default texture class) to best match the range of expected curve numbers encountered in mine permits. The design storm depth typically corresponds to the 25 year event and is used as the

default value. Once these two conditions are specified, the corresponding functional relationship between the curve number CN and the equivalent soil depth *D* is determined. The functional relationship derived from the curve fit between curve number and soil depth then defines an equivalent *D* for a given *CN* value entered by the user. The WCMS-HSPF software interface then computes the corresponding PERLND parameters *LZSN* and *UZSN* using equations 4 and 6 respectively. The value of *INFILT* is a function of the soil texture class and is listed in Table 1. The parameters *LZSN* and *UZSN* are the only ones calculated in real time. The remaining parameters are all pre-specified, and are not entered by the user.

Table 1. Soil Texture Class Hydraulic Properties

Soil Texture Class	Total Porosity η	Residual Moisture Content θ_r	Pore Size Distribution Index λ	Bubbling Pressure ψ_b (cm)	Initial Soil Moisture Content θ_i at AMCII	Green-Ampt Soil Hydraulic Conductivity K (cm/hr)	Wetting Front Cap. Pressure Head ψ (cm)	Green-Ampt $\Delta\theta$	Green-Ampt Infiltration Capacity at $F(t)$ = 1 cm $f(t)$ (cm/hr)	Hydro-logic Soil Group[1]	*INFILT* Estimate[2] (cm/hr)
Sand	0.437	0.020	0.546	17.340	0.102	11.78	4.95	0.335	31.309	A	2.50
Loamy Sand	0.437	0.036	0.449	9.078	0.117	2.99	6.13	0.320	8.850	A	1.45
Sandy Loam	0.453	0.041	0.378	16.777	0.173	1.09	11.01	0.280	4.450	A	1.00
Silt Loam	0.501	0.015	0.207	43.337	0.332	0.65	16.68	0.169	2.479	B	0.65
Loam	0.463	0.029	0.246	23.196	0.253	0.34	8.89	0.210	0.974	B	0.27
Sandy Clay Loam	0.398	0.068	0.345	25.868	0.204	0.15	21.85	0.194	0.786	C	0.24
Silty Clay Loam	0.471	0.039	0.164	36.855	0.339	0.10	27.30	0.132	0.460	C	0.19
Clay Loam	0.464	0.155	0.259	27.249	0.316	0.10	20.88	0.148	0.410	C	0.18
Silty Clay	0.479	0.056	0.186	27.167	0.320	0.05	29.22	0.158	0.282	C	0.14
Sandy Clay	0.430	0.109	*	*	0.277[3]	0.06	23.90	0.153	0.279	C	0.13
Clay	0.475	0.090	0.187	32.917	0.339	0.03	31.63	0.136	0.159	D	0.05

All values derived from Brakensiek, Engleman, and Rawls (1981) and Rawls, Brakensiek, and Miller (1983), unless otherwise noted.
[1] Nearing, Liu, Risse, and Zhang (1996). [2] Figure 5. [3] Estimated using Rosetta (1999). [*] Unavailable.

Table 2. *INFILT* versus Hydrologic Soil Group (BASINS Technical Note 6, U.S. EPA, 2001)

SCS Hydrologic Soil Group	*INFILT* Estimate (mm/hr)	Runoff Potential
A	25.4 – 63.5	Low
B	6.35 – 25.4	Moderate
C	3.175 – 6.35	Moderate to High
D	0.635– 3.175	High

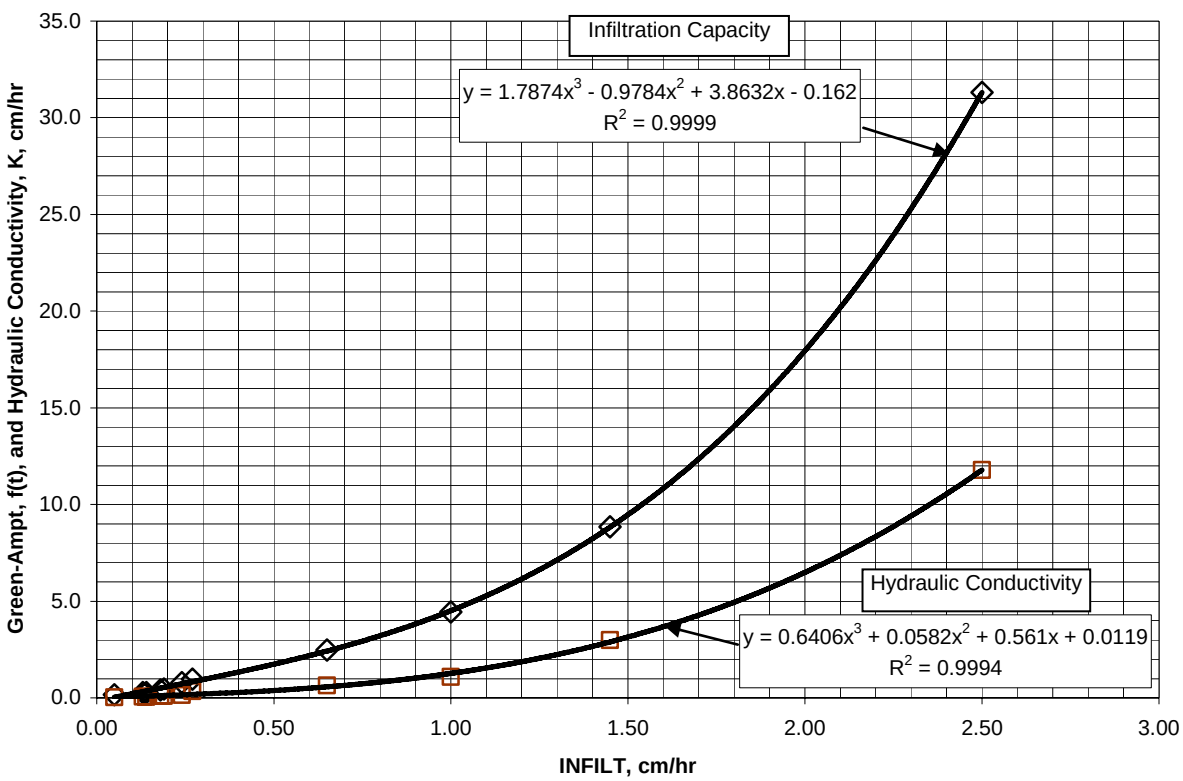

Figure 7. INFILT as a Function of Green-Ampt Infiltration Capacity and Soil Hydraulic Conductivity

Model Representation of the Mine Sediment Pond

Each mine site is modeled as one or more mine land segments using a specifically tailored version of the HSPF Pervious Land Segment (PERLND) module, as detailed in the previous section. Each mine segment PERLND outflows into a specifically tailored version of the HSPF stream reach/reservoir simulation module (RCHRES). Since considerable differences exist between the application of the RCHRES in simulating the stream drainage network segments (stream reaches) and its application to the sediment/runoff control structures (sediment ponds), the term PONDRES is used to differentiate between the two.

Mine segment model data input requirements are to be minimized to avoid overloading the mine permit reviewer. The minimal data input requirements are listed as follows:

- Drainage Area (acres)
- Weighted Curve Number (CN)
- Design Storm Frequency (25 years is the default)
- Pond Peak Outflow Discharge (cfs)
- Mine Drainage Concentrations
- Outflow Stream Segment Number

The receiving stream number is entered in the WCMS user interface to the PONDRES component. The remaining data input values dictate the conceptual design of the mine segment PERLND and the associated PONDRES.

The PONDRES conceptual design follows the standard SCS TR-55 method (Soil Conservation Service, 1986). The SCS Graphical Peak Discharge method (chapter 4, SCS, 1986) is used to determine pond inflow peak discharge. The Storage Volume for Detention Basins method (chapter 6, SCS, 1986) is used to determine the pond design volume. This design approach is consistent with the hydrologic design methods typically used in completing mine permits.

The hydraulic performance of the sediment pond is also required to match that typically found in mine permit designs. The PONDRES, therefore, includes a perforated outflow riser and an emergency spillway so that the proper stage versus storage volume and stage versus outflow relationships are reproduced.

WCMS-HSPF User Interface

A suite of tools has been developed in the ArcGIS 9.x environment to support CHIA analyses for proposed mine site scenarios (Figure 8).

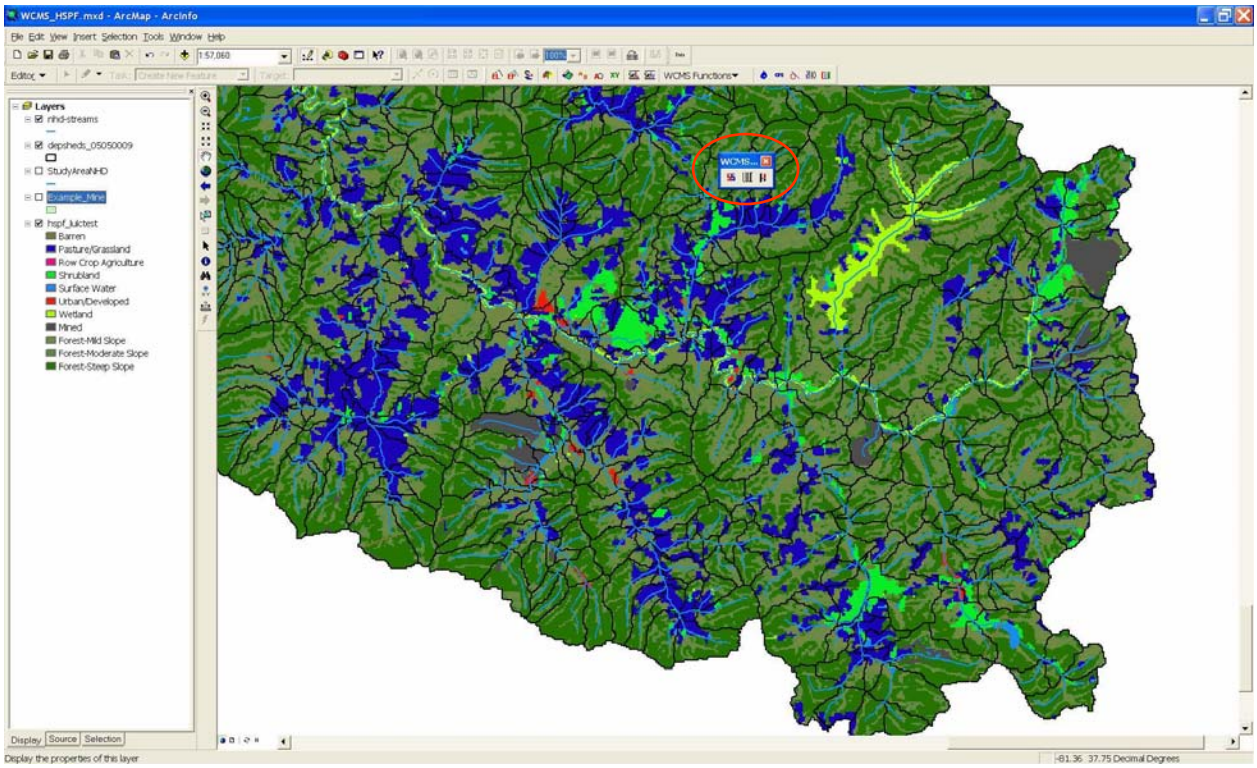

Figure 8: WCMS-HSPF Toolbar

The first step in the WCMS-HSPF CHIA analysis is to define the study area. This is accomplished by selecting the "SS" tool from toolbar, specifying the necessary data layers and clicking the screen at the location representing the desired watershed pour point. The GIS spatial data layers required for the analysis consist of a segment-level watershed (SLW) layer and its accompanying flow table, which designates the linkages between each SLW. The appropriate landuse/landcover layer representing the HSPF calibration coefficients and a polygon representing the mine site area are also required. All of the SLW's draining to the clicked point are then selected as the study site (Figure 9).

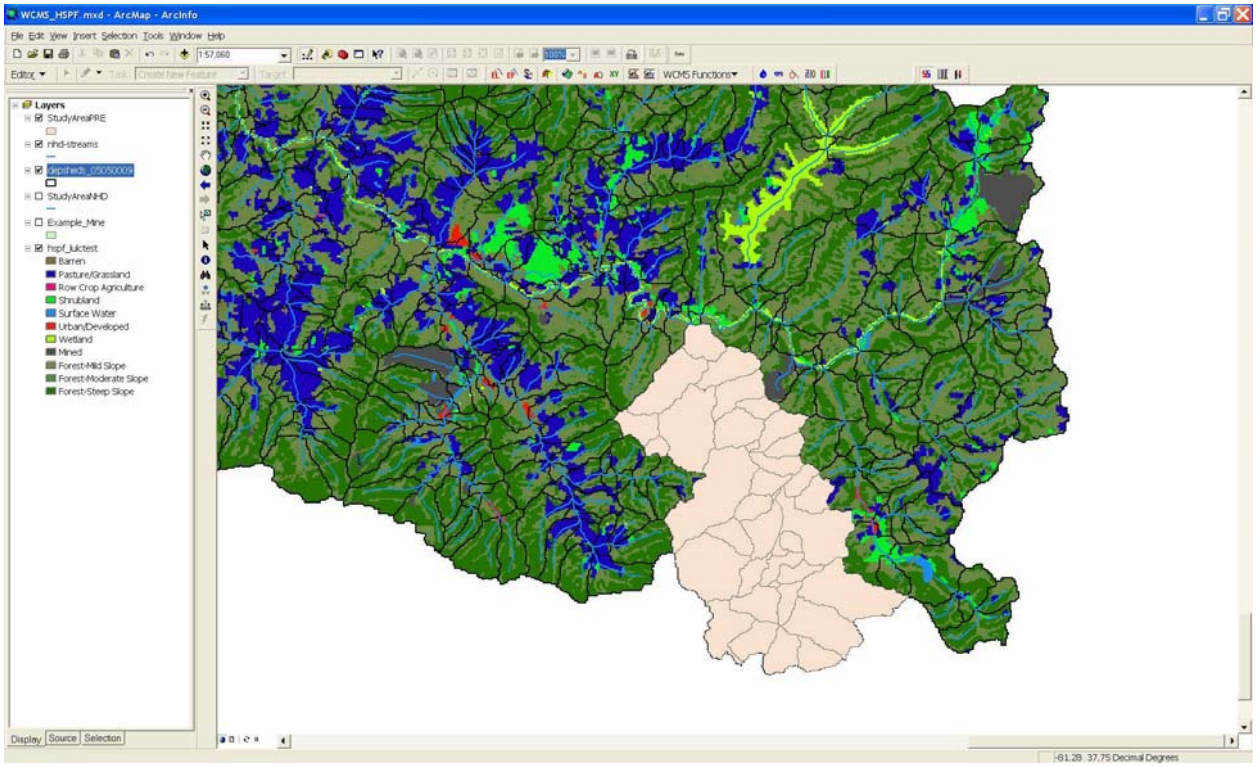

Figure 9: WCMS-HSPF Study Area

In the event that the study area consists of a large number of SLW's (over 300), a routine has been developed to aggregate the individual SLW's into larger sub-watersheds while still maintaining their flow connectivity.

The next step in the WCMS-HSPF CHIA analysis is to integrate the landuse/landcover (LULC) and mine site layers into the study area. This is done by selecting the "LULC" tool from the WCMS-HSPF toolbar, and specifying the study area, LULC, and mine polygon layers (Figure 10). The area of each landuse/cover type is re-calculated to include the area of the proposed mine site and a post-mine site study area layer is created.

The final tool used in the analysis is the data input window (Figure 11). This is where the information from the proposed mine permit is entered which allows for equivalent HSPF parameters and mine sedimentation pond dimensions (PONDRES) to be calculated. The mine outflow water quality concentrations are also entered here, along with options controlling the display of the information contained on the output report. This form also contains a tool allowing the user to connect the outflow from the proposed mine site sedimentation pond to an existing SLW. Once the necessary information has been entered, HSPF is run for the pre and post-mine scenarios by clicking the "Run HSPF" button.

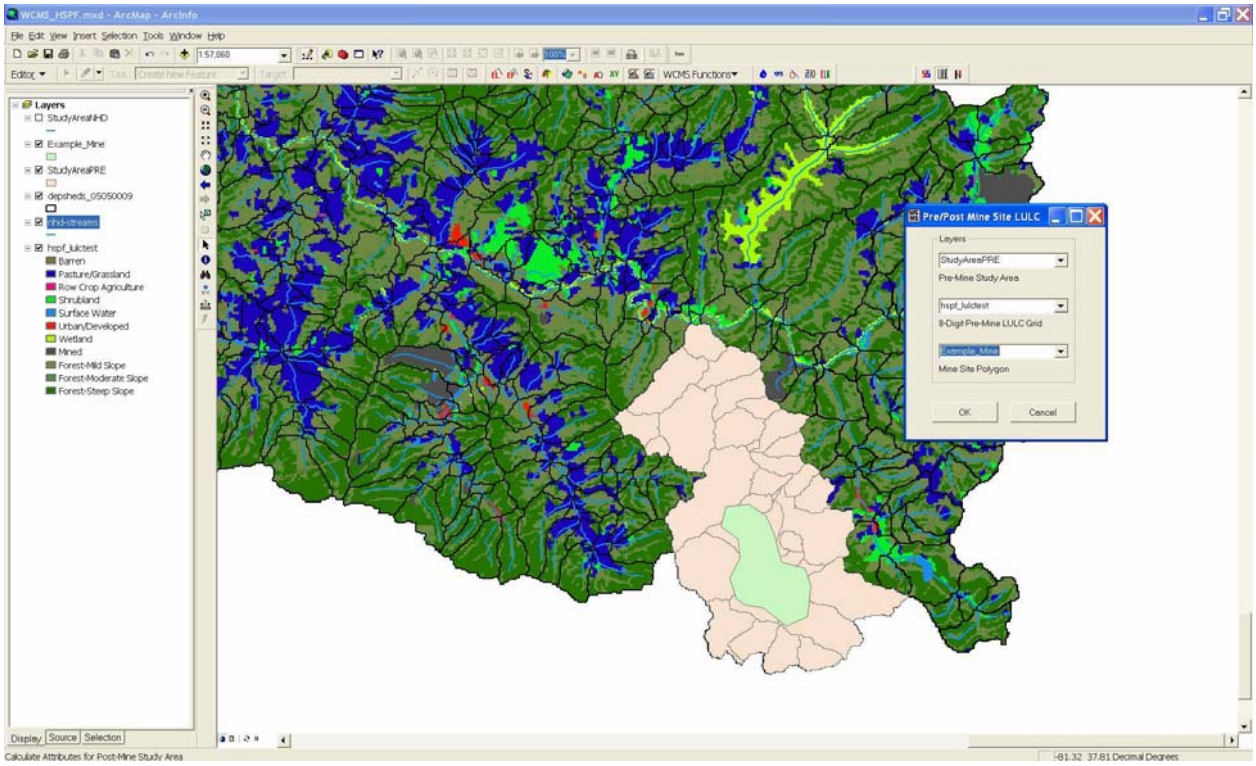

Figure 10: WCMS-HSPF LULC Tool

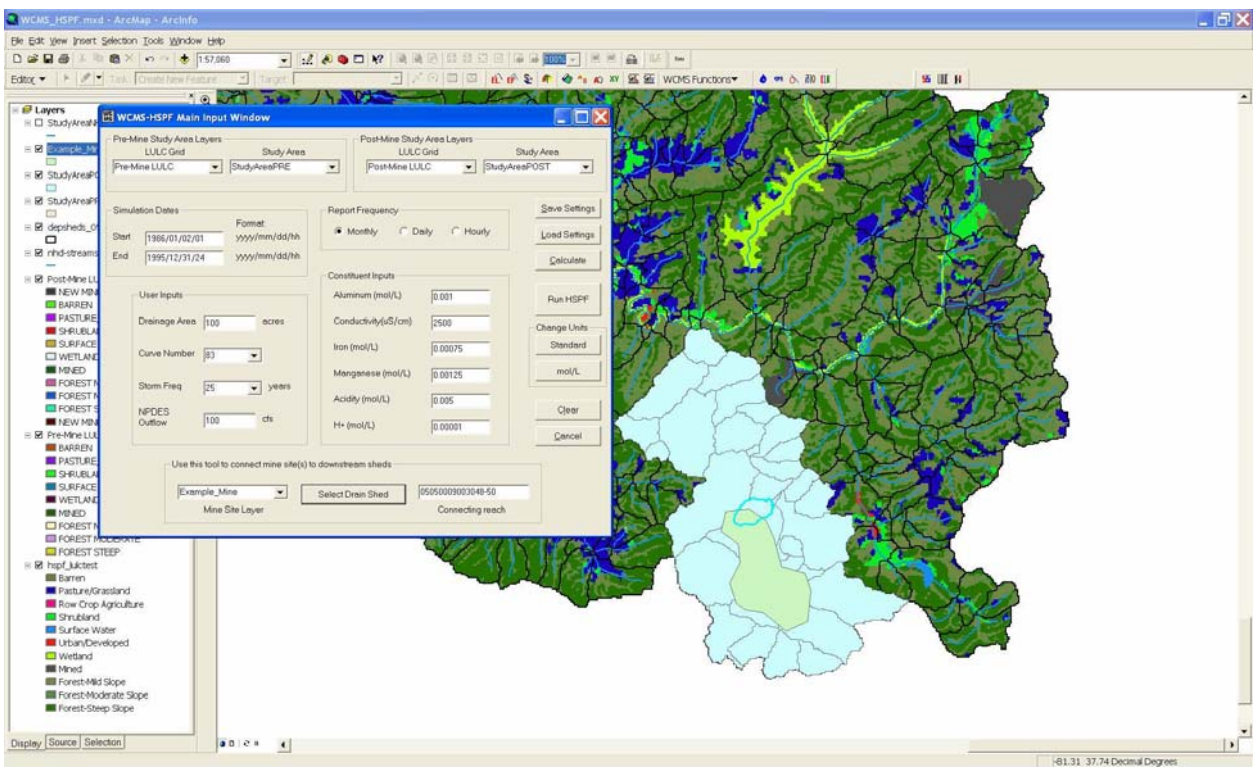

Figure 11: WCMS-HSPF Data Input Tool

When the water quality and quantity has been simulated for the pre and post-mine scenarios using HSPF, an output report is displayed which can be saved in various formats or sent to a printer (Figure 12). While the output report is still in the development phase, the goal

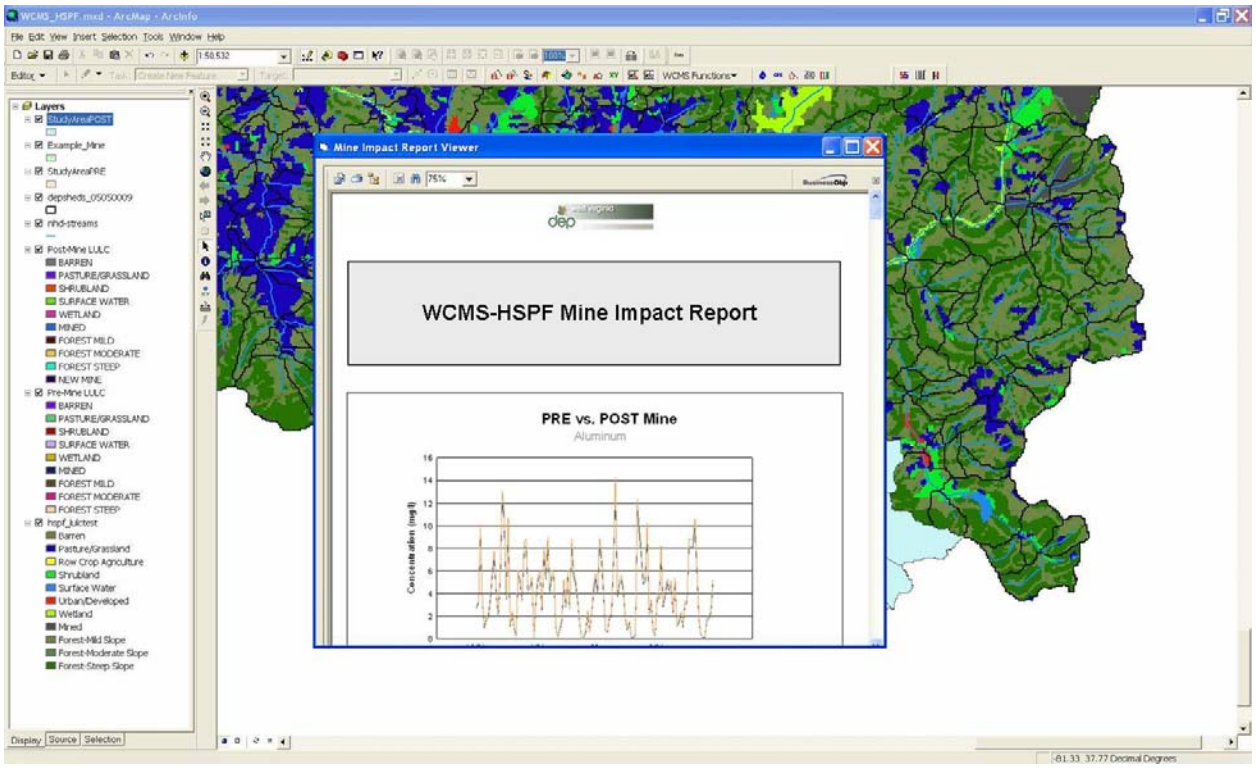

Figure 12: WCMS-HSPF Output Report

is to represent the data from both the before and after simulations in graphical and tabular forms to best serve the needs of the user.

Summary

The WCMS-HSPF modeling system provides non-experts the ability to predict the hydrologic impacts of proposed surface coal mine sites in West Virginia. Because of the lack of available data for model calibrations, one set of HSPF parameters was selected to represent the surface hydrology for the entire region of concern. It is recognized that the results are therefore inaccurate in an absolute sense; however the main purpose of this model is scenario comparison using identical hypothetical model inputs for each case. The overall simplicity of the WCMS-HSPF design was also important. In order for the system to be used frequently by a large number of personnel, the interface and procedure must be simple and logical. Many of the

processes such as the calculation of the equivalent HSPF-CN parameters and the mine pond design take place automatically, without direct user input. Calibration of the WCMS-HSPF ACIDPH routine to the WVDEP database of water quality samples is in progress. While additional development is necessary to complete the GIS interface and output report display, considerable effort has been made to produce a model that is easy to use, yet still accurate. Currently the system is applicable only to West Virginia. However, its ability to be used in other states depends only on the availability of spatial, streamflow, and water quality data necessary for model calibration.

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