D R A F T T E C H N I C A L M E M O R A N D U M

TECHNICAL APPROACH AND WORK PLAN FOR HYDROLOGIC MODELING FOR MIDNITE MINE RI/FS

Prepared for
EPA Region 10

September 21, 2001

URS

URS Corporation
8181 E. Tufts Avenue
Denver, CO 80237

Project No. 53-F4001800.06.04060

Table of Contents

Section — Page

1.0 INTRODUCTION 1

2.0 OVERALL HYDROLOGIC MODELING OBJECTIVES 1

3.0 POTENTIAL REMEDIAL ALTERNATIVES 1

3.1 Source Control of MA and Natural Attenuation of PIA Groundwater 3

3.2 Source Control of MA and Active Restoration of Southern PIA 3

3.3 Source Control of MA and Contaminant of PIA 3

4.0 SPECIFIC MODELING OBJECTIVES FOR FS 4

5.0 MODELING APPROACH AND SELECTED MODELING CODES 5

5.1 Surface Water Modeling 5

5.2 Groundwater Recharge Estimation 6

5.3 Groundwater Modeling 8

5.3.1 Modeling Hydrogeologic Complexities at the Midnite Mine Site 8

5.3.2 Approach for Site Groundwater Flow Model 9

5.3.3 Approach for Site Groundwater Solute Transport Model 10

6.0 SCOPE OF WORK 11

7.0 REFERENCES 17

LIST OF FIGURES

Figure 1 Hydrologic Modeling Calibration Processes

Figure 2 Hydrologic Modeling Prediction Simulation Processes

Figure 3 Schedule of Numerical Model Development and Calibration and Predictive Simulations of Remedial Alternatives

1.0 INTRODUCTION

The purpose of this work plan document is to describe the technical approach, rationale, and scope of work for hydrologic modeling needed to support the Remedial Investigation (RI) and the Feasibility Study (FS) for the Midnite Mine Superfund Site. This work plan describes the activities involved in setting up the models and how the results of each model will be used. It provides descriptions of modeling objectives, modeling methods, selected modeling codes, and the anticipated scope of work. For the RI, the hydrologic modeling will serve to integrate site data and thus provide further hydrologic characterization of the site. To address the FS needs in evaluating remedial alternatives, hydrologic modeling will be used to simulate surface water flow, groundwater flow, and mass transport resulting from various remedial alternatives.

The following description of the technical approach for this modeling has been developed based upon the current understanding of the site conditions and the most likely remedial alternatives that will be evaluated in the FS. However, the response actions and alternatives assembled for the purposes of this planning document have not yet been selected through the FS process. During the upcoming FS, the response actions and alternatives listed herein may be added to, modified or eliminated. Also, the remedial action alternatives (RAOs) for this site have not yet been finalized. As the RAOs and FS screening steps proceed, and as the statistical evaluations of data further refine the extent of mining-related effects, adjustments will be made, if necessary, to the hydrologic modeling task.

2.0 OVERALL HYDROLOGIC MODELING OBJECTIVES

The objective of the upcoming modeling activity is to quantitatively evaluate the site hydrologic system and the effectiveness of the potential remedial alternatives, from a hydrologic perspective, to achieve the remedial action objectives. Accordingly, URS will develop site-specific mathematical models to simulate surface water and groundwater flows for existing conditions and for future remedial alternatives. Models will also be developed to predict changes in dissolved constituent concentrations in influent flows to the treatment plant resulting from various alternatives, to support the conceptual designs and evaluation of alternatives for the FS. More specific modeling objectives for the FS are described in Section 3, following a description of potential remedial alternatives.

3.0 POTENTIAL REMEDIAL ALTERNATIVES

To develop an appropriate modeling approach, the remedial alternatives to be evaluated in the FS should be anticipated as much as possible, particularly those influencing water management decisions. However, at this stage of the study, the potential response actions and remedial alternatives to be evaluated in the FS have not yet been defined. Nonetheless, at this time it is possible to anticipate general response actions and potential remedial alternatives that may be evaluated in the FS. Each remedial alternative will consist of an integrated system of remedial action components. Thus, for the purpose of scoping the hydrologic modeling work, URS has identified several preliminary remedial action options. Even though these preliminary remedial action components are subject to revision based on the results of data collection and analyses currently underway, these options are likely to represent the range of possible alternatives that may need to be evaluated in the FS using hydrologic modeling. However, depending on the actual remedial alternatives defined in the FS, some of the following remedial action components may not be addressed by the modeling.

Potential remedial action components may include:

1. Capping, in place, selected (or all) ore/protore/waste rock materials throughout the mined area (MA) to reduce groundwater recharge and leachate generation.
2. Consolidation of ore/protore/waste rock and capping of only selected portions of the MA to reduce groundwater recharge and leachate generation.
3. Continue dewatering of the open pits to capture affected groundwater, surface water and prevent overflow of pit lake water.
4. Continued dewatering of the existing backfilled pits to prevent outflow of contaminated water.
5. Partially or fully backfilling the existing open pits with ore/protore/waste rock to minimize contaminated runoff from the open pit walls and avoid collection of precipitation water.
6. Improved capture and containment of seep surface water at the southern MA boundary.
7. Physical/hydraulic containment of shallow groundwater at the southern MA boundary.
8. Hydraulic containment of affected groundwater in the fractured bedrock.
9. Physical/hydraulic containment of shallow groundwater at the confluence of the Eastern Drainage and Blue Creek.
10. In situ treatment of groundwater (e.g., via a flow-through treatment wall or permeable reactive barrier) at the southern MA boundary.
11. In situ treatment of shallow groundwater near the confluence of the Eastern Drainage and Blue Creek.
12. Aboveground treatment of contaminated surface water and/or groundwater.
13. More effective diversion of uncontaminated surface runoff around potential contaminant sources in the MA.
14. Containment and/or routing of contaminated surface runoff from the MA.
15. Discharge of treated water and/or uncontaminated surface runoff to the drainages south of the MA.
16. Active restoration of shallow groundwater in the southern potentially impacted area (PIA) through pump and treat methods.

17. Passive restoration of shallow groundwater in the southern PIA through natural attenuation of existing contamination.

Potential remedial alternatives, which consist of an integrated system of the components listed above, may include:

1. Control of MA Sources and Natural Attenuation of PIA Groundwater
2. Control of MA Sources and Active Restoration of Southern PIA Groundwater
3. Control of MA Sources and Containment of PIA Groundwater

These three generic remedial alternatives will be evaluated using three distinct model scenarios during the FS. Additional alternatives or refinements to these alternatives may be evaluated as separate scenarios if necessary for the FS.

3.1 Source Control of MA and Natural Attenuation of PIA Groundwater

- Consolidation and capping of surface materials in the MA
- Maintain dewatering of the open pits and existing backfilled pits
- Capture and containment of seeps at the southern MA boundary
- Physical/hydraulic containment of shallow groundwater at the southern MA boundary
- Treatment and discharge of contaminated water collected by the containment systems
- Diversion of uncontaminated runoff away from the MA and into the drainages south of the MA
- Natural attenuation of existing shallow groundwater contamination in the southern PIA

Modeling simulations will be used to evaluate the details of the alternatives as defined in the FS. For example, the capping component of a model scenario will specify capping of all waste rock and protore areas (in place) throughout the MA or consolidation of such materials and capping of only that portion of the MA. Another alternative may include the components listed above plus consolidation of reactive MA surface materials into the open pits, encapsulated by engineered barriers.

3.2 Source Control of MA and Active Restoration of Southern PIA

This alternative is the same as above for the MA but differs for the PIA; it would involve active pumping and treatment of shallow groundwater in the southern PIA instead of natural attenuation.

3.3 Source Control of MA and Containment of PIA

This alternative is the same as above (Section 3.1) for the MA, but differs for the PIA; it would involve physical/hydraulic containment or in situ treatment of shallow groundwater near the confluence of the Eastern Drainage and Blue Creek.

4.0 SPECIFIC MODELING OBJECTIVES FOR FS

The model results will be used to support the conceptual design and evaluation of alternatives for the FS. Specifically, the models will be used to estimate or evaluate the following components for the potential remedial alternatives, including:

- Surface water runoff under normal and extreme weather conditions to support the design of the treatment plant.
- Flow rates of uncontaminated runoff diverted from the MA and into the drainages south of the MA under normal and extreme weather conditions to support the conceptual design of storm water drainage system.
- Average groundwater recharge rates in the MA.
- Average groundwater flow rates from the MA to the PIA.
- Average seep flow rates at the southern MA boundary, which will be part of the influent flow to the treatment plant.
- Water levels in the open pits and existing backfilled pits under normal and extreme weather conditions.
- Dewatering rates (active pumping) from the open pits and existing backfilled pits under normal and extreme weather conditions.
- Average contaminant concentrations in the mixed surface water and groundwater conveyed to the treatment plant.
- Effectiveness of the capping alternatives for reducing infiltration and water treatment plant flows.
- In addition to applying source controls in the MA, evaluate effectiveness of natural attenuation to reduce the shallow groundwater contamination south of the MA.
- In addition to applying source controls in the MA, evaluate effectiveness and pumping rates of a pump and treat system south of the MA in the shallow groundwater system.
- In addition to applying source controls in the MA, evaluate effectiveness of a physical/hydraulic containment system and an in situ treatment system in shallow groundwater near the confluence of the Eastern Drainage and Blue Creek.

5.0 MODELING APPROACH AND SELECTED MODELING CODES

To meet the specific modeling objectives, the general modeling approach will include the following three steps:

- Perform overall water budget analyses to improve the basic understanding of the site hydrologic conditions.
- Develop corresponding surface water and groundwater models and calibrate model parameters based on the current site conditions using site data.
- Simulate future hydrologic conditions for the selected remedial alternatives to support conceptual designs of passive and active water treatment systems.

Three types of modeling will be involved to simulate the important components of the entire hydrologic processes at the site under current conditions and under various potential remedial conditions: (1) surface water modeling, (2) groundwater recharge estimation, and (3) groundwater modeling. The three types of modeling will be performed separately, but the models will be integrated to represent the complete hydrologic system. Input and output of each model will be developed and checked for consistency. An illustration of the work activities integrating the three types of modeling are provided in Figures 1 and 2 (flow charts of the calibration process and of the prediction process), respectively.

Prior to numerical modeling, a water budget analysis (WBA) will be conducted. All the water components in the system, including precipitation, infiltration, runoff, inter-flow, groundwater recharge, evapotranspiration, stream flow, seep flow, and operational flow will be evaluated using analytical approaches. This process is also a data integration process, which can be helpful in identifying data gaps. The process will be useful in supporting conceptual model development, and developing constraints in the follow-up numerical modeling.

5.1 Surface Water Modeling

Surface water modeling will be used to perform rainfall-runoff simulations at the site for the historical conditions and the future conditions under various remedial alternatives.

The HEC-1 computer program developed by the U.S. Army Corps of Engineers (1998) or a WBA will be applied to simulate the surface runoff response of the watershed to precipitation by representing the basin as an interconnected system of hydrologic and hydraulic components.

The entire watershed surrounding the MA will be simulated. Six sub-basins will be delineated based on existing topographic maps: Open Pit 3, Open Pit 4, West Drainage, Central Drainage, East Drainage, and Far West Drainage. Historical site data provide more than two years of record, including precipitation events, stream flow measurements of the drainages south of the MA, pit lake level measurements, and pump-back operation flow rates. This information will be used as the primary data set for parameter calibration to simulate the current site conditions.

During the process of model calibration, excess precipitation will be calculated for each sub-basin by subtracting infiltration and detention losses based on a soil water infiltration rate function that is consistent with the sub-basin characteristics for each individual historical storm. The resulting excess precipitation will then be routed to the outlet of the basin to produce a basin runoff hydrograph. The calculated hydrographs will be compared to the available measurements at the basin outlet.

For the model prediction simulations, the calibrated parameters will be used for the sub-basin areas that remain unchanged by remediation. However, for areas where material consolidation, capping, or other remediation may occur, the hydrologic parameter values will be modified to reflect the expected future hydrologic characteristics of materials in those areas. Synthetic storms (rainfall and snow), including magnitude, pattern, and weather conditions, will be generated based on the historical data for various return periods such as 2-year, 5-year, 10-year, 25-year, or 100-year. The generated synthetic storms will be used as input to simulate the future runoff hydrographs under various remedial alternative conditions to support conceptual design.

For prediction of future chemical concentrations in surface water, we will use simple analytical solutions, such as dilution by mixture. This analytical approach will address the major factors influencing surface water quality and will provide a basis for evaluating the relative effectiveness of the FS alternatives.

5.2 Groundwater Recharge Estimation

Infiltration to the soil surface does not necessarily become recharge to groundwater. The infiltrated water is subject to evapotranspiration, and part of it becomes inter-flow that discharges to the ground surface before reaching the groundwater table. Thus, the net groundwater recharge needs to be estimated for the purposes of numerical groundwater modeling.

The Hydrologic Evaluation of Landfill Performance (HELP) computer program (Schroeder et al. 1994) will be used to estimate groundwater recharge in different areas containing different surface materials at the site. The HELP model is a quasi-two-dimensional hydrologic model that is designed to simulate the vertical movement of water across, into, through, and out of a landfill. The model accepts weather, soil, and design data and uses mathematical solution techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate re-circulation, unsaturated vertical drainage, and leakage through soil geomembrane or composite liners. In our case, the HELP model will be used to estimate groundwater recharge that percolates through the unsaturated zone to reach the groundwater table.

The HELP model parameters will be estimated for different types of soils, including undisturbed soil, disturbed soil, and re-vegetated soil, in different sub-basins consistent with the delineation of the basins for the surface water modeling which will be used to estimate average groundwater recharge. The HELP model estimated infiltration rate and detention loss would be checked with the HEC-1 results for those factors. The HELP estimate of groundwater recharge will be checked with the measured groundwater seep flow at different seep locations, adjusted as needed to match the measured seep flows, and then will be used as input to the groundwater model calibration. The HELP model results will also be used to support the initial water budget analysis.

For the model prediction simulations, the HELP model will be used to estimate the groundwater recharge for the various remedial alternatives for materials consolidation, re-configuration, capping, and re-vegetation considering the hydraulic properties of the capping materials and the results of the model calibration process. The groundwater recharge estimated by HELP will be used for the numerical groundwater model simulations of the future groundwater conditions.

In conjunction with the HELP modeling, another model, SoilCover (Unsaturated Soil Group, University of Saskatchewan 1997), will be used to estimate groundwater recharge through the alternative capping materials. Specifically, SoilCover will be used to evaluate the performance of different capping alternatives. If there is uncertainty as to what specific capping materials will be used, then conservative assumptions will be made to represent the range of alternatives.

SoilCover is a one dimensional finite element package that models transient water and heat transport in a soil profile, and can be used in conjunction with other commercially available flow model packages such as the HELP model. It uses a physically based method for predicting the exchange of water and energy between the atmosphere and a soil surface. The theory is based on the well-known principles of Darcy's and Fick's Laws which describe the flow of liquid water and water vapor, and Fourier's Law to describe conductive heat flow in the soil profile below the soil/atmosphere boundary. SoilCover predicts the evaporative flux from a saturated or an unsaturated soil surface on the basis of atmospheric conditions, soil properties and conditions, and vegetative cover.

The main objective in applying SoilCover is to evaluate alternative cover designs with respect to drying and de-saturation under atmospheric conditions. The flow of moisture between the soil and the atmosphere is a complex process in which three factors dominate. The first factor is the supply of and demand for water at the soil surface by atmospheric conditions such as total precipitation, solar radiation, wind speed, and air temperature. The second factor is the ability of the soil to transmit water and the associated water regime, controlled by hydraulic conductivity and storage characteristics. The final factor involves the influence of vegetation. The type and density of vegetation affects evaporation through the consumption of water through root uptake, and also runoff rates and surface retention.

5.3 Groundwater Modeling

Numerical groundwater modeling will be performed to simulate the groundwater flow and solute transport in the shallow flow system and the bedrock flow system in the site area. The shallow flow system refers to the groundwater flow through the unconsolidated materials including alluvium, colluvium, waste rock, and ore/protore stockpiles. Bedrock refers to the consolidated rock units, which primarily include meta-sedimentary and igneous rocks, underlying the unconsolidated materials in the MA and the site vicinity.

5.3.1 Modeling Hydrogeologic Complexities at the Midnite Mine Site

Numerical modeling of groundwater flow at this site presents several technical challenges because of the complex geometry of preferred pathways in the unconsolidated MA materials and the physical complexities of groundwater flow in fractured rock. The major technical challenge for modeling this site is the transient nature of flow in the unconsolidated MA materials and discharge from the seeps south of the MA. The highly transient flow processes at the seeps indicate that several preferred pathways are within and beneath the unconsolidated waste rock dumps. These preferred pathways include buried pre-mining drainages, buried mining haul roads, and the interfaces between layers of unconsolidated materials. When groundwater recharge percolates downward, some moves slowly through smaller pores in the waste materials but some of the flow moves faster through such preferred pathways, and converges in the channels underlying the waste material. Thus, in response to major precipitation-snowmelt events in the early springtime, some groundwater quickly flows into the pre-mining drainages and emerges as seep flow near the base of the South Spoils.

Peak flow rates at the seeps have been observed to be as high as 500 gpm (e.g., West Seep). Based on the observed data, the seep rates start to decline rapidly soon after the peak, which is usually in early March. Flow in the finer grained portions of the waste rock piles, and flow originating in areas further from the buried channels, moves much slower and lasts much longer than the flow moving along preferred pathways to the seeps. Peak flows typically decline and reach lower base flow conditions within about three months. For instance, base flows at West Seep range from about 10 to 20 gpm.

Realistically simulating flow through the fractured bedrock (e.g. deep groundwater) is another challenge for mathematical modeling of this site. The available fracture-based model codes are not practical to use for large scale modeling studies of mine sites underlain by fractured bedrock because such codes require a detailed characterization and quantification of the geometry and hydraulic parameters for individual fractures. Such parameters include fracture length, orientation, aperture, surface roughness, and interconnection. At most sites, there is limited available information concerning these fracture properties: this is also true for the Midnite Mine Site. Collection of the minimum data necessary to meet the needs of a large-scale discrete fracture model is not feasible because of the excessively high level of effort and cost. For other large-scale mining projects, URS has successfully simulated fractured groundwater systems using a porous media approach with MODFLOW and confirmed that the systems behave as equivalent porous media on a large scale. At Midnite Mine, the available hydraulic head measurements from monitor wells and piezometers in the PIA show that the bedrock potentiometric surface is closely correlated with the topographic elevations. This data correlation indicates the groundwater flow system in the PIA bedrock may be modeled using an equivalent porous media model at the site scale. Given that we must view the fractured bedrock as a porous medium on a large scale, this will constrain the level of detail that is realistic to evaluate using the model, particularly the hydraulic effects of the remedial alternatives on the bedrock flow system.

5.3.2 Approach for Site Groundwater Flow Model

Considering the modeling objectives and the site complexities, URS will apply an equivalent porous media approach using the USGS groundwater flow computer program MODFLOW (McDonald and Harbaugh 1988; Harbaugh and McDonald 1996) to simulate groundwater flow on a large scale in the fractured bedrock and in the unconsolidated material. MODFLOW is a standard, state of the practice, well-documented model code that has been used to simulate all types of groundwater flow systems.

For this RI/FS, a two-layer steady-state MODFLOW model will be developed to represent the long-term average flow conditions in the shallow unconsolidated materials and bedrock systems. The post-mining bedrock surface will be used as the bottom of the first layer. The open pits 3 and 4 will be simulated using the General Head Boundary package of MODFLOW to simulate the hydraulic interactions between the pit lakes and groundwater.

The unconsolidated materials in the MA and the alluvium in the PIA will be simulated as the first (top) model layer. An *equivalent* hydraulic conductivity distribution for the *shallow layer* will be calibrated so the results match the *average annual base flow rates* at the seeps that exist along the south side of the MA. The HELP model will be used to simulate seep flows during the high-flow period as "interflow". For the MODFLOW model, the equivalent hydraulic conductivity is intended to represent the large-scale water conductive capability of the materials that transmit seep flows, at equivalent average rates. Applying this concept is needed to model a system consisting of a heterogeneous porous media containing preferred pathways. The equivalent hydraulic conductivity of the preferred pathways in the unconsolidated materials should be greater than that of the actual materials but smaller than that of an open channel.

Hydraulic conductivity data from the backfilled pit dewatering plan monitoring conducted by SMI and slug tests conducted in individual wells will be evaluated to develop the conceptual model and initiate the parameter estimation and calibration process. The model parameters will then be adjusted to match the calibration targets. The calibrated equivalent hydraulic conductivity distribution may then be used to simulate the average future seep flow rates under the various FS alternatives (e.g., scenarios for capping waste materials in place, consolidation of materials in the MA prior to capping, and encapsulation of materials in the pits). The simulated average future seep flow rate will be interpreted to estimate the transient flow process, including peak flow and base flow. These estimates will be based on the output quantities for interflow from the HELP model and for base flow from MODFLOW.

The bedrock flow system will be simulated as the second layer of the steady-state MODFLOW model. At this site, groundwater flow is known to occur through fracture zones, joints, dikes, and faults in the bedrock. However, as noted above, it is technically impractical to define discrete or individual preferred flow pathways because of the extreme complexity of the geometry, spatial interconnections, and hydraulic properties of these secondary porosity features. Nevertheless, it is possible to reflect the complex heterogeneity of the fractured bedrock by calibrating the hydraulic conductivity distribution to match the available site data.

The steady-state MODFLOW model calibration will be performed using MODAC, an automated parameter estimation program (Guo and Zhang 2000). The equivalent hydraulic conductivity distribution of the shallow system will be calibrated to match the average annual flow rates of seeps, and the bedrock hydraulic conductivity distribution will be calibrated to match the areal distribution of hydraulic heads and gradients existing at the site. The principal goal of calibration is to develop a numerical model that simulates hydraulic conductivity, seep flow rates at the southern MA boundary, and hydraulic interactions between the shallow system and the bedrock system that are consistent with the range of available site data.

5.3.3 Approach for Site Groundwater Solute Transport Model

Predicting the changes in surface water and groundwater quality in the PIA that are attributable to remediation in the MA are important issues to be addressed in the FS. To address this need, the groundwater solute transport program MT3DMS (Zheng and Wang 1998) will be used to develop a site-specific model for simulating migration of dissolved chemicals of concern in the alluvium and bedrock in the PIA. Input to this solute transport model will include the calibrated flow conditions and simulated flow conditions from the MODFLOW model. The MT3DMS model will simulate the mass transport of selected dissolved constituents, such as sulfate, total dissolved solids, uranium, manganese, nickel, and zinc. The observed concentration distribution will be assumed as the initial condition for the prediction simulations. The concentration of groundwater entering the PIA will be specified based on the current observed condition as the source concentration. Other fate and transport parameters in the model will be estimated based on site-specific conditions or published technical references.

6.0 SCOPE OF WORK

Consistent with the technical approach described above, the scope of work for the hydrologic modeling includes the following tasks.

Task 1. Data Evaluation and Conceptual Model Development

The hydrologic conceptual model is the basis for the numerical model development. For this study, a detailed site-specific conceptual model will be developed to define the hydro-meteorological conditions, the watershed characteristics, the ground surface topography, surface material characteristics, the subsurface geologic features, and the features of the existing seep pump-back system. The hydraulic relationships between all the hydrologic components will also be evaluated for the site-specific conditions using a hydrologic budget analysis.

The development of the conceptual model will be based on the available data. From September 1998 to April 2001, Shepherd Miller, Inc has collected an extensive set of hydrologic data that include the following measurements:

- Precipitation and evaporation at an on-site station
- Surface water levels in the Pollution Control Pond, Pit 3 and Pit 4
- Seep flow rates and field parameters for WD Seep, WDJ Seep, Dam Toe Seep, Pumphouse Seep, and East Seep
- Water treatment plant treatment flow rates
- Pump-back volumes for the seep collection system
- Groundwater levels in monitoring wells
- Groundwater pumping rates, volumes, and field parameters for the backfilled pit dewatering test (from December 1999 to date)

These data have been collected over various time intervals. For some locations during the backfilled pit dewatering testing, water levels and flow rates were measured on frequent intervals (e.g., daily or weekly) and at other locations the data were collected much less frequently (e.g., monthly). Data are available at many locations to characterize the spatial variations in water quality and the hydraulic properties of the groundwater and surface water flow systems.

In addition, the BLM has collected data from two on-site weather stations (i.e. precipitation, temperature, wind speed, solar radiation, and relative humidity) and the USGS has collected data from stream flow gages near the site (i.e. gages SW-4, SW-6 and SW-7). These data will be useful in augmenting the other hydrologic data collected by SMI.

During development of the conceptual model, the available hydrologic, geologic, and physical data will be evaluated to estimate values for the respective model parameters. During the course of this data analysis the modeling approach may be modified or refined if needed to be consistent with the available data. If any significant questions or issues arise as to the representativeness of field measurements or if actual field measurements are not available for some model parameters, the best professional judgement of the modeling team will be used for assigning model parameters. The basis for such assumptions will be documented in the technical memoranda on the models.

Task 2. Water Budget Analysis

Task 2.1: Site-Wide Water Budget Analysis

A site-wide water budget analysis will be performed as an early step in developing the site hydrologic model. This water budget will be developed on an annual basis based on a lump-sum quantitative evaluation. Historical meteorological data, surface water flow rate data, seep flow rate data, and open pit dewatering data will be evaluated, and hydrologic budget calculations will be performed. Results of the water budget analysis will be used in supporting the conceptual model development, and will be useful for developing constraints for the distributed surface water model and the groundwater model.

Task 2.2: Sub-basin Water Budget Analysis

Water budget analyses will be performed for all sub-basins delineated during Task 3.1 described below. The HELP model will be used to estimate the groundwater recharge following (1) the surface water sub-basin delineation, and (2) the potential groundwater sub-basin delineation to evaluate if groundwater flows across the bedrock surface along the buried mining haul roads. This will be useful to improve the understanding about the areas that contribute to groundwater to those seeps, thus supporting the groundwater modeling needs.

Task 3. Surface Water Model Development

Task 3.1: Surface Water Model Setup

Setting up the surface water model will involve the following steps:

- Delineate the watershed boundaries based on the existing topographic maps
- Delineate sub-basins in the watersheds based on the existing topographic maps for:
    - Open Pit 4
    - Open Pit 3
    - West Drainage
    - Central Drainage
    - East Drainage

- Far West Drainage

- Estimate the basin characteristics, including size, slope, soil-type, vegetation, percentage of soil and vegetation distributions, and hydraulic/hydrologic properties for each sub-basin
- Develop storage-area-elevation curves for open pit 3 and open pit 4 based on existing information available from SMI

Task 3.2: Surface Water Model Calibration

Using the historical weather data and the estimated basin characteristic parameters as the input, HEC-1 or the WBA will be used to simulate the surface runoff for each sub-basin. The simulated flow rates will be compared to the observed ones, based on the data availability. For Pit 3 and Pit 4, water budget calculations will be developed to transfer flow to storage of water in the lake for comparison.

Task 4. HELP Model Development

Task 4.1: HELP Model Setup

Setting up the HELP model will involve the following steps:

- Delineate groundwater sub-basins based on the results of Task 2.2 and the post-mining bedrock surface map
- Estimate the HELP parameters for layer features, drainage features, runoff features, subsurface profiles, and soil characteristics for all sub-basins

Task 4.2: HELP Model Calibration

The HELP model parameters will be calibrated by comparing the simulated groundwater recharge rate and volume in different areas for different soil conditions using the historical weather data with the measured annual seep flow rate and volume at different seep locations. The high seep flows during the spring time that are simulated as interflow by HELP will be calibrated to match the integrated seep flow volumes over the high-flow period. Additional data collected from the on-site weather stations by BLM will be used as needed.

Task 5. Groundwater Flow Model Development

Task 5.1: Groundwater Flow Model Setup

Setting up the groundwater flow model will involve the following steps:

- Develop post-mining bedrock surface map based on the existing information available from SMI
- Develop a groundwater potentiometric surface map for shallow groundwater, and develop a bedrock groundwater potentiometric surface map
- Estimate the representative annual average seep flow rate for each seep
- Evaluate the hydraulic conductivities from the borehole hydraulic tests and the backfilled pit dewatering test

Task 5.2: Groundwater Flow Model Calibration

Calibration of the flow model will involve the following steps:

- Calibrate the equivalent hydraulic conductivity distribution for the shallow groundwater flow system in the MA, given the estimated groundwater recharge by HELP, and comparing the model results to the representative annual average seep flow rate at each seep
- Calibrate the alluvial hydraulic conductivity distribution and stream bed conductance for the shallow groundwater flow system in the PIA
- Calibrate the bedrock hydraulic conductivity distribution in the model domain to match the interpreted potentiometric surface

Task 6. Evaluation of Capping Material Alternatives

The SoilCover model will be used to evaluate performance of different capping materials, including various types of soil, vegetation, and cover thickness.

A continuous historical meteorological data series for the site will be used as the climatic data input to SoilCover, which will include typical dry and typical wet conditions. This data series includes daily precipitation, air temperature, solar radiation, wind speed, and relative humidity.

SoilCover will be used to simulate transient water and heat transport in the conceptual design soil profiles. Transient water-soil profiles for the selected alternatives of soil and vegetation will be simulated under the site-specific climatic conditions to estimate the groundwater recharge rates through the cover, the necessary depth of cover, and the actual evapotranspiration rates of vegetation. Based on evaluating the results of the SoilCover model, selected capping materials will be incorporated in the site scale hydrologic model simulations for different remedial alternatives.

Task 7. Synthetic Storm Generation

For the future remedial alternative simulations, synthetic storms (rain and snow) will be generated to represent the most likely weather conditions with various return periods such as 2-year, 5-year, 10-year, 25-year, and 100-year.

The site historical weather data, particularly the typical storm pattern and antecedent soil moisture conditions and air temperature, and the regional weather data will be used to support the generation of the synthetic storms.

The generated synthetic storms with different return periods will be applied to all remedial alternative simulations.

Task 8. Hydrologic Simulations of Remedial Alternatives for Source Control and Natural Attenuation

This task will involve using the previously described site-specific hydrologic models to simulate the hydrologic effects of remedial alternatives for source control and natural attenuation. These simulations will be performed during the FS evaluation process:

- Task 8.1: HEC-1 simulations of alternatives
- Task 8.2: HELP simulations of alternatives
- Task 8.3: MODFLOW simulations of alternatives
- Task 8.4: MT3DMS simulations of alternatives

Task 9. Hydrologic Simulations of Alternatives for Source Control and Active Restoration

This task will involve using site-specific hydrologic models to simulate the hydrologic effects of remedial alternatives for source control and active restoration . These simulations will be performed during the FS evaluation process:

- Task 9.1: MODFLOW simulations of alternatives
- Task 9.2: MT3DMS simulations of alternatives

Task 10. Hydrologic Simulations of Alternatives for Source Control and Containment

This task will involve using site-specific hydrologic models to simulate the hydrologic effects of remedial alternatives for source control and containment. These simulations will be performed during the FS evaluation process:

- Task 10.1: MODFLOW simulations of alternatives
- Task 10.2: MT3DMS simulations of alternatives

Task 11. Scheduling and Reporting

The planned sequence and estimated schedule for the modeling tasks is shown on Figure 3. Modeling will be performed in 2 phases. The first phase will involve data compilation, evaluation, model setup and calibration of the models. Developing the conceptual model for the site and performing a detailed water budget analysis are early steps in the process. Subsequently, we will set up and calibrate the mathematical models for groundwater recharge, surface water and groundwater. The second phase of modeling work will focus on simulating future scenarios to evaluate the remedial alternatives for the FS evaluation. The last step of the each phase of modeling will be to prepare a technical memorandum describing the modeling work performed in that work phase, which will be submitted to the EPA and other stakeholders for review and comment.

Written descriptions of the modeling work will be prepared to describe the:

- Conceptual model
- Water budget analysis approach and results
- Surface water modeling approach, model development, and calibration results
- HELP model approach, model development, and calibration results
- Groundwater modeling approach, model development, and calibration results
- SoilCover model approach, model development, and performance evaluation results of capping alternatives
- Synthetic storms generation approach and results
- Prediction simulation assumptions and results for all selected alternatives
- Conclusions
- Model limitations

URS plans to prepare two Draft Technical Memoranda (TM), which will be submitted for EPA review and comment. After EPA review comments are addressed, each draft TM will be transmitted to stakeholders for review and comment. One TM will be prepared after the hydrologic models have been set up and calibrated for existing conditions (i.e. first modeling phase), and another will be prepared after simulating the FS alternatives (i.e. second modeling phase). In the first TM we plan to provide detailed descriptions of the water budget analysis, modeling approach, model development, and calibration results. We also expect to identify the contaminant fate and transport parameters that will be assumed for the simulations of FS alternatives. In the second TM, we plan to provide prediction simulation assumptions and results for all alternatives selected for evaluation in the FS. After addressing EPA and stakeholder comments on the draft technical memoranda, the TMs will be incorporated into the RI and the FS reports. The report sections describing the setup, calibration, and simulation of existing hydrologic system will be included in the RI, while the FS will include the results of the remedial alternative simulations.

7.0 REFERENCES

Guo, X. and C-M. Zhang. 2000. Hydraulic gradient comparison method to estimate aquifer hydraulic parameters under steady-state conditions. *Ground Water* 38, no. 6: 815-826.

Harbaugh, A. W. and McDonald, G. M. 1996. Programmer's Documentation for MODFLOW-96, an update to the U.S. Geological Survey Modular finite-difference Ground-Water Flow Model. U.S. Geologic Survey, Open-file Report 96-486.

McDonald, M.G., and A. W. Harbaugh. 1988. A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, Techniques of Water-Resources Investigations of the United States Geological Survey, Chapter A1, Book 6, U.S. Geological Survey.

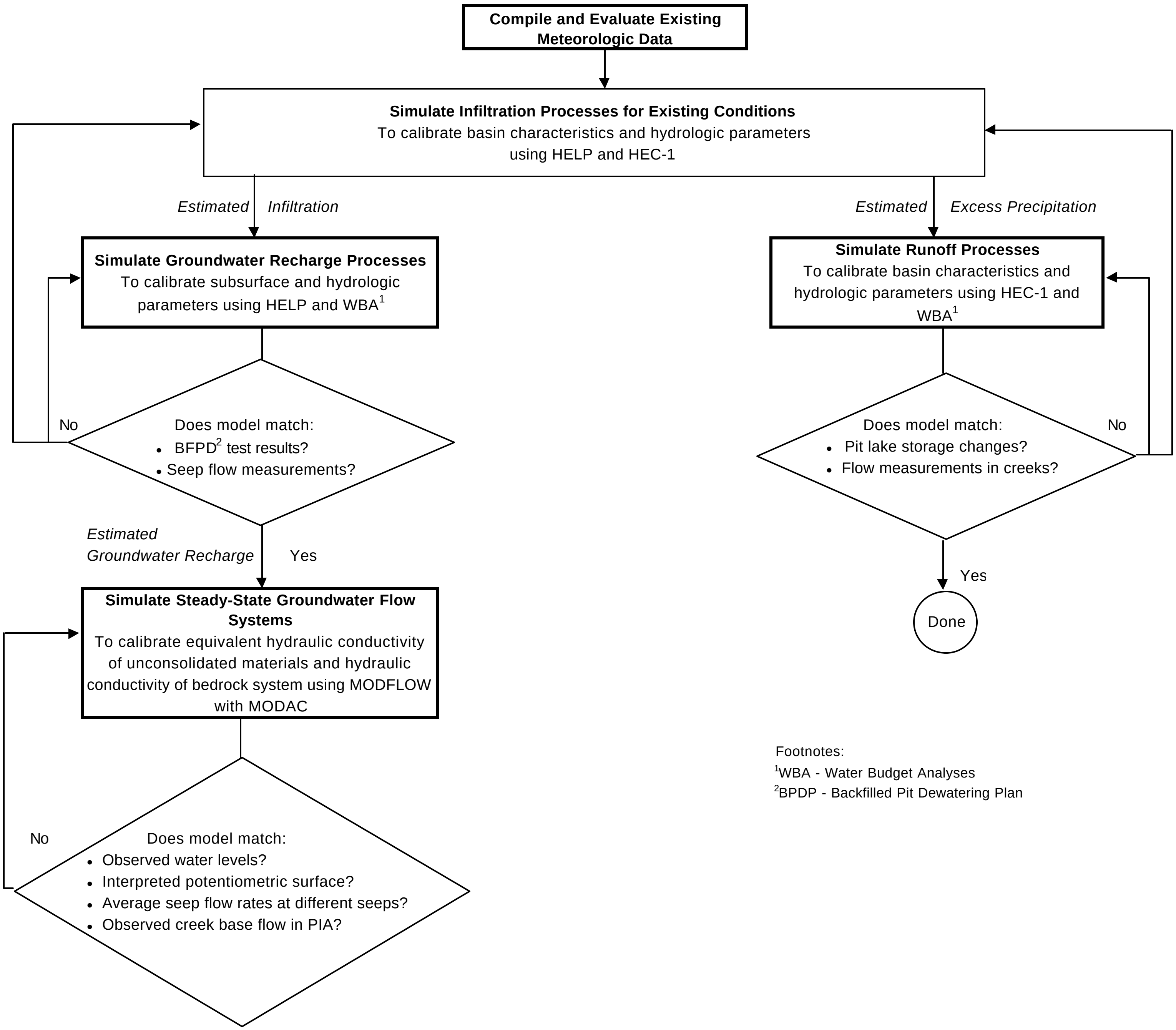
Schroeder, P. R., Lloyd, C. M., Zappi, P. A., Aziz, N. M. 1994. The Hydrologic Evaluation of Landfill Performance (HELP) Model, User's Guide for Version 3.

U.S. Army Corps of Engineers, Hydrologic Engineering Center. 1998. HEC-1, Flood Hydrograph Package, User's Manual, Version 4.1. June.

Unsaturated Soil Group, University of Saskatchewan. 1997. SOILCOVER, User's Manual, Version 4.01, September.

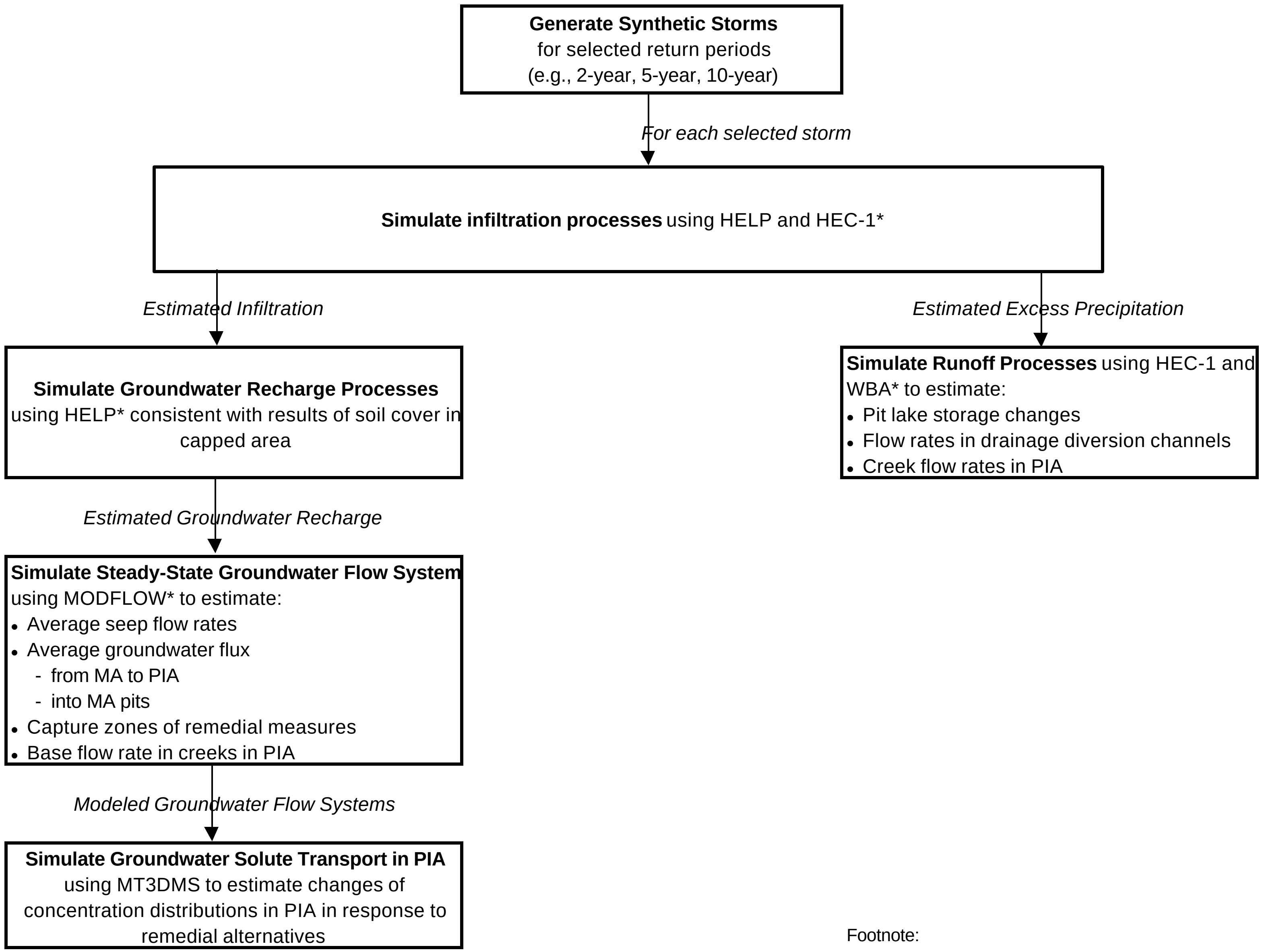
Zheng, C. and Wang, P. P. 1998. MT3DMS, A Modular Three-Dimensional Multispecies Transport Model, US Army Corps of Engineers.

Figure 1
Hydrologic Modeling Calibration Processes



Footnotes:
[1]WBA - Water Budget Analyses
[2]BPDP - Backfilled Pit Dewatering Plan

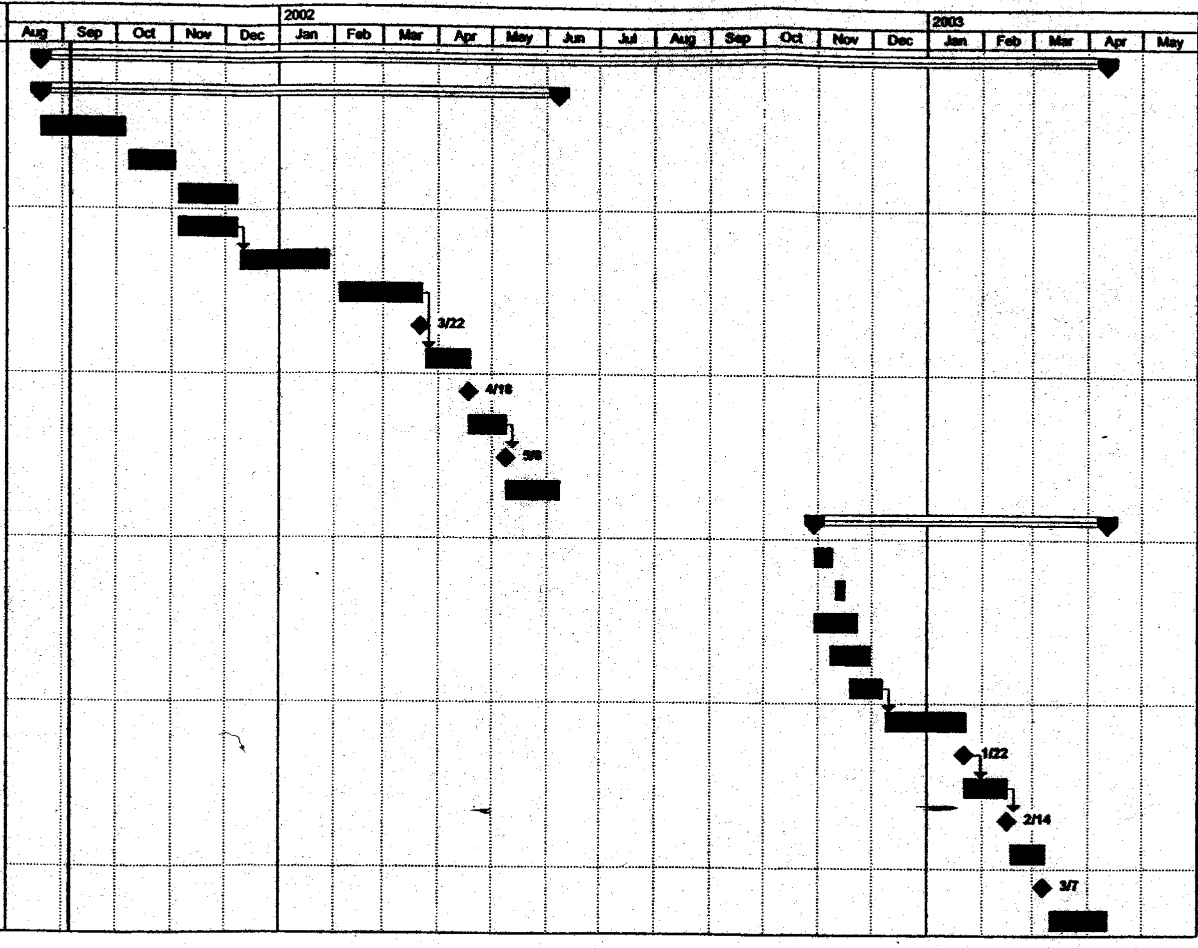
Figure 2
Hydrologic Modeling Prediction Simulation Processes



Footnote:
* To predict future conditions, model will use calibrated parameters for unchanged areas and estimated parameters for areas changed by remediation.

FIGURE 3
SCHEDULE OF NUMERICAL MODEL DEVELOPMENT AND CALIBRATION AND PREDICTIVE SIMULATIONS OF REMEDIAL ALTERNATIVES

ID	Task Name	Duration	Start	Finish
1	**PROJECT**	430 d	8/20/2001	4/11/2003
2	**FIRST MODELING PHASE**	210 d	8/20/2001	6/7/2002
3	Data Compilation/Analysis/Conceptual Model Development	35 d	8/20/2001	10/5/2001
4	Water Budget Analysis	20 d	10/8/2001	11/2/2001
5	Surface Water Model Setup/Calibration	25 d	11/5/2001	12/7/2001
6	Unsaturated Zone Model Setup/Calibration	25 d	11/5/2001	12/7/2001
7	Groundwater Model Setup/Calibration	36 d	12/10/2001	1/28/2002
8	Prepare Draft Technical Memo	35 d	2/4/2002	3/22/2002
9	Submit Draft Technical Memo to EPA	0 d	3/22/2002	3/22/2002
10	EPA Review	19 d	3/25/2002	4/18/2002
11	EPA provides Comments on Draft TM	0 d	4/18/2002	4/18/2002
12	Revise TM to address EPA Comments	15 d	4/18/2002	5/8/2002
13	Transmit Draft TM to Stakeholders	0 d	5/8/2002	5/8/2002
14	Stakeholder Review and Comments	22 d	5/9/2002	6/7/2002
15	**SECOND MODELING PHASE**	118 d	10/30/2002	4/11/2003
16	Soil Cover Simulations	8 d	10/30/2002	11/8/2002
17	Synthetic Storm Simulations	5 d	11/11/2002	11/15/2002
18	Scenario 1 - HEC-1, HELP, MODFLOW, MT3DMS	18 d	10/30/2002	11/22/2002
19	Scenario 2 - MODFLOW, MT3DMS	16 d	11/8/2002	11/29/2002
20	Scenario 3 - MODFLOW, MT3DMS	14 d	11/19/2002	12/6/2002
21	Draft Report	33 d	12/9/2002	1/22/2003
22	Submit Draft TM to EPA	0 d	1/22/2003	1/22/2003
23	EPA Review	18 d	1/22/2003	2/14/2003
24	EPA provides Comments on Draft TM	0 d	2/14/2003	2/14/2003
25	Revise TM to address EPA Comments	15 d	2/17/2003	3/7/2003
26	Transmit Draft TM to Stakeholders	0 d	3/7/2003	3/7/2003
27	Stakeholder Review and Comments	24 d	3/11/2003	4/11/2003



Project: HydroModeling
Date: 9/5/2001

Task | Progress | Milestone ◆ | Summary

W:\projects\53F4001800_Midnite\Sub_00\12.0 WP\HydroModeling.mpp 9/5/2001 (4:50 PM)

Figure 1
Hydrologic Modeling Calibration Processes