Groundwater Modeling Work Plan for BMI Upper and Lower Ponds Area

Submitted to:

NEVADA DIVISION OF ENVIRONMENTAL PROTECTION
protecting the future for generations

June 2, 2006

Prepared for:

Basic Remediation COMPANY

Daniel B. Stephens & Associates, Inc.
6020 Academy NE, Suite 100 • Albuquerque, New Mexico 87109

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state, and local statutes, regulations, and ordinances.

T. Neil Blandford

T. Neil Blandford, P.G.

Stephen J. Cullen

Stephen J. Cullen, Ph.D., C.E.M. (No. 1839, Exp. 11/12/07)

Ranajit Sahu

Ranajit Sahu, Ph.D., C.E.M. (No. 1699, Exp. 10/07/07)

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1. Introduction

This document is a proposed work plan for groundwater flow modeling at the BMI Upper and Lower Ponds area at the Basic Remediation Company (BRC) Eastside property (the Site) delineated in Figure 1. The groundwater flow modeling is to be completed by Daniel B. Stephens & Associates, Inc. (DBS&A) on behalf of BRC for submittal to the Nevada Division of Environmental Protection (NDEP). As discussed in detail in Section 2, solute transport modeling is also planned, but at a later date. The model developed under this work plan, which will be referred to as the BRC Eastside Site groundwater flow model, will serve as the basis for the development of the later solute transport model. This overall work plan has been developed in accordance with American Society for Testing and Materials (ASTM) Standard Guide D-5447, *Application of a Ground-Water Flow Model to a Site-Specific Problem.* Other ASTM standard guides applicable to the modeling process are listed in Section 3, and are referenced within the appropriate sections of the work plan.

Because some of the work on the modeling has already been initiated for exploratory purposes, the work plan makes occasional reference to preliminary model runs. However, our intent is to develop a groundwater flow model that meets or exceeds the expectations and requirements of NDEP; it is therefore our intent to incorporate and address NDEP comments, concerns, and suggestions regarding model development and application. This work plan addresses applicable comments on a draft work plan discussed at a meeting held on March 16, 2006 at BRC's offices in Henderson, Nevada, attended by representatives of BRC, DBS&A, NDEP, and the NDEP consultant. At this meeting, NDEP's written comments dated January 2005 (actually 2006) were discussed, as were a variety of related issues. The topics and results of these discussions are documented in the meeting minutes and are incorporated into this work plan.

The remainder of this work plan consists of the following sections:

- Section 2. Statement of Model Purpose
- Section 3. ASTM Standard Guides
- Section 4. Conceptual Model Development
- Section 5. Computer Code Selection

- Section 6. Numerical Model Development
- Section 7. Model Calibration
- Section 8. Sensitivity Analysis
- Section 9. Predictive Simulations
- Section 10. Documentation

Significant detail has been included as needed and where possible. There are some decisions and issues, however, that cannot be addressed in detail until the remainder of the modeling work is actually performed. It is our intent to provide updates to NDEP at key points during the modeling process, to obtain input, suggestions, and address concerns prior to proceeding to the next model development step. We believe that status meetings or conference calls are appropriate at the following stages of the model development process:

- Near the beginning of the modeling process, once the major components of the model and modeling approach have been determined. One of the purposes of this work plan is to present some of these issues; this objective was met, in large part, during the March 16 meeting. BRC is willing to hold an additional meeting if or when required to finalize this modeling work plan.

- At completion of the model calibration. Proposed predictive simulations and input parameters can also be discussed at this point.

- Upon completion of the predictive simulations.

- Upon completion and prior to submittal of the draft report.

BRC will be responsible for coordinating and scheduling these meetings as appropriate. Additional meetings or conference calls may also be held at the request of NDEP.

2. Statement of Model Purpose

The intended purpose of the modeling effort is as follows:

1. Evaluate the future groundwater flow conditions at the Site assuming a variety of possible future changes at the land surface, such as development of the Site (roads, houses, etc.) and the removal of phreatophytes (Tamarisk). Of particular importance is the evaluation of any potential for groundwater to rise in the future to a point where it is near or intersects the land surface.

2. Estimate the impacts to the groundwater flow field attributable to past groundwater mounding beneath the Upper and Lower Ponds and other sources of groundwater recharge.

3. Evaluate the transport and discharge of dissolved contaminants in groundwater from Site historical operations to the Las Vegas Wash, either directly or indirectly. This also includes evaluation of the potential effects that a rising water table may have on future contaminant transport, including remobilization of contaminants that potentially exist in the vadose zone beneath source areas. In addition, this includes evaluation of contaminant mass flux to the upper unconfined water-bearing zone (referred to as the alluvial aquifer, or Aa) through leaching of contaminants in the vadose zone due to recharge.

The first phase of model development will focus on the first two items above, which involve simulations of historical groundwater flow and predictive simulations of future groundwater flow. Simulations of contaminant transport will be conducted later, and the specific approaches concerning transport model input parameters and the definition and simulation of source terms will be provided as an addendum to this work plan, or as a separate document, at a future date. The term "Site" as used in this document refers specifically to the BRC Eastside property, which includes the Upper and Lower Ponds area, as delineated on Figure 1. Note that some areas that are not owned by BRC, but are adjacent to the BRC property, will be included in the model domain in order to develop a physically reasonable groundwater flow and solute transport model. Where a distinction in terms is important, the terms "Site" and "model domain" will be used to convey the relevant distinction.

3. ASTM Standard Guides

The ASTM has developed a series of Standard Guides for certain aspects of groundwater flow and solute transport modeling. At the request of NDEP, these Standard Guides will be consulted and utilized as appropriate during development and application of the BRC Site groundwater flow model, and for the solute transport model to be completed at a later date. The applicable ASTM Standard Guides are listed below in the approximate order of their application to the model development process. For simplicity, the last two numerals for each Standard Guide will be omitted when referring to the Standard Guides elsewhere in this work plan (e.g., D-5447-93 will be referenced as D-5447).

- D-5447-93: Application of a Ground-Water Flow Model to a Site-Specific Problem
- D-6170-97: Selecting a Ground-Water Modeling Code
- D-5609-94: Defining Boundary Conditions in Ground-Water Flow Modeling
- D-5610-94: Defining Initial Conditions in Ground-Water Flow Modeling
- D-5981-96: Calibrating a Ground-Water Flow Model Application
- D-5490-93: Comparing Ground-Water Flow Model Simulations to Site-Specific Conditions
- D-5611-94: Conducting a Sensitivity Analysis for a Ground-Water Flow Application
- D-5718-95: Documenting a Ground-Water Flow Model Application
- D-5880-95: Subsurface Flow and Transport Modeling

It should be noted that the above documents were specifically developed as Standard Guides, rather than standards, in recognition of the state of the art of groundwater model development and with appreciation for the site-specific nature of modeling applications. Due to site-specific conditions and complexities, available data, computer code limitations, and a variety of other factors, the ASTM development committees recognized that it is not possible or appropriate to prescribe every step or detail in the modeling process in a set of formal standards. As such, BRC will use the ASTM Standard Guides as guidance documents, consistent with their intended use.

4. Conceptual Model Development

The proposed numerical groundwater flow model is based on the conceptual site model (CSM) currently being developed for the Site by BRC. The CSM is a representation, or concept, of how groundwater flow occurs at the Site within the aquifer system and what the various sources of recharge to, and discharge from, the groundwater system are. Development of the conceptual and numerical model can be an evolving, interrelated, and iterative process. For example, experience gained and observations made during numerical model calibration may indicate additional areas of the model or certain model input parameters that need to be re-evaluated, as well as concepts of groundwater flow that may need to be re-evaluated. This section presents some key aspects of the CSM that are important to development of the groundwater flow model.

Based on our analyses and data review conducted to date, some key components of the CSM include the following:

- Groundwater flow occurs in two geologic units at the site, the Quaternary alluvium (alluvium) and the Tertiary Upper Muddy Creek formation (Upper Muddy Creek) that underlies the alluvium. Horizontal groundwater flow occurs throughout the alluvium where it is saturated, while horizontal groundwater flow in the Upper Muddy Creek beneath the Site north of the active ponds area occurs primarily in sporadically encountered thin sand or coarse-grained layers found to occur in primarily silty and clayey matrices. Groundwater flow in both units is generally from south to north.

- The hydraulic conductivity of the alluvium is substantially greater than that of the Upper Muddy Creek. The exchange of water between the two units is primarily controlled by the vertical hydraulic conductivity of the Upper Muddy Creek, which is significantly lower than that of the alluvium due to the predominance of silt and clay in this unit at most locations. In one location (MCF-27) near the upgradient end of the Site, coarse-grained, and likely more permeable, Upper Muddy Creek sediments have been identified to be in direct contact with alluvium.

- The hydraulic conductivity of the alluvium is variable, but existing field observations of hydraulic parameters and contaminant distributions, geologic interpretation, and other groundwater models indicate that hydraulic conductivity is greater within paleochannels than it is in interchannel areas. Existing hydraulic parameter tests have been conducted on adjacent sites, but not on the BRC Site. Aquifer tests are proposed for the BRC Site in Section 6.8 of this work plan. These tests will be conducted, upon NDEP approval, as part of the current quarterly groundwater monitoring being conducted at the Site.

- Available data indicate that the hydraulic conductivity of the alluvium deposited or re-worked by Las Vegas Wash appears to be greater than that of the alluvium deposited adjacent to the wash.

- Recharge to the alluvium occurs primarily from the following sources:

  - Infiltration from precipitation and stormwater runoff
  - Infiltration at several rapid infiltration basins (RIBs) on and near the Site, when in use
  - Groundwater inflow from saturated portions of the alluvium adjacent to and upgradient of the Site
  - Injection or infiltration of treated water from remediation systems (does not occur on the Site)
  - Seepage of water from Las Vegas Wash where the water level in the channel is higher than that in the adjacent alluvium

- Discharge from the alluvium occurs primarily from the following sources:

  - Seepage to Las Vegas Wash where the water level in the alluvium is greater than that in the wash
  - Evapotranspiration from phreatophytes and possibly other plants where depths to water are within their rooting depth
  - Groundwater outflow within Las Vegas Wash alluvium northeast of the Site

- Groundwater pumping for remediation (does not occur on the Site)

Quantitative estimates of water budget components for the current and future condition remain to be completed. Once these estimates have been completed, they will be provided to NDEP for review and comment. For the Las Vegas Wash portion of the model area, we intend to utilize information previously compiled by McGinley & Associates (2003) for the current conditions model, as well as other sources of information that may have become available since completion of that report. A second estimated water budget will be developed for the historical conditions model. Our proposed approach to the current and historical conditions models is presented in Section 7.

NDEP has commented that within the main paleochannel area west of the Upper Ponds area and beneath a portion of the Lower Ponds area, the total dissolved solids (TDS) concentration of the groundwater may approach or exceed 5,000 milligrams per liter (mg/L). The significance of this observation is that inclusion of the effects of higher density groundwater should be considered in the modeling. Alternatively, if the effects of density variation are not simulated directly, an appropriate explanation should be provided. BRC will evaluate this issue during development of the groundwater flow model, and will provide documentation and rationale for simulating, or not simulating, such density-driven flow effects.

5. Computer Code Selection

Computer code selection is generally a formal step in the modeling process, most often completed after development of the conceptual model. However, quite a bit of information is already known and some analysis has already been conducted concerning groundwater flow at the Site, and several groundwater flow models have already been developed that encompass the Site or adjoining areas. Based on our knowledge of the Site, the conceptual model of groundwater flow at the Site as developed to date, review of the previous modeling studies, and previous experience with numerous groundwater simulation models, we propose to apply the MODFLOW-SURFACT code developed by HydroGeoLogic, Inc. of Herndon, Virginia. Selection of the MODFLOW-SURFACT code was conducted in accordance with the general procedure outlined in ASTM Standard Guide D-6170.

MODFLOW-SURFACT is an upgraded, proprietary version of the USGS MODFLOW code that can be commercially purchased. The code includes all of the functionality of the standard MODFLOW-98 software developed by the U.S. Geological Survey (USGS), but also includes a number of added simulations capabilities and advanced simulation algorithms that will be useful for simulating groundwater flow beneath the Site. MODFLOW-SURFACT has been employed by numerous governmental and private entities since 1996, and contains the following simulation capabilities and advantages:

- Saturated or variably saturated three-dimensional groundwater flow for water of uniform density and temperature for steady-state or transient conditions. The saturated groundwater flow module will be used for the Site.

- Capability to incorporate a wide variety of boundary conditions, including rivers, drains (often used to simulate springs), evapotranspiration, and many others.

- Capability to incorporate heterogeneity in aquifer and boundary condition parameters.

- Advanced solution algorithm for rigorous simulation of model cell drying (simulated water level below the base elevation of the cell) and rewetting that conserves mass balance.

This capability is very useful for simulating groundwater flow in hydrogeologic units of limited saturated thickness, such as occurs within the alluvium at the Site.

- Solution algorithm for implementation of a seepage face boundary condition.

- Solution algorithm for implementation of a modified recharge package that allows for ponding at the surface.

- Full three-dimensional transport simulation capability for saturated or variably saturated groundwater flow. Although transport simulations are not contemplated as part of the current study, this capability will assist implementation of transport simulations in the future.

- HydroGeoLogic, Inc. is currently developing a version of MODFLOW-SURFACT capable of simulating density-dependent groundwater flow. If density-dependent flow simulation capability is required, we can potentially apply an updated version of the code.

A full description of the MODFLOW-SURFACT code is available online at www.hgl.com. Once at the home page, the user can browse to "modeling", then "software", then "MODFLOW SURFACT".

6. Numerical Model Development

This task involves implementation of the CSM into a numerical model of groundwater flow, including development of the model grid and active model domain extent, assignment of appropriate boundary conditions for the top, bottom, and sides of the model domain, assignment of aquifer hydraulic properties (e.g., hydraulic conductivity, storage coefficient), and assignment of "internal" boundary conditions such as infiltration and evapotranspiration. Based on our current understanding of the Site, and a series of initial model simulations that have already been conducted, our proposed numerical model structure and assignment of hydraulic properties and boundary conditions are provided below. Development of the numerical model will be completed in accordance with ASTM Standard Guides D-5447, D-6170, D-5609, and D-5610 (Section 3).

6.1 Extent of Active Model Domain

The extent of the proposed active model domain is provided in Figure 1. The proposed domain covers the majority of the BMI Eastside property, including the entire Upper and Lower Ponds area, but does not include the plants areas or portions of the BRC Common Areas (i.e., the CAMU area) west of Boulder Highway.

Note that some portions of the active model domain illustrated in Figure 1 were determined through some initial analytical and numerical model simulations of groundwater mounding beneath the Upper Ponds, as discussed during the March 16 meeting. The numerical analyses will be documented in the groundwater flow model documentation. The analytical mounding calculations are being submitted as a technical memorandum in conjunction with this work plan. Should additional simulations with future versions of the model indicate that significant mounding occurs along model boundaries, adjustments will be made to the boundary locations as necessary.

6.2 Horizontal Discretization

We propose a horizontal discretization (cell area) of 1 acre, which leads to cells about 209 feet on a side. This cell size is sufficiently small to implement characteristic site features in reasonable detail. The proposed model grid is also provided in Figure 1.

6.3 Vertical Discretization

We propose a two-layer groundwater flow model representing both unconfined, saturated alluvium as model layer 1, and the unconfined water that occurs in uppermost portion of the Upper Muddy Creek Formation (typically encountered in the eastern portion of the Site) as model layer 2. Together, these two layers have been previously referred to as the Upper Unconfined Water Bearing Zone. In the CSM currently being developed, they are collectively referred to as the alluvial aquifer (Aa). We propose to include approximately the uppermost 20 to 30 feet of Upper Muddy Creek formation as layer 2 in the model, the intent being to simulate water table conditions encountered in the skin of the Upper Muddy Creek where the alluvium is partially saturated. Flow of water in the deep aquifer (400 feet or so into the deep Muddy Creek Formation) will not be simulated explicitly. Flow of water in the Upper Muddy Creek at depths greater than approximately 20 to 30 feet below the contact between the alluvium and the Upper Muddy Creek will be considered as a boundary condition to the bottom of model layer 2. The top of the model will be land surface.

6.4 Time Discretization

Both steady-state and transient simulations will be performed. Steady-state simulations will be obtained using the direct steady-state simulation approach or, if difficulties arise with the numerical solution, through transient simulation until steady-state conditions are obtained (i.e., change in storage is essentially zero). Time discretization for transient simulations will be divided into stress periods and time steps. Stress periods represent periods of time where hydrologic inputs and outputs are considered to be constant. Time steps represent the intervals at which the hydraulic heads and groundwater fluxes will be solved using the numerical model. Typically, stress periods are divided into multiple time steps. Although the exact nature of transient simulations that will be performed is not known, we propose a maximum stress period length of one year, although it is likely that stress periods of one month may be applied to adequately represent seasonal fluctuations in some model inputs, such as evapotranspiration from phreatophytes. Regardless, each stress period will be subdivided into at least five time steps.

6.5 Top Boundary Conditions

The top of the model domain will be set to the land surface elevation determined for the center point of each model cell. During the simulations, the top model boundary is actually the simulated location of the water table. Boundary conditions applied to the top of the model include inflow from recharge, discharge due to evapotranspiration, and direct discharge of groundwater at seeps where the water table intersects the land surface.

Recharge from precipitation will be simulated using the Recharge Package, which requires that a recharge rate, location, and associated time period be prescribed. It is expected that the rate and geographic distribution of recharge will be modified during the model calibration process. For example, precipitation that falls on the bermed ponds cannot run off; therefore, recharge beneath the ponds area may be greater than that at some other places within the model domain. Similarly, one would expect recharge to be greater beneath unlined ditches that convey stormwater runoff than at other locations.

Historical recharge at the Upper and Lower Ponds will be simulated using the Recharge Seepage Face (RSF4) Package available in MODFLOW-SURFACT. The RSF4 Package requires specification of a pool (ponding) elevation related to the recharge source; if the ponding elevation is exceeded, the "excess" water is assumed to be runoff and is eliminated from the model. This feature is useful to ensure that reasonable infiltration rates are applied at specific point sources.

evapotranspiration from phreatophytes (e.g., salt cedar) will be simulated using the Evapotranspiration Package. The Evapotranspiration Package required input of a maximum evapotranspiration rate and an extinction depth, which is the depth below land surface below which it is assumed that evapotranspiration does not occur. Evapotranspiration rates and reasonable extinction depths will be determined based on available literature, and may be adjusted during model calibration if necessary. Determination of areas of the model where evapotranspiration may occur will be based on knowledge or surveys of vegetation occurrence and observed depth to water below land surface.

Discharge to seeps at the land surface will be simulated using the Drain Package in MODFLOW-SURFACT. Application of the Drain Package requires specification of the drain elevation, which will be set to the land surface at the appropriate model cells where seepage may occur, as well as specification of a drain conductance. The drain conductance is a function of the permeability of the aquifer materials in the vicinity of the drain, the geometry of the primary groundwater flow paths in the vicinity of the drain, and the cell size. Drain conductance will be determined during model calibration.

Groundwater/surface water interaction in Las Vegas Wash will be simulated using the River Package. The River Package simulates groundwater flow to or from a stream based on the difference in hydraulic head between the water in the channel and the simulated water level beneath the stream, multiplied by a streambed conductance term that incorporates channel geometry, area, and the effects of streambed permeability. Streambed conductance will be determined during model calibration. It is not our intent to develop a highly detailed simulation of groundwater/surface water interaction in Las Vegas Wash; rather, our intent is to develop a reasonable boundary condition for the downgradient portion (northern boundary) of the model that will lead to reasonable predictions and computations of the groundwater inflow toward Las Vegas Wash from beneath the Site.

6.6 Bottom Boundary Condition

The bottom boundary of the groundwater model will be simulated as a third-type boundary condition (most likely using the General Head Boundary [GHB] Package) where the simulated groundwater flow across the boundary is a function of the difference in hydraulic head between the shallow Upper Muddy Creek represented as model layer 2 (approximately the upper 20 to 30 feet of Upper Muddy Creek), and the deep portion of the Upper Muddy Creek that commonly occurs at about 400 to 500 feet below land surface. Available information indicates that, for the most part, the direction of hydraulic gradient between the deep and shallow zones of the Upper Muddy Creek is upward. Sensitivity analyses will also be conducted to evaluate the influence that this boundary condition has on the model simulation results. The bottom elevation of model layer 1 will be set to the elevation of the alluvium-Upper Muddy Creek contact determined for the center of each cell. The alluvium bottom elevation map has been constructed based on all available data for, and immediately adjoining, the active model domain. This map is provided in the CSM, and was presented to the NDEP at the March 16 meeting. The bottom of model layer 2 will be developed using the hydrogeologic cross sections developed as part of the Site CSM. As noted above, review of these draft cross sections indicates that approximately 20 to 30 feet of Upper Muddy Creek sediments will be included as model layer 2.

6.7 Lateral (Side) Boundary Conditions

Lateral model boundary conditions will be a combination of prescribed groundwater flux and prescribed hydraulic head in both model layers. Prescribed groundwater flux of zero (no-flow boundary) will be applied where the boundary of the active model domain coincides, or nearly coincides, with a groundwater flow pathline. Prescribed hydraulic head will be applied along other lateral boundary segments, with the exception of Las Vegas Wash, as described above.

6.8 Hydraulic Properties

Initial hydraulic properties used in the model will be based on (1) direct testing and observation of hydraulic parameters within or near the Site, (2) values of hydraulic properties used in previous modeling efforts such as by Ampac, and (3) knowledge of reasonable parameter values for various geologic material types. Of these three sources of information, the largest weight will be placed on observed hydraulic parameters from aquifer tests. The initial hydraulic properties applied in the model will be adjusted during the model calibration process. References for all hydraulic properties applied during the model development process will be provided in the model documentation.

As part of a separate work item, BRC proposes to complete multiple aquifer tests (pumping tests and/or slug tests and laboratory measurements of core samples) to provide site-specific data for use during development of the groundwater flow model and to assist with overall site characterization and quantitative analysis. A summary of the proposed test locations is provided in Figure 2.

Aquifer tests of the alluvium are proposed at two locations within the paleochannel that passes below the western side of the Upper Ponds area. If the selected wells are not capable of being pumped at a reasonable rate for a sufficient period of time (2 hours or more), slug tests will be conducted in lieu of pumping tests. Observation wells identified at this point in time are also provided on Figure 2. Other hydraulic (slug) tests are proposed for two additional locations within the west side of the Upper Ponds area, and one test is proposed along the north side of the City of Henderson northern rapid infiltration basins (RIBs).

Hydraulic testing of sediment cores is proposed for three locations within the east side of the Upper Ponds area as illustrated in Figure 2. Hydraulic testing of cores is proposed for this location because the alluvium is not saturated or has very little saturation; therefore, aquifer tests are not feasible. BRC has a substantial archive of undisturbed soil cores that were collected during the hydrogeologic investigation conducted on the Eastside area in 2004. BRC will investigate the viability of using these undisturbed, archived cores to obtain representative measurements of vertical and lateral hydraulic conductivity. In addition to vertical permeability, the feasibility of subcoring the archived cores will be evaluated to determine if horizontal hydraulic conductivity can be directly measured. The vertical hydraulic conductivity values measured from the core samples will assist with evaluation of historical mounding scenarios. Horizontal hydraulic conductivity will be used in the identification of anisotropy ratios. If utilization of the archived cores proves infeasible for the intended purpose, BRC will prepare a work plan, for NDEP review and concurrence, to obtain these cores.

In addition to the hydraulic testing of the alluvial sediments described above, two slug tests will be conducted on wells screened across only the Upper Muddy Creek sediments. The purpose of these tests is to better define hydraulic properties of the Upper Muddy Creek Formation for implementation into the model. The results of these tests will assist with determination of aquifer properties of model layer 2.

6.9 Initial Conditions

Initial conditions for transient simulations will be based on the results of steady-state simulations.

7. Model Calibration

The groundwater flow model will be calibrated to both historical and current hydrologic conditions observed at the Site in accordance with ASTM Standard Guides D-5981 and D-5490 (Section 3). Model calibration, sometimes called "history matching", is the process of adjusting model input parameters within reasonable physical limits to obtain a satisfactory match to observations of hydraulic head and/or groundwater fluxes. The primary method of model calibration will be comparison of simulated and observed hydraulic head values; however, other observations will be incorporated into the calibration as well, such as the presence or lack of groundwater seeps at certain locations, and the estimated magnitude of base flow to Las Vegas Wash. For example, review of historical aerial photographs for the site indicates the presence of a significant zone of what appears to be groundwater seepage along the northwestern corner of the Upper ponds area between the Alpha and Beta Ditches. Replication of this historical zone of seepage will be a goal during calibration of the historical model.

Although a model calibrated to observed current conditions can be used to conduct predictive simulations, greater confidence can be placed in predictions made using a model that has been calibrated to multiple historical hydrologic conditions, all other considerations being equal. We propose to calibrate the BRC model to both current and selected historical conditions. Current conditions are assumed to be hydrologic conditions representative of the period 2002 through 2006, including groundwater data presently being collected as part of quarterly monitoring at the Site. This approach allows us to take maximum advantage of previous work and available field data. This model is referred to as the "current conditions model". This model will assume steady-state conditions.

We also propose to conduct a historical model calibration to hydrologic conditions of the late 1960s (approximately 1967 through 1969), a period when groundwater seepage is apparent on aerial photographs along the northwestern extent of the Upper Ponds area. This model is referred to as the "historical conditions model". This model will either be a steady-state model or a combination of a steady-state model representative of the early to mid-1960s followed by a transient simulation for a period of several (2 to 4) years. The conceptual model mass balance for the historical conditions model will be significantly different than that of the current conditions model due to differences in hydrologic site conditions between the two time periods.

We believe that this approach is reasonable given (1) the relatively thin saturated thickness of the alluvium and (2) the generally high permeability of the alluvium. Because of these two conditions, changes to the groundwater flow field in the alluvial aquifer caused by changes in hydrologic sources or sinks occur relatively quickly (i.e., over a period of several years). This quick system response was also apparent in the analytical modeling that has been conducted. Therefore, we do not believe it is necessary to conduct a historical calibration over a period of contiguous decades because groundwater flow conditions observed today are a function of hydrologic conditions or changes that occurred over the past several years, as opposed to those that occurred decades ago, such as during the 1960s. In addition, it would be very difficult to compile and estimate, to a reasonable degree of accuracy, all of the hydrologic inputs and changes in hydrologic conditions (such as the location and rate of infiltration to the Upper and Lower Ponds areas) necessary to conduct a continuous, accurate historical model calibration.

8. Sensitivity Analysis

Sensitivity analysis will be conducted for all key model input parameters, and the results will be reported in the model documentation. During this portion of the study, particular attention will be paid to those model input parameters that appear to have the greatest effect on the rise and/or position of the water table in relation to land surface, particularly in lower-land surface elevation areas. The sensitivity analysis will be conducted in accordance with ASTM Standard Guide D-5611.

9. Predictive Simulations

Predictive simulations will be conducted using the simulated groundwater flow field from the current conditions simulation as the starting point for the predictive simulation. Predictive simulations will be conducted for a sufficient period of time such that a new steady-state groundwater flow field is obtained. Anticipated changes in land use will be incorporated into the model through their anticipated changes in groundwater recharge. For example, areal recharge beneath residential development may be different than that beneath undeveloped areas due to development grading, landscape watering, and possibly leakage from subsurface water supply and sewer systems. Estimates of post-development water balance components will be developed and included in the modeling report for review by NDEP.

Other known or anticipated changes during the predictive simulation period that may affect the groundwater flow system will also be incorporated into the model. Such components could include, for example, changes in the infiltration and/or pumping rates of neighboring entities.

10. Documentation

All of the modeling tasks presented above will be thoroughly documented in a completion report. The report and electronic model input and output files with be provided to NDEP in draft form for review and comment prior to completion of the final report. The modeling documentation and report will be prepared in accordance with ASTM Standard Guide D-5718.

Figures

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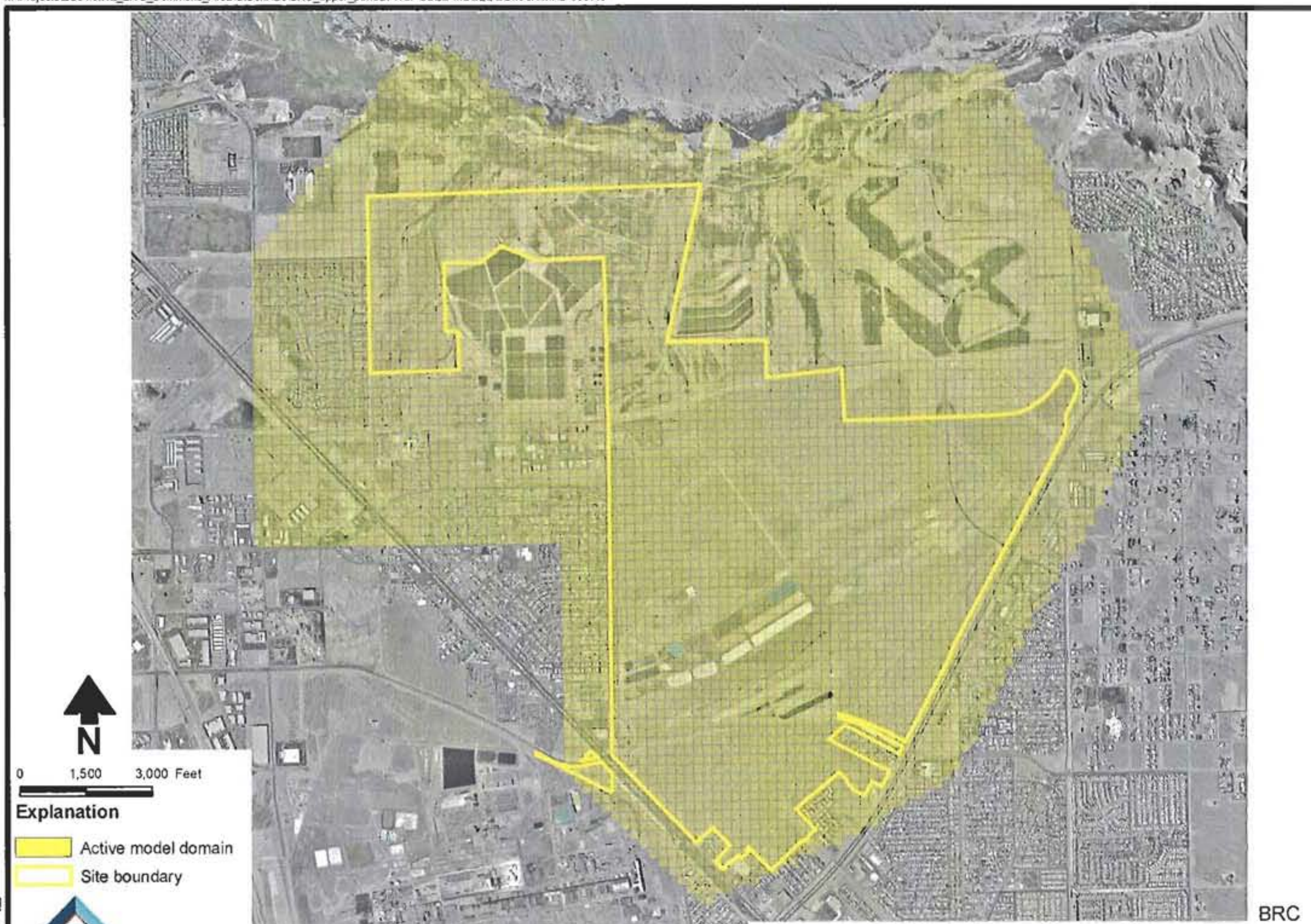


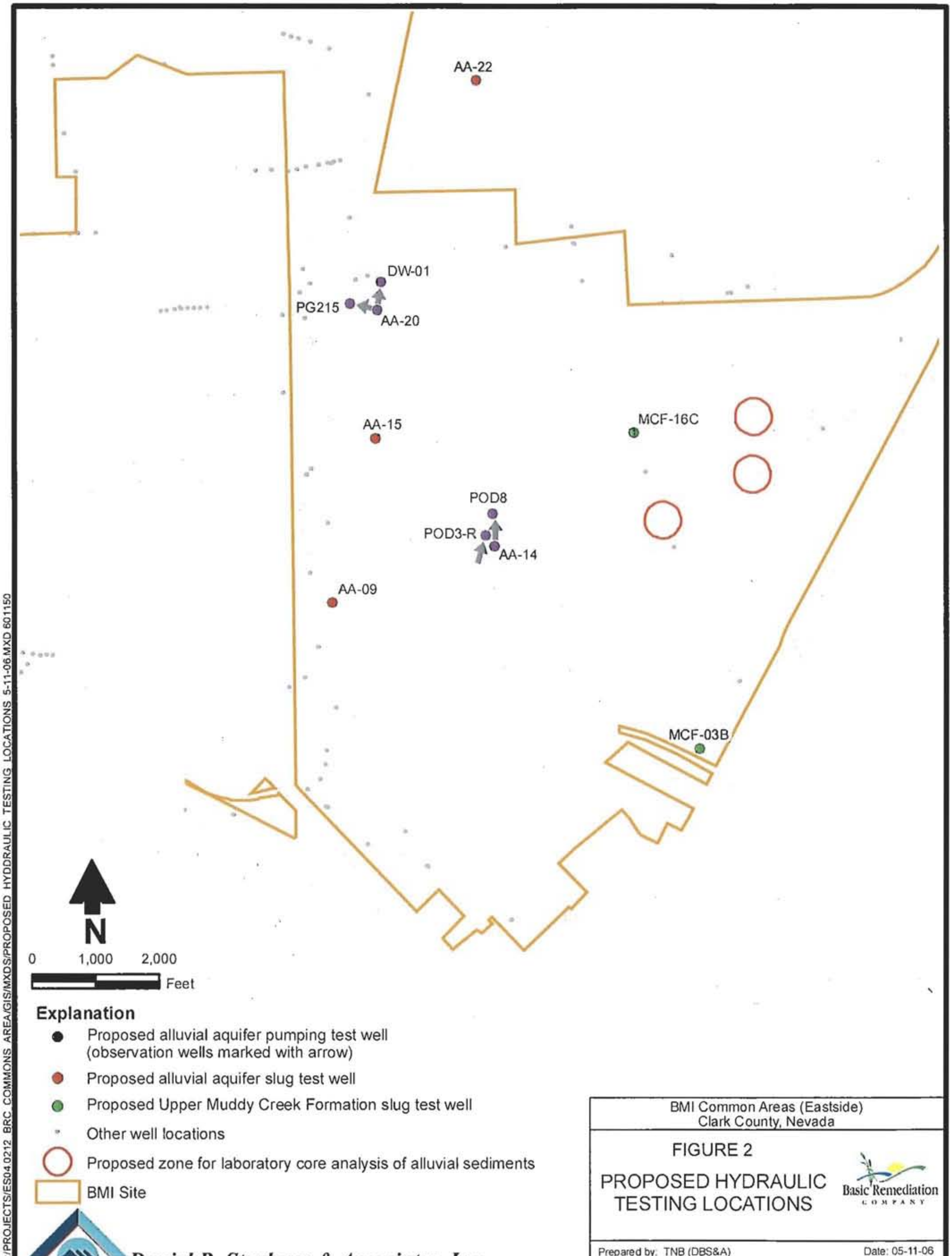
BRC

Proposed Model Domain and Discretization

Daniel B. Stephens & Associates, Inc.

JN ES04.0212

Figure 1



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