Golder Associates Inc.
670 Commercial Street, Suite 103
Manchester, NH 03101-1146
Telephone: (603) 668-0880
Fax: (603) 668-1199
www.golder.com

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DRAFT

OPTIMIZATION WORK PROPOSAL FOR THE MONITORING WELL AND RECOVERY WELL NETWORKS FORMER BOEING FACILITY WICHITA, KANSAS

Prepared for:

The Boeing Company
2727 East MacArthur
Wichita, Kansas 67216

Prepared by:

Golder Associates Inc.
670 North Commercial Street
Suite 103
Manchester, NH 03101

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Golder Associates Inc.
670 Commercial Street, Suite 103
Manchester, NH 03101-1146
Telephone: (603) 668-0880
Fax: (603) 668-1199
www.golder.com

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September 30, 2009

The Boeing Company
2727 East MacArthur
Wichita, Kansas 67216

Attn: Mr. Michael Spain

**RE: OPTIMIZATION WORK PROPOSAL
FOR THE MONITORING WELL AND RECOVERY WELL NETWORKS
FORMER BOEING FACILITY, WICHITA, KANSAS**

Dear Mr. Spain:

As requested by the Boeing Company (Boeing), Golder Associates Inc. (Golder) prepared this Optimization Work Proposal (OWP) for the Monitoring Well and Recovery Well Networks at the Former Boeing Facility at 4615 South Oliver Street in Wichita, Kansas. This OWP is submitted in response to the July 27, 2009 Kansas Department of Health and Environment (KDHE) letter to Boeing requesting a "Optimization Work Plan" for "optimizing the current groundwater monitoring and recovery systems." For monitoring wells, the OWP is to provide "recommendations for optimizing the number of monitoring wells sampled, sampling methods, frequency of sampling, and analytical parameters." For recovery wells, the OWP is to "address the location and number of wells to achieve containment and achievement of remedial action objectives for the Site."

Additionally, as requested in KDHE's July 27th letter, the Work Plan is to include an appendix "describing the groundwater modeling that was conducted, including a detailed description of all assumptions and input used in the modeling." This report, the 2009 Groundwater Modeling Report, is provided herein as Appendix A.

Should you have any questions regarding this report, please do not hesitate to call.

Sincerely,

GOLDER ASSOCIATES INC.

Eric Kern, Ph.D.
Senior Microbiologist

Ross Bennett, P.E.
Project Engineer

Todd H. Rees, Ph.D., P.E.
Program Leader and Principal

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1.0 INTRODUCTION

As requested by the Boeing Company (Boeing), Golder Associates Inc. (Golder) prepared this Optimization Work Proposal (OWP) for the Monitoring Well and Recovery Well Networks at the Boeing Facility at 4615 South Oliver Street in Wichita, Kansas (the Site) (Figure 1-1).

This OWP is submitted in response to the July 27, 2009 Kansas Department of Health and Environment (KDHE) letter to Boeing requesting for an "Optimization Work Plan," a title modified to "Work Proposal" instead of "Work Plan." By using the term "optimization", Golder does not imply that the opinions in this report represent a unique or absolute solution to the problem of improving the efficiency of the monitoring or recovery well networks at the Site. Along with the 2009 Groundwater Modeling Report (contained herein as Appendix A), the OWP provides the technical basis upon which monitoring, extraction/injection and treatment alternatives can be developed for the site.

As KDHE noted, the OWP "should include an evaluation of the existing monitoring and recovery well networks and recommendations for optimizing the number of monitoring wells sampled, sampling methods, frequency of sampling, and analytical parameters… For recovery wells, the evaluation should address location and number of wells to achieve containment and achievement of remedial action objectives for the Site."

Since the recovery well network optimization represents a potential change in site groundwater flow, Golder recommends that the full monitoring well optimization be performed after allowing the aquifer to respond to the recovery well network optimization. As such, Golder is proposing a phased approach to implementation of the optimization effort described in this report. The three phases of the optimization effort will be as follows:

- Phase 1: Implementation of the OWP for recovery and monitoring wells systems. Work proposed includes reduction in number of recovery wells, minor reduction in monitoring wells, and a reduction in the frequency of sampling for both recovery and monitoring wells. The number of monitoring wells during the first year of the OWP remains purposely high for one year, to monitor potential changes in groundwater arising from the optimization of the recovery well system (1st Quarter, 2010).

- Phase 2: Following one year of monitoring since implementing recovery well optimization, a review of groundwater data will be used to then optimize the monitoring well system (2011).
- Phase 3: After one additional year of data collection, a final re-evaluation of recovery well and monitoring well optimizations will be conducted and potential modifications for further optimization of the systems will be recommended (2012).

As will be discussed below in more detail, preliminary estimates of recover well and monitoring well reductions were developed for calendar years 2010, 2011 and 2012. The proposed monitoring well network for years 2011 and 2012 may vary depending on results of the recovery well optimization monitoring. The analytical parameters for the proposed monitoring well network will not change from the existing monitoring well network, including annual observation of water levels in the sampled wells.

2.0 MONITORING WELL NETWORK OPTIMIZATION

2.1 Introduction

The goal of Golder's optimization of the monitoring well network (MWN) is to reduce the number monitoring wells sampled and frequency of sampling while still collecting sufficient data to monitor potential spatial and temporal changes in groundwater quality. Golder developed the proposed optimization monitoring well network based on a qualitative evaluation of the temporal and spatial characteristics of the existing monitoring well network. Specifically, Golder considered the following factors (from USEPA, 2005):

- The hydrogeologic conceptual model (i.e. properties and behavior) of the groundwater system; and
- The historic trends or stability in the movement and fate of contaminants.

Golder used these factors to develop an MWN that includes monitoring locations on the perimeter of existing plumes (to continue to evaluate the potential for overall plume movement) and within source areas of existing plumes (to allow for continued evaluation of the effectiveness of interim remedial measures).

2.2 Existing Monitoring Well Network

The existing MWN is presented in Table 2-1 and Figure 2-1. As shown on Table 2-1, the current monitoring program calls for the following:

- Monitoring wells: monthly sampling of 18 wells and semi-annual sampling of 108 wells in the first quarter and 184 wells in the third quarter for approximately 490 groundwater samples collected annually.
- House wells (4300 S.Clifton, 3422 Craig, 3431 Craig, and 3524 Craig): semi-annual sampling of 4 wells for a total of 8 groundwater samples collected annually.

- Recovery wells: monthly sampling of 1 well and semi-annual sampling of 21 wells in the first quarter and 179 wells in the third quarter for a total of approximately 211 groundwater samples collected annually.

- Air strippers: quarterly sampling of 11 locations for a total of 44 samples collected annually.

The existing MWN and frequency of sample collection has resulted in a detailed understanding of plume dynamics at the Site. Furthermore, this data is consistent with the hydrogeologic conceptual model, which indicates that groundwater flow velocities are relative slow[1]. Numerous monitoring wells have been installed at the Site for initial characterization of the nature and extent of groundwater plumes; however, the minimal changes observed over time suggests that both the number of monitoring wells and frequency of analysis can be reduced while still maintaining an appropriate understanding of plume dynamics at the Site.

2.3 Proposed Monitoring Well Network

The proposed MWN for monitoring during optimization of the recovery well network is presented in Table 2-1 and Figure 2-2. The proposed MWN is based on utilization of historic groundwater concentration data as the guide to identifying the most important monitoring wells at the site. This approach retains the most useful historic information while providing the spatial coverage to monitor plume movement(s) (which is relatively slow at the Site) and changes in plume concentration(s).

Golder used the following guidelines in developing the proposed MWN:

- "Index" monitoring wells that were previously sampled on a monthly frequency will be sampled quarterly.
- Monitoring Wells that were previously sampled at a semi-annual or annual frequency will be sampled annually.
- 15 monitoring wells that have not historically had detections of volatile organic compounds (VOCs) above laboratory reporting limits have been removed from the monitoring program (e.g. MW-033).

[1] A detailed discussion on groundwater flow directions and velocities is provided here in as Appendix A (2009 Groundwater Modeling Report).

- Active recovery wells will be sampled on a semi-annual frequency.
- Inactive recovery wells have been added to the monitoring program to be used as monitoring wells during monitoring of the initial year of the recovery well optimization.
- Select monitoring wells and recovery wells will be sampled on a quarterly basis in key portions of the recovery well network.

The proposed MWN calls for the following sampling for the year 2010:

- Monitoring wells: monthly sampling of 2 wells, quarterly sampling of 35 wells and annual sampling of 169 wells in the third quarter for a total of approximately 296 groundwater samples collected annually, a reduction of 194 monitoring well samples per year (a 40% reduction).

- Recovery wells: quarterly sampling of 3 wells, semi-annual sampling of 70 wells in the first quarter and annual sampling of 179 wells in the third quarter for a total of approximately 258 groundwater samples collected annually, an increase of 47 recovery well samples per year (a 22% increase).

The proposed sampling frequency for the house wells and air strippers does not change from the existing frequency.

The proposed MWN calls for the following sampling for the year 2011:

- Monitoring wells: quarterly sampling of 2 wells, semi-annual sampling of 35 wells and annual sampling of 169 wells in the third quarter for a total of approximately 210 groundwater samples collected annually, a reduction of 280 monitoring well samples per year (a 57% reduction from existing monitoring frequencies).

- Recovery wells: Semi-annual sampling of 3 wells and annual sampling of 179 wells in the third quarter for a total of approximately 182 groundwater samples collected annually, a decrease of 29 recovery well samples per year (a 14% reduction from existing monitoring frequencies).

The proposed MWN calls for the following sampling for the year 2012:

- Monitoring wells: Semi-annual sampling of 10 wells and annual sampling of 169 wells in the third quarter for a total of approximately 179 groundwater samples collected annually, a reduction of 311 monitoring well samples per year (a 63% reduction from existing monitoring frequencies).

- Recovery wells: Annual sampling of 179 wells in the third quarter for a total of approximately 179 groundwater samples collected annually, a decrease of 32 recovery well samples per year (a 15% reduction from existing monitoring frequencies).

A summary of the number of sample locations and samples collected per year for the 2010-2012 proposed monitoring well networks is presented in Table 2-2. The proposed monitoring well network for years 2011 and 2012 may vary depending on results of the recovery well optimization monitoring. The analytical parameters for the proposed monitoring well network will not change from the existing monitoring well network, including annual observation of water levels in the sampled wells.

3.0 RECOVERY WELL NETWORK OPTIMIZATION

3.1 Introduction

The goal of Golder's optimization of the recovery well system is to reduce the number of active recovery wells and the total flow rate of the recovery well system, while maintaining capture of impacted groundwater at the site. As part of optimization of the recovery well system, Golder performed the following:

- Predictive simulations for optimization to develop a primary recovery well network,
- An uncertainty analysis on the predicted capture zone of the primary recovery well network, and
- Predictive simulations for addition of secondary recovery wells to the network to add redundancy and additional capacity in areas where the sensitivity analysis indicated potential for compromised capture during optimization of the recovery well network.

Golder developed the groundwater flow model for the site using the United States Geological Survey (USGS) Modular Three-Dimensional Finite-Difference Groundwater Flow Model (MODFLOW; MacDonald and Harbaugh, 1988). Details of groundwater flow model development are included in the 2009 GMR (Appendix A). Golder completed predictive simulations using MODPATH (Pollack, 1989) for particle trace analysis. Details of groundwater flow model predictive simulations are included in the RWOR (Appendix B).

Golder's recovery well optimization effort did not include the 31st and Clifton, 500 Ramp or Englewood recovery well networks. These 31st/Clifton and Englewood well networks have been kept on as an additional level of redundancy in the recovery well network.

3.2 Primary Recovery Well Network

Golder identified the candidate wells for the primary recovery well network (RWN) through an iterative process. The primary RWN represents an array of recovery wells that reduces the number of active recovery wells and the total flow rate of the recovery well system, while maintaining capture of more than 95% of the particles originating from portions of the site with known or historic

groundwater impacts. Initially, Golder selected a sub-set of highly productive wells located downgradient of impacted areas. Golder completed a preliminary site wide capture zone analysis using this sub-set of highly productive wells, identified areas where capture was not complete, and turned on additional wells in those areas. After several iterations of this approach, Golder arrived at the primary RWN shown in Table 3-1 and Figure 3-1.

The primary RWN comprises 58 active recovery wells for a total recovery rate of 19,500 cubic feet per day (cfd) (101 gallons per minute (gpm)). When compared to the 2007 Q1 modeled recovery well network which comprises 135 active wells (>1 cfd extraction rate) for a combined recovery rate of 22,000 cfd (114 gpm), the primary RWN results in a reduction of 77 active wells and 2,500 cfd (13 gpm) less flow from the recovery well network.

3.3 Secondary Recovery Well Network

Based on the results of the uncertainty analysis, Golder included the secondary RWN to add redundancy and additional capacity in areas where the sensitivity analysis indicated potential for compromised capture during optimization of the recovery well network. The wells comprising the secondary RWN are shown in Table 3-1 and Figure 3-1 and Figure 3-2.

The primary and secondary RWN combined comprise 68 active recovery wells for a total recovery rate of 21,100 cfd (110 gpm). When compared to the 2007 Q1 modeled recovery well network which comprises 135 active wells (>1 cfd extraction rate) for a combined recovery rate of 22,000 cfd (114 gpm), the primary RWN results in a reduction of 67 wells and 900 cfd (approximately 4.7 gpm) less flow from the recovery well network.

4.0 SUMMARY AND CONCLUSIONS

The OWP summarizes the ongoing monitoring and recovery well optimization program at the Site. Along with the 2009 Groundwater Modeling Report (contained herein as Appendix A), the OWP provides the basis for the proposed modifications to the existing monitoring well and recovery well networks.

Since the recovery well network optimization represents a change in site groundwater flow, Golder recommends that the full monitoring well optimization be performed after allowing the aquifer to respond to the recovery well network optimization. As such, Golder is proposing a phased approach to implementation of the optimization effort described in this report. The three phases of the optimization effort will be as follows:

- Phase 1: Implementation of the OWP for recovery and monitoring wells systems. Work proposed includes reduction in number of recovery wells, minor reduction in monitoring wells, and a reduction in the frequency of sampling for both recovery and monitoring wells. The number of monitoring wells during the first year of the OWP remains purposely high for one year, to monitor potential changes in groundwater arising from the optimization of the recovery well system (1st Quarter, 2010).
- Phase 2: Following one year of monitoring since implementing recovery well optimization, a review of groundwater data will be used to then optimize the monitoring well system (2011).
- Phase 3: After one additional year of data collection, a final re-evaluation of recovery well and monitoring well optimizations will be conducted and potential modifications for further optimization of the systems will be recommended (2012).

During recovery well network optimization evaluations; Golder identified the candidate wells for the primary recovery well network (RWN) that reduces the number of active recovery wells and the total flow rate of the recovery well system, while maintaining capture. Golder also included a secondary RWN to add redundancy and additional capacity in areas where the sensitivity analysis indicated potential for compromised capture during optimization of the recovery well network. The primary and secondary RWN combined comprise 68 active recovery wells for a total recovery rate of 21,100 cfd (110 gpm). When compared to the 2007 Q1 modeled recovery well network which comprises 135 active wells (>1 cfd extraction rate) for a combined recovery rate of 22,000 cfd (114 gpm), the

primary RWN results in a reduction of 67 wells and 900 cfd (approximately 4.7 gpm) less flow from the recovery well network.

Following establishment of the optimized recovery well system, the sampling programs were developed. The proposed MWN calls for the following sampling for the year 2010:

- Monitoring wells: monthly sampling of 2 wells, quarterly sampling of 35 wells and annual sampling of 169 wells in the third quarter for approximately 296 groundwater samples collected annually, a reduction of 194 monitoring well samples per year (a 40% reduction).

- Recovery wells: quarterly sampling of 3 wells, semi-annual sampling of 70 wells in the first quarter and annual sampling of 179 wells in the third quarter for a total of approximately 258 groundwater samples collected annually, an increase of 47 recovery well samples per year (a 22% increase).

The proposed sampling frequency for the house wells and air strippers does not change from the existing frequency.

The proposed MWN calls for the following sampling for the year 2011:

- Monitoring wells: quarterly sampling of 2 wells, semi-annual sampling of 35 wells and annual sampling of 169 wells in the third quarter for approximately 210 groundwater samples collected annually, a reduction of 280 monitoring well samples per year (a 57% reduction from existing monitoring frequencies).

- Recovery wells: Semi-annual sampling of 3 wells and annual sampling of 179 wells in the third quarter for approximately 182 groundwater samples collected annually, a decrease of 29 recovery well samples per year (a 14% reduction from existing monitoring frequencies).

The proposed MWN calls for the following sampling for the year 2012:

- Monitoring wells: Semi-annual sampling of 10 wells and annual sampling of 169 wells in the third quarter for approximately 179 groundwater samples collected annually, a reduction of 311 monitoring well samples per year (a 63% reduction from existing monitoring frequencies).

- Recovery wells: Annual sampling of 179 wells in the third quarter for approximately 179 groundwater samples collected annually, a decrease of 32 recovery well samples per year (a 15% reduction from existing monitoring frequencies).

A summary of the number of sample locations and samples collected per year for the 2010-2012 proposed monitoring well networks is presented in Table 2-2. The proposed monitoring well network for years 2011 and 2012 may vary depending on results of the recovery well optimization monitoring. The analytical parameters for the proposed monitoring well network will not change from the existing monitoring well network, including annual observation of water levels in the sampled wells.

5.0 REFERENCES

Environmental Simulations Inc., 2007. Groundwater Vistas Version 5.36. Reinholds, Pennsylvania.

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

Pollack, D.W., 1989. Documentation of Computer Programs to Compute and Display Pathlines using results from the United States Geological Survey modular Three-Dimentional Finite-Difference Ground-Water Model. United States Geological Survey Open File Report 89-381, Reston, Virginia.

United States Environmental Protection Agency (USEPA). 2005. Roadmap to Long-Term Monitoring Optimization. EPA 542-R-05-003.

TABLES

TABLE 2-1
EXISTING AND PROPOSED MONITORING WELL NETWORK

FORMER BOEING FACILITY
WICHITA, KANSAS

MONITORING WELLS

	Existing Sampling Frequency			2010 Proposed Sampling Frequency		
Sample ID	Monthly	1st Qtr.	3rd Qtr.	Monthly	Quarterly	Annual
MW-03-01	X		X		X	X
MW-003MK			X			X
MW-004A			X			X
MW-005A			X			X
MW-006A			X			X
MW-007A			X			X
MW-008A	X		X		X	X
MW-015A	X		X		X	X
MW-018A			X			X
MW-019			X			X
MW-020C	X		X		X	X
MW-021C		X	X			X
MW-023			X			X
MW-024A	X		X		X	X
MW-032A			X			X
MW-033		X	X			
MW-034		X	X			
MW-035			X			X
MW-037		X	X			X
MW-039			X			X
MW-040		X	X			X
MW-041A			X			X
MW-043		X	X			
MW-044A			X			X
MW-046			X			X
MW-047		X	X			X
MW-053		X	X		X	X
MW-055			X			X
MW-056	X		X		X	X
MW-058			X			X
MW-058A			X			X
MW-059			X			X
MW-060		X	X			X
MW-061			X			X
MW-061A			X			X
MW-062			X			X
MW-064		X	X			
MW-065		X	X			X
MW-067			X			X
MW-069		X	X			X
MW-074			X			X
MW-075			X			X
MW-076			X			X
MW-078			X			X
MW-080			X			X
MW-081			X			X
MW-082		X	X		X	X
MW-083	X		X	X		X
MW-084		X	X			X
MW-085		X	X			X
MW-086A	X		X		X	X
MW-087A		X	X			
MW-088		X	X			
MW-089	X		X		X	X
MW-092			X			X
MW-093		X	X			
MW-094R			X			X
MW-095R			X			X
MW-096			X			X
MW-097D			X			X
MW-097S	X		X		X	X
MW-102		X	X			
MW-103		X	X			X
MW-104	X		X		X	X
MW-105		X	X			X
MW-109			X			X
MW-110	X		X		X	X
MW-113	X		X		X	X

	Existing Sampling Frequency			2010 Proposed Sampling Frequency		
Sample ID	Monthly	1st Qtr.	3rd Qtr.	Monthly	Quarterly	Annual
MW-117		X	X			X
MW-118			X			X
MW-120		X	X		X	X
MW-121		X	X		X	X
MW-122		X	X		X	X
MW-123		X	X			X
MW-124		X	X			
MW-125			X			
MW-137		X	X			X
MW-138		X	X			X
MW-141			X			X
MW-143			X			X
MW-144			X		X	X
MW-145	X		X		X	X
MW-146			X			X
MW-149		X	X			X
MW-150			X			X
MW-151		X	X			X
MW-152		X	X		X	X
MW-153		X	X		X	X
MW-154		X	X		X	X
MW-155		X	X		X	X
MW-156		X	X		X	X
MW-157		X	X		X	X
MW-158		X	X			X
MW-159		X	X			
MW-160		X	X			X
MW-161		X	X			X
MW-162			X			
MW-163		X	X		X	X
MW-164			X			X
MW-165		X	X			
MW-166		X	X			X
MW-167		X	X			X
MW-168			X			X
MW-169		X	X			X
MW-176			X		X	X
MW-177			X		X	X
MW-178		X	X			X
MW-179		X	X		X	X
MW-180		X	X		X	X
MW-181		X	X			X
MW-182		X	X			X
MW-185	X		X		X	X
MW-186		X	X			X
MW-187		X	X			X
MW-188			X			X
MW-189			X			X
MW-190	X		X	X		X
MW-191			X			X
MW-192			X			X
MW-193	X		X		X	X
MW-194			X			
MW-195			X			
MW-196			X			X
MW-197		X	X			X
MW-198	X		X		X	X
MW-199		X	X		X	X
MW-200			X			X
MW-201			X			X
MW-202			X			X
MW-203			X		X	X
MW-204			X			X
MW-205		X	X			X
MW-206		X	X			X
MW-207		X	X			X
MW-208		X	X			X
MW-209		X	X			X

	Existing Sampling Frequency			2010 Proposed Sampling Frequency		
Sample ID	Monthly	Quarterly	Annual	Monthly	Quarterly	Annual
MW-210		X	X			X
MW-211		X	X			X
MW-212		X	X			X
MW-213		X	X			X
MW-214		X	X			X
MW-215		X	X			X
MW-216		X	X			X
MW-217		X	X			X
MW-218		X	X			X
MW-219		X	X			X
MW-220		X	X			X
MW-221		X	X			X
MW-222		X	X			X
MW-223		X	X			X
MW-224		X	X			X
MW-225		X	X			X
MW-226		X	X			X
BH-02-01S		X	X			X
BH-02-01		X	X			X
BH-02-02S		X	X			X
BH-02-02		X	X			X
BH-02-03S		X	X			X
BH-02-03		X	X			X
BH-02-04S		X	X			X
BH-02-04		X	X			X
BH02-05S		X	X			X
BH-02-05		X	X			X
BH-02-06S		X	X			X
BH-02-06		X	X			X
BH-02-09S		X	X			X
BH-02-09		X	X			X
BH-03-02		X	X			X
BH-03-03		X	X			X
BH-03-04		X	X			X
BH-03-05		X	X			X
BH-03-06		X	X			X
Inj-03-01		X	X			X
Inj-03-02		X	X			X
Inj-03-03		X	X			X
Inj-03-04		X	X			X
Inj-03-05		X	X			X
Inj-03-06		X	X			X
Inj-03-07		X	X			X
Inj-03-08		X	X			X
Inj 05-01		X	X			X
Inj 05-02		X	X			X
Inj 05-03		X	X			X
Inj 05-04		X	X			X
SUBTOTAL Per Event =	18	108	184	2	35	169
Samples Per Year =	11	1	1	11	3	1
Subtotal samples per year =	198	108	184	22	105	169
Total MW Samples per Year =			**490**			**296**

House Wells

	Existing Frequency			Proposed Frequency		
Sample ID	Monthly	1st Qtr.	3rd Qtr.	Monthly	Quarterly	Annual
4300 S.Clifton		X	X			X
3431 Craig		X	X			X
3524 Craig		X	X			X
3422 Craig		X	X			X

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TABLE 2-1
EXISTING AND PROPOSED MONITORING WELL NETWORK

FORMER BOEING FACILITY
WICHITA, KANSAS
RECOVERY WELLS

	Existing Sampling Frequency			2010 Proposed Sampling Frequency		
Sample ID	Monthly	1st Qtr.	3rd Qtr.	Quarterly	Semi-Annual	Annual
RW-002B			X			X
RW-002FF			X			X
RW-004AA			X		X	X
RW-004FF			X			X
RW-005A			X			X
RW-006A			X			X
RW-007A			X			X
RW-008A			X			X
RW-009A			X			X
RW-010AA			X			X
RW-011A			X		X	X
RW-012A			X		X	X
RW-013A			X			X
RW-014			X			X
RW-015A			X			X
RW-016			X			X
RW-017			X			X
RW-018A			X			X
RW-019A			X		X	X
RW-020			X			X
RW-026			X		X	X
RW-027A			X			X
RW-028A			X		X	X
RW-029			X			X
RW-030			X			X
RW-031			X			X
RW-033A			X		X	X
RW-034			X			X
RW-035A			X			X
RW-040			X			X
RW-041			X			X
RW-042			X			X
RW-043			X			X
RW-044			X			X
RW-045			X		X	X
RW-046A			X		X	X
RW-047A			X		X	X
RW-049A			X		X	X
RW-052			X			X
RW-053			X		X	X
RW-054			X		X	X
RW-055			X		X	X
RW-056			X			X
RW-057			X		X	X
RW-058			X		X	X
RW-059			X			X
RW-060			X		X	X
RW-061			X		X	X
RW-062			X		X	X
RW-063			X	X		X
RW-064			X			X
RW-065			X			X
RW-066			X		X	X
RW-067			X			X
RW-068			X	X		X
RW-069			X			X
RW-070			X		X	X
RW-071			X			X
RW-072			X			X
RW-073			X	X		X
RW-074			X			X
RW-075			X			X
RW-076			X			X
RW-077			X			X
RW-078			X			X
RW-079			X		X	X
RW-080			X		X	X
RW-081			X		X	X

	Existing Sampling Frequency			2010 Proposed Sampling Frequency		
Sample ID	Monthly	1st Qtr.	3rd Qtr.	Quarterly	Semi-Annual	Annual
RW-082			X		X	X
RW-083			X			X
RW-084			X			X
RW-085			X		X	X
RW-086			X			X
RW-087			X		X	X
RW-088			X			X
RW-089			X			X
RW-090			X			X
RW-091			X			X
RW-092			X			X
RW-093			X		X	X
RW-094			X		X	X
RW-095			X		X	X
RW-096			X		X	X
RW-097			X		X	X
RW-098			X		X	X
RW-099A			X			X
RW-100			X			X
RW-101			X		X	X
RW-102			X			X
RW-103			X			X
RW-104			X			X
RW-105			X			X
RW-106			X			X
RW-107			X			X
RW-108			X			X
RW-113			X			X
RW-114			X			X
RW-115			X			X
RW-116			X		X	X
RW-117			X			X
RW-118			X			X
RW-120			X			X
RW-122			X			X
RW-125			X			X
RW-127			X		X	X
RW-128			X			X
RW-129			X			X
RW-130			X			X
RW-131			X			X
RW-132			X			X
RW-133			X			X
RW-134			X			X
RW-135			X			X
RW-136			X			X
RW-137			X			X
RW-138			X			X
RW-139			X			X
RW-140			X			X
RW-141			X			X
RW-142			X		X	X
RW-143			X		X	X
RW-144			X			X
RW-145			X		X	X
RW-146			X		X	X
RW-147			X		X	X
RW-148			X			X
RW-149	X		X		X	X
RW-150			X			X
RW-151			X			X
RW-152			X		X	X
RW-153			X		X	X
RW-154			X			X
RW-155			X			X
RW-156			X			X
RW-157			X			X
RW-158			X			X

	Existing Sampling Frequency			2010 Proposed Sampling Frequency		
Sample ID	Monthly	1st Qtr.	3rd Qtr.	Quarterly	Semi-Annual	Annual
RW-159			X			X
RW-160			X			X
RW-161R			X			X
RW-162R			X			X
RW-163R			X			X
RW-164R		X	X			X
RW-165R			X			X
RW-170			X			X
RW-171			X			X
RW-181			X		X	X
RW-182			X			X
RW-183			X			X
RW-184			X			X
RW-185			X			X
RW-186			X			X
RW-187			X			X
RW-188			X			X
RW-189			X			X
RW-190			X		X	X
RW-191			X		X	X
RW-192			X		X	X
RW-193			X		X	X
RW-194			X		X	X
RW-195		X	X		X	X
RW-196		X	X		X	X
RW-197		X	X		X	X
RW-198		X	X		X	X
RW-199		X	X		X	X
RW-200		X	X		X	X
RW-201		X	X		X	X
RW-202		X	X		X	X
RW-203		X	X		X	X
RW-204		X	X		X	X
RW-205		X	X		X	X
RW-206		X	X		X	X
RW-207		X	X		X	X
RW-208		X	X		X	X
RW-209		X	X		X	X
RW-210		X	X		X	X
RW-211		X	X		X	X
RW-212		X	X		X	X
RW-213		X	X		X	X
RW-214		X	X		X	X
SUBTOTAL Per Event =	1	21	179	3	70	179
Samples Per Year =	11	1	1	3	1	1
Subtotal Samples Per Year =	11	21	179	9	70	179
Total RW Samples per Year =			**211**			**258**

Air Strippers

	Existing Frequency	Proposed Frequency		
Sample ID	Quarterly	Quarterly	Annual	Bi-annual
Main	X	X		
S. Campus	X	X		
Plant 1	X	X		
Plant 2	X	X		
Activity Center	X	X		
Fuel Farm	X	X		
D-9	X	X		
K-15	X	X		
IPB2	X	X		
Clifton	X	X		
Englewood	X	X		

Reference:
Existing monitoring well network based on excel spreadsheet "monitoring schedule 2009.xls" provided by Boeing.

Prepared by: _____
Checked by: _____
Reviewed by: _____

DRAFT

TABLE 2-2
ANNUAL SAMPLING QUANTITIES FOR THE EXISTING AND PROPOSED MONITORING WELL NETWORK

FORMER BOEING FACILITY
WICHITA, KANSAS

	2009	2010	2011*	2012*
NUMBER OF SAMPLE LOCATIONS				
Monitoring Wells	184	169	169	169
Recovery Wells	179	179	179	179
House Samples	4	4	4	4
Air Strippers	11	11	11	11
TOTAL	378	363	363	363
% Reduction from 2009	0%	-4%	-4%	-4%

ANALYTICAL SAMPLES PER YEAR				
Monitoring Wells	490	296	210	179
Recovery Wells	211	258	182	179
House Samples	8	4	4	4
Air Strippers	44	44	44	44
TOTAL	753	602	440	406
% Reduction from 2009	0%	-20%	-42%	-46%

* 2011 and 2012 sampling quantities are projected and may vary depending on the results of recovery well optimiz monitoring.

Prepared by: _____
Checked by: _____
Reviewed by: _____

DRAFT

TABLE 3-1
PRIMARY AND SECONDARY RECOVERY WELL NETWORK RATES

BOEING FACILITY
WICHITA, KANSAS

Extraction Well ID	Flow Rate[1] ft^3/day	gpm
RW-004AA	-389	-2.02
RW-011A	-1003	-5.21
RW-012A	-87	-0.45
RW-019A	-631	-3.28
RW-026	-1196	-6.21
RW-028A	-264	-1.37
RW-033	-566	-2.94
RW-045	-1985	-10.31
RW-046A	-55	-0.29
RW-047A	-174	-0.90
RW-049A	-272	-1.41
RW-053	-617	-3.21
RW-054	-375	-1.95
RW-055	-179	-0.93
RW-057	-1154	-5.99
RW-058	**-252**	**-1.31**
RW-060	***-40***	***-0.21***
RW-061	-107	-0.56
RW-062	-173	-0.90
RW-066	-245	-1.27
RW-070	-689	-3.58
RW-079	**-11**	**-0.06**
RW-080	-255	-1.32
RW-081	**-25**	**-0.13**
RW-082	-437	-2.27
RW-085	-381	-1.98
RW-087	-392	-2.04
RW-093	-526	-2.73
RW-094	-2713	-14.09
RW-095	-1551	-8.06
RW-096	-387	-2.01
RW-097	-794	-4.12
RW-098	**-67**	**-0.35**
RW-101	**-344**	**-1.79**
RW-116	**-308**	**-1.60**
RW-127	**-475**	**-2.47**
RW-142	**-22**	**-0.11**
RW-143	**-29**	**-0.15**
RW-145	-28	-0.15
RW-146	-35	-0.18
RW-147	-14	-0.07
RW-149	**-86**	**-0.45**
RW-152	***-85***	***-0.44***
RW-153	***-25***	***-0.13***
RW-181	-7.3	-0.04
RW-192	-433	-2.25
RW-193	-32	-0.17
RW-194	-132	-0.69
RW-195	-15	-0.08
RW-196	-133	-0.69
RW-197	-18	-0.09
RW-198	-178	-0.92
RW-199	-26	-0.14
RW-200	-9.4	-0.05
RW-201	-78	-0.41
RW-202	-55	-0.29
RW-203	-213	-1.11
RW-204	-0.42	<0.01
RW-205	-1.6	<0.01
RW-206	-4.1	-0.02
RW-207	-51	-0.26
RW-208	-26	-0.14
RW-209	-212	-1.10
RW-210	-14	-0.07
RW-211	-6.2	-0.03
RW-212	-8.8	-0.05
RW-213	-12	-0.06
RW-214	-14	-0.07
Sum of Modeled Extraction Well Rates =	**-21,123**	**-110**

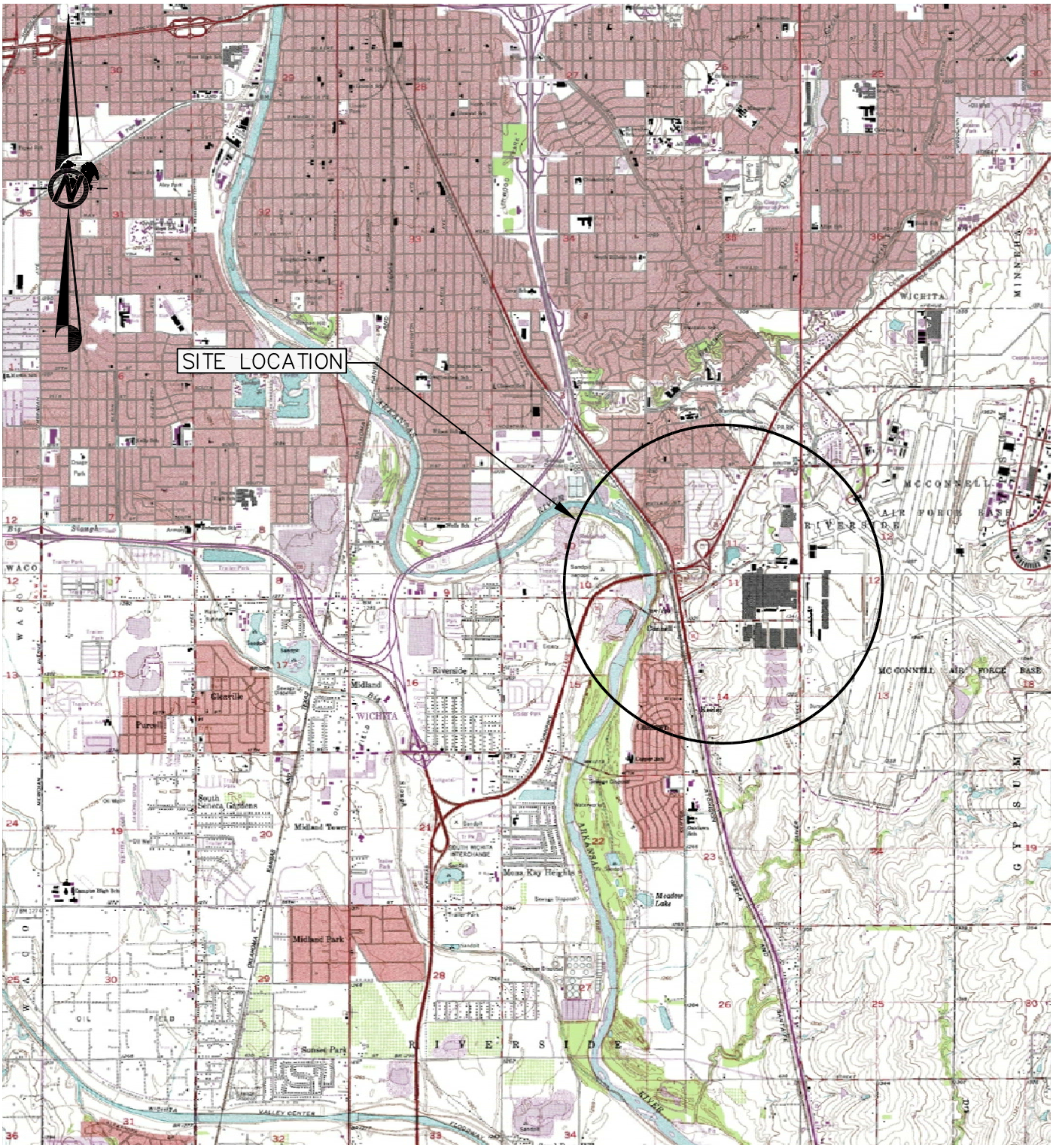
Notes:
1) Well rates based on 2006-2007 average well rates from "Pumping_rates_Model08.xls" provided by Franz Environmental Inc
gpm = gallons per minute
Negative rates indicate water being removed from model
BOLD indicates secondary recovery well
BOLD ITALICS indicates primary recovery well with increased flow rate

Reference:
Pumping and extraction rates from monthly extraction well meter reading excel spreadsheet files provided by Boeing and summary files provided by Franz Environmental Inc.

Prepared by: _____
Checked by: _____
Reviewed by: _____

DRAFT

FIGURES



REFERENCES

BASE MAPS TAKEN FROM 7.5 MINUTE USGS QUADRANGLE MAPS TITLED, "DERBY, KS.", DATED 1961. AND "WICHITA EAST, KS" DATED 1960.

5000 0 5000

SCALE APPROXIMATE FEET

Golder Associates
Manchester, New Hampshire

FILE No.	09381501A008	SCALE	AS SHOWN
PROJECT No.	093-81501	REV. 0	DATE 08/21/09
			DESIGN RWB
			CADD MPB
			CHECK RWB
			REVIEW THR

TITLE

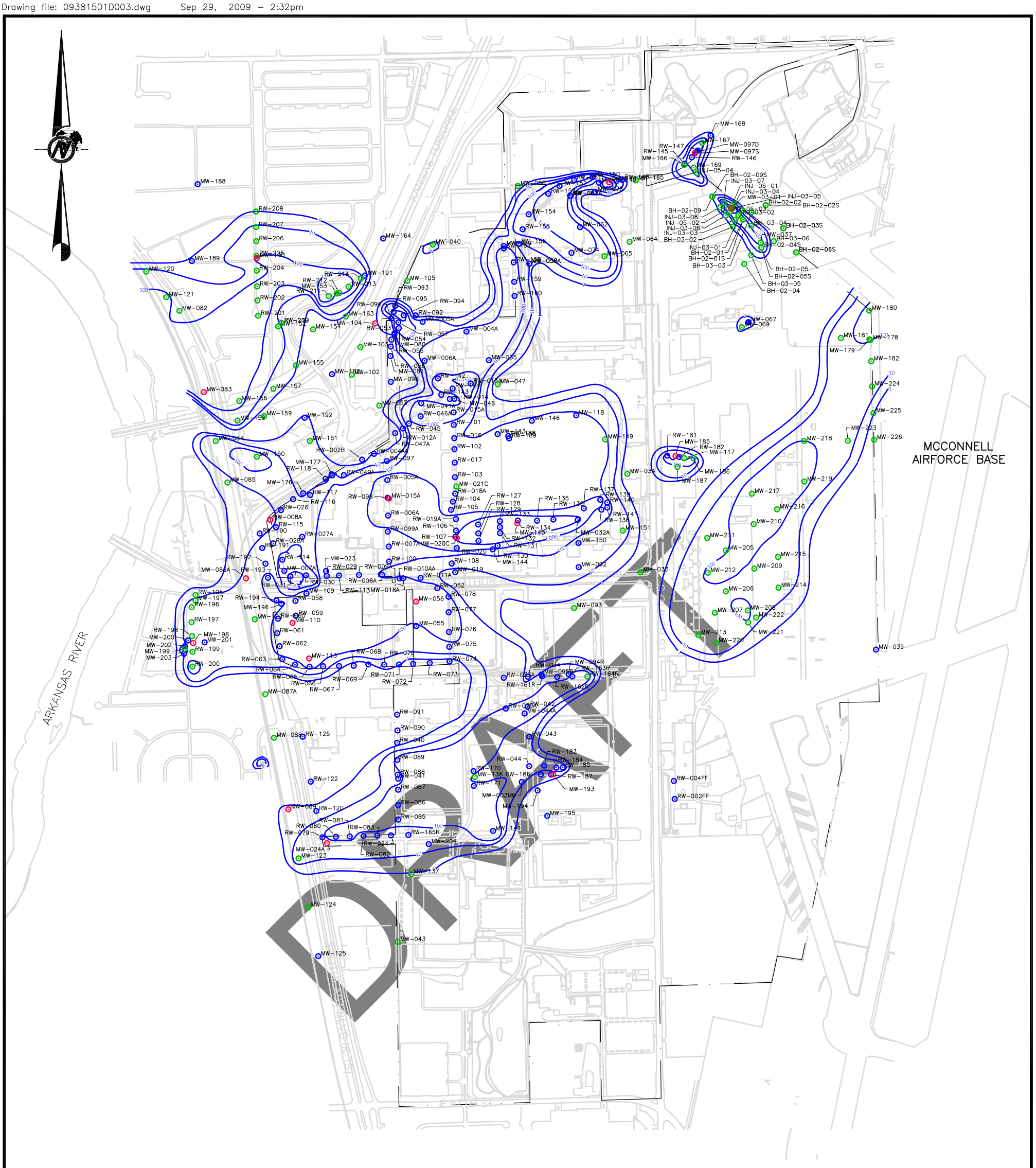
SITE LOCATION MAP

THE BOEING COMPANY
BOEING AND MCCONNELL AIR FORCE BASE
WICHITA, KANSAS

FIGURE 1

Drawing file: 09381501A008.dwg Aug 21, 2009 - 4:24pm

Drawing file: 09381501D003.dwg Sep 29, 2009 – 2:32pm



LEGEND

APPROXIMATE BOEING PROPERTY BOUNDARY

TVOC CONTOURS

NOTE

2008 TOTAL VOLATILE ORGANIC COMPOUND (TVOC) CONTOURS BASED ON CAD FILE "208TVOC.DXF" PROVIDED BY BOEING

FREQUENCIES

- MONTHLY FREQUENCY
- QUARTERLY FREQUENCY
- SEMI–ANNUAL FREQUENCY
- ANNUAL FREQUENCY
- NOT SAMPLED

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

2.) EXTENT OF STREAMS AND RIVERS BASED ON CADD FILE TITLED "STREAMS.DXF" PROVIDED BY FRANZ ENVIRONMENTAL INC.

1000 0 1000
SCALE FEET

FIGURE 2-1

REVIEW		
CHECK		
CADD	BCL	09/28/09
DESIGN	RWB	05/11/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501D003	
PROJECT No.	093–81501	

TITLE

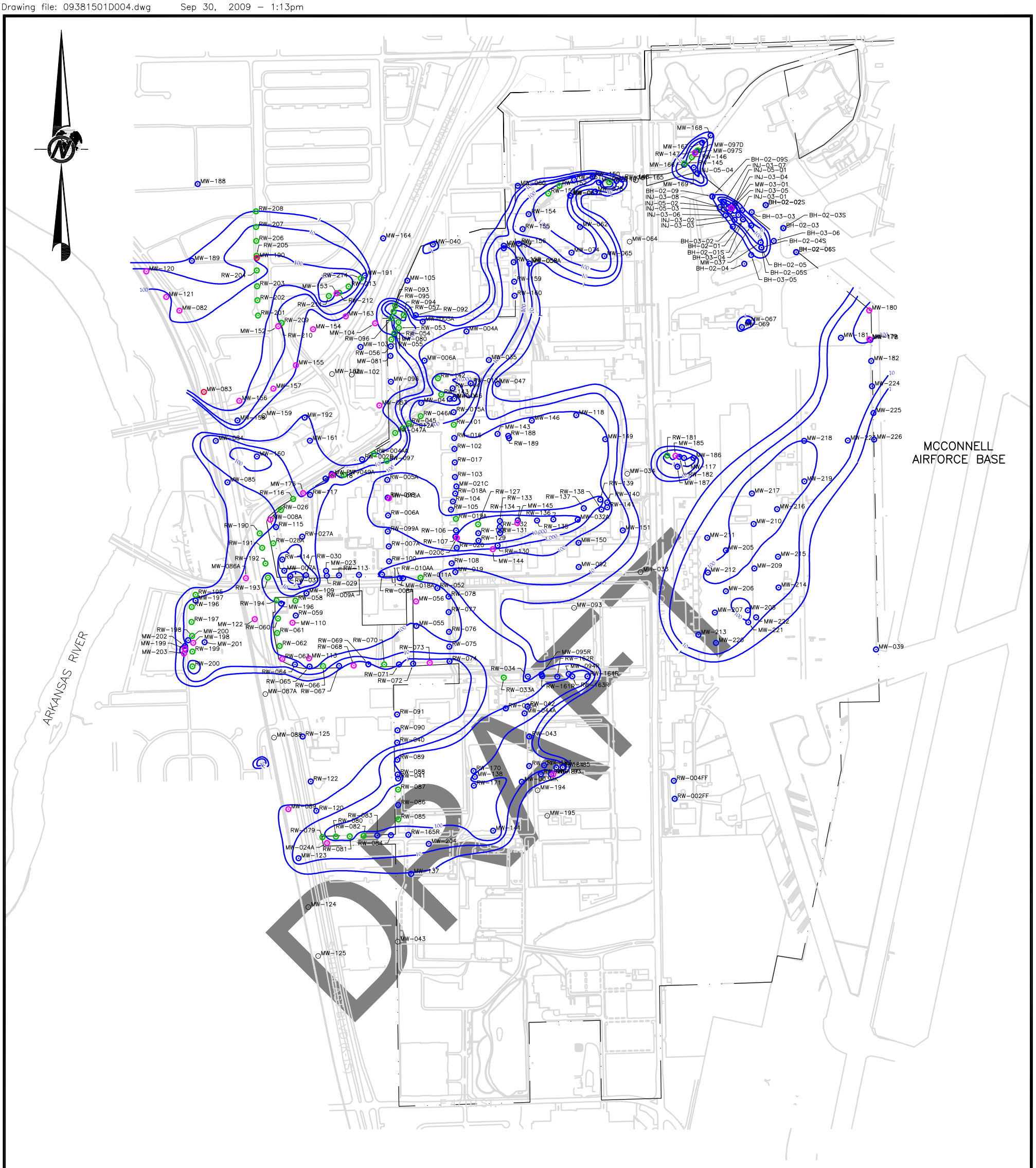
EXISTING MONITORING WELL NETWORK

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501D004.dwg Sep 30, 2009 – 1:13pm



LEGEND

APPROXIMATE BOEING PROPERTY BOUNDARY

TVOC CONTOURS

NOTE

2008 TOTAL VOLATILE ORGANIC COMPOUND (TVOC) CONTOURS BASED ON CAD FILE "208TVOC.DXF" PROVIDED BY BOEING

FREQUENCIES

- MONTHLY FREQUENCY
- QUARTERLY FREQUENCY
- SEMI–ANNUAL FREQUENCY
- ANNUAL FREQUENCY
- NOT SAMPLED

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

2.) EXTENT OF STREAMS AND RIVERS BASED ON CADD FILE TITLED "STREAMS.DXF" PROVIDED BY FRANZ ENVIRONMENTAL INC.

1000 0 1000
SCALE FEET

FIGURE 2-2

REVIEW		
CHECK		
CADD	BCL	09/29/09
DESIGN	RWB	05/11/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501D004	
PROJECT No.	093–81501	

TITLE

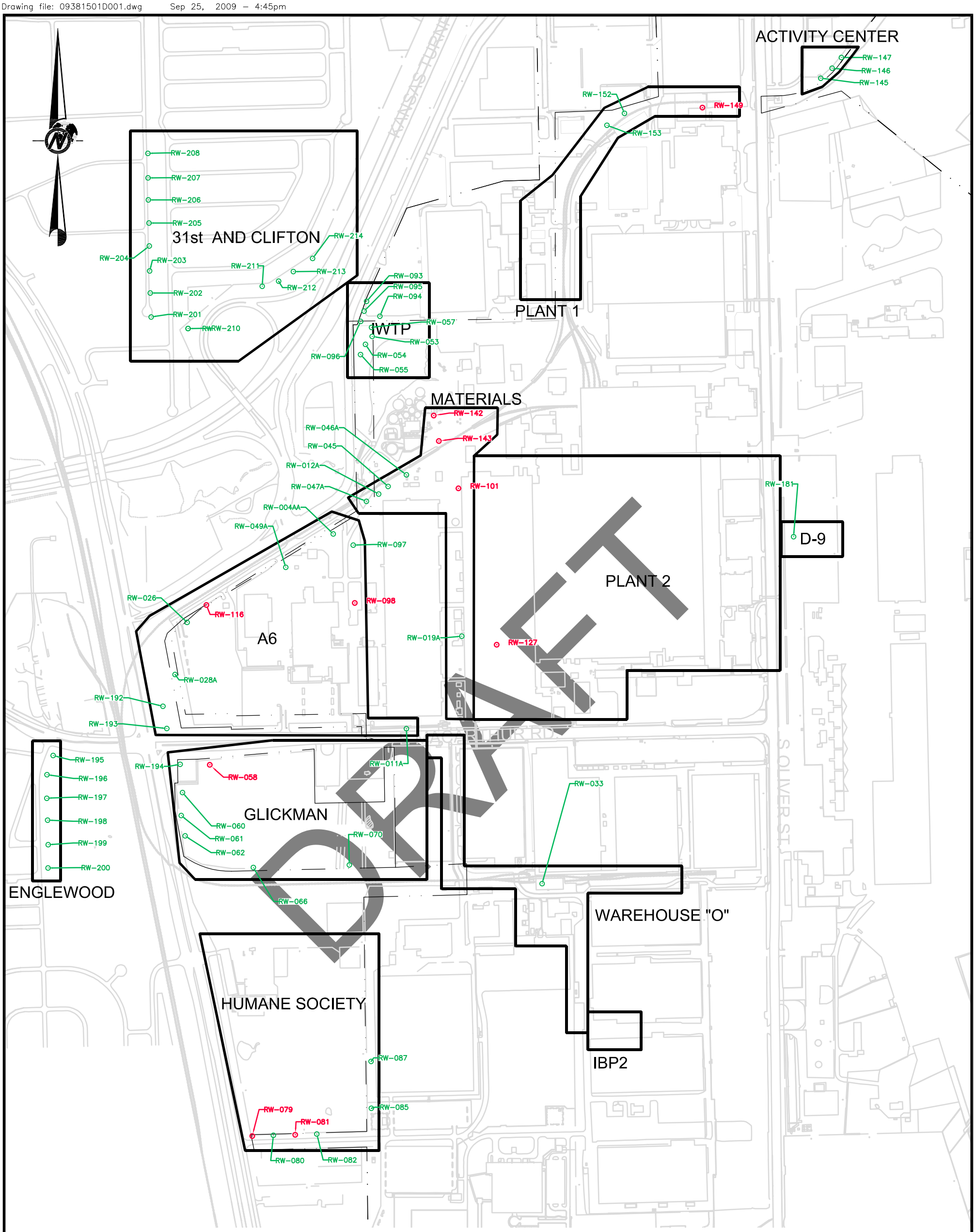
PROPOSED MONITORING WELL NETWORK

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501D001.dwg Sep 25, 2009 – 4:45pm



LEGEND

- APPROXIMATE BOEING PROPERTY BOUNDARY
- RECOVERY WELL NETWORK SUB–AREAS
- RW–087 PRIMARY RECOVERY WELL NETWORK WELLS
- RW–079 SECONDARY RECOVERY WELL NETWORK WELLS

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

600 0 600
SCALE FEET

FIGURE 3-1

REVIEW	
CHECK	
CADD	BCL 09/25/09
DESIGN	RWB 05/11/09
REV. 0	SCALE AS SHOWN
FILE No.	09381501D001
PROJECT No.	093–81501

TITLE

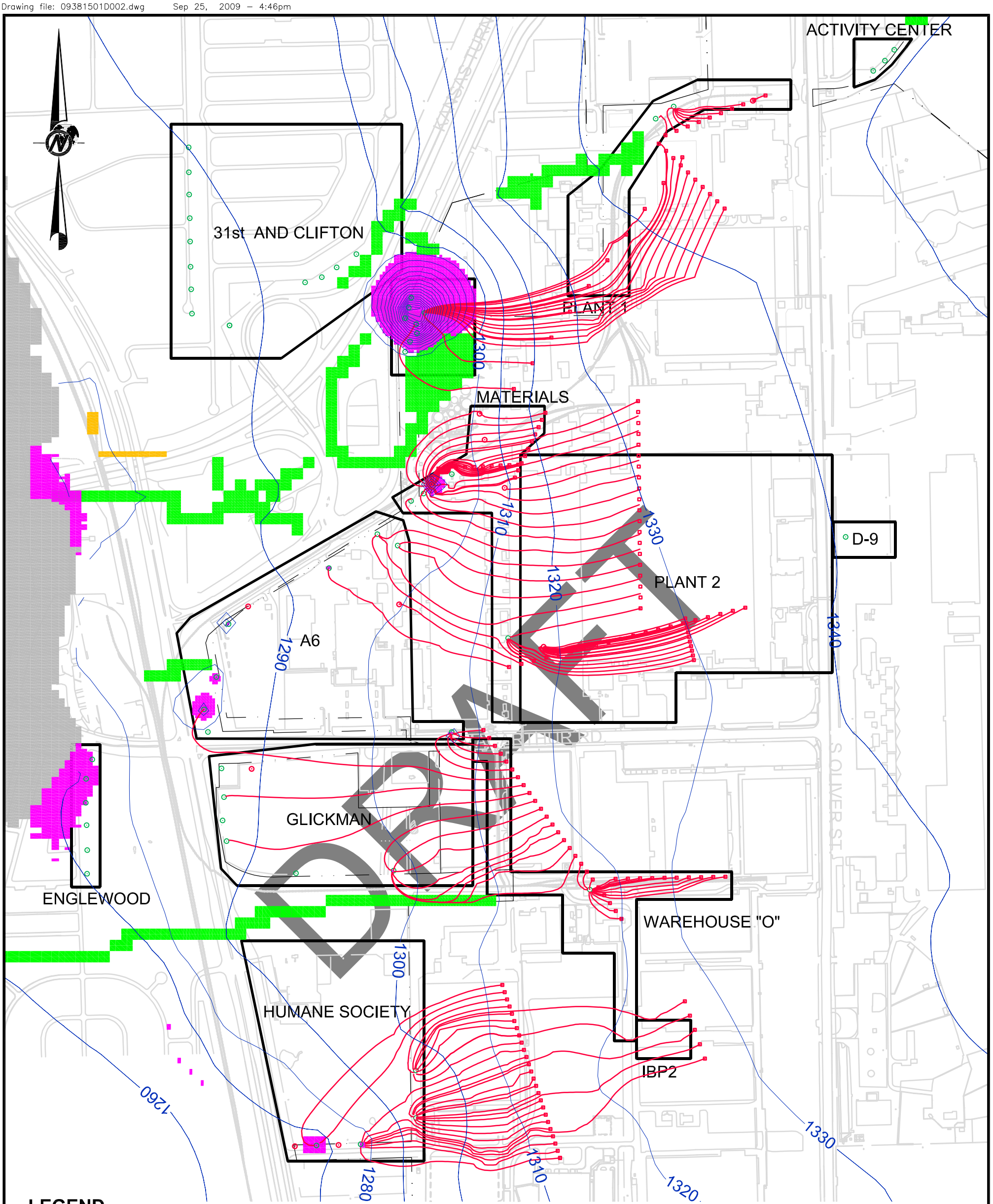
PRIMARY AND SECONDARY OPTIMIZATION RECOVERY WELL LOCATIONS

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501D002.dwg Sep 25, 2009 – 4:46pm



LEGEND

- PARTICLE TRACE
- 1270 GROUNDWATER ELEVATION CONTOUR
- APPROXIMATE BOEING PROPERTY BOUNDARY
- RECOVERY WELL NETWORK SUB–AREAS
- DRY
- GHB
- RIVER
- DRAIN
- NO FLOW
- PRIMARY RECOVER WELL NETWORK
- SECONDARY RECOVERY WELL NETWORK

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

NOTES

1.) GHB = GENERAL HEAD BOUNDARY

2.) NO FLOW CELLS REPRESENT PARTIALLY SATURATED OR UNSATURATED CONDITIONS.

600 0 600
SCALE FEET

FIGURE 3-2

REVIEW		
CHECK		
CADD	BCL	09/25/09
DESIGN	RWB	05/11/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501D002	
PROJECT No.	093–81501	

TITLE

MODPATH MODEL - PRIMARY AND SECONDARY OPTIMIZATION CAPTURE ANALYSIS

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

APPENDIX A

2009 GROUNDWATER MODELING REPORT

Golder Associates Inc.
670 Commercial Street, Suite 103
Manchester, NH 03101-1146
Telephone: (603) 668-0880
Fax: (603) 668-1199
www.golder.com

2009 GROUNDWATER MODELING REPORT
FORMER BOEING FACILITY
WICHITA, KANSAS

Prepared for:

The Boeing Company
2727 East MacArthur
Wichita, Kansas 67216

Prepared by:

Golder Associates Inc.
670 North Commercial Street
Suite 103
Manchester, NH 03101

Distribution:

6 Copies – Boeing
2 Copies – Golder

August 2009 Our Ref.: 093-81501

Golder Associates Inc.
670 Commercial Street, Suite 103
Manchester, NH 03101-1146
Telephone: (603) 668-0880
Fax: (603) 668-1199
www.golder.com

August 21, 2009

The Boeing Company
2727 East MacArthur
Wichita, Kansas 67216

Attn: Mr. Michael Spain

RE: 2009 GROUNDWATER MODELING REPORT
BOEING FACILITY
WICHITA, KANSAS

Dear Mr. Spain:

As requested by the Boeing Company (Boeing), Golder Associates Inc. (Golder) prepared this 2009 Groundwater Modeling Report (2009 GMR) for the Former Boeing Facility at 4615 South Oliver Street in Wichita, Kansas. The 2009 groundwater modeling studies serve as part of the "Optimization Work Plan" (OWP) requested by the Kansas Department of Health and Environment (KDHE) in their July 27, 2009 letter. The OWP will provide the technical basis upon which monitoring, extraction/injection and treatment alternatives can be developed for the site. The OWP will be submitted to KDHE separately, and will include the 2009 GMR as an appendix.

Should you have any questions regarding this report, please do not hesitate to call.

Sincerely,

GOLDER ASSOCIATES INC.

Eric Kern, Ph.D.
Senior Microbiologist

Ross Bennett, P.E.
Project Engineer

Todd H. Rees, Ph.D., P.E.
Program Leader and Principal

EXECUTIVE SUMMARY

As requested by the Boeing Company (Boeing), Golder Associates Inc. (Golder) prepared this 2009 Groundwater Modeling Report (2009 GMR) for the Boeing Facility at 4615 South Oliver Street in Wichita, Kansas (the Site) (Figure 1-1).

The 2009 GMR follows the KDHE Bureau of Environmental Remediation/Remedial (BER) Section Guideline "Minimum Standards for Model Use," (BER-RS-007) for developing a calibrated and verified groundwater flow model. This includes defining/describing:

a) Purpose and scope;
b) Geology, hydrology, lithology and analytical data;
c) Data sources;
d) Conceptual model;
e) Model selection (numerical);
f) Documentation of calculations (numerical implementation);
g) Calibration and verification; and
h) Sensitivity analysis.

To accomplish these goals, Golder developed a steady-state groundwater flow model using the United States Geological Survey (USGS) Modular Three-Dimensional Finite-Difference Groundwater Flow Model (MODFLOW; MacDonald and Harbaugh, 1988) and MODPATH (Pollack, 1989) for particle trace analysis.

Prior to development of the groundwater flow model, Golder reviewed data pertaining to the Site hydrogeologic conceptual model. The Site hydrogeologic conceptual model is controlled by silt, sand, and clay aquifer materials overlaying bedrock and weathered bedrock (grey clay) aquicludes. Aquifers are predominantly fluvial sands and silts and loess silts and clays. Groundwater generally flows from northeast to southwest with components of flow to the west and northwest in areas of the model.

Development of the steady-state Site numerical groundwater flow model involved the following steps:

- Definition of the model geometry including lateral and vertical extent, number of model layers, grid layout, and location of recharge and discharge areas (boundary conditions);
- Selection of input parameters such as hydraulic conductivity (horizontal and vertical) and precipitation/evapotranspiration;
- Calibration to measured conditions (First Quarter 2007) and completion of sensitivity analysis; and
- Model verification to evaluate the calibration against an additional measured conditions (Third Quarter 1990).

Through standard numerical groundwater modeling procedures, Golder designed and constructed a steady state groundwater flow model of the Site that is considered calibrated and verified, as determined by using the model to simulate recent conditions as well as a time period with fewer recovery wells pumping at a lower pumping rate. The numerical groundwater model can be used to evaluate proposed changes to the groundwater monitoring and recovery systems, and to enhance groundwater remediation at the Site.

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1.0 INTRODUCTION

1.1 Objectives

As requested by the Boeing Company (Boeing), Golder Associates Inc. (Golder) prepared this 2009 Groundwater Modeling Report (2009 GMR) for the Former Boeing Facility at 4615 South Oliver Street in Wichita, Kansas (the Site) (Figure 1-1). The 2009 GMR is a component of the ongoing monitoring and recovery well optimization program at the Site. In their July 27, 2009 letter, the Kansas Department of Health and Environment (KDHE) identified three tasks to be completed by Boeing to "update the current administrative framework for investigation and remediation activities." Those tasks included:

- Vapor Intrusion Investigation Work Plan;
- Groundwater Monitoring and Recovery Well Optimization, including an "Optimization Work Plan" (OWP); and
- Feasibility Study (FS) Revisions.

The 2009 groundwater modeling studies serve as part of the OWP, and provide the technical basis upon which monitoring, extraction/injection and treatment alternatives can be developed for the site. The OWP will be submitted to KDHE separately, and will include the 2009 GMR as an appendix.

The general purpose for using groundwater modeling at a site is to assist in developing more optimal, technical solutions to overall site remediation. As KDHE noted, the OWP "should include an evaluation of the existing monitoring and recovery well networks and recommendations for optimizing the number of monitoring wells sampled, sampling methods, frequency of sampling, and analytical parameters… For recovery wells, the evaluation should address location and number of wells to achieve containment and achievement of remedial action objectives for the Site."

Groundwater monitoring and remediation systems need accurate 3-dimensional groundwater direction and velocity information to best utilize resources for more optimal monitoring networks and treatment applications. For the OWP, the general scope of the groundwater modeling is to:

- Simulate the groundwater flow regimes;
- Predict the extent of existing capture zones;
- Optimize the groundwater monitoring and recovery systems;

- Predict the results of in-situ remedial pilot test(s) (i.e., flow components); and
- Demonstrate hydraulic control/capture will be maintained during optimization of the groundwater extraction system.

The 2009 GMR generally follows the KDHE Bureau of Environmental Remediation/Remedial (BER) Section Guideline "Minimum Standards for Model Use," (BER-RS-007). As stated in BER-RS-007, the report must include (very briefly):

a) Purpose and scope;
b) Geology, hydrology, lithology and analytical data;
c) Data sources;
d) Conceptual model;
e) Model selection (numerical);
f) Documentation of calculations (numerical implementation);
g) Calibration and verification;
h) Sensitivity analysis;
i) Model results (predictive simulations); and
j) Probable results (uncertainty simulations).

This 2009 GMR will provide details on the tasks a) through h). However, both predictive and uncertainty simulations (tasks i) and j), respectively) will be performed as part of the OWP and the FS revisions.

2.0 GEOLOGIC/HYDROGEOLOGIC CHARACTERIZATION AND CONCEPTUALIZATION

2.1 Geology

2.1.1 Regional Geology

The Site is located in the Arkansas River Lowland (or Great Bend Lowland) in Sedgwick County, about five miles south of downtown Wichita, Kansas (see Figures 1-1 and 2-1). The Arkansas River Lowland is described as a flat, smooth plain that drains to the Arkansas River (Bevins, 1989).

2.1.2 Site Geology

The Site vicinity is underlain at the surface by unconsolidated deposits of loess (silt with caliche nodules and sand) and the Arkansas River Valley fill (fluvial sands) (Bevins, 1989). Permian age bedrock of the Wellington formation underlies the unconsolidated deposits. The Wellington Formation consists of "gray and blue shale with small, thin beds of maroon shale, impure limestone, gypsum, and anhydrite" (Bevins, 1989). A detailed discussion of Site Geology is presented in the report titled 3-D Groundwater Flow Model for the Boeing Facility, Wichita, Kansas prepared by Beatty Franz Associates (BFA, 1998). BFA summarized site geology in terms of four geologic units:

- Brown clay: surface deposits of loess silts and clays;
- Fluvial deposits: relatively higher transmissivity sand, sandstone, silty sand and clayey sand;
- Olive clay: weathered Wellington Shale; and
- Wellington Shale bedrock.

Geological cross sections illustrating site lithology are provided in Appendix A and on Figure 2-2. The cross sections provided in Appendix A present a detailed view of lithology at the Site, as developed during previous modeling efforts (Franz, 1998). Golder's conceptual interpretation of these sections (as defined in the Modflow model, Golder, herein) is provided on Figure 2-2.

2.2 Hydrogeology

2.2.1 Site Hydrogeology

The Site receives groundwater from precipitation recharge (precipitation minus runoff and evapotranspiration losses), groundwater inflow from adjacent areas, and losing stream reaches. The aquifer in the Site vicinity discharges groundwater to the Arkansas River and its tributaries.

The climate of the Arkansas River Lowland is continental, with approximately 30 inches of annual rainfall. The majority of annual rainfall (approximately three quarters) occurs between the months of April and September. However, Bevins (1989) indicated that the majority of groundwater recharge likely occurs during late winter and early spring due to diminished evapotranspiration during this time.

Groundwater at the site is generally encountered at a depth of 15 to 25 feet bgs. Groundwater flow occurs in the interbedded sand units in the aquifer, which are not continuous throughout the site. The majority of aquifer materials encountered in the Site vicinity typically exhibit low hydraulic conductivities. Relatively thin layers of sandy, higher hydraulic conductivity, fluvial deposits are observed in several borings just above the weathered bedrock surface of the Wellington Shale. The high contrast in hydraulic conductivity between the sand layers, overlying silts/clays and the underlying shale may create a condition such that the sand layers and the underlying bedrock surface exert a strong influence on groundwater flow and contaminant transport. The geometry of the sand layers will exert a strong local influence on the movement of groundwater and contaminants. The location and geometry of the sand units at the site, as defined by borehole logs, are included in Appendix A.

2.2.2 Hydraulic Conductivity Testing

BFA (1998) summarized historic aquifer test analysis results for Site monitoring and recovery wells in terms of the four geologic materials presented in Section 2.1.2. Golder interpreted these aquifer test results, as summarized in Appendix A, to assign initial model hydraulic conductivity values to Site Aquifer materials. According to BFA, the average calculated hydraulic conductivities were

- Between 1.75×10^{-4} to 1.29×10^{-3} cm/s (0.50 to 3.7 ft/day) for wells screened in the brown clay materials;
- Between 7.11×10^{-4} to 1.95×10^{-2} cm/s (2.0 to 32 ft/day) for wells screened in the fluvial materials; and
- Between 2.76×10^{-5} to 1.27×10^{-3} cm/s (0.080 to 3.7 ft/day) for wells screened in the olive clay materials.

2.2.3 Groundwater Recovery

Boeing has operated a groundwater recovery system at the Site since 1987. The recovery system commenced in 1987 with approximately 50 recovery wells in operation. A major upgrade to the recovery system was completed ca. 1992-1993 with the addition of the IWTP wells and other wells at the site. Additional wells have been connected to the system since 1992, and the current number of operating recovery wells is approximately 140. Table 2-1 summarizes the total volume of groundwater pumped from the recovery system wells between 1987 and 2008. The recently active Boeing groundwater recovery system wells are shown as RW - wells on Figure 3-8. As of 2008, the Boeing groundwater recovery system extracts approximately 86.0 million gallons per year. Extracted groundwater is currently treated and either recycled on-site as process water or discharged to surface water under a National Pollution Discharge Elimination System (NPDES) permit.

2.2.4 Conceptual Hydrogeologic Model

The Site hydrogeologic conceptual model is controlled by silt, sand, and clay aquifer materials overlaying bedrock and weathered bedrock (grey clay) aquicludes. The aquifers are recharged primarily by precipitation recharge during late winter and early spring (Bevins, 1989). The Site hydrogeologic model is also influenced by the Boeing remedial extraction system. Aquifers are predominantly fluvial sands and silts, loess silts/clays and weathered bedrock clays. Groundwater generally flows from northeast to southwest with components of flow to the west and northwest in areas of the model.

3.0 GROUNDWATER FLOW MODEL DEVELOPMENT

3.1 Introduction

Golder developed the groundwater flow model for the site using the United States Geological Survey (USGS) Modular Three-Dimensional Finite-Difference Groundwater Flow Model (MODFLOW; MacDonald and Harbaugh, 1988). We selected this code because:

- MODFLOW's flexibility allows for extensive calibration and sensitivity analysis;
- MODFLOW can be used for steady state and transient simulations; and
- MODFLOW is generally considered one of the most reliable, verified, and commonly used groundwater flow models available.

The pre- and post-processing software we used for the modeling was Groundwater Vistas Version 5.05 (Environmental Simulations Inc., 2007). The following discussions present the model approach, design assumptions, calibration, verification, sensitivity analysis and results.

3.2 Numerical Implementation

Development of a numerical groundwater flow model involves the following steps:

- Definition of the model geometry including lateral and vertical extent, number of model layers, grid layout, and location of recharge and discharge areas, rivers and streams;
- Selection of input parameters such as hydraulic conductivity (horizontal and vertical) and precipitation/evapotranspiration;
- Calibration to measured conditions (First Quarter 2007) and completion of sensitivity analysis;
- Model verification to evaluate the calibration against a second set of measured conditions (Third Quarter 1990); and
- Use of the model as predictive tool.

The following sections describe these steps used to develop the model.

3.2.1 Model Geometry

The southwest corner of the model grid (model coordinates 0, 0) corresponds with Site coordinates E1,657,500 and N1,651,740. The model grid is oriented along the axis of the state plane coordinate system (zero degree rotation). The finite-difference model grid location is shown on Figure 3-1**.** The model area (excluding no-flow cells) is approximately 11,525 feet (along x-axis) by 20,145 feet (along y-axis). As shown in Figure 3-1, the active cells of the model grid are bounded to the north by Gypsum creek and its tributaries, to the west by the Arkansas River, to the south by McConnell Creek and to the east by no-flow cells along a groundwater divide near the McConnell Air Force Base runways. The model contains cells in 254 rows and 161 columns. Horizontal cell dimensions range from approximately 70 ft by 70 ft within the Site property boundary to 220 ft by 280 ft around the perimeter of the model. The model is divided into two layers:

- Layer 1: Overburden: Brown Clay (loess), Fluvial Deposits, and Olive Clay (weathered bedrock)
- Layer 2: Bedrock: Wellington Formation

Golder received the model grid and assigned layer elevations from Franz Environmental Inc. of Vancouver, British Columbia (FEI). Golder modified the layer elevations in along the Arkansas River west of Clifton to address issues with dry cells and grid connectivity. The layer interface elevations are shown in Figures 3-2 and 3-3. A cross section of model geometry along model row 84 is shown on Figure 2-2.

3.2.2 Model Boundary Conditions

Boundary conditions in groundwater models consist of physical and hydraulic boundaries within the model area. Physical boundary conditions are well-defined geologic and hydrologic features that influence groundwater flow patterns. Examples include contacts between two geologic units, faults, surface water bodies, or anthropogenetic structures such as a drain (Kresic, 1997).

Hydraulic boundaries are based on the hydrogeologic conceptual site model and are established by the model designer. Examples include known hydraulic heads represented by equipotential lines (e.g., constant heads). It is desirable to use as few hydraulic boundaries (constant head boundaries) as possible because they are not permanent features and can change over time; however, constant heads

are typically required in groundwater flow models. The main requirement of hydraulic boundaries is placement far enough from the area of interest to not influence flow patterns created by project activity (e.g., pumping). The most common use of constant head boundaries is at the outside edge of a model and in areas where there is a lack of field data beyond the area of immediate interest (Kresic, 1997).

To model regional groundwater conditions at the Site, Golder used a combination of river, general head, drain, and no flow boundary conditions.

A river boundary (RIV) is a type of head-dependant boundary that uses river geometry (e.g. length, width, depth) and riverbank conductivity to calculate a conductance term to control the amount of water entering the model from the boundary condition. Golder received the river boundary conditions from FEI as included with the model grid. The river boundary conditions provided by FEI included row, column, head, and conductance information, but did not include the river geometry (e.g. length, width, depth) and riverbank conductivity values used to calculate a conductance term. Golder divided the FEI river boundary conditions into reaches and adjusted the head or conductance to improve model calibration fit, where required. The location and reach assignments of these river boundary conditions are shown on Figure 3-4. Table 3-1 summarizes the location and characteristics of the modeled river boundary conditions.

A general head boundary (GHB) is a type of constant head boundary that includes a conductance term to control the amount of water entering the model from the boundary condition. Golder included general head boundary conditions in model Layer 1 to simulate influx of water from off-site areas to the north and east of the Ramp 500 area. The location of modeled general head boundary conditions are shown on Figure 3-4. Table 3-1 summarizes the location and characteristics of the modeled general head boundary conditions.

A drain (DRN) is a head-dependant boundary condition that modifies the flux through the boundary condition depending on the calculated head from the model. If the calculated head is below the head in the drain boundary condition, the model does not allow the boundary condition to gain or lose water. Golder included drain boundary conditions near the intersection of the Kansas Turnpike (I-35) and state highway K-15. The characteristics (e.g. stage, width, length, bed thickness, and bed conductivity) were provided to Golder by Boeing based on as-built construction reports. The location

of modeled drain boundary conditions are shown on Figure 3-4. Table 3-1 summarizes the location and characteristics of the modeled drain boundary conditions.

Golder assigned no-flow boundary cells to portions of the model outside of the river boundary conditions and along the reported groundwater divide near the McConnell Air Force Base runway. The locations of no flow boundary conditions are shown in Figure 3-4.

3.2.3 Model Input Parameters

Input parameters required for the steady state numerical model include:

- Aquifer hydraulic conductivity (horizontal and vertical);
- Precipitation recharge; and
- Groundwater recovery well rates.

As Golder only simulated steady state conditions in the model, transient dependent parameters such as porosity and storage/storativity were not included in the model calibration process.

The following paragraphs describe the final calibrated input data set used for the model. Calibration methods and procedures are described in Section 3.2.4 below.

Hydraulic Conductivity – In numerical groundwater modeling, hydraulic conductivity is often the most critical and sensitive modeling parameter (Kresic, 1997). Golder based hydraulic conductivity values for the Site model on pumping test analysis results as documented in BFA, 1998 (Appendix 1). We used these results to assign initial hydraulic conductivity values to the groundwater flow model, and to check that the hydraulic conductivity values resulting from model calibration were within the range of values observed.

Hydraulic conductivity zones used in the model are presented in Table 3-2. Golder assigned model cells in the overburden (Layer 1) to one of seven hydraulic conductivity zones based on the geologic setting and the extent of relatively highly-transmissive fluvial overburden aquifer materials as presented in site boring logs and BFA's interpretation (Appendix A). Figure 3-5 shows the horizontal distribution of hydraulic conductivity zone assignments in model Layer 1. Golder assigned model cells in the bedrock (Layer 2) to one of three hydraulic conductivity zones. The majority of site

bedrock was assigned to hydraulic conductivity zone #7 with the exception of bedrock in the vicinity of the Arkansas River which was assigned a higher horizontal hydraulic conductivity due to dry cells in model Layer 1 limiting the flux of water between the model and the Arkansas River boundary condition cells in that area. Figure 3-6 shows the horizontal distribution of hydraulic conductivity zone assignments in model Layer 2.

Because model Layer 1 includes brown clay (loess), fluvial, and olive clay (weathered bedrock) materials, Golder assigned aquifer materials a vertical hydraulic conductivity equal to the vertical hydraulic conductivity for the olive clay since this layer would be controlling in terms of vertical hydrogeology and transport. The vertical hydraulic conductivity of model Layer 1 materials was assigned a value of 0.06 ft/day (2.12×10^{-5} cm/s) based on BFA's assigned value of 0.6 ft/day (2×10^{-4} cm/s) for olive clay materials (BFA, 1998) and an assumed anisotropy of 10. The vertical hydraulic conductivity of model Layer 2 was assigned based on calibrated horizontal hydraulic conductivity values and an assumed anisotropy of 10.

Precipitation and Evapotranspiration – Precipitation recharge is the amount of precipitation that recharges an aquifer, which is generally the precipitation rate minus losses due to runoff and evapotranspiration. Precipitation recharge rates are difficult to define in groundwater models because recharge depends on various factors such as climate, land cover, land use, topography, etc. (Kresic, 1997). To simulate the effects of development on precipitation recharge, Golder divided Layer 1 of the model into the following three precipitation recharge "reaches" based on land use and ground cover, as shown on Figure 3-7:

- Precipitation Recharge Reach 98 for undeveloped portions of the Site with open ground or landscaped areas;
- Precipitation Recharge Reach 99 for paved, developed, or hardscaped portions of the Site; and
- Precipitation Recharge Reach 100 for off-Site residential areas.

The calibrated property values and horizontal distribution of precipitation zone assignments for precipitation recharge in Layer 1 are shown on Table 3-2. The calibrated property values for precipitation recharge are within the range of values previously calculated for the Site using the Hydrologic Evaluation of Landfill Performance (HELP) model (BFA, 1998).

Groundwater Extraction and Recharge Wells – Golder simulated Boeing extraction and recharge wells in the groundwater flow model as grid independent (analytic element) wells. For the first quarter 2007 (2007 Q1) calibration model, Golder assigned extraction and recharge rates based on 2006-2007 historic monthly totalizer volumes as provided by FEI. The 2006-2007 calculated average monthly flow rates are shown in Table 3-3. The location of modeled groundwater extraction and recharge wells are shown in Figure 3-8.

3.3 Model Calibration and Verification

3.3.1 Numerical Model Calibration

Golder conducted numerical model calibration by comparing simulated hydraulic head values to measured water levels at the corresponding well locations using groundwater elevation data observed during 2007 Q1. We used the trial-and-error calibration technique to calibrate the model, where model input parameters are adjusted over a given range until the model satisfactorily matches measured field conditions.

After each calibration model run, Golder completed a statistical evaluation to evaluate the model calibration. At each well location, the residual was calculated by the post-processing software (i.e., the difference between the measured and simulated groundwater elevations). Positive residual values indicate simulated head values lower than measured elevations, while negative residual values indicate simulated head elevations higher than measured elevations.

As a measure of the accuracy of the model, the post-processing software calculates statistical measures of the residuals. The residual mean (RM) is the arithmetic mean of all calculated residual values. The absolute residual mean (ARM) is the arithmetic mean of the absolute value of the residuals (i.e., all negative residuals are considered positive). It is possible that large positive and negative residuals can cancel one another when calculating the RM. Other statistics such as the residual standard deviation (RSD) (i.e., the square root of the variance [the average of the squared deviations from the mean]), and the sum of squared residuals (SSR) (computed by squaring each residual and adding them together) can also be useful in evaluation of the calibration process.

3.3.2 Numerical Model Verification

A model is considered valid, or verified, if its accuracy and predictive capability have been proven to lie within acceptable limits of error by tests independent of the calibration data (Konikow, 1978, in Anderson and Woessner, 1992). If the calibrated model parameters such as boundary conditions, stresses and distribution of hydrogeologic characteristics are correct, the simulation of the new boundary conditions and stresses should closely match the additional independent field data set. If the verification data are collected during a recession period (dry conditions), the corresponding boundary conditions and stresses (recharge and pumping rates) must be changed accordingly. The model is considered verified if the model simulation with the changed conditions produces simulated heads that reasonably match the measured values. Once the model is calibrated and verified, it can be used for prediction (Kresic, 1997).

Golder verified the Site model by simulating the groundwater flow conditions that occurred during Third Quarter 1990 (1990 Q3). The 1990 Q3 conditions represent a time period with significantly less groundwater extraction than subsequent years, but with sufficient groundwater elevation (i.e. calibration target) data to allow for model verification. Model verification to pre-pumping conditions was not feasible due to limited available groundwater elevation (i.e. calibration/verification target) data prior to 1990. Golder held constant the model input parameter values defined in the 2007 Q1 simulation except for the recovery well pumping rates which were updated to the values presented in Table 3-6.

3.3.3 Simulated Heads Calibrated to 2007 Q1 Conditions

The model files for 2007 Q1 conditions use the root file name *GAI-03_V5.9*. The 2007 Q1 simulated heads and residuals for targets screened in the overburden are presented in Figure 3-9. Based on the contours of constant head, groundwater flows from the northeast generally towards the west and southwest.

Dry cells exist in the overburden near the western edge of the model along the Arkansas River northeast of Englewood and MacArthur Road. The dry cells in this area are due to the relatively steep relief of the overburden aquifer near the Arkansas River. Dry cells also occur near recovery well clusters with high recovery well rates (e.g. the IWTP wells).

Final calibration statistics for the 2007 Q1 model are summarized in Table 3-4. The results indicate an unweighted RM of +0.48 feet, which represent 0.5 percent of the total hydraulic head difference for the model area (approximately 99 feet). The absolute residual mean for the model run is 3.38 feet, which is 3.4 percent of the total hydraulic head difference for the entire modeling area. The residual mean and the absolute residual mean are within the generally accepted standard of 10 percent of the total hydraulic head difference for the modeling area, and we consider the 2007 Q1 model as calibrated.

3.3.4 Water Balance

An effective measure of model calibration is the analysis of the water budget calculated by MODFLOW. The model provides flows across boundaries, flows to and from all sources and sinks, and flows generated by storage (Kresic, 1997). Table 3-5 presents the total inflow and outflows calculated by the model for 2007 Q1 conditions.

The outflow deficit is 2.30 cubic feet per day (ft^3/d), which is equivalent to error between outflow and inflow estimates of approximately 0.003 percent. This indicates that model inflows and outflows are balanced.

3.3.5 Model Verification to 1990 Q3 Conditions

To provide model verification using a time step with fewer recovery wells pumping at a lower pumping rate, Golder modified the 2007 Q1 model to simulate third quarter 1990 (1990 Q3) conditions by changing the extraction/recharge well rates to values listed in Table 3-6 and shown on Figure 3-10.

The model files for 1990 Q3 conditions use the root file name GAI-04_V3.1. Model verification results for the 1990 Q3 model are presented in Table 3-7 and Figure 3-11. The verification results for 1990 Q3 simulation indicate a residual mean of 1.82 feet, which represents 1.8 percent of the total hydraulic head difference for the model area. The absolute residual mean for this simulation was 4.60 feet, which is 4.6 percent of the total hydraulic head difference for the entire model area. This suggests that the model can reasonably simulate stress conditions related to periods of reduced groundwater recovery well operation such as in 1990 Q3.

3.4 Sensitivity Analysis

A sensitivity analysis is a quantitative evaluation of the impact of variability or uncertainty in model inputs on the degree of calibration of a model and on its results or conclusions. In a sensitivity analysis, model input values are varied over a specific range and simulations. For each simulation, the calibration residuals are plotted as functions of the input values and type of sensitivity that the model has with respect to the modified input parameter (ASTM 2002). The sensitivity analysis included modifying the modeled input values and boundary conditions as follows:

- **Hydraulic conductivity:** Golder varied hydraulic conductivity values using multipliers between 0.1 and 10 for vertical hydraulic conductivity (Kz) and between 0.5 and 4 for horizontal hydraulic conductivity.
- **Recharge:** Golder varied recharge values using multipliers between 0.5 and 2.
- **River stage and conductance:** Golder varied river stage (head) values using multipliers between 0.999 and 1.001. For an initial river stage of 1340.0 ft, this would result in a variation between 1338.6 and 1341.3. Golder varied river conductance values using multipliers between 0.5 and 2.0.
- **Drain head and conductance:** Golder varied drain head values using multipliers between 0.999 and 1.001. Golder varied drain conductance values using multipliers between 0.5 and 2.0.
- **GHB head and conductance:** Golder varied GHB head values using multipliers between 0.999 and 1.001. Golder varied GHB conductance values using multipliers between 0.5 and 2.0.

The results of the sensitivity analysis conducted of the Site model are presented in Appendix B.

4.0 SUMMARY AND CONCLUSIONS

Through standard numerical groundwater modeling procedures, Golder designed and constructed a steady state groundwater flow model of the Site that is considered calibrated and verified, as determined by using the model to simulate recent conditions and a time period with fewer recovery wells pumping at a lower pumping rate. The numerical groundwater model can be used to evaluate proposed changes to the groundwater monitoring and recovery systems, and to enhance groundwater remediation at the Site.

5.0 REFERENCES

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TABLES

TABLE 2-1
SUMMARY OF GROUNDWATER RECOVERY SYSTEM VOLUMES

BOEING FACILITY
WICHITA, KANSAS

Year	Recovery Well Volume in Millions of Gallons	Recovery Well Average Combined Flow Rate (gpm)
1985	0	0
1986	1.99	3.79
1987	10.0	19.0
1988	20.8	39.6
1989	45.5	86.6
1990	47.8	90.9
1991	49.7	94.6
1992	64.1	122
1993	107.9	205.3
1994	111.97	213
1995	86.4	164.4
1996	80.6	153
1997	96.5	184
1998	105.9	201.5
1999	111.8	213
2000	99.6	189.5
2001	100.3	190.8
2002	88.2	167.8
2003	90.42	172.0
2004	99.39	189.1
2005	88.5	168.4
2006	56.36	107.2
2007	77.1	146.7
2008	85.96	163.5

Reference:
Spreadsheet titled "Historical Recovery Well Production Boeing Site ONLY.xls" provided by Boeing.

Prepared by: RWB 08/21/09
Checked by: RWB 08/21/09
Reviewed by: THR 08/21/09

TABLE 3-1
SUMMARY OF MODEL BOUNDARY CONDITIONS

BOEING FACILITY
WICHITA, KANSAS

River Boundary Conditions			Range of Heads (ft-msl)		Range of Conductances (ft^2/day)	
Reach	No. Cells	Description	Max	Min	Max	Min
0	236	Arkansas River	1271	1248	627	0.0001
10	84	IWTP Pond and surrounding drainages	1330	1315	24	24
11	41	North Creek between ITWP pond and Arkansas River	1298	1261	5600	5.6
12	24	Drainage west of Plant 1	1347	1331	1453	0.0001
13	7	Drainage swale west of Plant 2	1289	1282	2	0.30
20	50	Creek south of "O Lot"	1301	1270	41	0.56
50	129	Tributary of Gypsum creek, northwest from Plainview Park	1341	1273	268	0.0001
61	71	Tributary of Gypsum creek, flowing north from Ramp 500	1347	1284	357	0.20
62	78	Gypsum Creek upstream of reach 50	1350	1271	225	1.4
63	33	Gypsum Creek downstream of reach 50	1272	1269	434	29
70	130	Unnamed creek in south campus	1320	1269	266	0.0001
71	8	Unnamed pond in south campus	1308	1308	1453	1453
75	37	Two unnamed ponds and Meadow Lake in Southwest Corner of Model	1265	1264	87	0.29
80	73	"McConnell Creek", southwest of runways	1294	1260	611	0.0001
81	51	"McConnell Creek" tributary, west of runways	1330	1294	417	20
82	48	"McConnell Creek" tributary, south and southeast of runways	1301	1294	455	0.0001

General Head Boundary Conditions			Boundary Condition	
Reach	Layer	Description	Head (ft msl)	Conductivity (ft/day)
10	*1*	*NE corner of model in the vicinity of the* McConnell Air Force Base property boundary	1355.7	10

Drain Boundary Conditions			Range of Heads (ft-msl)		Conductivity (ft/day)	Total Length (ft)	Width (ft)
Reach	No. Cells	Description	Max	Min			
0	5	Drain running north-south to the west of K-15.	1279.00	1279	50	356	10
1	6	Drain running east-west norht of I-35 under K-15	1282.00	1280	50	432	3

Notes:
ft msl = feet mean sea level

Prepared by: RWB 08/21/09
Checked by: RWB 08/21/09
Reviewed by: THR 08/21/09

TABLE 3-2
SUMMARY OF MODEL INPUT VALUES

BOEING FACILITY
WICHITA, KANSAS

Hydraulic Conductivity

Numerical Model Zone	Description	Horizontal Hydraulic Conductivity (ft/day)	Horizontal Hydraulic Conductivity (cm/s)	Vertical Hydraulic Conductivity (ft/day)	Vertical Hydraulic Conductivity (cm/s)
Overburden					
2	Fluvial materials	3.0	1.1E-03	0.060	2.1E-05
3	Brown clay	0.43	1.5E-04	0.060	2.1E-05
4	Fluvial materials, Plant 2, Hangar 118F and Ramp 500 vicinity	5.7	2.0E-03	0.060	2.1E-05
5	Fluvial materials, Arkansas River valley	50	1.8E-02	0.060	2.1E-05
9	Fluvial materials, Arkansas River valley	75	2.6E-02	0.060	2.1E-05
15	Overburden, Plant 1 vicinity	1.5	5.3E-04	0.060	2.1E-05
20	Brown and olive clay, west of Englewood	0.25	8.8E-05	0.060	2.1E-05
Bedrock					
7	Bedrock, except Arkansas River vicinity	0.12	4.2E-05	0.012	4.2E-06
8	Bedrock, Arkansas River vicinity	0.36	1.3E-04	0.036	1.3E-05
40	Bedrock, Arkansas River vicinity, north of I-35	0.50	1.8E-04	0.060	2.1E-05

Precipitation Recharge

Zone	Description	Calibrated Value (ft/day)	Calibrated Value (in/year)
98	on-site landscaped areas	4.00E-04	1.75
99	on-site paved/hardscape areas	3.00E-04	1.31
100	off-site residential areas	1.72E-04	0.75

Notes:
ft/day = feet per day
cm/s = centimeters per second
in/yr = inches per year

Prepared by: RWB 08/21/09
Checked by: RWB 08/21/09
Reviewed by: THR 08/21/09

TABLE 3-3
SUMMARY OF 2007 Q1 RECOVERY WELL RATES

BOEING FACILITY
WICHITA, KANSAS

Extraction Well ID	2007 Flow Rate[1] ft^3/day	gpm
RW-003A	-0.60	<0.01
RW-004AA	-273	-1.42
RW-005A	-107	-0.56
RW-006A	0	<0.01
RW-007A	-2.6	-0.01
RW-008A	-84	-0.44
RW-009A	-30	-0.16
RW-010A	-320	-1.66
RW-011A	-214	-1.11
RW-012A	-69	-0.36
RW-013A	-23	-0.12
RW-014	-0.78	<0.01
RW-15A	-3.3	-0.02
RW-016	-0.32	<0.01
RW-017	-29	-0.15
RW-018A	0	<0.01
RW-019A	-298	-1.55
RW-020	-198	-1.03
RW-026	-992	-5.15
RW-027A	-3.1	-0.02
RW-028A	-228	-1.18
RW-029	-27	-0.14
RW-030	-112	-0.58
RW-031	-3.7	-0.02
RW-033	-395	-2.05
RW-034	-78	-0.41
RW-035A	-89	-0.46
RW-040	-14	-0.07
RW-042	-39	-0.20
RW-043	-135	-0.70
RW-044	-152	-0.79
RW-045	-1986	-10.32
RW-046A	-353	-1.83
RW-047A	-144	-0.75
RW-049A	-219	-1.14
RW-052	-209	-1.09
RW-053	-1316	-6.84
RW-054	-290	-1.51
RW-055	-107	-0.56
RW-056	-9.4	-0.05
RW-057	-1037	-5.39
RW-058	-142	-0.74
RW-059	-9.9	-0.05
RW-060	-4.1	-0.02
RW-061	-69	-0.36
RW-062	-57	-0.30
RW-063	-3.3	-0.02
RW-064	-4.1	-0.02
RW-065	-34	-0.18
RW-066	-171	-0.89
RW-067	-50	-0.26
RW-068	-170	-0.88
RW-069	-2.3	-0.01
RW-070	-514	-2.67
RW-071	-67	-0.35
RW-072	-56	-0.29
RW-073	-22	-0.11
RW-074	-21	-0.11

Extraction Well ID	2007 Flow Rate[1] ft^3/day	gpm
RW-075	-270	-1.40
RW-076	-61	-0.32
RW-077	-155	-0.81
RW-078	-38	-0.20
RW-079	-5.0	-0.03
RW-080	-186	-0.97
RW-081	-22	-0.11
RW-082	-241	-1.25
RW-083	-88	-0.46
RW-084	-38	-0.20
RW-085	-180	-0.94
RW-086	-52	-0.27
RW-087	-168	-0.87
RW-088	-21	-0.11
RW-089	-155	-0.81
RW-090	-1.7	<0.01
RW-091	-23	-0.12
RW-092	0	<0.01
RW-093	-468	-2.43
RW-094	-379	-1.97
RW-095	-304	-1.58
RW-096	-387	-2.01
RW-097	-578	-3.00
RW-098	-28	-0.15
RW-100	-21	-0.11
RW-101	-226	-1.17
RW-102	-48	-0.25
RW-103	0	<0.01
RW-104	-69	-0.36
RW-105	-59	-0.31
RW-106	-214	-1.11
RW-107	-18	-0.09
RW-108	-59	-0.31
RW-113	-333	-1.73
RW-114	-0.14	<0.01
RW-115	-35	-0.18
RW-116	-284	-1.48
RW-117	-49	-0.25
RW-118	-1.6	<0.01
RW-119	0	<0.01
RW-120	0	<0.01
RW-122	0	<0.01
RW-125	0	<0.01
RW-127	-157	-0.82
RW-128	-48	-0.25
RW-129	-192	-1.00
RW-130	-127	-0.66
RW-131	-75	-0.39
RW-132	-89	-0.46
RW-133	-281	-1.46
RW-134	-112	-0.58
RW-135	-108	-0.56
RW-136	-498	-2.59
RW-137	-61	-0.32
RW-138	-1.4	<0.01
RW-139	-61	-0.32
RW-140	-201	-1.04
RW-141	-102	-0.53

Extraction Well ID	2007 Flow Rate[1] ft^3/day	gpm
RW-142	-7.2	-0.04
RW-143	-23	-0.12
RW-144	-5.8	-0.03
RW-145	-26	-0.14
RW-146	-31	-0.16
RW-147	-12	-0.06
RW-148	-14	-0.07
RW-149	-76	-0.39
RW-150	-74	-0.38
RW-151	-6.2	-0.03
RW-152	-60	-0.31
RW-153	-3.7	-0.02
RW-154	-104	-0.54
RW-155	-18	-0.09
RW-156	-0.74	<0.01
RW-157	-32	-0.17
RW-158	-0.66	<0.01
RW-159	-244	-1.27
RW-160	-17	-0.09
RW-161	-378	-1.96
RW-162	-164	-0.85
RW-163	-162	-0.84
RW-164	-64	-0.33
RW-181	-42	-0.22
RW-182	0	<0.01
RW-183	-36	-0.19
RW-184	-504	-2.62
RW-185	-252	-1.31
RW-186	-169	-0.88
RW-187	-96	-0.50
RW-188	-452	-2.35
RW-189	-490	-2.55
RW-190	-7.4	-0.04
RW-191	-39	-0.20
RW-192	-341	-1.77
RW-193	-23	-0.12
RW-194	-65	-0.34
RW-195	-13	-0.07
RW-196	-108	-0.56
RW-197	-18	-0.09
RW-198	-180	-0.94
RW-199	-20	-0.10
RW-200	-10	-0.05
RW-201	-72	-0.37
RW-202	-50	-0.26
RW-203	-158	-0.82
RW-204	-0.25	<0.01
RW-205	-0.92	<0.01
RW-206	-2.9	-0.02
RW-207	-38	-0.20
RW-208	-22	-0.11
RW-209	-292	-1.52
RW-210	-0.28	<0.01
RW-211	-4.3	-0.02
RW-212	-6.6	-0.03
RW-213	-9.6	-0.05
RW-214	-9.7	-0.05

Sum of Modeled Extraction Well Rates = -23,422 -122

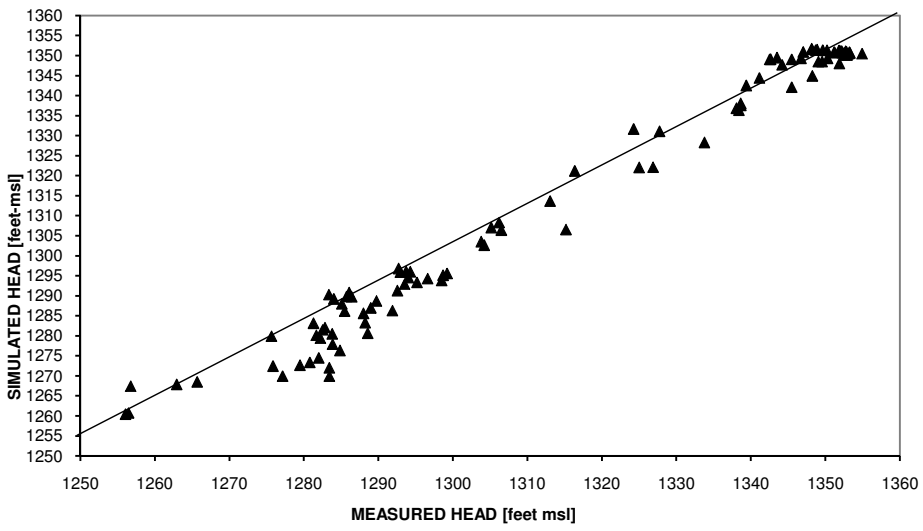
Notes:
2007 well rates based on 2006-2007 average well rates from "Pumping_rates_Model08.xls" provided by Franz Environmental Inc
gpm = gallons per minute
Negative rates indicate water being removed from model

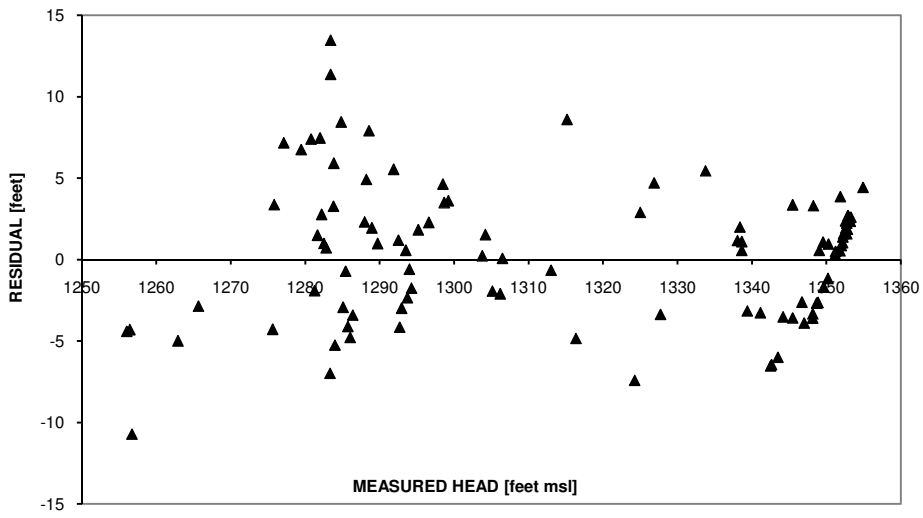
Prepared by: RWB 08/21/09
Checked by: RWB 08/21/09
Reviewed by: THR 08/21/09

Reference:
Pumping and extraction rates from monthly extraction well meter reading excel spreadsheet files provided by Boeing and summary files provided by Franz Environmental Inc.

TABLE 3-4
CALIBRATION DATA SUMMARY -2007 Q1 CONDITIONS
BOEING FACILITY
WICHITA, KANSAS

Well ID	X [feet]	Y [feet]	Layer	Measured Head [feet msl]	Simulated Head [feet msl]	Weight (1)	Residual [feet]
BH02-01	1,666,459	1,665,583	1	1352.01	1351.14	1	0.87
BH02-01S	1,666,459	1,665,583	1	1352.18	1351.14	1	1.04
BH02-05	1,666,645	1,665,298	1	1350.23	1351.39	1	-1.16
BH02-05S	1,666,645	1,665,298	1	1348.72	1351.39	1	-2.67
BH02-09	1,666,148	1,665,816	1	1352.92	1350.22	1	2.70
BH02-09	1,666,148	1,665,816	1	1352.88	1350.22	1	2.66
BH02-09S	1,666,148	1,665,816	1	1352.60	1350.22	1	2.38
BH03-02	1,666,355	1,665,510	1	1352.22	1350.82	1	1.40
BH03-03	1,666,546	1,665,656	1	1349.66	1351.35	1	-1.69
BH03-04	1,666,541	1,665,521	1	1351.85	1351.31	1	0.54
BH03-05	1,666,541	1,665,223	1	1351.20	1350.88	1	0.32
BH03-06	1,666,770	1,665,364	1	1348.17	1351.77	1	-3.60
INJ03-01	1,666,450	1,665,676	1	1352.73	1351.13	1	1.60
INJ03-02	1,666,412	1,665,628	1	1347.04	1350.94	1	-3.90
INJ03-03	1,666,373	1,665,580	1	1352.83	1350.96	1	1.87
INJ03-04	1,666,377	1,665,745	1	1353.24	1350.89	1	2.35
INJ03-05	1,666,344	1,665,693	1	1351.25	1350.75	1	0.50
INJ03-06	1,666,283	1,665,625	1	1353.14	1350.56	1	2.58
INJ03-07	1,666,264	1,665,758	1	1352.73	1350.49	1	2.24
INJ03-08	1,666,226	1,665,709	1	1354.93	1350.49	1	4.44
INJ05-01	1,666,348	1,665,724	1	1353.30	1350.69	1	2.61
INJ05-02	1,666,310	1,665,700	1	1352.63	1350.69	1	1.94
INJ05-03	1,666,327	1,665,662	1	1352.33	1350.75	1	1.58
INJ05-04	1,665,995	1,666,054	1	1350.30	1349.35	1	0.95
MW-008A	1,661,675	1,662,544	1	1281.66	1280.16	1	1.50
MW-015A	1,662,874	1,662,761	1	1296.61	1294.33	1	2.28
MW-020C	1,663,562	1,662,359	1	1304.21	1302.67	1	1.54
MW-021C	1,663,557	1,662,880	1	1306.50	1306.43	1	0.07
MW-033	1,665,421	1,662,015	1	1327.74	1331.11	1	-3.37
MW-034	1,665,287	1,663,009	1	1324.27	1331.69	1	-7.42
MW-040	1,663,319	1,665,330	1	1325.01	1322.11	1	2.90
MW-043	1,662,963	1,658,272	1	1291.89	1286.35	1	5.54
MW-047	1,663,975	1,663,918	1	1326.87	1322.16	1	4.71
MW-053	1,662,777	1,663,701	1	1294.01	1294.60	1	-0.59
MW-056	1,663,149	1,661,717	1	1299.23	1295.62	1	3.61
MW-060	1,664,178	1,665,923	1	1339.40	1342.55	1	-3.15
MW-064	1,665,311	1,665,358	1	1348.26	1344.95	1	3.31
MW-065	1,665,055	1,665,212	1	1345.49	1342.13	1	3.36
MW-069	1,666,446	1,664,494	1	1341.16	1344.42	1	-3.26
MW-082	1,660,753	1,664,660	2	1284.84	1276.38	1	8.46
MW-083	1,661,000	1,663,838	1	1275.65	1279.93	1	-4.28
MW-084	1,661,120	1,663,342	1	1282.22	1279.45	1	2.77
MW-085	1,661,240	1,662,923	1	1283.80	1280.52	1	3.28
MW-086	1,661,426	1,661,954	1	1283.85	1277.93	1	5.92
MW-087	1,661,628	1,660,759	1	1288.97	1287.02	1	1.95
MW-088	1,661,711	1,660,339	1	1288.22	1283.29	1	4.93
MW-089	1,661,855	1,659,615	1	1256.74	1267.45	1	-10.71
MW-093	1,664,748	1,661,652	1	1316.37	1321.21	1	-4.84
MW-097S	1,665,972	1,666,253	1	1342.65	1349.10	1	-6.45
MW-102	1,662,497	1,664,012	1	1298.68	1295.17	1	3.51
MW-103	1,662,586	1,664,291	1	1294.28	1296.03	1	-1.75
MW-104	1,662,734	1,664,532	1	1293.73	1296.08	1	-2.35
MW-105	1,663,060	1,664,964	1	1315.18	1306.57	1	8.61
MW-110	1,661,898	1,661,502	1	1287.99	1285.67	1	2.32
MW-113	1,662,065	1,661,141	1	1289.74	1288.75	1	0.99
MW-117	1,665,861	1,663,168	1	1338.66	1337.55	1	1.11
MW-120	1,660,418	1,665,057	2	1262.91	1267.90	1	-4.99
MW-121	1,660,620	1,664,798	2	1275.84	1272.46	1	3.38
MW-123	1,661,959	1,659,118	1	1256.05	1260.46	1	-4.41
MW-124	1,662,058	1,658,623	1	1256.45	1260.75	1	-4.30
MW-137	1,663,098	1,658,959	1	1295.19	1293.36	1	1.83
MW-138	1,663,743	1,659,941	1	1303.80	1303.57	1	0.23
MW-145	1,664,174	1,662,509	1	1313.04	1313.69	1	-0.65
MW-151	1,665,241	1,662,436	1	1333.78	1328.33	1	5.45
MW-152	1,661,753	1,664,501	1	1285.73	1289.84	1	-4.11
MW-153	1,662,345	1,664,835	1	1292.71	1296.86	1	-4.15
MW-154	1,662,106	1,664,471	1	1293.52	1292.95	1	0.57
MW-155	1,661,932	1,664,106	1	1286.06	1290.83	1	-4.77
MW-156	1,661,359	1,663,747	1	1282.82	1282.09	1	0.73
MW-157	1,661,704	1,663,870	1	1285.10	1288.02	1	-2.92
MW-158	1,661,340	1,663,548	1	1282.52	1281.53	1	0.99
MW-159	1,661,610	1,663,594	1	1285.45	1286.16	1	-0.71
MW-160	1,661,537	1,663,184	1	1281.28	1283.19	1	-1.91
MW-161	1,662,074	1,663,344	1	1292.54	1291.35	1	1.19
MW-162	1,662,298	1,664,018	1	1298.50	1293.86	1	4.64
MW-163	1,662,438	1,664,602	1	1292.95	1295.93	1	-2.98
MW-164	1,662,816	1,665,392	1	1305.15	1307.08	1	-1.93
MW-165	1,665,374	1,665,980	1	1351.89	1348.03	1	3.86
MW-166	1,665,863	1,666,136	1	1345.49	1349.07	1	-3.58
MW-167	1,666,045	1,666,360	1	1342.52	1349.06	1	-6.54
MW-169	1,665,959	1,666,108	1	1346.74	1349.35	1	-2.61
MW-182	1,667,757	1,664,150	1	1343.51	1349.51	1	-6.00
MW-185	1,665,775	1,663,190	1	1338.41	1336.41	1	2.00
MW-186	1,665,957	1,663,169	1	1338.64	1338.07	1	0.57
MW-187	1,665,795	1,663,081	1	1338.07	1336.90	1	1.17
MW-188	1,660,938	1,665,942	2	1286.40	1289.81	1	-3.41
MW-189	1,660,879	1,665,163	2	1288.57	1280.66	1	7.91
MW-190	1,661,537	1,665,194	2	1283.35	1290.33	1	-6.98
MW-192	1,662,020	1,663,577	1	1284.00	1289.25	1	-5.25
MW-193	1,664,537	1,659,967	1	1306.20	1308.30	1	-2.10
MW-197	1,660,916	1,661,725	1	1282.00	1274.52	1	7.48
MW-198	1,660,893	1,661,298	1	1279.47	1272.72	1	6.75
MW-199	1,660,807	1,661,238	1	1277.12	1269.95	1	7.17
MW-200	1,660,841	1,661,325	1	1283.41	1272.04	1	11.37
MW-201	1,661,008	1,661,305	1	1280.79	1273.39	1	7.40
MW-202	1,660,809	1,661,265	1	1283.42	1269.95	1	13.47
MW-203	1,660,799	1,661,189	1	1265.67	1268.53	1	-2.86
TMW-003	1,666,623	1,664,586	1	1349.07	1348.50	1	0.57
TMW-004	1,666,579	1,664,587	1	1349.57	1348.50	1	1.07
SWMU207-MW30	1,668,162	1,664,604	1	1348.90	1351.53	0.20	-2.63
SWMU207-MW31	1,668,167	1,664,599	1	1348.20	1351.53	0.20	-3.33
SWMU207-MW33	1,667,879	1,663,504	1	1344.19	1347.71	0.20	-3.52





Statistics for 2007 Q1 Model Overburden and Bedrock Targets

	Unweighted		Unweighted
RM	0.48	Minimum Residual:	-10.71
RSD	4.19	Maximum Residual:	13.47
SSR	1815.41	Head Range:	98.88
ARM	3.38	RSD/Head Range:	0.04
As precentage of Head Range:			
RM	0.5%		
RSD	4.2%		
ARM	3.4%		

Notes:
(1) Off-site wells assigned a calibration weight of 0.2, but calibration weights not used in statistics
Calibration output from model "GAI-03_V5.9D"
msl = mean sea level
RM = Residual mean
RSD = Residual Squared Deviation
SSR = Sum of Squared Residuals
ARM = Absolute Residual Mean

Prepared by: RWB 08/21/09
Checked by: RWB 08/21/09
Reviewed by: THR 08/21/09

TABLE 3-5
WATER BALANCE SUMMARY - 2007 Q1 CONDITIONS

BOEING FACILITY
WICHITA, KANSAS

MODEL SUMMARY			
Sum of Layers	**Flow [ft^3/day]**	**Sum of Layers**	**Percent of Total Inflow/Outflow**
INFLOWS		**INFLOWS**	
Recharge	39,135.02	Recharge	44.54%
River	46,013.15	River	52.37%
Drain	0.00	Drain	0.00%
GHB	2,710.29	GHB	3.08%
Well	0.00	Well	0.00%
Total Inflow	**87,858.46**	**Total Inflow**	**99.99%**
OUTFLOWS		**OUTFLOWS**	
Recharge	0.00	Recharge	0.00%
River	63,891.39	River	72.72%
Drain	1,466.11	Drain	1.67%
GHB	0.00	GHB	0.00%
Well	22,498.66	Well	25.61%
Total Ouflow	**87,856.16**	**Total Ouflow**	**100.00%**

ERROR SUMMARY			
Total Outflow-Inflow Deficit [ft^3/day]:	**-2.30**		
Total Outflow/Inflow Ratio:	**0.99997**	**Percent Total Outflow-Inflow Deficit divided by Total Inflow:**	**-0.0026%**

Notes:
Calibration output from model "GAI-03_V5.9D"
ft^3/day = cubic feet per day
GHB = general head boundary

Prepared by: RWB 08/21/09
Checked by: RWB 08/21/09
Reviewed by: THR 08/21/09

TABLE 3-6
SUMMARY OF 1990 Q3 RECOVERY WELL RATES

BOEING FACILITY
WICHITA, KANSAS

Extraction Well ID	2007 Flow Rate[1] ft^3/day	gpm
RW-003A	-44	-0.23
RW-004AA	-200	-1.04
RW-005	-459	-2.39
RW-006	-200	-1.04
RW-007	-148	-0.77
RW-008MK	-0.74	<0.01
RW-009MK	-0.01	<0.01
RW-011	-530	-2.75
RW-012	-623	-3.24
RW-013	-0.62	<0.01
RW-014	-0.06	<0.01
RW-015	-5.0	-0.03
RW-016	-0.15	<0.01
RW-017	-88	-0.46
RW-018	-403	-2.09
RW-019	-319	-1.65
RW-020	-349	-1.81
RW-021	-1189	-6.18
RW-022	-62	-0.32
RW-026	-185	-0.96
RW-027	0	<0.01
RW-028	-980	-5.09
RW-029	-311	-1.62
RW-030	-9.1	-0.05
RW-031	-10	-0.05
RW-032	-90	-0.47
RW-033	-202	-1.05
RW-034	-36	-0.18
RW-035	-271	-1.41
RW-036	-3.5	-0.02
RW-037	-425	-2.21
RW-038	-0.05	<0.01
RW-039	-28	-0.15
RW-040	-0.02	<0.01
RW-041	-0.03	<0.01
RW-042	-0.16	<0.01
RW-043	-77	-0.40
RW-044	-449	-2.33
RW-045	-701	-3.64
RW-046	-1001	-5.20
RW-047	-611	-3.17
RW-048	-8.2	-0.04
RW-049	-699	-3.63
RW-050	-0.15	<0.01
RW-051	0	<0.01
RW-052	0	<0.01
Sum of Modeled Extraction Well Rates =	**-10,718**	**-56**

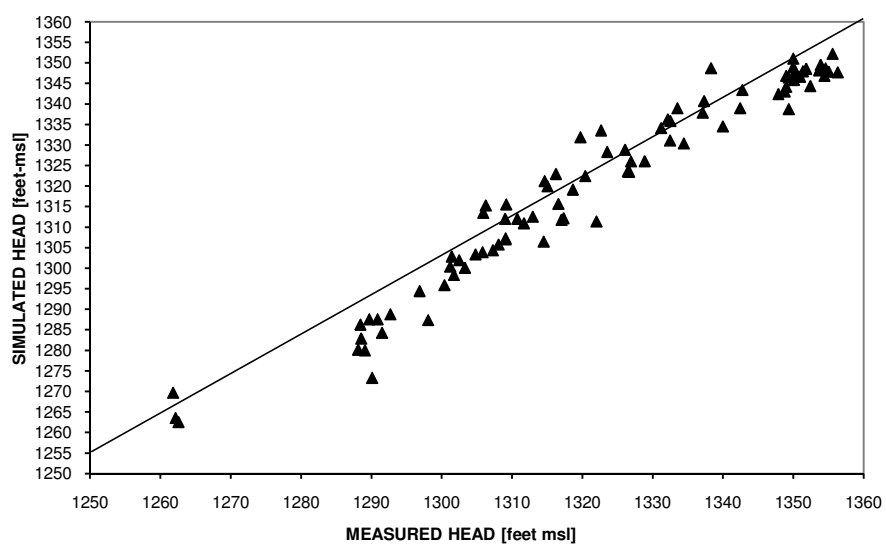
Notes:
1990 Q3 well rates based on spreadsheet file titled "Table IV-5 Third Qtr 1990.xls" provided by Boeing
gpm = gallons per minute
Negative rates indicate water being removed from model

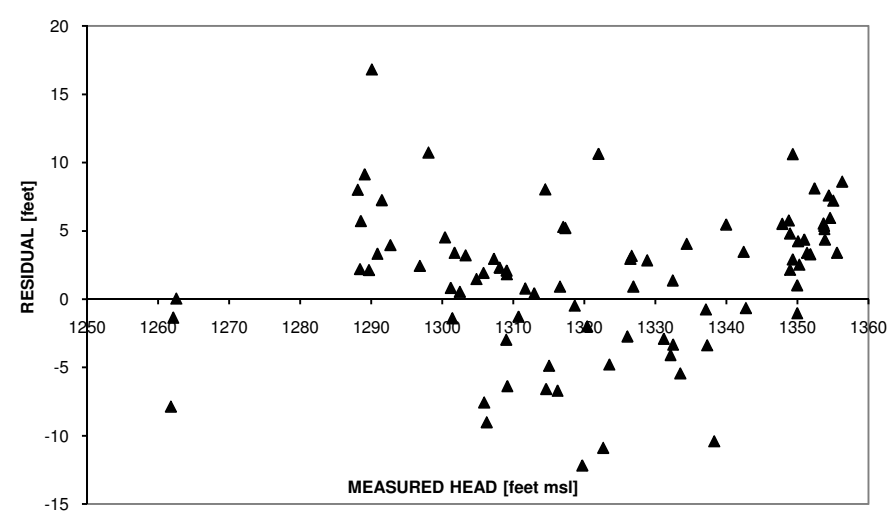
Prepared by: RWB 08/21/09
Checked by: RWB 08/21/09
Reviewed by: THR 08/21/09

Reference:
Pumping and extraction rates from monthly extraction well meter reading excel spreadsheet files provided by Boeing and summary files provided by Franz Environmental Inc.

TABLE 3-7
VERIFICATION DATA SUMMARY - 1990 Q3 CONDITIONS
BOEING FACILITY
WICHITA, KANSAS

Well ID	X [feet]	Y [feet]	Layer	Measured Head [feet msl]	Simulated Head [feet msl]	Weight (1)	Residual [feet]
MW-001-2AU	1,665,705	1,659,995	1	1319.74	1331.91	1	-12.17
MW-001-2U	1,665,808	1,660,061	1	1322.68	1333.56	1	-10.88
MW-002MK	1,663,619	1,659,738	1	1309.04	1312.00	1	-2.96
MW-003-4U	1,666,289	1,660,296	1	1333.54	1338.97	1	-5.43
MW-003MK	1,664,219	1,659,891	1	1315.06	1319.93	1	-4.87
MW-004MK	1,663,696	1,664,441	1	1326.50	1323.54	1	2.96
MW-005MK	1,663,258	1,664,555	1	1314.52	1306.48	1	8.04
MW-006A	1,663,234	1,664,154	1	1305.82	1303.89	1	1.93
MW-007-8U	1,665,833	1,662,683	1	1337.33	1340.70	1	-3.37
MW-008MK	1,661,684	1,662,535	1	1288.45	1286.24	1	2.21
MW-011MK	1,662,869	1,661,996	1	1307.30	1304.35	1	2.95
MW-011U	1,664,935	1,665,826	1	1356.33	1347.72	1	8.61
MW-012U	1,664,733	1,665,913	1	1362.18	1347.04	1	15.14
MW-013U	1,663,937	1,664,733	1	1332.48	1331.11	1	1.37
MW-015A	1,662,874	1,662,761	1	1301.22	1300.40	1	0.82
MW-018A	1,663,017	1,661,952	1	1308.10	1305.79	1	2.31
MW-019	1,663,545	1,662,014	1	1311.71	1310.93	1	0.78
MW-020C	1,663,562	1,662,359	1	1312.97	1312.55	1	0.42
MW-021C	1,663,557	1,662,880	1	1310.76	1312.04	1	-1.28
MW-021U	1,666,064	1,664,561	1	1349.00	1344.18	1	4.82
MW-022B	1,663,550	1,663,436	1	1317.35	1312.14	1	5.21
MW-022U	1,665,797	1,664,180	1	1347.90	1342.38	1	5.52
MW-023	1,662,237	1,662,025	1	1296.87	1294.43	1	2.44
MW-024	1,662,207	1,659,279	1	1290.11	1273.30	1	16.81
MW-024U	1,664,049	1,659,176	1	1309.19	1315.55	1	-6.36
MW-025	1,665,488	1,658,783	1	1314.65	1321.22	1	-6.57
MW-026U	1,663,207	1,658,617	1	1301.75	1298.36	1	3.39
MW-027U	1,663,882	1,663,070	1	1318.67	1319.14	1	-0.47
MW-028U	1,664,585	1,660,037	1	1316.26	1322.96	1	-6.70
MW-029U	1,663,820	1,661,690	1	1306.28	1315.28	1	-9.00
MW-030	1,663,028	1,660,505	1	1304.83	1303.35	1	1.48
MW-032	1,664,786	1,662,543	1	1326.09	1328.81	1	-2.72
MW-033	1,665,421	1,662,015	1	1332.53	1335.85	1	-3.32
MW-034	1,665,287	1,663,009	1	1332.17	1336.25	1	-4.08
MW-035	1,663,886	1,664,160	1	1328.88	1326.03	1	2.85
MW-036	1,664,647	1,664,027	1	1331.22	1334.11	1	-2.89
MW-037	1,666,673	1,665,310	1	1355.60	1352.20	1	3.40
MW-038	1,667,787	1,664,257	1	1350.01	1351.04	1	-1.03
MW-039	1,667,805	1,661,230	1	1338.32	1348.72	1	-10.40
MW-040	1,663,319	1,665,330	1	1326.68	1323.51	1	3.17
MW-041	1,663,205	1,663,758	1	1303.31	1300.10	1	3.21
MW-042	1,663,601	1,660,196	1	1317.05	1311.76	1	5.29
MW-043	1,662,963	1,658,272	1	1298.08	1287.34	1	10.74
MW-044A	1,664,247	1,660,584	1	1316.61	1315.69	1	0.92
MW-046	1,663,536	1,663,769	1	1322.02	1311.38	1	10.64
MW-047	1,663,975	1,663,918	1	1326.93	1326.00	1	0.93
MW-048	1,664,716	1,658,112	1	1305.93	1313.48	1	-7.55
MW-055	1,663,152	1,661,469	1	1309.09	1307.00	1	2.09
MW-056	1,663,149	1,661,717	1	1309.11	1307.29	1	1.82
MW-057	1,664,299	1,664,698	1	1340.00	1334.54	1	5.46
MW-058	1,664,298	1,665,136	1	1342.45	1338.98	1	3.47
MW-059	1,664,037	1,665,317	1	1337.14	1337.89	1	-0.75
MW-060	1,664,178	1,665,923	1	1342.77	1343.41	1	-0.64
MW-061	1,664,708	1,665,824	1	1349.00	1346.85	1	2.15
MW-062	1,664,808	1,665,506	1	1350.11	1345.87	1	4.24
MW-063	1,665,103	1,665,959	1	1353.79	1348.42	1	5.37
MW-064	1,665,311	1,665,358	1	1354.45	1346.86	1	7.59
MW-065	1,665,055	1,665,212	1	1352.44	1344.33	1	8.11
MW-066	1,665,051	1,664,640	1	1349.38	1338.76	1	10.62
MW-067	1,666,514	1,664,546	1	1350.30	1347.77	1	2.53
MW-068	1,666,654	1,664,480	1	1350.00	1348.99	1	1.01
MW-069	1,666,446	1,664,494	1	1349.37	1346.47	1	2.90
MW-070	1,666,408	1,664,590	1	1350.99	1346.63	1	4.36
MW-071	1,665,424	1,666,151	1	1353.91	1349.54	1	4.37
MW-072	1,665,154	1,666,561	1	1351.37	1347.98	1	3.39
MW-073	1,665,387	1,666,567	1	1351.85	1348.56	1	3.29
MW-074	1,664,723	1,665,247	1	1348.81	1343.04	1	5.77
MW-075	1,665,000	1,665,957	1	1353.70	1348.16	1	5.54
MW-076	1,665,177	1,665,973	1	1354.62	1348.67	1	5.95
MW-077	1,665,188	1,666,049	1	1353.84	1348.70	1	5.14
MW-078	1,664,963	1,665,864	1	1355.07	1347.86	1	7.21
MW-079	1,663,893	1,664,825	1	1334.44	1330.39	1	4.05
MW-080	1,662,930	1,664,421	1	1301.44	1302.83	1	-1.39
MW-081	1,662,890	1,664,202	1	1302.49	1301.95	1	0.54
MW-082	1,660,753	1,664,660	1	1290.90	1287.58	1	3.32
MW-083	1,661,000	1,663,838	1	1289.10	1279.96	1	9.14
MW-084	1,661,120	1,663,342	1	1288.13	1280.13	1	8.00
MW-085	1,661,240	1,662,923	1	1288.56	1282.85	1	5.71
MW-086	1,661,426	1,661,954	1	1289.71	1287.58	1	2.13
MW-087	1,661,628	1,660,759	1	1292.72	1288.76	1	3.96
MW-088	1,661,711	1,660,339	1	1291.52	1284.27	1	7.25
MW-089	1,661,855	1,659,615	2	1261.82	1269.67	1	-7.85
MW-090	1,662,251	1,657,628	1	1262.57	1262.52	1	0.05
MW-091	1,662,431	1,656,788	1	1262.15	1263.50	1	-1.35
MW-094	1,664,694	1,660,982	1	1323.55	1328.33	1	-4.78
MW-095	1,664,418	1,660,978	1	1320.44	1322.43	1	-1.99
RW-002B	1,662,602	1,663,154	1	1300.41	1295.89	1	4.52





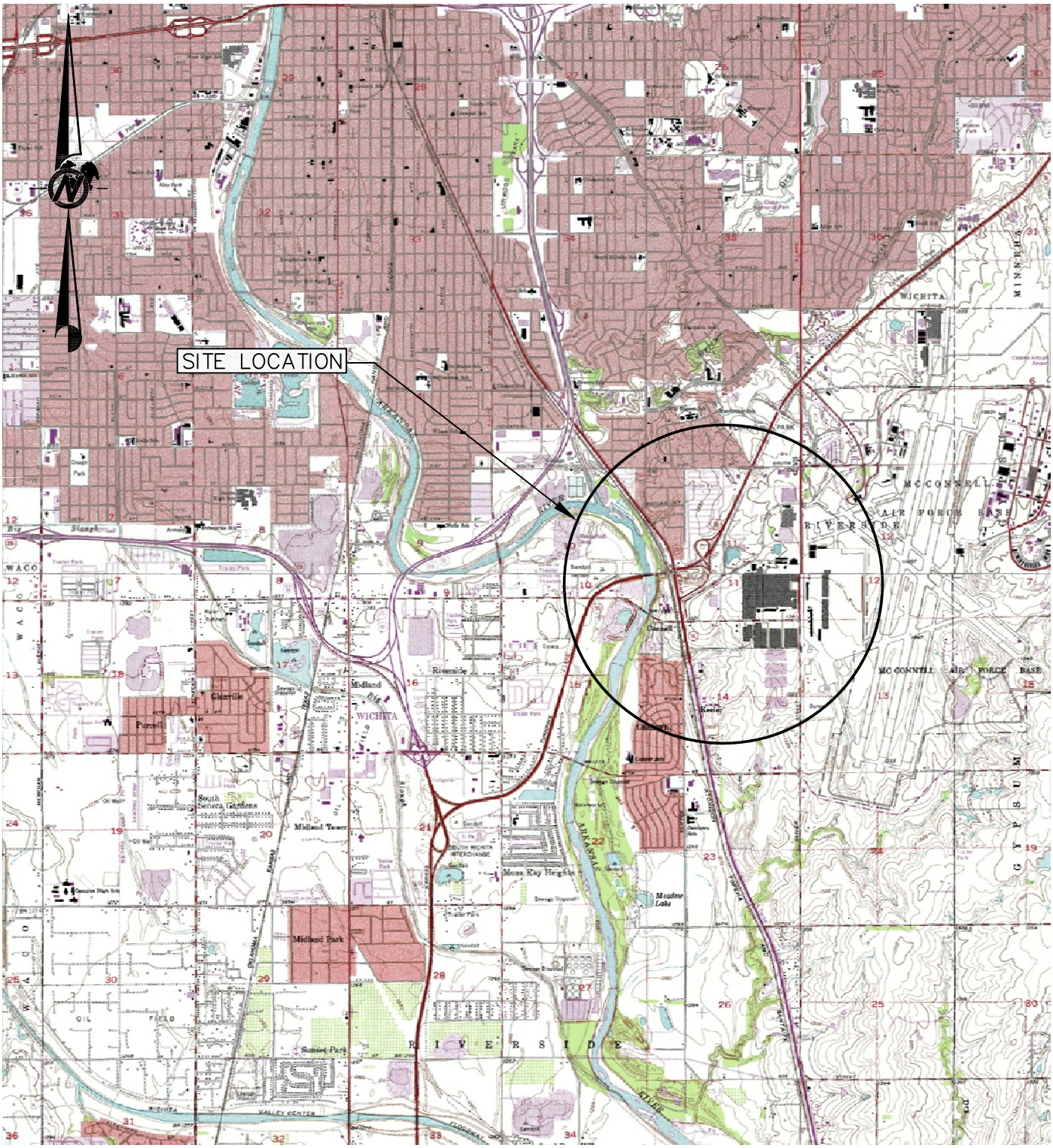
Statistics for 1990 Q3 Model Overburden and Bedrock Targets

	Unweighted		Unweighted
RM	1.82	Minimum Residual:	-12.17
RSD	5.40	Maximum Residual:	16.81
SSR	2831	Head Range:	100.36
ARM	4.60	RSD/Head Range:	0.05
As precentage of Head Range:			
RM	1.8%		
RSD	5.4%		
ARM	4.6%		

Notes:
Calibration output from model "GAI-04_V3.1D"
msl = mean sea level
RM = Residual mean
RSD = Residual Squared Deviation
SSR = Sum of Squared Residuals
ARM = Absolute Residual Mean

Prepared by: RWB 08/21/09
Checked by: RWB 08/21/09
Reviewed by: THR 08/21/09

FIGURES



REFERENCES

BASE MAPS TAKEN FROM 7.5 MINUTE USGS QUADRANGLE MAPS TITLED, "DERBY, KS.", DATED 1961. AND "WICHITA EAST, KS" DATED 1960.

5000 0 5000

SCALE APPROXIMATE FEET

Golder Associates
Manchester, New Hampshire

FILE No.	09381501A008	SCALE	AS SHOWN
PROJECT No.	093-81501	REV. 0	DATE 08/21/09
			DESIGN RWB
			CADD MPB
			CHECK RWB
			REVIEW THR

TITLE

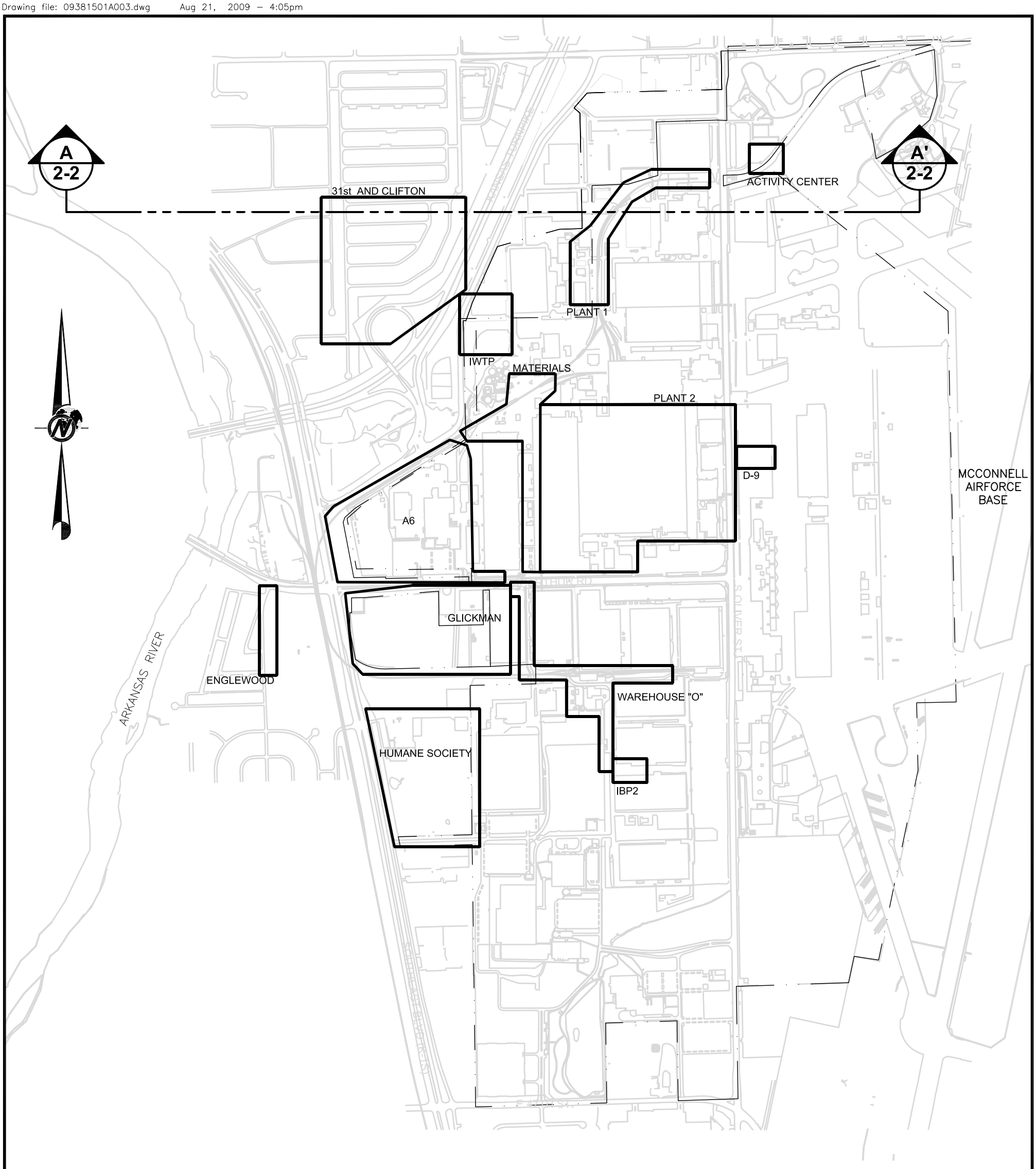
SITE LOCATION MAP

THE BOEING COMPANY
BOEING AND MCCONNELL AIR FORCE BASE
WICHITA, KANSAS

FIGURE 1

Drawing file: 09381501A008.dwg Aug 21, 2009 - 4:24pm

Drawing file: 09381501A003.dwg Aug 21, 2009 – 4:05pm



LEGEND

APPROXIMATE BOEING PROPERTY BOUNDARY

SEE FIGURE 2–2 "GEOLOGIC CROSS SECTION" FOR DETAILS

NOTE

1.) SUB AREAS NAMED BASED ON RECOVERY WELL NETWORK.

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

2.) EXTENT OF STREAMS AND RIVERS BASED ON CADD FILE TITLED "STREAMS.DXF" PROVIDED BY FRANZ ENVIRONMENTAL INC.

1000 0 1000
SCALE FEET

FIGURE 2-1

REVIEW	THR	08/21/09
CHECK	RWB	08/21/09
CADD	BCL	08/21/09
DESIGN	RWB	05/11/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501A003	
PROJECT No.	093-81501	

TITLE

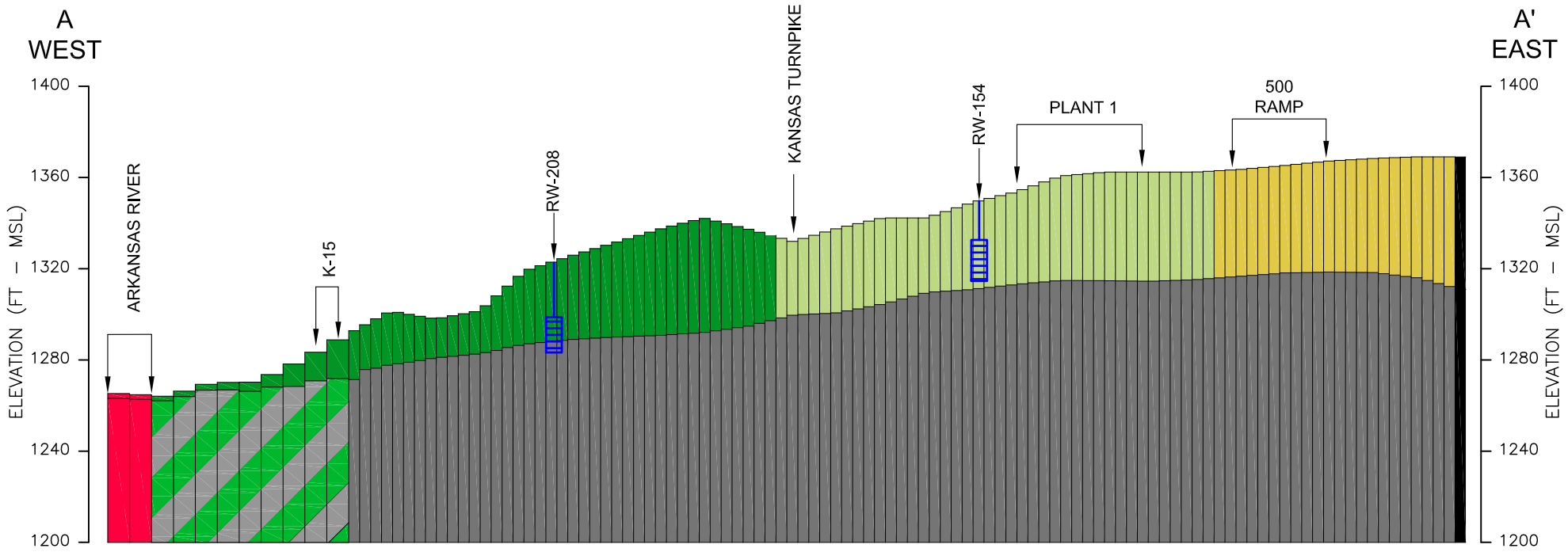
AREA WIDE SITE VICINITY MAP AND SUB AREA LOCATIONS

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501A018.dwg Aug 21, 2009 – 4:41pm



CROSS-SECTION ALONG MODEL ROW 84

LEGEND

- MODEL GRID CELLS
- NO FLOW BOUNDARY
- RIVER BOUNDARY (ARKANSAS RIVER)
- BROWN CLAY
- FLUVIAL DEPOSITS
- OLIVE CLAY
- BEDROCK
- BEDROCK AND FLUVIAL DEPOSITS (INTERFACE UNKNOWN)
- EXISTING RECOVERY WELL

NOTE

1. SITE FEATURES AND SCALE ARE APPROXIMATE.

1000 0 1000
SCALE FEET
VERTICAL SCALE EXAGGERATED 15X

PROJECT
THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

TITLE
GEOLOGIC CROSS SECTION

Golder Associates
Manchester, New Hampshire

PROJECT No.		093-81501	FILE No.	09381501A018
DESIGN	RWB	08/20/09	SCALE AS SHOWN	REV. 0
CADD	BCL	08/21/09		
CHECK	RWB	08/21/09		
REVIEW	THR	08/21/09		

FIGURE 2-2

Drawing file: 09381501A001.dwg Aug 21, 2009 – 4:02pm

LEGEND

NO FLOW CELLS

FINITE DIFFERENCE GRID

NOTES

1.) FINITE DIFFERENCE GRID BASE POINT = 1651740 N AND 1657500 E.

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

2.) EXTENT OF STREAMS AND RIVERS BASED ON CADD FILE TITLED "STREAMS.DXF" PROVIDED BY FRANZ ENVIRONMENTAL INC.

2000 0 2000
SCALE FEET

FIGURE 3-1

REVIEW	THR	08/21/09
CHECK	RWB	08/21/09
CADD	BCL	08/20/09
DESIGN	RWB	05/22/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501A001	
PROJECT No.	093–81501	

TITLE

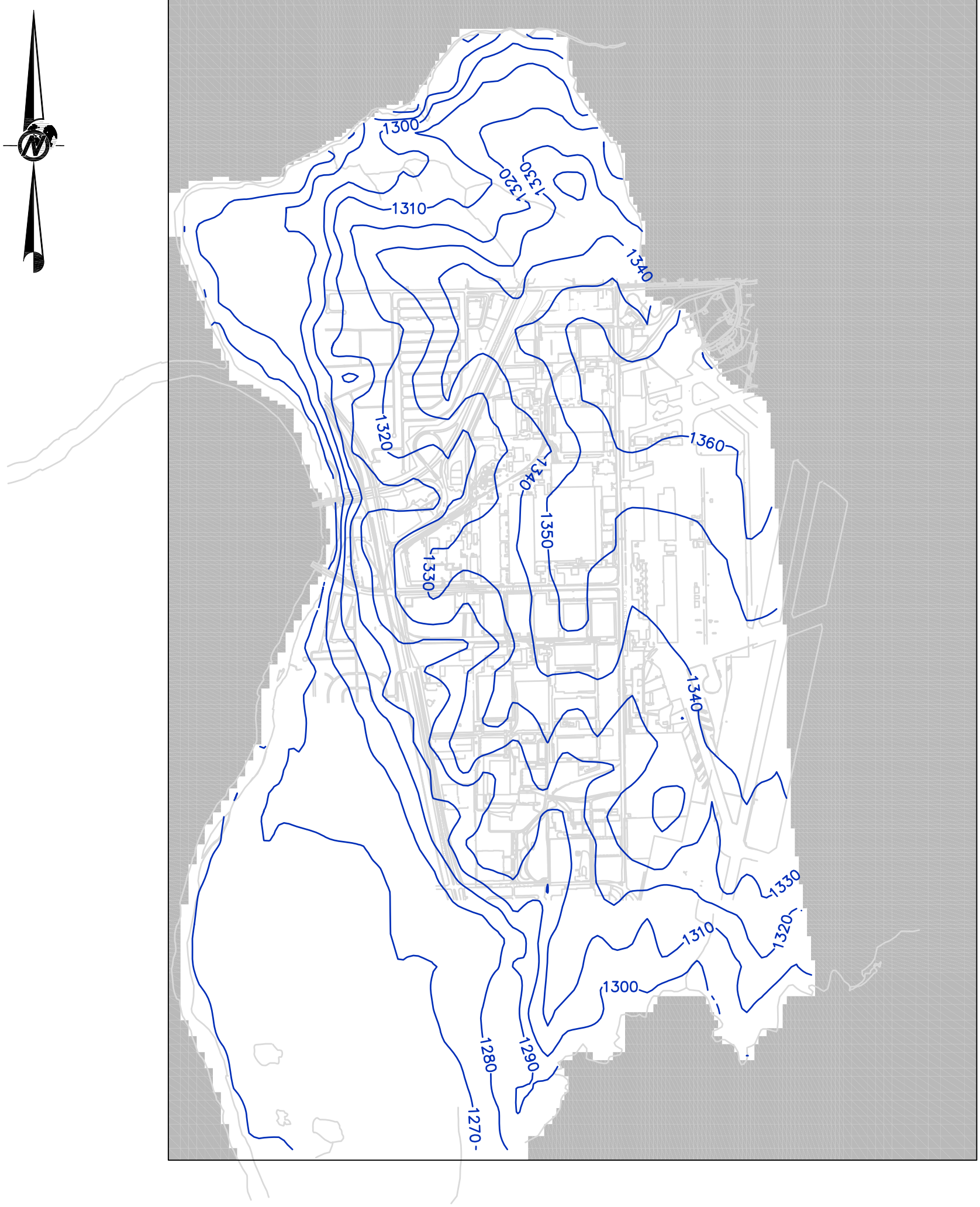
MODEL FINITE DIFFERENCE GRID LAYOUT

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501A002.dwg Aug 21, 2009 – 4:03pm



LEGEND

▭	MODEL GRID EXTENTS
—1300—	GROUND SURFACE CONTOURS (FT–MSL)
▒	NO FLOW CELLS

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

2000 0 2000
SCALE FEET

FIGURE 3-2

REVIEW	THR	08/21/09
CHECK	RWB	08/21/09
CADD	MPB	05/11/09
DESIGN	RWB	05/11/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501A002	
PROJECT No.	093-81501	

TITLE

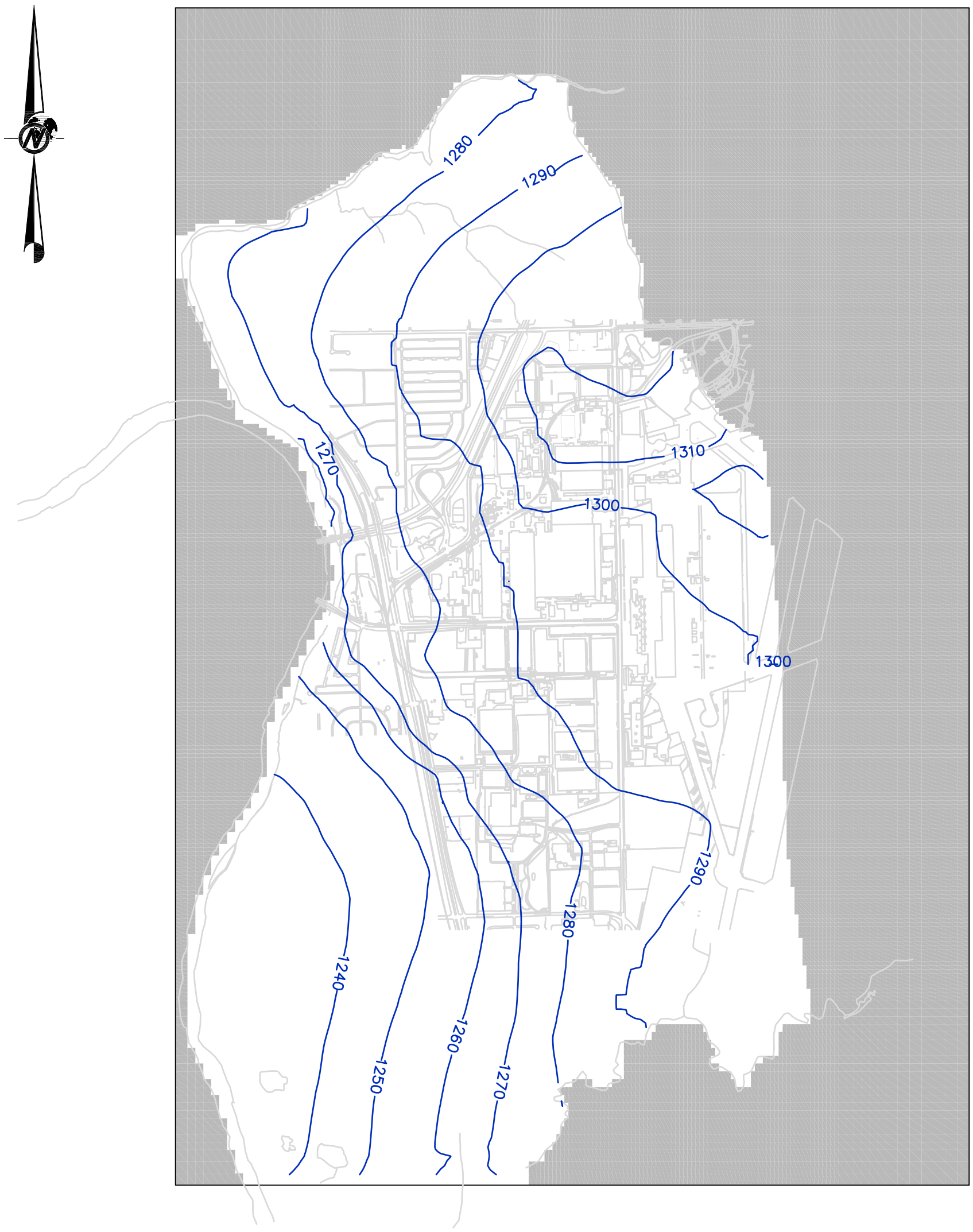
TOP ELEVATION OF LAYER 1 (GROUND SURFACE)

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501A007.dwg Aug 21, 2009 – 4:18pm



LEGEND

▭	MODEL GRID EXTENTS
—1250—	BOTTOM ELEVATION OVERBURDEN
▒	NO FLOW CELLS

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

2.) EXTENT OF STREAMS AND RIVERS BASED ON CADD FILE TITLED "STREAMS.DXF" PROVIDED BY FRANZ ENVIRONMENTAL INC.

2000 0 2000
SCALE FEET

FIGURE 3-3

REVIEW	THR	08/21/09
CHECK	RWB	08/21/09
CADD	MPB	05/11/09
DESIGN	RWB	05/11/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501A007	
PROJECT No.	093-81501	

TITLE

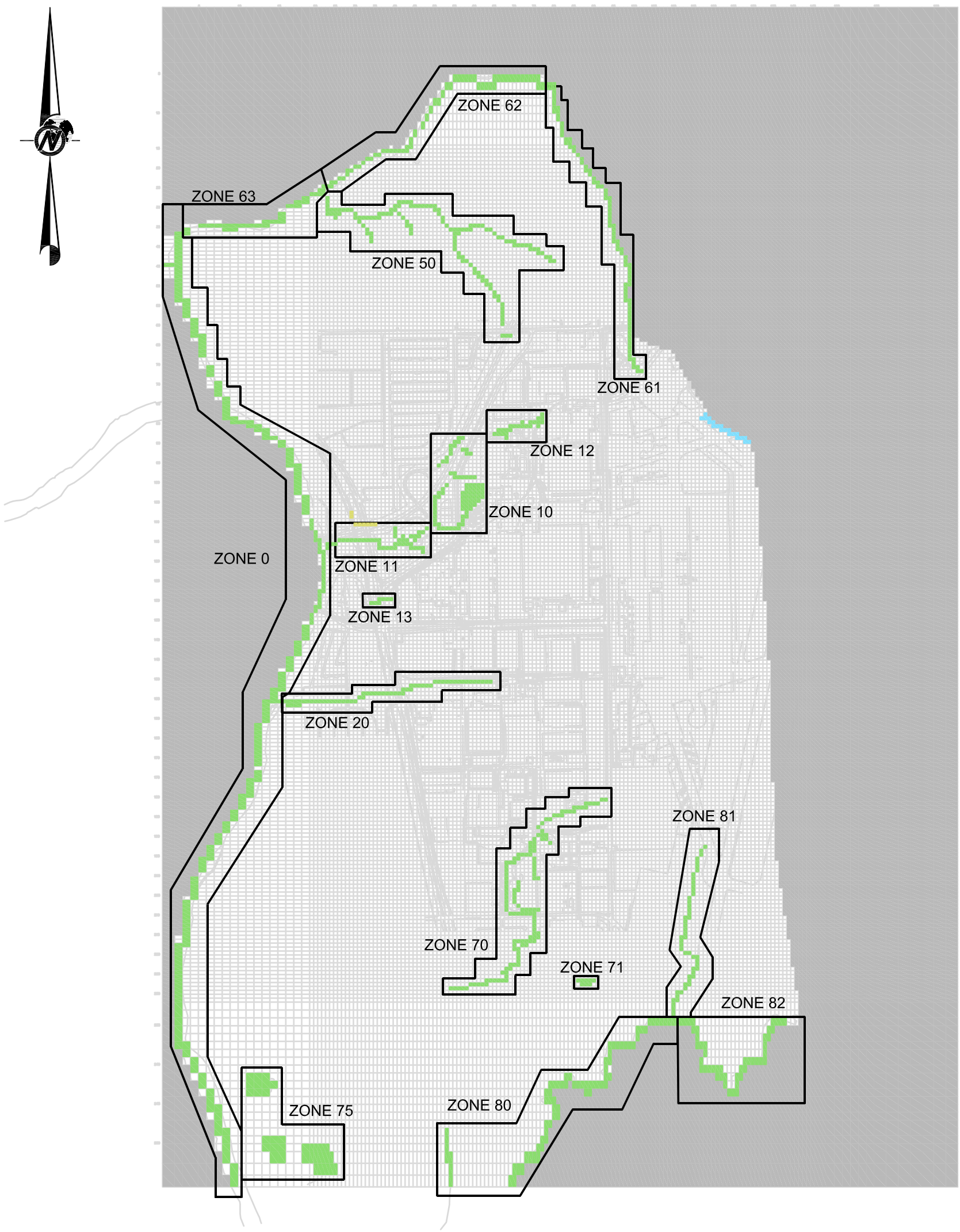
BOTTOM ELEVATION OF LAYER 1 (BASE OF OVERBURDEN)

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501A004.dwg Aug 21, 2009 – 4:06pm



LEGEND

- NO FLOW
- RIVER
- GHB
- DRAIN

NOTES

1.) GHB = GENERAL HEAD BOUNDARY

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

2.) EXTENT OF STREAMS AND RIVERS BASED ON CADD FILE TITLED "STREAMS.DXF" PROVIDED BY FRANZ ENVIRONMENTAL INC.

2000 0 2000
SCALE FEET

FIGURE 3-4

REVIEW	THR	08/21/09
CHECK	RWB	08/21/09
CADD	MPB	05/11/09
DESIGN	RWB	05/11/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501A004	
PROJECT No.	093-81501	

TITLE

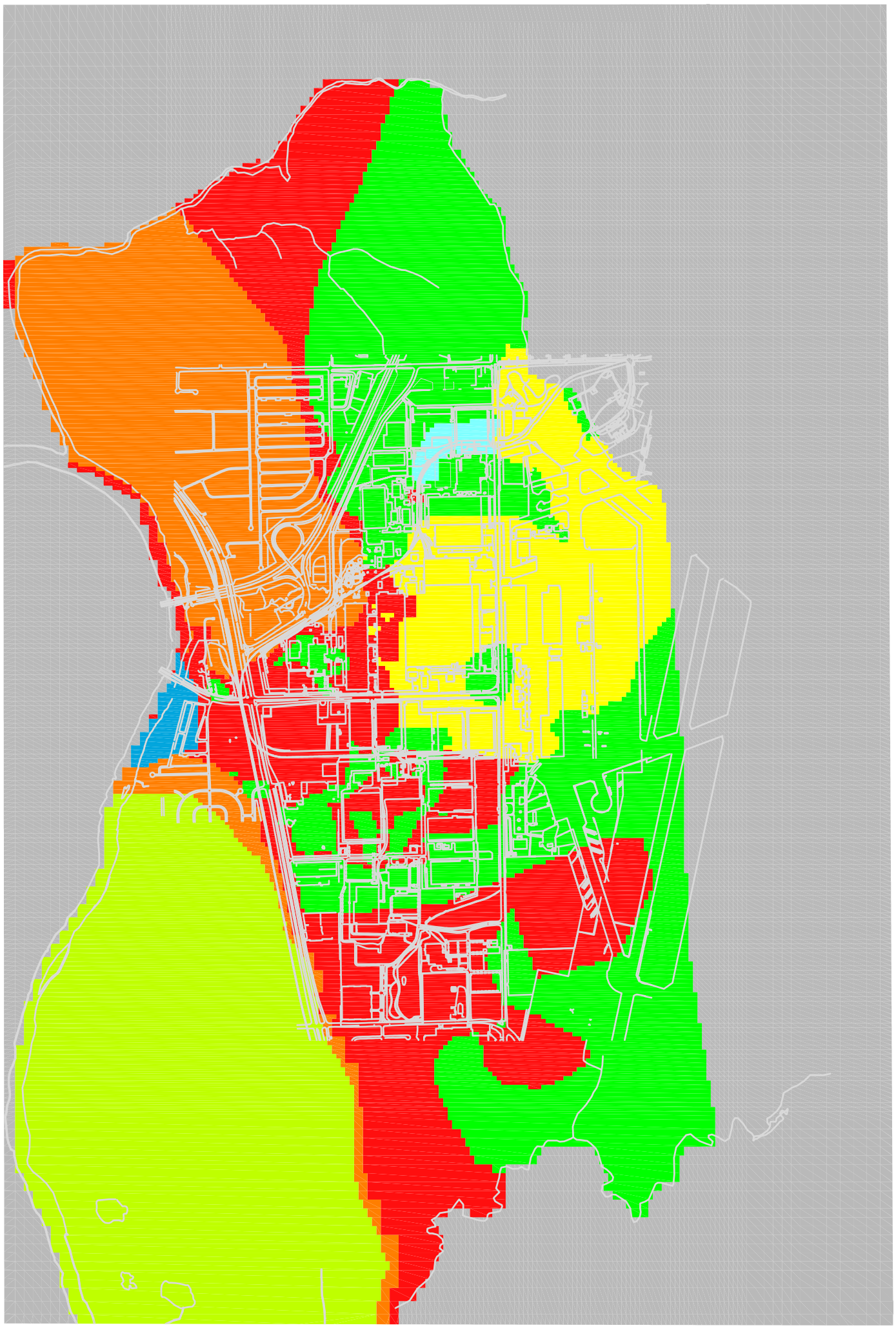
MODEL FINITE DIFFERENCE BOUNDARY CONDITIONS

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501A012.dwg Aug 24, 2009 – 1:30pm



LEGEND

NO FLOW

HYDRAULIC ZONE	CONDUCTIVITY VALUE
2	3.000
3	0.425
4	5.669
5	50.00
15	75.00
20	1.500
30	0.250

NOTES

1.) HYDRAULIC CONDUCTIVITY VALUES IN FEET PER DAY (FT/DAY)

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

2.) EXTENT OF STREAMS AND RIVERS BASED ON CADD FILE TITLED "STREAMS.DXF" PROVIDED BY FRANZ ENVIRONMENTAL INC.

2000 0 2000
SCALE FEET

FIGURE 3-5

REVIEW	THR	08/21/09
CHECK	RWB	08/21/09
CADD	MPB	05/22/09
DESIGN	RWB	05/22/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501A012	
PROJECT No.	093-81501	

TITLE

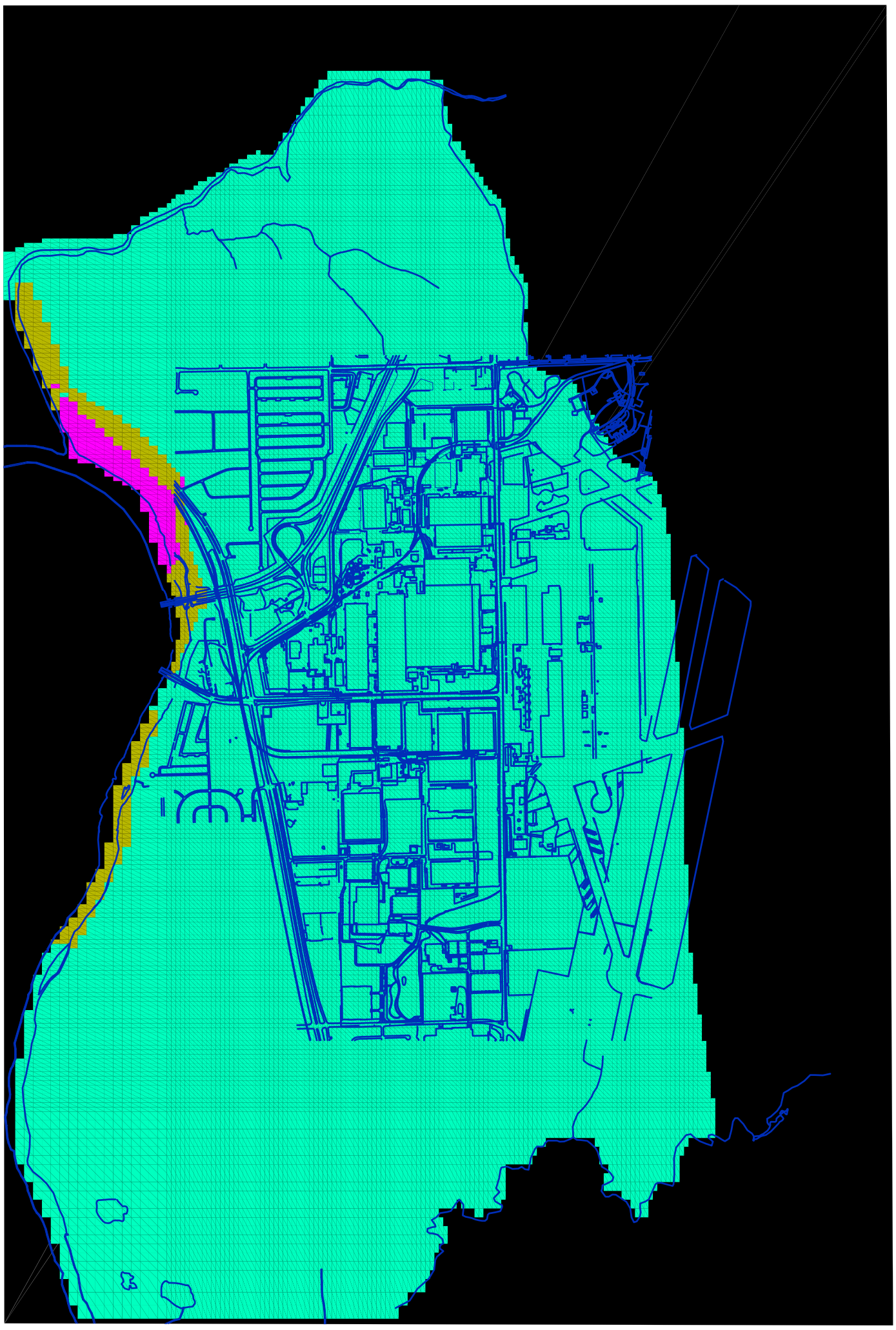
HORIZONTAL HYDRAULIC CONDUCTIVITY OF LAYER 1 OVERBURDEN

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501A014.dwg Aug 21, 2009 – 4:39pm



LEGEND

NO FLOW

HYDRAULIC ZONE	CONDUCTIVITY VALUE
7	0.120
8	0.360
40	0.500

NOTES

1.) HYDRAULIC CONDUCTIVITY VALUES IN FEET PER DAY (FT/DAY)

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

2.) EXTENT OF STREAMS AND RIVERS BASED ON CADD FILE TITLED "STREAMS.DXF" PROVIDED BY FRANZ ENVIRONMENTAL INC.

2000 0 2000
SCALE FEET

FIGURE 3-6

REVIEW	THR 08/21/09
CHECK	RWB 08/21/09
CADD	BCL 08/21/09
DESIGN	RWB 05/22/09
REV. 0	SCALE AS SHOWN
FILE No.	09381501A012
PROJECT No.	093-81501

TITLE

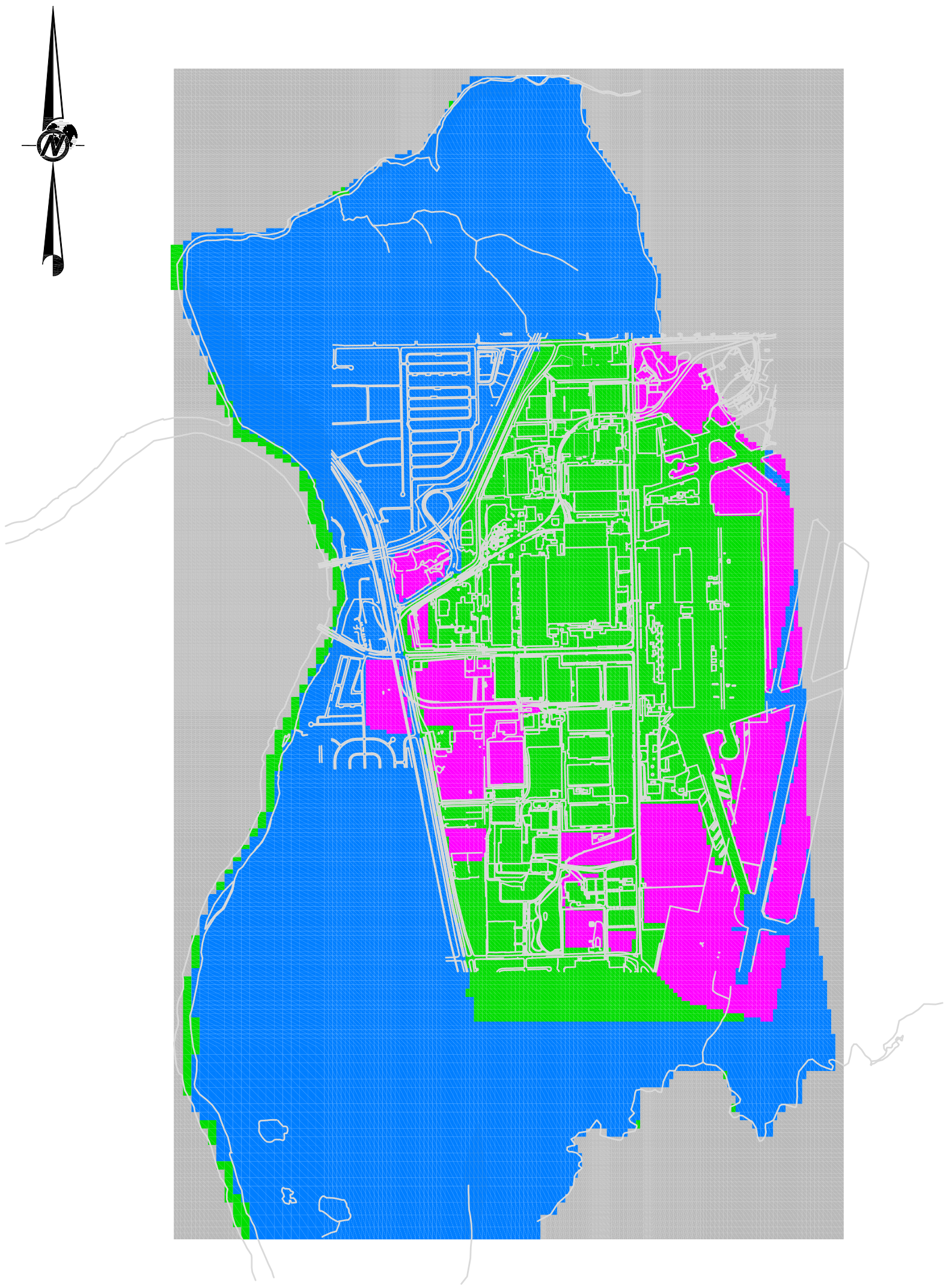
HORIZONTAL HYDRAULIC CONDUCTIVITY OF LAYER 2 BEDROCK

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501A005.dwg Aug 21, 2009 – 4:10pm



LEGEND

RECHARGE

ZONE	ZONE NUMBER
■	98
■	99
■	100

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

2.) EXTENT OF STREAMS AND RIVERS BASED ON CADD FILE TITLED "STREAMS.DXF" PROVIDED BY FRANZ ENVIRONMENTAL INC.

2000 0 2000
SCALE FEET

FIGURE 3-7

REVIEW	THR	08/21/09
CHECK	RWB	08/21/09
CADD	BCL	08/20/09
DESIGN	RWB	05/11/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501A005	
PROJECT No.	093-81501	

TITLE

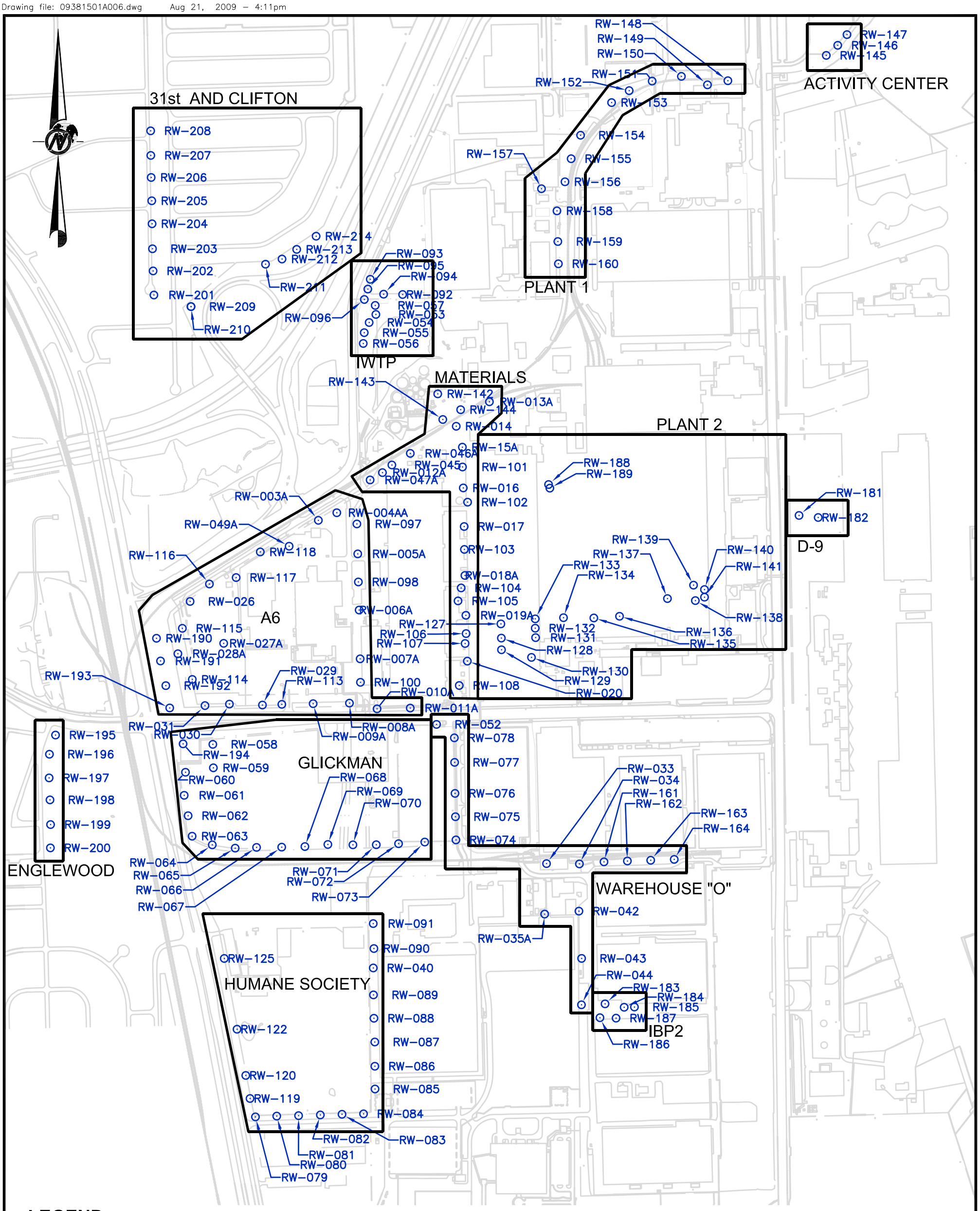
PRECIPITATION RECHARGE OF LAYER 1

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501A006.dwg Aug 21, 2009 – 4:11pm



LEGEND

⊙ RW-200 2007 RECOVERY WELL LOCATIONS

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

600 0 600
SCALE FEET

PROJECT No. 093-81501		
FILE No. 09381501A006		
REV. 0 SCALE AS SHOWN		
DESIGN	RWB	05/11/09
CADD	MPB	05/11/09
CHECK	RWB	08/21/09
REVIEW	THR	08/21/09

FIGURE 3-8

TITLE

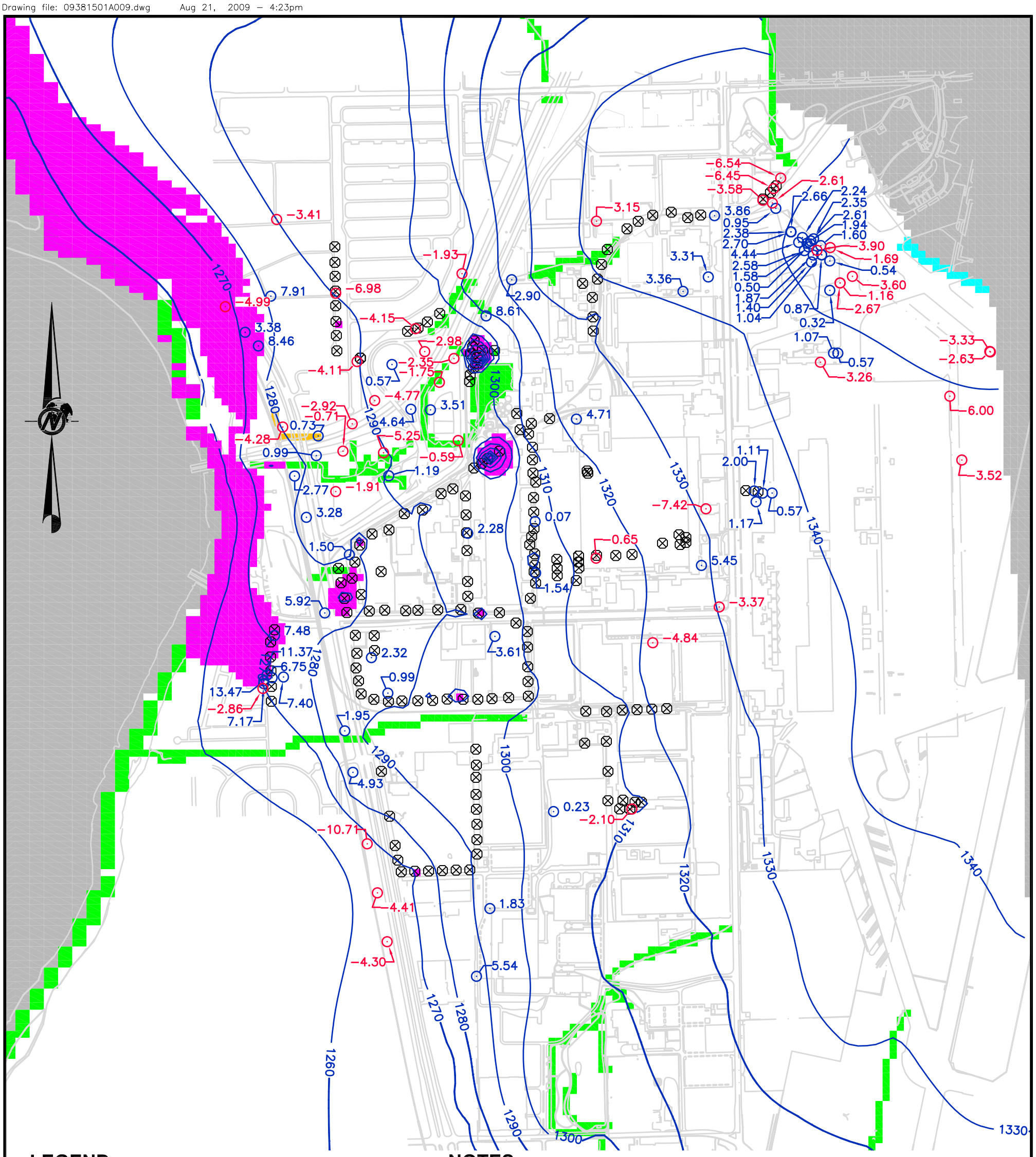
2007 MODEL RECOVERY WELL LOCATIONS

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501A009.dwg Aug 21, 2009 – 4:23pm



LEGEND

O –0.5	NEGATIVE TARGET RESIDUAL VALUE POINTS
O 5.5	POSITIVE TARGET RESIDUAL VALUE POINTS
⊗	RECOVERY WELL
—1270—	GROUNDWATER ELEVATION CONTOUR
	DRY
	GHB
	RIVER
	DRAIN
	NO FLOW

NOTES

1.) GHB = GENERAL HEAD BOUNDARY

2.) NO FLOW CELLS REPRESENT PARTIALLY SATURATED OR UNSATURATED CONDITIONS.

3.) SEE TABLE 3–4 FOR DETAILED CALIBRATION OUTPUT DATA.

4.) TARGET RESIDUALS IN FEET. NEGATIVE RESIDUALS (RED) INDICATE PREDICTED MODEL VALUE IS GREATER THAN OBSERVED VALUE. POSITIVE RESIDUALS (BLUE) INDICATE PREDICTED MODEL VALUE IS LESS THAN OBSERVED VALUE.

5.) RESULTS BASED ON MODEL "GAI–03_V5.9D".

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY..

1000 0 1000
SCALE FEET

FIGURE 3-9

REVIEW	THR	08/21/09
CHECK	RWB	8/21/09
CADD	BCL	08/20/09
DESIGN	RWB	08/20/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501A009	
PROJECT No.	093–81501	

TITLE

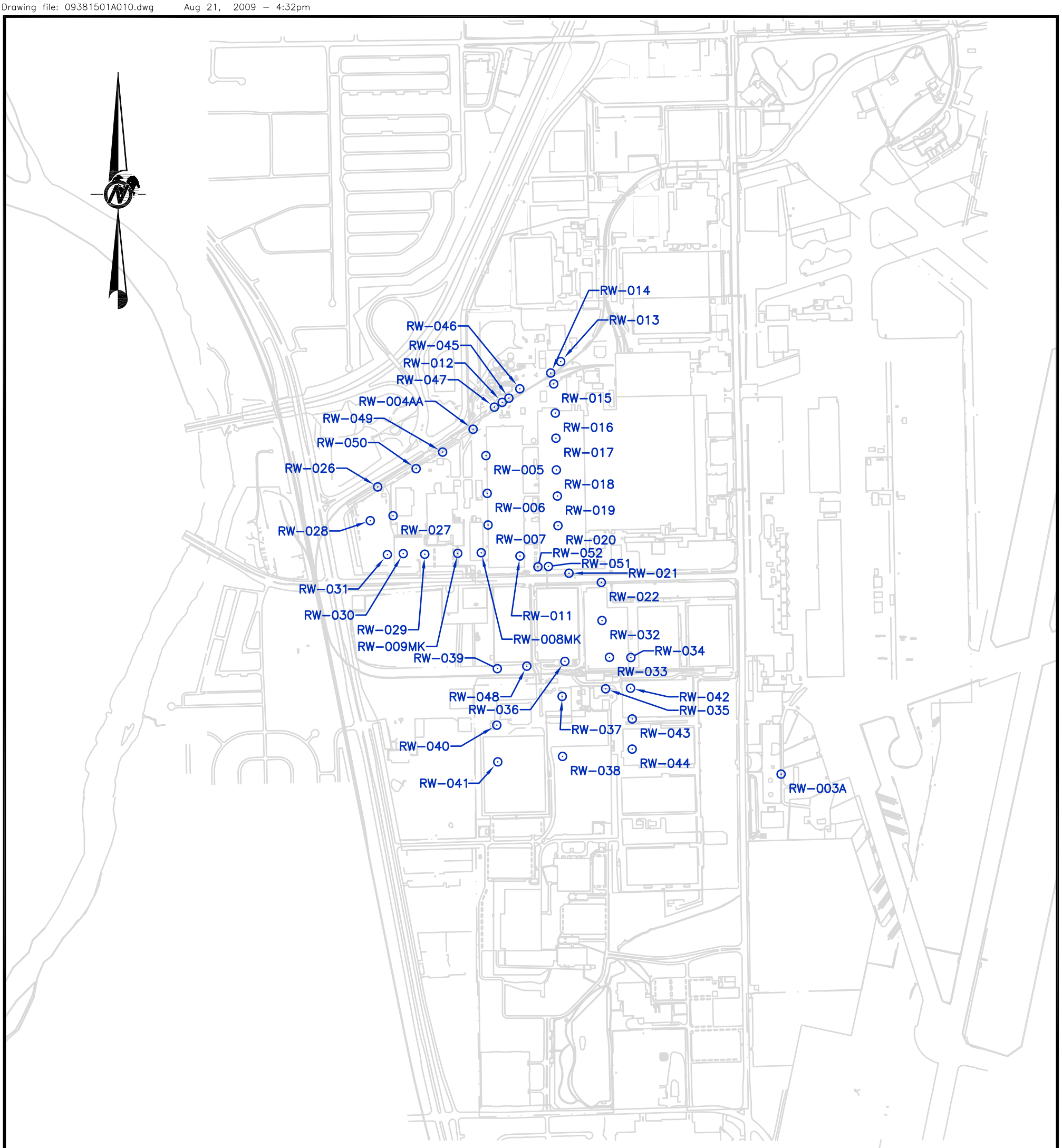
MODFLOW MODEL CALIBRATION RESULTS OVERBURDEN 1ST QUARTER 2007 CONDITIONS

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501A010.dwg Aug 21, 2009 – 4:32pm



LEGEND

RW-041 1990 RECOVERY WELL LOCATIONS

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

1000 0 1000
SCALE FEET

FIGURE 3-10

REVIEW	THR	08/21/09
CHECK	RWB	08/21/09
CADD	MPB	05/11/09
DESIGN	RWB	05/11/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501A010	
PROJECT No.	093-81501	

TITLE

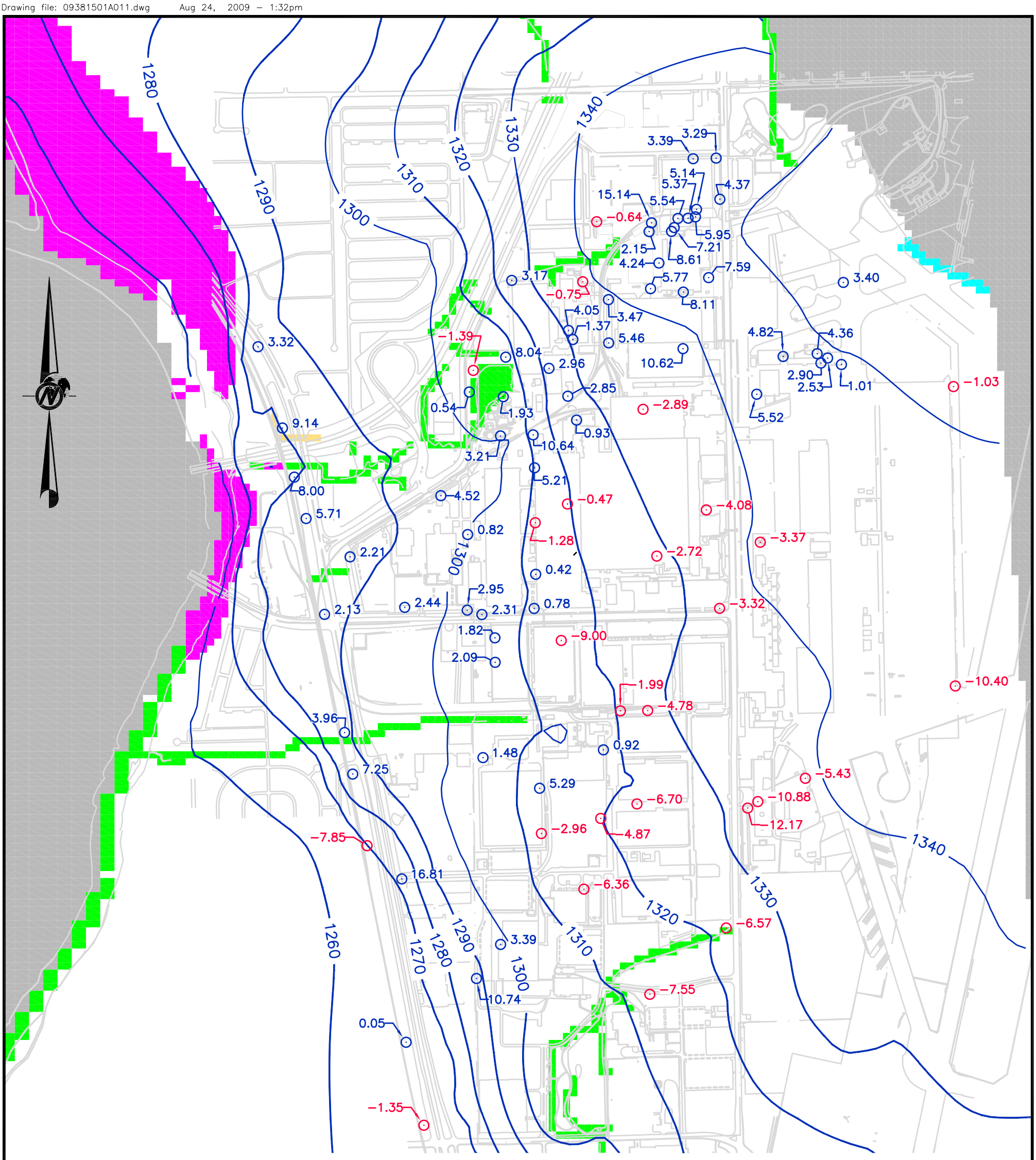
1990 MODEL RECOVERY WELL LOCATIONS

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501A011.dwg Aug 24, 2009 – 1:32pm



LEGEND

−0.5	NEGATIVE RESIDUAL VALUE POINTS
5.5	RESIDUAL VALUE POINTS
1270	GROUNDWATER ELEVATION CONTOUR
	DRY
	GHB
	RIVER
	NO FLOW
	NO FLOW

NOTES

1.) GHB = GENERAL HEAD BOUNDARY

2.) NO FLOW CELLS REPRESENT PARTIALLY SATURATED OR UNSATURATED CONDITIONS.

3.) SEE TABLE 3–7 FOR DETAILED VERIFICATION OUTPUT DATA.

4.) TARGET RESIDUALS IN FEET. NEGATIVE RESIDUALS (RED) INDICATE PREDICTED MODEL VALUE IS GREATER THAN OBSERVED VALUE. POSITIVE RESIDUALS (BLUE) INDICATE PREDICTED MODEL VALUE IS LESS THAN OBSERVED VALUE.

5.) RESULTS BASED ON MODEL "GAI–04_V3.1D".

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

1000 0 1000
SCALE FEET

FIGURE 3-11

REVIEW	THR	08/21/09
CHECK	RWB	08/21/09
CADD	BCL	08/21/09
DESIGN	RWB	05/11/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501A011	
PROJECT No.	093–81501	

TITLE

MODFLOW MODEL VERIFICATION LAYER 1 3RD QUARTER 1990 GROUNDWATER ELEVATION CONDITIONS

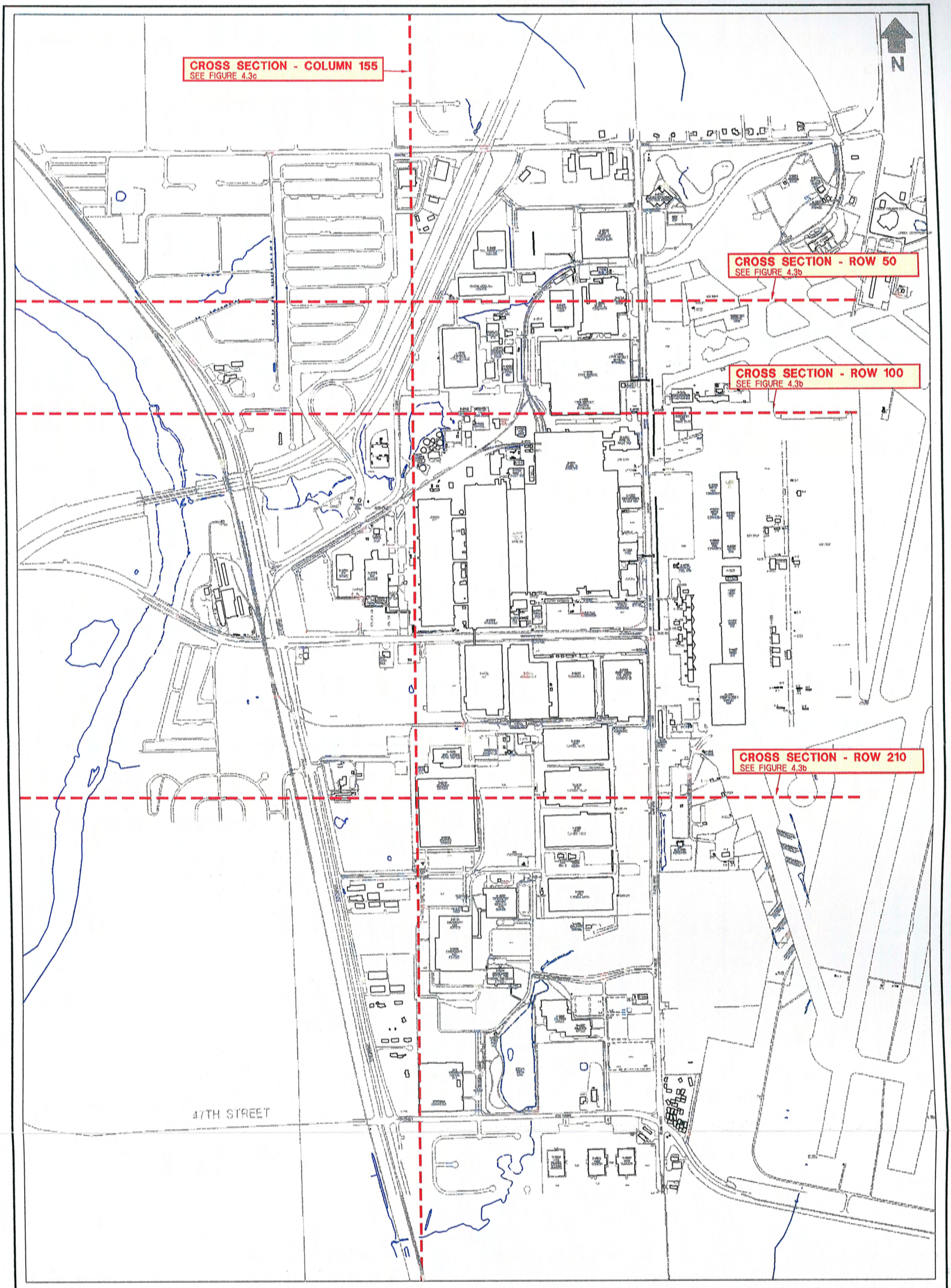
PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

APPENDIX A

GEOLOGIC CROSS SECTION, HISTORIC AQUIFER TEST RESULTS AND EXTENT OF FLUVIAL UNITS (BFA, 1998)



waterloo hydrogeologic

BEATTY FRANZ & ASSOCIATES

Title: PLAN VIEW OF CROSS SECTIONS THROUGH MODEL GRID

Project: 3D GROUNDWATER FLOW MODEL FOR THE BOEING FACILITY, WICHITA, KANSAS

Client: BOEING COMMERCIAL AIRPLANE GROUP WICHITA, KANSAS

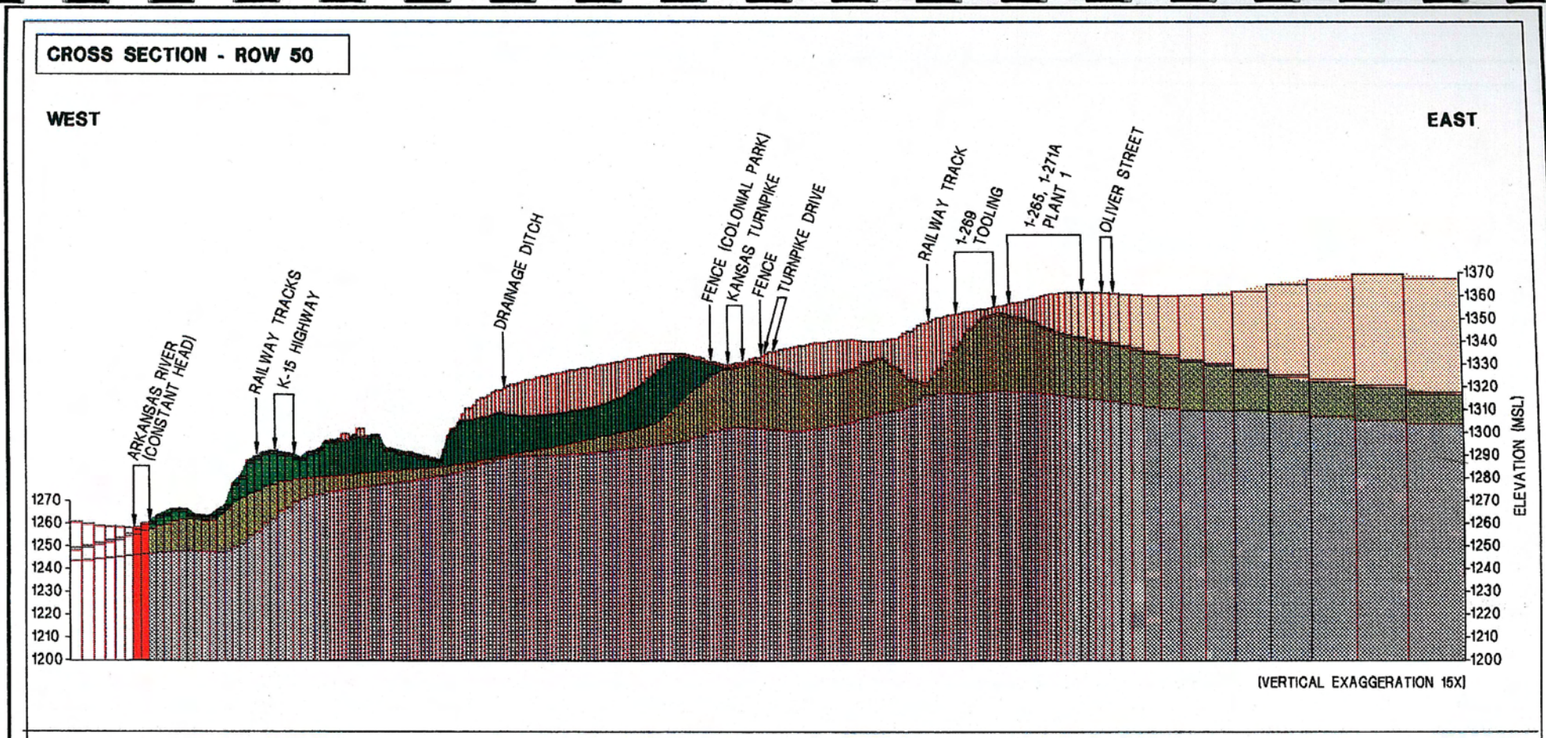
BKS P006513
BvL

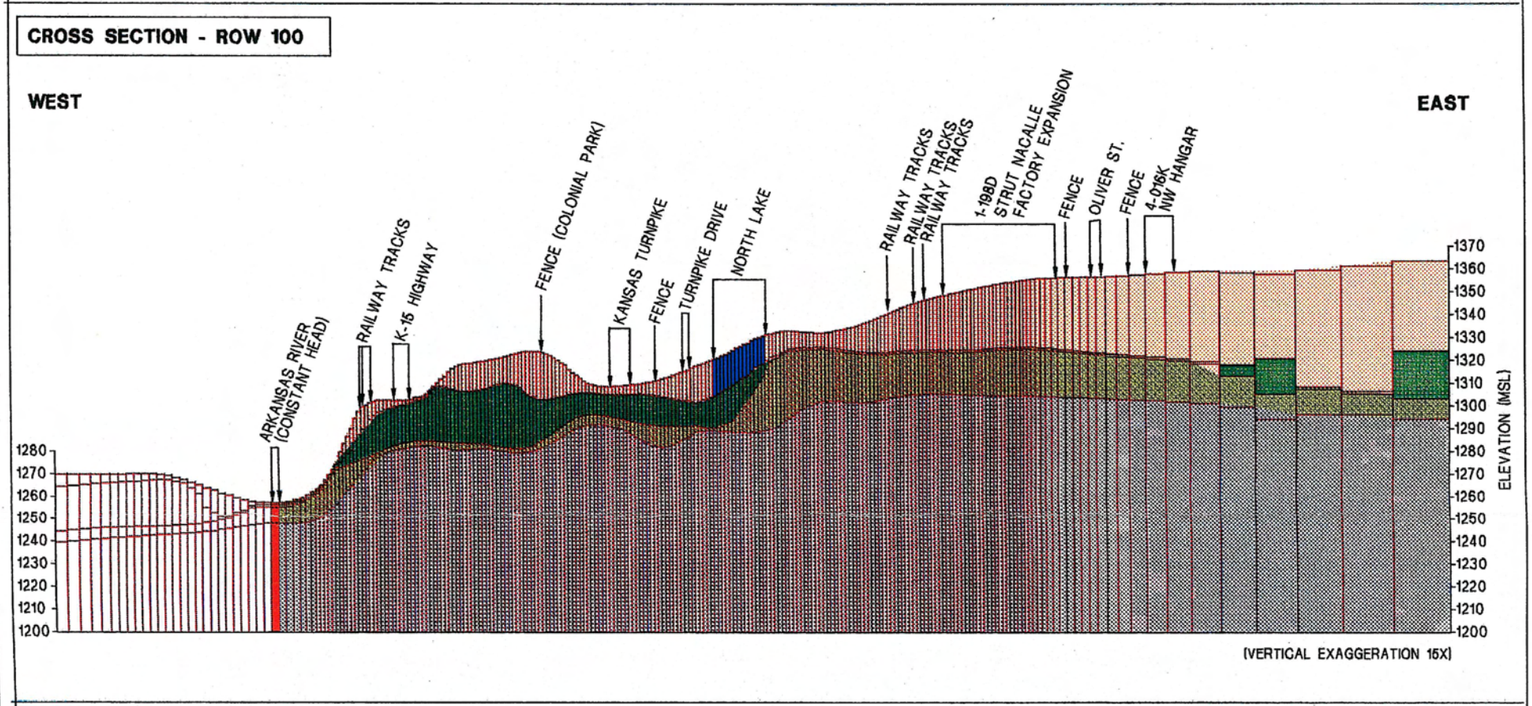
SCALE 1":1000'
1000 800 600 0 600 1000
feet

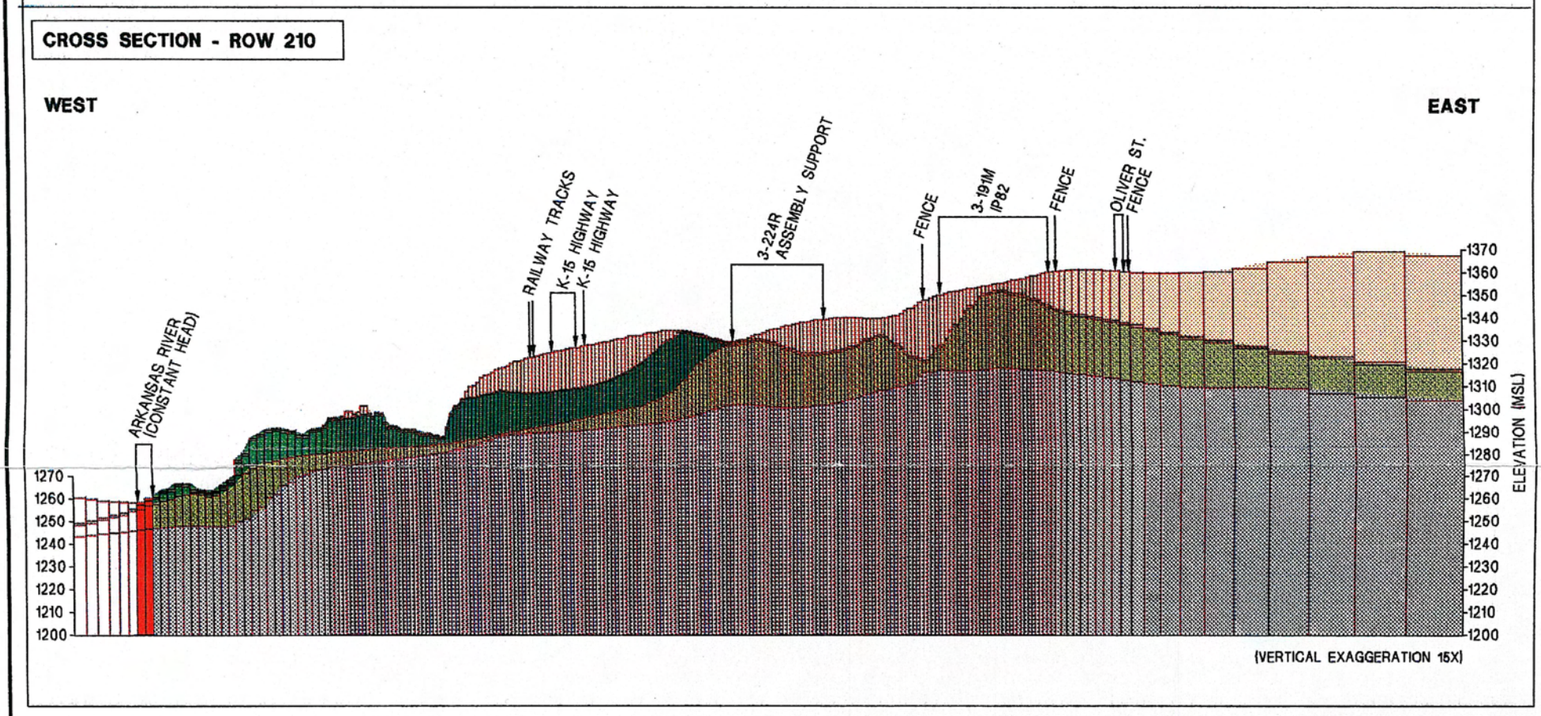
PRIVILEGED & CONFIDENTIAL
ATTORNEY WORK PRODUCT

AUG. 1998

FIGURE 4.3a







LEGEND

- MODEL GRID CELLS
- INACTIVE CELLS
- CONSTANT HEAD BOUNDARY (ARKANSAS RIVER)
- BROWN CLAY
- FLUVIAL DEPOSITS
- OLIVE CLAY
- BEDROCK
- RIVER BOUNDARY

BKS P006514
BvL

HORIZONTAL SCALE 1":1000'
1000 800 600 0 500 1000
feet

waterloo hydrogeologic

BEATTY FRANZ & ASSOCIATES

PRIVILEGED & CONFIDENTIAL
ATTORNEY WORK PRODUCT

Title: EAST-WEST CROSS-SECTIONS THROUGH MODEL GRID

Project: 3D GROUNDWATER FLOW MODEL FOR THE BOEING FACILITY, WICHITA, KANSAS

Client: BOEING COMMERCIAL AIRPLANE GROUP WICHITA, KANSAS

AUG. 1998

FIGURE 4.3b

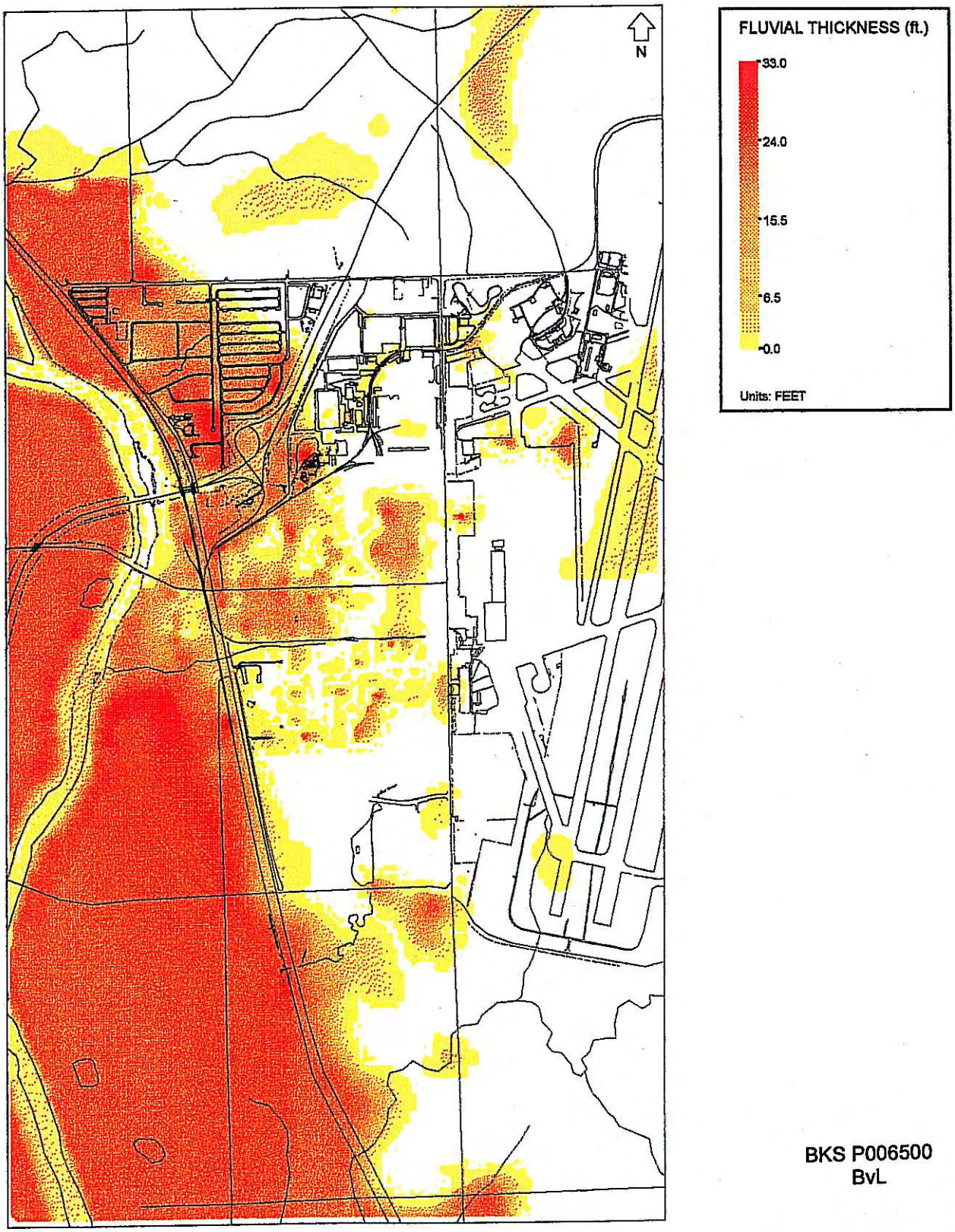
Table 3.1	Hydraulic Conductivities Determined From Pumping Tests		
Well Name	**Location**	**Unit**	**K (cm/s)**
RW-054	IWTP	fluvial	1.17E-02
MW-080	IWTP	fluvial	5.81E-02
Test Wells	Glickman	fluvial	4.47E-03
MW-063	Plant 1	brown and olive clay	1.07E-05

Table 3.2a	Hydraulic Conductivities Determined From Slug Tests From Reports			
Unit	**# Wells**	**Average K (cm/s)**	**Maximum K (cm/s)**	**Minimum K (cm/s)**
brown clay	9	1.29E-03	9.98E-03	1.60E-05
fluvial	6	7.11E-04	5.30E-03	1.12E-05
olive clay	4	2.76E-05	7.70E-05	3.42E-06

Table 3.2b	Hydraulic Conductivities Determined From Slug Tests Analysed by BFA			
Unit	**# Wells**	**Average K (cm/s)**	**Maximum K (cm/s)**	**Minimum K (cm/s)**
brown clay	10	1.75E-04	8.40E-04	8.23E-06
fluvial	27	1.83E-03	1.24E-02	7.40E-05
olive clay	3	5.86E-05	9.66E-05	2.30E-05

Table 3.3a	Hydraulic Conductivities Determined From Well Efficiency Tests Analysed by Boeing			
Unit	**# Wells**	**Average K (cm/s)**	**Maximum K (cm/s)**	**Minimum K (cm/s)**
brown clay and fluvial	4	1.16E-03	4.77E-03	4.76E-05
fluvial	7	1.13E-02	7.63E-02	7.68E-05
brown and olive clays	5	1.10E-04	2.84E-04	1.99E-05

Table 3.3b	Hydraulic Conductivities Determined From Well Efficiency Tests Analysed by BFA			
Unit	**# Wells**	**Average K (cm/s)**	**Maximum K (cm/s)**	**Minimum K (cm/s)**
brown clay	0	na	na	na
fluvial	16	1.95E-02	0.147	2.40E-04
olive clay	12	1.27E-03	3.66E-03	1.81E-04



BKS P006500
BvL

waterloo hydrogeologic

BEATTY FRANZ & ASSOCIATES

PRIVILEGED & CONFIDENTIAL
ATTORNEY WORK PRODUCT

Title: THICKNESS OF FLUVIAL UNITS

Project: 3D GROUNDWATER FLOW MODEL FOR THE BOEING FACILITY, WICHITA, KANSAS

Client: BOEING COMMERCIAL AIRPLANE GROUP WICHITA, KANSAS

AUG. 1998

FIGURE 3.7 a

SCALE 1":2500'

1000 0 1000 2000 3000
feet

SURFACES-BASE.DWG

APPENDIX B

MODFLOW MODEL SENSITIVITY ANALYSIS

MODFLOW MODEL SENSITIVITY ANALYSIS

BOEING FACILITY
WICHITA, KANSAS

BASE Model Run (1x multiplier on all parameters)*

	1	**1815.4**	**3.38**	**4.19**

Parameter: Kz Zone: 2

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.1	1815.4	3.38	4.19
2	0.5	1815.4	3.38	4.19
3	2	1815.4	3.38	4.19
4	10	1815.4	3.38	4.19

Parameter: Kx Zone: 2

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1954.5	3.44	4.37
2	0.8	1857.2	3.38	4.26
3	0.9	1799.4	3.35	4.18
4	1.1	1824.1	3.42	4.19
5	1.25	1873.9	3.50	4.23
6	2	2022.6	3.69	4.33

Parameter: Kz Zone: 3

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.1	1815.4	3.38	4.19
2	0.5	1815.4	3.38	4.19
3	2	1815.4	3.38	4.19
4	10	1815.4	3.38	4.19

Parameter: Kx Zone: 3

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1860.2	3.33	4.27
2	0.8	1842.8	3.36	4.24
3	0.9	1842.7	3.37	4.24
4	1.1	1820.1	3.41	4.19
5	1.5	1837.8	3.47	4.20
6	2	1871.3	3.53	4.22

Parameter: Kx Zone: 4

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	2267.5	3.69	4.71
2	0.8	1881.0	3.43	4.28
3	0.9	1812.5	3.37	4.19
4	1.1	1824.6	3.39	4.21
5	1.5	1893.4	3.47	4.31
6	2	2186.3	3.62	4.61

BOEING FACILITY
WICHITA, KANSAS

BASE Model Run (1x multiplier on all parameters)*

	1	**1815.4**	**3.38**	**4.19**

Parameter: Kx Zone: 5

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	2094.1	3.63	4.53
2	0.8	1881.1	3.45	4.28
3	0.9	1820.1	3.39	4.21
4	1.1	1805.0	3.36	4.17
5	1.5	1799.2	3.30	4.14
6	2	1821.7	3.29	4.14
7	4	1903.9	3.38	4.20

Parameter: Kx Zone: 9

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1903.8	3.46	4.30
2	0.8	1823.1	3.38	4.21
3	0.9	1811.6	3.37	4.19
4	1.1	1809.2	3.37	4.18
5	1.5	1801.8	3.36	4.17
6	2	1793.1	3.32	4.16
7	4	1837.7	3.32	4.21

Parameter: Kx Zone: 15

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1815.3	3.38	4.19
2	0.8	1815.1	3.38	4.19
3	0.9	1815.2	3.38	4.19
4	1.1	1815.6	3.38	4.19
5	2	1805.9	3.37	4.18
6	4	1811.3	3.39	4.18

Parameter: Kx Zone: 20

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1815.4	3.38	4.19
2	0.8	1815.4	3.38	4.19
3	0.9	1815.4	3.38	4.19
4	1.1	1815.4	3.38	4.19
5	2	1815.5	3.38	4.19
6	4	1815.5	3.38	4.19

BOEING FACILITY
WICHITA, KANSAS

BASE Model Run (1x multiplier on all parameters)*

	1	**1815.4**	**3.38**	**4.19**

Parameter: Kx Zone: 7

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1841.0	3.22	4.25
2	0.8	1795.7	3.31	4.18
3	0.9	1804.6	3.35	4.19
4	1.1	1830.6	3.43	4.20
5	2	2058.8	3.75	4.35
6	4	2719.1	4.34	4.81

Parameter: Kx Zone: 8

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1808.1	3.37	4.19
2	0.8	1798.3	3.36	4.18
3	1.4	1824.4	3.38	4.20
4	2	1820.1	3.36	4.19

Parameter: Kx Zone: 40

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1818.7	3.37	4.21
2	0.8	1808.9	3.38	4.19
3	1.4	1832.1	3.39	4.20
4	2	1853.2	3.39	4.22

Parameter: Recharge Zone: 98

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1892.4	3.57	4.20
2	0.8	1854.2	3.47	4.22
3	1.4	1844.2	3.30	4.25
4	2	2055.0	3.43	4.41

Parameter: Recharge Zone: 99

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	2301.3	3.94	4.33
2	0.8	1914.9	3.60	4.20
3	1.4	2232.4	3.63	4.57
4	2	4345.4	5.16	5.72

BOEING FACILITY
WICHITA, KANSAS

BASE Model Run (1x multiplier on all parameters)*

	1	**1815.4**	**3.38**	**4.19**

Parameter: Recharge Zone: 100

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1885.9	3.39	4.23
2	0.8	1812.9	3.36	4.18
3	1.4	1835.3	3.38	4.23
4	2	1996.5	3.46	4.42

Parameter: River Stage Reach: 0

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.999	1804.8	3.35	4.18
2	0.9995	1815.7	3.38	4.19
3	1.0005	1805.2	3.37	4.18
4	1.001	1821.1	3.39	4.20

Parameter: River Stage Reach: 10

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.999	1861.8	3.37	4.19
2	0.9995	1829.4	3.37	4.18
3	1.0005	1828.5	3.41	4.22
4	1.001	1860.2	3.45	4.27

Parameter: River Stage Reach: 11

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.999	3467.2	4.56	5.83
2	0.9995	1854.2	3.41	4.21
3	1.0005	1832.0	3.39	4.22
4	1.001	1832.1	3.38	4.23

Parameter: River Stage Reach: 12

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.999	1824.8	3.40	4.19
2	0.9995	1819.5	3.39	4.19
3	1.0005	1800.1	3.35	4.18
4	1.001	1798.3	3.34	4.18

Parameter: River Stage Reach: 13

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.999	1817.4	3.38	4.19
2	0.9995	1816.3	3.38	4.19
3	1.0005	1802.5	3.36	4.18
4	1.001	1814.2	3.38	4.19

BOEING FACILITY
WICHITA, KANSAS

BASE Model Run (1x multiplier on all parameters)*

	1	**1815.4**	**3.38**	**4.19**

Parameter: River Stage Reach: 20

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.999	1842.9	3.44	4.21
2	0.9995	1826.4	3.41	4.20
3	1.0005	1832.1	3.39	4.21
4	1.001	1819.0	3.38	4.19

Parameter: River Stage Reach: 50

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.999	1814.9	3.38	4.19
2	0.9995	1815.1	3.38	4.19
3	1.0005	1815.8	3.38	4.19
4	1.001	1816.2	3.38	4.19

Parameter: River Stage Reach: 61

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.9995	1816.0	3.39	4.19
2	1.0005	1815.1	3.37	4.19
3	1.001	1815.1	3.36	4.20
4	1.0015	1803.5	3.34	4.19

Parameter: River Stage Reach: 70

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.999	1808.5	3.37	4.18
2	0.9995	1818.1	3.39	4.19
3	1.0005	1801.6	3.36	4.18
4	1.001	1812.6	3.39	4.19

Parameter: River Conductance Reach: 0

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1810.2	3.37	4.19
2	0.8	1816.8	3.38	4.19
3	1.2	1814.8	3.38	4.19
4	2	1813.8	3.38	4.19
5	5	1813.7	3.38	4.19

BOEING FACILITY
WICHITA, KANSAS

BASE Model Run (1x multiplier on all parameters)*

	1	**1815.4**	**3.38**	**4.19**

Parameter: River Conductance Reach: 10

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	2496.9	3.76	4.71
2	0.8	1829.9	3.34	4.17
3	1.2	1842.5	3.43	4.24
4	2	2243.4	3.70	4.67
5	5	4410.7	4.74	6.25

Parameter: River Conductance Reach: 11

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1848.9	3.40	4.22
2	0.8	1805.6	3.37	4.18
3	1.2	1812.1	3.38	4.19
4	2	1806.9	3.37	4.19

Parameter: River Conductance Reach: 12

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1817.5	3.39	4.19
2	0.8	1815.9	3.38	4.19
3	1.2	1815.1	3.38	4.19
4	2	1802.5	3.36	4.18

Parameter: River Conductance Reach: 13

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1804.6	3.37	4.18
2	0.8	1817.0	3.38	4.19
3	1.2	1802.2	3.36	4.18
4	2	1809.8	3.37	4.19

Parameter: River Conductance Reach: 20

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1893.9	3.50	4.26
2	0.8	1828.1	3.41	4.20
3	1.2	1833.4	3.40	4.21
4	2	1808.6	3.36	4.19

BOEING FACILITY
WICHITA, KANSAS

BASE Model Run (1x multiplier on all parameters)*

	1	**1815.4**	**3.38**	**4.19**

Parameter: River Conductance Reach: 61

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1803.3	3.34	4.19
2	0.8	1815.1	3.37	4.19
3	1.2	1815.7	3.39	4.19
4	2	1816.9	3.40	4.19

Parameter: River Conductance Reach: 70

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1816.9	3.38	4.19
2	0.8	1815.7	3.38	4.19
3	1.2	1815.4	3.38	4.19
4	2	1803.6	3.36	4.18

Parameter: Drain Head Reach: 0

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.999	1815.9	3.38	4.19
2	0.9995	1814.9	3.38	4.19
3	1.0005	1816.5	3.38	4.19
4	1.001	1817.4	3.38	4.19

Parameter: Drain Head Reach: 1

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.999	1815.0	3.39	4.19
2	0.9995	1814.8	3.38	4.19
3	1.0005	1816.6	3.38	4.19
4	1.001	1818.3	3.38	4.20

Parameter: Drain Conductance Reach: 0

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1815.4	3.38	4.19
2	0.8	1815.4	3.38	4.19
3	1.2	1815.4	3.38	4.19
4	2	1815.4	3.38	4.19

MODFLOW MODEL SENSITIVITY ANALYSIS

BOEING FACILITY
WICHITA, KANSAS

BASE Model Run (1x multiplier on all parameters)*

	1	**1815.4**	**3.38**	**4.19**

Parameter: Drain Conductance Reach: 1

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1815.4	3.38	4.19
2	0.8	1815.4	3.38	4.19
3	1.2	1815.4	3.38	4.19
4	2	1815.4	3.38	4.19

Parameter: GHB Conductance Reach: 10

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.5	1815.4	3.38	4.19
2	0.8	1815.4	3.38	4.19
3	1.2	1815.4	3.38	4.19
4	2	1815.4	3.38	4.19

Parameter: GHB Head Reach: 10

Run	Multiplier	Sum of Squares	Residual Mean	Residual Std.
1	0.999	1828.8	3.47	4.14
2	0.9995	1808.1	3.42	4.16
3	1.0005	1825.6	3.33	4.22
4	1.001	1852.1	3.32	4.26

* Note: Sensitivity analysis based on model run GAI-03_V5.9D

APPENDIX B

RECOVERY WELL OPTIMIZATION REPORT

Golder Associates Inc.
670 Commercial Street, Suite 103
Manchester, NH 03101-1146
Telephone: (603) 668-0880
Fax: (603) 668-1199
www.golder.com

DRAFT

RECOVERY WELL OPTIMIZATION REPORT
FORMER BOEING FACILITY
WICHITA, KANSAS

Prepared for:

The Boeing Company
2727 East MacArthur
Wichita, Kansas 67216

Prepared by:

Golder Associates Inc.
670 North Commercial Street
Suite 103
Manchester, NH 03101

Distribution:

6 Copies – Boeing
2 Copies – Golder

September 30, 2009 Our Ref.: 093-81501

Golder Associates Inc.
670 Commercial Street, Suite 103
Manchester, NH 03101-1146
Telephone: (603) 668-0880
Fax: (603) 668-1199
www.golder.com

DRAFT

September 30, 2009

The Boeing Company
2727 East MacArthur
Wichita, Kansas 67216

Attn: Mr. Michael Spain

RE: RECOVERY WELL OPTIMIZATION REPORT
FORMER BOEING FACILITY
WICHITA, KANSAS

Dear Mr. Spain:

As requested by the Boeing Company (Boeing), Golder Associates Inc. (Golder) prepared this Recovery Well Optimization Report (RWOR) for the Recovery Well Network at the Former Boeing Facility at 4615 South Oliver Street in Wichita, Kansas. The RWOR and the 2009 Groundwater Modeling Report (2009 GMR) serve as part of the "Optimization Work Plan" (OWP) requested by the Kansas Department of Health and Environment (KDHE) in their July 27, 2009 letter. The OWP will provide the technical basis upon which monitoring, extraction/injection and treatment alternatives can be developed for the site. The OWP will be submitted to KDHE separately, and will include the 2009 GMR and the RWOR as appendices.

Should you have any questions regarding this report, please do not hesitate to call.

Sincerely,

GOLDER ASSOCIATES INC.

Eric Kern, Ph.D.
Senior Microbiologist

Ross Bennett, P.E.
Project Engineer

Todd H. Rees, Ph.D., P.E.
Program Leader and Principal

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1.0 INTRODUCTION

1.1 Objectives

As requested by the Boeing Company (Boeing), Golder Associates Inc. (Golder) prepared this Recovery Well Optimization Report (RWOR) for the Recovery Well Network at the Boeing Facility at 4615 South Oliver Street in Wichita, Kansas (the Site) (Figure 1-1).

This recovery well network optimization report is intended to be used in conjunction with the 2009 Groundwater Modeling Report (2009 GMR) dated August 21, 2009. The RWOR and the 2009 GMR are components of the ongoing monitoring and recovery well optimization program at the Site. In their July 27, 2009 letter, the Kansas Department of Health and Environment (KDHE) identified three tasks to be completed by Boeing to "update the current administrative framework for investigation and remediation activities." Those tasks included:

- Vapor Intrusion Investigation Work Plan;
- Groundwater Monitoring and Recovery Well Optimization, including an "Optimization Work Plan" (OWP); and
- Feasibility Study (FS) Revisions.

The general purpose for using groundwater modeling at a site is to assist in developing more optimal, technical solutions to overall site remediation. As KDHE noted, the OWP "should include an evaluation of the existing monitoring and recovery well networks and recommendations for optimizing the number of monitoring wells sampled, sampling methods, frequency of sampling, and analytical parameters… For recovery wells, the evaluation should address location and number of wells to achieve containment and achievement of remedial action objectives for the Site."

Groundwater monitoring and remediation systems need accurate 3-dimensional groundwater direction and velocity information to best utilize resources for more optimal monitoring networks and treatment applications. For the OWP, the general scope of the groundwater modeling is to:

- Simulate the groundwater flow regimes;
- Predict the extent of existing capture zones;
- Optimize the groundwater monitoring and recovery systems;
- Predict the results of in-situ remedial pilot test(s) (i.e., flow components); and

- Demonstrate hydraulic control/capture will be maintained during optimization of the groundwater extraction system.

The 2009 GMR generally follows the KDHE Bureau of Environmental Remediation/Remedial (BER) Section Guideline "Minimum Standards for Model Use," (BER-RS-007). As stated in BER-RS-007, the report must include (very briefly):

a) Purpose and scope;
b) Geology, hydrology, lithology and analytical data;
c) Data sources;
d) Conceptual model;
e) Model selection (numerical);
f) Documentation of calculations (numerical implementation);
g) Calibration and verification;
h) Sensitivity analysis;
i) Model results (predictive simulations); and
j) Probable results (uncertainty simulations).

The 2009 GMR provided details on the tasks a) through h). The predictive and uncertainty simulations (tasks i) and j), respectively) are the focus of this Recovery Well Optimization Report.

2.0 GROUNDWATER FLOW MODEL PREDICTIVE SIMULATIONS AND RECOVERY WELL OPTIMIZATION

2.1 Introduction

Golder developed the groundwater flow model for the site using the United States Geological Survey (USGS) Modular Three-Dimensional Finite-Difference Groundwater Flow Model (MODFLOW; MacDonald and Harbaugh, 1988). Details of groundwater flow model development are included in the 2009 GMR dated August 21, 2009. Golder completed predictive simulations using MODPATH (Pollack, 1989) for particle trace analysis.

Prior to completing MODPATH simulations, Golder refined the model grid described in the 2009 GMR by decreasing the grid spacing. For the first quarter 2007 (2007 Q1) calibration model documented in the 2009 GMR, the grid size of 70 x 70 ft was sufficient to simulate the flow regime of the site. However, preliminary MODPATH simulations indicated that the 70 x 70 ft grid size of the 2007 Q1 calibration model resulted in weak sink issues. For the MODPATH simulations, Golder reduced the grid size in areas of the model to 12 x 18 ft to reduce the occurrence of weak sinks. To improve model convergence, Golder converted dry cells in layer 1 along the Arkansas River in the 2007 model output to no flow cells. The model files for MODPATH simulations use the root file name GAI-03_V6.91D.

The pre- and post-processing software we used for the modeling was Groundwater Vistas Version 5.36 (Environmental Simulations Inc., 2007). The following discussions present the predictive modeling scenarios for the existing groundwater recovery system as well as optimization scenarios.

As part of the OWP, Golder has used the term “optimization” in keeping with KDHE correspondence. As part of Golder’s optimization of the recovery well system, Golder has attempted to reduce the number of active recovery wells and the total flow rate of the recovery well system, while maintaining capture of impacted groundwater at the site. By using the term “optimization”, Golder does not imply that the opinions in this report represent a unique or absolute solution to the problem of improving the efficiency of the recovery well network at the Site.

2.2 Existing Conditions – 2007 Recovery Well System

For evaluation of site-wide capture of the existing recovery well system, Golder completed MODPATH simulations as described in the following sections.

2.2.1 2007 Recovery Well Rates

Golder simulated Boeing extraction and recharge wells in the groundwater flow model as grid independent (analytic element) wells. For the 2007 Q1 calibration model, Golder assigned extraction and recharge rates based on historic monthly totalizer volumes observed between January 2006 and December 2007 as provided by Franz Envionmental Inc. of Mississauga, Ontario (FEI). The period from January 2006 to December 2007 represents the most recent period with available monthly recovery well totalizer data. For the purpose of evaluating the performance of the existing recovery well network, Golder calculated average (arithmetic mean) of the monthly recovery well rates over the two year period, including months with low or zero flow in the wells. The 2006-2007 calculated average monthly flow rates are shown in Table 2-1. The locations of modeled groundwater recovery wells are shown in Figure 2-1.

2.2.2 MODPATH Particle Starting Locations

For MODPATH simulations, Golder placed particles in portions of the model with known or historic groundwater impacts at the top of each cell or water table surface in each layer. The particle starting locations for MODPATH simulations along with 2008 total volatile organic compound (TVOC) contours prepared by Boeing are presented in Figure 2-2.

2.2.3 2007 MODPATH Simulation Results

Flow paths for 2007 Q1 model generated by the MODPATH computer code are presented in Figure 2-3. The MODPATH simulations indicate that the Boeing recovery well system captured the majority of the placed particles, with the exception of the following:

- One of the 30 particles placed in the Plant 1 vicinity was not captured by the modeled recovery well network. This particle ends up in the vicinity of the K-15 drain system. The un-captured particle travels under Boeing North Lake between the IWTP wells and Materials wells in the vicinity of MW-006A, MW-081, and MW-096. Recent analytical

results from MW-006A, MW-081, and MW-096 did not detect VOCs above analytical reporting limits, suggesting that the existing recovery well network is providing capture in this area.

MODPATH particle trace analysis results indicate that the existing recovery well network is capable of capturing groundwater originating from under the Site.

2.3 Recovery Well Optimization

As part of optimization of the recovery well system, Golder performed the following:

- MODPATH simulations for optimization to develop a primary recovery well network (RWN),
- An uncertainty analysis on the predicted capture zone of the primary RWN, and
- MODPATH simulations for addition of secondary recovery wells to the network to add redundancy and extra capacity in areas where the sensitivity analysis indicated potential for compromised capture during optimization.

Golder's recovery well optimization effort did not include the 31st and Clifton, 500 Ramp/Activity Center, and Englewood recovery well networks. These well sub-networks have been kept on as an additional level of redundancy in the recovery well network.

2.3.1 Primary Recovery Well Network

Golder identified the candidate wells for the primary recovery well network (RWN) through an iterative process. The primary RWN represents an array of recovery wells that reduces the number of active recovery wells and the total flow rate of the recovery well system, while maintaining capture of more than 95% of the particles originating from portions of the site with known or historic groundwater impacts. Initially, Golder selected a sub-set of highly productive wells located downgradient of impacted areas. Golder completed a preliminary site wide capture zone analysis using this sub-set of highly productive wells, identified areas where capture was not complete, and turned on additional wells in those areas. After several iterations of this approach, Golder arrived at the primary RWN shown in Table 2-2 and Figure 2-4. The model files for the primary RWN MODPATH simulations use the root file name GAI-03_V6.91Dmp_OT-9B.

For the primary RWN, Golder assigned extraction rates based on historic monthly totalizer volumes observed between January 2006 and December 2007 as provided by FEI. For the purpose of

optimizing the existing recovery well network, Golder calculated average (arithmetic mean) of the monthly recovery well rates over the two year period, excluding months with low or zero flow in the wells. These average optimization recovery well rates represent historic hydrogeologic performance of the recovery wells, and do not include the influence of recovery well shut-down or underperformance due to mechanical or operational issues.

The primary RWN comprises 58 active recovery wells for a total recovery rate of 19,500 cubic feet per day (cfd) (101 gallons per minute (gpm)). When compared to the 2007 Q1 modeled recovery well network which comprises 135 active wells (>1 cfd extraction rate) for a combined recovery rate of 22,000 cfd (114 gpm), the primary RWN results in a reduction of 77 wells and 2,500 cfd (13 gpm) less flow from the recovery well network.

2.3.2 MODPATH Results – Primary RWN

Flow paths for the primary RWN generated by the MODPATH computer code are presented in Figure 2-5. The MODPATH simulations predict the following:

- The optimized recovery well system captured the majority of the placed particles.
  - Plant 1/Reclamation/Materials: Out of 30 particles placed, 29 particles are simulated as captured and one particle simulated as not captured (97% captured).
  - Plant 2: Out of 85 particles placed, 82 particles are simulated as captured and three particles simulated as not captured (96% captured).
  - South Campus: Out of 45 particles placed, 44 particles are simulated as captured and one particle simulated as not captured (98% captured).

MODPATH particle trace analysis results suggest the primary RWN is capable of capturing the majority of groundwater originating from under the Site.

2.3.3 MODPATH Optimization Uncertainty Analysis

To account for subsurface heterogeneity and parameter uncertainty inherent in subsurface modeling, Golder performed an uncertainty analysis on the predicted capture of the primary RWN by varying the property values of the hydraulic conductivity zones containing recovery wells. Based on the results of the groundwater flow model sensitivity analysis, the model calibration results were generally not sensitive to hydraulic conductivity multipliers between 0.8 and 1.2. Based on these results, Golder performed an uncertainty analysis on hydraulic conductivity using multipliers of 0.7

and 1.5, as shown in Table 2-3. The results of the uncertainty analysis are presented in Appendix A.

2.3.4 Secondary Recovery Well Network

The results of the sensitivity analysis indicate that the flow model's predicted capture is not achieved in all areas of the site under the range of conductivity values tested. For areas where uncertainty exists, Golder has included a secondary RWN comprised of additional wells or increased flow rate in existing wells to add redundancy to the primary RWN. Based on the results of the uncertainty analysis, Golder included the secondary RWN wells in the following areas:

- Plant 1:
  - Addition of recovery well RW-149,
  - Increased the flow rate in RW-152 from 70 cfd (0.36 gpm) to 85 cfd (0.44 gpm)
  - Increased the flow rate in RW-153 from 16 cfd (0.08 gpm) to 25 cfd (0.13 gpm)
- Materials:
  - Addition of recovery wells RW-101, RW-142, and RW-143 in the vicinity of recovery well RW-045.
- Plant 2:
  - Main building sub-area:
    - Addition of recovery well RW-127 near recovery well RW-019A in the vicinity of the Plant 2 source zone.
    - Addition of recovery well RW-098.
    - Addition of recovery well RW-116 near recovery well RW-026.
  - Glickman sub-area:
    - Addition of recovery well RW-058 near recovery wells RW-060 and RW-194.
    - Increased the flow rate in recovery well RW-060 from 17 cfd (0.09 gpm) to 40 cfd (0.21 gpm).
- South Campus:
  - Addition of recovery wells RW-079 and RW-08 in the vicinity of recovery well RW-080.

The primary and secondary RWN are shown on Table 2-4 and Figure 2-6. The model files for the primary RWN MODPATH simulations use the root file name GAI-03_V6.91Dmp_OT-9D.

The primary and secondary RWN combined comprise 68 active recovery wells for a total recovery rate of 21,100 cfd (110 gpm). When compared to the 2007 Q1 modeled recovery well network which comprises 135 active wells (>1 cfd extraction rate) for a combined recovery rate of 22,000 cfd (114

gpm), the primary RWN results in a reduction of 67 wells and 900 cfd (approximately 4.7 gpm) less flow from the recovery well network.

3.0 SUMMARY AND CONCLUSIONS

As part of optimization of the recovery well system, Golder performed the following:

- MODPATH simulations for optimization to develop a primary recovery well network,
- An uncertainty analysis on the predicted capture zone of the primary recovery well network, and
- MODPATH simulations for addition of secondary recovery wells to the network to add redundancy and extra capacity in areas where the sensitivity analysis indicated potential for compromised capture during optimization of the recovery well network.

The primary and secondary RWN combined comprise 68 active recovery wells for a total recovery rate of 21,100 cfd (110 gpm). When compared to the 2007 Q1 modeled recovery well network which comprises 135 active wells (>1 cfd extraction rate) for a combined recovery rate of 22,000 cfd (114 gpm), the primary RWN results in a reduction of 67 wells and 900 cfd (4.7 gpm) less flow from the recovery well network.

4.0 REFERENCES

Environmental Simulations Inc., 2007. Groundwater Vistas Version 5.36. Reinholds, Pennsylvania.

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

Pollack, D.W., 1989. Documentation of Computer Programs to Compute and Display Pathlines using results from the United States Geological Survey modular Three-Dimentional Finite-Difference Ground-Water Model. United States Geological Survey Open File Report 89-381, Reston, Virginia, 188 p.

TABLES

TABLE 2-1
RECOVERY WELL RATES FOR EXISTING SYSTEM

BOEING FACILITY
WICHITA, KANSAS

Extraction Well ID	2007 Flow Rate[1] ft^3/day	gpm
RW-003A	-0.60	<0.01
RW-004AA	-273	-1.42
RW-005A	-107	-0.56
RW-006A	0	<0.01
RW-007A	-2.6	-0.01
RW-008A	-84	-0.44
RW-009A	-30	-0.16
RW-010A	-320	-1.66
RW-011A	-214	-1.11
RW-012A	-69	-0.36
RW-013A	-23	-0.12
RW-014	-0.78	<0.01
RW-15A	-3.3	-0.02
RW-016	-0.32	<0.01
RW-017	-29	-0.15
RW-018A	**0**	**<0.01**
RW-019A	-298	-1.55
RW-020	-198	-1.03
RW-026	-992	-5.15
RW-027A	-3.1	-0.02
RW-028A	-228	-1.18
RW-029	-27	-0.14
RW-030	-112	-0.58
RW-031	-3.7	-0.02
RW-033	-395	-2.05
RW-034	-78	-0.41
RW-035A	-89	-0.46
RW-040	-14	-0.07
RW-042	-39	-0.20
RW-043	-135	-0.70
RW-044	-152	-0.79
RW-045	-1986	-10.32
RW-046A	-353	-1.83
RW-047A	-144	-0.75
RW-049A	-219	-1.14
RW-052	-209	-1.09
RW-053	-1316	-6.84
RW-054	-290	-1.51
RW-055	-107	-0.56
RW-056	-9.4	-0.05
RW-057	-1037	-5.39
RW-058	-142	-0.74
RW-059	**0**	**<0.01**
RW-060	-4.1	-0.02
RW-061	-69	-0.36
RW-062	-57	-0.30
RW-063	-3.3	-0.02
RW-064	-4.1	-0.02
RW-065	-34	-0.18
RW-066	-171	-0.89
RW-067	-50	-0.26
RW-068	**0**	**<0.01**
RW-069	**0**	**<0.01**
RW-070	-514	-2.67
RW-071	**0**	**<0.01**
RW-072	**0**	**<0.01**
RW-073	**0**	**<0.01**
RW-074	**0**	**<0.01**

Extraction Well ID	2007 Flow Rate[1] ft^3/day	gpm
RW-075	-270	-1.40
RW-076	-61	-0.32
RW-077	-155	-0.81
RW-078	-38	-0.20
RW-079	-2.9	-0.02
RW-080	-186	-0.97
RW-081	-22	-0.11
RW-082	-241	-1.25
RW-083	-88	-0.46
RW-084	-38	-0.20
RW-085	-180	-0.94
RW-086	-52	-0.27
RW-087	-168	-0.87
RW-088	-21	-0.11
RW-089	-155	-0.81
RW-090	**0**	**<0.01**
RW-091	**0**	**<0.01**
RW-092	**0**	**<0.01**
RW-093	-468	-2.43
RW-094	-379	-1.97
RW-095	-304	-1.58
RW-096	-387	-2.01
RW-097	-578	-3.00
RW-098	-28	-0.15
RW-100	-21	-0.11
RW-101	-226	-1.17
RW-102	-48	-0.25
RW-103	**0**	**<0.01**
RW-104	-69	-0.36
RW-105	-59	-0.31
RW-106	**0**	**<0.01**
RW-107	-18	-0.09
RW-108	-59	-0.31
RW-113	-333	-1.73
RW-114	-0.14	<0.01
RW-115	-35	-0.18
RW-116	-284	-1.48
RW-117	-49	-0.25
RW-118	-1.6	<0.01
RW-119	0	<0.01
RW-120	0	<0.01
RW-122	0	<0.01
RW-125	0	<0.01
RW-127	-157	-0.82
RW-128	**0**	**<0.01**
RW-129	-192	-1.00
RW-130	-127	-0.66
RW-131	-75	-0.39
RW-132	**0**	**<0.01**
RW-133	-281	-1.46
RW-134	-112	-0.58
RW-135	**0**	**<0.01**
RW-136	**0**	**<0.01**
RW-137	-61	-0.32
RW-138	-1.4	<0.01
RW-139	-61	-0.32
RW-140	-201	-1.04
RW-141	-102	-0.53

Extraction Well ID	2007 Flow Rate[1] ft^3/day	gpm
RW-142	-7.2	-0.04
RW-143	-23	-0.12
RW-144	-5.8	-0.03
RW-145	-26	-0.14
RW-146	-31	-0.16
RW-147	-12	-0.06
RW-148	-14	-0.07
RW-149	-76	-0.39
RW-150	**0**	**<0.01**
RW-151	-6.2	-0.03
RW-152	-60	-0.31
RW-153	-3.7	-0.02
RW-154	-104	-0.54
RW-155	-18	-0.09
RW-156	-0.74	<0.01
RW-157	-32	-0.17
RW-158	-0.66	<0.01
RW-159	-244	-1.27
RW-160	-17	-0.09
RW-161	-378	-1.96
RW-162	-164	-0.85
RW-163	-162	-0.84
RW-164	-64	-0.33
RW-181	-42	-0.22
RW-182	0	<0.01
RW-183	-36	-0.19
RW-184	-504	-2.62
RW-185	-252	-1.31
RW-186	-169	-0.88
RW-187	-96	-0.50
RW-188	-452	-2.35
RW-189	-490	-2.55
RW-190	-7.4	-0.04
RW-191	-39	-0.20
RW-192	-341	-1.77
RW-193	-23	-0.12
RW-194	-65	-0.34
RW-195	-13	-0.07
RW-196	-108	-0.56
RW-197	-18	-0.09
RW-198	-180	-0.94
RW-199	-20	-0.10
RW-200	-10	-0.05
RW-201	-72	-0.37
RW-202	-50	-0.26
RW-203	-158	-0.82
RW-204	-0.25	<0.01
RW-205	-0.92	<0.01
RW-206	-2.9	-0.02
RW-207	-38	-0.20
RW-208	-22	-0.11
RW-209	-292	-1.52
RW-210	-0.28	<0.01
RW-211	-4.3	-0.02
RW-212	-6.6	-0.03
RW-213	-9.6	-0.05
RW-214	-9.7	-0.05

Sum of Modeled Extraction Well Rates = -22,016 -114

Notes:
2007 well rates based on 2006-2007 average well rates from "Pumping_rates_Model08.xls" provided by Franz Environmental Inc
gpm = gallons per minute
Negative rates indicate water being removed from model
BOLD indicates inactive well based on spreadsheet titled "Recovery Wells and SVE Systems" provided by Boeing

Reference:
Pumping and extraction rates from monthly extraction well meter reading excel spreadsheet files provided by Boeing and summary files provided by Franz Environmental Inc.

Prepared by: _____
Checked by: _____
Reviewed by: _____

TABLE 2-2
PRIMARY RECOVERY WELL NETWORK RATES

BOEING FACILITY
WICHITA, KANSAS

Extraction Well ID	Flow Rate[1] ft^3/day	gpm
RW-004AA	-389	-2.02
RW-011A	-1003	-5.21
RW-012A	-87	-0.45
RW-019A	-631	-3.28
RW-026	-1196	-6.21
RW-028A	-264	-1.37
RW-033	-566	-2.94
RW-045	-1985	-10.31
RW-046A	-55	-0.29
RW-047A	-174	-0.90
RW-049A	-272	-1.41
RW-053	-617	-3.21
RW-054	-375	-1.95
RW-055	-179	-0.93
RW-057	-1154	-5.99
RW-060	-17	-0.09
RW-061	-107	-0.56
RW-062	-173	-0.90
RW-066	-245	-1.27
RW-070	-689	-3.58
RW-080	-255	-1.32
RW-082	-437	-2.27
RW-085	-381	-1.98
RW-087	-392	-2.04
RW-093	-526	-2.73
RW-094	-2713	-14.09
RW-095	-1551	-8.06
RW-096	-387	-2.01
RW-097	-794	-4.12
RW-145	-28	-0.15
RW-146	-35	-0.18
RW-147	-14	-0.07
RW-152	-70	-0.36
RW-153	-16	-0.08
RW-181	-7.3	-0.04
RW-192	-433	-2.25
RW-193	-32	-0.17
RW-194	-132	-0.69
RW-195	-15	-0.08
RW-196	-133	-0.69
RW-197	-18	-0.09
RW-198	-178	-0.92
RW-199	-26	-0.14
RW-200	-9.4	-0.05
RW-201	-78	-0.41
RW-202	-55	-0.29
RW-203	-213	-1.11
RW-204	-0.42	<0.01
RW-205	-1.6	<0.01
RW-206	-4.1	-0.02
RW-207	-51	-0.26
RW-208	-26	-0.14
RW-209	-212	-1.10
RW-210	-14	-0.07
RW-211	-6.2	-0.03
RW-212	-8.8	-0.05
RW-213	-12	-0.06
RW-214	-14	-0.07
Sum of Modeled Extraction Well Rates =	**-19,457**	**-101**

Notes:
1) Well rates based on 2006-2007 average well rates from "Pumping_rates_Model08.xls" provided by Franz Environmental Inc
gpm = gallons per minute
Negative rates indicate water being removed from model

Reference:
Pumping and extraction rates from monthly extraction well meter reading excel spreadsheet files provided by Boeing and summary files provided by Franz Environmental Inc.

Prepared by: _____
Checked by: _____
Reviewed by: _____

TABLE 2-3
UNCERTAINTY ANALYSIS PARAMETERS

BOEING FACILITY
WICHITA, KANSAS

Numerical Model Zone	Description	Horizontal Hydraulic Conductivity (ft/day)	Horizontal Hydraulic Conductivity (cm/s)	Uncertainty Analysis Values (ft/day) 0.7 x multiplier	Uncertainty Analysis Values (ft/day) 1.5 x multiplier
Overburden					
2	Fluvial materials	3.0	1.1E-03	2.1	4.5
3	Brown clay	0.43	1.5E-04	0.30	0.64
4	Fluvial materials, Plant 2, Hangar 118F and Ramp 500 vicinity	5.7	2.0E-03	4.0	8.5
5	Fluvial materials, Arkansas River valley	50	1.8E-02	35	75
15	Overburden, Plant 1 vicinity	1.5	5.3E-04	1.1	2.3
Bedrock					
7	Bedrock, except Arkansas River vicinity	0.12	4.2E-05	0.084	0.18

Notes:
ft/day = feet per day
cm/s = centimeters per second
NA = Not Applicable - Recovery wells not installed in zone.

Prepared by: _____
Checked by: _____
Reviewed by: _____

TABLE 2-4
PRIMARY AND SECONDARY RECOVERY WELL NETWORK RATES

BOEING FACILITY
WICHITA, KANSAS

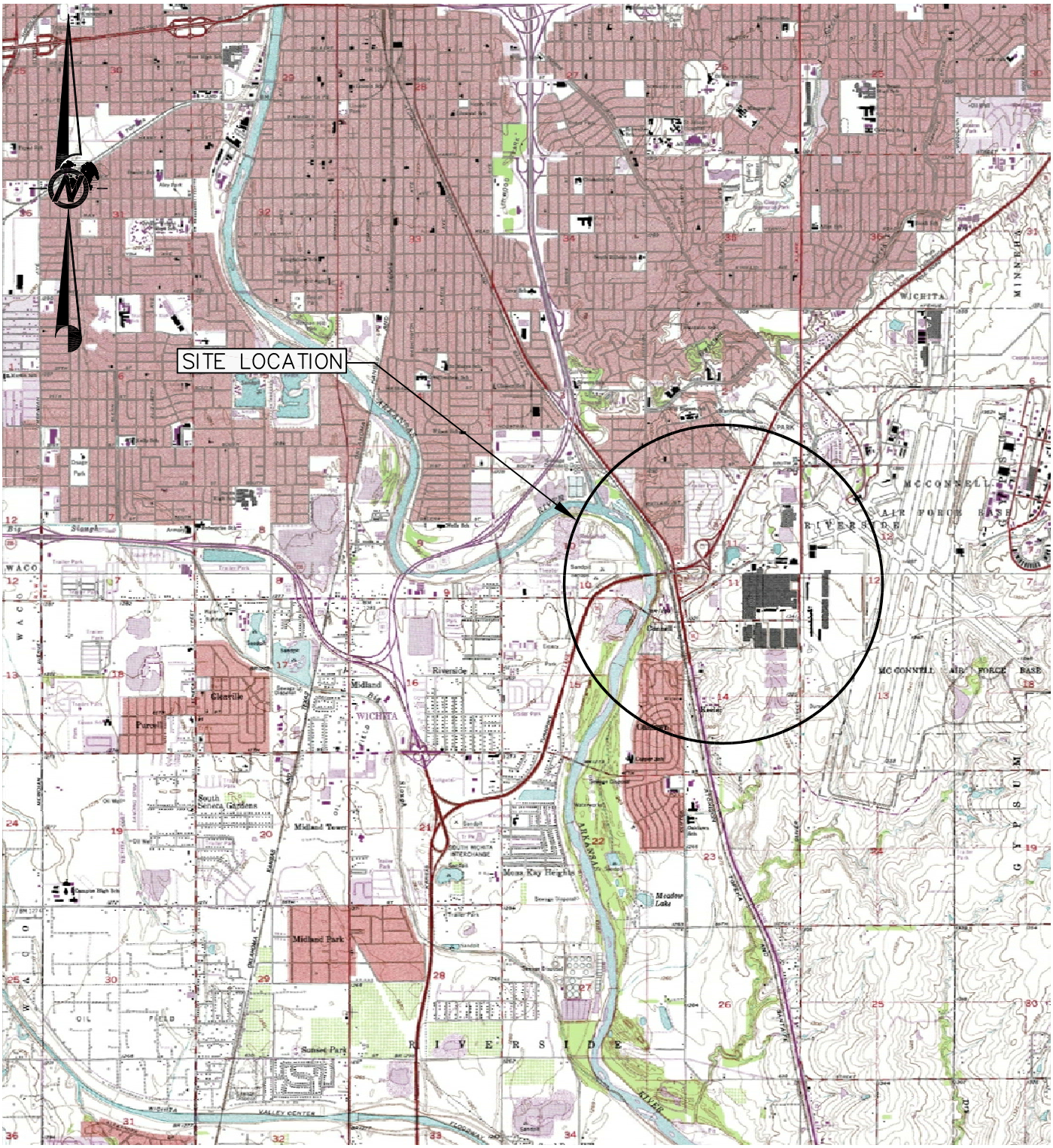
Extraction Well ID	Flow Rate[1] ft^3/day	gpm
RW-004AA	-389	-2.02
RW-011A	-1003	-5.21
RW-012A	-87	-0.45
RW-019A	-631	-3.28
RW-026	-1196	-6.21
RW-028A	-264	-1.37
RW-033	-566	-2.94
RW-045	-1985	-10.31
RW-046A	-55	-0.29
RW-047A	-174	-0.90
RW-049A	-272	-1.41
RW-053	-617	-3.21
RW-054	-375	-1.95
RW-055	-179	-0.93
RW-057	-1154	-5.99
RW-058	**-252**	**-1.31**
RW-060	***-40***	***-0.21***
RW-061	-107	-0.56
RW-062	-173	-0.90
RW-066	-245	-1.27
RW-070	-689	-3.58
RW-079	**-11**	**-0.06**
RW-080	-255	-1.32
RW-081	**-25**	**-0.13**
RW-082	-437	-2.27
RW-085	-381	-1.98
RW-087	-392	-2.04
RW-093	-526	-2.73
RW-094	-2713	-14.09
RW-095	-1551	-8.06
RW-096	-387	-2.01
RW-097	-794	-4.12
RW-098	**-67**	**-0.35**
RW-101	**-344**	**-1.79**
RW-116	**-308**	**-1.60**
RW-127	**-475**	**-2.47**
RW-142	**-22**	**-0.11**
RW-143	**-29**	**-0.15**
RW-145	-28	-0.15
RW-146	-35	-0.18
RW-147	-14	-0.07
RW-149	**-86**	**-0.45**
RW-152	***-85***	***-0.44***
RW-153	***-25***	***-0.13***
RW-181	-7.3	-0.04
RW-192	-433	-2.25
RW-193	-32	-0.17
RW-194	-132	-0.69
RW-195	-15	-0.08
RW-196	-133	-0.69
RW-197	-18	-0.09
RW-198	-178	-0.92
RW-199	-26	-0.14
RW-200	-9.4	-0.05
RW-201	-78	-0.41
RW-202	-55	-0.29
RW-203	-213	-1.11
RW-204	-0.42	<0.01
RW-205	-1.6	<0.01
RW-206	-4.1	-0.02
RW-207	-51	-0.26
RW-208	-26	-0.14
RW-209	-212	-1.10
RW-210	-14	-0.07
RW-211	-6.2	-0.03
RW-212	-8.8	-0.05
RW-213	-12	-0.06
RW-214	-14	-0.07
Sum of Modeled Extraction Well Rates =	**-21,123**	**-110**

Notes:
1) Well rates based on 2006-2007 average well rates from "Pumping_rates_Model08.xls" provided by Franz Environmental Inc
gpm = gallons per minute
Negative rates indicate water being removed from model
BOLD indicates secondary recovery well
BOLD ITALICS indicates primary recovery well with increased flow rate

Reference:
Pumping and extraction rates from monthly extraction well meter reading excel spreadsheet files provided by Boeing and summary files provided by Franz Environmental Inc.

Prepared by: _____
Checked by: _____
Reviewed by: _____

FIGURES



REFERENCES

BASE MAPS TAKEN FROM 7.5 MINUTE USGS QUADRANGLE MAPS TITLED, "DERBY, KS.", DATED 1961. AND "WICHITA EAST, KS" DATED 1960.

5000 0 5000

SCALE APPROXIMATE FEET

Golder Associates
Manchester, New Hampshire

FILE No.	09381501A008	SCALE	AS SHOWN
PROJECT No.	093-81501	REV. 0	DATE 08/21/09
			DESIGN RWB
			CADD MPB
			CHECK RWB
			REVIEW THR

TITLE

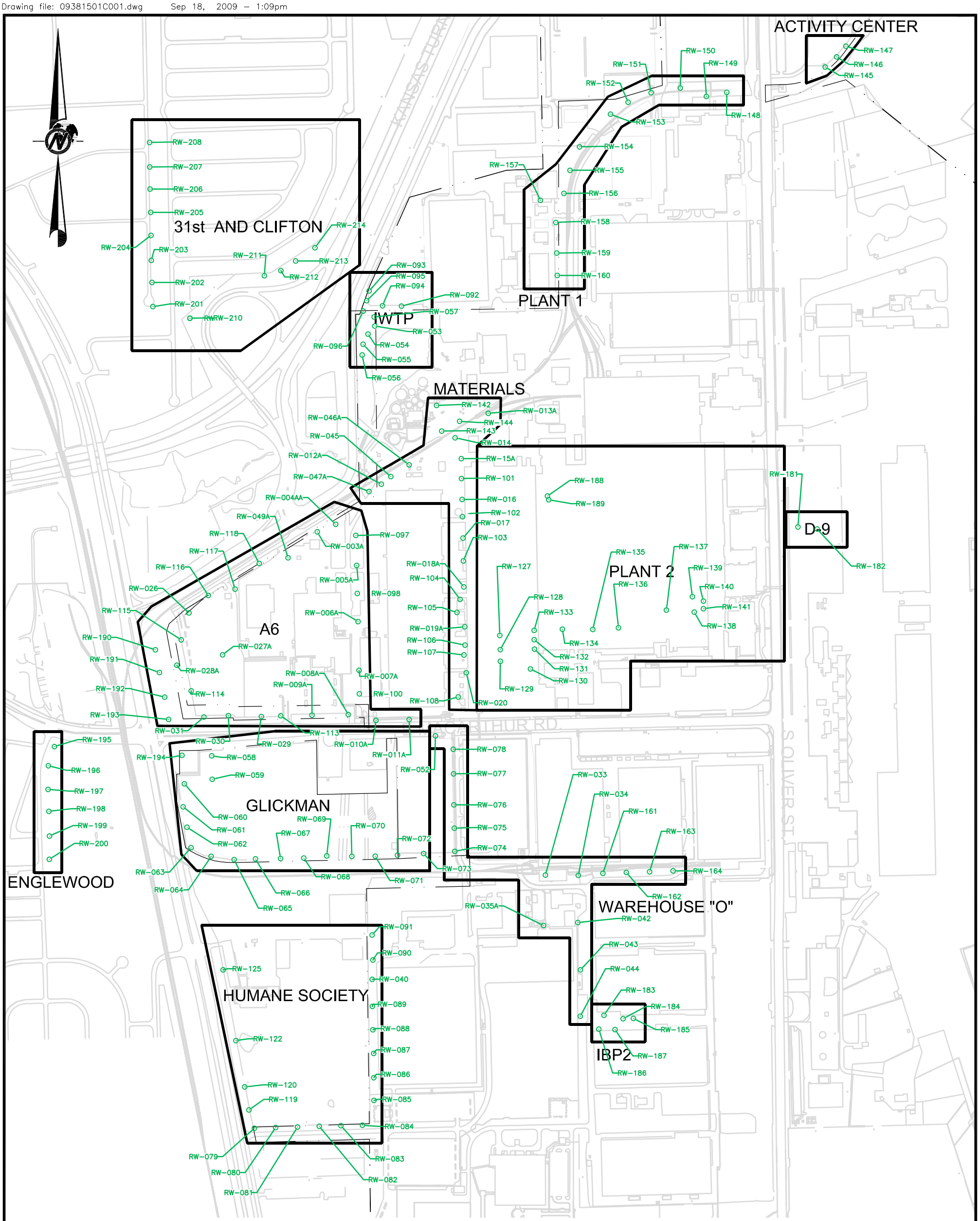
SITE LOCATION MAP

THE BOEING COMPANY
BOEING AND MCCONNELL AIR FORCE BASE
WICHITA, KANSAS

FIGURE 1

Drawing file: 09381501A008.dwg Aug 21, 2009 - 4:24pm

Drawing file: 09381501C001.dwg Sep 18, 2009 – 1:09pm



LEGEND

APPROXIMATE BOEING PROPERTY BOUNDARY

RECOVERY WELL NETWORK SUB-AREAS

RW-120 RECOVERY WELL LOCATION

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

600 0 600
SCALE FEET

FIGURE 2-1

REVIEW		
CHECK		
CADD	BCL	09/18/09
DESIGN	RWB	05/11/09
REV. 0 SCALE AS SHOWN		
FILE No. 09381501C001		
PROJECT No. 093-81501		

TITLE

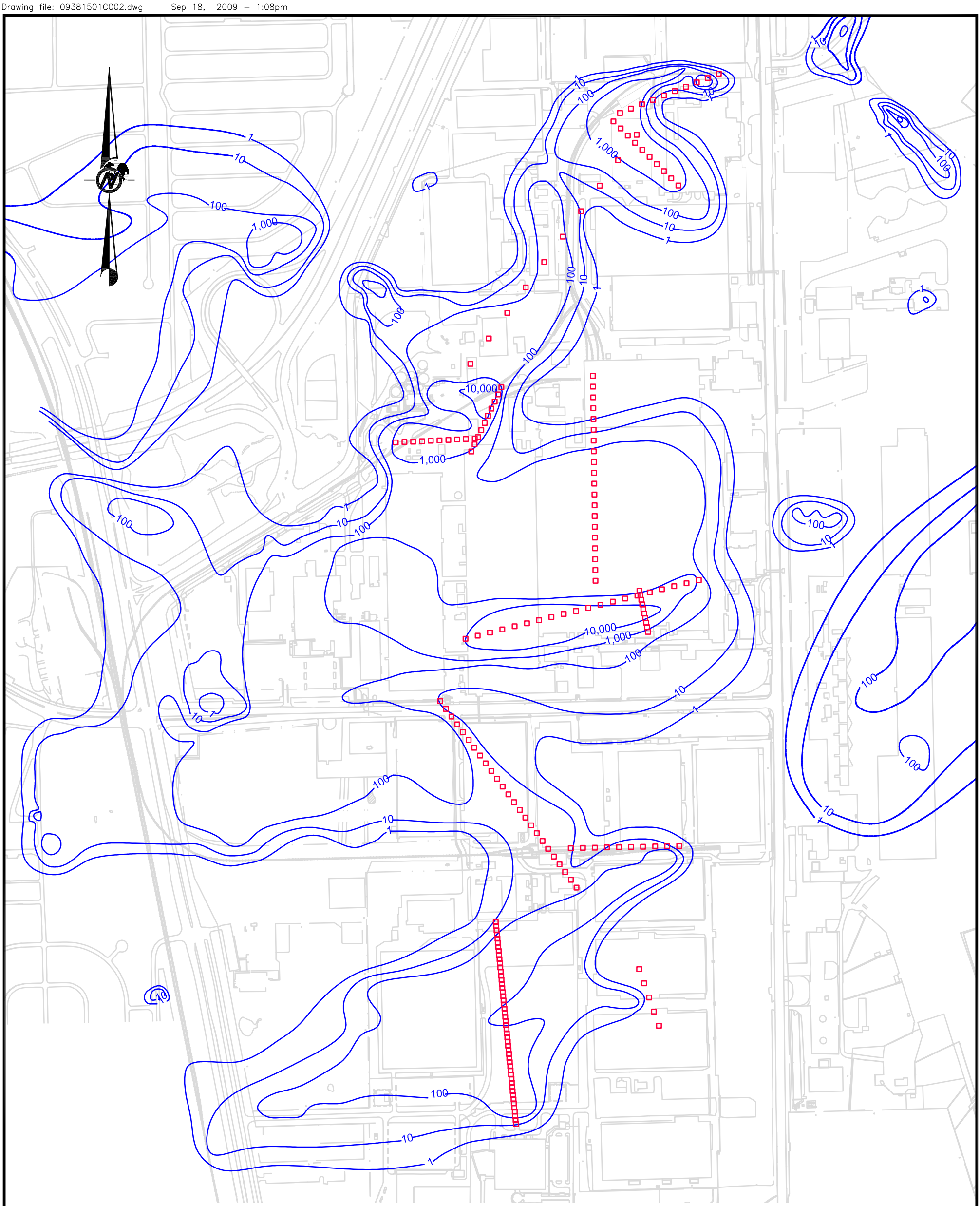
2007 MODEL RECOVERY WELL LOCATIONS

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501C002.dwg Sep 18, 2009 – 1:08pm



LEGEND

PARTICLE STARTING LOCATIONS

10,000 — 2008 TVOC CONTOUR

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

NOTES

1.) 2008 TOTAL VOLATILE ORGANIC COMPOUND (TVOC) CONTOURS BASED ON CAD FILE "208TVOC.DXF" PROVIDED BY BOEING.

600 0 600
SCALE FEET

FIGURE 2-2

REVIEW	
CHECK	
CADD	BCL 09/18/09
DESIGN	RWB 05/11/09
REV. 0	SCALE AS SHOWN
FILE No.	09381501C002
PROJECT No.	093-81501

TITLE

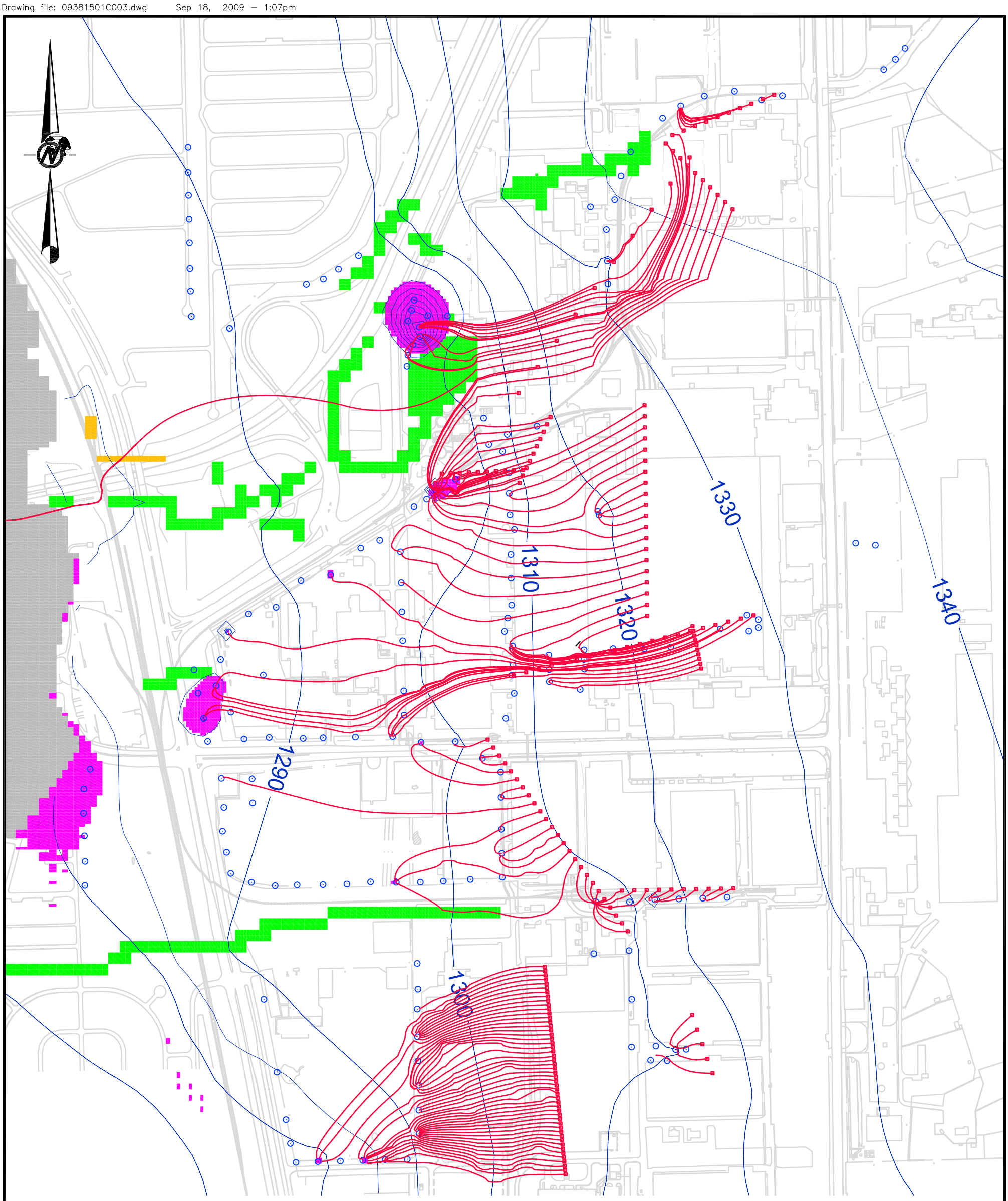
MODPATH MODEL - PARTICLE STARTING LOCATIONS

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501C003.dwg Sep 18, 2009 – 1:07pm



LEGEND

- PARTICLE TRACE
- 1270 — GROUNDWATER ELEVATION CONTOUR
- DRY
- GHB
- RIVER
- DRAIN
- NO FLOW
- RECOVERY WELL LOCATIONS

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

NOTES

1.) GHB = GENERAL HEAD BOUNDARY

2.) NO FLOW CELLS REPRESENT PARTIALLY SATURATED OR UNSATURATED CONDITIONS.

600 0 600
SCALE FEET

FIGURE 2-3

REVIEW	
CHECK	
CADD	BCL 09/18/09
DESIGN	RWB 05/11/09
REV. 0	SCALE AS SHOWN
FILE No.	09381501C003
PROJECT No.	093-81501

TITLE

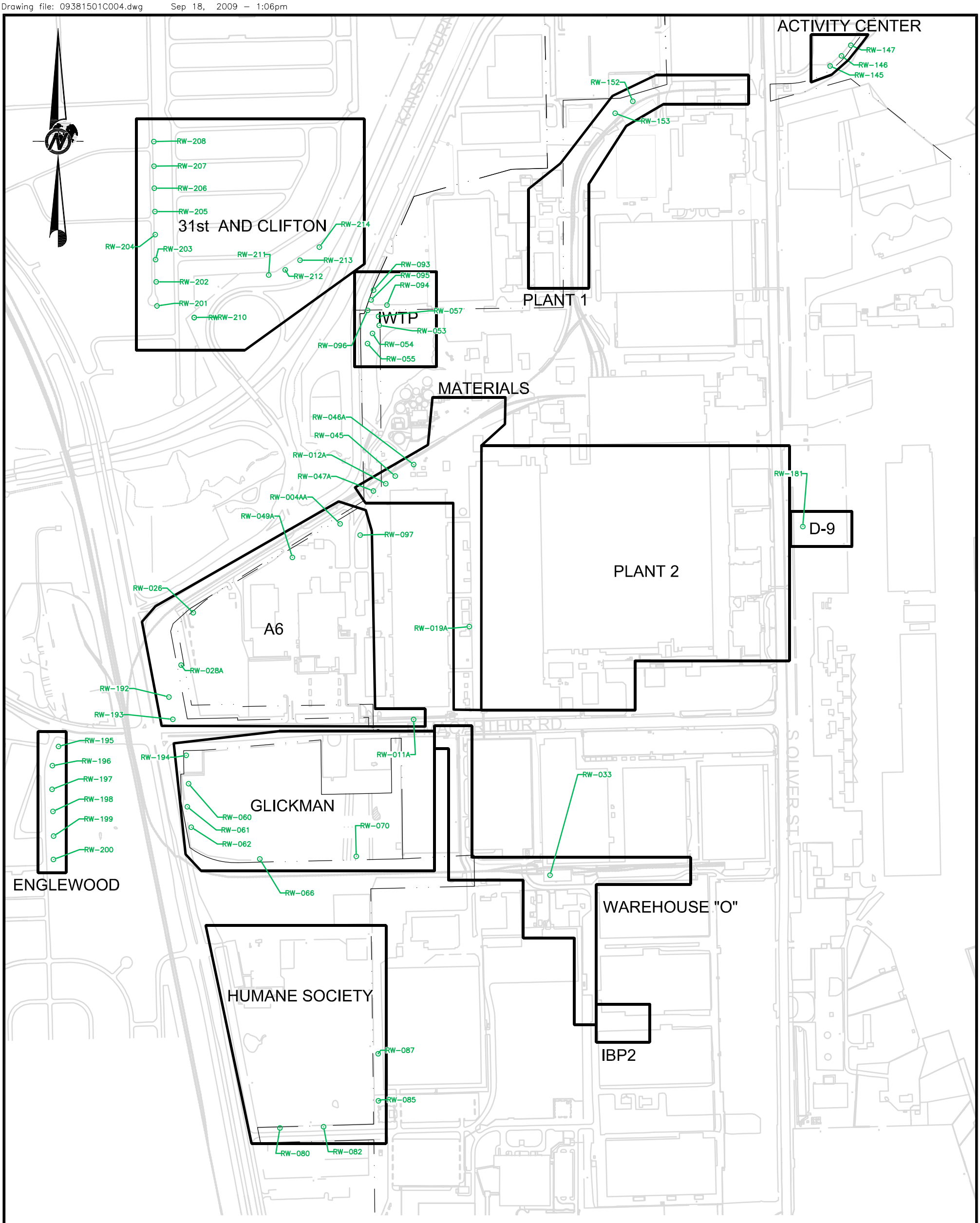
MODPATH MODEL - SITE WIDE CAPTURE ANALYSIS

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501C004.dwg Sep 18, 2009 – 1:06pm



LEGEND

APPROXIMATE BOEING PROPERTY BOUNDARY

RECOVERY WELL NETWORK SUB–AREAS

RW-087 PRIMARY RECOVERY WELL NETWORK WELLS

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

600 0 600
SCALE FEET

FIGURE 2-4

REVIEW	
CHECK	
CADD	BCL 09/18/09
DESIGN	RWB 05/11/09
REV. 0	SCALE AS SHOWN
FILE No.	09381501C004
PROJECT No.	093-81501

TITLE

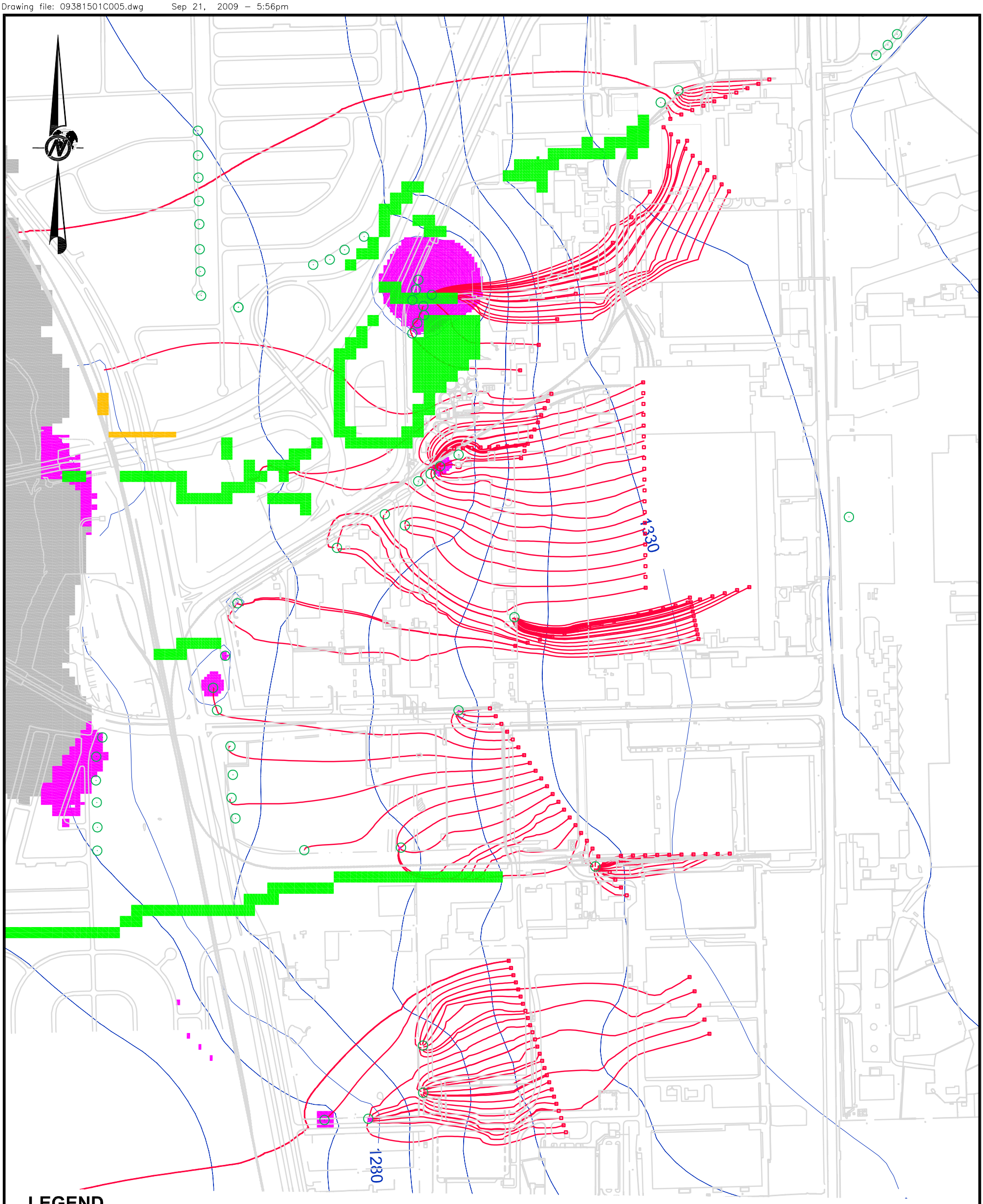
PRIMARY OPTIMIZATION RECOVERY WELL LOCATIONS

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501C005.dwg Sep 21, 2009 – 5:56pm



LEGEND

- PARTICLE TRACE
- 1270 — GROUNDWATER ELEVATION CONTOUR
- DRY
- GHB
- RIVER
- DRAIN
- NO FLOW
- PRIMARY RECOVER WELL NETWORK

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

NOTES

1.) GHB = GENERAL HEAD BOUNDARY

2.) NO FLOW CELLS REPRESENT PARTIALLY SATURATED OR UNSATURATED CONDITIONS.

600 0 600
SCALE FEET

FIGURE 2-5

REVIEW		
CHECK		
CADD	BCL	09/21/09
DESIGN	RWB	05/11/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501C005	
PROJECT No.	093-81501	

TITLE

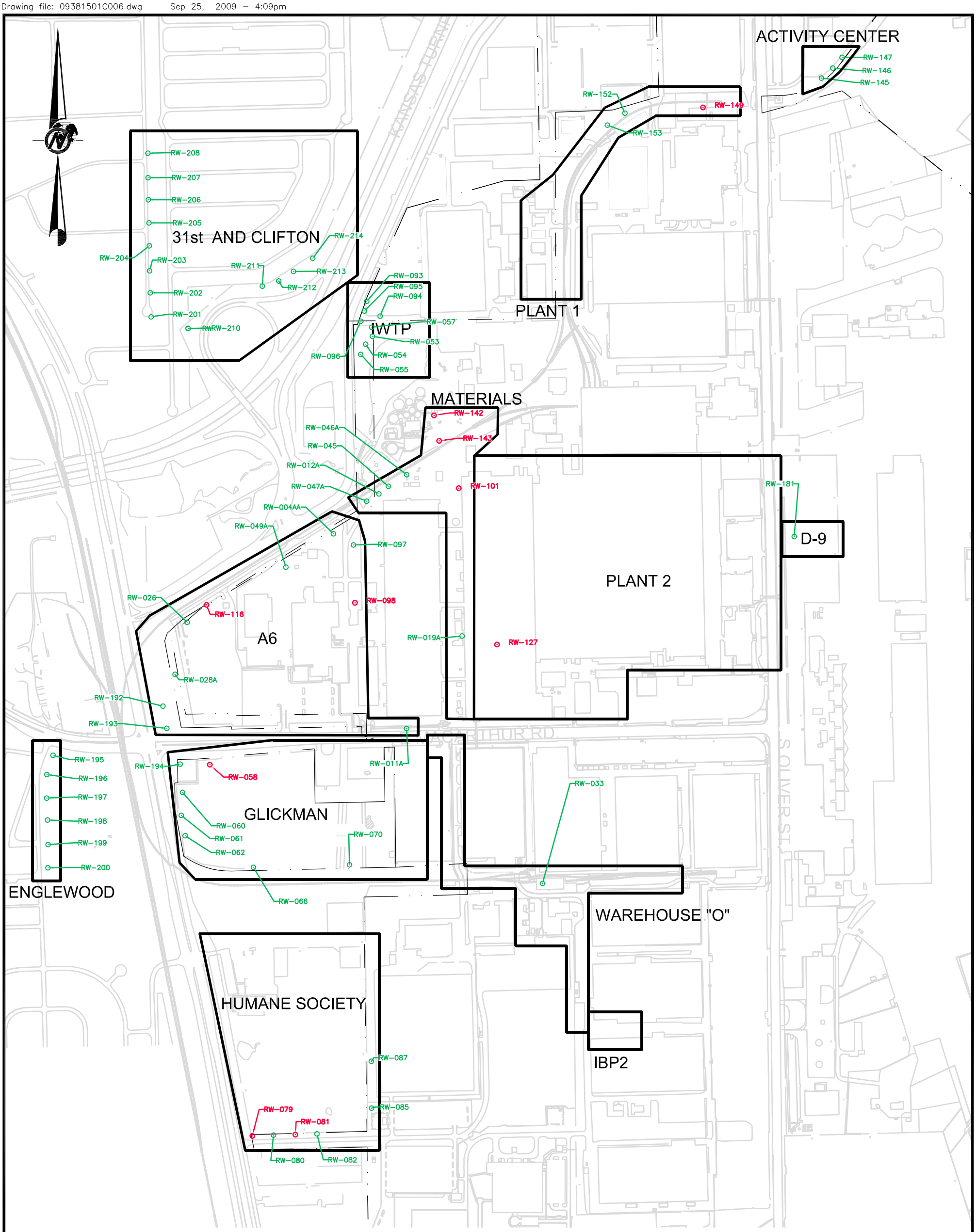
MODPATH MODEL - PRIMARY OPTIMIZATION CAPTURE ANALYSIS

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501C006.dwg Sep 25, 2009 – 4:09pm



LEGEND

- APPROXIMATE BOEING PROPERTY BOUNDARY
- RECOVERY WELL NETWORK SUB–AREAS
- RW–087 PRIMARY RECOVERY WELL NETWORK WELLS
- RW–079 SECONDARY RECOVERY WELL NETWORK WELLS

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

600 0 600
SCALE FEET

FIGURE 2-6

REVIEW	
CHECK	
CADD	BCL
DESIGN	RWB
REV. 0	SCALE AS SHOWN
FILE No.	09381501C006
PROJECT No.	093–81501

TITLE

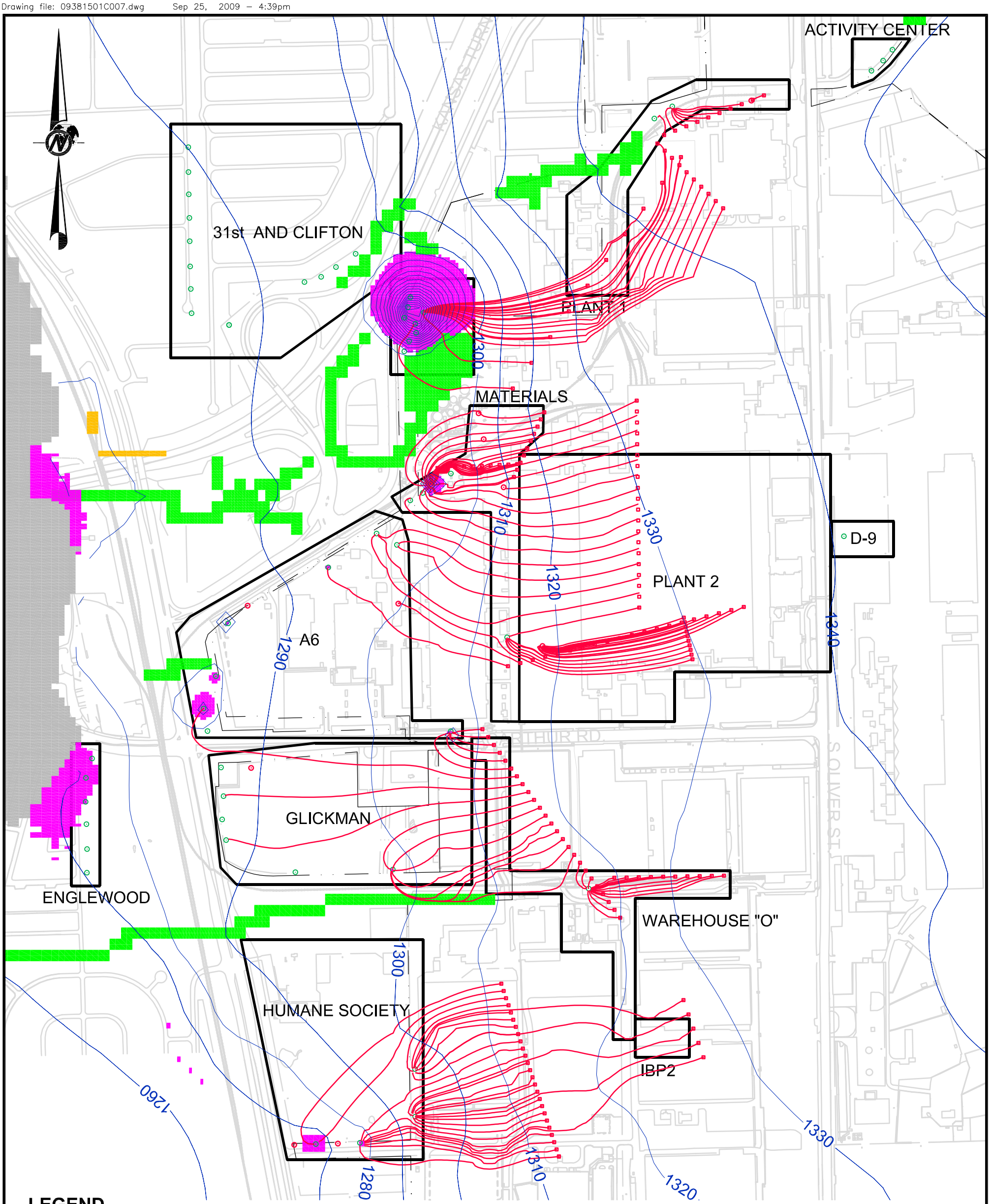
PRIMARY AND SECONDARY OPTIMIZATION RECOVERY WELL LOCATIONS

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

Golder Associates
Manchester, New Hampshire

Drawing file: 09381501C007.dwg Sep 25, 2009 – 4:39pm



LEGEND

- PARTICLE TRACE
- 1270 GROUNDWATER ELEVATION CONTOUR
- APPROXIMATE BOEING PROPERTY BOUNDARY
- RECOVERY WELL NETWORK SUB–AREAS
- DRY
- GHB
- RIVER
- DRAIN
- NO FLOW
- PRIMARY RECOVER WELL NETWORK
- SECONDARY RECOVERY WELL NETWORK

REFERENCES

1.) BASE MAP FROM CADD FILE TITLED "NEWBASEMAP2.DWG", PROVIDED BY THE BOEING COMPANY.

NOTES

1.) GHB = GENERAL HEAD BOUNDARY

2.) NO FLOW CELLS REPRESENT PARTIALLY SATURATED OR UNSATURATED CONDITIONS.

600 0 600
SCALE FEET

FIGURE 2-7

REVIEW		
CHECK		
CADD	BCL	09/25/09
DESIGN	RWB	05/11/09
REV. 0	SCALE AS SHOWN	
FILE No.	09381501C007	
PROJECT No.	093-81501	

TITLE

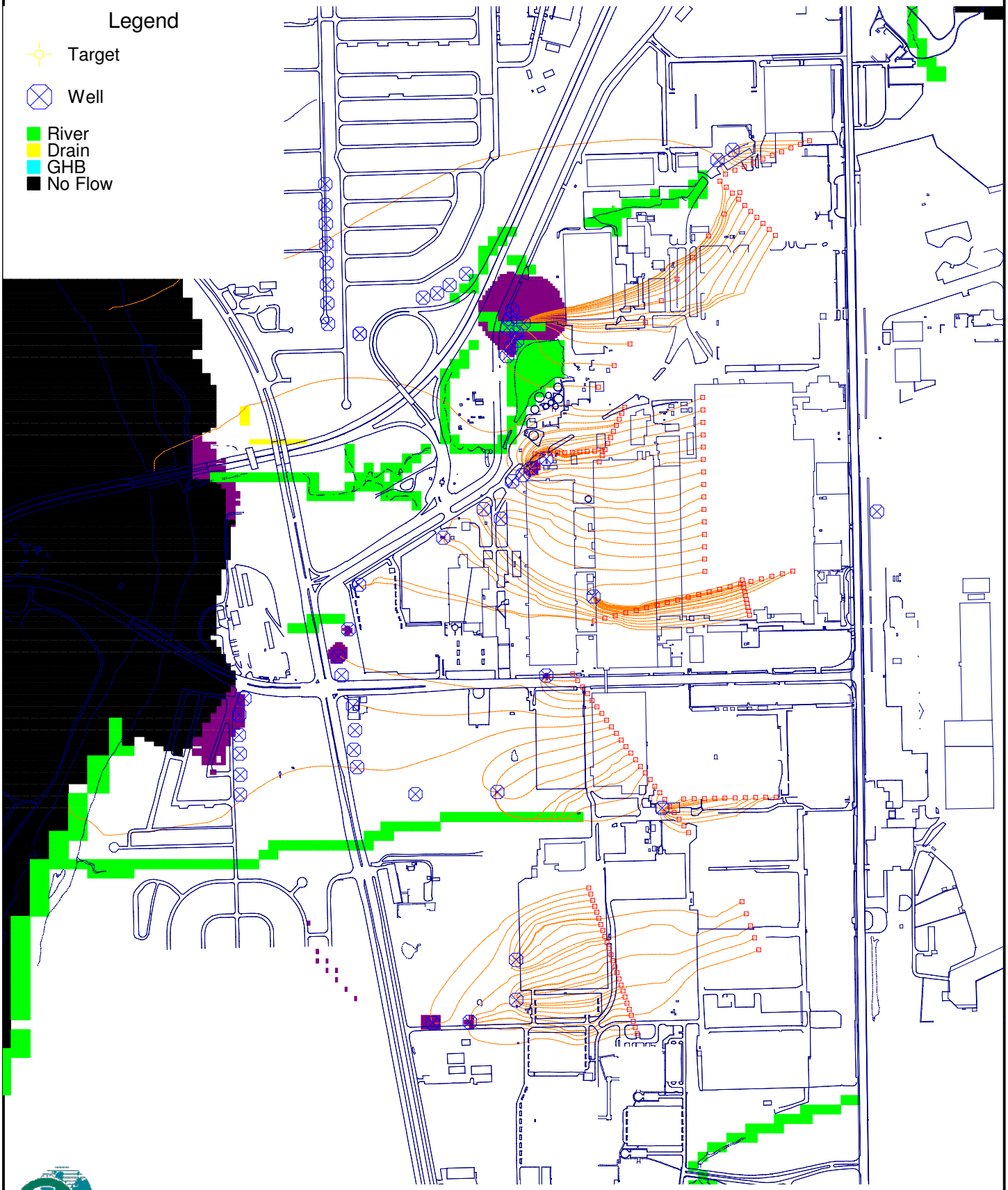
MODPATH MODEL - PRIMARY AND SECONDARY OPTIMIZATION CAPTURE ANALYSIS

PROJECT

THE BOEING COMPANY
MODFLOW REPORT
WICHITA, KANSAS

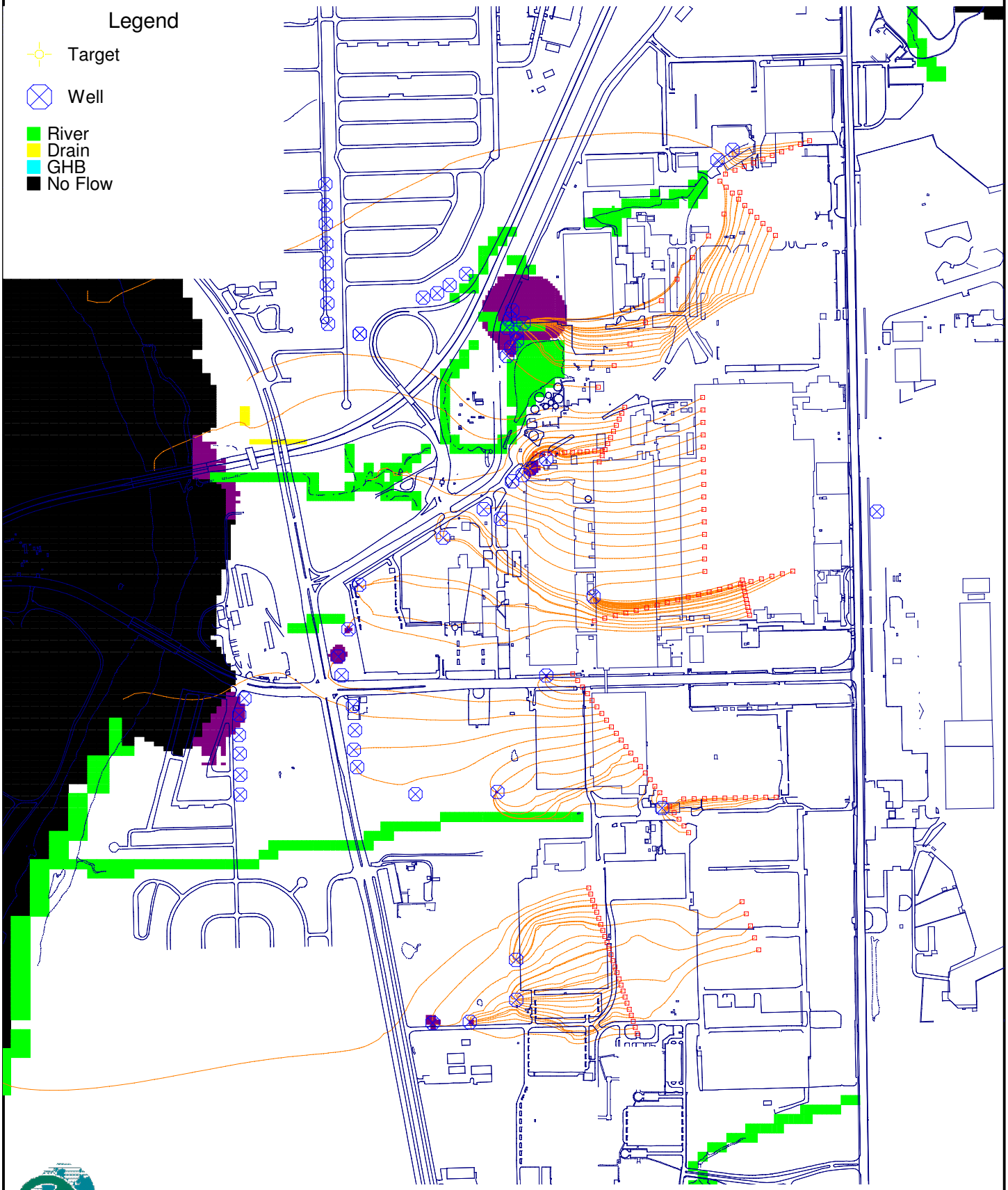
Golder Associates
Manchester, New Hampshire

APPENDIX A
UNCERTAINTY ANALYSIS



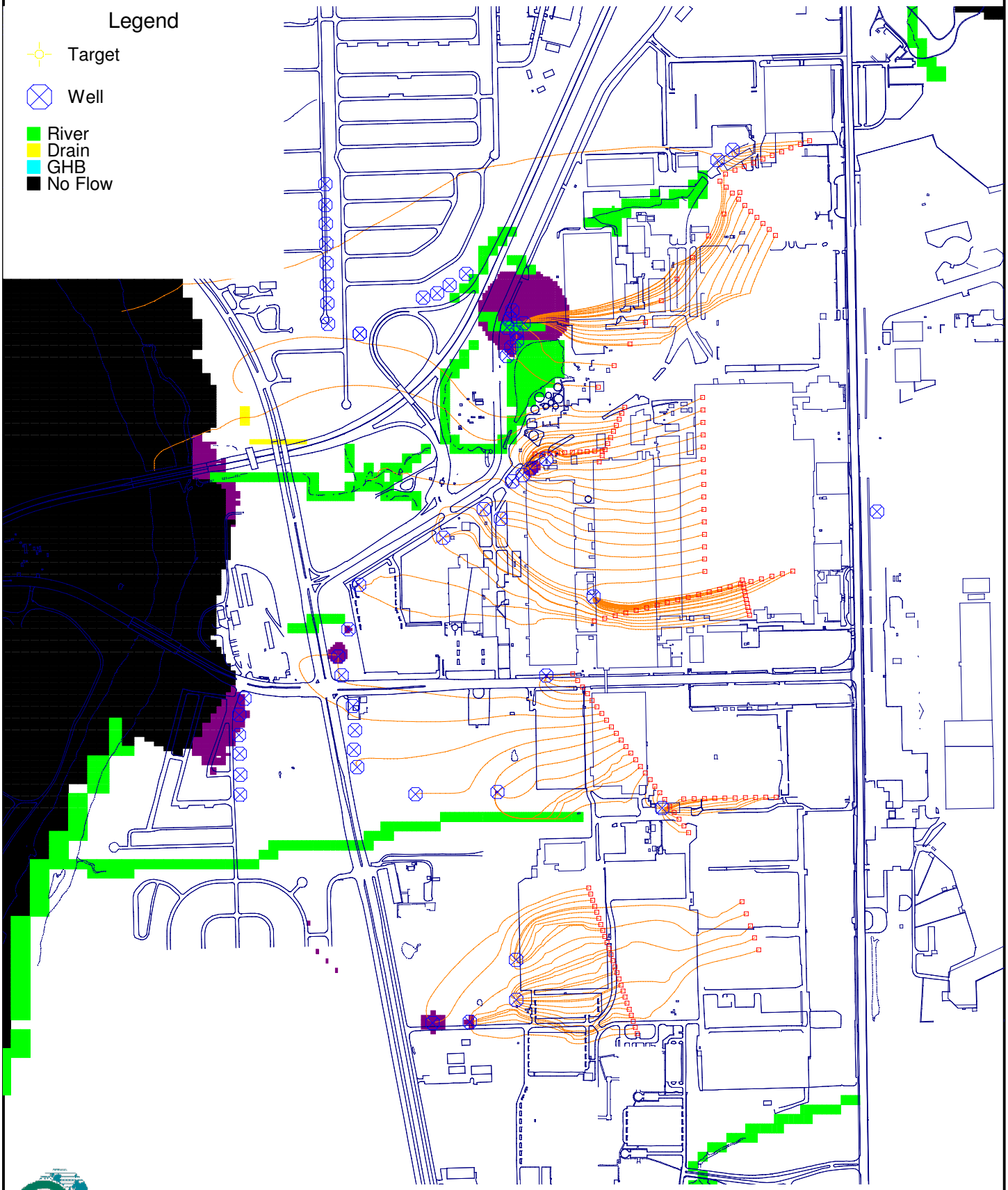
Golder Associates

Figure A-1 MODPATH Sensitivity Analysis
Horizontal Hydraulic Conductivity Zone 2 0.7 x Multiplier
Boeing Site, Wichita, Kansas



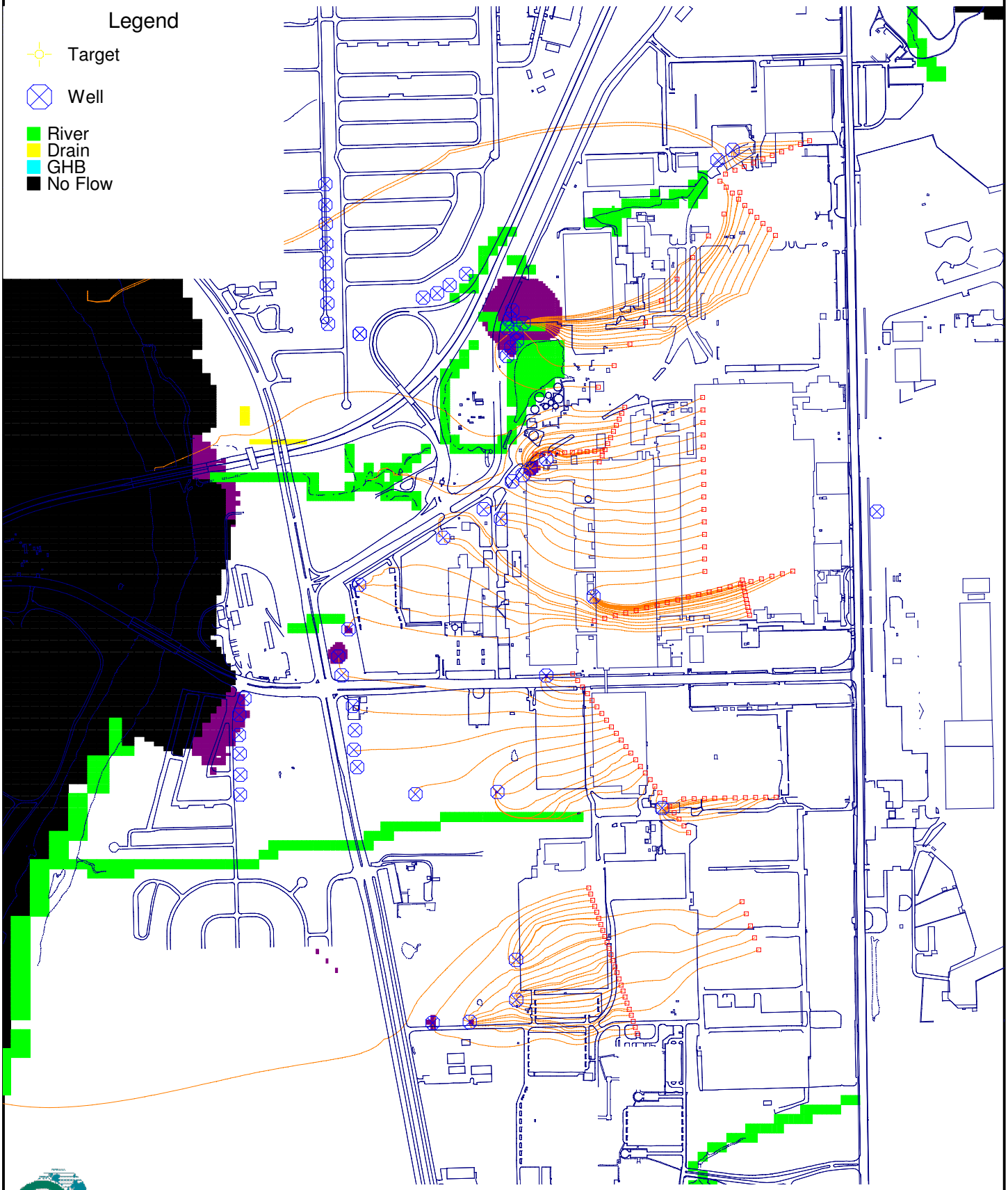
Golder Associates

Figure A-2 MODPATH Sensitivity Analysis
Horizontal Hydraulic Conductivity Zone 2 1.5 x Multiplier
Boeing Site, Wichita, Kansas



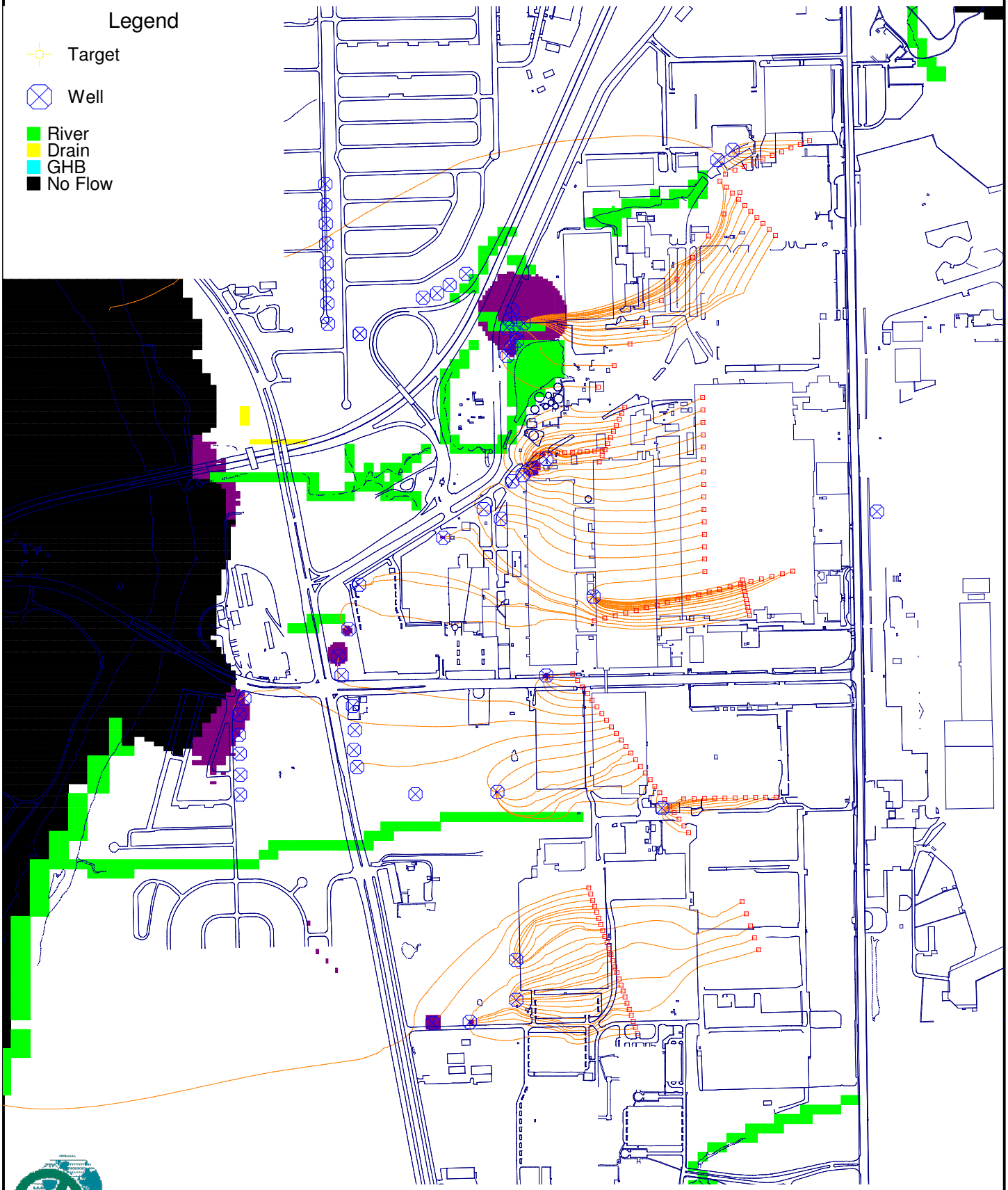
Golder Associates

Figure A-3 MODPATH Sensitivity Analysis
Horizontal Hydraulic Conductivity Zone 3 0.7 x Multiplier
Boeing Site, Wichita, Kansas



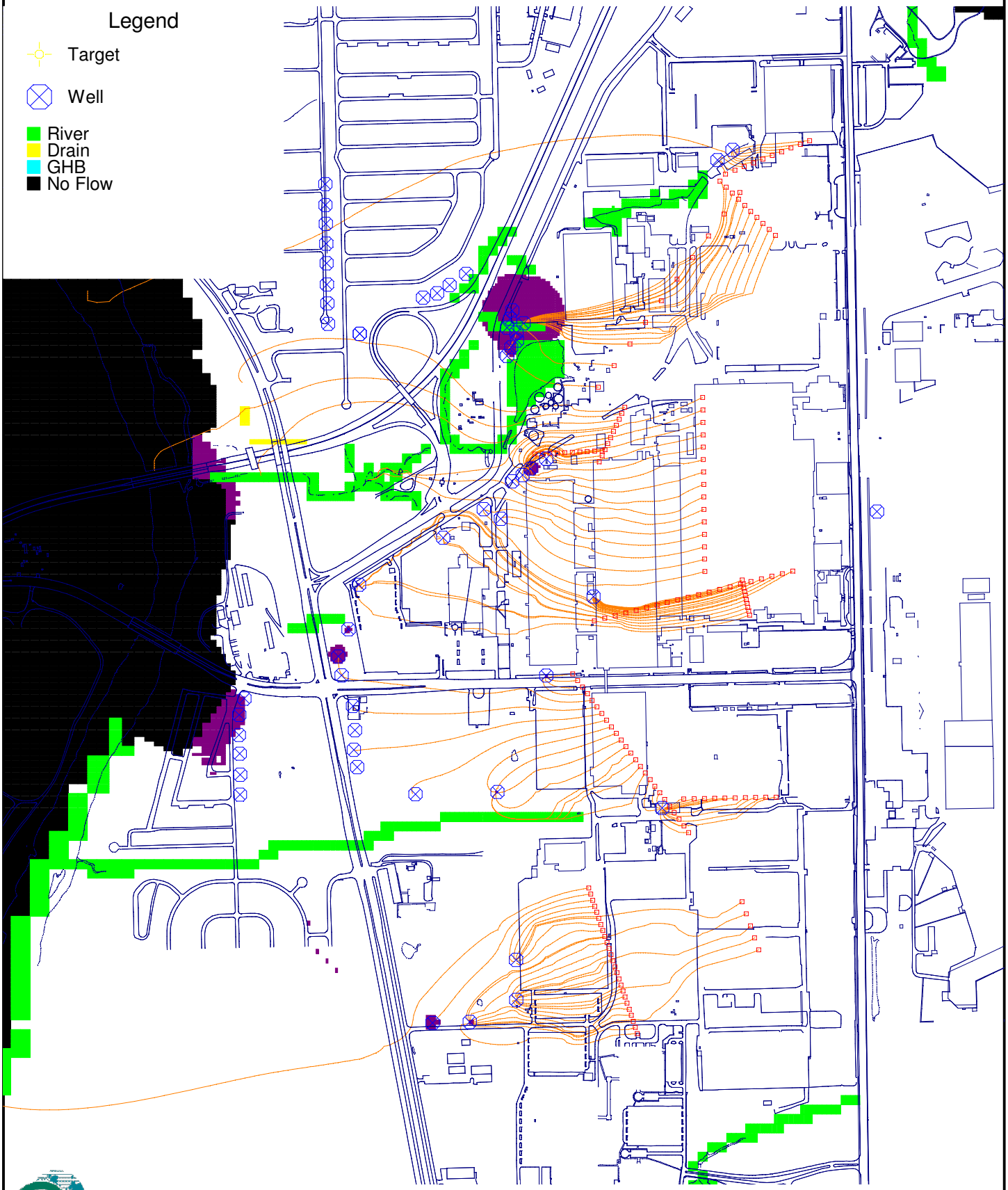
Golder Associates

Figure A-4 MODPATH Sensitivity Analysis
Horizontal Hydraulic Conductivity Zone 3 1.5 x Multiplier
Boeing Site, Wichita, Kansas



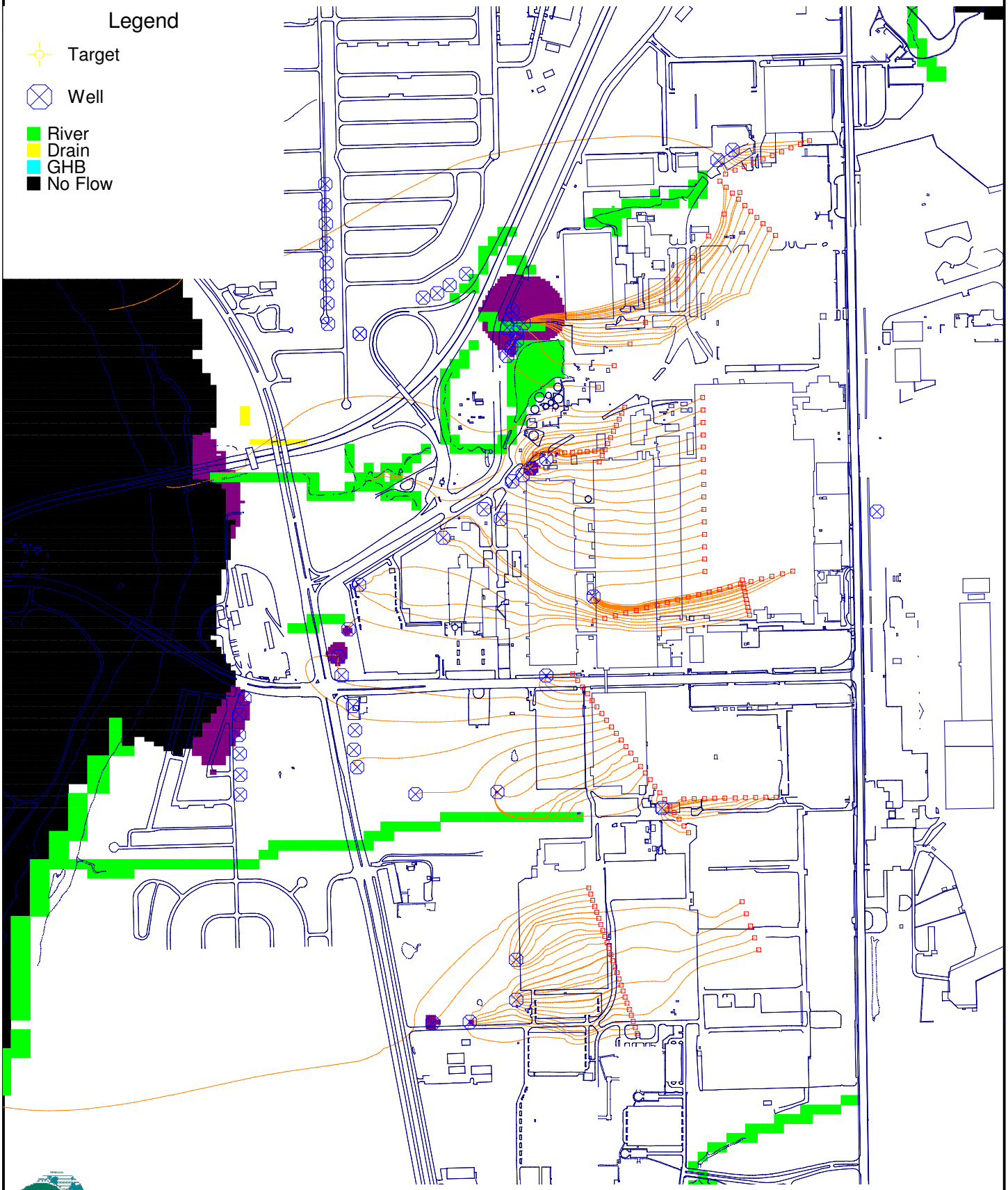
Golder Associates

Figure A-5 MODPATH Sensitivity Analysis
Horizontal Hydraulic Conductivity Zone 4 0.7 x Multiplier
Boeing Site, Wichita, Kansas



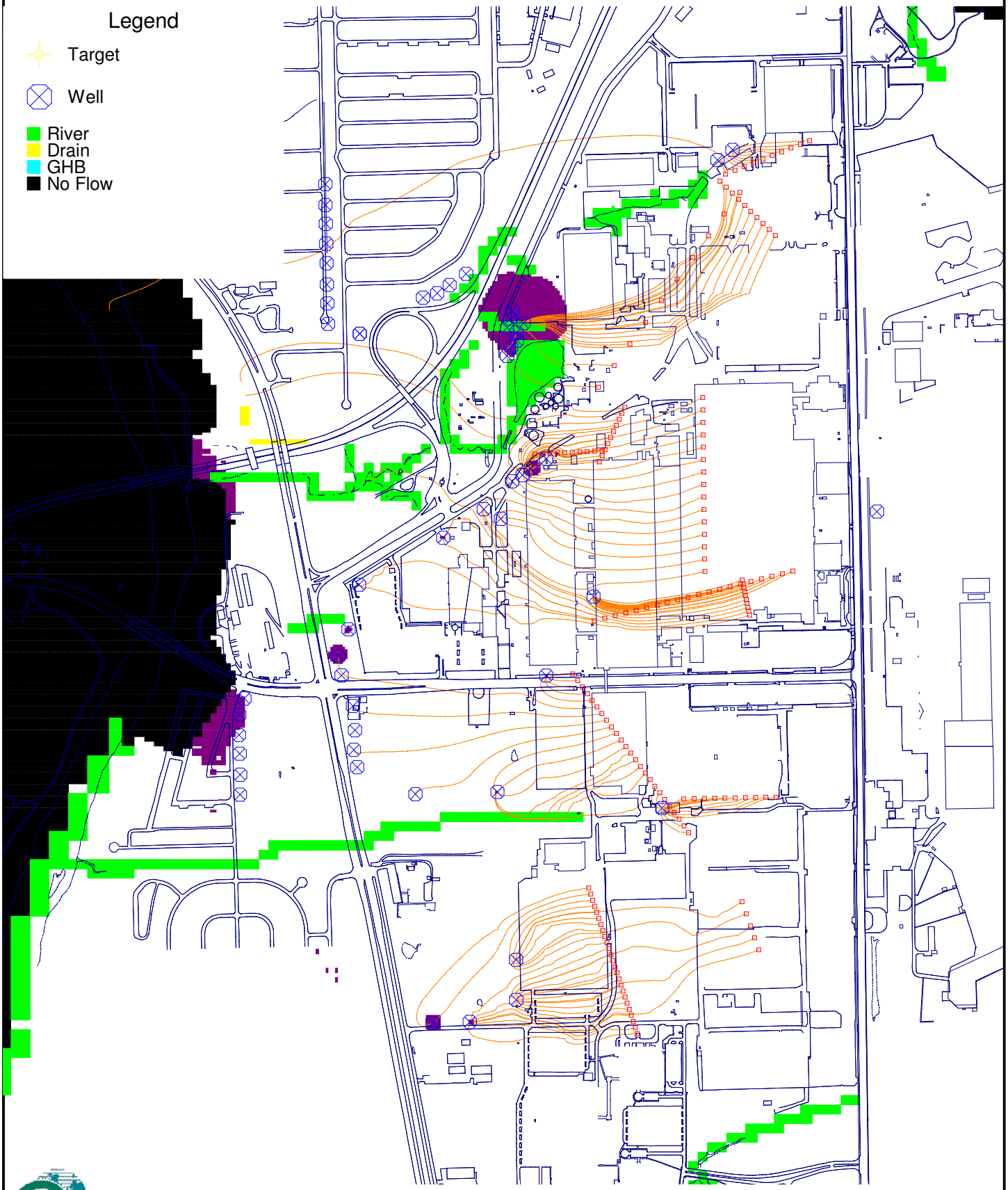
Golder Associates

Figure A-6 MODPATH Sensitivity Analysis
Horizontal Hydraulic Conductivity Zone 4 1.5 x Multiplier
Boeing Site, Wichita, Kansas



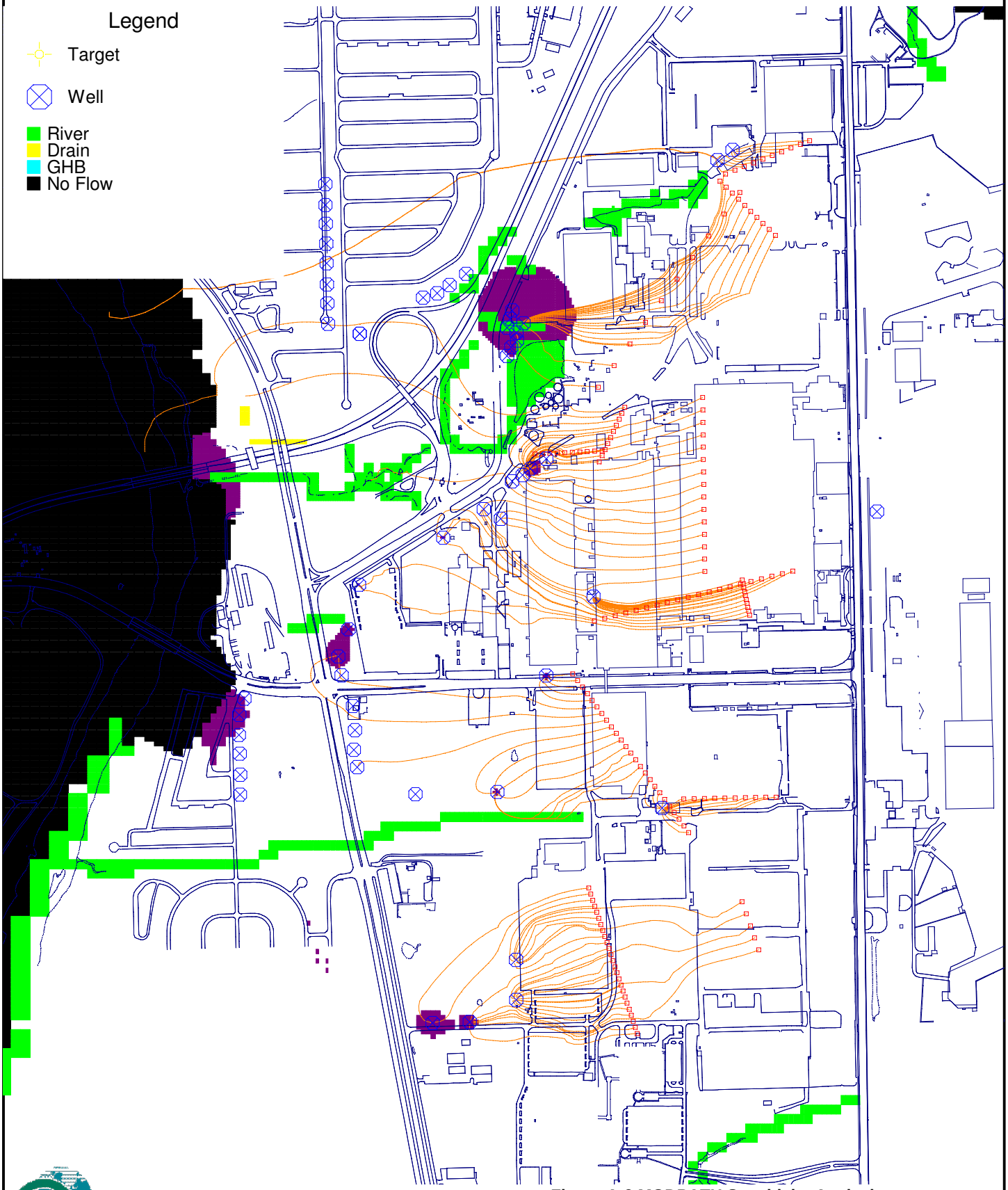
Golder Associates

Figure A-7 MODPATH Sensitivity Analysis
Horizontal Hydraulic Conductivity Zone 5 0.7 x Multiplier
Boeing Site, Wichita, Kansas



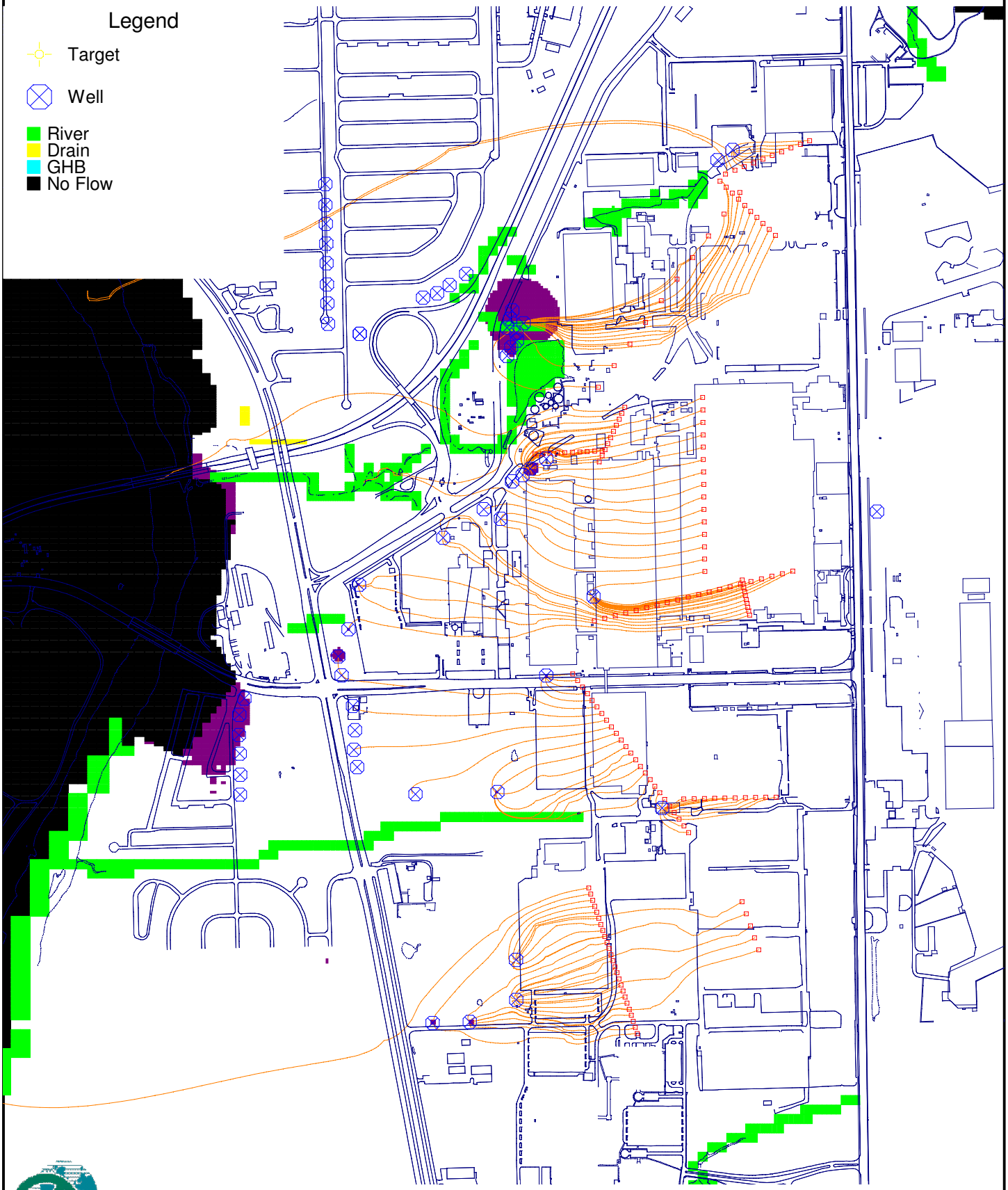
Golder Associates

Figure A-8 MODPATH Sensitivity Analysis
Horizontal Hydraulic Conductivity Zone 5 1.5 x Multiplier
Boeing Site, Wichita, Kansas



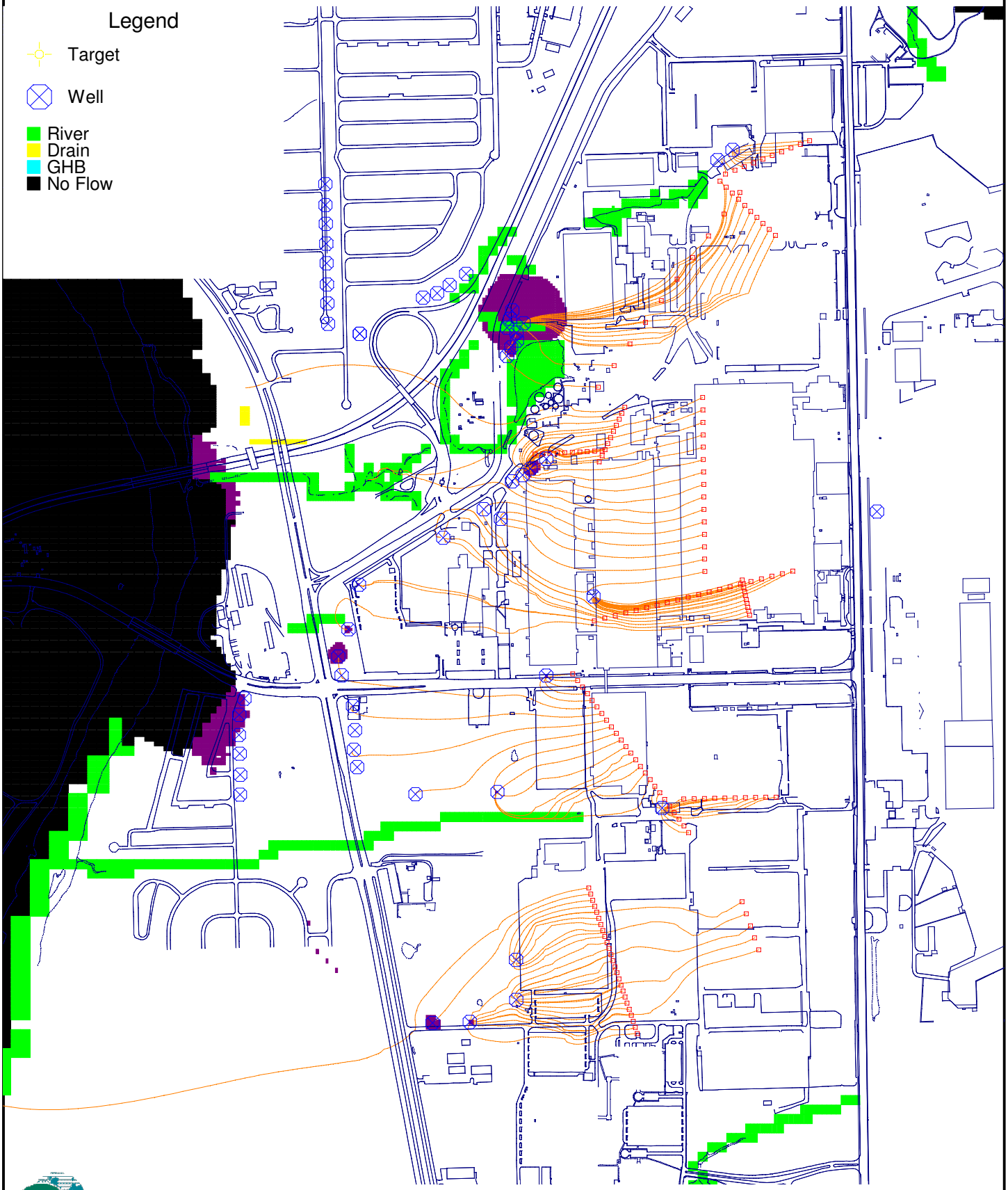
Golder Associates

Figure A-9 MODPATH Sensitivity Analysis
Horizontal Hydraulic Conductivity Zone 7 0.7 x Multiplier
Boeing Site, Wichita, Kansas



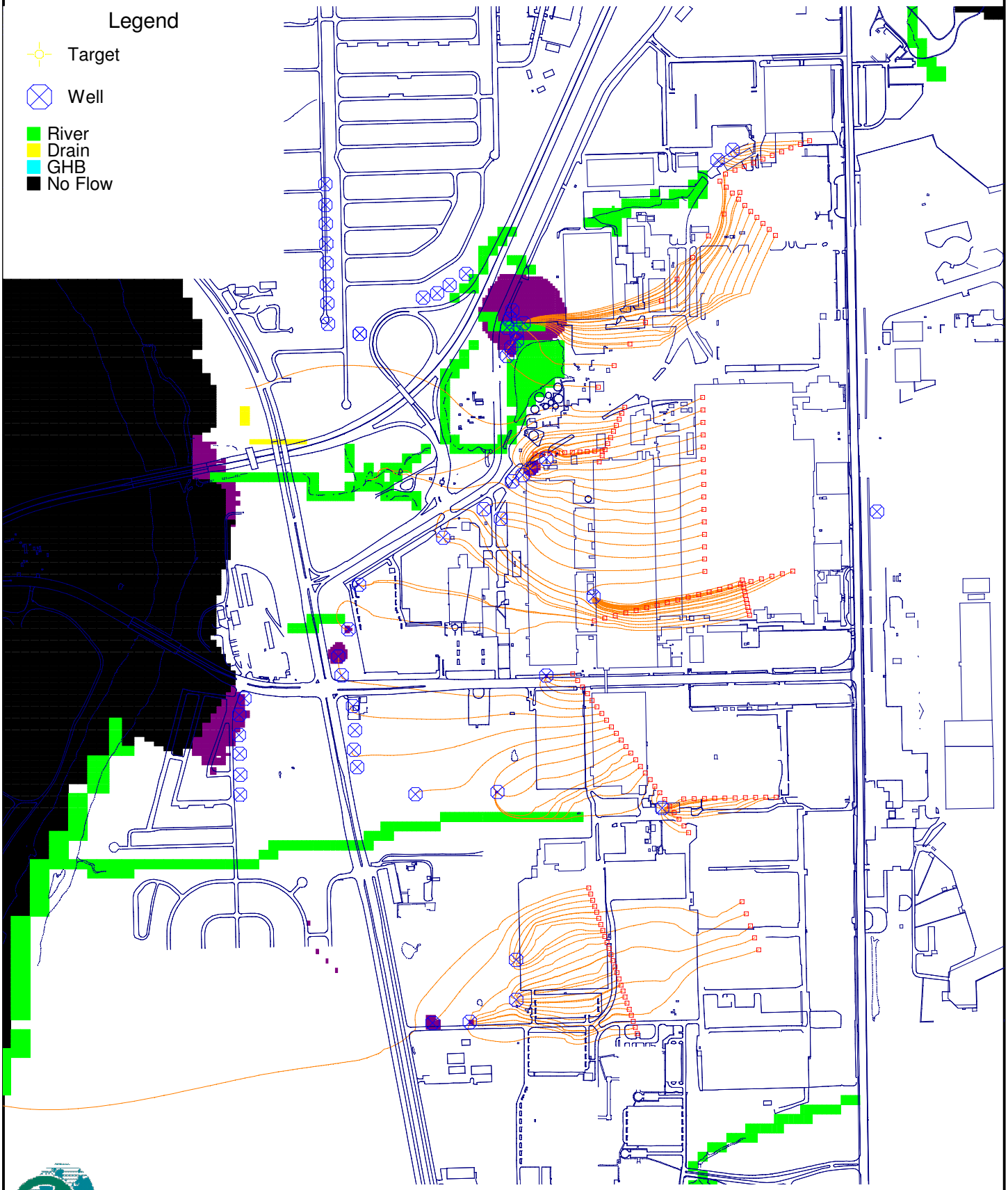
Golder Associates

Figure A-10 MODPATH Sensitivity Analysis
Horizontal Hydraulic Conductivity Zone 7 1.5 x Multiplier
Boeing Site, Wichita, Kansas



Golder Associates

Figure A-11 MODPATH Sensitivity Analysis
Horizontal Hydraulic Conductivity Zone 15 0.7 x Multiplier
Boeing Site, Wichita, Kansas



Golder Associates

Figure A-12 MODPATH Sensitivity Analysis
Horizontal Hydraulic Conductivity Zone 15 1.5 x Multiplier
Boeing Site, Wichita, Kansas