ENTERED

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS 377TH AIR BASE WING (AFMC)

Colonel Robert L. Maness
Commander
2000 Wyoming Blvd SE
Kirtland AFB, NM 87117-5000

RECEIVED
SEP 2010
NMED Hazardous Waste Bureau

Mr. James P. Bearzi, Chief
Hazardous Waste Bureau
New Mexico Environment Dept
2905 Rodeo Park Dr East, Bldg 1
Santa Fe NM 87505-6303

Mr. Bearzi,

Kirtland AFB is submitting a Transport Velocity and Travel Time Report for the estimate of the contaminant migration rate of the dissolved-phase contaminant plume as required by your 6 Aug 10 letter. Additionally, we are submitting a copy of the Indoor Air Quality Report that was required for submittal no later than 6 Oct 10.

If you have any questions with regard to this submittal, please contact Mr. John Pike, 377 MSG/CEAN at (505) 846-8546.

Sincerely

ROBERT L. MANESS, Colonel, USAF
Commander

Attachment:
1.Transport Velocity and Travel Time Report
2. Indoor Air Quality Report

cc:
NMED-HWB, Mr. Moats
NMED-GWQB, Mr. Olson

KAFB3467

MEMORANDUM CH2MHILL

Screening-level Risk Evaluation for Petroleum Hydrocarbon Fuel Compounds in Subslab Soil Vapor - Bulk Fuels Facility, Kirtland Air Force Base

PREPARED FOR: Kirtland AFB Environmental Restoration

PREPARED BY: CH2M HILL

DATE: October 27, 2009

Introduction

Petroleum hydrocarbon fuel impacts in the vadose zone soils exist on the Kirtland Air Force Base (AFB) Bulk Fuels Facility. The hydrocarbon impacts have produced a hydrocarbon vapor plume in the vadose zone on the premises of the Bulk Fuels Facility. In addition to impacts to the vadose zone, phase-separated hydrocarbon (PSH) is known to be present on the water table below the Bulk Fuels Facility. The potential exists for vapor-phase hydrocarbon fuel to pose a risk to potential receptors if it moves from the subsurface to indoor air in occupied buildings at the Bulk Fuels Facility. The vapor-phase hydrocarbon fuel can result from volatilization of either the fuel in the vadose zone or the PSH on the groundwater table. Receptors could potentially be exposed to hydrocarbon fuel compounds through an indoor air vapor intrusion pathway. This potential exposure may occur in the vicinity of vadose zone impacts or overlying areas where PSH is present on the groundwater.

Subslab soil vapor samples were collected from two buildings (Buildings 1032 and 1048) that are located within the general Bulk Fuels Facility area. Two subslab soil vapor samples were collected in Building 1032, which is in the vicinity of the main source area where fuel discharged to the subsurface and where there is vadose contamination. Building 1032 is the Fuels Facility office. The vapor probe was installed through the concrete floor in the garage area on the west side of the structure away from exterior walls. One subslab soil vapor sample was collected in Building 1048 which is not located within the immediate vicinity of the known vadose zone contamination, but which overlies the area of the site where there is PSH on the groundwater. Building 1048 is the 90-Day Hazardous Storage area office building. The vapor probe was installed in the interior janitor's closet in the structure.

The analytical results from these subslab samples were used to assess the potential risk to workers in the buildings from subsurface petroleum hydrocarbon vapors through the vapor intrusion pathway. As a simplified, screening-level approach, subslab vapor-phase petroleum hydrocarbon concentrations were compared to shallow soil vapor screening levels for an industrial land use setting. The shallow soil vapor screening levels are based on USEPA Regional Screening Levels (RSLs) for ambient air with an attenuation factor of 0.1 applied to account for the reduction of concentrations between the subslab soil vapor and ambient outdoor air. This attenuation factor of 0.1 is recommended in USEPA vapor intrusion guidance to be used for estimating indoor air concentrations from shallow soil vapor concentrations. Additional information regarding the purpose, scope, and methods associated with samples collected for this vapor intrusion evaluation is presented in the *Vapor Intrusion Workplan, Bulk Fuels Facility (ST-106), Kirtland AFB memorandum* (CH2M HILL, 2008).

Sampling Activities- Subslab Soil Vapor Sampling

Subslab vapor sampling was conducted to assess the potential for soil vapor intrusion of air concentrations of petroleum hydrocarbon fuel compounds attributable to the PSH release at the facility to present unacceptable risk to potential indoor receptors.

Subslab soil vapor samples were collected from installed soil vapor probes in Buildings 1032 and 1048 on July 24, 2009 and again from Building 1032 on July 27, 2009. Entrance to Building 1048 could not be gained on July 27, 2009 so a second sample was not collected from that location. Sampling was conducted as outlined in the *Vapor Intrusion Workplan, Bulk Fuels Facility (ST-106), Kirtland AFB memorandum* (CH2M HILL, 2008).

Vapor samples were analyzed by CH2M HILL's Applied Sciences Laboratory in Corvallis, Oregon for VOCs including the target petroleum hydrocarbon compounds benzene, toluene, ethylbenzene, xylenes, and naphthalene by Method TO-14, and fixed gases (oxygen, nitrogen, carbon monoxide, carbon dioxide, and methane) by Method SM 2720C. This is a subset of the suite of parameters routinely analyzed for as part of other vapor sampling conducted in support of the Bulk Fuels Facility remedial actions.

Screening-level Risk Evaluation

Analytical results for soil vapor samples are presented in Table 1. The direct subslab soil vapor analytical results have the attenuation factor applied to them and then are compared to soil vapor screening levels developed from USEPA RSLs for air for industrial land use (USEPA, 2009). The EPA standard attenuation factor of 0.1 was used to account for dilution between the subsurface soil vapor and indoor air. Table 1 provides both the direct vapor sample results as well as the analytical results modified to reflect the 0.1 attenuation factor applied to the results for use in risk assessment comparisons.

Table 1 presents the subslab soil vapor results, as well as the modified results to account for attenuation, and the residential and industrial shallow soil vapor screening levels. Only one constituent, benzene, in one sample has a concentration that, modified for attenuation, exceeds the industrial soil vapor screening levels.

In addition to comparing each measured result to the industrial soil vapor screening levels, potential cumulative carcinogenic risks and noncarcinogenic hazard indices (HI) were calculated using the data from each sample. EPA's risk management range for site-related exposures is 1×10^{-4} to 1×10^{-6}. An excess lifetime cancer risk of 1×10^{-6} indicates that an individual experiencing the reasonable maximum site exposure estimate has a 1 in one million chance of developing cancer as a result of that exposure. A hazard index less than one indicates that, based on the sum of all hazard quotients, noncarcinogenic adverse effects are unlikely.

To obtain an estimate of excess carcinogenic risk, detected concentrations were divided by the risk–based screening level (based on carcinogenic effects and a target carcinogenic risk of 1×10^{-6}), and the resulting ratio was multiplied by the target risk of 1×10^{-6}. The carcinogenic risk estimates for the individual petroleum hydrocarbon fuel compounds were then summed to provide a cumulative carcinogenic risk estimate. To obtain the noncarcinogenic hazard quotient (HQ) for the individual petroleum hydrocarbon fuel compounds, each compound's concentration was divided by the risk–based screening level (based on noncarcinogenic effects and a HQ of 1), and the resulting ratio was multiplied by the target HQ of 1. The HQs for the individual compounds were summed to provide the cumulative HI.

Table 1 presents the results for carcinogenic risk and noncarcinogenic HI estimates for the industrial scenario. Cumulative carcinogenic risk estimates for Building 1032 ranged from 6×10^{-7} to 1×10^{-6}, which is at the low end and below EPA's risk management range of 1×10^{-4} to 1×10^{-6}. The cumulative carcinogenic risk estimate for Building 1048 was 2×10^{-6}, also at the low end of EPA's risk management range. Noncarcinogenic HI estimates were below 1 for the three subslab soil vapor samples from both buildings.

Uncertainties

Uncertainties associated with the screening-level risk results presented above include the following:

As part of this assessment, a total of three subslab soil vapor samples were collected at two locations, one location in each of two buildings. The buildings where samples were collected are those most commonly occupied by workers. Uncertainty associated with the building-specific and overall potential for vapor intrusion in buildings at or near the Bulk Fuels Facility will increase or decrease with a greater or lesser sampling frequency.

Soil vapor screening levels for vapor-phase petroleum hydrocarbon fuel compounds were calculated using EPA's generic attenuation factor of 0.1 based on indoor air vapor intrusion guidance. This attenuation is generally considered a conservative (i.e. protective), screening-level assumption for evaluating potential vapor intrusion using subslab soil vapor data.

Summary

Petroleum hydrocarbon fuel compounds were detected in the subslab soil vapor samples from Buildings 1032 and 1048. The detected fuel compound concentrations are below screening levels for the industrial use scenario except for benzene in Building 1048 where the concentration slightly exceeds the screening level; cumulative carcinogenic risk estimates and non-carcinogenic hazard index estimates based on the industrial scenario are at the low end or below the EPA's acceptable ranges. More data are needed to confirm this preliminary assessment.

Soil Gas Cumulative Cancer Risk and Noncancer Hazard Index
Kirtland Bulk Fuels Facility
Kirtland Air Force Base, Albuquerque, New Mexico

FieldID	Analyte	Result (ug/m^3)	Result Modifed for Attenuation Factor (ug/m3)	Carcinogenic Residential Air RSL[1,2,3] (ug/m^3)	Noncancer Residential Air RSL[1,2,3] (ug/m^3)	Residential Risk	Residential HI	Carcinogenic Industrial Air RSL[1,2,3] (ug/m^3)	Noncancer Industrial Air RSL[1,2,3] (ug/m^3)	Industrial Risk	Industrial HI
Bldg-1032											
Bldg-1032	Ethylbenzene	1.39	0.14	0.97	1000	1.4E-07	1.4E-04	4.9	4400	2.8E-08	3.2E-05
Bldg-1032	Styrene	1.35	0.13		1000	--	1.3E-04		4400	--	3.1E-05
Bldg-1032	cis-1,3-Dichloropropene	ND		0.61	21	--	--	3.1	88	--	--
Bldg-1032	trans-1,3-Dichloropropene	ND		0.61	21	--	--	3.1	88	--	--
Bldg-1032	1,4-DCB	3.31	0.33	0.22	830	1.5E-06	4.0E-04	1.1	3500	3.0E-07	9.5E-05
Bldg-1032	1,2-EDB	ND		0.0041	9.4	--	--	0.02	39	--	--
Bldg-1032	1,2-DCA	ND		0.094	2500	--	--	0.47	11000	--	--
Bldg-1032	m,p-Xylene	3.51	0.35		730	--	4.8E-04		3100	--	1.1E-04
Bldg-1032	1,3,5-Trimethylbenzene	ND			6.3	--	--		26	--	--
Bldg-1032	Toluene	80.52	8.05		5200	--	0.002		22000	--	3.7E-04
Bldg-1032	Chlorobenzene	ND			52	--	--		220	--	--
Bldg-1032	1,2,4-Trichlorobenzene	ND			4.2	--	--		18	--	--
Bldg-1032	Tetrachloroethylene	ND		0.41	280	--	--	2.1	1200	--	--
Bldg-1032	cis-1,2-DCE	ND				--	--			--	--
Bldg-1032	MTBE (Methyl tert-Butyl Ether)	3.03	0.30	9.4	3100	3.2E-08	9.8E-05	47	13000	6.4E-09	2.3E-05
Bldg-1032	1,3-DCB	ND		0.22	830	--	--	1.1	3500	--	--
Bldg-1032	Carbon tetrachloride	ND		0.16	200	--	--	0.82	830	--	--
Bldg-1032	Acetone	61.44	6.14		32000	--	1.9E-04		140000	--	4.4E-05
Bldg-1032	Chloroform	ND		0.11	100	--	--	0.53	430	--	--
Bldg-1032	Benzene	8.23	0.82	0.31	31	2.7E-06	0.03	1.6	130	5.1E-07	0.006
Bldg-1032	1,1,1-TCA	ND			5200	--	--		22000	--	--
Bldg-1032	Bromomethane	ND			5.2	--	--		22	--	--
Bldg-1032	Chloromethane	1.01	0.10		94	--	0.001		390	--	2.6E-04
Bldg-1032	Chloroethane	ND			10000	--	--		44000	--	--
Bldg-1032	Vinyl chloride	ND		0.16	100	--	--	2.8	440	--	--
Bldg-1032	Methylene chloride	9.80	0.98	5.2	1100	1.9E-07	8.9E-04	26	4600	3.8E-08	2.1E-04
Bldg-1032	1,1-DCA	ND		1.5		--	--	7.7		--	--
Bldg-1032	1,1-DCE	ND			210	--	--		880	--	--
Bldg-1032	Trichlorofluoromethane	1.40	0.14		730	--	1.9E-04		3100	--	4.5E-05
Bldg-1032	Dichlorodifluoromethane	2.52	0.25		210	--	0.001		880	--	2.9E-04
Bldg-1032	1,1,2-Trichloro-1,2,2-trifluoroethane	1.84	0.18		31000	--	5.9E-06		130000	--	1.4E-06
Bldg-1032	1,2-Dichloro-1,1,2,2-tetrafluoroethane	ND				--	--			--	--
Bldg-1032	1,2-Dichloropropane	1.43	0.14	0.24	4.2	6.0E-07	0.03	1.2	18	1.2E-07	0.008
Bldg-1032	MEK (2-Butanone)	12.50	1.25		5200	--	2.4E-04		22000	--	5.7E-05
Bldg-1032	1,1,2-TCA	ND		0.15		--	--	0.77		--	--
Bldg-1032	TCE	3.24	0.32	1.2		2.7E-07	--	6.1		5.3E-08	--
Bldg-1032	1,1,2,2-Tetrachloroethane	ND		0.042		--	--	0.21		--	--
Bldg-1032	Hexachlorobutadiene	ND		0.11		--	--	0.56		--	--
Bldg-1032	o-Xylene	1.39	0.14		730	--	1.9E-04		3100	--	4.5E-05
Bldg-1032	1,2-DCB	ND			210	--	--		880	--	--
Bldg-1032	1,2,4-Trimethylbenzene	ND			7.3	--	--		31	--	--
		Bldg-1032 Cumulative Risk and HI:				**5.E-06**	**0.07**			**1.E-06**	**0.02**
Bldg-1048											
Bldg-1048	Ethylbenzene	1.39	0.14	0.97	1000	1.4E-07	1.4E-04	4.9	4400	2.8E-08	3.2E-05
Bldg-1048	Styrene	2.49	0.25		1000	--	2.5E-04		4400	--	5.7E-05
Bldg-1048	cis-1,3-Dichloropropene	ND		0.61	21	--	--	3.1	88	--	--
Bldg-1048	trans-1,3-Dichloropropene	ND		0.61	21	--	--	3.1	88	--	--
Bldg-1048	1,4-DCB	2.70	0.27	0.22	830	1.2E-06	3.3E-04	1.1	3500	2.5E-07	7.7E-05
Bldg-1048	1,2-EDB	ND		0.0041	9.4	--	--	0.02	39	--	--
Bldg-1048	1,2-DCA	ND		0.094	2500	--	--	0.47	11000	--	--
Bldg-1048	m,p-Xylene	3.15	0.31		730	--	4.3E-04		3100	--	1.0E-04
Bldg-1048	1,3,5-Trimethylbenzene	ND			6.3	--	--		26	--	--
Bldg-1048	Toluene	7.07	0.71		5200	--	1.4E-04		22000	--	3.2E-05
Bldg-1048	Chlorobenzene	ND			52	--	--		220	--	--
Bldg-1048	1,2,4-Trichlorobenzene	ND			4.2	--	--		18	--	--
Bldg-1048	Tetrachloroethylene	3.27	0.33	0.41	280	8.0E-07	0.001	2.1	1200	1.6E-07	2.7E-04
Bldg-1048	cis-1,2-DCE	ND				--	--			--	--
Bldg-1048	MTBE (Methyl tert-Butyl Ether)	ND		9.4	3100	--	--	47	13000	--	--
Bldg-1048	1,3-DCB	ND		0.22	830	--	--	1.1	3500	--	--
Bldg-1048	Carbon tetrachloride	ND		0.16	200	--	--	0.82	830	--	--
Bldg-1048	Acetone	69.51	6.95		32000	--	2.2E-04		140000	--	5.0E-05
Bldg-1048	Chloroform	ND		0.11	100	--	--	0.53	430	--	--
Bldg-1048	Benzene	20.64	2.06	0.31	31	6.7E-06	0.07	1.6	130	1.3E-06	0.02
Bldg-1048	1,1,1-TCA	1.97	0.20		5200	--	3.8E-05		22000	--	8.9E-06
Bldg-1048	Bromomethane	ND			5.2	--	--		22	--	--
Bldg-1048	Chloromethane	ND			94	--	--		390	--	--
Bldg-1048	Chloroethane	ND			10000	--	--		44000	--	--
Bldg-1048	Vinyl chloride	ND		0.16	100	--	--	2.8	440	--	--
Bldg-1048	Methylene chloride	3.62	0.36	5.2	1100	7.0E-08	3.3E-04	26	4600	1.4E-08	7.9E-05
Bldg-1048	1,1-DCA	ND		1.5		--	--	7.7		--	--
Bldg-1048	1,1-DCE	ND			210	--	--		880	--	--
Bldg-1048	Trichlorofluoromethane	154.50	15.45		730	--	0.02		3100	--	0.005
Bldg-1048	Dichlorodifluoromethane	954.45	95.45		210	--	0.5		880	--	0.1
Bldg-1048	1,1,2-Trichloro-1,2,2-trifluoroethane	ND			31000	--	--		130000	--	--
Bldg-1048	1,2-Dichloro-1,1,2,2-tetrafluoroethane	ND				--	--			--	--
Bldg-1048	1,2-Dichloropropane	ND		0.24	4.2	--	--	1.2	18	--	--
Bldg-1048	MEK (2-Butanone)	7.82	0.78		5200	--	1.5E-04		22000	--	3.6E-05
Bldg-1048	1,1,2-TCA	ND		0.15		--	--	0.77		--	--
Bldg-1048	TCE	1.70	0.17	1.2		1.4E-07	--	6.1		2.8E-08	--
Bldg-1048	1,1,2,2-Tetrachloroethane	ND		0.042		--	--	0.21		--	--
Bldg-1048	Hexachlorobutadiene	ND		0.11		--	--	0.56		--	--
Bldg-1048	o-Xylene	1.57	0.16		730	--	2.2E-04		3100	--	5.1E-05
Bldg-1048	1,2-DCB	ND			210	--	--		880	--	--
Bldg-1048	1,2,4-Trimethylbenzene	ND			7.3	--	--		31	--	--
		Bldg-1048 Cumulative Risk and HI:				**9.E-06**	**0.5**			**2.E-06**	**0.1**
Bldg-1032-2											
Bldg-1032-2	Ethylbenzene	0.72	0.07	0.97	1000	7.4E-08	7.2E-05	4.9	4400	1.5E-08	1.6E-05
Bldg-1032-2	Styrene	ND			1000	--	--		4400	--	--
Bldg-1032-2	cis-1,3-Dichloropropene	ND		0.61	21	--	--	3.1	88	--	--
Bldg-1032-2	trans-1,3-Dichloropropene	ND		0.61	21	--	--	3.1	88	--	--
Bldg-1032-2	1,4-DCB	1.41	0.14	0.22	830	6.4E-07	1.7E-04	1.1	3500	1.3E-07	4.0E-05
Bldg-1032-2	1,2-EDB	ND		0.0041	9.4	--	--	0.02	39	--	--
Bldg-1032-2	1,2-DCA	ND		0.094	2500	--	--	0.47	11000	--	--
Bldg-1032-2	m,p-Xylene	1.89	0.19		730	--	2.6E-04		3100	--	6.1E-05
Bldg-1032-2	1,3,5-Trimethylbenzene	ND			6.3	--	--		26	--	--
Bldg-1032-2	Toluene	1.24	0.12		5200	--	2.4E-05		22000	--	5.6E-06
Bldg-1032-2	Chlorobenzene	ND			52	--	--		220	--	--
Bldg-1032-2	1,2,4-Trichlorobenzene	ND			4.2	--	--		18	--	--
Bldg-1032-2	Tetrachloroethylene	ND		0.41	280	--	--	2.1	1200	--	--
Bldg-1032-2	cis-1,2-DCE	ND				--	--			--	--
Bldg-1032-2	MTBE (Methyl tert-Butyl Ether)	ND		9.4	3100	--	--	47	13000	--	--
Bldg-1032-2	1,3-DCB	ND		0.22	830	--	--	1.1	3500	--	--
Bldg-1032-2	Carbon tetrachloride	ND		0.16	200	--	--	0.82	830	--	--
Bldg-1032-2	Acetone	22.37	2.24		32000	--	7.0E-05		140000	--	1.6E-05
Bldg-1032-2	Chloroform	ND		0.11	100	--	--	0.53	430	--	--
Bldg-1032-2	Benzene	1.63	0.16	0.31	31	5.2E-07	0.005	1.6	130	1.0E-07	0.001
Bldg-1032-2	1,1,1-TCA	ND			5200	--	--		22000	--	--
Bldg-1032-2	Bromomethane	ND			5.2	--	--		22	--	--
Bldg-1032-2	Chloromethane	1.16	0.12		94	--	0.001		390	--	3.0E-04
Bldg-1032-2	Chloroethane	ND			10000	--	--		44000	--	--
Bldg-1032-2	Vinyl chloride	ND		0.16	100	--	--	2.8	440	--	--
Bldg-1032-2	Methylene chloride	3.13	0.31	5.2	1100	6.0E-08	2.8E-04	26	4600	1.2E-08	6.8E-05
Bldg-1032-2	1,1-DCA	ND		1.5		--	--	7.7		--	--
Bldg-1032-2	1,1-DCE	ND			210	--	--		880	--	--
Bldg-1032-2	Trichlorofluoromethane	1.40	0.14		730	--	1.9E-04		3100	--	4.5E-05
Bldg-1032-2	Dichlorodifluoromethane	2.57	0.26		210	--	0.001		880	--	2.9E-04
Bldg-1032-2	1,1,2-Trichloro-1,2,2-trifluoroethane	ND			31000	--	--		130000	--	--
Bldg-1032-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane	ND				--	--			--	--
Bldg-1032-2	1,2-Dichloropropane	ND		0.24	4.2	--	--	1.2	18	--	--
Bldg-1032-2	MEK (2-Butanone)	11.24	1.12		5200	--	2.2E-04		22000	--	5.1E-05
Bldg-1032-2	1,1,2-TCA	ND		0.15		--	--	0.77		--	--
Bldg-1032-2	TCE	1.97	0.20	1.2		1.6E-07	--	6.1		3.2E-08	--
Bldg-1032-2	1,1,2,2-Tetrachloroethane	ND		0.042		--	--	0.21		--	--
Bldg-1032-2	Hexachlorobutadiene	1.60	0.16	0.11		1.5E-06	--	0.56		2.9E-07	--
Bldg-1032-2	o-Xylene	ND			730	--	--		3100	--	--
Bldg-1032-2	1,2-DCB	ND			210	--	--		880	--	--
Bldg-1032-2	1,2,4-Trimethylbenzene	ND			7.3	--	--		31	--	--
		Bldg-1032-2 Cumulative Risk and HI:				**3.E-06**	**0.009**			**6.E-07**	**0.002**

Notes:

[1] 1,3-dichloropropene was used as a surrogate for cis-1,3-dichloropropene and trans-1,3-dichloropropene.

[2] m-xylene was used as a surrogate for m,p-xylene.

[3] 1,4-dichlorobenzene was used as a surrogate for 1,3-dichlorobenzene.

(yellow highlight) = main contributors to risk estimates

Groundwater Travel Time from Bulk Fuels Facility
Kirtland Air Force Base, KAFB, New Mexico

Executive Summary and Conclusions

Groundwater transport velocity and travel time along flow paths from the known limits of the Kirtland BFF plume to production wells have been made on the basis of available site and regional groundwater data. Appropriately conservative assumptions have been employed to address data uncertainties. The detailed technical basis for assumptions, estimates and calculations is provided in subsequent sections of this report.

Key results and conclusions of the analysis include:

- Flow paths from the Kirtland BFF plume are not expected to intercept production wells KAFB-15, KAFB-16, and the VA Hospital. This suggests that migration from the plume toward these wells is not expected to occur provided pumping rates from the production wells do not change from recent conditions.
- Because the VA Hospital well is located near the former Fuel Offloading Rack and contamination is present in the vadose zone, continued monitoring of groundwater wells at this location is important to provide an early warning of any future changes in groundwater conditions.
- Flow paths do exist from the Kirtland BFF plume toward production wells Ridgecrest 5 and KAFB-3. Flow paths toward KAFB-3 may be active only seasonally. However, flow paths toward Ridgecrest 5 are active throughout the year. Existing data indicate that there are no flow paths from the plume toward production well Burton 5. However, data near Burton 5 are limited. As a worst-case scenario, it is appropriate to assume that flow paths from the plume to Burton 5 may exist.
- The best estimate of transport velocity along flow paths from the Kirtland BFF plume toward production wells is 0.45 ft/day. Transport velocity under a worst-case scenario is 0.90 ft/day.

Estimates of travel time from the Kirtland BFF plume to production wells are provided in the following table. Travel times have been calculated for best-available estimates of calculation parameters, as well as under a worst-case scenario.

Table ES-1. Transport Velocities and Travel Times from the Kirtland BFF Plume to Production Wells

Production Well	*Flow Path from Plume to Well*	*Travel Time for Best Estimate of Parameters*		*Travel Time for Worst Case Scenario*	
		(days)	*(years)*	*(days)*	*(years)*
Ridgecrest 5	Yes	13,510	37.0	6,755	18.5
Burton 5	Possible	8,222	22.5	4,111	11.3
VA Hospital	No				
KAFB-3	Seasonal	8,822	24.2	4,411	12.1
KAFB-15	No				
KAFB-16	No				

Introduction

This letter report provides calculations showing the estimated velocity of and travel time for the dissolved-phase contaminant plume at the Kirtland AFB Bulk Fuels Facility (BFF) to first reach the closest water supply wells in the vicinity of the plume. The following water-supply wells are considered in the calculations:

- City of Albuquerque Ridgecrest well field, Ridgecrest 5
- City of Albuquerque Burton well field, Burton 5
- Veteran Administration (VA) Hospital well
- Kirtland AFB well KAFB-3
- Kirtland AFB well KAFB-15
- Kirtland AFB well KAFB-16

The letter report is prepared to fulfill a requirement of New Mexico Environment Department, Hazardous Waste Bureau identified in letter dated August 6, 2010.

Calculations assumptions include:

1. No efforts are undertaken to contain or remediate the dissolved-phase plume.
2. Migration continues to occur in response to current hydrologic conditions.
3. Advective transport velocities and travel times are calculated from known margins of the EDB plume to downgradient production wells.
4. Calculations consider the direction and gradient of groundwater flow, and the geologic and hydrologic properties of the aquifer under a worse-case scenario.
5. Calculations provide an evaluation of conservative transport of EDB.

Determination of Flow Paths to Production Wells and Hydraulic Gradients

Flow paths to production wells have been determined from water-table contour maps of the area that include the Kirtland BFF site and eastern Albuquerque production wells. Available maps were reviewed that show production well locations (Figure 1) and the configuration of the regional-scale water table (Figure 2). These maps provide insight to production wells that may be affected by migration of the Kirtland BFF plume but are not sufficiently detailed for determining flow paths. Available water-table contour maps of the Kirtland BFF site provide the required detail but do not extend north of the site to include the Ridgecrest or Burton well fields. Therefore, water-level contour maps at the required intermediate scale were developed (Figures 3 and 4) on the basis of monitoring well data from the Kirtland BFF site (Figures 5 through 8) and water-level data available from the U.S. Geological Survey, Water Resources District, New Mexico Water Center and other references (Tables 1 and 2).

Table 1. USGS Water Level Measurements for Cluster Wells with Continuous Record in the Vicinity of the Kirtland BFF Site and Nearby Production Wells

USGS Site Number	*Site Name*	*Location*		*Top of Screen (ft/bgs)*	*Water Level (ft/msl)*	
		Latitude	*Longitude*		*7 Oct 2009*	*11 Jan 2010*
350534106354701	10N.03E.14.324 DEL SOL DIVIDER	35°05‘34"	106°35‘47"	1567	4874.07	4884.19
350534106354702	10N.03E.14.324A DEL SOL DIVIDER	35°05‘34"	106°35‘47"	842	4859.55	4870.66
350534106354703	10N.03E.14.324B DEL SOL DIVIDER	35°05‘34"	106°35‘47"	425	4852.73	4854.13
350545106335901	10N.04E.18.133A JERRY CLINE	35°05‘45"	106°33‘59"	1455	4842.3	4854.75
350545106335902	10N.04E.18.133B JERRY CLINE	35°05‘45"	106°33‘59"	1050	4837.62	4844.50
350545106335903	10N.04E.18.133C JERRY CLINE	35°05‘45"	106°33‘59"	510	4833.36	4838.74

Table 2. USGS Water Level Measurements at Miscellaneous Field Locations in the Vicinity of the Kirtland BFF Site and Nearby Production Wells

USGS Site Number	*Site Name*	*Location*		*Period of Record*		*Last Measurement (ft msl)*
		Latitude	*Longitude*	*Begin Date*	*End Date*	
350219106360901	09N.03E.02.131 KAFB 0417	35°02'19"	106°36'09"	1992-06-05	2008-09-11	4857.75
350229106350901	09N.03E.02.224 KAFB 0114	35°02'29"	106°35'09"	1992-08-13	2006-10-03	<4859 (dry)
350401106331401	10N.04E.30.243 Ridgecrest 3	35°04'01"	106°33'14"	1974-11-15	2010-02-16	4848.38
350445106334001	10N.04E.19.322 Ridgecrest 4	35°04'45"	106°33'40"	1974-12-11	2006-04-11	4844.80

The configuration of the regional water table (Figure 2) suggests that flow paths from the Kirtland BFF site converge toward the Ridgecrest well field. Ridgecrest 5 is the production well within this well field that is nearest the Kirtland BFF plume. Flow paths and hydraulic gradients inferred from regional mapping also suggest that future migration of the BFF plume may bypass the Burton well field. Intermediate-scale maps of the water-table configuration provide the level of detail required to identify flow paths and hydraulic gradients toward production wells near the Kirtland BFF plume (Figures 3 and 4). Water-table contour maps were developed at this scale for October 2009 and January 2010 because the database for these time periods is the most extensive available. A review of historical water-level fluctuations at well clusters in the region with long periods of record (Figure 9) suggests that the October 2009 map corresponds to a seasonal low water-level period. January 2010 corresponds to a seasonal high water-level period.

The known extent of contamination is required to identify flow paths and travel times from the Kirtland BFF plume. Maps of the known extent of the dissolved-phase plume at the Bulk Fuels Facility (BFF) have been presented in semiannual remediation and site investigation reports (CH2M Hill, 2009; CH2M Hill, 2010). These reports show that 1,2-dibromoethane (EDB) has migrated over greater distances than other potential contaminants of concern. For purposes of calculating travel times, extent of the EDB plume as shown in these reports has provided the basis for identifying flow paths and travel times. Plume extent is identified in Figures 3 and 4.

Intermediate-scale maps of water-table configuration (Figures 3 and 4) show that flow paths from the Kirtland BFF plume are not expected to intercept production wells KAFB-15, KAFB-16, and the VA Hospital. This is an important conclusion and suggests that migration from the plume toward these wells is not expected to occur provided pumping rates from the production wells do not appreciably change from recent conditions. Therefore, transport velocities and travel times from the BFF plume to production wells KAFB-15, KAFB-16 and the VA Hospital well are not calculated in this report.

The VA Hospital well is not located hydraulically downgradient of the dissolved-phase groundwater plume. However, the lateral extent of contamination in the vadose zone includes the known source area at the former Fuel Offloading Rack (FFOR), which overlies groundwater that is hydraulically upgradient of the well. Contaminants of concern have not been detected at two monitoring wells located hydraulically upgradient of the VA Hospital well and at the FFOR (KAFB-1062, KAFB-1063). Nor have contaminants been detected at monitoring well KAFB-1064 located between the FFOR and the VA Hospital. If conditions at these monitoring wells change, a groundwater flow path from the dissolved-phase plume to the VA Hospital would be likely and relatively short travel times would be expected.

Flow paths do exist from the Kirtland BFF plume toward production wells Ridgecrest 5 and KAFB-3. Water levels in the area fluctuate seasonally and reflect spatial shifts in hydraulic gradients and flow paths. However, flow paths toward Ridgecrest 5 are expected to be present during most if not all seasons. Comparison of Figures 3 and 4 suggest that flow paths from the Kirtland BFF plume toward KAFB-3 may only be active when seasonal pumping is highest (i.e. summer). However, for purposes of this letter report, seasonal variations are neglected and it is assumed that migration toward KAFB-3 may occur continuously without implementation of mitigation efforts.

As mapped in Figures 3 and 4, there are no flow paths from the Kirtland BFF plume toward production well Burton 5. This interpretation is consistent with that shown in regional water-table maps such as Figure 2. Nevertheless, flow paths from the plume to the Burton 5 well are hypothesized due to the large volume of water withdrawn by the Burton well field. Water-level data in the vicinity of the well field and areas to the west such as the Nob Hill neighborhood are not available to support hypothesized flow paths or to determine hydraulic gradients. Therefore, in the interest of evaluating a worst-case scenario for plume migration, calculations of transport velocity and travel time to Burton 5 are included in this report. For the Burton 5 well, the hypothesized flow path is the shortest straight line from Burton 5 to the plume.

Figures 3 and 4 have been used to determine the shortest flow paths from the Kirtland BFF plume to production wells, and to calculate hydraulic gradients along these flow paths (Table 3). Hydraulic gradients are calculated only for production wells where flow paths from the plume indicate potential for migration toward the well. Hydraulic gradients in Table 2 were calculated along the shortest flow path, resulting in a value of 0.00097 ft/ft for Ridgecrest 5 and 0.00095 ft/ft for KAFB-3.

Table 3. Flow Paths and Hydraulic Gradients from the Kirtland BFF Plume to Production Wells

Production Well	*Flow Path from Plume to Well*	*Shortest Flow Path from Plume*		*Hydraulic Gradient along Flow Path (ft/ft)*
		Distance (ft)	*Month*	
Ridgecrest 5	Yes	6080	Oct	0.00097
Burton 5	Possible[1]	3700[2]		
VA Hospital	No			
KAFB-3	Seasonal	3970	Oct	0.00095
KAFB-15	No			
KAFB-16	No			

Notes:

1. Flow paths from the plume to the Burton 5 well are suspected due to the large volume of water withdrawn by the Burton well field. However, water-level data in the vicinity of the well field are not available to support hypothesized flow paths or to determine hydraulic gradients.
2. Distance shown is shortest straight line from Burton 5 to the plume.

Figures 5 through 8 have been used to calculate hydraulic gradients along the plume axis (Table 4). Hydraulic gradients along the plume axis vary seasonally in a range from approximately 0.0012 ft/ft to 0.0015 ft/ft. Because data density is greater in the vicinity of the plume than in downgradient areas, these hydraulic gradients may be better estimates of actual condition throughout the area.

Table 4. Hydraulic Gradients along the Kirtland BFF Plume Axis (ft/ft)

Apr 2009	*Jul 2009*	*Oct 2009*	*Jan 2009*
0.00121	0.00123	0.00130	0.00146

A best estimate for hydraulic gradient at the scale of interest is approximately 0.0012 ft/ft. The range of measured values deviates by approximately 25 percent from this value. Given this relatively narrow range of estimates, the maximum observed hydraulic gradient provides an appropriate value for use in calculating transport velocities and travel times. Seasonal variations in observed gradients and limitations in the available data set in the vicinity of production wells also support the use of the maximum value. Therefore, a single value of 0.0015 ft/ft is applied to all flow paths and is used in all subsequent calculations requiring hydraulic-gradient estimates. Over estimation of the hydraulic gradient results in over estimation of Darcy flux and transport velocity, as well as under estimation of travel time. As such, this approach is consistent with the intent of addressing a worst-case scenario.

Calculations of Transport Velocity and Travel Time

The rate of EDB transport toward downgradient production wells is controlled principally by the rate of groundwater advection and is quantified as the advective transport velocity, also called the average linear velocity. EDB transport may be affected by volatilization from the water table, sorption of EDB on aquifer sediments and organic material, as well as degradation reactions. If present, these processes would tend to increase EDB travel time to downgradient production wells. However, as a conservative (worst-case) assumption, it is appropriate to predict travel time of EDB assuming that the chemical is transported as a non-reacting chemical subject only to advection.

Groundwater travel times to production wells in the vicinity of the BFF plume are calculated from groundwater Darcy flux, advective transport velocity (also called average linear velocity), and distance from the BFF dissolved-phase plume to downgradient production wells. In order to provide worst-case estimates of EDB transport, values of equation parameters used to these calculations have been selected that represent the range of measurements or estimates.

Groundwater Advective Transport Velocity

Advective transport velocity and Darcy flux are calculated with the following equation.

$$v = \frac{q}{n} = -\frac{K}{n}\nabla$$

where v is advective transport velocity, q is Darcy flux, n is effective porosity, K is hydraulic conductivity, and ∇ is hydraulic gradient. Site data and estimates for each equation parameter are provided later in this section of the report. Using the parameter values identified in the following paragraphs, best estimates and worst-case estimates of transport velocity are provided in Table 5 for flow lines from the plume to each production well.

Table 5. Transport Velocities and Travel Times from the Kirtland BFF Plume to Production Wells

Production Well	*Flow Path from Plume to Well*	*Transport Velocity (ft/day)*		*Travel Time (days)*	
		Best Estimate	*Worst Case Scenario*	*Best Estimate*	*Worst Case Scenario*
Ridgecrest 5	Yes	0.45	0.90	13,510	6,755
Burton 5	Possible			8,222	4,111
VA Hospital	No				
KAFB-3	Seasonal	0.45	0.90	8,822	4,411
KAFB-15	No				
KAFB-16	No				

For calculations of Darcy flux, estimates of hydraulic conductivity along flow paths are needed. A value of 30 ft/day is a best estimate of conditions from the known BFF plume to production well fields located downgradient of the plume. This value represents hydraulic conductivity along horizontal flow paths at or near the water table. Existing wells are not available to evaluate the depth of EDB contamination. Available vertical gradient data (Figure 9) suggest that vertical hydraulic gradients in areas north of the Kirtland BFF plume may be upward. If similar conditions occur in the vicinity of the plume, the vertical extent of EDB contamination may be limited. Nevertheless, production wells extract water from deeper zones in the aquifer. Though not expected to occur, it is appropriate to evaluate travel time if EDB is present in deeper parts of the aquifer where production wells have been completed. Estimated hydraulic conductivity in deeper zones is 57 ft/day. Therefore, a value of 60 ft/day is used in transport velocity calculations to reflect a worst-case scenario where it is assumed that EDB transport occurs at depths corresponding to the screened intervals of production wells. A more detailed technical evaluation supporting these hydraulic conductivity values is provided as a separate section later in this report.

For calculations of transport velocity, an estimate of effective porosity is needed. No site-specific information is available to estimate effective porosity. For alluvial aquifers, typical values of effective porosity are in a range from 0.1 to 0.3. A value of 0.1 is used in subsequent calculations. The small value in this range is selected because it results in a larger value of average linear velocity and therefore shorter groundwater travel times. This approach will tend to underestimate travel times to production well fields and therefore provides a conservative approach when site-specific data are not available.

Travel Time from BFF Dissolved Plume to Production Wells

Travel times to production wells are calculated as the ratio of distance to transport velocity. In order to provide worst-case estimates of EDB transport, values of travel distance used to calculate travel times represent the shortest estimated flow path. Results are provided in Table 5 for both best estimates and worst-case scenarios.

Hydraulic Conductivity in the Vicinity of the Bulk Fuels Facility Plume

This section of the report provides additional description of hydraulic-conductivity estimates used in transport velocity and travel-time calculations.

Approach

No reliable estimates of hydraulic conductivity are available from aquifer tests performed at the Kirtland BFF site. However, there is a large database of hydraulic conductivity values from aquifer tests performed with large-capacity production wells in east Albuquerque. Production wells are completed at greater depths in the Rio Grande aquifer than the known depth interval of the BFF plume. Hydraulic-conductivity estimates for the depth interval of the BFF plume are available from groundwater flow models of the Albuquerque area.

Results

Horizontal hydraulic conductivity is anisotropic in the vicinity and depth intervals of the BFF plume and nearby production wells. The best estimate of hydraulic conductivity obtained from aquifer tests in east Albuquerque is 57 ft/day. This value is indicative of the more productive depth intervals that underlie the BFF plume. The best estimate of the depth intervals that are known to contain the BFF plume, obtained from model calibration, is 30 ft/day in the north-south direction and 15 ft/day in the east-west direction. Vertical hydraulic conductivity is at least two orders of magnitude less than horizontal values. This vertical-to-horizontal ratio is based on aquifer test and model-derived estimates.

The BFF plume is migrating approximately in a northerly direction. Therefore, the best estimate of horizontal hydraulic conductivity to use for calculating travel time in the vicinity of the BFF plume is 30 ft/day. Vertical hydraulic gradients near the BFF plume are poorly defined. However, as a worst-case scenario, it is appropriate to evaluate travel time at the depths utilized by large production wells.

Summary of Reports Providing Hydraulic Conductivity Estimates

Thorn et al. (1993) provides a compilation of aquifer tests in the basin. Data were from aquifer tests of high capacity production wells with relatively long screens (hundreds of feet).

Basin-Wide Summary of Hydraulic Conductivity Estimates (ft/d)

Minimum	1
Maximum	133
Mean	41
Median	25
Std Dev.	36.8
25th Percentile	11.9
75th Percentile	63.8
Coeff. Variations % (mean/stddev)	91
Skewness	0.94
Total samples	65

Separating the data set into tests east and west of the Rio Grande provides distinctly different probability plots. This separation is justified on the basis of changes in depositional environment. A contour map of hydraulic conductivity estimates shows a prominent north-south oriented zone of relatively uniform high values that has been interpreted as axial-channel deposits of the ancestral Rio Grande. Outside this zone, hydraulic conductivity estimates decrease abruptly suggesting locations where alluvial and piedmont-slope deposits predominate.

Median Hydraulic Conductivity (ft/d)

West of the Rio Grande	11
East of the Rio Grande	57

Zimmerman et al. (2000) and McAda (2001) describe long-term aquifer tests with multiple observation wells. Tests were located a short distance east of the Rio Grande and north of I-40. Three-dimensional flow models were used to estimate aquifer properties. The hydraulic-conductivity values of the upper part of the Santa Fe Group resulting from model calibration varied by zone in the model and ranged from 12 to 33 feet per day. The hydraulic conductivity of the inner-valley alluvium was 45 feet per day.

Reiter (2001) provides estimates from analysis of borehole temperature logs. Results reflect conditions in the more productive zones penetrated by wells. Zones of predominately low permeability sediments are not represented. Typical horizontal hydraulic conductivity values range from 28 to 1400 ft/d. Typical vertical hydraulic conductivity values range from 0.0057 to 1.1 ft/d.

Ruskauff (1996) provides an evaluation of horizontal anisotropy. The channel deposits that comprise the more productive portions of the aquifer follow a general north-south trend and produce elongated zones of higher hydraulic conductivity running north-south, with lower hydraulic conductivity material tending to isolate the elongated zones in the east-west direction. Thus, materials are likely to be horizontally isotropic within a major facies (e.g. channels), but the overall arrangement of the deposits has a definite orientation. Geostatistical analysis of the data of Thorn et al. (1993) showed that hydraulic conductivity was statistically anisotropic, with a major direction of continuity running north-south. Using stochastic theories that relate physical and statistical anisotropy a rough estimate of anisotropy was derived.

McAda and Barroll (2002) document the most recent of several regional-scale models that have been developed for the Albuquerque groundwater basin. Estimates of hydraulic conductivity were based on previous modeling efforts as well as aquifer test results described above. Horizontal hydraulic conductivity varied spatially throughout the model domain as did ratios of horizontal anisotropy. In the BFF plume area and production well fields north of the plume, horizontal hydraulic conductivity in the shallow portions of the saturated zone was estimated to be 15 ft/d in the east-west direction, and 30 ft/day in the north-south direction. Horizontal anisotropy was consistent with the predominant north-south orientation of faults. The ratio of horizontal to vertical anisotropy was 150:1 throughout the model domain. Horizontal hydraulic conductivity of the depth intervals used by production well fields was 30 ft/d in the east-west direction, and 60 ft/day in the north-south direction.

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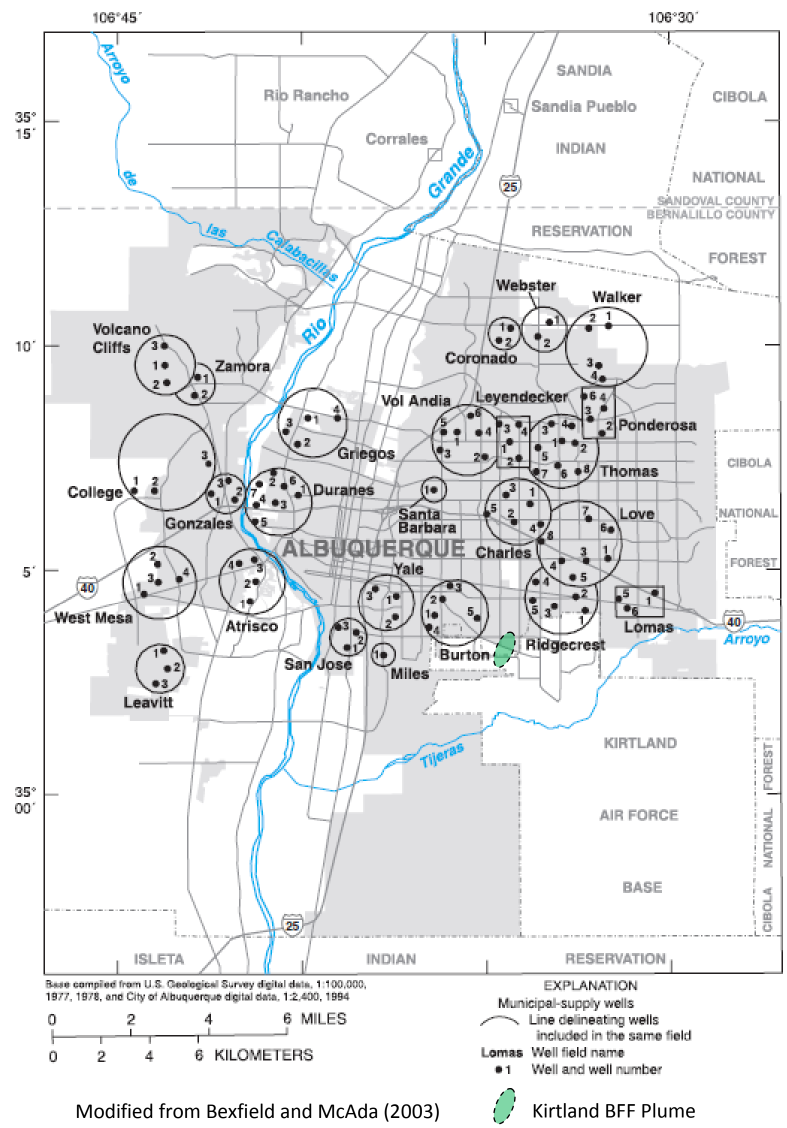


Figure 1. City of Albuquerque Production Wells

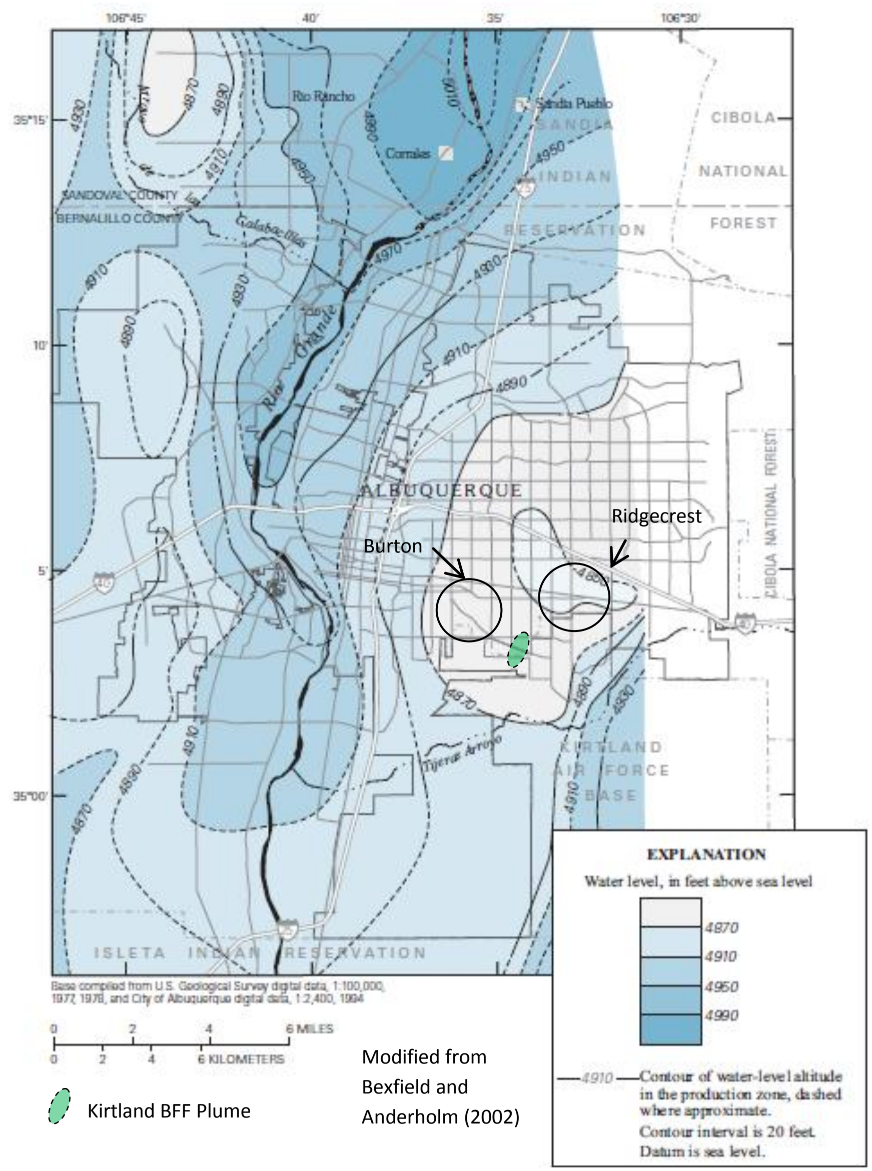
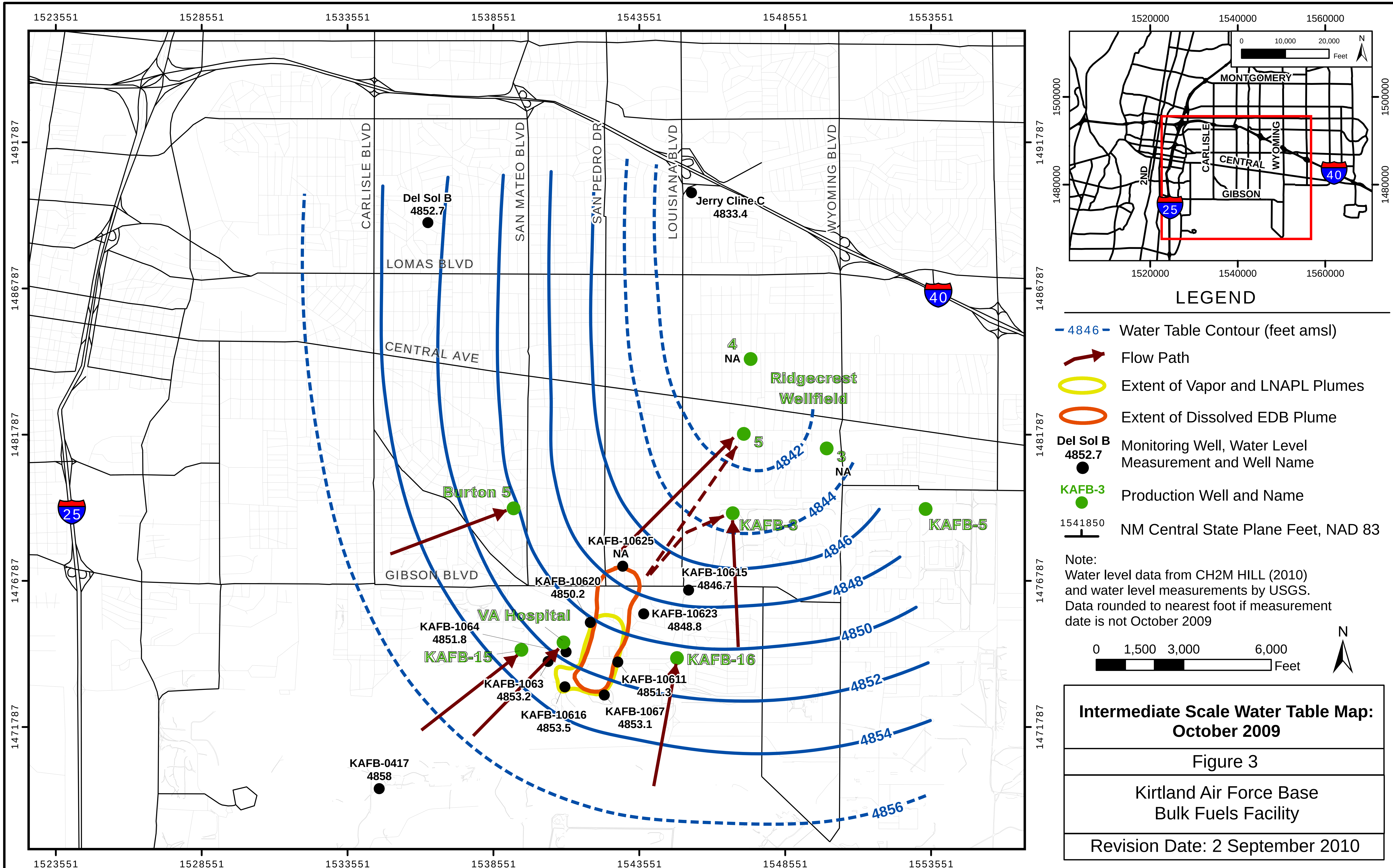


Figure 2. Relation of Kirtland BFF Plume to Regional Water Table



Intermediate Scale Water Table Map: October 2009

Figure 3

Kirtland Air Force Base
Bulk Fuels Facility

Revision Date: 2 September 2010

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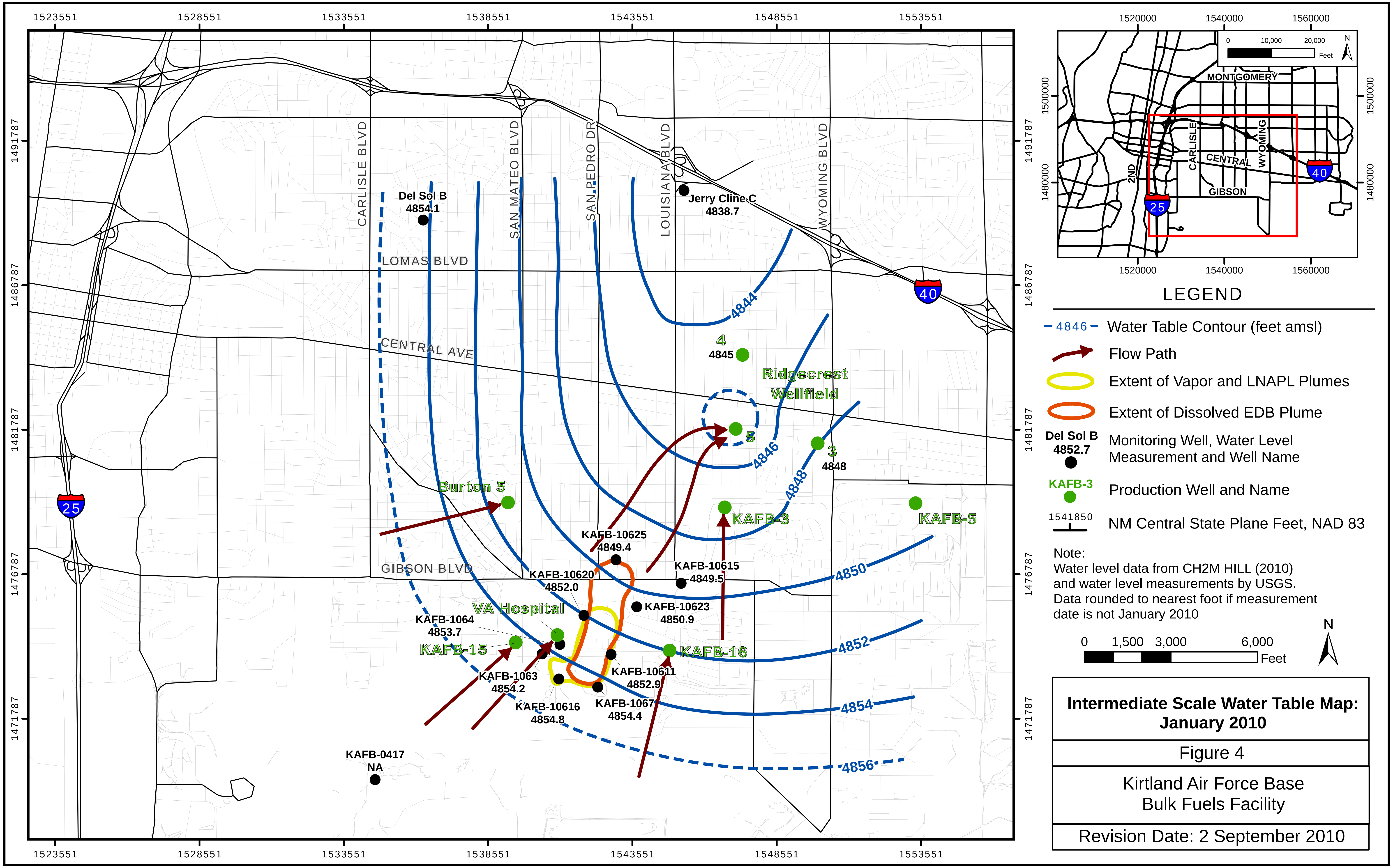

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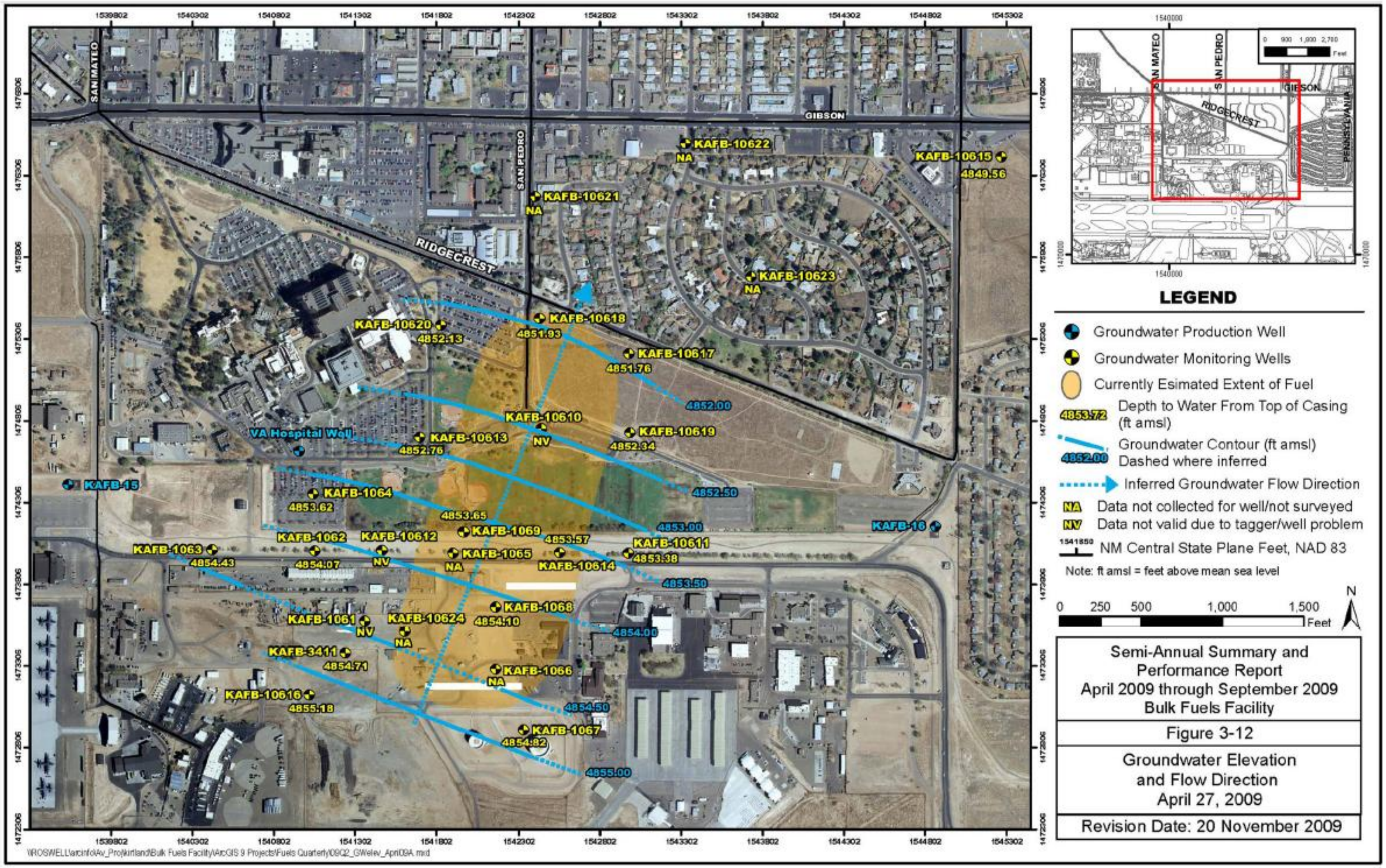

Figure 5. Potentiometric Surface at the Kirtland BFF Site, April 2009 (from CH2M-Hill, 2009)

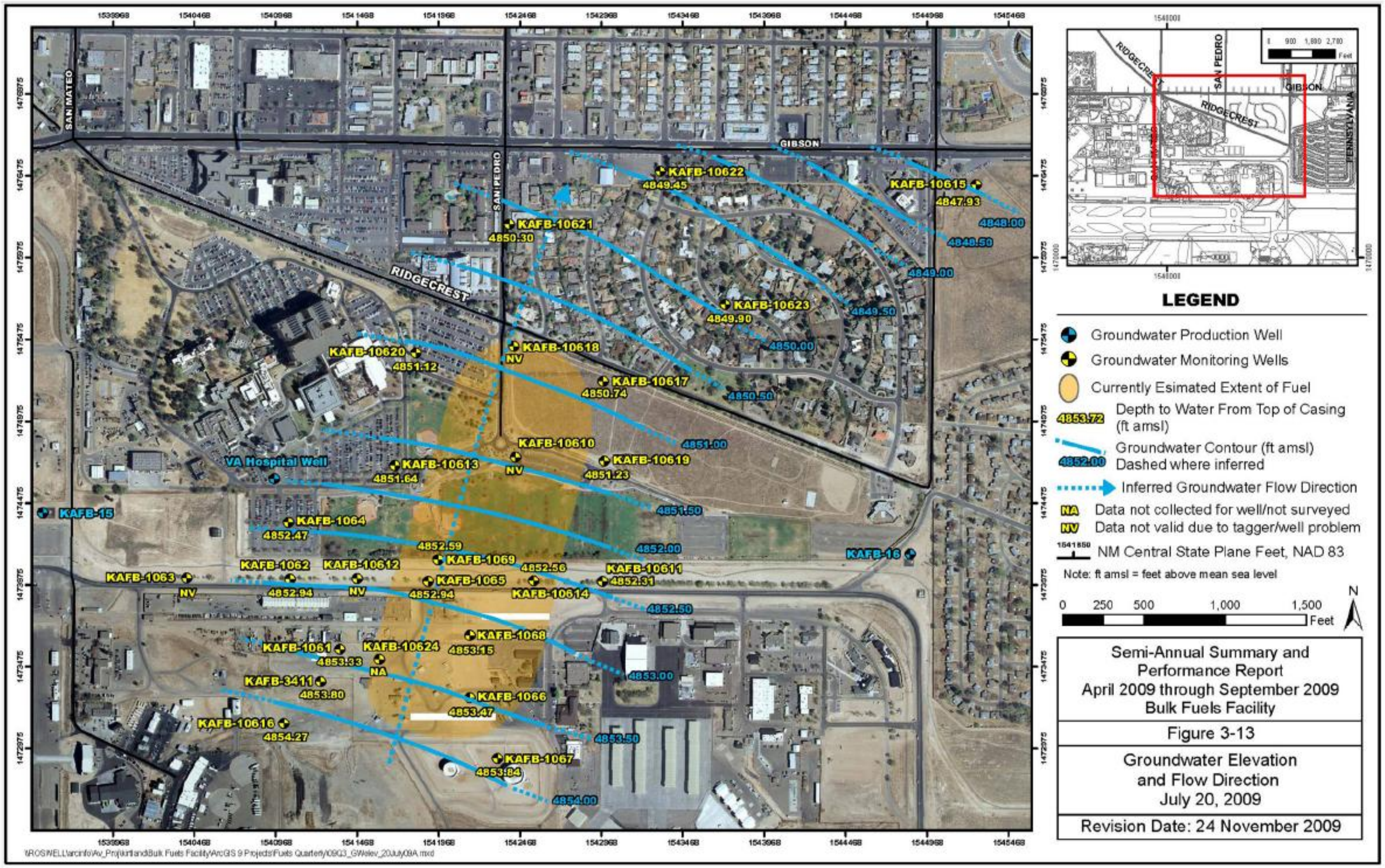

Figure 6. Potentiometric Surface at the Kirtland BFF Site, July 2009 (from CH2M-Hill, 2009)

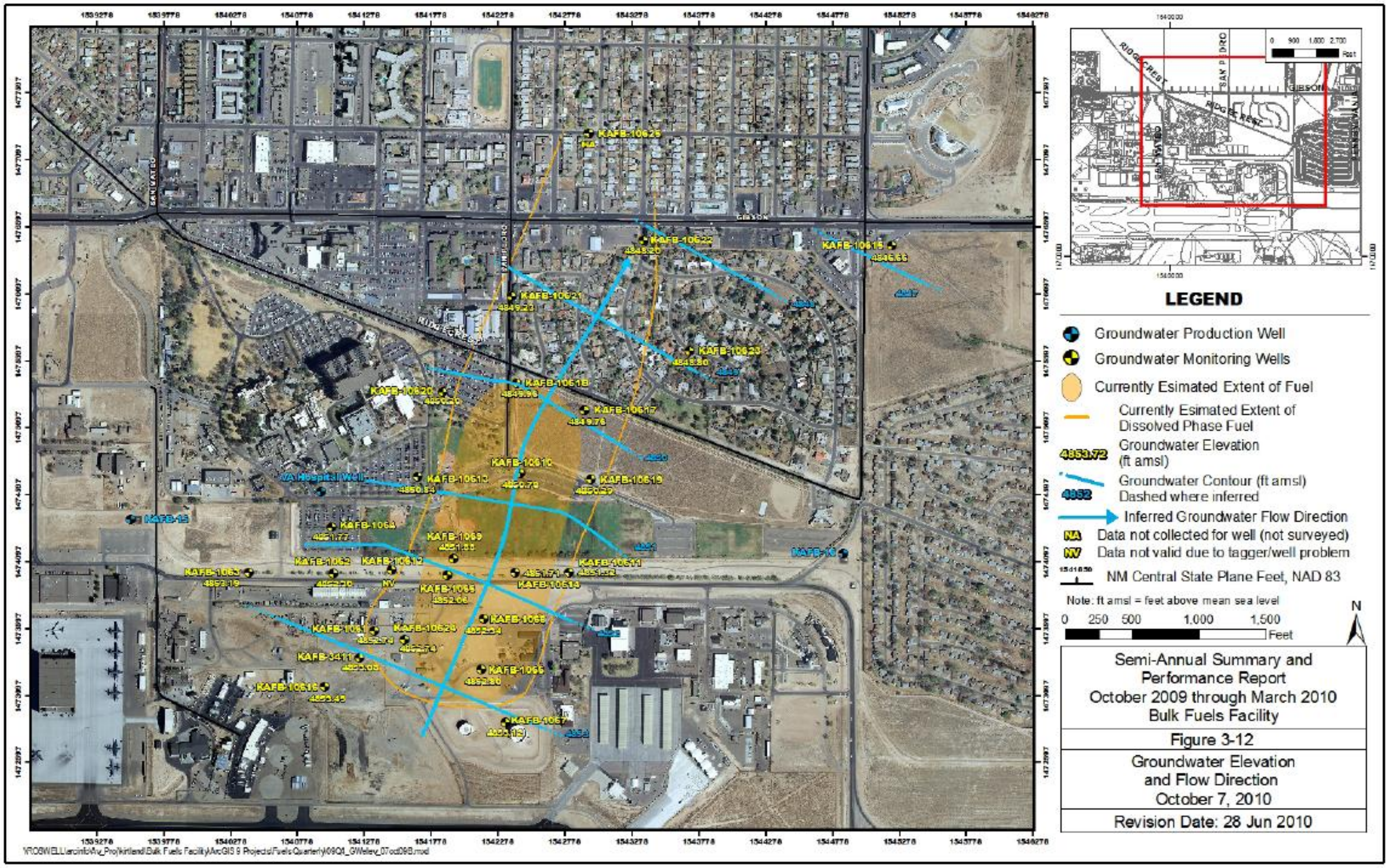

Figure 7. Potentiometric Surface at the Kirtland BFF Site, October 2009 (from CH2M-Hill, 2010)

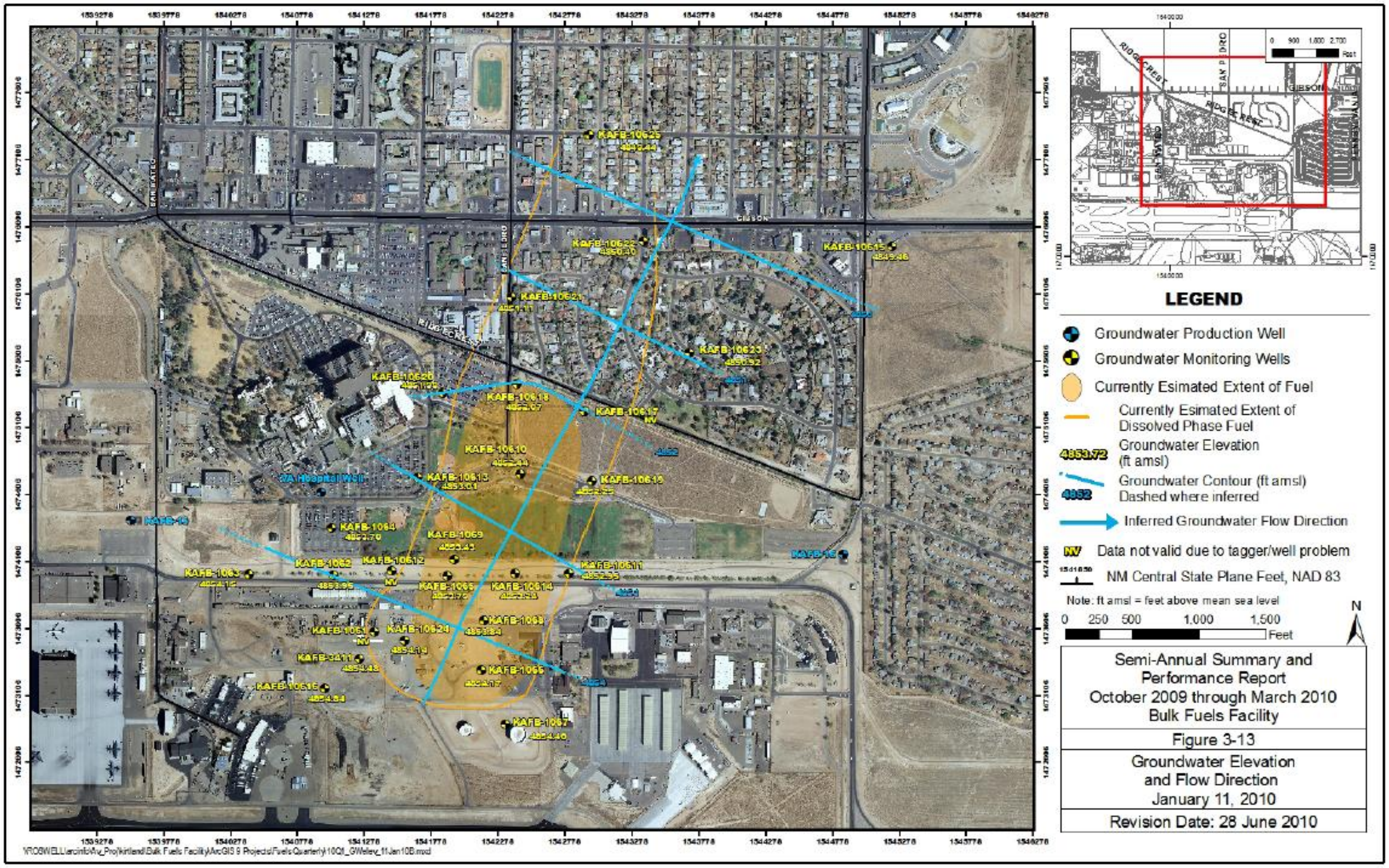

Figure 8. Potentiometric Surface at Kirtland BFF Site, January 2010 (from CH2M-Hill, 2010)

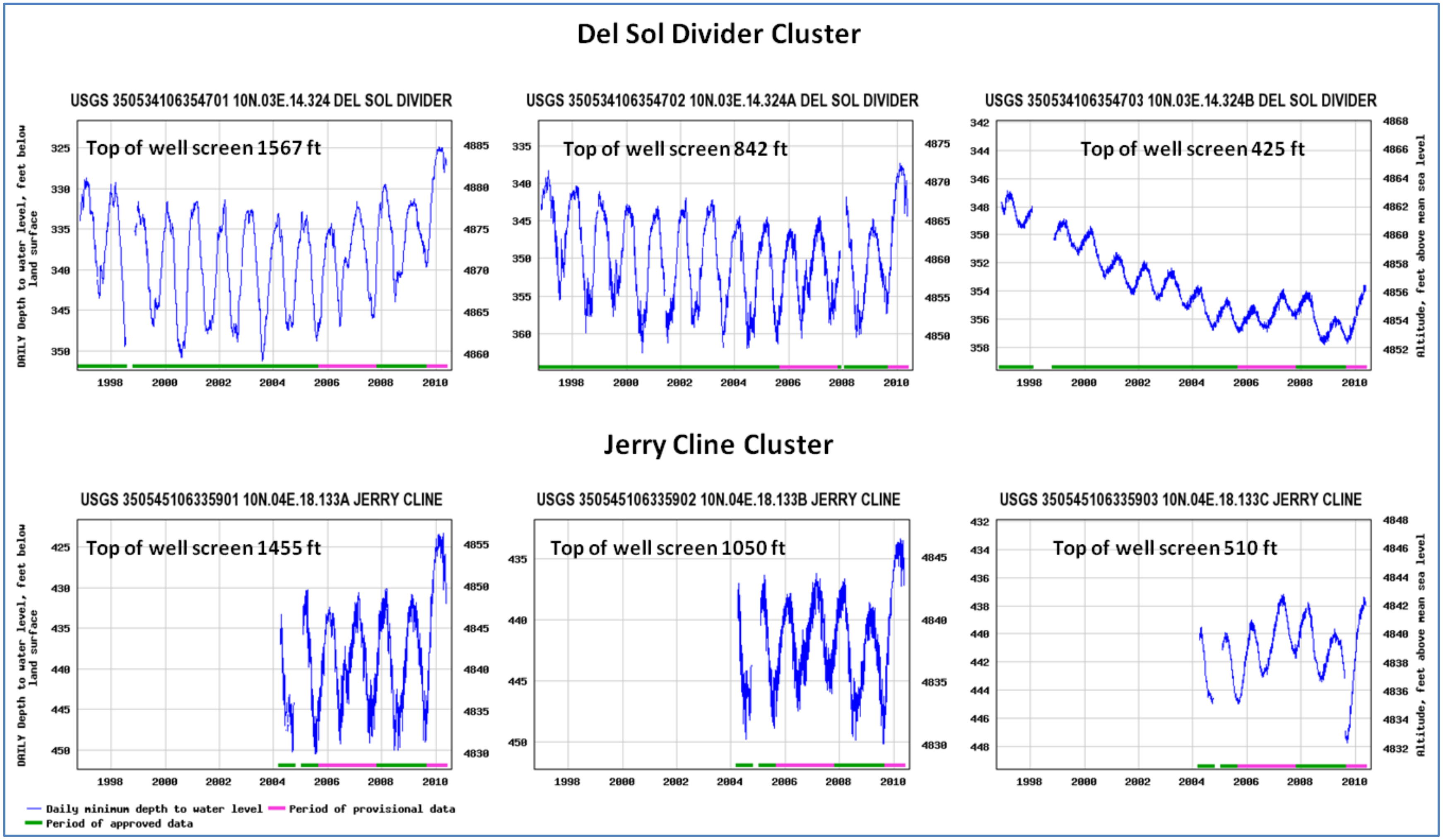

Figure 9. Water-Level Hydrographs at USGS Well Clusters near the Kirtland BFF Site