HYDROGEOLOGY AND ENVIRONMENTAL GEOLOGY OF THE KEENE AREA, NEW HAMPSHIRE

by
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INTRODUCTION

On this field trip, we will tour a number of sites on and adjacent to the Keene State College campus to provide an introduction to the hydrogeology of the Keene area, and to discuss issues of soil and sediment contamination. We will then hit the road to visit three other sites in Keene and Swanzey where Keene State College students have done hydrogeologic studies, after which we will visit the town of Marlborough to visit the site of a new town water supply well currently undergoing the Large Groundwater Withdrawal permitting process.

ROAD LOG

The field trip will assemble at the Keene State College Visitor's Parking Lot on Wyman Way off of Main Street, Keene. We will leave the cars here for the first part of the morning and proceed on foot.

STOP 1. ELLIOT HALL (15 minutes).

Lead contamination of Child Development Center playground soils from paint coming off the building led to my students and I to do an assessment of lead contamination in the soils around buildings across

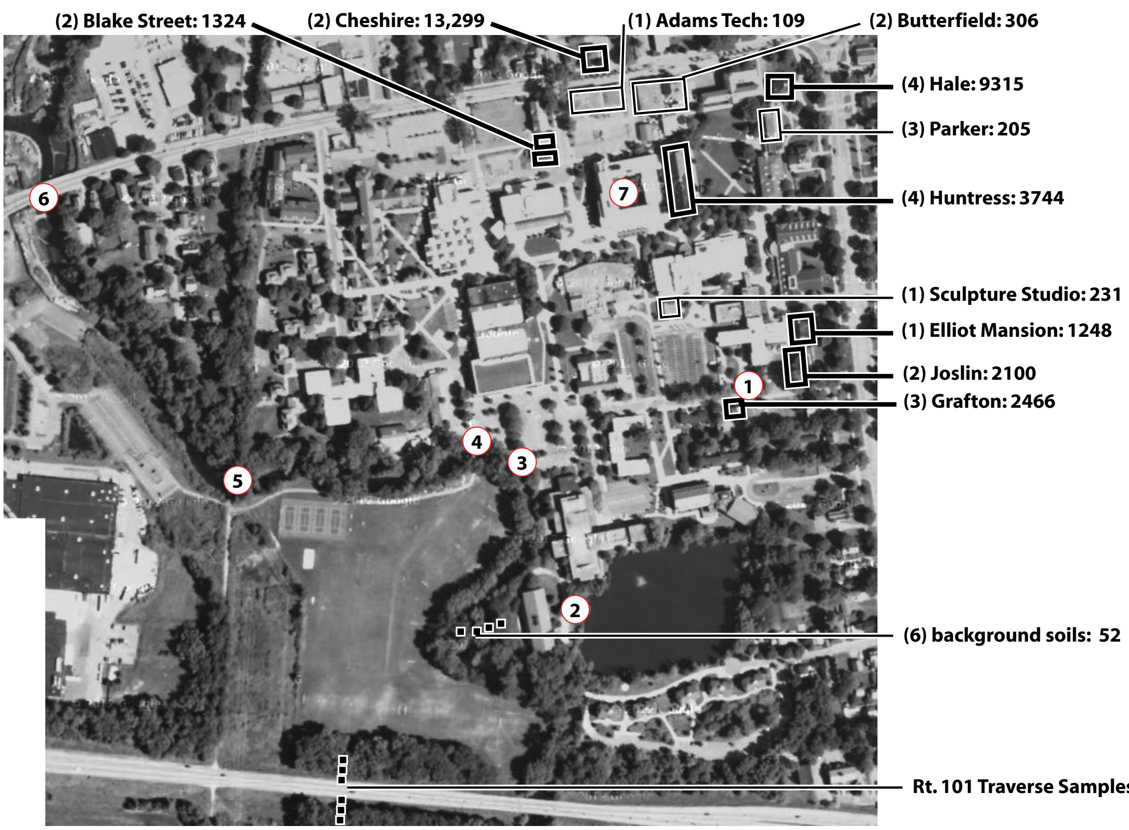
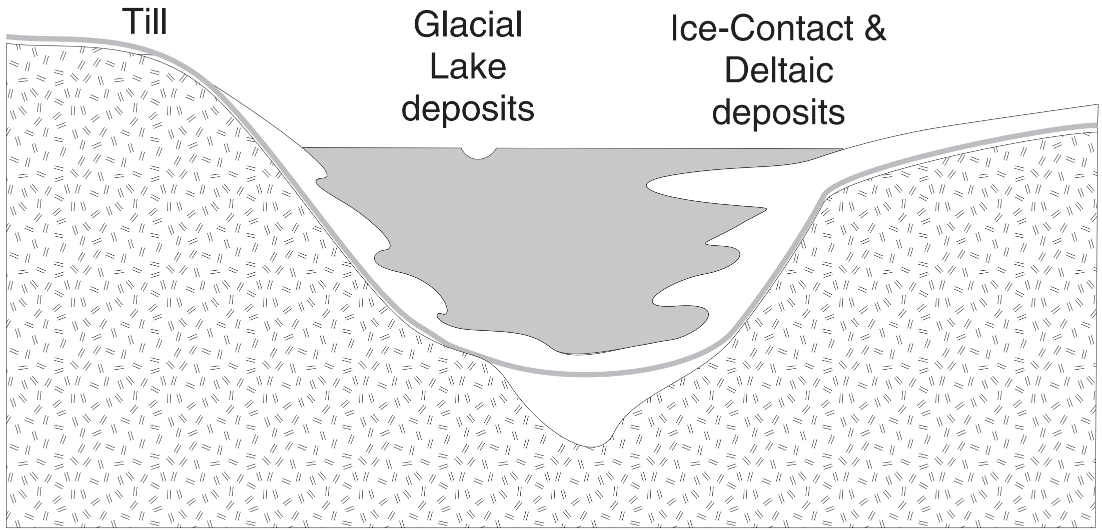


Figure 1: Building "dripline" average soil lead concentrations, mg/kg (Allen, 2008). Many of the values are well in excess of 1200 mg/kg, the EPA recommended action level for bare soil exposed in non-play areas in the yards of homes with children (400 mg/kg in play areas). Numbers in parantheses are the number of samples included in the reported average. The numbers in white circles are stop locations for our on-campus walking tour.

campus (Allen, 2008).We collected samples of paint chips and soils from around the perimeter of selected buildings built prior to the banning of lead paint. Paint chips were qualitatively scanned for the presence of lead using X-ray fluorescence spectrometry (XRF). Soil samples were dried, pulverized and pressed into powder pellets, which were then quantitatively analyzed for total lead concentration by XRF. All of the paint chip samples scanned had lead present. Soil lead concentrations range from 109 mg/kg to 22,486 mg/kg. Most of the buildings we sampled have soil lead levels well above the US-EPA's recommended action levels of 400 mg/kg for bare soil in the play areas of yards of homes with children, and 1200 mg/kg for non-play areas.

STOP 2. BRICKYARD POND (5 minutes)

There are some stories to be told here about ghost horses, gyttja, and the like. This provides an opportunity to take a sneak peak at the hydrogeology of the Keene basin, as represented in the schematic cross section below.



STOP 3. STORM DRAIN OUTFALL, ASHUELOT RIVER (10 minutes)

We've done a lot of research on the metals composition of sediments in the Ashuelot river (Allen et al, 2003; Allen & Burns, 2006; Allen, 2008; Dickinson, 2010), with a primary interest in Lead (which we'll talk about more at the next stop). What we want to look at here are metals composition data from our river sediment samples suggesting these storm drains may be a source of metals to the river (Figure 3).

Throughout, we compare our sediment metals concentrations with thresh-hold levels determined from toxicological studies, as compiled in the NOAA Sediment Quality Screening Quick Reference Tables (Buchman, 1999; Buchman, 2008). For sediments with concentrations below the TEL or Threshold Effect Level, there are not likely to be any adverse impacts observed on the benthic community. Above the PEL or Probable Effects Level, adverse impacts are likely to be observed, and above the UET or Upper Effects Threshold, adverse impacts will almost always be observed.

STOP 4. ATHLETIC FIELD BRIDGE (15 minutes)

An early reconnaissance of metals content in sediments of the Ashuelot River (Allen, et al, 2003) suggested extremely high levels of Lead (Pb) in the reaches of the river where it passes through the Keene State College campus. Further investigations (Allen & Burns, 2006; Allen, 2008; Dickinson, 2010) have revealed that the high-Pb content is relatively restricted to areas underneath bridges that have peeling Pb-based paint (Figures 4). A subsequent survey of bridges over the entire length of the Ashuelot suggests that Pb-based paint is not uncommon on roadway and railway bridges, and that similar contamination of river sediment may exist under other bridges as well.

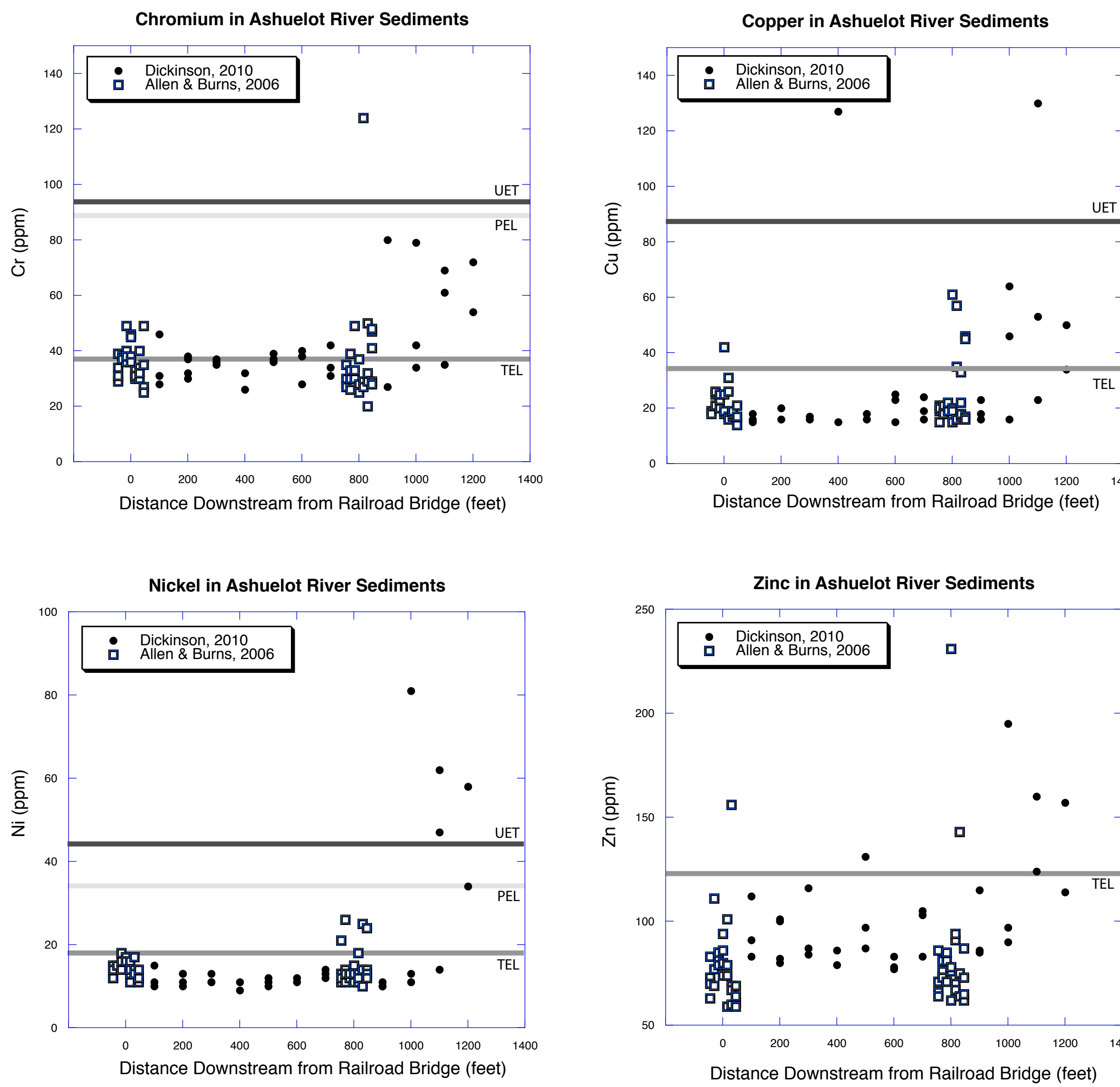


Figure 3: Metals (Cr, Cu, Ni, Zn) composition (in ppm or mg/kg) of river sediment in the Ashuelot river on the Keene State College campus, from Dickinson, 2010, and Allen & Burns, 2006.

As we walk on to Stop 6, another group of students (Morrison, 2010) did a survey of soil metals composition adjacent to NH Route 101 on the south side of the athletic fields here, sampling in transects perpendicular to the roadway on both sides (see Figure 1). Their results showed elevated metals contents adjacent to the roadway, declining with distant away from the road, until you got into wetlands on the north side, where the metals seem to be concentrated again (Figure 5).

STOP 5. RAILROAD BRIDGE (10 minutes)

You can't see much paint on this bridge now—it's all peeled off and fallen into the river! We were able to sample some of the little bit of paint remaining however, and it is loaded with Pb, as now so is the soil and sediment underneath. One of my students used dirt taken from under this bridge to do an experiment investigating the viability of phytoremediation to remove the lead (Ritter, 2004).

On our walk to the next stop, we will pass by a monitoring well. A leaky underground storage tank at a gas station to the west contaminated the area. That gas station no longer exists.

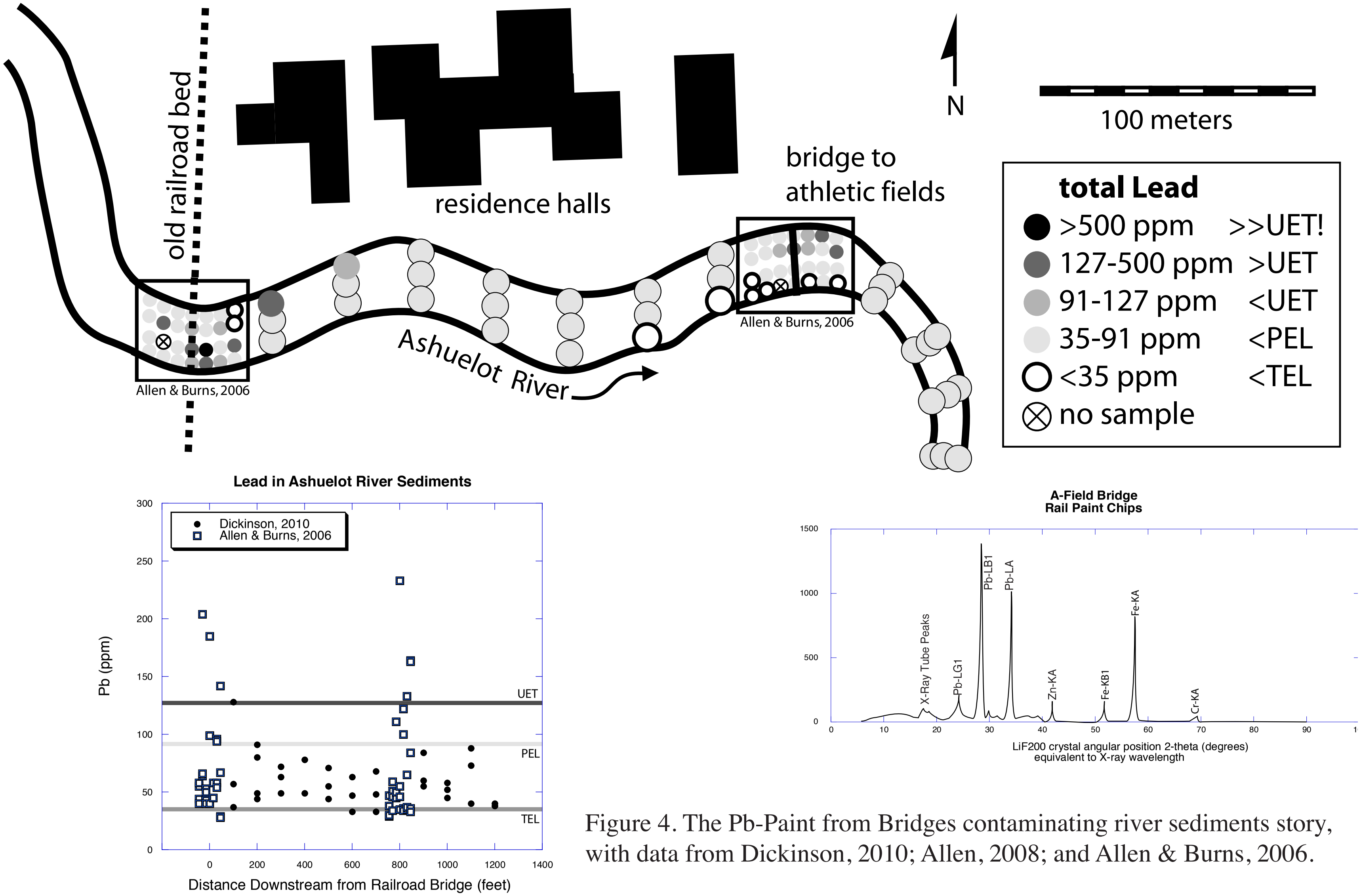


Figure 4. The Pb-Paint from Bridges contaminating river sediments story, with data from Dickinson, 2010; Allen, 2008; and Allen & Burns, 2006.

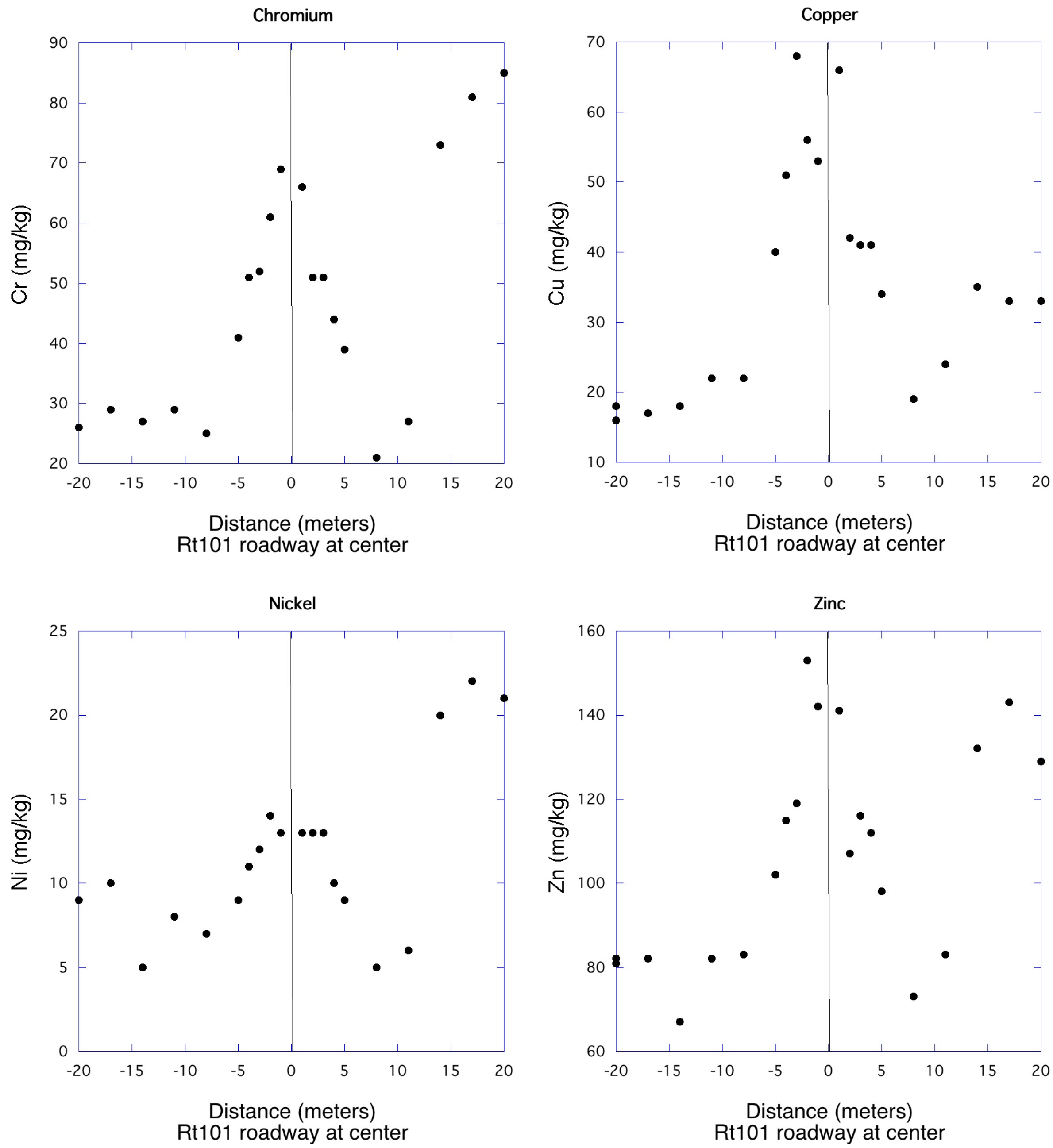


Figure 5. Soil metals contents along a traverse perpendicular to NH Route 101 (Morrison, 2010). There is a wetland area at approximatley +20 meters, where metals appear to be concentrated.

STOP 6. WINCHESTER STREET BRIDGE (10 minutes)

A coal gasification plant at the end of Emerald Street to our north contaminated Mill Brook and the Ashuelot River with residues loaded in PAHs. A significant remediation project was carried out over the last several years to clean up the mess. The paint on this bridge is also rich in Pb, but our limited sampling here, prior to the remediation effort, did not detect Pb contamination in the sediments (of course, there is Pb, just not at levels in excess of expected background values).

STOP 7: DAVID F. PUTNAM SCIENCE CENTER (15 minutes)

When the Science Center was renovated in 2004-2005, part of the plan was to turn what would become an enclosed courtyard into an outdoor learning space. Native plants were chosen and planted different New England habitats, giant boulders were imported, a stone wall built, and the walkway laid out to provide props from learning about geology, and two ground water monitoring wells were installed. We'll pop these wells open, measure their levels, and discuss what can be learned from them.

After this, we will return to the vehicles at that start of the trip, and head out to some additional stops in Keene, North Swanzey, and Marlborough (Figure 6). The mileage log begins at the KSC Visitor Parking lot on Wyman Way.

0.0	Leave the parking lot and return to Main Street
0.0+	turn right onto Main Street, heading southerly
0.3	turn right onto NH Rt. 101, heading westerly
1.0	enter the Winchester Street round-about and exit at 270° heading southerly on NH Rt. 10
1.4	turn left (easterly) onto KRIF Road, following the large sign for the KSC Athletics facility.
1.9	cross over the rail trail and pass through gate in the chain link fence and park under the powerlines. From here we will walk to south on a mowed trail under those powerlines.

STOP 8: COLLEGE FIELDS WELLS (20 minutes)

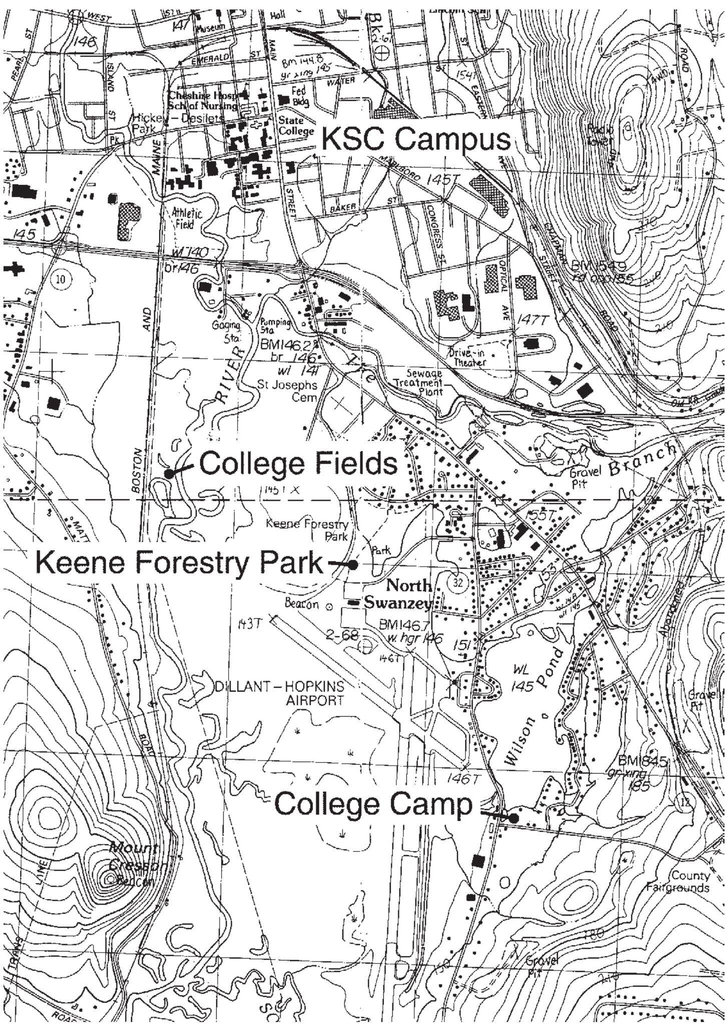


Figure 6: Map of the Keene-Swanzey area showing field trip stops.

A group of 3" test wells, labeled Test Wells 6, 8, & 9, were installed off KRIF Road as part of a water resource exploration project commissioned by the City of Keene and conducted by Camp Dresser & McKee in 1979 (Cheyer, 1981). In addition, an 8" test well was installed adjacent to Test Well no. 6. Of these, only Test Well no. 6 and the 8" test well remain. The 8" well had been abandoned and plugged with grout, but has subsequently been re-opened for use in supplying irrigation water for the Keene State College athletic fields. Test Well no. 6 remained open. It was installed to a depth of 161 feet, with a 7-foot screened interval set between 139 and 147 feet below land surface; it is cased with 3" galvanized steel or iron pipe.

These wells were re-visited in 1986 by another water resource exploration project commissioned by the City of Keene and conducted by BCI Geonetics (Emery & Tinkham, 1988).

Between these two studies, it was determined that a significant aquifer—capable of supply several million gallons of water per day—exists underneath the glacial lake bed sediments filling the Keene basin, and extending to the south and east under the Keene Airport. This is a confined aquifer that often exhibits artesian conditions at this location (meaning that the hydraulic head in the aquifer is greater than the elevation of the land surface).

Water quality analyses determined by CDM in 1979 indicated generally good water, except for manganese levels exceeding secondary drinking water standards (Cheyer, 1981, p. A–7).. BCI Geonetics (Emery & Tinkham,1988) also observed Mn concentrations in several other Keene wells that were above the secondary standards. The 8" well was sampled by BCI Geonetics for a volatile organic compound (VOC) analysis in December 1986 after having been left "free-flowing" for a month; no VOC contamination was detected (Emery & Tinkham, 1988, p. 4).

Despite the potential for a water supply to be developed in this aquifer, it was not pursued because of concerns that pumping from the aquifer could induce recharge from several nearby sites known to be contaminated, including two old city landfills (we'll drive by one of these at the end of the trip).

Keene State students have used this site for a variety of studies over the years, installing some additional instrumentation including several shallow water table wells. One interesting problem we investigated is that water sampled from the top of the 3" observation well had a very strong odor somewhat reminiscent of diesel fuel and contained a lot of black particulate matter, giving the water a distinct greyish color; the inside of the well casing was coated with a black slimy substance. A portable Photo Ionization Detector (PID) was used to check for organic vapors, and a water sample was sent to the State labs for VOC analysis, with both tests returning non-detect results. The pH of the water was high (~10) and the Oxidation Reduction Potential was low (approx. -200 millivolts). We hypothesized that perhaps the black gunk was a Manganese oxide precipitate—analysis of soils from around Keene all showed elevated Mn concentrations—however an XRF analysis of the black gunk itself revealed it to be an Iron oxide or hydroxide. The Eh-pH diagram for Iron oxides and hydroxides are consistent with the observed conditions, and shows that

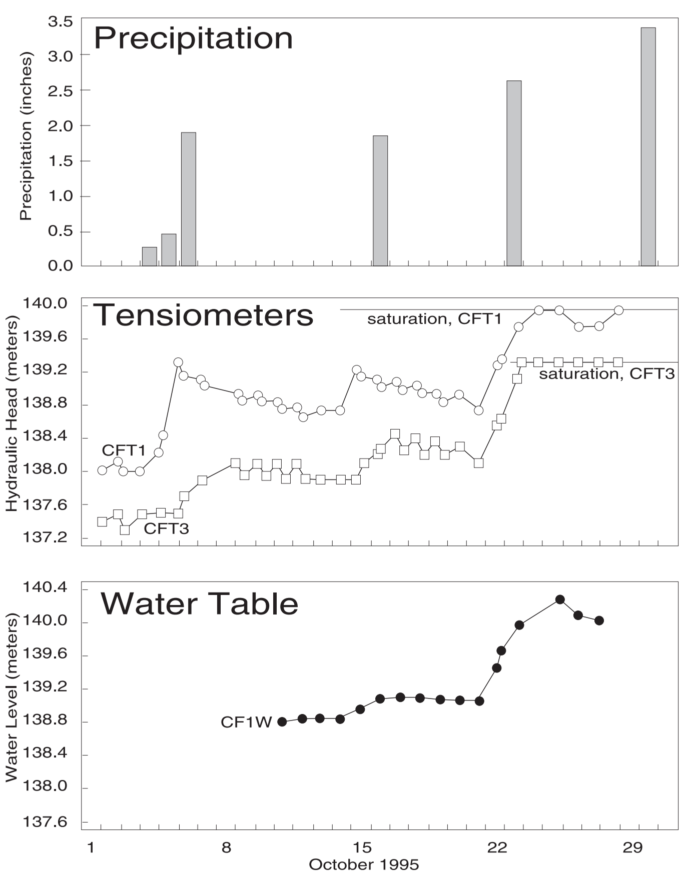


Figure 7: Hydrographs from a water table well and soil moisture tensiometers at the College Fields site, show response soil moisture and the water table to precipitation events.

the standing water in a closed well (isolated from the atmosphere) will seek an equilibrium with the well casing material (in this case, iron pipe).

Another interesting study looked at hydraulic heads in the unsaturated zone for a period in the month of October (Figure 7; Ravella et al,.1995)

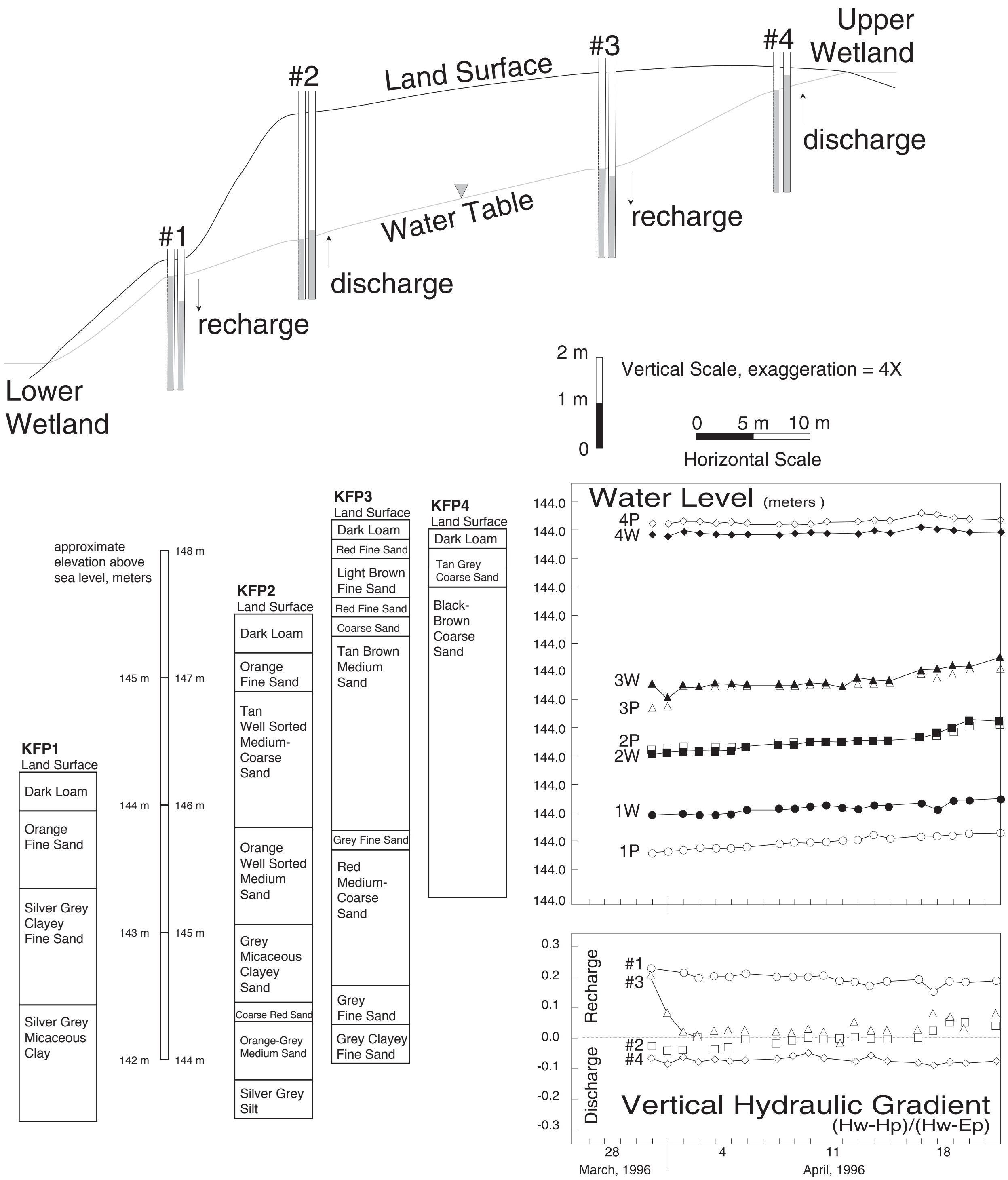


Figure 8: hydrologic cross section showing vertical gradients, boring logs, and hydrographs including vertical gradients, from the Keene Forestry Park site (Ravella et al, 1995)

1.9 turn the vehicles around, and return along KRIF road to Winchester Street (NH Rt. 10).
2.4 turn right (northerly) onto Winchester Street (NH Rt. 10)
2.7 bear right (easterly) onto NH Rt. 101 at the Winchester Street roundabout (i.e. exiting at 90°).
3.5 turn right (southerly) onto Lower Main Street (NH Rt. 12)
4.4 bear right (southerly) onto NH Rt. 32 (Old Homestead Highway)
4.5+ turn right (westerly) onto Airport Road at the sign for the Keene Airport. As we drive in, note the coarse sandy soil evident along side both sides of the road.
5.0 park at the far end of the parking lot for the Keene Airport, just before signs and a gate for the Keene Sewage Treatment Facility. We will walk along a gated road into the woods across the road from the Airport (there used to be a sign here identifying this place as the Keene Forestry Park).

STOP 9. KEENE FORESTRY PARK (EDGEWOOD) (15 minutes)

This was selected for study following a review of the Cheshire County Soil Survey, looking for areas with soils of high permeability that might be ground water recharge zones. The site features two wetlands, one of which is a large abandoned oxbow of the Ashuelot river, the other perched among a surroundings of coarse sandy soil. We installed a series of nested well/piezometer pairs between the two wetlands, and the data we collected suggests that the upper wetland is spring-fed from the deep confined (artesian) aquifer, draining over a clay layer to the lower wetland (Figure 8; O'Rourke et al, 1998; Ravella et al, 1995).

5.0 return back on Airport Road to NH Rt. 32
5.4+ turn right (southerly) onto NH Rt. 32, continue past Wilson Pond on the left (one of at least two Wilson Ponds in this area).
6.4 turn left (east southeasterly) onto Stafford Drive (sort of an industrial park)
6.7 turn left (west northwesterly) onto Page Court at the stop sign
6.8 turn right into the parking lot for the Keene State College Camp on Wilson Pond and park.

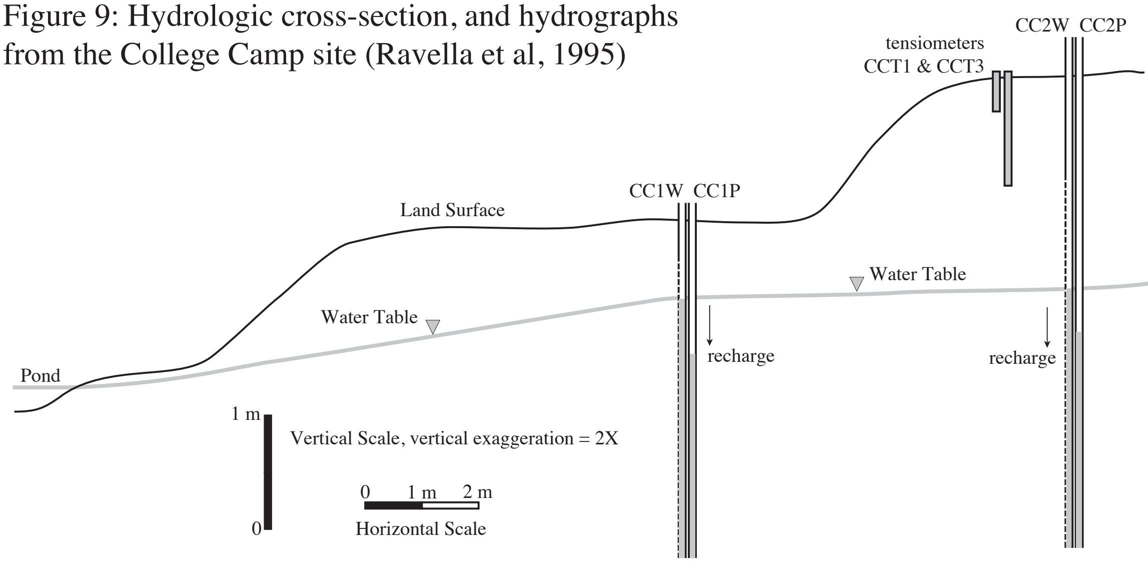
STOP 10. COLLEGE CAMP ON WILSON POND (45 minutes starting with lunch)

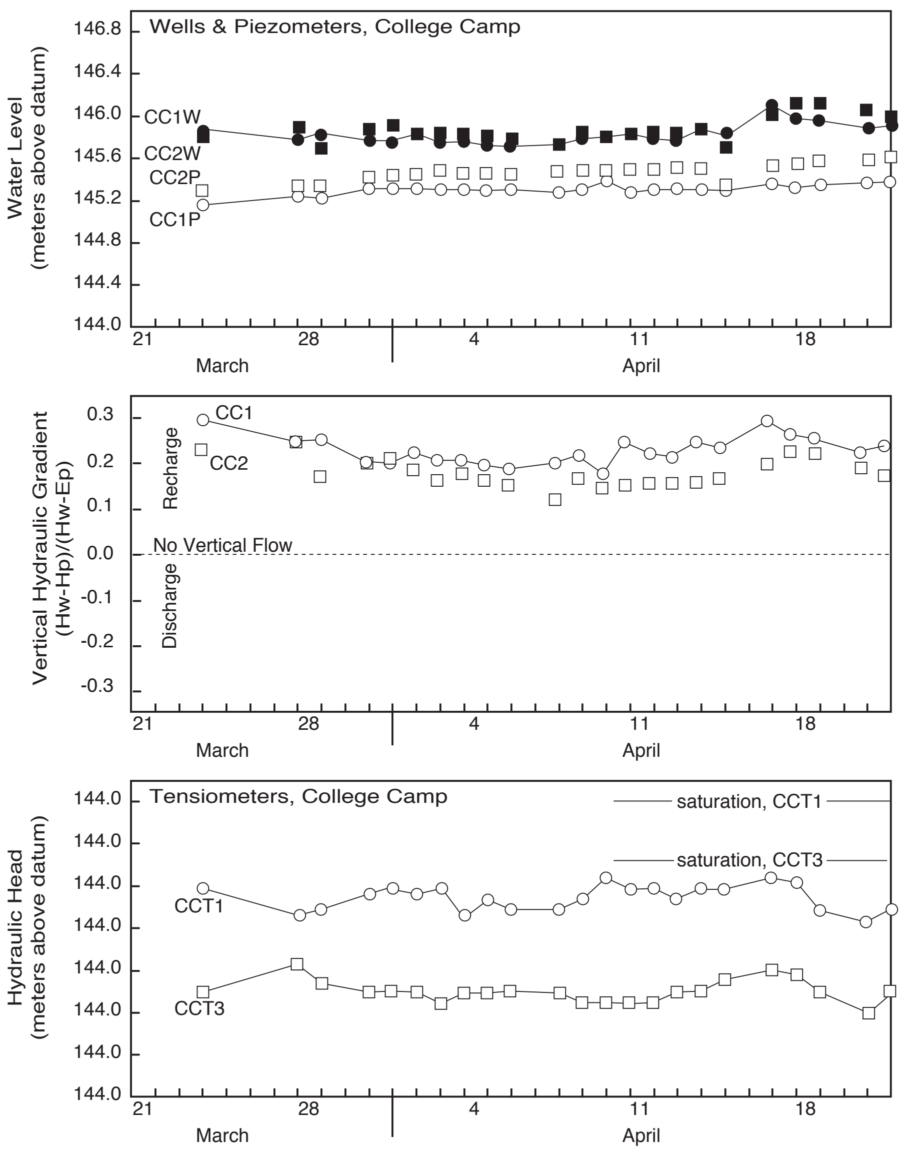
This was another site mapped as having high-permeability soils that might represent and area of recharge, and is also College property, so was a natural place to install some additional nested well/piezometer pairs, coupled with soil-moisture tensiometers. Nothing remarkable in the data collected here (Figure 9; O'Rourke et al, 1998; Ravella et al, 1995)—clearly it was indeed a recharge area, certainly at this time of year—but it did lead us to try measuring seepage through the bottom of Wilson Pond using home-made seepage meters made from sawed-off 5-gallon buckets, plastic bags, and rubber stoppers—the results were unfortunately inconclusive.

Thus concludes the Keene State College portion of the field trip. The work presented here involved student–faculty research projects done as independent studies or within the context of a class over the past 20 years or so. Now we are off to Marlborough to see a large groundwater withdrawal permitting project!

6.8 return to Page Court and out.
6.9 turn right onto Safford Drive
7.2 turn right (northerly) onto NH Rt. 32 (Old Homestead Highway)
7.9 bear right onto Lake Street, following signs to get to NH Rt. 12 South.
8.2 stop sign at NH Rt. 12 — when it is safe to do so, continue straight across onto Swanzey Factory Road, following signs to get to NH Rt. 101 East
9.0 turn right onto NH Rt. 101 (easterly)
11.1 turn left onto Water Street, shortly after a Sunoco gas station on the left and just before some fluorescent yellow/green signs marking a pedestrian crossing (school crossing)
11.2 turn left onto Fitch Court towards the Marlboro School
11.3 the small cinder block building you are passing on your right, between the ballfield and the road, is the Town of Marlborough's current public water supply well.
11.4+ make your way through the school parking lot and park at the far end, near the gates.

Figure 9: Hydrologic cross-section, and hydrographs from the College Camp site (Ravella et al, 1995)





STOP 11: TOWN OF MARLBOROUGH WATER SUPPLY WELL PROJECT (120 minutes)

The town of Marlborough's current water supply well does not have an adequate well-head protection area, so the town undertook an exploration project to identify a new well site. The newly constructed well field is currently undergoing New Hampshire's Large Groundwater Withdrawal permitting process, so we will take a look at some of the issues involved in that as well as some of the data collection that is required. This work has been done by Jim Vernon—unfortunately he is unable to join us today, but Richard Pendleton, who has worked on other sites in town (e.g. that Sunoco gas station we passed on our drive in) will be with us.

11.4+	return back on Fitch Court to Water Street
11.6	turn right onto Water Street
11.7	turn right onto Main Street (NH Rt. 101)
14.6	traffic lights for Optical Avenue, continue westerly on NH Rt. 101
14.8	for about a 1/4 mile stretch here there are several monitoring wells visible to the left. The area behind them is used as a depot by the City of Keene Public Works Department, and is in turn underlain by an old municipal landfill in which hazardous materials were once disposed, back in the day.
15.3	bear left onto Main Street (northerly), get into the left lane
15.6	turn left onto Wyman Way (westerly), returning to the KSC Visitor Parking lot to retrieve vehicles left here by carpoolers. This is the end of the trip. We hope you enjoyed this year's New England Intercollegiate Geological Conference!

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Eastview Environmental
Consulting & Field Services

Marlborough Sunoco Gas Station, Main St, Marlborough

Summary of Groundwater Impact from Former Underground Storage Tanks

Location & Groundwater Sampling
The Sunoco Station is located on the opposite side of the Minnewawa Brook, about 1,000 feet southeast of the Town of Marlborough's new well site (Well Site #3 & #4) and 430 feet south of the Town's existing well site (#2).

Four petroleum underground storage tanks were removed and replaced in 1996. Typical gasoline contaminants and the gasoline additive MtBE were detected in soil and groundwater. Soil standards were exceeded for benzene, MTBE, naphthalene, and alkylbenzenes. Seven hundred and sixty tons of soils were removed from the site.

In the same year, MTBE concentrations peaked at 7 ppb in the town's Well #2; presently MtBE is non-detectable.

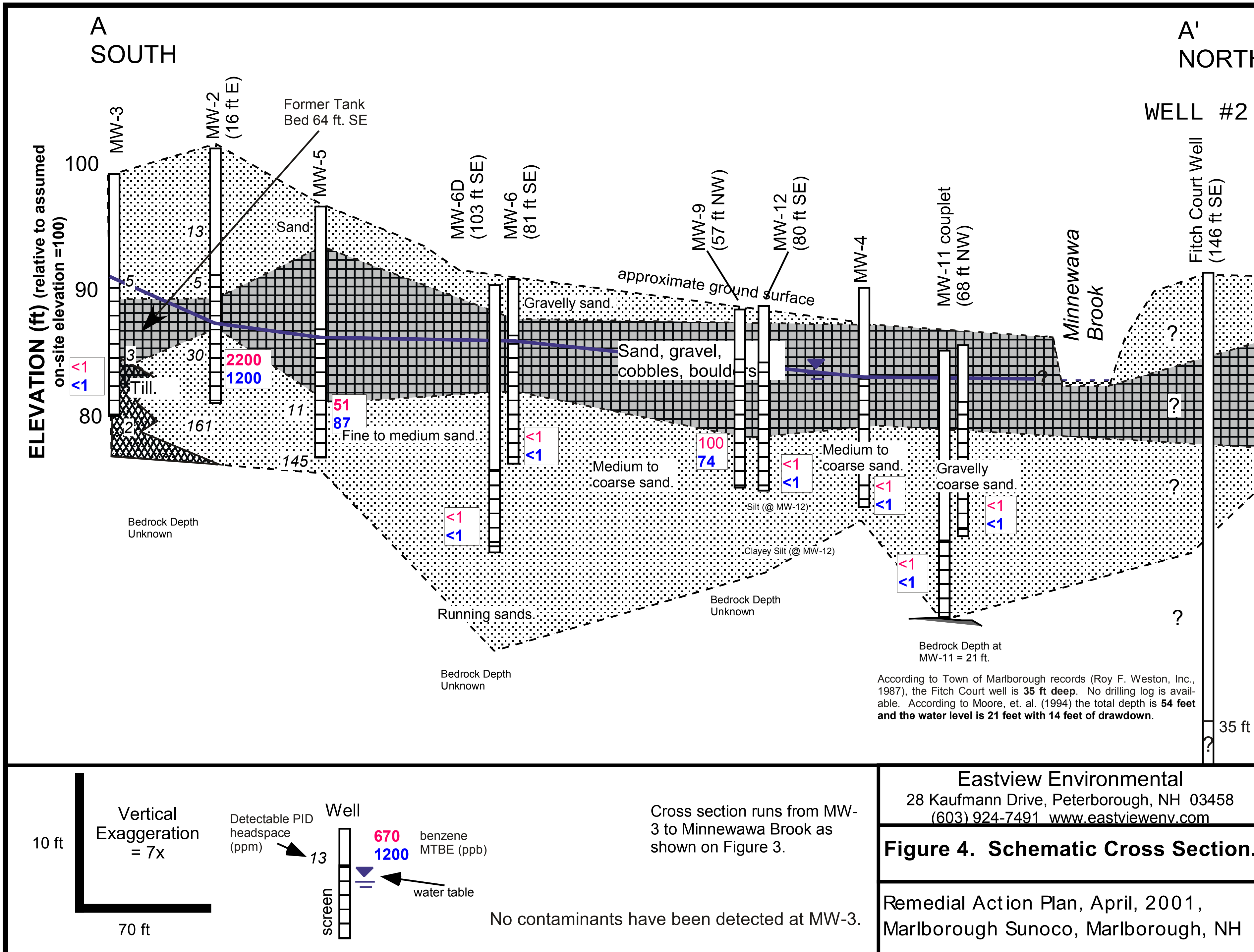
Over the following few years, 14 monitoring wells were installed on the Site and on properties to the north and northwest. Maximum MtBE concentrations in groundwater were 5,000 parts per billion (ppb) on site and 1,200 ppb off site (1998). The MtBE plume extended as far as monitoring wells near Minnewawa Brook, about 600 feet from Well Site #3 & #4. However the levels (2 ppb) were below the state's groundwater quality standard of 13 ppb.

Geology
The Site is underlain by a five to ten foot sand and gravel unit that is underlain by six feet of bouldery, cobbly sand and gravel, grading to compact till 15 feet below the ground. Downgradient (to the north), the boulder unit is first encountered three to six feet below the ground and is four to eight feet thick (see attached cross section). A well-sorted fine to coarse sand begins around twelve feet; it is underlain in places by silt (0.5 to 8 or more feet thick). The confining layer (bedrock or till) is more than 27 feet below the ground surface near the river.

Groundwater Treatment
Eastview directed the injection of powdered magnesium peroxide at the Site in 2002 and 2003. MgO_2, when in contact with water, releases oxygen and is intended to facilitate aerobic microbial biodegradation.

As of 2012, MtBE levels have dropped below detectable levels. Benzene and naphthalene are at levels less than 100 ppb and the plume has retreated to on site only. Monitoring continues on a twice yearly basis.

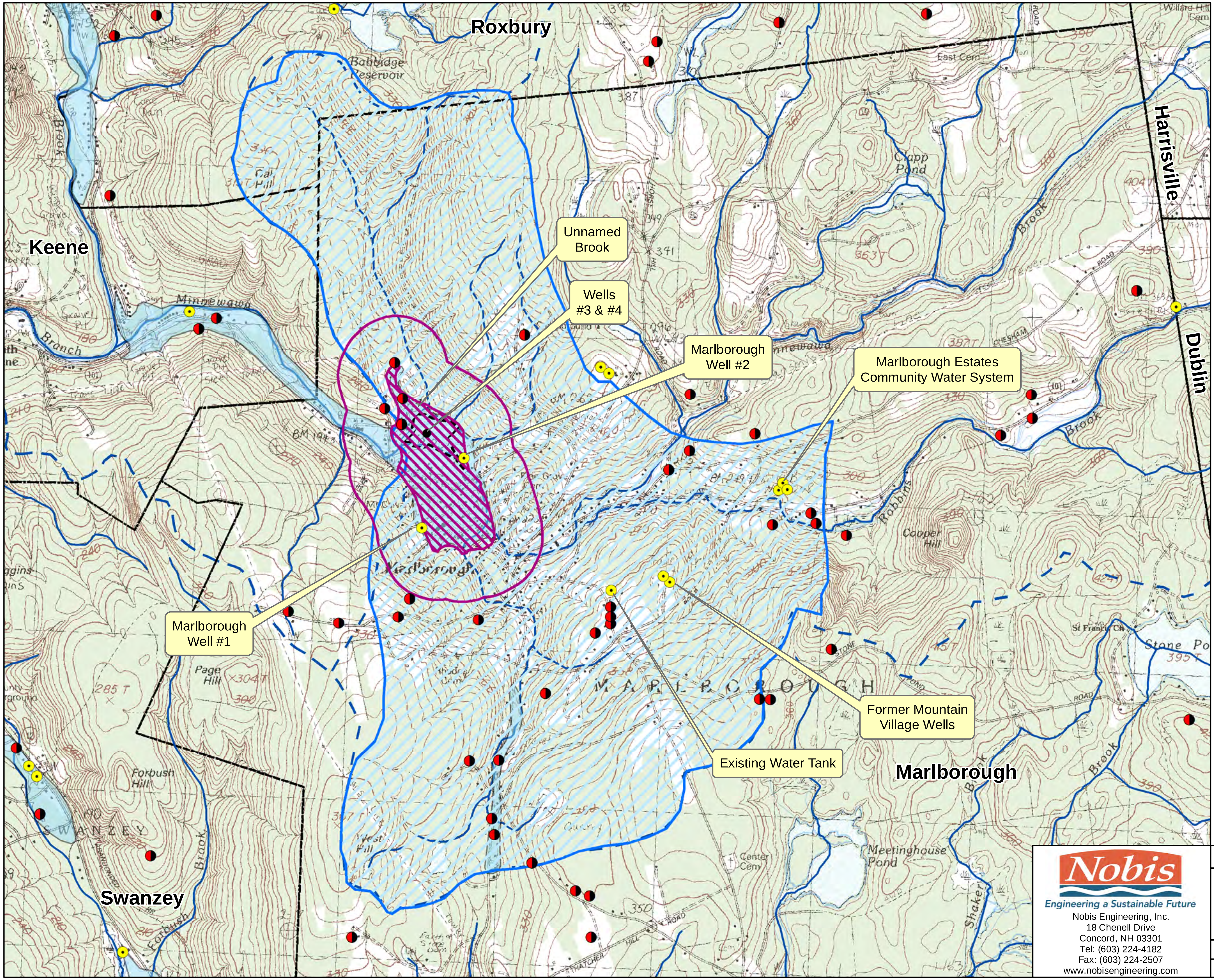
Richard Pendleton, PG
October 2012



Eastview Environmental
28 Kaufmann Drive, Peterborough, NH 03458
(603) 924-7491 www.eastviewenv.com

Figure 4. Schematic Cross Section.

Remedial Action Plan, April, 2001,
Marlborough Sunoco, Marlborough, NH



Notes:
1. Map projection is NH State Plane Coordinate System, NAD83, US Feet.
2. Base map from USGS topographic quadrangle map, Marlborough, NH.
3. Public water supplies, domestic wells, surface water and aquifer, town and watershed boundaries from NHGRANIT online GIS database.
4. Noting small inaccuracies at this scale, watershed boundaries were moved slightly from the Maximum Extent of Recharge Area Delineation. See text for explanation of Potential Impact Area.
5. Figure 1 was partially prepared by AECOM.

Legend

- 6" PW
- Domestic Wells (2011)
- Public Water Supply (2011)
- Published Watershed Boundary
- Town Boundary

PRELIMINARY POTENTIAL IMPACT AREA COMPONENTS

- Potential Impact Area/ Maximum Extent of Recharge Area
- Maximum Extent of Cone of Depression
- 1000 ft from COD
- Site Boundary
- Stratified Drift Aquifer Boundaries

N W E S

0 1000 2000 4000 Feet

1 inch = 2,000 feet

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FIGURE 1

SITE MAP AND POTENTIAL IMPACT AREA
PRELIMINARY REPORT FOR WELLS #3 AND #4

PAVILION SITE, MARLBOROUGH WATER WORKS, MARLBOROUGH, NH

PREPARED BY: JH	CHECKED BY: JV
PROJECT NO. 84560	DATE: AUGUST 2011

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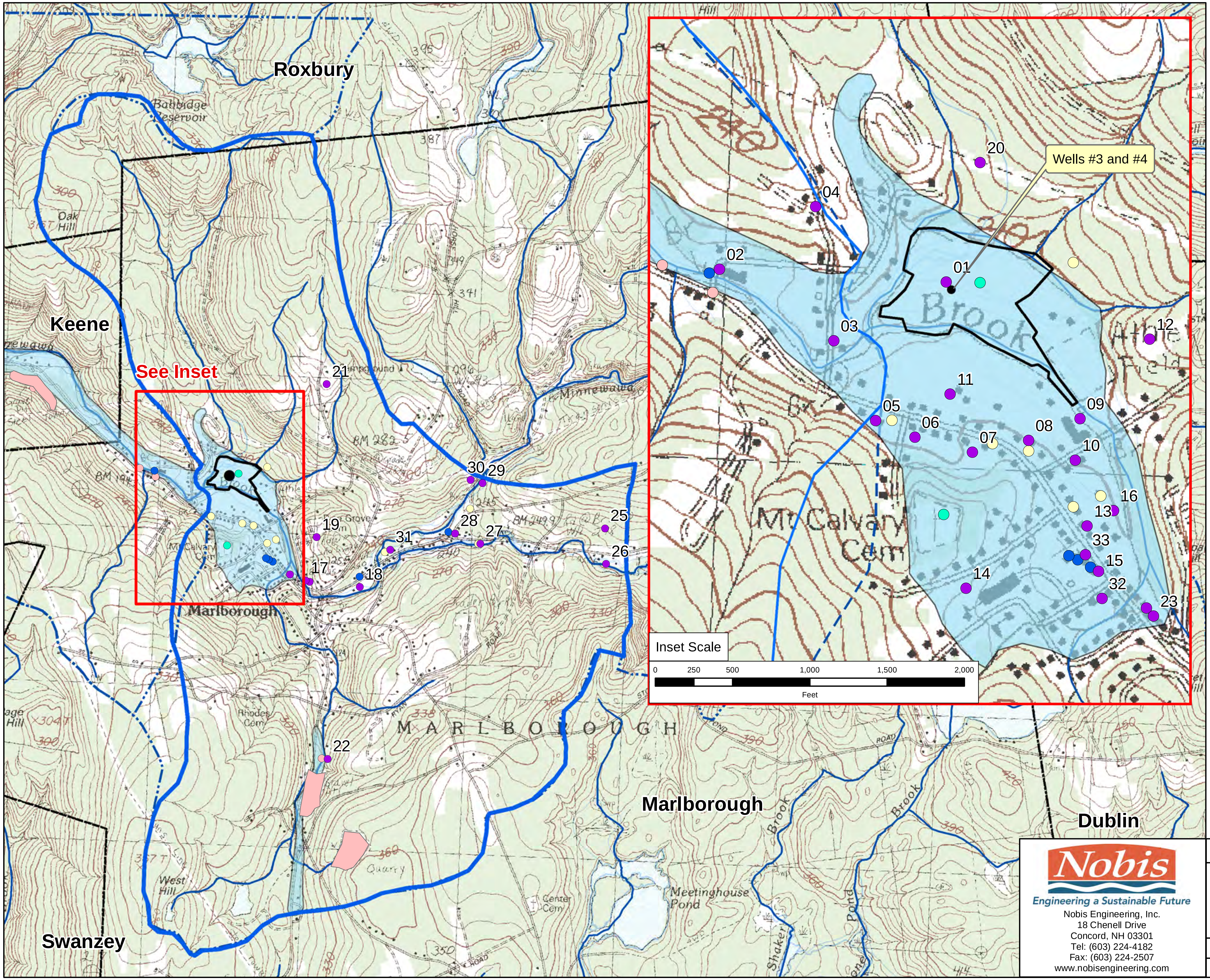

Notes:
1. Map projection is NH State Plane Coordinate System, NAD83, US Feet.
2. Base map from USGS topographic quadrangle map, Marlborough, NH.
3. Public water supplies, domestic wells, surface water and aquifer, town and watershed boundaries from NHGRANIT online GIS database.
4. Noting small inaccuracies at this scale, watershed boundaries were moved slightly for the Maximum Extent of Recharge Area Delineation. See text for explanation of Potential Impact Area.
5. See Figure 7 for domestic well locations.
6. Figure 6 was partially prepared by AECOM.
7. Numbered items are from windshield survey (Appendix I)

Legend

- Site Boundary
- New Wells #3 and #4
- Stratified Drift Aquifer Boundaries
- Potential Impact Area Outline
- Town Boundary
- Surface Water
- Published Watershed Boundary
- Non Point Source Area
- Registered Water User
- Underground Storage Tank
- RCRA Site
- Non Point Source
- Local Inventory

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FIGURE 6

PRELIMINARY POTENTIAL CONTAMINATION SOURCE INVENTORY
PRELIMINARY REPORT FOR WELLS #3 AND #4
PAVILION SITE, MARLBOROUGH WATER WORKS, MARLBOROUGH, NH

PREPARED BY: JH	CHECKED BY: JV
PROJECT NO. 84560	DATE: AUGUST 2011

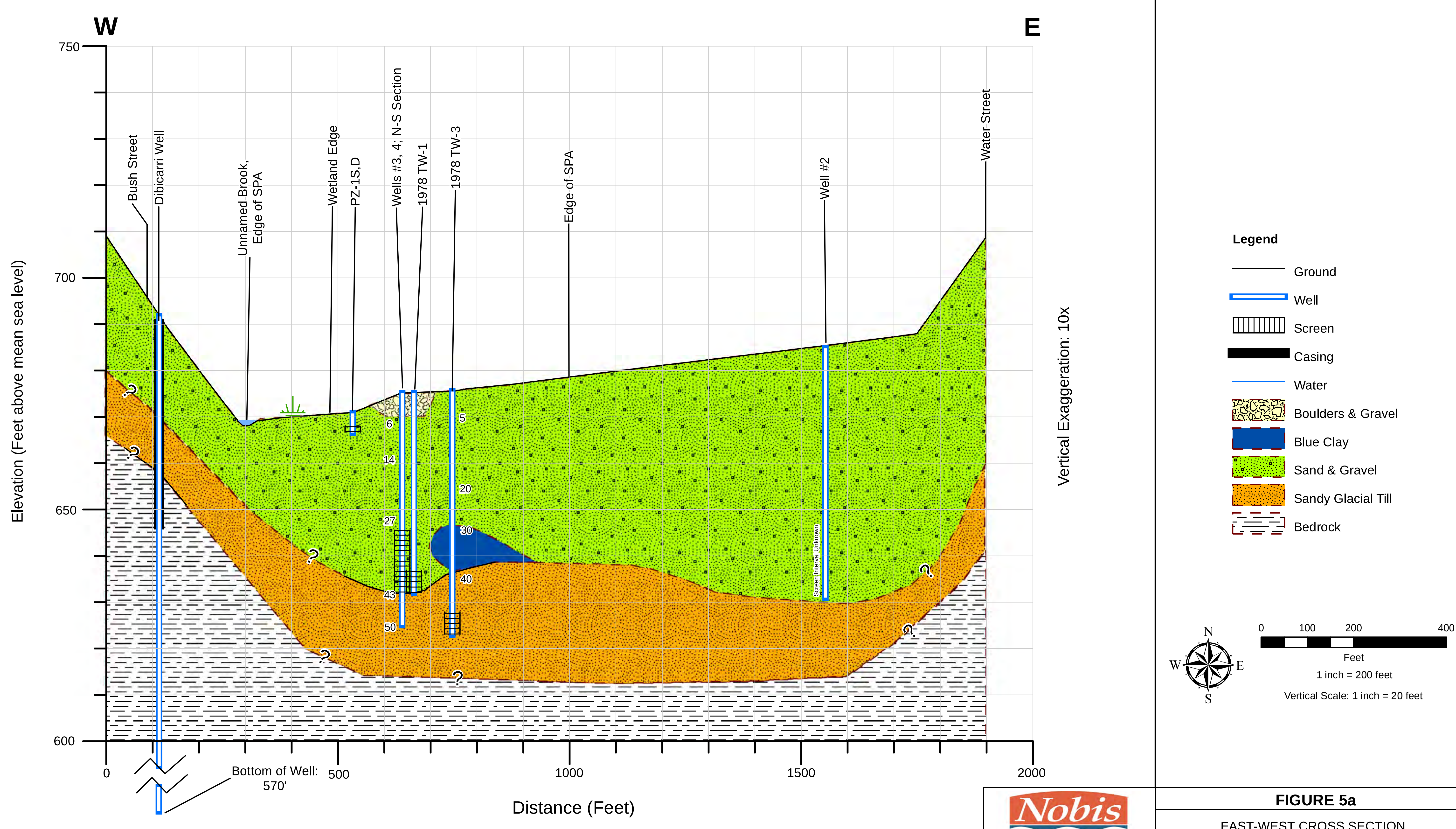

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FIGURE 5a

EAST-WEST CROSS SECTION
PRELIMINARY REPORT FOR WELLS #3 AND #4

PAVILION SITE, MARLBOROUGH WATER WORKS, MARLBOROUGH, NH

PREPARED BY: JH	CHECKED BY: JV
PROJECT NO. 84560	DATE: AUGUST 2011

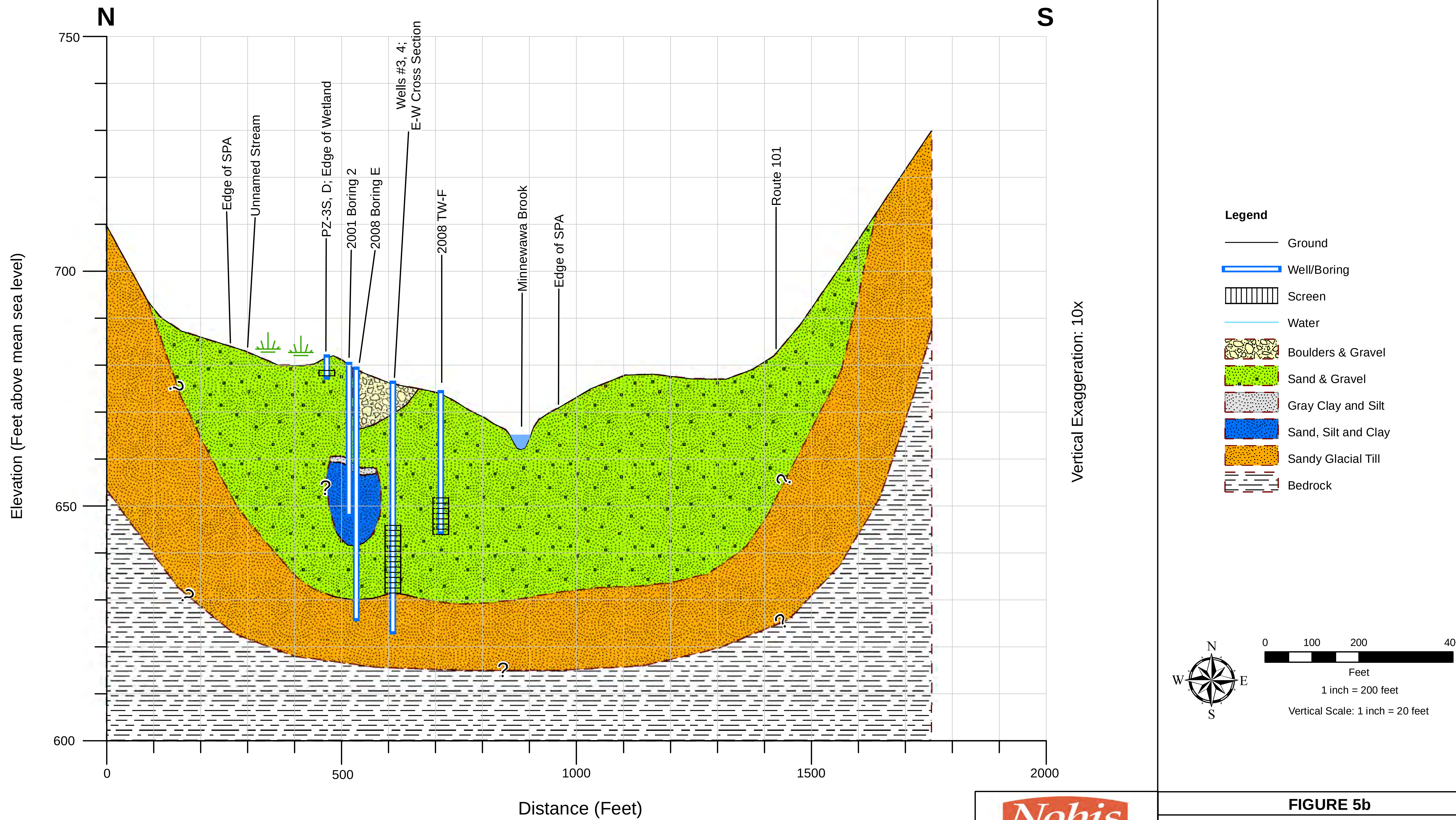

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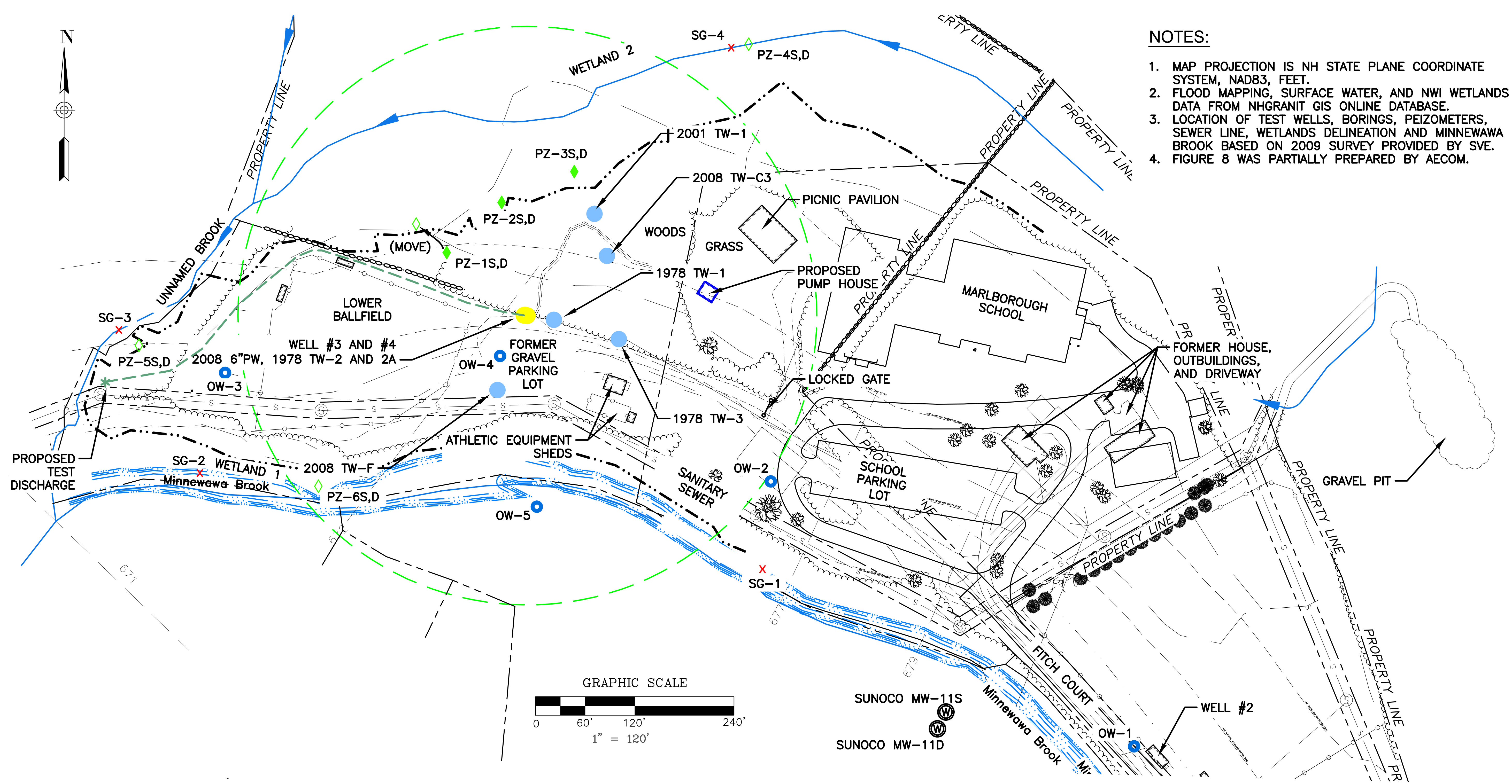
FIGURE 5b

NORTH-SOUTH CROSS SECTION
PRELIMINARY REPORT FOR WELLS #3 AND #4

PAVILION SITE, MARLBOROUGH WATER WORKS,
MARLBOROUGH, NH

PREPARED BY: JH	CHECKED BY: JV
PROJECT NO. 84560	DATE: AUGUST 2011



NOTES:

1. MAP PROJECTION IS NH STATE PLANE COORDINATE SYSTEM, NAD83, FEET.
2. FLOOD MAPPING, SURFACE WATER, AND NWI WETLANDS DATA FROM NHGRANIT GIS ONLINE DATABASE.
3. LOCATION OF TEST WELLS, BORINGS, PEIZOMETERS, SEWER LINE, WETLANDS DELINEATION AND MINNEWAWA BROOK BASED ON 2009 SURVEY PROVIDED BY SVE.
4. FIGURE 8 WAS PARTIALLY PREPARED BY AECOM.

LEGEND:

- NEW WELLS 3 AND 4
- TEST WELLS (EXISTING)
- 350 FOOT WELL SANITARY PROTECTIVE AREA
- SURFACE WATER
- DISCHARGE HOSE
- WETLAND PEIZOMETERS (EXISTING)
- WETLAND PEIZOMETERS (PROPOSED)
- OBSERVATION WELLS (PROPOSED)
- STAFF GAUGE

SURVEY DATA (2009):

- SEWER LINE
- MINNEWAWA BROOK
- WETLANDS DELINEATION

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FIGURE 8

PROPOSED PUMPING TEST MONITORING POINTS

PRELIMINARY REPORT FOR WELLS #3 AND #4
PAVILION SITE, MARLBOROUGH WATER WORKS
MARLBOROUGH, NEW HAMPSHIRE

DRAWN BY:	BW	APPROVED BY:	JV
PROJECT:	84560	DATE:	AUGUST, 2011

Table 2
Potential Impact Area Water Budget
Preliminary Report Permit Application for Well #3 and #4, Pavilion Site
Marlborough, New Hampshire

Category	Inputs	Outputs	Comments
Recharge from precipitation	Recharge from Precipitation = **1,471,781 gpd;** includes output from evapotranspiration	0	Input: Assumed 7 inches/year on 110,467,340 sq ft of till/bedrock uplands and 20.7 inches per year on 4,298,963 sq ft of stratified drift aquifer. Output: ET is accounted for in recharge input so not added as an output.
Groundwater flow	**0**	**90,882 gpd**	Input: Assumed 0 because inflow from east of the PIA is primarily through streamflow in Minnewawa Brook; Output: Estimated by a Darcy flow calculation; See text for explanation.
Streamflow	Minnewawa Brook = 6.44 cfs = **4,161,992 gpd**; Robbins Brook = 0.64 cfs = **413,614 gpd**; Total = **4,575,606 gpd**	Minnewawa Brook = 8.11cfs = **5,241,266 gpd**	Input: from the NHDES duration and flow estimation tool at 80% flow duration for Minnewawa and Robbins Brooks; see text for explanation. Output: from NHDES duration and flow estimation tool at 80% flow duration; see text for explanation.
Existing water withdrawals & wastewater discharges		Sewer system = **116,479 gpd**	Output: 2008 data from Keene Wastewater Treatment Plant; represents net loss of water from existing municipal water withdrawals and export of wastewater outside the study area.
New Wells		Proposed new Pavilion Site Wells = 99 gpm = **142,560 gpd**	Output: A net output because most of the water withdrawn will end up in the Marlborough wastewater system, located outside of the Recharge Area. This will only be an added discharge during the withdrawal testing of the new wells #3 and #4, when Well #2 would still be operating.
TOTAL	**6,047,387 gpd**	**5,591,187 gpd**	

Table 3
Known and Selected Potential Sources of Contamination, Well #3 and #4, Proposed WHPA

Known or Potential Source of Contamination	Approx Distance from Well #3 and #4 (ft)	Address	Preliminary Threat Assessment	Notes
Marlborough Sunoco - *known source*	500	122 Main St (Tax Map 12, Lot 51)	Minimal	gasoline spill in 1996; plume extremely limited; NHDES GMP; no influence in December 2008 test
IOOF Building - *known source*	2500	Route 101	Minimal	25 gal heating oil spill in 2005; flushed away by Minnewawa Brook; one-time incident; NHDES GMP
Sewer interceptor line - *potential*	120	Pavilion site off Fitch Court	low, after upgrades	gravity sewer line; knife joints removed; will be slip lined; monitoring program will be proposed
School bus or auto accident, Marlborough School or Fitch Court	>350	Marlborough School, Fitch Court	Low	storm drainage system would direct any spill away from wells
Mountain Company ("Tee shirt Factory") - *Potential*	1200	Water Street	Low	dyes used; BMPs will minimize threat
former Eastern Transmission shop - *potential*	1700	Tarbox Court	Low	currently a welding/workshop; BMPs will minimize threat
Marlborough Citgo - *potential*	1000	142 Main Street (Tax Map 13, Lot 74)	Low	potential for gasoline leak; farther from wells than Marl Sunoco
Doody's Inc/Jai Food Mart	1000	151 Main Street (Tax Map 13, Lot 26)	Minimal	former gas station; closed as of 2011; could pose slight risk if re-opens

Notes:

1. For more details, see Section 7.0, Appendix H, I, and J.
2. For locations, see Figure 6; numbered items identified in Appendix I.
3. Additional potential sources of contamination are identified in Appendix I.

Table 5
Marlborough Pumping Test Monitoring Points and Schedule

Well	Approx Distance from Well #3 (ft)	Approx Distance from Well #4 (ft)	Phase 1 Antecedent	Phase 2 Well #3 Pumping	Phase 3 Well #3 Recovery	Phase 4 Well #4 Pumping	Phase 5 Well #4 Recovery
3	-	3.9	Hourly (T)	Log cycle (T)	Log cycle (T)	Log cycle (T)	Log cycle (T)
4	3.9		Hourly (T)	Log cycle (T)	Log cycle (T)	Log cycle (T)	Log cycle (T)
1978 TW-2	2	2	3x	Log cycle (m)	Log cycle (m)	Log cycle (m)	Log cycle (m)
1978 TW-2A	4	5	3x	2x/day	2x/day		
OW-4	59	59	3x	Log cycle (T)	Log cycle (T)	Log cycle (T)	Log cycle (T)
2008 TW-F	94	94	3x	Log cycle (T)	Log cycle (T)	Log cycle (T)	Log cycle (T)
1978 TW-1	34	38	3x	Log cycle (T)	Log cycle (T)	Log cycle (T)	Log cycle (T)
1978 TW-3	117	121	3x	Log cycle (m10)	Log cycle (m10)	1x/day	1x/day
2008 TW-C3	120	120	3x	Log cycle (m10)	Log cycle (m10)		
2001 TW-1	151	151	3x	Log cycle (m10)	Log cycle (m10)	1x/day	1x/day
PZ-3S	188	188	3x	2x/day	2x/day	1x/day	1x/day
PZ-3D	188	188	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)
OW-2	350	350	Every 10 min (T)	Log cycle (T)	Log Cycle (T)	Log Cycle (T)	Log Cycle (T)
SG-1	421	421	2x/day	2x/day	2x/day	1x/day	1x/day
PZ-4S	426	426	3x	2x/day	2x/day	1x/day	1x/day
PZ-4D	426	426	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)
SG-4	412	412	2x/day	2x/day	2x/day	1x/day	1x/day
PZ-2S	132	132	3x	2x/day	2x/day		
PZ-2D	132	132	Hourly (T)	Hourly (T)	Hourly (T)		
PZ-1S	121	121	3x	2x/day	2x/day	2x/day	2x/day
PZ-1D	121	121	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)
OW-3	364	364	3x	Log cycle (T)	Log cycle (T)	1x/day	1x/day
PZ-5S	475	475	3x	2x/day	2x/day	2x/day	2x/day
PZ-5D	475	475	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)
SG-3	498	498	2x/day	2x/day	2x/day	2x/day	2x/day
Discharge (meter)	512	512	N/A	Log cycle (m10)	NA	Log cycle (m10)	NA
Disch (weir or bckt/stopw)	512	512	N/A	Log cycle (m10)	NA	Log cycle (m10)	NA
SG-2	426	426	2x/day	2x/day	2x/day	1x/day	1x/day
PZ-6S	313	313	3x	2x/day	2x/day		
PZ-6D	313	313	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)
OW-1	327	327	Every 10 min (T)	Every 10 min (T)	Every 10 min (T)	Every 10 min (T)	Every 10 min (T)
OW-5	232	232	Hourly (T)	Log cycle (T)	Log cycle (T)	1x/day	1x/day
Sunoco-11S	698	698	3x	2x/day	2x/day		
Sunoco-11D	705	705	Hourly (T)	Hourly (T)	Hourly (T)		
Dibicarri	495	495	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)
Quadrini	500	500	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)
Derosier	760	760	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)
Well #1	2000	2000	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)
Rain Gauge	-	-	Daily (m)	Daily (m)	Daily (m)	Daily (m)	Daily (m)
Barometric Pressure	-	-	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)	Hourly (T)
Site Activities/Weather	-		Daily (m)	Daily (m)	Daily (m)	Daily (m)	Daily (m)

Notes: 1. Highlighted items are proposed to meet direct requirements of Env-Dw 302.11 (c).
2. T = Transducer measurements
3. m = Manual measurements
4. m10 = Manual measurements after 1st 10 minutes
5. 3x = 3 times during antecedent period
6. SG-4 will be monitored only if water is flowing.