PETROLEUM MANAGEMENT, INC.
Environmental Services Division
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November 14, 2019

Maryland Department of the Environment
Oil Control Program
Attn: Susan Bull
1800 Washington Blvd., Suite 620
Baltimore, MD 21230

RE: EFR Evaluation Report
Wiley H. Bates Middle School
701 Chase Street, Annapolis
Facility ID# 3200

Dear Ms. Bull,

In cooperation with HP Environmental, Inc. (HPE), Petroleum Management, Inc. (PMI) has completed most of the directed corrective action measures in accordance with the *Corrective Action Plan Approval* dated June 11, 2019. The following report prepared by HPE details and summarizes the Enhanced Fluid Recovery (EFR) events competed to date as well as present the proposal for permanently installed LPH recovery system for the site.

Please review all reports now submitted and respond with comment or approval of the proposed next phase of correction action .

Thank you for your attention to this case.

W. Scott Alexander
W. Scott Alexander
Environmental Projects Manager

Enc.

cc: *Mr. Christopher Williams*
Environmental Issues Program Manager
Anne Arundel County Public Schools
9034 Fort Smallwood Rd.
Pasadena, MD 21122

HP ENVIRONMENTAL
INCORPORATED

November 13, 2019

Ms. Susan R. Bull
Eastern Region Supervisor
Maryland Department of the Environment
Oil Control Program
Remediation Division
1800 Washington Boulevard
Suite 620
Baltimore, Maryland 21230

Re: Enhanced Fluid Recovery Evaluation Report
OCP Case No. 2018-0559-AA
Bates Middle School
701 Chase Street
Annapolis, Anne Arundel County, Maryland
Facility ID No. 3200

Ms. Bull:

HP Environmental, Inc. (HPE) and Petroleum Management, Inc. (PMI) have prepared this correspondence to present an evaluation of the data and information collected during the completion of enhanced fluid recovery events (EFRs) at the Bates Middle School site in Annapolis, Maryland (OCPCase No. 2018-0559-AA). This report has been prepared in part in response to a condition presented by the Maryland Department of the Environment's (MDE's) Corrective Action Plan (CAP) Approval for the Site dated June 11, 2019. In the CAP approval letter, the MDE approved EFR events as an interim remedial measure and required that:

1) EFR Events be performed on a bi-weekly basis for all wells with measurable thicknesses of liquid-phase hydrocarbons (LPH).
2) Prior to each EFR event all groundwater monitoring wells were to be manually gauged for LPH thickness and depth to groundwater. The manual collection of this data was later amended to collect the data using down-well data loggers.
3) The MDE required the use of magnehelic gauges on the well heads to collect vacuum gauge readings in an effort to define vapor influence during the EFR events.
4) The EFR events were to be conducted by vacuum truck using stingers set to a depth of not more than two feet below the groundwater elevation.

EFR events were conducted by PMI using vacuum trucks on a bi-weekly basis beginning on August 8, 2019 and continuing through October 10, 2019 whereby the EFR frequency was changed to once a week with the concurrence of the MDE. The once a week events continue to this date. Prior to each event LPH thickness and depth to groundwater were measured to the nearest 0.01-foot using an oil/water interface probe. Measurements were made from a singular point on the top of each well casing so that measurements were consistent from event to event. All data recorded in a dedicated field notebook as well. During the EFR events LPH were only detected in groundwater monitoring wells MW-1, MW-2 and MW-3 with the product thickness being greatest in MW-1. Prior to the initiation of the first EFR event on August 8, 2019 13.49 feet of LPH were measured in MW-1. This apparent thickness had decreased over time. Prior to the most recent EFR event on 11/06/19 the LPH thickness was measured at 7.44 feet. LPH measurements are summarized in Table 1. To date, a total of 655.27 gallons of LPH have been recovered from the Site (Table 2).

EFR Data Evaluation

The following sections detail the data collected during the EFR events and their utility in characterizing the groundwater and LPH conditions at the Site.

Groundwater/LPH Recovery

Both groundwater and LPH have been recovered from the Site during each of the scheduled EFR events. Total fluids have been recovered from groundwater monitoring wells MW-1, MW-2, and MW-3 using a vacuum truck attached to a 2-inch diameter PVC pipe, or "stinger." In each case the depth to groundwater was measured to the nearest 0.01-foot depth and the stinger was set to a depth of no more than two feet below the measured depth to groundwater. For the majority of the EFR events a vacuum of 20 inches of mercury was applied to individual well head for a two-hour period. Upon completion of the EFR event the fluids within the vacuum truck were allowed to "settle" in an effort to eliminate foaming of the LPH that occurs during the event. Once the fluids had settled a graduated wooden staff was used to measure the thickness of recovered water and LPH in the vacuum truck. The fluid thickness measurements were then converted to gallons using a "stick chart" for the vacuum truck. Measurements and fluid volume calculations for the EFR events are summarized in Table 1.

The declining trend in LPH thickness indicate that the overall volume of the contaminant mass can be impacted and reduced through the use of fairly standard LPH extraction and recovery technologies. In general, LPH measurements presented in Table 2 show a declining volume of LPH available for recovery. The LPH measurement for 11/06/19 shows an increase in the LPH thickness in MW-1 from previous events. This change in the LPH thickness trend is attributed to recent precipitation events as the data set does show a correlation between precipitation events and increased LPH thickness in MW-1 , MW-2 and, to a lesser degree, MW-3. The data set does not show an increased downgradient migration of the LPH plume away from MW-1. MW-2, and MW-3 after precipitation events, indicating that the continued performance of EFR events is capable of controlling plume migration.

Note that the neither the source area nor LPH mass volume have been determined. The quarterly groundwater analytical data previously presented to the MDE shows that there is no substantive dissolved-phase plume associated with the LPH and the LPH measurements themselves show that the lateral extent of the LPH is limited to an area around MW-1, MW-2, and MW-3. All three of these wells are located immediately downgradient of the boiler room foundation wall. Given these two facts the lack of LPH source area definition nor LPH mass volume estimate are thought to be significant.

Vacuum Propagation

Magnehelic vacuum gauges were attached to each groundwater monitoring well via air-tight PVC caps during the initial EFR events. Vacuum gauge readings were recorded prior to the initiation of the EFR event and then every 30 minutes thereafter. Vacuum gauge readings were collected for each EFR event from inception though 8/22/19. No significant vacuum readings were recorded for any of the wells during this time period and vacuum gauge use was terminated on 8/27/19 with the concurrence of the MDE. The complete lack of vacuum propagation away from the EFR wells is unusual and could be the result of one or more of the following: long well screens that extend 10 feet or more above the groundwater table; the amount of unpaved surface in the EFR area that could allow for vacuum to short circuit vertically before propagating laterally away from the well; and the relatively high soil porosity at the Site that could also lead to vertical short circuiting of the vacuum.

The lack of vacuum propagation away from the EFR wells indicates that remediation technologies such as soil vapor extraction that rely on controlled air flow to facilitate remediation may not be well-suited to this Site without the installation of additional recovery wells or extraction points that are specifically designed for use as vapor extraction systems. Given the limited human health and environmental risks that may be posed by vapors emanating from the LPH plume this situation is not thought to be significant as other remedial technologies are available that may be better suited to the site-specific conditions.

Groundwater Assessment

LPH thickness and groundwater elevation data were manually collected from all monitoring wells at the site from 08/08/19 through 9/19/19. The data collected in this fashion was found to be not useful for evaluation of the Site's groundwater parameters as the groundwater recharge rates were too fast to allow for the recharge rate to be captured by manual measurements. Groundwater elevation measurements were collected using dedicated down-hole data loggers from 8/20/19 through 9/19/19.

OnSet® HOBO® data loggers were installed in all monitoring wells during EFR events from August 20, 2019 through September 19, 2019. For instances where the depth of the EFR "stinger" was within 6 feet of the bottom of the monitoring well the logger was installed only after pumping as the logger would have been disturbed by the turbulence introduced into the well during the EFR. A data logger was inserted into the respective well immediately upon removal of the stinger to capture as much direct recharge data as possible. This condition was only an issue in monitoring well MW-1.

As the EFR events progressed, and less LPH was present initially in MW-1, it became possible to deploy the data logger into MW-1 during the EFR and the dataset was improved dramatically, yielding better derivations of the hydraulic conductivity of the subsurface when analyzed using AQTESOLV©.

AQTESOLV© is a commercially available aquifer characterization software that utilizes extant hydrologic equations to derive a variety of parameters from data composed of pumping rates, drawdown displacement, and slug tests, including hydraulic conductivity (K). Data logger data sets from wells MW-1 and MW-3 were the predominant data used in the valuation of groundwater parameters at the Site. These were chosen primarily for reasons of creating reproducible datasets from their recovery curves, but also as they represented the wells with the greatest and least influx of free product. The recovery curves analyzed for MW-1 and MW-3 were all end-of-event curves. This was done to prevent previously noticed visible stepped recovery curves from skewing the data during a subsequent EFR. Displacement over time as well as Agarwal curves were matched using Theis (1935), Cooper-Jacob (1946), and Neuman (1974) solution sets for unconfined partially penetrating wells. In the course of analyzing and matching curves, the Cooper-Jacob method was matched using the Agarwal curve, while the Theis and Neuman curve matching was accomplished against the displacement over time. While you must match the curve after the initial influx, but before the beginning of stasis, observed as the asymptote, this can yield a mix of results usually around a similar value. AQTESOLV© has automatic curve matching available in its suite of uses, and these were recorded, however final determination of the K value for each well was better matched using the visual matching feature. A series of 20 curve matches were completed individually on each curve and an average and median, high and low result recorded for each. While these did not vary significantly, this was in an attempt to achieve reproducible results. Across all solution methods the final variability seen in K value was less than 10 percent, and in close agreement with the AQTESOLV© generated automatic curve matching results.

To verify our recovery results that were based on groundwater recharge rates calculated from EFR events, HPE performed slug tests on MW-1, MW-4 and MW-6. The slug itself was constructed of a four-foot-long cylinder of 2.375" outer diameter PVC, capped at each end, filled with sand, and affixed with an eyehook for deployment and retrieval via steel cable. Data loggers were deployed in each well to record rising and falling head during the insertion and retrieval of each slug. The static head was recorded before and during slug testing with a water level meter. The slug was inserted into the well until submerged, head was recorded by both the logger in the well and the water level meter and observed until it approached stasis again. Once stasis was achieved or within five hundredths of a foot, the slug was extracted and once again the head was observed until stasis was reached by water level meter. The dataset results of these tests were also analyzed using AQTESOLV©. There are many variables that affect which equation or model is chosen to most accurately predict hydraulic conductivity. HPE selected the Bouwer-Rice (1976) model as the model that best applied to both our known conditions, an unconfined aquifer with a well screened across the water table, and our recovery curves. Using the recommended head reading function to reduce the area of curve matching to its most critical point for accurate analysis, another round of curve matching was conducted maintaining at least 20 matches per curve with two separate curves for each slug test, rising and falling head. The results were again tabulated into a table of the average, median, high, low and automatically derived values for K.

These analyses yielded a site-specific average hydraulic conductivity value of 303ft/yr. This site-specific calculated value lies within the generally accepted range of hydraulic conductivity for silty sand lithologies similar to the soil lithologies observed in samples recovered during the prior Geoprobe and hollow-stem auger drilling performed at the Site.

If in the future a total fluids recovery system is deemed necessary for installation this groundwater data can be used to design the recovery and treatment system.

Proposed Remediation System

The EFR events were initiated and performed as an interim measure to control the migration of dissolved-phase and LPH contamination at the Site. HPE and PMI evaluated data and information generated during the EFR events performed at the Site in an effort to design a permanent remediation system to be installed at the Site as a replacement for the EFR events. The remediation system as designed should be technically effective at controlling migration of dissolved-phase contamination and LPH and provide a more cost-effective approach to the continued remediation of the site.

In general, two separate systems were evaluated for the Site; one that provided for the recovery for the LPH without depressing the local groundwater table (aka a "skimmer system") and one that recovered LPH and groundwater (aka a "total fluids system"). Skimmer systems tend to be less costly to install and operate and require less overall maintenance than total fluids systems. Total fluids systems also require the discharge of a treated effluent to the local sewer system. The downside of skimmer systems is that they do not control groundwater flow so run the risk that the LPH plum can migrate and expand.

HPE's evaluation of the groundwater data indicate a skimmer pump should be effective in recovering the LPH from the Site while also being able to limit the migration of LPH away from the immediate vicinity of monitoring wells MW-1, MW-2, and MW-3.

Table 2 shows that the LPH thickness in MW-3 has been less than 0.02 feet for a significant time. Skimmer pumps specifications usual indicate that the pumps are capable of removing accumulated LPH down to a thickness of 0.02 feet. Given the recent measurements in MW-3 HPE is proposing to install static hydrophobic absorbents within MW-3 to recovery the LPH that is present in this well.

LPH thicknesses in MW-1 and MW-2 are of sufficient thickness that skimmer pumps can be deployed to recover the LPH. HPE has selected QED Genie® pumps for use in MW-1 and MW-2. Specifications for the pump system are attached to this correspondence. These pumps are equipped with hydrophobic inlet screens that are mounted on a vertical control rod that allows the inlet screen to float on the LPH/groundwater interface and continue to recover LPH only even as the LPH/groundwater interface elevation fluctuates. For this application these pumps will be equipped to allow for the hydrophobic inlet screens to float over a range of up to 40 inches. The pumps will be driven by compressed air and no electrical connections to the monitoring wells will be required which provides and intrinsically safe condition at the well heads. Recovered LPH will be transferred from the QED Genie® pumps into two 275-gallon capacity plastic toes that will be manifolded together to provide for approximately 550 gallons of total LPH storage. The totes, air compressor and pump controllers will all be staged in the boiler room. A high-level controller switch will be installed on the LPH storage containers and will shut down LPH recovery should the totes fill to more than 90 percent of storage capacity. The pump controller system will be Bluetooth enabled so that it can be remotely monitored. Lastly a vacuum collection pipe will be connected to the totes and piped to the surface so that recovered LPH can be collected and transported off-site by vacuum trucks.

System Operation and Reporting

Operation – The remediation system is designed to operate 24 hours per day, seven days per week anytime that recoverable thicknesses of LPH are present in either MW-1 or MW-2.

Reporting – An LPH Recovery Report will be submitted to the Client and the MDE on a monthly basis. The report will include a summary of the number of days of system operation, number of LPH gallons recovered by month and project total, groundwater monitoring well measurements, and a discussion of any operational issue and/or recommendations for system modifications.

Please feel free to contact me should you have any questions or comments on this remedial action plan. On receipt of approval from the MDE HPE and PMI will commence system installation.

Sincerely,

KDC

Kent D. Campbell, CPG
Director of Site Assessment Monitoring and Compliance

Attachments

Table 1

EFR Event Summary
Bates Middle School
701 Chase Street
Annapolis, Maryland

Well	Date	DTW (ft)	DTP (ft)	Thickness LPH (ft)	Duration EFR (min)	Fluid Recovered (gal)		
						Water	LPH	Total Fluids
MW-1	8/8/2019	27.81	14.32	13.49	180	756	53	809
MW-2		15.81	14.08	1.73	90			
MW-3		14.96	14.02	0.94	60			
MW-1	8/13/2019	26.45	14.41	12.04	130	925	50	975
MW-2		15.41	14.10	1.31	120			
MW-3		14.88	14.08	0.80	126			
MW-1	8/15/2019	23.45	14.78	8.67	133	870	26	896
MW-2		15.44	14.22	1.22	120			
MW-3		14.54	14.23	0.31	123			
MW-1	8/20/2019	26.99	14.53	12.46	112	731	37	768
MW-2		16.54	15.21	1.33	120			
MW-3		14.72	14.19	0.53	120			
MW-1	8/22/2019	22.30	14.90	7.40	120	358	41	399
MW-2		15.51	14.30	1.21	120			
MW-3		14.50	14.26	0.24	120			
MW-1	8/27/2019	25.64	14.60	11.04	60	646	24	670
MW-2		15.51	14.26	1.25	124			
MW-3		14.54	14.21	0.33	122			
MW-1	8/30/2019	24.66	14.68	9.98	119	646	24	670
MW-2		15.49	14.32	1.17	120			
MW-3		14.44	14.29	0.15	120			
MW-1	9/3/2019	23.47	14.90	8.57	120	600	23	623
MW-2		15.56	14.35	1.21	120			
MW-3		14.39	14.29	0.10	120			
MW-1	9/5/2019	20.35	15.30	5.05	120	339	9	348
MW-2		15.62	14.39	1.23	31			
MW-3		14.40	14.35	0.05	30			
MW-1	9/10/2019	23.91	14.96	8.95	120	512	18	530
MW-2		15.57	14.38	1.19	122			
MW-3		14.53	14.35	0.18	120			
MW-1	9/12/2019	19.91	15.35	4.56	120	472	13	485
MW-2		15.44	14.42	1.02	120			
MW-3		14.43	14.37	0.06	120			

Table 1 (cont'd)

Well	Date	DTW (ft)	DTP (ft)	Thickness LPH (ft)	Duration EFR (min)	Fluid Recovered (gal)		
						Water	LPH	Tot. Fluids
MW-1	9/17/19	22.18	15.21	6.97	120	472	13	485
MW-2		15.81	14.40	1.41	120			
MW-3		14.40	14.38	0.02	120			
MW-1	9/19/19	18.97	15.61	3.36	60	507	24	531
MW-2		15.56	14.46	1.10	60			
MW-3		14.49	14.42	0.07	121			
MW-1	9/24/19	21.49	15.27	6.22	120	759.5	26.5	786
MW-2		15.61	14.44	1.17	132			
MW-3		14.49	14.41	0.08	34			
MW-1	9/26/19	19.20	15.68	3.52	120	1168	33	1201
MW-2		15.45	14.53	0.92	120			
MW-3		14.53	14.46	0.07	120			
MW-1	10/1/19	21.25	15.52	5.73	120	1381	52	1433
MW-2		15.55	14.50	1.05	120			
MW-3		14.50	14.48	0.02	120			
MW-1	10/3/19	18.74	15.94	2.80	120	545	32	577
MW-2		15.61	14.44	1.17	120			
MW-3		14.52	14.52	0.00	0			
MW-1	10/8/19	19.89	15.90	3.99	120	430.38	10.6	441
MW-2		15.58	14.54	1.04	120			
MW-3		14.51	14.50	0.01	120			
MW-1	10/10/19	18.52	16.09	2.43	120	474.08	10.9	485
MW-2		15.77	14.58	1.19	120			
MW-3		14.57	14.55	0.02	120			
MW-1	10/16/19	19.90	15.91	3.99	120	769.66	50.3	820
MW-2		16.14	14.54	1.60	120			
MW-3		14.52	14.50	0.02	120			
MW-1	10/23/19	20.56	15.55	5.01	120	820	51	871
MW-2		15.75	14.50	1.25	120			
MW-3		14.43	14.43	0.00	60			
MW-1	10/30/19	21.28	15.38	5.90	120	269.84	9.16	279
MW-2		15.42	14.47	0.95	120			
MW-3		14.40	14.40	0.00	60			
MW-1	11/6/19	22.65	15.21	7.44	120	744.11	24.7	768.84
MW-2		15.40	14.45	0.95	120			
MW-3		14.40	14.40	0.00	60			
					Total Gallons	**15,195.57**	**655.27**	**15,850.84**

Table 2
LPH Thickness Over Time
Bates Middle School
Annapolis, Maryland

Date	Day	Product Thickness (feet)		
		MW-1	MW-2	MW-3
8/8/2019	Thursday	13.49	1.73	0.94
8/13/2019	Tuesday	12.04	1.31	0.80
8/15/2019	Thursday	8.67	1.22	0.31
8/20/2019	Tuesday	12.46	1.33	0.53
8/22/2019	Thursday	7.4	1.21	0.24
8/27/2019	Tuesday	11.04	1.25	0.33
8/30/2019	Friday	9.98	1.17	0.15
9/3/2019	Tuesday	8.57	1.21	0.10
9/5/2019	Thursday	5.05	1.23	0.05
9/10/2019	Tuesday	8.95	1.19	0.18
9/12/2019	Thursday	4.56	1.02	0.06
9/17/2019	Tuesday	6.97	1.41	0.02
9/19/2019	Thursday	3.36	1.10	0.07
9/24/2019	Tuesday	6.22	1.17	0.08
9/26/2019	Thursday	3.52	0.92	0.07
10/1/2019	Tuesday	5.73	1.05	0.02
10/3/2019	Thursday	2.80	1.17	0.00
10/08/19	Tuesday	3.99	1.04	0.01
10/10/19	Thursday	2.43	1.19	0.02
10/16/19	Wednesday	3.99	1.6	0.02
10/23/19	Wednesday	5.01	1.25	0.00
10/30/2019	Wednesday	5.90	0.95	0.00
11/6/2019	Wednesday	7.44	0.95	0.00

4" SPG4 AutoGenie™

4" SPG AutoGenie™ Skimmers

The 4" SPG4 AutoGenie™ is a safe, reliable and complete system for removing free product layers from wells. The 4" SPG4 AutoGenie system consists of an air-powered pumping unit with a floating inlet that tracks changes in the water level. The SPG float uses specific gravity to avoid water intake and includes multiple inlet hole positions to allow fine-tuning of the inlet level as the floating layer thickness is reduced. The special Genie bladder pump with high suction capacity delivers proven reliability and durability. The AutoGenie uses an integral pneumatic timer to control the bladder pump fill and discharge times. A complete line of matched accessories is available to help installation and performance, including in-well tubing, well caps, LNAPL collection tank full shutoffs and other items.

Warranty

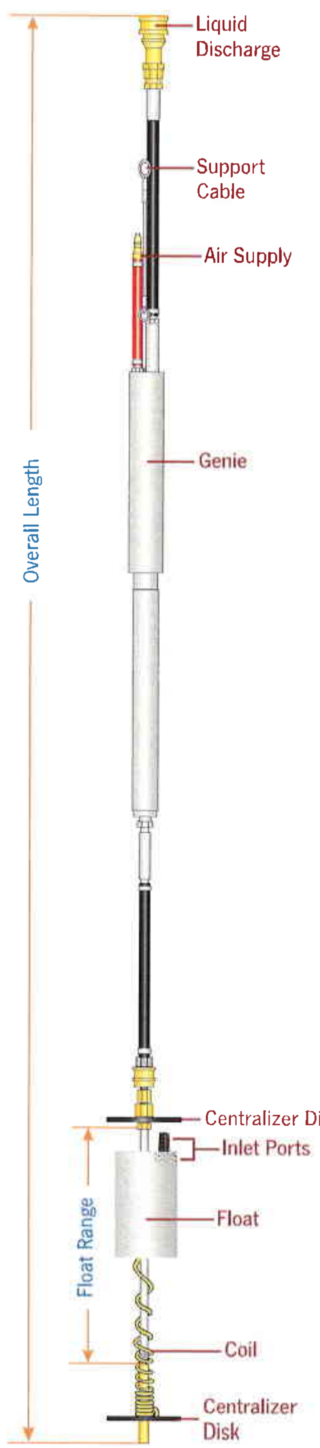
SPG4 AutoGenies are warranted for one (1) year.

Advantages

1. **Specialized bladder pump is extremely durable, provides high suction to maintain flow, and eliminate contact of drive air with pumped fluid.**
2. **Continuous, automatic operation that is 100% air powered.**
3. **Available in a range of flow rates and float travel ranges.**
4. **Low air consumption.**

Free Product Recovery (LNAPL)

4" SPG4 AutoGenie™



The 4" SPG4 AutoGenie™ is available in 8 different models with varying inlet float travel ranges and pumping rates. Why so many options? QED has found that each free product site and well can have its own challenges in terms of well depth, liquid column depth, water level fluctuation and desired LNAPL pumping rate. For example, the model with the longest pump and float travel range may be too long for some wells. Check the dimensions and flow rates below, or just call QED to help select the best match for your project.

Specifications

AutoGenie Model	Maximum LNAPL Recovery Rate*	Float Travel Range	Overall Length	Minimum Liquid Column
AG2424L SPG4	160 gpd (605 Lpd)	24 in. (61 cm)	124 in. (315 cm)	31 in. (79 cm)
AG2424C SPG4	160 gpd (605 Lpd)	24 in. (61 cm)	109 in. (277 cm)	15 in. (38 cm)
AG2445 SPG4	160 gpd (605 Lpd)	45 in. (114 cm)	129 in. (329 cm)	15 in. (38 cm)
AG2460 SPG4	160 gpd (605 Lpd)	60 in. (152 cm)	145 in. (368 cm)	16 in. (41 cm)
AG4824L SPG4	320 gpd (1,211 Lpd)	24 in. (61 cm)	148 in. (376 cm)	31 in. (79 cm)
AG4824C SPG4	320 gpd (1,211 Lpd)	24 in. (61 cm)	133 in. (338 cm)	15 in. (38 cm)
AG4845 SPG4	320 gpd (1,211 Lpd)	45 in. (114 cm)	153 in. (389 cm)	15 in. (38 cm)
AG4860 SPG4	320 gpd (1,211 Lpd)	60 in. (152 cm)	169 in. (429 cm)	16 in. (41 cm)

Minimum Well ID	4 in. (10 cm)
Maximum OD	3.79 in. (9.63 cm)
Maximum Depth	150 ft. (45.7 m)
Air Supply Pressure (min/max)	40/100 psi (2.7/6.9 bar)
LNAPL Fluid Density	< .85 SG
Kinematic Viscosity	1-1000 centistokes
Recommended Initial LNAPL Layer	> 3 in. (> 7.6 cm)
Residual LNAPL Layer	≥ 0.25 in. (.64 cm)
Suitable Types of LNAPL	Gasoline, diesel, jet fuels, kerosene, #2 - #5 fuel oils, light weight motor oil and hydraulic fluid
Materials	Brass, Tygon®, stainless steel, Viton®, Teflon®
Fitting Type	Quick-connect
Hose or Tubing	Both are available

Tygon is a registered trademark of Saint Gobain - Norton. Viton is registered trademark of DuPont Dow Elastomers.
Teflon is a registered trademark of Dupont.
* gpd = gallons per day, Lpd = liters per day

P.O. Box 3726 Ann Arbor, MI 48106 USA **800-624-2026** **F 734-995-1170** info@qedenv.com www.qedenv.com