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Technical Memorandum

Focused Off-Site Remedial Technology Evaluation

To: Jonathan Polonsky and Brent Chadwick, Plaid Pantries, Inc.

Copies: Aaren Fiedler, Department of Ecology Voluntary Cleanup Program

From: Paul Ecker, LHG; Brad Thoms, PE; Chris Rhea, LG; and Daniele Peters, EIT

Date: September 19, 2018

Regarding: Plaid Pantry Store #112
1002 W. Fourth Plain Boulevard
Vancouver, Washington
Washington Department of Ecology VCP Site ID SW1314
EES Project 1179-02

EES Environmental Consulting, Inc. (EES) prepared this technical memorandum to provide a summary of our evaluation of remedial technology screening alternatives to treat remaining offsite impacts originating from a former unknown underground storage tank (UST) at Plaid Pantry Store #112 (Property). A soil vapor extraction (SVE) system has been operated at the Plaid facility as an interim remedial action since 2013, and the performance and effectiveness of this treatment technology is discussed herein as a basis for comparison to other remedial options for addressing soil contamination that extends beyond Property boundaries.

BACKGROUND

The subject Property is located at the northwest corner of West Fourth Plain Boulevard and Kauffman Avenue in Vancouver, Washington (Figure 1). The 0.26-acre Property is developed with a single commercial building and a retail gasoline station. Building tenants include Plaid Pantry, which operates a convenience store and retail fueling station, and a Domino's Pizza Restaurant. Site features and underground utilities/infrastructure are illustrated on Figures 2a/2b.

Gasoline impacts were first confirmed in soils surrounding a previously unknown UST that was discovered south of the current fuel dispenser island during initial Site assessment activities conducted by Plaid in 2011. The identified gasoline release (source) area is located on the Property and appears to be associated with historical fueling infrastructure that pre-dates Plaid's operations at this Property. Soil impacts are present beyond the Property boundary to the south, extending beneath a limited portion of the adjacent sidewalk and Fourth Plain Boulevard roadway. Collectively, the area affected by gasoline contamination originating at the subject Property is designated as the Site.

EES installed and has operated an SVE system at the Site since September 2013 as an interim remedial action to mitigate gasoline-impacted soils at the Site (EES 2014). The SVE system applies a vacuum to the five-well array (SVE-1 through SVE-5) to remediate gasoline source zone impacts in soils between 5 and 20 feet below ground surface (bgs) in the vicinity of the fuel distribution island near the southern Property margin. The SVE system layout and observed zone of influence is shown on Figure 3. Within the SVE treatment zone, gasoline and related constituent vapors continue to be removed from the subsurface at concentrations indicating generally diminishing residual impacts and mass removal rates (EES 2018a). The zone of SVE influence covers the primary source area but does not fully mitigate soil impacts in the adjacent right-of-way.

Additional background information regarding overall project investigation and cleanup status is provided in the Remedial Investigation (RI) Report (EES 2018a), and other project correspondence with Ecology.

SVE SYSTEM PERFORMANCE AND EFFECTIVENESS

EES conducts monthly operations and maintenance, and quarterly monitoring of the SVE system to evaluate and adjust performance. SVE monitoring results are summarized in regular Interim Remedial Action Measure (IRAM) status reports. Since 2013 startup, cumulative removal of gasoline range hydrocarbons is estimated to be 200 pounds, or approximately 33 gallons. Vacuum influence monitoring conducted periodically during system operations indicate consistent measurable vacuum influence extending south to well B-17, and an estimated radius of influence of 6 to 10 feet for each SVE well. Periodic measurements of oxygen levels in soil vapor indicates that aerobic conditions are induced as intended within the observed zone of influence, which promotes natural biological degradation of subsurface gasoline vapors. System emissions and performance are summarized in the most recent IRAM status report (EES 2018b).

As summarized in the recent RI report (EES 2018a), source-area soil concentrations have been reduced significantly within the SVE treatment zone (see Figures 4a/4b and 5). Soil data collected in 2015 at source-area borings B-19 and B-20 indicated significant contaminant reduction in the treatment area due to active soil vapor extraction, with 2015 concentrations less than MTCA Method B CULs within this zone. Pre-treatment (2012) gasoline and benzene concentrations were measured at location Pit-E/6 at up to 64,200 and 93 mg/kg, respectively, compared to post-treatment (2015) concentrations measured at co-located boring B-20 at up to 475 mg/kg gasoline and no detectable benzene. Among 14 representative soil samples collected within 15 feet of the subject Property ground surface, gasoline and related constituent concentrations in soil are currently below MTCA Method B cleanup levels in all cases, following SVE operations. However, the current SVE configuration does not effectively mitigate residual soil impacts extending further to the south beneath portions of the right-of-way, where gasoline concentrations are nearly ten times greater than the MTCA Method B CUL of 2,619 mg/kg.

Although benzene and gasoline constituents are present in soil gas at the Site, these vapors diminish rapidly with distance from the residual source area, and do not create unacceptable vapor intrusion conditions in close proximity to or beneath the current Property building or in Site utility trench backfill locations (EES 2017). In general, the greatest gasoline impacts in soil gas remain near the former UST source area, although SVE operations have significantly reduced contaminant mass and vapor concentrations in this area based on data collected after several years of treatment. Additionally, residual soil gas impacts remain in the right-of-way area south of the source area, beyond the influence of SVE treatment, where gasoline contamination in soil exceeds CULs.

AREAS TARGETED FOR ADDITIONAL REMEDIATION

Current soil conditions on the subject Property satisfy MTCA Method B cleanup levels for all contaminants of interest. South of the Property boundary and below a portion of the adjoining sidewalk and West Fourth Plain Boulevard right-of-way, gasoline contamination remains in soil at concentrations exceeding the calculated MTCA Method B TPH direct contact cleanup level of 2,619 mg/kg. These residual contaminated soils also represent a continuing source of subsurface gasoline vapors that although unlikely, could indirectly impact indoor air quality if future building(s) were to be constructed above or near the source area. In order to address the vapor intrusion pathway, gasoline-related volatiles will be mitigated in an effort to achieve compliance with the most protective MTCA Method A cleanup criteria. Published Ecology guidance specifically allows for this approach of meeting Method A and Method B soil cleanup criteria as a basis to demonstrate that both vapor intrusion and direct contact pathways of concern, respectively, are adequately protective.

Residual impacts in off-Property soils located south of the gasoline source area will be remediated to be protective of Site receptors as designated under MTCA. The proposed area targeted for remediation is shown on Figure 6.

OFF-SITE REMEDIAL TECHNOLOGY SCREENING

Based on our understanding of current Site conditions as well as SVE performance in the contaminant source area, EES evaluated common remedial technologies that could be used to treat remaining hydrocarbon impacts at the Site in areas outside the Property boundary. The alternate remedial technologies and screening criteria are presented in Table 1.

In general, many remedial options were rejected due to implementation issues related to the limited access to the impacted soils under the City sidewalk and West Fourth Plain Boulevard.

- Soil mixing and excavation were screened out due to the added costs to be able to directly access contaminated soil below the right-of-way.
- Electrical resistance heating, conductive heating, and radio-frequency heating are all technically feasible. However, the capital costs for these approaches are typically very high for open-access sites, and implementation at this Site would not be cost-effective due to the limited access complexities.
- Soil flushing and steam injection typically do not perform well in low permeability soils such as the impacted glacial tills targeted for treatment, and therefore were rejected due to anticipated relatively low Site disturbance and poor technical feasibility/applicability.

Based on the proven effectiveness of SVE for treatment of impacted soils on the Property, as well as the moderate implementation costs and minimal disturbance for installing horizontal SVE wells, SVE is retained as the recommended remedial approach for areas outside the Property boundary. Additionally, bioventing is retained as a potential "polishing" approach, to be considered after the volatile hydrocarbon components are recovered via SVE and extraction vapor concentrations become asymptotic. Some lower volatility hydrocarbons are not easily removed via SVE and can likely be treated by bioventing via aerobic degradation.

CONCLUSIONS AND RECOMMENDATIONS

Based on the successful and effective SVE operation demonstrated at the Property and as supplemented by the technology screening comparisons summarized here, EES believes that expansion of SVE components into the areas outside of the Property boundary provides a reasonable, low-impact and effective remedy. Therefore, a more formal Feasibility Study is not anticipated as recommended for this Site cleanup.

In an effort to address MTCA cleanup requirements and achieve Method B unrestricted use criteria throughout the Site, EES recommends expansion of the existing SVE system to target the remaining gasoline impacts under the adjacent right-of-way area. In an effort to demonstrate vapor intrusion protectiveness, MTCA Method A criteria will be the remediation target for gasoline-related volatiles in Site soils.

The use of horizontal SVE wells is expected to be effective and implementable, with minimal disturbance or disruption to ongoing facility and right-of-way operations. SVE wells can easily and inexpensively be converted for bioventing, if necessary. If MTCA Method A and/or B cleanup goals are not achievable in a reasonable restoration timeframe, then an environmental covenant may be utilized to establish protective conditions and achieve satisfactory right-of-way cleanup.

ATTACHMENTS

Figure 1: Vicinity Map
Figure 2a: Site Features
Figure 2b: Utility Layout
Figure 3: SVE System Layout
Figure 4a: Maximum Gasoline Concentrations in Soil (2011-2012)
Figure 4b: Maximum Gasoline Concentrations in Soil (September 2015)
Figure 5: North-South Cross Section A-A' (September 2015)
Figure 6: Area Targeted for Remediation

Table 1: Remedial Technology Screening

REFERENCES

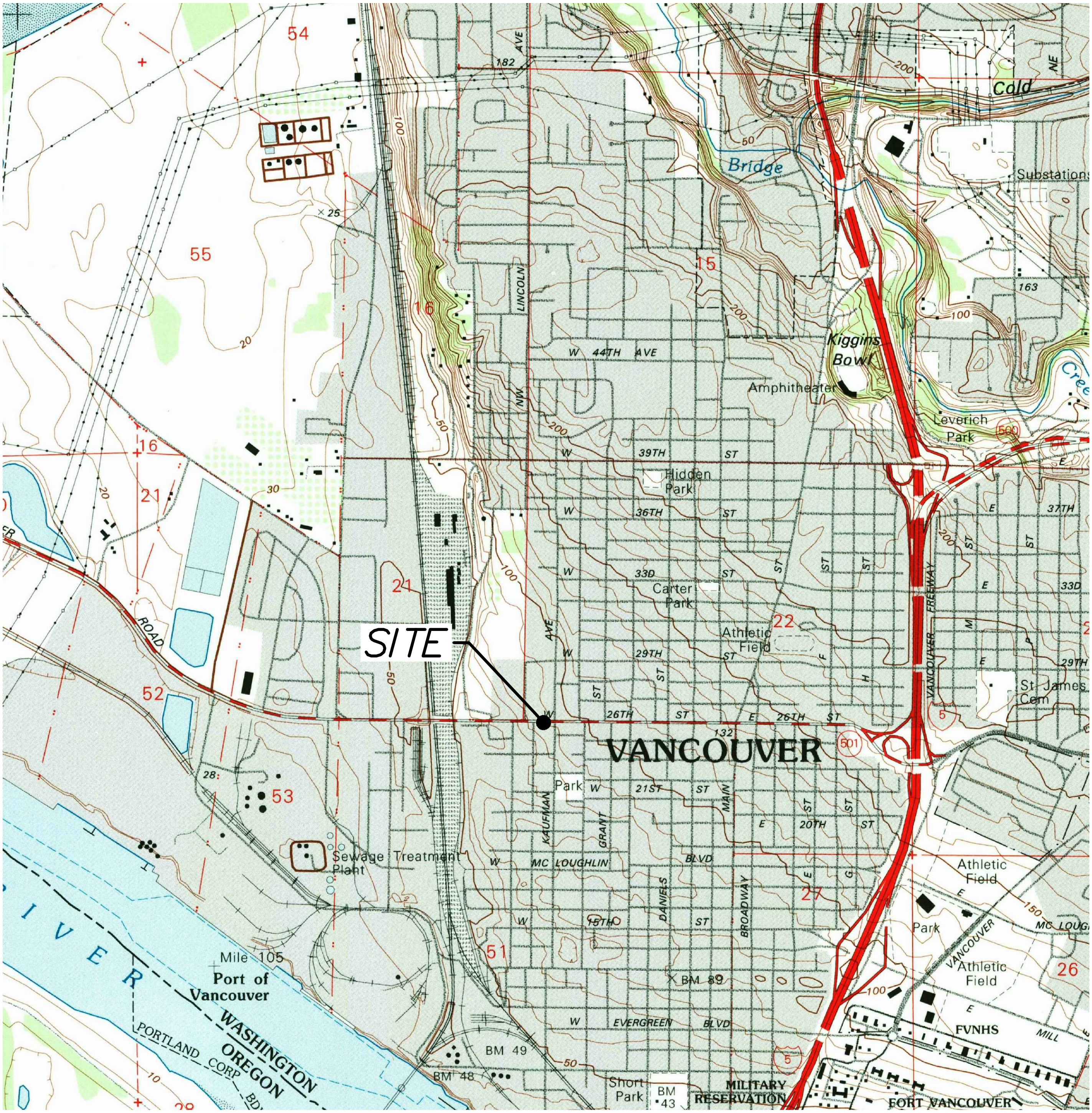
EES, 2014. *Interim Action Status Report – Plaid Pantry Store #112*. EES Environmental Consulting. February 3, 2014.

EES, 2017. *Technical Memorandum, Vapor Intrusion Assessment - Plaid Pantry Store #112*. EES Environmental Consulting. May 18, 2017.

EES, 2018a. *Remedial Investigation Report*. EES Environmental Consulting. September 19, 2018.

EES, 2018b. *Technical Memorandum, Status Report – SVE Monitoring (Second Quarter 2018)*. EES Environmental Consulting. July 31, 2018.

Figures



SOURCE:
USGS, VANCOUVER QUADRANGLE
WASHINGTON–OREGON
7.5 MINUTE SERIES (TOPOGRAPHIC)

N

APPROXIMATE SCALE IN FEET

0 1000 2000 4000

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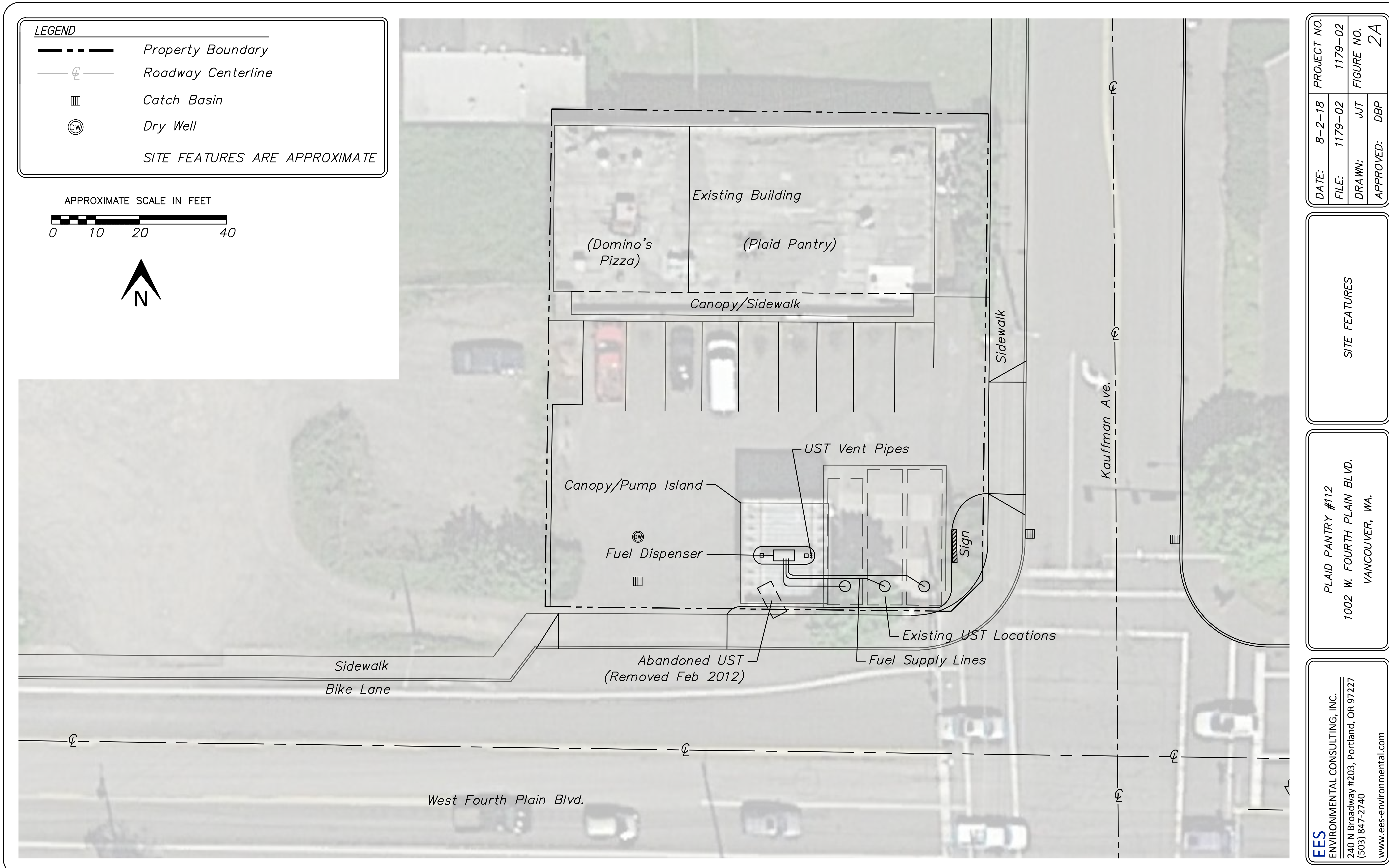
VICINITY MAP

PLAID PANTRY #112
1002 W. FOURTH PLAIN BLVD.
VANCOUVER, WA.

DATE:	8–2–18	PROJECT NO.	
FILE:	1179–02	1179–02	
DRAWN:	JJT	FIGURE NO.	
APPROVED:	DBP	1	


LEGEND
Property Boundary
Roadway Centerline
Catch Basin
Dry Well
SITE FEATURES ARE APPROXIMATE
APPROXIMATE SCALE IN FEET
0 10 20 40
N
Existing Building
(Domino's Pizza)
(Plaid Pantry)
Canopy/Sidewalk
Sidewalk
Kauffman Ave.
UST Vent Pipes
Canopy/Pump Island
Fuel Dispenser
Sign
Existing UST Locations
Fuel Supply Lines
Abandoned UST (Removed Feb 2012)
Sidewalk
Bike Lane
West Fourth Plain Blvd.
DATE: 8-2-18
FILE: 1179-02
DRAWN: JJT
APPROVED: DBP
PROJECT NO. 1179-02
FIGURE NO. 2A
SITE FEATURES
PLAID PANTRY #112
1002 W. FOURTH PLAIN BLVD.
VANCOUVER, WA.
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LEGEND

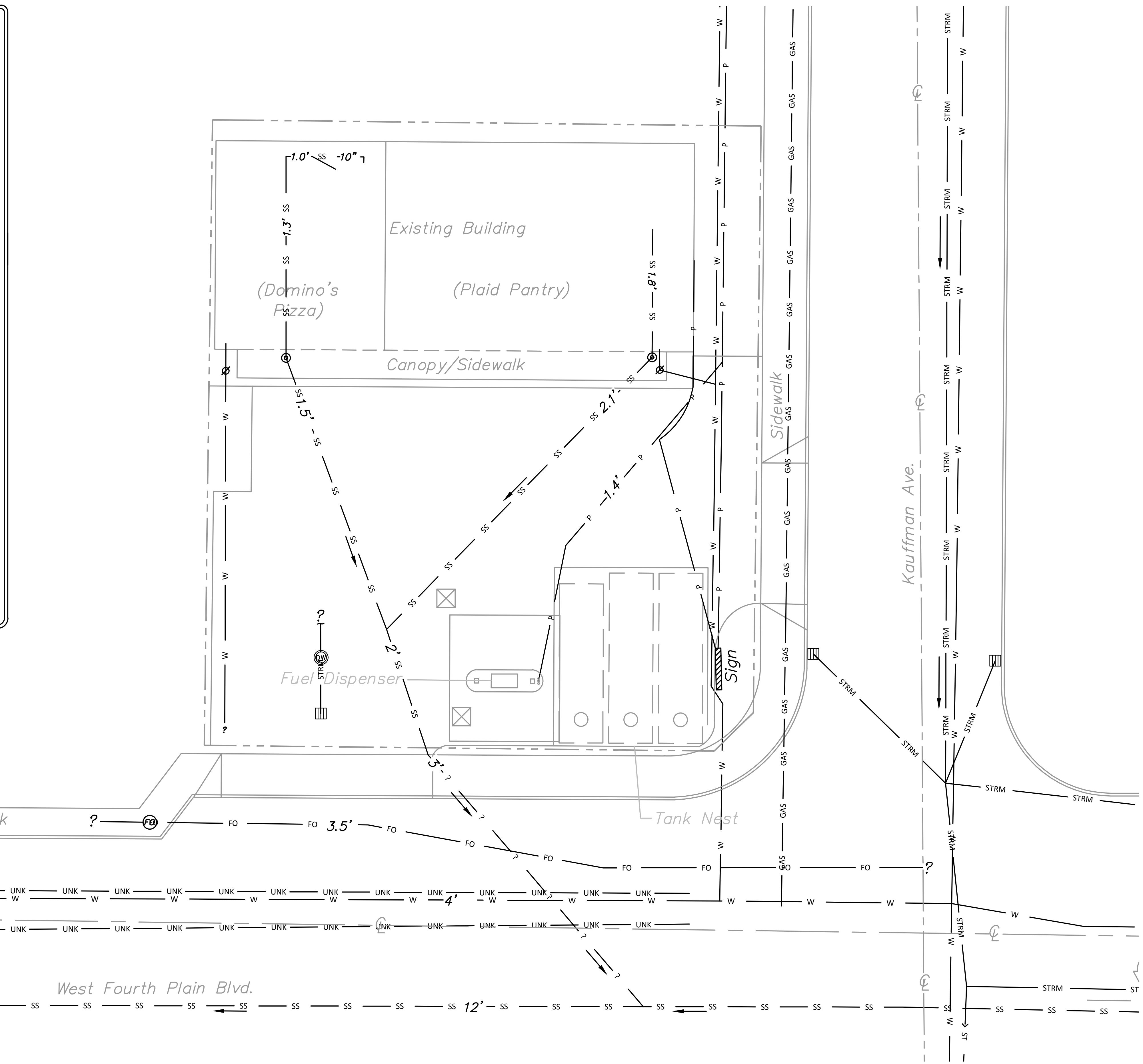
- Property Boundary
- Roadway Centerline
- Catch Basin
- Dry Well
- Vault
- W — Water Line
- SS — Sanitary Sewer
- STRM — Storm Sewer
- P — Power
- GAS — Natural Gas
- UNK — Unknown Utility
- FO — Fiber Optic
- Arrows Indicate Utility Flow Direction Where Known
- Water Shutoff Valve
- Sewer Cleanout
- Approximate Utility Depths Indicated Where Known (Feet)

SITE FEATURES ARE APPROXIMATE

APPROXIMATE SCALE IN FEET

0 10 20 40

N



PROJECT NO. 1179-02

FIGURE NO. 2B

DATE: 8-2-18

FILE: 1179-02

DRAWN: JJT

APPROVED: DBP

UTILITY LAYOUT

PLAID PANTRY #112
1002 W. FOURTH PLAIN BLVD.
VANCOUVER, WA.

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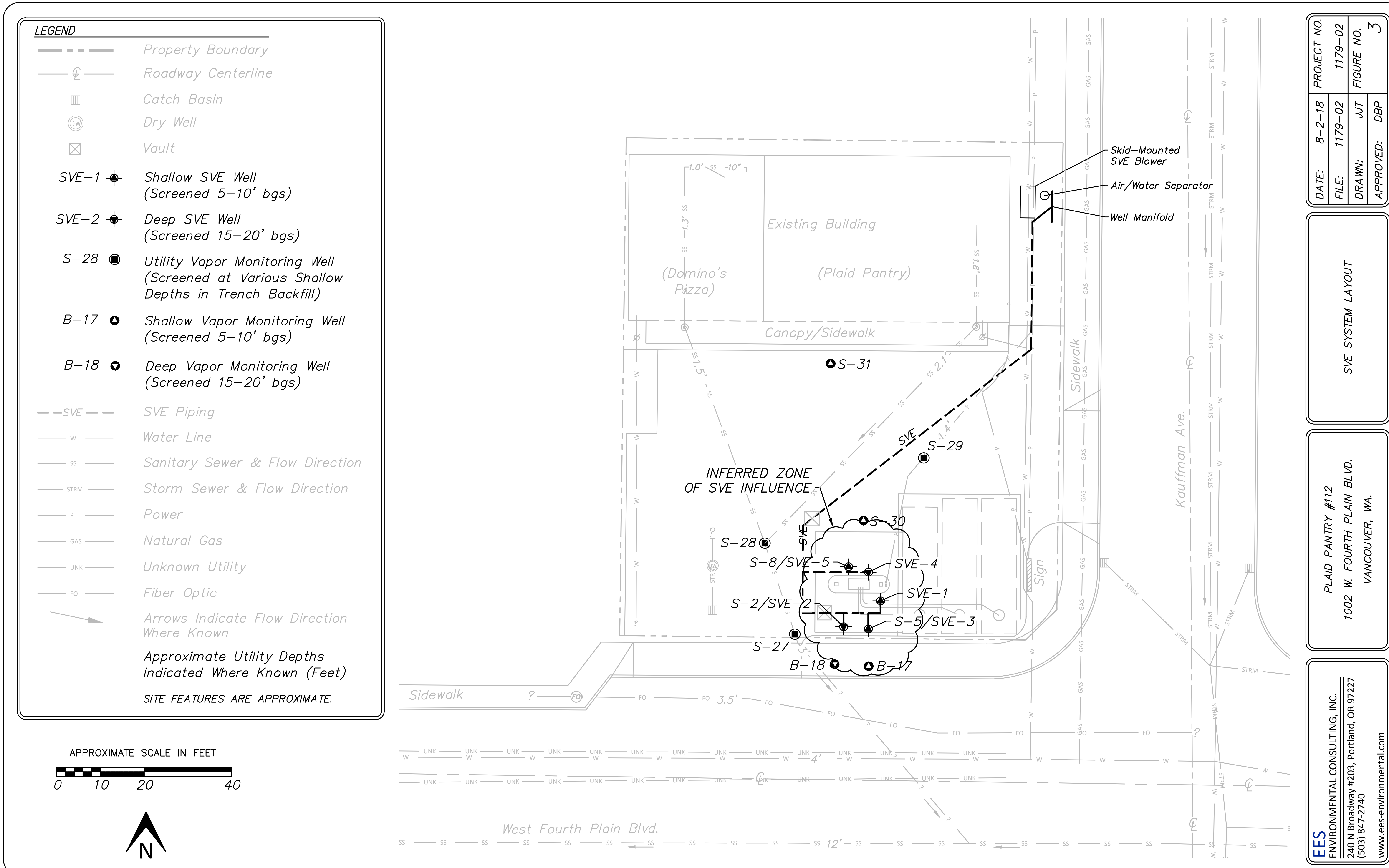
LEGEND
Property Boundary
Roadway Centerline
Catch Basin
Dry Well
Vault
SVE–1 Shallow SVE Well (Screened 5–10' bgs)
SVE–2 Deep SVE Well (Screened 15–20' bgs)
S–28 Utility Vapor Monitoring Well (Screened at Various Shallow Depths in Trench Backfill)
B–17 Shallow Vapor Monitoring Well (Screened 5–10' bgs)
B–18 Deep Vapor Monitoring Well (Screened 15–20' bgs)
SVE Piping
Water Line
Sanitary Sewer & Flow Direction
Storm Sewer & Flow Direction
Power
Natural Gas
Unknown Utility
Fiber Optic
Arrows Indicate Flow Direction Where Known
Approximate Utility Depths Indicated Where Known (Feet)
SITE FEATURES ARE APPROXIMATE.
APPROXIMATE SCALE IN FEET
0 10 20 40
N
Existing Building
(Domino's Pizza)
(Plaid Pantry)
Canopy/Sidewalk
Skid–Mounted SVE Blower
Air/Water Separator
Well Manifold
S–31
S–29
S–30
S–28
S–27
S–8/SVE–5
SVE–4
SVE–1
S–2/SVE–2
S–5/SVE–3
B–18
B–17
INFERRED ZONE OF SVE INFLUENCE
SVE
Sign
Sidewalk
Kauffman Ave.
West Fourth Plain Blvd.
DATE: 8–2–18
FILE: 1179–02
DRAWN: JJT
APPROVED: DBP
PROJECT NO. 1179–02
FIGURE NO. 3
SVE SYSTEM LAYOUT
PLAID PANTRY #112
1002 W. FOURTH PLAIN BLVD.
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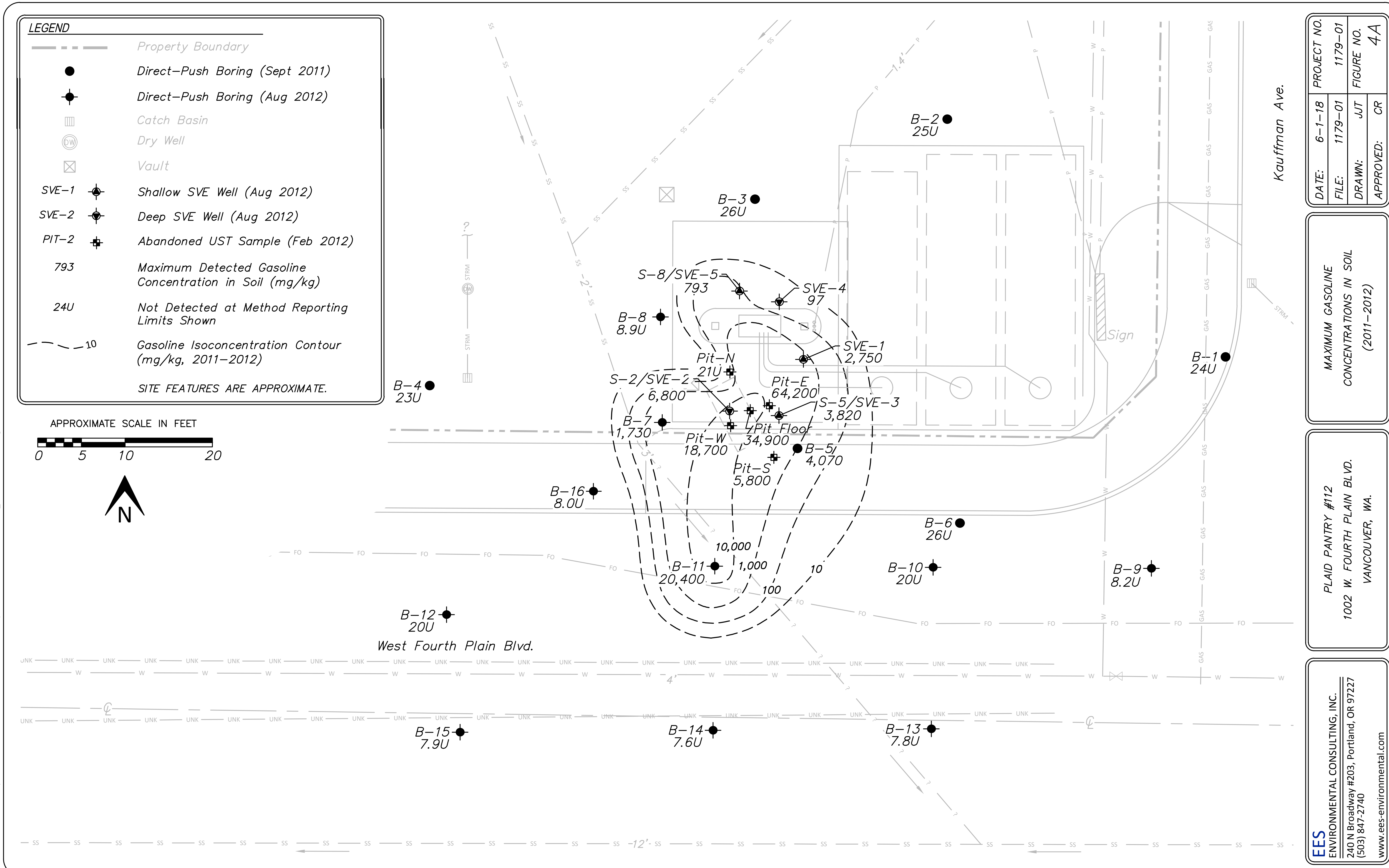

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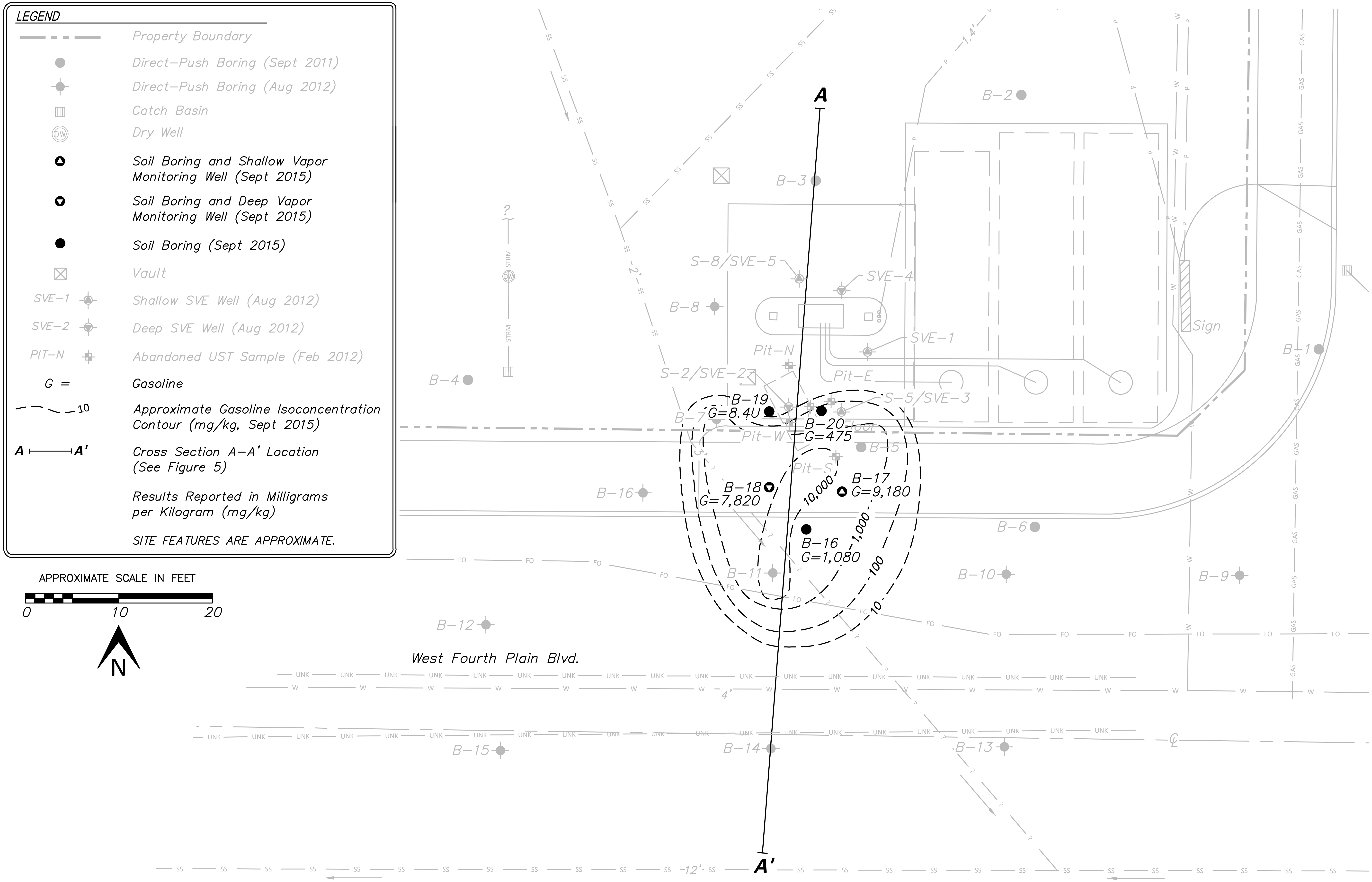

MAXIMUM GASOLINE CONCENTRATIONS IN SOIL (SEPTEMBER 2015)

PROJECT NO.	1179–01
FIGURE NO.	4B
DATE:	6–1–18
FILE:	1179–01
DRAWN:	JJT
APPROVED:	CR

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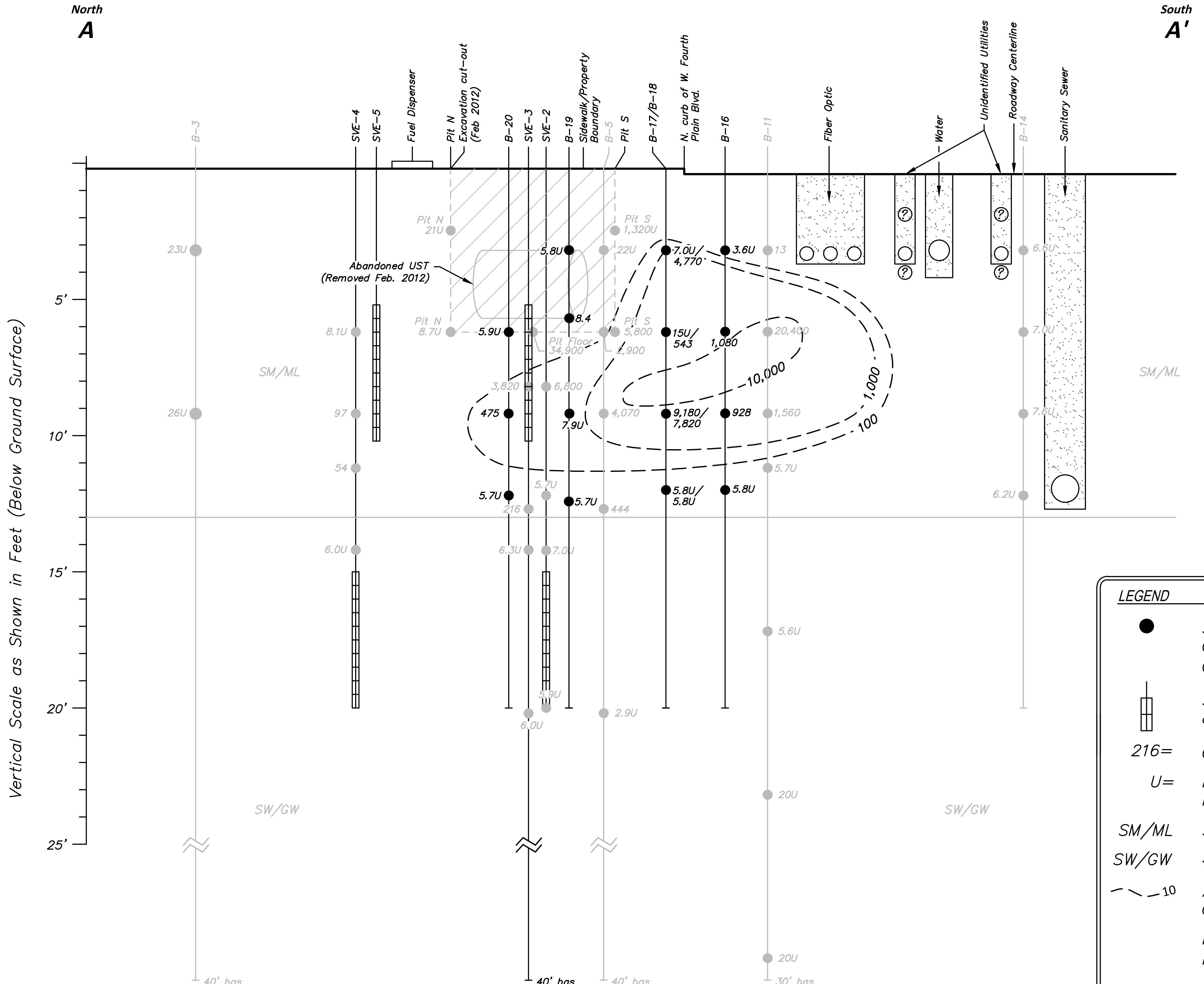

APPROXIMATE SCALE IN FEET

0 4 8 16

LEGEND

●	Soil Sample (Data shown in Black Collected in 2015. Data shown in Gray Collected in 2011–2012)
(well symbol)	SVE – Soil Vapor Extraction Well and Screened Interval
216=	Gasoline Concentration (mg/kg)
U=	Not Detected Above Method Reporting Limit
SM/ML	Sandy Silt/Silty Sand
SW/GW	Sand & Gravels
— — 10	Approximate Gasoline Isoconcentration Contour (mg/kg, Sept 2015)
	Results Reported in Milligrams per Kilogram (mg/kg)

SITE FEATURES ARE APPROXIMATE.

DATE: 6-1-18
FILE: 1179-01
DRAWN: JJT
APPROVED: CR
PROJECT NO. 1179-01
FIGURE NO. 5

NORTH–SOUTH CROSS SECTION A–A'
(SEPT. 2015)

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1002 W. FOURTH PLAIN BLVD.
VANCOUVER, WA.

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LEGEND

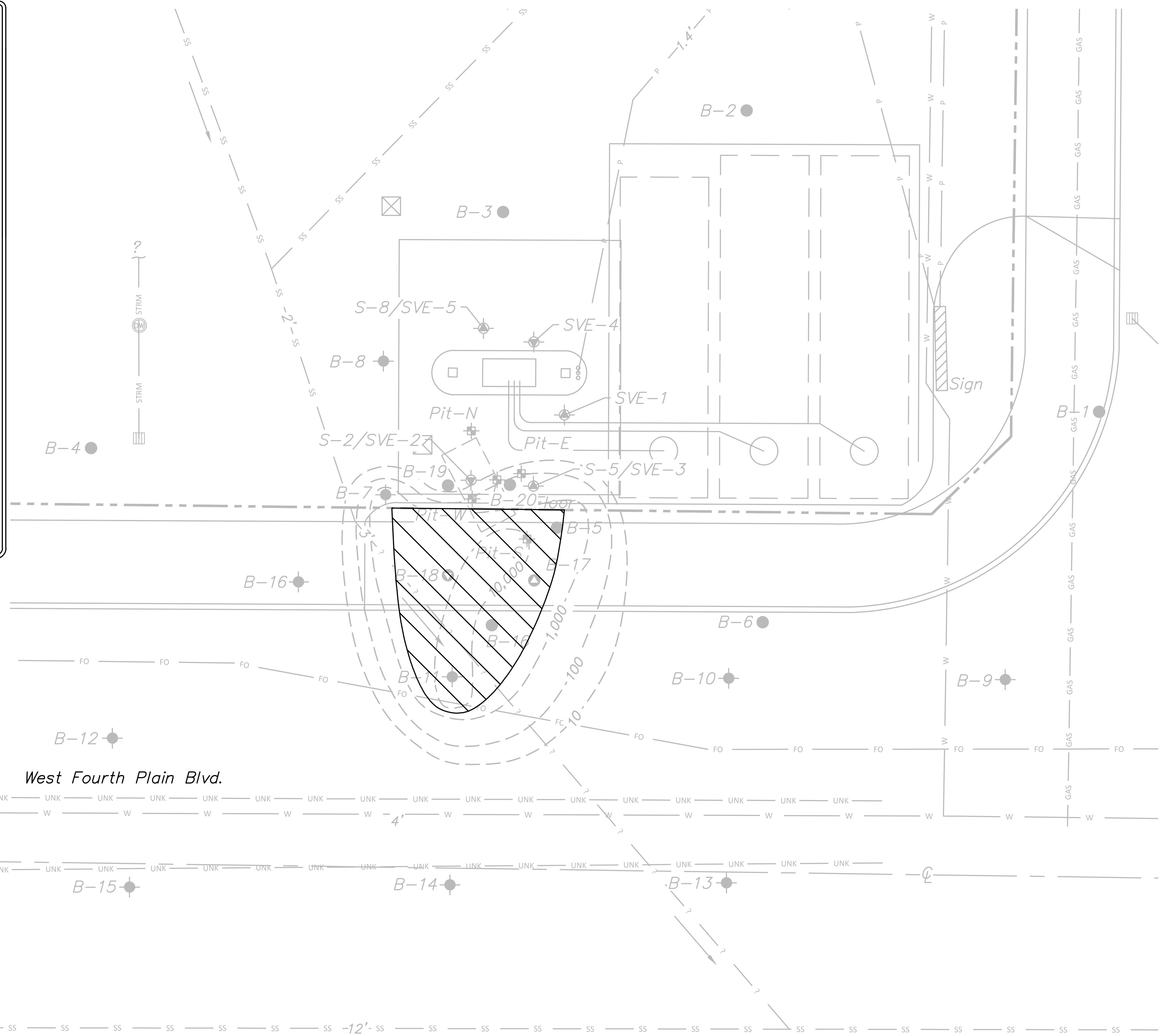
— · · —	Property Boundary
●	Direct–Push Boring (Sept 2011)
⊕	Direct–Push Boring (Aug 2012)
▥	Catch Basin
(DW)	Dry Well
▲	Soil Boring and Shallow Vapor Monitoring Well (Sept 2015)
▼	Soil Boring and Deep Vapor Monitoring Well (Sept 2015)
●	Soil Boring (Sept 2015)
☒	Vault
SVE–1	Shallow SVE Well (Aug 2012)
SVE–2	Deep SVE Well (Aug 2012)
PIT–N	Abandoned UST Sample (Feb 2012)
— — 10	Approximate Gasoline Isoconcentration Contour (mg/kg, Sept 2015)
(hatched)	Area Targeted for Remediation

SITE FEATURES ARE APPROXIMATE.

APPROXIMATE SCALE IN FEET

0 10 20

N



PROJECT NO. 1179–02

FIGURE NO. 6

DATE: 8–8–18

FILE: 1179–02

DRAWN: JJT

APPROVED: CR

AREA TARGETED FOR REMEDIATION

PLAID PANTRY #112

1002 W. FOURTH PLAIN BLVD.

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Tables

TABLE 1
REMEDIAL TECHNOLOGY SCREENING
Plaid Pantry #112
Vancouver, Washington

Remedial Technology	General Approach	Feasibility / Implementability	Effectiveness	Limiting Conditions	Relative Cost	Retain or Reject
In-Situ Treatment Options						
Soil Vapor Extraction via Horizontal Wells	Soil vapor from impacted zone is extracted via horizontal well(s) installed via directional drilling. A vacuum is induced in the targeted zone by an aboveground blower connected to the well(s), and effluent vapors are treated (if necessary) by either granular activated carbon or thermal/catalytic oxidation to achieve emissions requirements.	Good. This is a widely accepted technology that is easily implementable using widely available materials and equipment. Additionally, this site has existing spare conveyance piping installed in vaults directly adjacent to the dispensers available for use, which will minimize implementation costs and disruption.	Good. The existing SVE system has proven to be effective for source area treatment via existing wells SVE-1 through SVE-5. SVE treatment of contaminated soils below the southern right of way will likely require 2 to 3 years to achieve cleanup goals.	The impacted zone targeted for treatment contains lower permeability soil that could be more difficult to treat via SVE. Off-gas treatment costs could be high during the initial operating period.	Moderate. Moderate capital costs for well and equipment installation; relatively low operations and maintenance (O&M) costs.	Retain
Bioventing via Horizontal Wells	Bioventing involves the low-pressure injection of a gas (typically air or oxygen) into the subsurface to enhance biodegradation of the contaminants. For hydrocarbons, the gas is used to maintain aerobic conditions in the targeted treatment zone for optimal biodegradation. Aerobic bioventing is a widely accepted remedial approach for treatment of petroleum hydrocarbons.	Moderate. This approach is easily implementable using widely available materials and equipment, and existing spare conveyance piping could be used to minimize implementation costs. Some lower volatility hydrocarbons are not easily removed via SVE and can be treated by bioventing via aerobic degradation. Bioventing can be implemented as a polishing approach after SVE has removed the volatile hydrocarbon components.	Moderate. This approach is most effective in permeable and homogenous soils where oxygen is limited in the targeted treatment zone.	Gas distribution is limited in heterogeneous or lower permeability soils where the gas flow is limited to higher permeability zones, potentially leaving some soils untreated. This approach is only effective for impacted zones that are aerobically biodegradable. The relatively shallow depth of the contaminated zone and proximity relative to multiple buried utilities presents potential pathways for vapor migration.	Low to moderate. Moderate capital costs for well and equipment installation; relatively low O&M costs; off-gas treatment will likely not be necessary.	Retain
Soil Flushing	Soil flushing involves flooding a zone of contamination with an appropriate solution (e.g. surfactant/polymer mixture) to remove the contaminant from the soil. After passing through the contamination zone, the contaminant-bearing fluid is collected and brought to the surface for disposal or treatment/recirculation.	Poor. Soil flushing is most effective in relatively homogenous and permeable soil. For lower permeability soils, a high-induced gradient is required to move the fluids, which requires a large injection volume and longer implementation time. Additionally, given the depth to water (>60 feet bgs) and large depth interval of unsaturated soils, complete hydraulic capture of the injection fluids would be challenging requiring multiple wells targeting various depth intervals within the impacted area in Fourth Plain Blvd.	Poor. This approach is less effective in lower permeability soil that may limit contact between the treatment solution and the contaminated soils. Good hydraulic control is required throughout the targeted treatment zone, which is difficult in vadose zone soils. Other soil factors such as high buffering capacity, high organic soil content, and pH may limit the effectiveness.	Complex implementation due to limited access in the impacted area under Fourth Plain Blvd. Flushing fluids will increase contaminant mobility and there is a high risk of impacting the underlying groundwater.	Moderate. Moderate capital costs for well installation, moderate implementation costs for remedial subcontractor, fluid treatment/disposal, and permitting.	Reject
Soil Mixing	Contaminated soil is mixed with ambient air, dilute hydrogen peroxide, and/or other oxidant compounds using augers or specialized excavator arm to oxidize VOCs.	Moderate. Soil mixing with in-situ chemical oxidation is well suited to heterogeneous soils or relatively low permeability soils since the mixing provides greater opportunity for chemical oxidant contact and reaction with contaminants. Soil mixing with chemical oxidation is an evolving technology, and several vendors are capable of implementing the technology. However, regionally there may be limited vendors or contractors with the specialized equipment and/or substantial experience. Most cost-effective when treatment depths are relatively shallow (i.e., less than 30 to 40 ft.).	Moderate. Accelerated treatment with relatively short implementation time-frame. Requires use of vendors or contractors with specialized equipment for soil mixing and simultaneous introduction of the chemical oxidant. Soil with high organic carbon content are more difficult to treat. High organic carbon content soils require greater amounts of oxidant with corresponding greater treatment time frames and costs. Implementation often requires Underground Injection Control permitting and/or regulatory approval, as well as greater safety precautions with handling strong oxidants.	Extensive health and safety considerations due to targeted area in roadway within utility corridor. Subsurface infrastructure would extend into Fourth Plain Boulevard and require extensive coordination with utility companies, county, and local officials.	High capital costs. Much higher costs than SVE alone.	Reject
Electrical Resistance Heating	Electrical resistance heating uses an array of electrodes to pass electrical current through subsurface soils to heat the treatment zone. Vapors volatilize from the contaminated soils and are extracted via SVE and steam recovery. The heating enhances biodegradation which treats the residual lower volatility contamination remaining after the system is shutdown.	Moderate. Uses heating electrodes which require large amounts of electricity to volatilize hydrocarbons, and also requires steam and vapor recovery systems. Volatilization and steam stripping with SVE-capture are the primary removal mechanisms, which require emissions and fluid discharge treatment. This is a highly specialized technology and there are only a few qualified vendors with implementation experience.	Good. Accelerated treatment with relatively short implementation time-frame. Heat conducts preferentially in fine-grained soils. Highly effective in vadose zone soils.	Energy intensive. Very high capital costs for implementation. Vadose zone soils require water injection at the electrodes to maintain moisture content and electrical conductivity. Extensive health and safety considerations due to targeted area in roadway within utility corridor. Subsurface infrastructure would extend into Fourth Plain Boulevard and require extensive coordination with utility companies, county, and local officials.	High capital and utility costs. Much higher costs than SVE alone.	Reject
Conductive Heating	Conductive heating uses an array of vertical heater wells to heat the subsurface soils within the treatment zone. The heater well array typically consists of groups of heater wells surrounding one central vapor/steam extraction well. The heating enhances biodegradation which treats the residual lower volatility contamination remaining after the system is shutdown.	Moderate. Uses electrical powered heating coil or (other alternate heat source) which require large amounts of electricity or natural gas to volatilize hydrocarbons, and also requires steam and vapor recovery systems. This is a highly specialized technology and there are only a few qualified vendors with implementation experience.	Good. Accelerated treatment with relatively short implementation time-frame. Highly effective in vadose zone soils. Heat conducts preferentially in fine-grained soils, however higher temperatures generated by conductive heating can cause silt and clay to shrink and crack potentially causing subsidence.	Energy intensive. Extensive health and safety considerations due to targeted area in roadway within utility corridor. Subsurface infrastructure would extend into Fourth Plain Boulevard and require extensive coordination with utility companies, county, and local officials.	High capital and utility costs. Much higher costs than SVE alone.	Reject
Radio-frequency Heating	Radio-frequency heating uses a high frequency alternating electric field for in situ heating of soils. The technique depends on the presense of dielectric materials with unevenly electrical charges.	Low to moderate. RF technology can be implemented in most soil types for treatment of hydrocarbon impacts. An array of electrodes is installed targeting the treatment zone, and impacted vapors created by RF heating are recovered via SVE. This is a highly specialized technology and there are only a few qualified vendors with implementation experience.	Good. Effective in most soil types, and good for vadose zone soils with low to moderate soil moisture content.	Moderately energy intensive. Subsurface infrastructure would extend into Fourth Plain Boulevard and require extensive coordination with utility companies, county, and local officials.	High capital costs. Moderate energy costs. High O&M costs. Higher costs than SVE alone.	Reject
Steam Injection/Extraction	Steam is injected via a network of wells into the treatment zone to reduce viscosity and volatize hydrocarbons. Extraction wells are used to recover the mobilized groundwater, contaminants, and vapors.	Low to moderate. Steam injection is only viable in permeable soils. Requires steam and vapor recovery systems. Potential for subsidence problems due to higher injection pressures (above overburden pressure).	Good in sands and permeable soils. Poor in clays and organic rich soils. Interbedded sands and silts would lead to preferential pathways, preventing direct contact with all contaminants.	Energy intensive. High risk of vapor migration via steam injection due to the shallow target area in close proximity to utility corridor. Subsurface infrastructure would extend into Fourth Plain Boulevard and require extensive coordination with utility companies, county, and local officials.	High capital costs. Energy intensive. High O&M costs (requires onsite certified boiler operator whenever system is running). Higher costs than SVE alone.	Reject
Ex-Situ Treatment Options						
Excavation and Off-Site Disposal	Excavate impacted soils and transport off-site to appropriate disposal facility.	Poor to moderate. Excavation is best suited for impacted zones that are 1) unobstructed by surface features, 2) relatively shallow (<50 feet) to minimize the volume of overburden soils that must be removed to access the impacted soils, 3) do not extend offsite onto private property or public ROW, and 4) do not extend vertically at a significant depth below the water table to minimize the need for dewatering.	Good - excavation is a reliable and permanent remedial approach with a short implementation timeframe. Given that the vertical and lateral extent of the remaining soil impacts under Fourth Plain Boulevard is well delineated, there is a high likelihood that cleanup goals will be achieved quickly.	Impacted zone targeted for treatment/removal extends offsite under Fourth Plain Blvd where there are multiple buried utilities and surface obstructions (e.g. sidewalk).	Very high due to uncertainty of access/permitting issues, buried utility removal/replacement, traffic control, road resurfacing and sidewalk replacement, shoring design, and structural backfill / compaction requirements.	Reject

NOTES

1. Only remedial technologies applicable to vadose zone soil treatment were considered for screening. Saturated zone treatment approaches including (but not limited to) air sparging, in situ chemical oxidation, ozone/oxygen injection, bioamendments/nutrient injection, carbon slurry injection, and others are not feasible approaches for treating impacted soils with minimal pore-water present.