RISK ASSESSMENT SUPPORT FOR VAPOUR SAMPLING AT DEL AIR LODGE SENIORS CENTRE MANNING, ALBERTA

Final REPORT

October 2023

Prepared for: **Alberta Social Housing Corporation**

Attention: Brent Breakey

c/o:

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Table of Contents

Page

List of Tables

Page

List of Appendices

1.0 INTRODUCTION

ParklandGEO Ltd. (ParklandGEO) asked Intrinsik to complete a risk assessment of indoor air quality to aid with the assessment of petroleum hydrocarbon (PHC) vapour concentrations (i.e., indoor and sub-surface, or sub-slab) that have been measured at the Del Air Lodge Seniors Centre expansion located at 202 – 1 Avenue SW in Manning, Alberta. In 2022 an expansion to the existing seniors centre was being constructed on the adjacent lot to the east. During basement excavation, strong hydrocarbon odours and a sheen on pooling groundwater were identified and the samples of hydrocarbon impacts were greater than the Alberta Tier 1 Soil and Groundwater Remediation Guidelines for soil and groundwater. The concentrations were greater than the vapour inhalation guidelines (i.e., basement and slab-on-grade) for the protection of the indoor inhalation exposure pathway. Additional environmental investigations were completed to determine the extent of the soil and/or groundwater impacts on the Property and to help identify the potential off-site sources and these investigations are describe under separate cover (ParklandGEO 2023). As delineation of impacts in soil and groundwater are incomplete the environmental information is not suitable for regulatory submission; however, the aim of this inhalation assessment was to evaluate the inhalation risks to the occupants of the Senior Centre (i.e., patrons, visitors and workers). The Seniors Centre (i.e., Del Air Lodge) consists of a two-storey building located on the centre of the property and most of the building is constructed slab-on-grade and a section in the centre has a basement for storage (e.g., cleaning, construction and maintenance supplies) and utilities (e.g., electrical boxes, water softener, heating and ventilation system). The expansion was completed to the existing building on the adjacent lot to the east and consists of a single storey building on a steel framed floor supported by concrete pilings within a crawlspace. Adjacent properties generally consisted of residential land use and the Notikewin River is located approximately 50 metres to the north.

The inhalation assessment is being completed for the Alberta Social Housing Corporation (ASHC). Based on previous environmental investigations (ParklandGEO 2022) the following has been reported:

- A series of former bulk fuel stations with ongoing monitoring for existing hydrocarbon impacts were present to the south of the Seniors Centre. No suspected sources of soil and groundwater contamination were reported or suspected on the Property based on the recent or current site use or developments (see Appendix A for site diagrams and sample locations).
- Based on discussion with Chandos Construction Ltd. staff, the impacted soil and groundwater appears to be present within a portion of the base soils and groundwater seepage from the excavation and around the screw piles already installed. The staining was most prevalent in the base of the excavation running from the southwest to northeast, extending from the central west portion of the south wall to the central east portion of the north wall.
- The contaminants of potential concern (COPC) were identified as BTEX (i.e., benzene, toluene, ethylbenzene and xylenes) and PHC fractions F1 and F2 (ParklandGEO 2022).
- The Senior Centre was constructed prior to 1969 and provides an indoor space on the main floor for residents to smoke tobacco, which would be considered a significant source that contributes to indoor air volatile organic compound (VOC) concentrations (Health Canada 2013; US EPA 2011; Zhu et al. 2013).

As a result of this impact, a soil and groundwater investigation was completed (ParklandGEO 2022) and the results prompted an assessment of vapour concentrations (i.e., BTEX and PHC fractions F1 and F2) in the sub-soil, crawl space and basement of the building (ParklandGEO

2023). Measured benzene concentrations were identified to be greater than the health-based exposure limit in each of the two vapour samples (AS-01 and AS-02) collected during this assessment. It is possible that indoor sources are contributing to these indoor concentrations, as such, Intrinsik recommended additional vapour testing (i.e., sub-soil and ambient basement/crawl space) to supplement monitoring, which over time can be used to assess air quality.

2.0 SOIL VAPOUR AND INDOOR QUALITY GUIDELINES

Sub-slab soil vapour quality guidelines (SVQGs) presented in Table 2-1 were developed according to the methods, assumptions and equations described in the following guidance documents:

- Alberta Tier 1 Soil and Groundwater Remediation Guidelines (Alberta Environment and Parks [AEP] 2022a)
- Alberta Tier 2 Soil and Groundwater Remediation Guidelines (AEP 2022b); and
- A Protocol for the Derivation of Soil Vapour Quality Guidelines for Protection of Human Exposures via Inhalation of Vapours (CCME 2014).

Appendix B and C present the detailed assumptions, methods and calculations that were used to derive the commercial and residential land use SVQGs. Appendix B identifies any precluding factors that would limit the use of the guidelines at the Seniors Centre (e.g., earthen basements or soil vapour sample more than 1 metre distance from the foundation of building).

In addition to sub-slab soil vapour samples, environmental investigations have also sampled air of the crawl space of the Seniors Centre; therefore, suggested indoor air quality guidelines are presented in Table 2-2. The interpretation of indoor air testing results for BTEX and PHCs is complicated by the multiple possible “background” sources that exist within a dwelling or building. Due to background sources of chemicals, concentrations in indoor air are frequently higher than in outdoor air and are commonly measured above regulatory exposure limits for the protection of human health. Therefore, Table 2-2 presents ranges (i.e., 5th to 95th percentile) and a central estimate (i.e., average) of indoor air concentrations that are expected in dwellings and commercial properties. The indoor air study completed by Zhu et al. (2013) investigated over 3,000 buildings across Canada.

Finally, aerobic degradation is active at the Site as the measured oxygen content of the soil vapour samples ranged from 18 to 21%. Chemicals biodegrade under both anaerobic and aerobic conditions, with aerobic degradation occurring much more rapidly for BTEX and PHC. According to the United States Environmental Protection Agency, with adequate oxygen supply, biodegradation of PHCs can occur relatively quickly and can result in substantial attenuation of PHC vapours over relatively short distances (US EPA 2015). Minimum oxygen levels of 2 to 5% oxygen by volume have been established to indicate that aerobic degradation is dominant (CCME 2014; PDEP 2015). Based on the oxygen content measured in the soil vapour (i.e., oxygen ranged from 18 to 21%), it is expected that aerobic biodegradation has been and will continue to be prevalent at the Site.

Table 2-1 Calculated Sub-soil Soil Vapour Quality Guidelines for the Site

Chemical (COPC)	Soil Vapour Quality Guideline (µg/m³) (1)	
	Residential	Commercial
Benzene	63	230
Toluene	110,000	420,000
Ethylbenzene	100,000	370,000
Xylenes (Total)	49,000	18,000
PHC F1 (2)	220,000	820,000
Aliphatic C6-C8	920,000	3,400,000
Aliphatic >C8-C10	50,000	190,000
Aromatic >C8-C10	10,000	37,000
PHC F2 (2)	45,000	170,000
Aliphatic >C10-C12	50,000	190,000
Aromatic >C10-C12	50,000	190,000
Aliphatic >C12-C16	10,000	37,000
Aromatic >C12-C16	10,000	37,000

(1) Appendix B presents detailed assumptions and methods used to calculate the SVQGs.
(2) Appendix C presents the calculated SVQGs for PHC F1 and F2.

Table 2-2 Indoor Air Quality Guidelines and Background Ranges in Buildings for Comparison in Indoor Air Testing Results

Chemical (COPC)	Concentration (µg/m³)			
	Indoor Air Quality Guideline (1)	Background (2)		
		5th Percentile	Average	95th Percentile
Benzene	0.63	0.23	1.9	7.4
Toluene	2,300	1.7	18	73
Ethylbenzene	2,000	0.25	4.2	14
Xylenes (Total)	100	1.2	19	73
PHC F1 (4)	4,400(6)	6	77	256
Aliphatic C6-C8	18,400	NA	91.1 (3)	NA
Aliphatic >C8-C10	1,000	NA	38.8 (3)	NA
Aromatic >C8-C10	200	NA	37.5 (3)	NA
PHC F2 (5)	900(6)	0.5	7	24.2
Aliphatic >C10-C12	1,000	NA	NA	NA
Aromatic >C10-C12	200	NA	NA	NA
Aliphatic >C12-C16	1,000	NA	NA	NA
Aromatic >C12-C16	200	NA	NA	NA

Notes:
NA indicates not available.

(1) Appendix B provides a more detailed description of the selected toxicity reference values.
(2) Background ranges derived from Zhu et al. (2013) unless noted otherwise.
(3) CCME (2008).
(4) Constituents of PHC F1 include: camphene, limonene, α-pinene, hexane, decane, heptane, naphthalene, 1-methylethylbenzene, 1,2,4-trimethylbenzene, and 1,2,3-trimethylbenzene.
(5) Constituents of PHC F2 include: dodecane and undecane.
(6) Methods and assumptions used to estimate PHC F1 and F2 indoor air quality guideline presented in Appendix C.

3.0 AIR QUALITY AND TOXICITY ASSESSMENT

Guidance from US EPA (2015) recommends a vapour attenuation factor of 1.0 (i.e., no dilution) for the risk-based screening of vapour intrusion from a crawl space. As such, and because the crawl space was assumed similar to a basement, measured air concentrations in the crawl space were directly compared against indoor air toxicity reference values (TRVs). TRVs are typically used for comparison against indoor air concentrations (i.e., direct exposure to indoor air as recommended by AEP 2022a) and are appropriate for comparison against air samples collected from the basement and/or crawl space.

Table 3-1 presents a summary of the air quality testing that has been completed to date at the Seniors Centre. The sampling methodology, laboratory analytical reports, and quality control testing for sample collection is described under separate cover (ParklandGEO 2023). Table 3-2 presents a comparison of the measured crawl space and basement air samples to indoor air TRV. Table 3-3 presents a comparison of the measured sub-soil vapour concentrations to SVQGs. Further discussion of the measured indoor air and soil vapour concentrations is provided below.

Table 3-1 Chronological Summary of Air Quality Testing at the Site for BTEX and PHC F1 and F2

Date	Sample Location				
	Sampling Type	AS-01, AM-01 & 22-03 (Crawl Space)(1)	AS-02 (Basement)	22-01 (Sub-soil)	22-02 (Sub-soil)
30-Nov-2022	Suma cannister	○	○	○	●
07-Dec-2022	Suma cannister	●	○	●	○
01-Mar-2023	Suma cannister	●	●	○	○
16-Aug-2023	Sorbent tube	●	○	●	●

Notes: ● Indicates sample collected; ○ Indicates sample not collected.
(1) Crawl space samples collected from the same general area or southeast corner of the crawl space.

Table 3-2 Measured Indoor Air Concentrations and Comparison to Guidelines

Sample	Date	Measured Basement and Crawlspace Air Concentrations [µg/m^3]					
		Benzene	Ethylbenzene	Toluene	Xylenes	F1 PHC	F2 PHC
22-03 (crawlspace)	2022-12-07	1.02	<0.87	<0.75	<1.80	<15.00	<15.00
AS-01 (crawlspace)	2023-03-01	1.28	<0.87	2.41	<1.80	164.00	<15.00
AS-02 (basement)	2023-03-01	2.75	<0.87	7.31	<1.80	368.00	<15.00
AM-01 (crawlspace)	2023-08-16	<1.0	<2.5	<5.0	<7.5	<500	<500
Guideline(1)		0.63	2,300	2,000	100	4,400	900

Notes: Highlighted values indicates an exceedance of the indoor air TRV. "<" indicates sample non-detect
(1) Described in Table 2-2.

Table 3-3 Measured Sub-soil Vapour Concentrations and Comparison to Guidelines

Sample	Date	Measured Sub-soil Vapour Concentrations [µg/m^3]					
		Benzene	Ethylbenzene	Toluene	Xylenes	F1 PHC	F2 PHC
22-02	2022-11-30	1.41	1.48	3.54	8.30	766	715
22-01	2022-12-07	1.12	0.87	0.75	1.80	33	<15
22-01	2023-08-16	<1.0	<2.5	<5.0	<7.5	2300	<500
22-02	2023-08-16	<1.0	<2.5	<5.0	<7.5	1200	<500
Residential Guideline(1)		63	110,000	100,000	49,000	220,000	45,000
Commercial Guideline(1)		230	420,000	370,000	18,000	820,000	170,000

Notes: "<" indicates sample non-detect
(1) Described in Table 2-1.

Except for benzene, air samples collected from the basement and crawlspace of the building did not exceed corresponding TRVs for the COPCs (see sample data in Appendix C). Measured indoor air concentrations of benzene ranged from <1.0 to 2.8 ug/m^3 in 2022 and 2023 and the samples exceeded the TRV of 0.63 ug/m^3 (AEP 2022a). Indoor tobacco is considered a known (US EPA 2011) and significant (Health Canada 2013) indoor source of benzene and likely the source within the building (US EPA 2011). In all instances, the sub-soil vapour samples were below the calculated SVQGs indicating that the sub-surface is unlikely to be a major contributing source to the indoor air via infiltration. In addition, the sub-surface oxygen levels were more than adequate (i.e., 18 to 21%) to support aerobic biodegradation of PHCs, which can occur quite rapidly. Based on these factors, risks to human health from sub-surface sources and indoor

vapour infiltration are expected to be low for both on-site residents, workers and guests, as well as off-site receptors.

The indoor air quality guideline for benzene is 0.63 μg/m^3 (AEP 2022a; Health Canada 2021 is exceeded frequently in indoor air as measured concentrations in Canada are expected to range from 0.23 to 7.4 μg/m^3 (5th and 95th percentiles reported by Zhu et al. 2013), respectively. The Zhu et al. (2013) study included a total of 84 volatile organic carbon (VOC) measurements using passive sampling from 3218 houses, 546 apartments, and 93 other dwelling types. The study had a sufficient sample size and power to include a statistical comparison of nonsmoking and smoking dwellings, and BTEX levels in smoking dwellings were consistently and significantly higher than nonsmoking dwellings.

The Health Canada (2021) TRV for benzene was recently updated and is one of the lowest among national and international regulatory agencies. The Health Canada TRV is based on the geometric mean of benchmark values obtained from two studies that are described in Table 3-4. In addition, Table 3-4 presents the basis of the inhalation carcinogenic US EPA and WHO TRV for benzene. The Health Canada TRV used to be based on the same data as the US EPA (i.e., Ohio Pliofilm cohort); however, recently the China cohort data were included as part of the guideline derivation. Although the Chinese cohort studies provided a large data set, their use in the derivation of TRV remains problematic for the following reasons:

- Concurrent exposures to many different chemicals found in the factories where the benzene exposure occurred; and
- Lack of reliable exposure information in the early days of the observation period, when only 3% of the exposure estimates were based on actual measurements.

The limitations of these studies, except for the Ohio Pliofilm cohort (Rinsky et al. 1981, 1987), preclude their use in quantitative risk estimation (US EPA 2000). The WHO (2000) notes that below 32 mg/m^3 there is only weak evidence of adverse effects (i.e., haematological effects - decreased red and white blood cell counts) in human workers occupationally exposed to high levels of benzene.

Table 3-4 Summary of Benzene Non-threshold Inhalation Toxicity Limits

Agency	RsC - Risk-specific Concentration(1)	Inhalation Unit Risk	Derivation Method
Health Canada (2021)	0.63 μg/m^3	0.016 (mg/m^3)$^{-1}$	Geometric mean of upper bound estimates of leukemia unit risk estimates from these studies: • Ohio Pliofilm cohort • Chinese cohorts
US EPA (2000)	1.3 to 4.5 μg/m^3	0.0022 to 0.0078 (mg/m^3)$^{-1}$	Low-dose linearity utilizing maximum likelihood estimates of leukemia from this study: • Ohio Pliofilm cohort
World Health Organization (2000)	1.7 μg/m^3	0.006 (mg/m^3)$^{-1}$	Geometric mean of the range of estimates of the excess lifetime risk of leukaemia from this study: • Ohio Pliofilm cohort

(1) Based on acceptable incremental lifetime cancer risk benchmark of 1 in 100,000 (AEP 2022a).

4.0 CONCLUSION

Except for benzene, air samples collected from the basement and crawlspace of the building did not exceed corresponding TRVs for the COPC. In addition, the sub-soil vapour samples were below the calculated SVQGs indicating that risks from the sub-surface are acceptable. Measured indoor air concentrations of benzene (i.e., basement and crawlspace) at the Senior Centre ranged from <1.0 to 2.8 $\mu g/m^3$, which are within the range of the acceptable US EPA risk -specific concentrations (1.3 to 4.5 $\mu g/m^3$); however, the concentrations are slightly above the recently published Health Canada limit of 0.63 $\mu g/m^3$. In all instances, the measured indoor air benzene concentrations were within the range of expected background levels that are reported to range from 0.23 to 7.4 $\mu g/m^3$ and it is well known that tobacco smoking would be a significant contributor to indoor concentrations of benzene. Based on these factors, risks to human health from COPC via vapour inhalation are expected to be low for both on-site residents and guests, as well as off-site receptors.

5.0 REFERENCES

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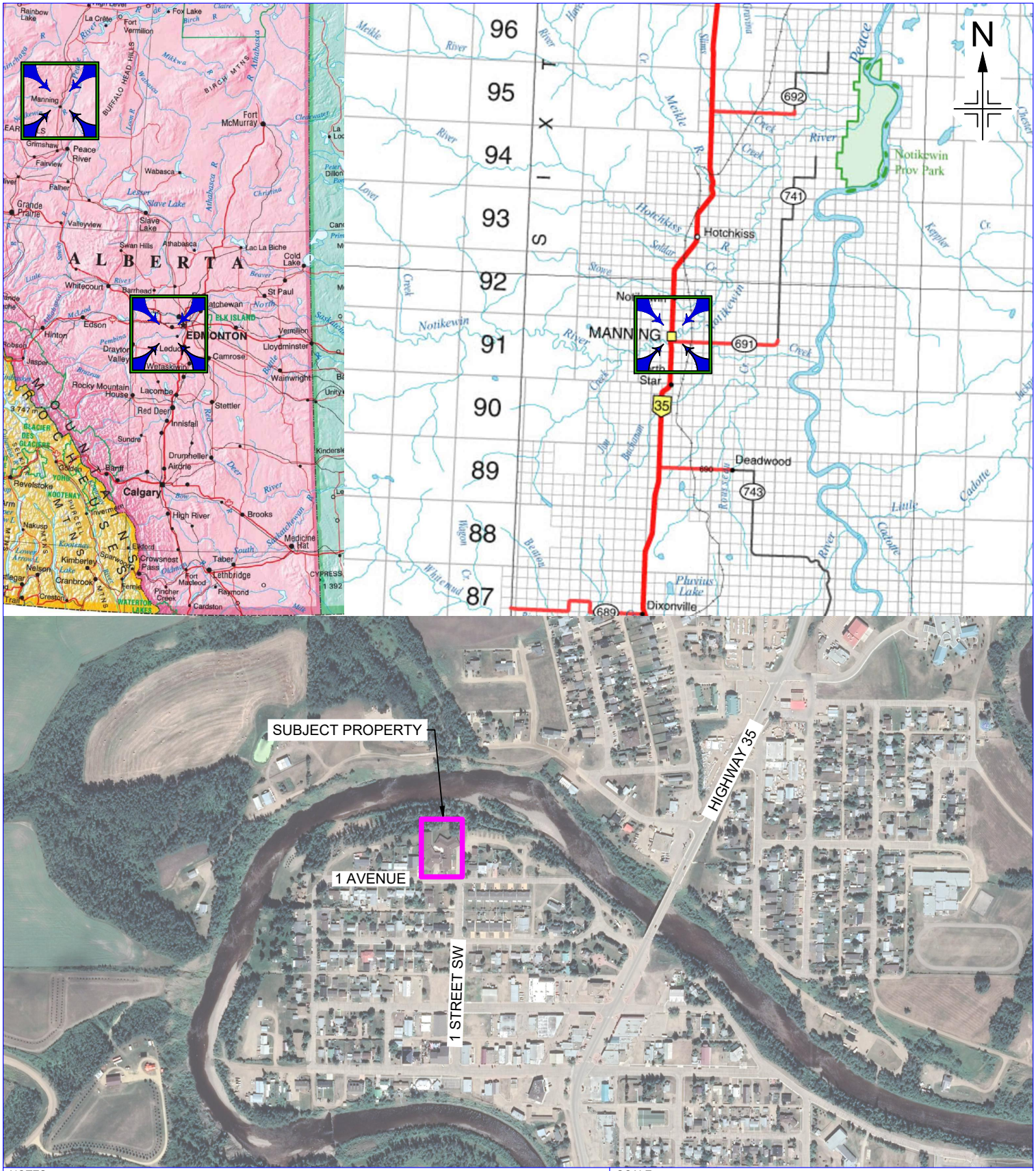
APPENDIX A

SITE DIAGRAMS



NOTES:

1. AERIAL PHOTOGRAPH FROM GOOGLE EARTH. JULY 10, 2021.

SCALE: NTS

ParklandGEO

CLIENT:

ALBERTA SOCIAL HOUSING CORPORATION

LOCATION PLAN

SUBGRADE AND INDOOR AIR VAPOUR MONITORING
202 - 1 AVENUE, MANNING, ALBERTA

DRAWN:	CHK'D.:	DATE:
MY	TG	SEPTEMBER 2023
PROJECT NO.	REV. NO.	FIGURE NO.
GP5996	0	1

NOTES:

1. AERIAL PHOTOGRAPH FROM GOOGLE EARTH. JULY 10, 2021.

SCALE: 0 10 20 40

SCALE (metres): 1:750

Parkland GEO

CLIENT:

ALBERTA SOCIAL HOUSING CORPORATION

AREA PLAN

SUBGRADE AND INDOOR AIR VAPOUR MONITORING
202 - 1 AVENUE, MANNING, ALBERTA

DRAWN:	CHK'D.:	DATE:
MY	TG	SEPTEMBER 2023
PROJECT NO.	REV. NO.	FIGURE NO.
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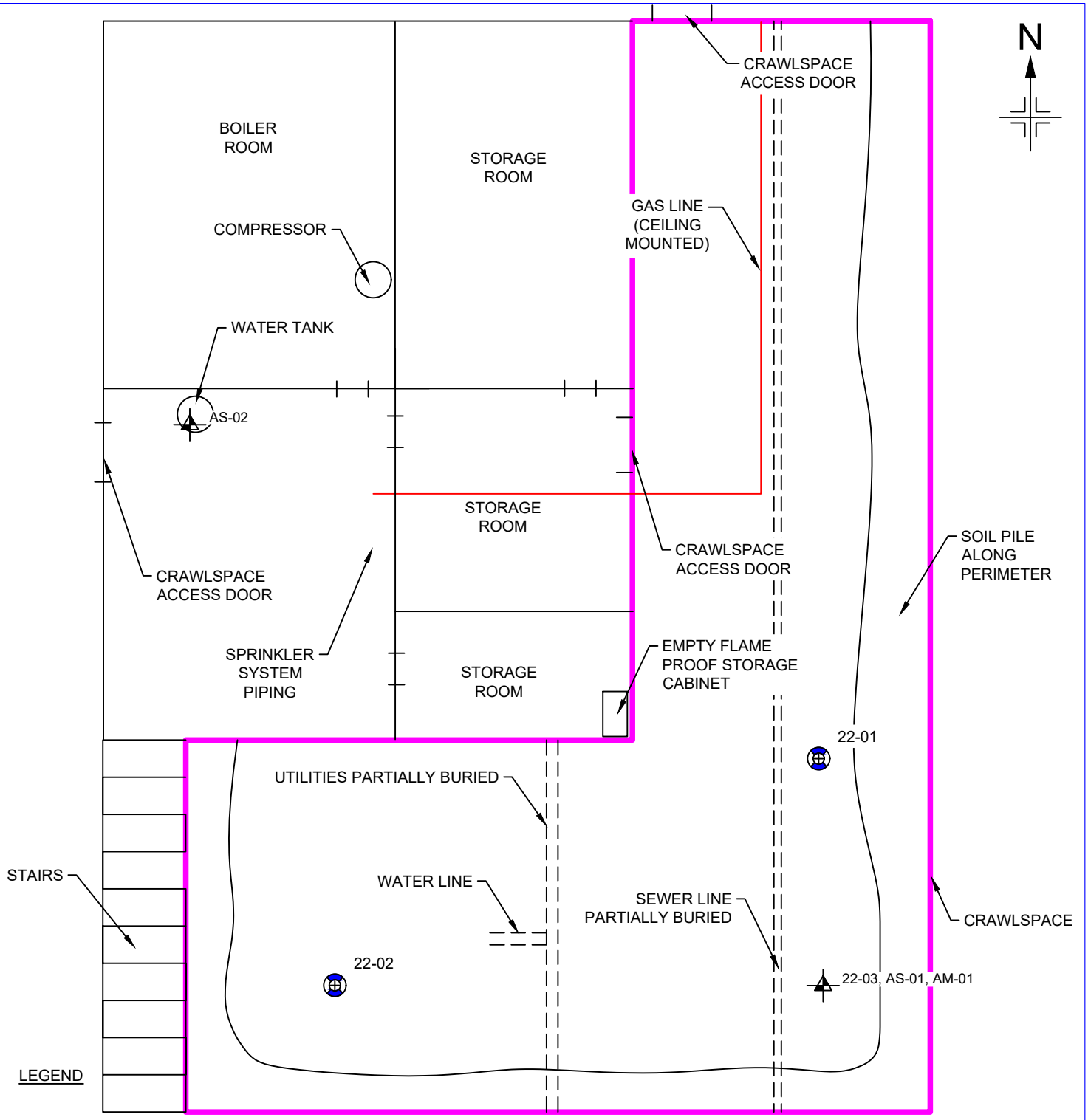

LEGEND:

- MONITORING WELL SAMPLING LOCATION
- PARKLAND VAPOUR MONITORING SAMPLING LOCATION

NOTES:

1. BUILDING EXTENTS ESTIMATED. DRAWING FOR VISUAL REPRESENTATION PURPOSES ONLY.

SCALE: 0 10 20 40

SCALE (metres): 1:1000

ParklandGEO

CLIENT:

ALBERTA SOCIAL HOUSING CORPORATION

SITE PLAN

SUBGRADE AND INDOOR AIR VAPOUR MONITORING
202 - 1 AVENUE, MANNING, ALBERTA

DRAWN:	CHK'D.:	DATE:
MY	TG	SEPTEMBER 2023
PROJECT NO.	REV. NO.	FIGURE NO.
GP5996	0	3

APPENDIX B

ASSUMPTIONS
AND
METHODS FOR CALCULATING
SOIL VAPOUR QUALITY GUIDELINES

APPENDIX B: **Appendix B: Development of Sub-Slab Soil Vapour Quality Guidelines**

TABLE OF CONTENTS

LIST OF TABLES

Appendix B: Development of Sub-Slab Soil Vapour Quality Guidelines for a Site in Alberta

1. INTRODUCTION

Intrinsik Corp. (Intrinsik) was retained by the Alberta Social Housing Corporation (ASHC) and c/o ParklandGEO Ltd (ParklandGEO) to develop soil vapour quality guidelines (SVQG) for the protection of indoor vapour inhalation that are applicable to a residential and commercial property called Del Aire Seniors Centre located at 202 – 1 Avenue SW in Manning, Alberta. Within a 30 m buffer of the Site are permanent residences; therefore, SVQG were also calculated for residential land use.

2. SOIL VAPOUR QUALITY GUIDELINES

Sub-slab SVQG were developed according to the methods, assumptions and equations defined in the following guidance documents:

- Alberta Tier 1 Soil and Groundwater Remediation Guidelines (Alberta Environment and Parks [AEP] 2022a)
- Alberta Tier 2 Soil and Groundwater Remediation Guidelines (AEP 2022b); and
- A Protocol for the Derivation of Soil Vapour Quality Guidelines for Protection of Human Exposures via Inhalation of Vapours (CCME 2014).

The following equations were used to calculate SVQG for the indoor air inhalation pathway (CCME 2014):

Threshold chemical $$SVQG = \frac{(RfC - C_{BKG}) \times AF \times BAF}{\propto \times ET}$$ ***(Equation 1)***

Non-threshold chemical $$SVQG = \frac{RsC \times BAF}{\propto \times ET}$$ ***(Equation 2)***

Where:

SVQG	=	soil vapour quality guideline for the protection of indoor air [µg/m³]
RfC	=	reference concentration [µg/m³]
C_{BKG}	=	background indoor air concentration [µg/m³]
AF	=	allocation factor [Unitless]
BAF	=	soil vapour bio-attenuation factor [Unitless], assumed = 1 (no biodegradation)
α	=	attenuation coefficient, default of 0.01 for depths <1 m (AEP 2022a)
ET	=	exposure term [Unitless]
RsC	=	risk-specific concentration [µg/m³]

Table 2-1 presents the major assumptions for input parameters used to calculate non-carcinogenic (threshold) and carcinogenic (non-threshold) SVQG. The calculated SVQG are suitable for screening soil vapour samples within 1 m the building foundation, including sub-slab soil vapour samples, and are applicable for coarse- and fine-grained soils. Table 2-2 presents the calculated SVQG for commercial and residential land use, developed for the protection of indoor vapour inhalation for the Site. A worked example for the calculation of the ethylbenzene SVQG is presented below in Section F4.0. Additional details regarding the assumptions and calculated SVQG are provided in Appendix C.

Table 2-1 Major Assumptions and Input Parameters for Calculating Sub-slab SVQG for Protection of Indoor Vapour Inhalation

Parameter	Non-carcinogenic (based on an RfC)	Carcinogenic (based on an RsC)	Rationale
Commercial Land Use			
Land use	Commercial (slab-on-grade)	Commercial (slab-on-grade)	Suitable land-use for site.
Depth	<1m	<1m	Default dilution factor was applied.
Alpha	0.01 (dilution factor of 100)	0.01 (dilution factor of 100)	Default attenuation coefficient for commercial buildings and soil-vapour samples less than 100cm distance to building (AEP 2022b).
Soil Vapour Bio-attenuation factor (BAF)	1 (assumed)	1 (assumed)	Conservatively assumed no biodegradation.
Background concentration (C_{BKG})	Background indoor air concentrations.	Not included; incremental risk evaluated for carcinogens.	Sourced values from AEP (2022a).
Exposure term (ET)	Default value of 0.27 for commercial land use.	Default value of 0.27 for commercial land use.	Based on an exposure of 10/24 hours per day × 5/7 days per week × 48/52 weeks per year. Assumed lifetime of exposure.
Allocation factor (AF)	0.5 (chemical dependant)	Assumed 1 for carcinogens.	Values from AEP 2022a; AF only applies to non-carcinogenic SVQG (CCME 2014).
Residential Land Use			
Land use	Residential (basement or slab-on-grade)	Residential (basement or slab-on-grade)	Suitable land-use for properties adjacent to the site.
Depth	<1m	<1m	Default dilution factor was applied.
Alpha	0.01 (dilution factor of 100)	0.01 (dilution factor of 100)	Default attenuation coefficient for commercial buildings and soil-vapour samples less than 100cm distance to building (AEP 2022b).
Soil Vapour Bio-attenuation factor (BAF)	1 (assumed)	1 (assumed)	Conservatively assumed no biodegradation.
Background concentration (C_{BKG})	Background indoor air concentrations.	Not included; incremental risk evaluated for carcinogens.	Sourced values from AEP (2022a).
Exposure term (ET)	Default value of 1.0 for residential land use.	Default value of 1.0 for residential land use.	Based on continuous exposure of 24/24 hours per day × 7/7 days per week × 52/52 weeks per year. Assumed lifetime of exposure.
Allocation factor (AF)	0.5 (chemical dependant)	Assumed 1 for carcinogens.	Values from AEP 2022a; AF only applies to non-carcinogenic SVQG (CCME 2014).

Table 2-2 Calculated Sub-slab Soil Vapour Quality Guidelines for the Assessment

Chemical	Sub-slab Soil Vapour Quality Guideline (µg/m³)	
	Residential	Commercial
Benzene	6.3E+01	2.3E+02
Toluene	1.1E+05	4.2E+05
Ethylbenzene	1.0E+05	3.7E+05
Xylenes (Total)	4.9E+03	1.8E+04
PHC F1(1)	2.2E+05	8.2E+05
Aliphatic C6-C8	9.2E+05	3.4E+06
Aliphatic >C8-C10	5.0E+04	1.9E+05
Aromatic >C8-C10	1.0E+04	3.7E+04
PHC F2(1)	4.5E+04	1.7E+05
Aliphatic >C10-C12	5.0E+04	1.9E+05
Aromatic >C10-C12	5.0E+04	1.9E+05
Aliphatic >C12-C16	1.0E+04	3.7E+04
Aromatic >C12-C16	1.0E+04	3.7E+04

(1) Appendix G presents assumptions and methods used to calculate SVQG for PHC F1 and F2.

3. TOXICITY REFERENCE VALUES

Chronic toxicity reference values (TRVs) used in the calculation of the SVQG were selected from AEP (2022a), which are based on Health Canada (2010) or other agencies, such as the United States Environmental Protection Agency, when a limit is not available from Canadian agencies. The following two types of TRVs were used for the development of the SVQG:

1. A risk-specific concentration (RsC) is used for a carcinogenic chemical (i.e., benzene) and is defined as the concentration that one can breathe every day for a lifetime without exceeding the acceptable benchmark level of increased cancer risk. The acceptable benchmark level for increased cancer risk in Alberta is 1 in 100,000 or 0.00001 (AEP 2022a, Health Canada 2021).

2. A reference concentration (RfC) is used for a non-carcinogenic chemical and is the concentration of the chemical that one can breathe every day for a lifetime that is not anticipated to cause harmful health effects.

If both cancer and non-cancer TRVs were available from an agency, the lowest (i.e., most conservative) value was selected. Toxicity reference values from AEP (2022a) are designed to be protective of sensitive individuals (i.e., children and the elderly) through the incorporation of uncertainty or safety factors. Table 3-1 presents a summary of the TRVs used in the development of SVQG.

Table 3-1 Summary of Toxicity Reference Values Used to Derive the SVQG

Group	Chemical	Type(a)	Value [µg/m³]	Source
BTEX	Benzene	RsC	0.625	AEP (2022a)
	Toluene	RfC	2300	AEP (2022a)
	Ethylbenzene	RfC	2000	AEP (2022a)
	Xylenes	RfC	100	AEP (2022a)
PHC	F1			
	Aliphatic C6-C8	RfC	18,400	AEP (2022a)
	Aliphatic >C8-C10	RfC	1,000	AEP (2022a)
	Aromatic >C8-C10	RfC	200	AEP (2022a)
	F2			
	Aliphatic >C10-C12	RfC	1,000	AEP (2022a)

	Aromatic >C10-C12	RfC	200	AEP (2022a)
	Aliphatic >C12-C16	RfC	1,000	AEP (2022a)
	Aromatic >C12-C16	RfC	200	AEP (2022a)

(a) RsC based on 1 in 100,000 risk level for carcinogens and RfC used for non-carcinogens.

4. WORKED EXAMPLE

The worked example outlined below is for the sub-slab SVQG for ethylbenzene and commercial land use that is protective of indoor air quality for the Site.

Soil vapour quality guideline for the protection of indoor air quality for commercial land use and ethylbenzene:

$$\text{SVQG} = \frac{(RfC - C_{BKG}) \times \text{AF} \times BAF}{\propto \times ET}$$

$$SVQG = \frac{(1000 - 7.5) \times 0.5 \times 1}{0.01 \times 0.27}$$

$$SVQG = 1.8\text{E}+05\ \mu g/m^3$$

5. UNCERTAINTY

The SVQG in this report were developed using a specific set of assumptions and equations. In some cases, the assumptions used to derive these guidelines may not be protective for certain sites. A number of conditions identified by the CCME (2014) and AEP (2022a,b) that may invalidate some of the assumptions used in the development of SVQG are discussed below (Table 5-1); however, none of the precluding assumptions are applicable the Site.

Table 5-1 Interpretation of Conditions That May Overturn Some Assumptions Used in Development of SVQG

Condition	*Interpretation*
The soil vapour sample is collected at a distance greater than 1 m from a building foundation.	Calculated SVQG were based on a default attenuation coefficient of 0.01 (i.e., a dilution factor of 100) for commercial buildings (AEP 2022b). In cases where soil vapour samples are collected at distances greater than 1 m from the building, these guidelines may be overly conservative and other guidelines should be considered.

Condition	Interpretation
The building is taller than four floors (possible enhanced stack effect resulting in greater pressure differential than typical default values) (CCME 2014). The "stack effect" can occur within a building, particularly during the heating season in the winter months as a result of hot air rising and leaving near the top of the building (e.g., through a chimney, leaky attic, exhaust vent), which creates a negative pressure in the building thereby drawing outdoor air and soil gas into the building through openings with the lower regions of the building (i.e., doors, windows, cracks and/or the building foundation) (OME 2010).	Calculated SVQG were based on a typical single story building of specific dimensions, which is appropriate for the Site. The possibility of the stack effect, which may occur in certain buildings taller than four floors, was not considered in the development of these guidelines. Therefore, the default assumptions used in developing these guidelines were appropriate for the Site.
Unique building features, including earthen floors or unusually low air exchange rates (AEP 2022a,b).	A site-specific risk assessment can be completed where physical site conditions (e.g., earthen floors or unusually low air exchange rates) violate default assumptions (AEP 2022b). However, the presence of earthen floors and low exchange rates were not applicable for the Site.
Preferential pathways present in the subsurface provide a direct conduit from the vapour source to the inside of the building over and above that of a typical building (e.g., wet basements, basements with a sump basin, highly permeable and atypical utility conduits, dirt floors, fractured media immediately below the building) (CCME 2014) and very coarse textured materials (i.e., gravel) that may enhance vapour transport (AEP 2022a,b). This condition refers to conduits located between the source of contamination and the building.	A site-specific risk assessment can be completed where physical site conditions (e.g., presence of very coarse textured materials or contamination in fractured bedrock) violate default assumptions (AEP 2022b); however, the presence of wet basements, basements with a sump basin and dirt floors was not applicable for the Site.
Methanogenic conditions, which are defined as environmental soil conditions that allow microorganisms to produce methane as a metabolic by-product in anoxic conditions, are observed in close proximity to the building foundation (possible gas pressure-driven flow and/or explosion risk) (CCME 2014).	Areas that are capable of producing methanogenic conditions (e.g., waste disposal or landfill areas) may affect convection or advection of soil vapours which can affect soil vapour intrusion; however, methanogenic areas are typically not be suitable for the construction of buildings. It should be noted that soil vapour testing in the area has indicated only low levels of methane in the sub-surface.

6. REFERENCES

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APPENDIX C

SAMPLE DATA
AND
CALCULATED
SOIL VAPOUR QUALITY GUIDELINES

Table C-1: Commercial Soil Vapour Quality Guidelines and Calculation Input Parameters

Chemical	Commercial SVQG [ug/m^3][(a)]			Health Based Guideline [ug/m^3]			Input Variables				
	Lowest SVQG	Non-carcinogenic	Carcinogenic	Lowest HBG	RfC [ug/m^3]	RsC [ug/m^3]	Alpha[(b)]	SV BAF[(c)]	C_{BKG} [ug/m^3][(d)]	ET[(e)]	AF[(f)]
Petroleum Hydrocarbons											
F1 PHC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aliphatic >C6-C8	3.4E+06	3.4E+06	NA	1.8E+04	1.8E+04	NA	1.0E-02	1.0E+00	9.1E-02	2.7E-01	5.0E-01
Aliphatic >C8-C10	1.9E+05	1.9E+05	NA	1.0E+03	1.0E+03	NA	1.0E-02	1.0E+00	3.9E-02	2.7E-01	5.0E-01
Aromatic >C8-C10	3.7E+04	3.7E+04	NA	2.0E+02	2.0E+02	NA	1.0E-02	1.0E+00	3.7E-02	2.7E-01	5.0E-01
F2 PHC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aliphatic >C10-C12	1.9E+05	1.9E+05	NA	1.0E+03	1.0E+03	NA	1.0E-02	1.0E+00	0.0E+00	2.7E-01	5.0E-01
Aliphatic >C12-C16	1.9E+05	1.9E+05	NA	1.0E+03	1.0E+03	NA	1.0E-02	1.0E+00	0.0E+00	2.7E-01	5.0E-01
Aromatic >C10-C12	3.7E+04	3.7E+04	NA	2.0E+02	2.0E+02	NA	1.0E-02	1.0E+00	0.0E+00	2.7E-01	5.0E-01
Aromatic >C12-C16	3.7E+04	3.7E+04	NA	2.0E+02	2.0E+02	NA	1.0E-02	1.0E+00	0.0E+00	2.7E-01	5.0E-01
Volatile Organic Compounds											
Benzene	2.3E+02	NA	2.31E+02	6.3E-07	NA	6.3E-01	1.0E-02	1.0E+00	0.0E+00	2.7E-01	1.0E+00
Toluene	4.2E+05	4.2E+05	NA	2.3E+03	2.3E+03	NA	1.0E-02	1.0E+00	4.4E+01	2.7E-01	5.0E-01
Ethylbenzene	3.7E+05	3.7E+05	NA	2.0E+03	2.0E+03	NA	1.0E-02	1.0E+00	7.5E+00	2.7E-01	5.0E-01
Total Xylenes	1.8E+04	1.8E+04	NA	1.0E+02	1.0E+02	NA	1.0E-02	1.0E+00	1.8E+00	2.7E-01	5.0E-01

Notes:

(a) Based on methods from AEP (2022a,b) and CCME 2014

(b) Default attenuation coefficient for sub-slab soil-gas sample or samples less than 100cm distance to receptor (AEP 2022b)

(c) SV BAF value of 1 assumed for depths less than 1m (AEP 2022a;CCME 2014)

(d) AEP 2022a

(e) Worker exposure assumed. (AEP 2022a)

(f) Values from AEP2022a; Assumed 0.2 when AF not available; AF only applies to non-carcinogenic SVQG (CCME 2014); Assumed value of 1 for carcinogenic chemicals (AEP 2022a)

Table C-2: Residential Soil Vapour Quality Guidelines and Calculation Input Parameters

Chemical	Residential SVQG [ug/m^3][(a)]			Health Based Guideline [ug/m^3]			Input Variables				
	Lowest SVQG	Non-carcinogenic	Carcinogenic	Lowest HBG	RfC [ug/m^3]	RsC [ug/m^3]	Alpha[(b)]	SV BAF[(c)]	C_{BKG} [ug/m^3][(d)]	ET[(e)]	AF[(f)]
Petroleum Hydrocarbons											
F1 PHC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aliphatic >C6-C8	9.2E+05	9.2E+05	NA	1.8E+04	1.8E+04	NA	1.0E-02	1.0E+00	9.1E-02	1.0E+00	5.0E-01
Aliphatic >C8-C10	5.0E+04	5.0E+04	NA	1.0E+03	1.0E+03	NA	1.0E-02	1.0E+00	3.9E-02	1.0E+00	5.0E-01
Aromatic >C8-C10	1.0E+04	1.0E+04	NA	2.0E+02	2.0E+02	NA	1.0E-02	1.0E+00	3.7E-02	1.0E+00	5.0E-01
F2 PHC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aliphatic >C10-C12	5.0E+04	5.0E+04	NA	1.0E+03	1.0E+03	NA	1.0E-02	1.0E+00	0.0E+00	1.0E+00	5.0E-01
Aliphatic >C12-C16	5.0E+04	5.0E+04	NA	1.0E+03	1.0E+03	NA	1.0E-02	1.0E+00	0.0E+00	1.0E+00	5.0E-01
Aromatic >C10-C12	1.0E+04	1.0E+04	NA	2.0E+02	2.0E+02	NA	1.0E-02	1.0E+00	0.0E+00	1.0E+00	5.0E-01
Aromatic >C12-C16	1.0E+04	1.0E+04	NA	2.0E+02	2.0E+02	NA	1.0E-02	1.0E+00	0.0E+00	1.0E+00	5.0E-01
Volatile Organic Compounds											
Benzene	6.3E+01	NA	6.3E+01	6.3E-07	NA	6.3E-01	1.0E-02	1.0E+00	0.0E+00	1.0E+00	1.0E+00
Toluene	1.1E+05	1.1E+05	NA	2.3E+03	2.3E+03	NA	1.0E-02	1.0E+00	4.4E+01	1.0E+00	5.0E-01
Ethylbenzene	1.0E+05	1.0E+05	NA	2.0E+03	2.0E+03	NA	1.0E-02	1.0E+00	7.5E+00	1.0E+00	5.0E-01
Total Xylenes	4.9E+03	4.9E+03	NA	1.0E+02	1.0E+02	NA	1.0E-02	1.0E+00	1.8E+00	1.0E+00	5.0E-01

Notes:

(a) Based on methods from AEP (2022a,b) and CCME 2014

(b) Default attenuation coefficient for sub-slab soil-gas sample or samples less than 100cm distance to receptor (AEP 2022b)

(c) SV BAF value of 1 assumed for depths less than 1m (AEP 2022a;CCME 2014)

(d) AEP 2022a

(e) Continuous exposure assumed. (AEP 2022a)

(f) Values from AEP2022a; Assumed 0.2 when AF not available; AF only applies to non-carcinogenic SVQG (CCME 2014); Assumed value of 1 for carcinogenic chemicals (AEP 2022a)

Table C-3: Commercial and Residential Soil Vapour Quality Guidelines and Calculation Input Parameters For PHCs F1 and F2

PHC	Residential SVQG [ug/m3]	Fraction Composition (%) [(a)]	Calculated Guideline [ug/m3] [(b)]
F1 PHC			
Aliphatic >C6-C8	919995	84.0%	2.2E+05
Aliphatic >C8-C10	49998	15.5%	
Aromatic >C8-C10	9998	0.5%	
F2 PHC			
Aliphatic >C10-C12	50000	76.6%	4.5E+04
Aliphatic >C12-C16	50000	20.7%	
Aromatic >C10-C12	10000	2.3%	
Aromatic >C12-C16	10000	0.5%	

(a) Health Canada (2009).
(b) AEP (2022a). Equation $PHC = \frac{1}{\sum_i \frac{Fi}{SVQGi}}$

PHC	Commercial SVQG [ug/m3]	Fraction Composition (%) [(a)]	Calculated Guideline [ug/m3] [(b)]
F1 PHC			
Aliphatic >C6-C8	3407391	84.0%	8.2E+05
Aliphatic >C8-C10	185178	15.5%	
Aromatic >C8-C10	37030	0.5%	
F2 PHC			
Aliphatic >C10-C12	185185	76.6%	1.7E+05
Aliphatic >C12-C16	185185	20.7%	
Aromatic >C10-C12	37037	2.3%	
Aromatic >C12-C16	37037	0.5%	

(a) Health Canada (2009).
(b) AEP (2022a). Equation $PHC = \frac{1}{\sum_i \frac{Fi}{SVQGi}}$

Table C-4: Indoor Air Quality Guidelines For PHCs F1 and F2

PHC	Residential SVQG [ug/m3]	Fraction Composition (%) [(a)]	Calculated Guideline [ug/m3] [(b)]
F1 PHC			
Aliphatic >C6-C8	18400	84.0%	4.4E+03
Aliphatic >C8-C10	1000	15.5%	
Aromatic >C8-C10	200	0.5%	
F2 PHC			
Aliphatic >C10-C12	1000	76.6%	9.0E+02
Aliphatic >C12-C16	1000	20.7%	
Aromatic >C10-C12	200	2.3%	
Aromatic >C12-C16	200	0.5%	

(a) Health Canada (2009).
(b) AEP (2022a). Equation $PHC = \frac{1}{\sum_i \frac{Fi}{SVQGi}}$

TABLE C-4 SAMPLE DATA SOIL VAPOUR ANALYSES - BTEX AND PHC FRACTIONS F1 AND F2

Sub-slab or Soil Vapour Samples	SVQG	Benzene	Ethylbenzene	Toluene	Xylenes	Total C6 to C10 (F1)	Total >C10 to C16 (F2)	nC6-nC8 (aromatic)	nC6-nC8 (non-aromatic)	nC8-nC10 (aromatic)	nC8-nC10 (non-aromatic)	nC10-nC12 (aromatic)	nC10-nC12 (non-aromatic)	nC12-nC16 (aromatic)	nC12-nC16 (non-aromatic)		
	SVQG Residential	63	110,000	100,000	49,000	220,000	45,000		920,000	10,000	50,000	50,000	50,000	10,000	10,000		
	SVQG Commercial	230	420,000	370,000	18,000	820,000	170,000		3,400,000	37,000	190,000	190,000	190,000	37,000	37,000		
	Max Conc	1.41	2.50	5.00	8.30	2300.00	715.95	5.00	550.00	5.00	1700.00	5.00	250.00	500.00	500.00		
Sample ID	**PARAMETER**	**Benzene**	**Ethylbenzene**	**Toluene**	**Xylenes**	**Total C6 to C10 (F1)**	**Total >C10 to C16 (F2)**	**nC6-nC8 (aromatic)**	**nC6-nC8 (non-aromatic)**	**nC8-nC10 (aromatic)**	**nC8-nC10 (non-aromatic)**	**nC10-nC12 (aromatic)**	**nC10-nC12 (non-aromatic)**	**nC12-nC16 (aromatic)**	**nC12-nC16 (non-aromatic)**	**O2**	**CO2**
		ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	Vol%	Vol%
22-02	2022-11-30	1.41	1.48	3.54	8.30	766.00	715.95	--	--	--	--	--	--	--	--	--	--
22-01	2022-12-07	1.12	0.87	0.75	1.80	33.00	15.00	--	--	--	--	--	--	--	--	--	--
22-01	2023-08-16	1.0	2.5	5.0	7.5	2300.0	500.0	5.0	550.0	5.0	1700.0	5.0	250.0	500.0	500.0	18.9	0.99
22-02	2023-08-16	1.0	2.5	5.0	7.5	1200.0	500.0	5.0	550.0	5.0	600.0	5.0	250.0	500.0	500.0	17.7	1.64

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Ambient Basement or Crawlspace Samples	TRV	Benzene	Ethylbenzene	Toluene	Xylenes	Total C6 to C10 (F1)	Total >C10 to C16 (F2)	nC6-nC8 (aromatic)	nC6-nC8 (non-aromatic)	nC8-nC10 (aromatic)	nC8-nC10 (non-aromatic)	nC10-nC12 (aromatic)	nC10-nC12 (non-aromatic)	nC12-nC16 (aromatic)	nC12-nC16 (non-aromatic)		
	RsC[1]	0.63	--	--	--	--	--	--	--	--	--	--	--	--	--		
	RfC[1]	--	2,300	2,000	100	4,400	900		18,400	200	1,000	200	1,000	200	1,000		
	Max Conc	2.75	0.87	7.31	1.80	368.00	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Sample ID	**PARAMETER**	**Benzene**	**Ethylbenzene**	**Toluene**	**Xylenes**	**Total C6 to C10 (F1)**	**Total >C10 to C16 (F2)**	**nC6-nC8 (aromatic)**	**nC6-nC8 (non-aromatic)**	**nC8-nC10 (aromatic)**	**nC8-nC10 (non-aromatic)**	**nC10-nC12 (aromatic)**	**nC10-nC12 (non-aromatic)**	**nC12-nC16 (aromatic)**	**nC12-nC16 (non-aromatic)**	**O2**	**CO2**
		ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	Vol%	Vol%
22-03 (ambient; crawlspace)	2022-12-07	1.02	0.87	0.75	1.80	15.00	15.00	--	--	--	--	--	--	--	--	--	--
AS-01 (ambient; crawlspace)	2023-03-01	1.28	0.87	2.41	1.80	164.00	15.00	--	--	--	--	--	--	--	--	--	--
AS-02 (ambient; basement)	2023-03-01	2.75	0.87	7.31	1.80	368.00	15.00	--	--	--	--	--	--	--	--	--	--
AM-01	2023-08-16	1.0	2.5	5.0	7.5	500.0	500.0	5.0	250.0	5.0	250.0	5.0	250.0	500.0	500.0	20.9	0.07

<DL

Exceeds TRV

[1] AEP (Alberta Environment and Parks). 2022a. Alberta Tier 1 Soil and Groundwater Remediation Guidelines. Environment and Parks 2022 Government of Alberta. August 26, 2022. ISBN 978-1-4601-5501-1.