CoPY #3

Volume I
Final Draft Report
Environmental, Health and Safety Assessment of the Sutherland Avenue Operations Facility in Winnipeg, Manitoba
Phase II: Detailed Site Characterization

Prepared for:

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Executive Summary

Centra Gas Manitoba Limited (Centra Gas) commenced an Environmental, Health and Safety Assessment (EHSA) of its Sutherland Avenue Operations Facility in 1993. The primary objective of the EHSA was to identify whether by-products are present from the coal gasification facility formerly located at the site and to assess the potential effect of any by-products found. A four-phased approach was adopted for the EHSA:

Phase I:	Preliminary Site Characterization
Phase II:	Detailed Site Characterization
Phase III:	Feasibility Study and Risk Management
Phase IV:	Remediation

CH2M HILL Engineering Limited (CH2M HILL) was retained to conduct Phase I which was undertaken between September, 1993 and April, 1994. Phase I identified the presence of residues at levels that warranted proceeding to Phase II, although it was concluded that there was little, if any, risk to the health of employees working in the onsite buildings.

Centra Gas adopted the recommendations for a Phase II EHSA and retained CH2M HILL to complete the assessment. One component of Phase II, involving investigation of sediment and water quality in the Red River, was initiated in March, 1994 to allow work to proceed when an ice cover was present thus providing access for sampling. The remainder of Phase II was initiated in June, 1994.

Phase II focused on investigating the presence of residues offsite to the north and in the Red River, whereas Phase I focused on assessing the presence of residues onsite. Phase II also included assessing the potential impacts of residues on human health and the environment.

The specific tasks that comprised Phase II of the EHSA included:

- Assessing Soil and Groundwater Quality Across Rover Avenue Toward the Red River
- Assessing Water and Sediment Quality in the Red River Adjacent to the Former Coal Gasification Site
- Supplementary Onsite Hydrogeologic Testing
- Sewer Inspection and Sampling
- Biological Impact Assessment in the Red River
- Data Evaluation and Impact Assessment

- Baseline Risk Assessment
- Phase II Reporting

Soil borings were advanced at two off-site locations between Centra's property and the Red River. These locations were selected to assess the suspected presence of residues in this area and their potential for impact on the Red River. Soil samples were taken and wells were installed to assess hydrogeologic characteristics and groundwater quality.

Groundwater flow was confirmed to be north towards the Red River. The estimated rate of groundwater flow was 0.5 to 2.8 metres/day. This resulted in an estimated flux to the Red River of 0.00025 m^3/sec (15 Litres/minute) which is approximately a factor of 100,000 less than the normal flow in the river (100 to 800 m^3/sec).

Residues were found in the offsite soil and groundwater at concentrations exceeding the level at which the Canadian Council of Ministers of the Environment (CCME) recommend that action be undertaken to mitigate adverse impacts. The concentrations of the residues were comparable to many of the locations sampled onsite. The highest concentrations were encountered in the northwest part of the area investigated (both onsite and offsite).

The residues are believed to be contained at depth by a clay till deposit of low permeability encountered at a depth of approximately 15 metres. However, exhaustive investigation of soils in the Winnipeg area (by others) found that fissures may exist at shallow depth reducing the amount of containment provided. The consequence of any incidental migration below 15 metres is not expected to be significant given the absence of groundwater use in the area.

Sewer water and gas characteristics were examined near the site to determine if residues were possibly entering and migrating along the sewers. No impacts were identified implying that the sewers do not represent a migration pathway of concern.

An investigation of river sediments and water quality was undertaken in the Red River adjacent to the site to determine if residues were present and, if so, whether an impact could be detected. Visual, olfactory and chemical characterization of sediments identified:

- A total area of approximately 9000 square meters containing residues which are predicted to cause an adverse impact on aquatic life based on comparison to draft guidelines (i.e. Probable Effect Level - PEL) issued by Environment Canada
- An area of approximately 1250 square meters was found within the above zone which was characterized by higher residue concentrations and/or visual evidence of tarry residues and/or strong naphthalene odours
- The most significant concentrations of residues were restricted to the upper 0.8 to 1.5 metres of river-bottom sediment

A subsequent biological testing program was undertaken to provide a preliminary indication of potential impacts on aquatic life. Laboratory-based biological testing, indicative of "worst case" conditions, indicated that only the zone characterized by higher residue concentrations (ie. 1250 square meters) was:

- Chronically toxic, based on mortality, to the three species tested
- Resulted in accumulation of residues in the species tested

The remaining sediments above background conditions in the river, but not included above in the 1250 square metres, did not exhibit chronic toxicity or accumulation suggesting no adverse impacts in this area. This interpretation is complicated by the inconclusive results of a benthic survey, a survey of sediment dwelling organisms. The benthic survey found low numbers and low diversity of species, both adjacent to and upstream of the area containing residues. The low numbers and low diversity of organisms in areas believed to be unaffected suggests that either the testing is not reliable or that the river sediments are degraded by some other upstream source. The possibility of an upstream source of pollution is supported by the chemical testing of sediments which found that areas believed to be unaffected have low levels of residues present. Prior to determining if any mitigative measure is warranted, further information would be required.

The results from the river sediment and water testing were compared to the land-based investigation to determine if any correlations existed. It was apparent that residues in the soil were closely correlated to the residues present in the river sediments. It was concluded that the residues in soil were more likely than not the source of residues in the sediment based on the observations that residues in soil:

- Extended off-site, to the north towards the river
- Were highest in the area adjacent to where they were found at their highest level in sediments
- Were found to exist at their highest concentration at a depth of 6 to 8 meters which corresponds to the bottom of the river where affected sediments were encountered
- Were found at low to negligible levels below 11 metres in depth

Analysis of water from the Red River found that no residues were present in the water, including water from the zone with residues in the sediment. Residues in groundwater may be reacting (ie. adsorbing) to the sediments or undergoing dilution, and are therefore not detected in the river water. This shows that although groundwater containing residues is flowing towards the river, the concentrations reaching the river are too low to be detected and are unlikely to affect aquatic life through consumption of water alone.

A baseline human health risk assessment was conducted to estimated whether an adverse human health risk was expected based on current land uses at the site. The chemicals of potential concern considered in the risk assessment were based on:

- Detection frequency in the soil and groundwater
- Current or historical site activities
- Concentration exceedances of reference criteria, and
- Known chemical toxicity and mobility for specific chemicals

The primary exposure pathway considered in the risk assessment was inhalation of gaseous residues. The other two pathways often considered in a risk assessment, ingestion and dermal contact, were considered unlikely to be significant due to the site conditions. Potential dermal and/or ingestion contact in excavations was identified in Phase I as a concern and it was presumed that risk would be mitigated through the use of proper health and safety equipment. The receptors considered in the risk assessment were current and future adult workers on the site. While the baseline human health risk assessment focused solely on onsite workers, an offsite risk assessment was not carried out for three main reasons:

- The results of offsite sewer sampling for residues were negative
- The onsite risk assessment suggested risks were within acceptable levels
- There is a lack of data on the factors required to determine offsite risks

Inhalation risks were estimated for gaseous residues (ie. polynuclear aromatic hydrocarbons - PAHs) entering the onsite operations building using the concentrations of residues found in the northern portion of the site, referred to as Area 1. This portion of the site contained the highest levels of residues encountered. The estimated risk in Area 1 did not exceed the accepted criteria (ie. 1 in a million excess cancer risk for known carcinogens or a hazard index of one for non-carcinogens). These results indicate that risks to workers are within accepted limits. These results are also supported by air sampling conducted in the buildings during Phase I which found no detectable residues under worst case conditions in the basement of the operations buildings and that workers are likely not affected by residues.

The risk assessment was not repeated for chemicals found in the central or southern portions of the site, Areas II and III, where residues were present at lower levels than Area I. Based on the assessment of Area I, it was concluded that risk to onsite workers from Areas II and III would be well below acceptable levels.

It was concluded that regulatory agencies should be advised of the results of Phase II and these agencies should be consulted to develop a management plan for the site.

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Section 1
Introduction

Background

In November of 1992, Centra Gas Manitoba Inc. (Centra Gas) approved an Environmental Policy as part of an overall Environmental Management System (EMS). The policy and the EMS, when fully developed, will allow the company to effectively address areas of possible environmental concern at Centra Gas sites. As part of an environmental risk assessment study that was carried out early in 1993, and from the experience of other gas utilities in Canada and the United States, Centra Gas identified the former coal gasification plant located at the Sutherland Avenue Operations Facility in Winnipeg, Manitoba as a location for further environmental investigation. Centra Gas voluntarily initiated an assessment of this property as part of its proactive environmental management program. Terms of reference were developed by the company and reviewed by Manitoba Environment prior to the assessment commencing.

CH2M HILL ENGINEERING LTD. (CH2M HILL) was invited by Centra Gas to submit a proposal to complete an Environmental Health and Safety Assessment (EHSA) of the Sutherland Avenue Operations Facility. The Request for Proposal (RFP), dated July 5, 1993, requested a phased program to determine if the site posed any environmental or health risks and to provide recommendations for followup services, if required. CH2M HILL was subsequently authorized to complete Phase I of a four-phased program. Phase I was completed between September 1993 and April 1994. A report documenting the results of Phase I of the EHSA was completed in April 1994.

The recommendations in the Phase I report were adopted by Centra Gas and the project proceeded to Phase II. One component of Phase II, involving investigation of sediment and water quality in the Red River, was initiated in March 1994 to allow the work to proceed when an ice cover was present on the river. The remainder of Phase II was initiated in June 1994.

Objectives

The following represents CH2M HILL's understanding of the main objectives of the four-phased EHSA:

- To identify the onsite distribution of buried structures and residuals of the coal gasification plant complex
- To establish the physical extent of contaminated soils, sediments, sewer water and groundwater onsite

- To identify existing impacts on human health and the environment and, where necessary, to develop recommendations to mitigate or prevent these impacts

- To determine compliance of chemical results obtained from the investigation against guidelines established by the Canadian Council of Resource and Environment Ministers (CCME), as well as criteria established/adopted by Manitoba Environment

- To ensure that any site investigation and/or followup services required meets or exceeds the requirements established by government and regulatory agencies

- To communicate findings and recommendations clearly to all affected stakeholders

- To determine whether or not the air quality in buildings on the site is affected by manufactured gas plant residuals that may still exist in the subsurface

- To determine the potential for discharge of coal gasification wastes through the underlying soil medium to offsite receptors such as the Red River

Approach

The phased approach adopted for the EHSA is composed of the following components:

- Phase I: Preliminary Site Characterization
- Phase II: Detailed Site Characterization
- Phase III: Risk Assessment and Feasibility Study
- Phase IV: Remediation

Our understanding of the major activities of each of the phases is briefly outlined below.

Phase I

The main goal of Phase I was to determine the presence/absence of gas plant residues in each area of potential concern. This investigation focused on source areas as well as affected areas but was limited in areal extent to the former gas plant property now owned by Centra Gas.

Although Phase I involved intrusive testing, the extent of testing required in Phase I was only sufficient to ascertain whether or not waste by-products were present. Environmental or health data required to assess risks in more detail and/or delineate waste by-products was obtained in Phase II. Phase I data formed the basis for further work in Phase II.

Phase I was limited to:

- A site information assessment
- Non-intrusive testing
- Preliminary intrusive testing

Concerns over worker health and safety as well as public well-being were addressed to the extent practicable given the preliminary nature of Phase I. Addressing these concerns involved assessing compliance with the applicable regulatory guidelines/criteria for air, soil/waste, and groundwater.

Phase II

The approach adopted for Phase II was to first define the presence and characteristics of the by-products. Then, the existence of an impact on human health or the environment was evaluated to determine if the impact was acceptable or not. The impact was determined by referring to environmental regulations and guidelines and completing a site-specific risk assessment. A comparison of site conditions to other sites with similar chemicals was also conducted to confirm the validity of findings. Remedial action may be required if an unacceptable impact has resulted, based on these tasks.

The specific tasks comprising Phase II of the EHSA included:

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Phase III

Phase III, if required, relies on data collected in Phase II. Phase III activities could include:

- Monitoring and/or remedial investigations
- Technical/economic evaluation of potential monitoring and/or remedial alternatives
- Focused feasibility study
- Monitoring and/or remedial design/approvals

Phase IV

Phase IV, if required, will involve implementation of monitoring and/or remediation. Two basic approaches for remediation exist:

- Conventional design, build, own, operate
- "Turn-key" delivery, guided by performance specifications

Section 2
Supplementary Soil and Groundwater Investigation

Field Methodology

Soil Sampling and Monitoring Well Installation

A total of four boreholes were drilled between June 8 and June 10, 1994 followed by the installation of five monitoring wells. The wells were completed along the north side of Rover Avenue, in the grassed area between the road and the river's edge. Permission was obtained from the City of Winnipeg prior to initiating drilling activities in this area. The locations of the monitoring wells are identified in Figure 2-1.

The rationale for completion of the borehole and monitoring wells is identified as follows:

- The silty clay till has been inferred to be a low permeability boundary which acts as the lower boundary to migration of gas plant residues. MW23A and MW24A were completed to define the soil and groundwater conditions at the lower boundary of this zone where contaminant migration would be expected to occur.

- MW23B and MW24C were completed to assess soil and groundwater conditions at shallower depths, close to the water table.

- MW24B was completed to assess soil and groundwater conditions in a highly permeable zone comprised of sand with silty clay seams located above a zone of grey silty clay and silty clay till.

Paddock Drilling Ltd. was retained to advance and sample the boreholes under the supervision of CH2M HILL. The boreholes were advanced similar to Phase I drilling activities with a conventional truck-mounted Canterra CT250 drill equipped with hollow-stem augers and split-spoon samplers. All soil samples collected during the investigation were inspected in detail and grouped into categories based on the physical level of contamination observed. Most of the samples collected were further characterized with the use of headspace analyses. The approach to completion of soil observations and classification is identified in the Phase I report.

Decontamination, site access and clearance of underground utilities was completed in a manner similar to Phase I drilling activities.

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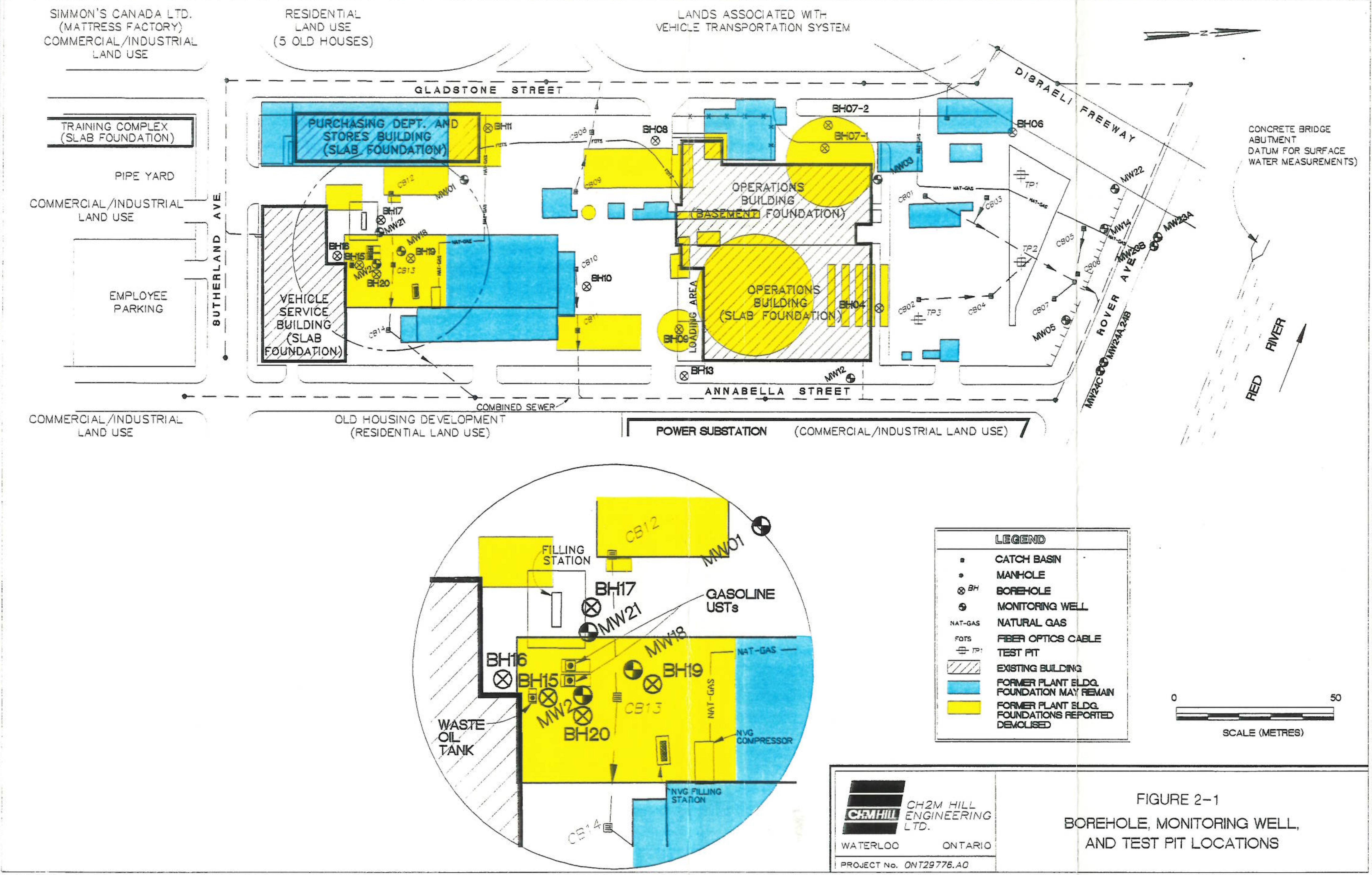

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FIGURE 2-1
BOREHOLE, MONITORING WELL, AND TEST PIT LOCATIONS

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Based on the site characterization conducted in Phase I, it was unnecessary to install a permanent large diameter steel casing to support the advancement of the deeper boreholes at MW23A and MW24A. In Phase I, residues were observed extending down to the silty clay till at MW22. This observation suggested that a casing was unnecessary during completion of the deeper wells offsite, as long as the borehole did not extend beyond the silty clay till.

A total of five monitoring wells were installed offsite. MW23A, MW23B and MW24C were completed in separate boreholes. MW24A and MW24B were completed in the same borehole. The approach to the monitoring well installation was similar to that detailed in the Phase I report except that clean borehole cuttings were used to backfill above the bentonite seal at MW23B, MW24A and MW24B. The other wells utilized a bentonite seal which was emplaced close to ground surface. A hand slotted monitoring well (2.5 cm I.D.) was installed at MW24B because of limited annular space in the hollow-stem augers during installation procedures. MW24B was completed as an additional well to assess groundwater conditions. Borehole logs which include monitoring well details for each location advanced are presented in Appendix A.

A location and elevation survey was conducted by CH2M HILL to correlate subsurface information located onsite and offsite. The top of the monitoring well pipe at MW05 was used as the datum for the elevation survey for the newly installed wells.

Water level monitoring was completed on March 20, 1994 for only a portion of the old wells because frozen conditions would not permit access to all the wells. Water levels at the old and new wells were monitored throughout June 1994. The data obtained from water level monitoring activities was tabulated and is presented with the discussion of the hydrogeology in this report. The procedure for completing water level measurements has been detailed in the Phase I report.

Hydraulic Conductivity Measurements

Aquifer-response tests were conducted to estimate the hydraulic conductivity of the subsurface medium. In these tests, either a slug of known volume is introduced into the well or a bailer of known volume is withdrawn from the well to cause a water level change. The water level in the monitoring well is allowed to recover to static conditions. Water level data was recorded manually using a water level tape and stopwatch until it returned to its equilibrium level. The rate of water level recovery is used to estimate the hydraulic conductivity of the soil that the well is screened across by the Bouwer and Rice method. The analytical data was graphed and is presented in Appendix B. Results are presented in the discussion of the hydrogeology of the site.

Handling of Excess Liquids and Solids

All soil cuttings and contaminated waters generated during the investigation were disposed of by Laidlaw Environmental Services on August 26, 1994 using Generator Number

MB1000799. A total of 8 drums of waste soil and 10 drums of purge water were disposed. The liquid and solid waste was transported to Sarnia, Ontario.

Analytical results for the wash water were below the sewer use bylaw criteria allowing for discharge to the City of Winnipeg water pollution control plant. Approximately 1500 litres of wash water was pumped from the drums by A-1 Sewage Limited in late August 1994 and was disposed of at the City of Winnipeg dump station in accordance with established protocols.

Groundwater Sampling

Following Phase I activities, two additional sampling rounds were completed in the study area. Prior to groundwater sampling, development and purging procedures were completed to ensure that representative groundwater samples were obtained. Field parameters such as pH, temperature, electrical conductance, and redox potential were collected throughout these activities to determine when groundwater sampling could be completed. The results from these activities are presented in the discussion of the analytical results. The methodology used for these procedures is detailed in the Phase I report.

Groundwater sampling was completed on June 26 and 27, 1994 (Round No. 2) and on August 13, 1994 (Round No. 3). The approach to sampling was completed with the same procedures as those detailed in the Phase I report.

In Round No. 2, samples were collected at all monitoring wells, except at MW24B (additional well), in the study area for the following analytical parameters:

- PAHs (polynuclear aromatic hydrocarbons)
- BTEX (benzene, toluene, xylenes and ethylbenzene)
- Phenolics
- Trace metals

This approach ensured that at least one round of data was available across the entire study area for evaluation. The rationale for selection of the analytical parameters is detailed in the Phase I report.

In Round No. 3, samples were collected from only some of the monitoring wells for the above-mentioned parameters. MW24B was the only location analyzed for trace metals in Round No. 3. The trace metal results at MW23A and MW23B from Round No. 2 indicated some inconsistencies which were overlooked prior to collection of groundwater samples in Round No. 3. Samples for trace metals were not collected at MW23A or MW23B in Round No. 3. With the exception of MW23A and MW23B, trace metal results in Round No. 2 at the other locations were not significant enough to warrant additional confirmatory sampling in Round No. 3. At MW03, MW12, MW18, MW23A, MW23B, MW24A, MW24B and MW24C, samples were collected for PAHs, BTEX, and phenolics in Round No. 3. Only PAHs and BTEX samples were collected at MW05. No other locations were sampled in Round No. 3 either because the groundwater exceeded criteria on more than one occasion and trends were well established or the levels were very low suggesting that degraded groundwater was not an issue.

Subsurface Characterization

Geology and Fill Distribution

The geology and distribution of fill across the site was characterized in detail in the Phase I investigation. The details of this characterization are provided in the Phase I report (CH2M HILL, 1994). A summary of the main native overburden stratigraphic units identified at this site include:

- Weathered Glaciolacustrine Silty Clay/Clayey Silt Deposit
- Unweathered Glaciolacustrine Silty Clay/Clayey Silt Deposit
- Stratified Glaciolacustrine/Glaciofluvial Deposit
- Silty Clay Till

The fill material delineated onsite was categorized into four main groups which are summarized below:

- Topsoil
- Granular Fill
- Fill without Industrial Debris
- Fill with Industrial Debris

The locations of two geologic cross sections of the Centra Gas study area are shown in Figure 2-2. Figure 2-3 provides a south-north cross section of the east side of the site along section line A-A' while Figure 2-4 provides a south-north cross section of the west side of the site along section line B-B'. Specific geologic details are provided in the borehole logs in Appendix A.

The geology and fill materials identified offsite were consistent with the findings identified from the Phase I investigation at the north end of the site. Some of the observations are identified as follows:

- Although limited, the silty clay fill observed at MW23A contained traces of cinder and ash. No cinder or ash were present at MW24A so the material was classified as a fill without industrial debris.

- A zone of stratified glaciolacustrine/glaciofluvial materials consisting of interbeds of fine-grained, low permeability materials and coarser-grained, high permeability materials were encountered below the fill materials at MW23A and MW24A. Some fracturing was observed in this zone at MW24A.

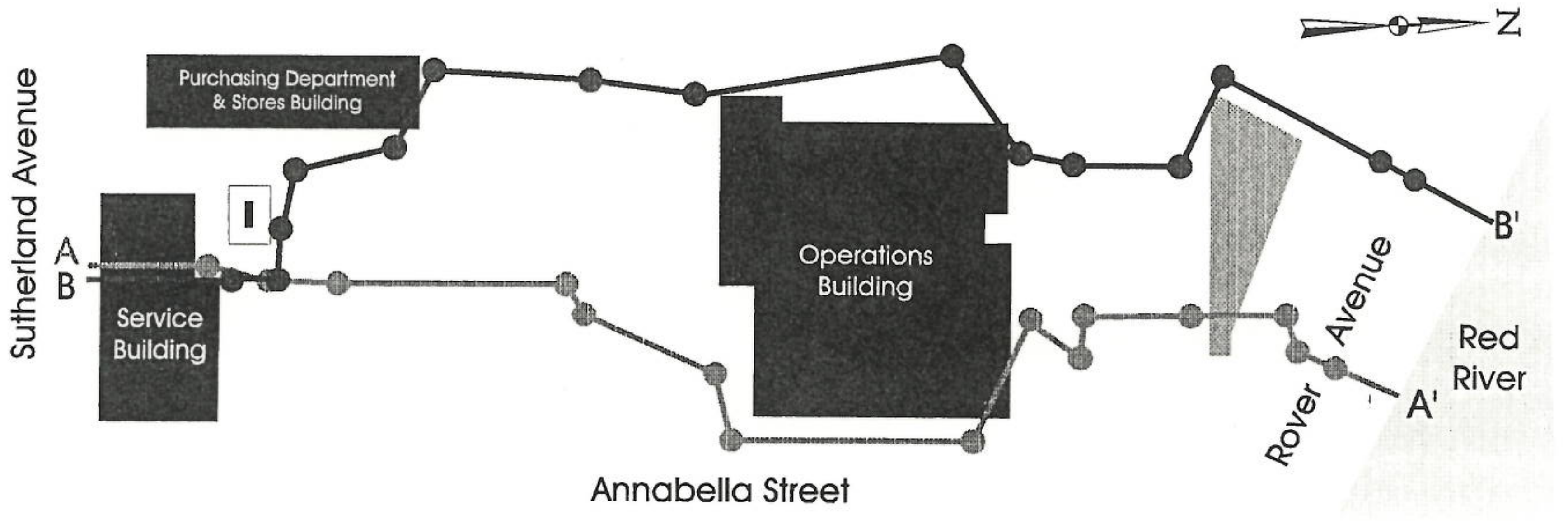

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FIGURE 2–2
PLOT PLANS SHOWING
GEOLOGIC SECTION LINES FOR
CROSS SECTIONS A-A' & B-B'

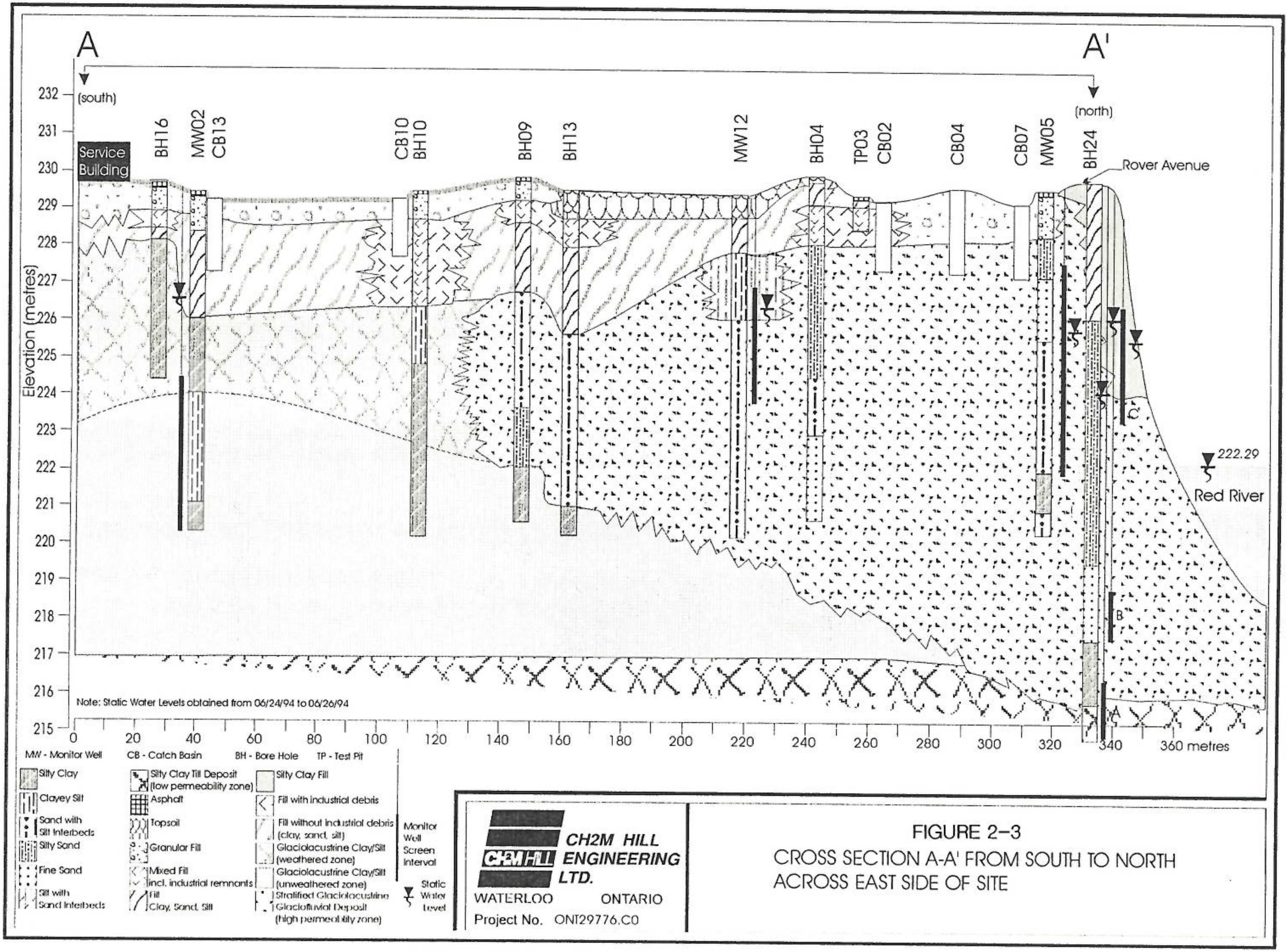

FIGURE 2–3
CROSS SECTION A-A' FROM SOUTH TO NORTH
ACROSS EAST SIDE OF SITE

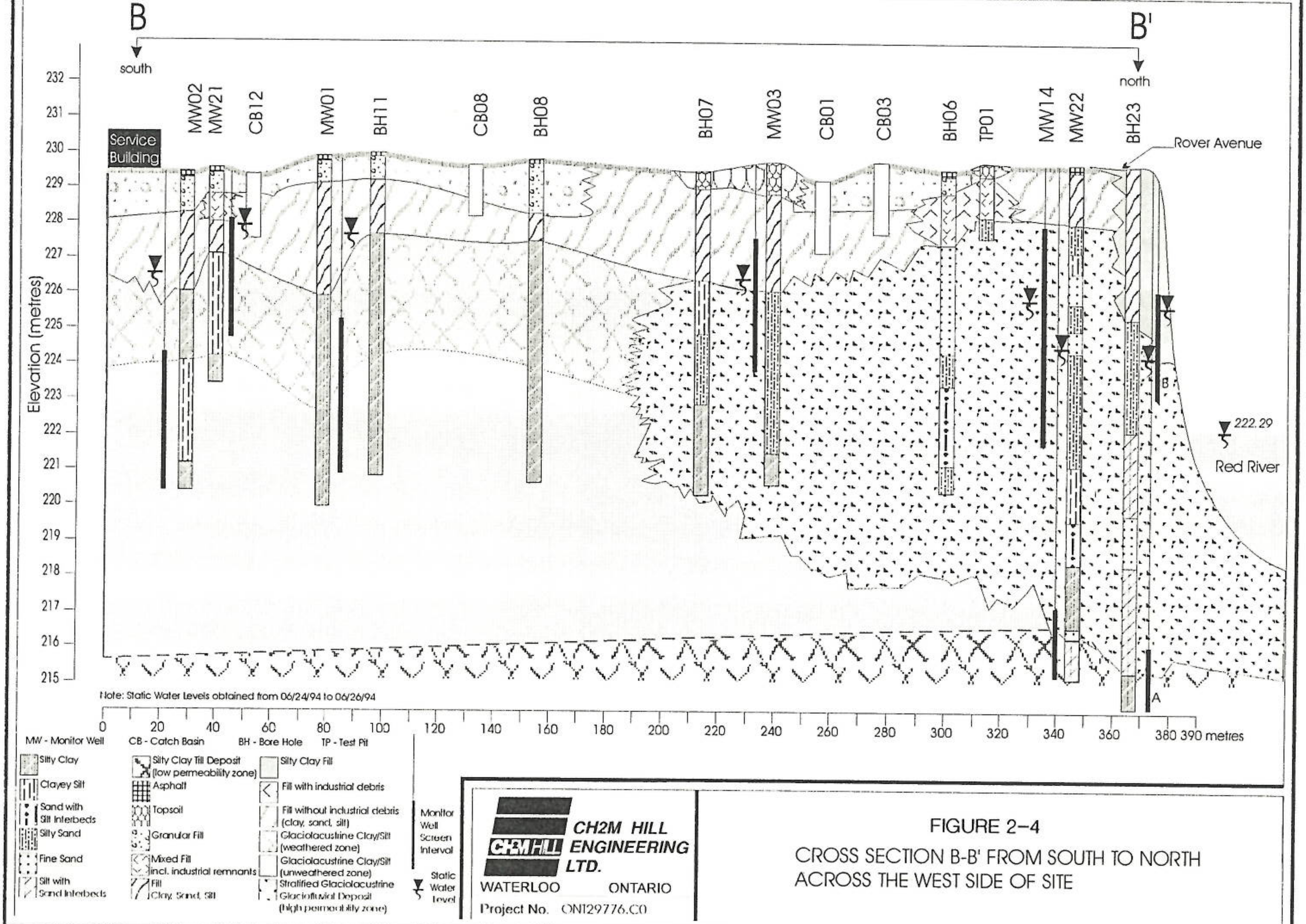

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FIGURE 2–4

CROSS SECTION B-B' FROM SOUTH TO NORTH ACROSS THE WEST SIDE OF SITE

- The silty clay intercepted directly above the silty clay till was grouped into the stratified zone.

- The silty clay till was composed of numerous angular sand and gravel fragments with a silty clay matrix.

The zone of silty clay till existing at depth is inferred to have a low permeability which will act to impede migration of by-product wastes to greater depths. However, extensive studies of fissuring in clay tills in the area have found that fissuring exists at shallow depths. This phenomena has not been assessed beneath the Centra Gas site to date. Any incidental migration through fissures is not believed to be significant due to the absence of groundwater use in this area.

The zone of stratified interbedded materials is very extensive across the north section of site and appears to extend directly to the Red River.

Distribution of By-products

The distribution of by-products offsite (adjacent to the Red River), based on the assigned classification detailed in Phase I, is outlined below:

- From 0 to 3.8 metres bgs at MW23A, a no contamination (NC) or trace contamination (TC) classification was identified in the silty clay fill. Black staining or strong naphthalene odours were not identified from inspection. Most of this zone was below the water table level.

- A VC classification (visual contamination) was used extending from 3.8 to 10 metres below ground surface (bgs) at MW23A. Black staining and strong naphthalene odours were noted in the stratified glaciolacustrine/ glaciofluvial deposit. Total organic vapour (TOV) readings were as high as 360 ppm in this zone.

- At MW23A, visual contamination was not observed from 10 metres down to the termination depth of 15.24 metres. From 12.2 metres down, an NC classification was used. A lower permeability glaciolacustrine/glaciofluvial silty clay and silty clay till were encountered where the NC classification was identified.

- From 0 to 4.5 metres bgs at MW24A, an NC classification was identified in the silty clay fill. All TOV readings were 0 ppm within this interval.

- A VC classification was identified extending from 4.5 to 7.6 metres below ground surface at MW24A. Black staining, strong naphthalene odours and elevated TOV readings up to 112 ppm were noted in the stratified deposit.

Tar was noted in the fractures of the fine sandy silt material at a depth of approximately 7.6 metres.

- From 10.6 metres bgs down to 14.94 metres a TC or NC classification was identified at MW24A. The NC classification was observed in the silty clay and silty clay till deposits.

These observations suggest that the waste by-products are not as extensive in depth as identified at MW22 onsite, and that less of an impact has occurred at MW24A which is located further to the east. MW23A has a more extensive thickness of waste by-products likely caused by source materials in the vicinity of BH06, MW22 and MW14.

Hydrogeology

The hydrogeology of the site was interpreted from information obtained during Phases I and II from 1993 to 1994. The regional hydrogeology of the area was summarized in detail in the Phase I report. Similar shallow groundwater conditions were observed in Phases I and II. The shallow groundwater was measured at elevations ranging from 227.7 metres at the south end of the site to 225.6 metres at the north section of the study area. The water level measurements are summarized in Table 2.1. The cross section (Figure 2-5) and water table contour plan (Figure 2-6) summarize the hydrogeology of the site. The general direction of groundwater flow across the site is north toward the Red River which has remained consistent with Phase I findings.

An important parameter in defining groundwater flow is the permeability of the various materials in the subsurface. The permeability is described by the "hydraulic conductivity" of the materials. Hydraulic conductivity values usually vary depending on the direction (i.e. horizontal or vertical) of groundwater flow being considered. For example, layered silt and fine sand will have greater hydraulic conductivity in the horizontal plane than in the vertical plane. The hydraulic test results are presented in Table 2.2. It is worth mentioning that hydraulic test results are generally accurate to within one order of magnitude. For highly permeable deposits that have rapid groundwater recovery rates, the hydraulic conductivity values may only be accurate to two orders of magnitudes.

The results suggest that more permeable materials exist at the north end of the site with less permeable materials at the south end. The geometric mean calculated for the measured hydraulic conductivities in the north study area is 7.2×10^{-5} m/s. The low hydraulic conductivity values identified at MW01 and MW21 are consistent with the glaciolacustrine clay and silt materials encountered at the south end of the site but were not used in calculating the geometric mean.

Groundwater flux calculations can be used to determine the potential for migration of groundwater impacted by coal tar residues to enter the Red River. These calculations were completed at the north end of the site because of the presence of coal tar residues and

Table 2.1
Water Level Elevations for Monitor Well Locations (Phase II – Round No. 2)

Monitor Well Location	Datum Elevation (metres)	Monitoring Date												
		March 20 1994		June 5 1994	June 6 1994	June 12 1994	June 16 1994	June 17 1994	June 20 1994	June 21 1994	June 24 1994	June 25 1994	June 26 1994	June 24 to 26 1994
		Dtw	Elevations	Dtw	Dtw	Dtw	Dtw	Dtw	Dtw	Dtw	Dtw	Dtw	Dtw	Elevations
MW-01	229.77	2.65	227.12	--	2.07	--	--	--	--	--	2.09	--	--	227.68
MW-02	229.34	Ice		--	2.87	--	--	--	--	--	2.76	--	--	226.58
MW-03	229.73	Ice		--	3.53	--	--	--	--	--	3.3	--	--	226.43
MW-05	229.45	Ice		--	3.24	--	--	--	--	--	--	3.57	--	225.88
MW-12	229.26	3.15	226.11	--	2.95	--	--	--	--	--	2.98	--	--	226.28
MW-14	229.49	3.71	225.78	--	3.55	--	--	--	--	--	3.59	3.59	--	225.9
MW-18	229.25	2.72	226.53	--	1.47	--	--	--	--	--	1.55	--	--	227.7
MW-21	229.5	2.88	226.62	--	2.07	--	--	--	--	--	1.6	--	--	227.9
MW-22	229.68	5.39	224.29	--	--	--	--	--	--	--	5.1	--	--	224.58
MW-23A	229.72	--	--	--	--	4.02	4.72	6.17	5.31	5.29	--	--	5.41	224.31
MW-23B	229.67	--	--	--	--	3.94	3.99	3.96	3.95	3.68	--	--	4	225.67
MW-24A	229.8	--	--	--	--	4.54	5.67	5.7	5.65	--	--	--	5.7	224.1
MW-24B	229.77	--	--	--	--	3.63	3.72	2.68	--	--	--	--	3.71	226.06*
MW-24C	229.81	--	--	--	--	4.18	4.2	4.2	4.22	--	--	--	4.23	225.58

Note: River Elevation assumed to be 222.18 metres based on ice elevation (March 20, 1994)

* This elevation is not representative of the site conditions and therefore was not used in the contour plan (Water level was assumed to be in error)

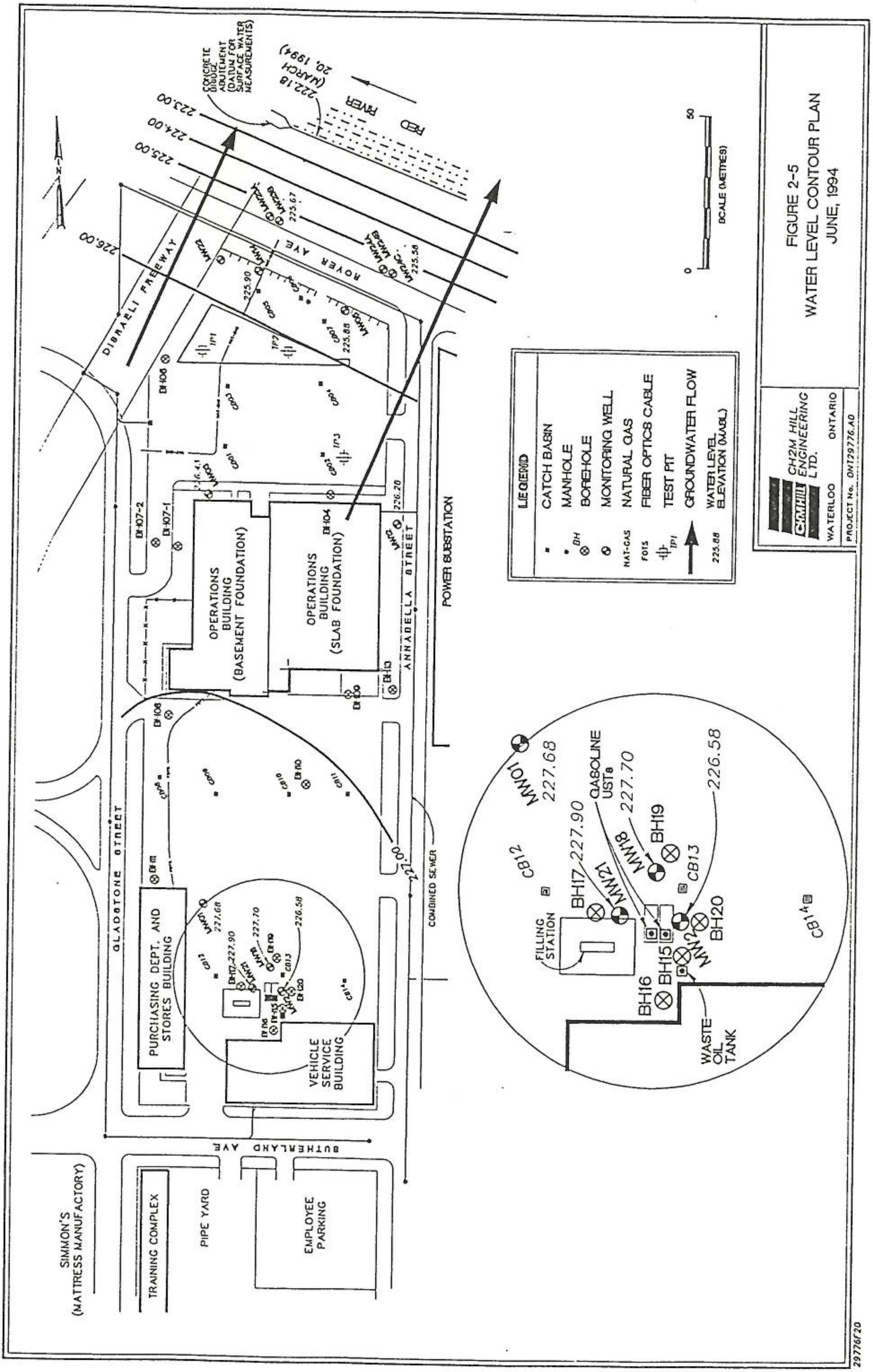
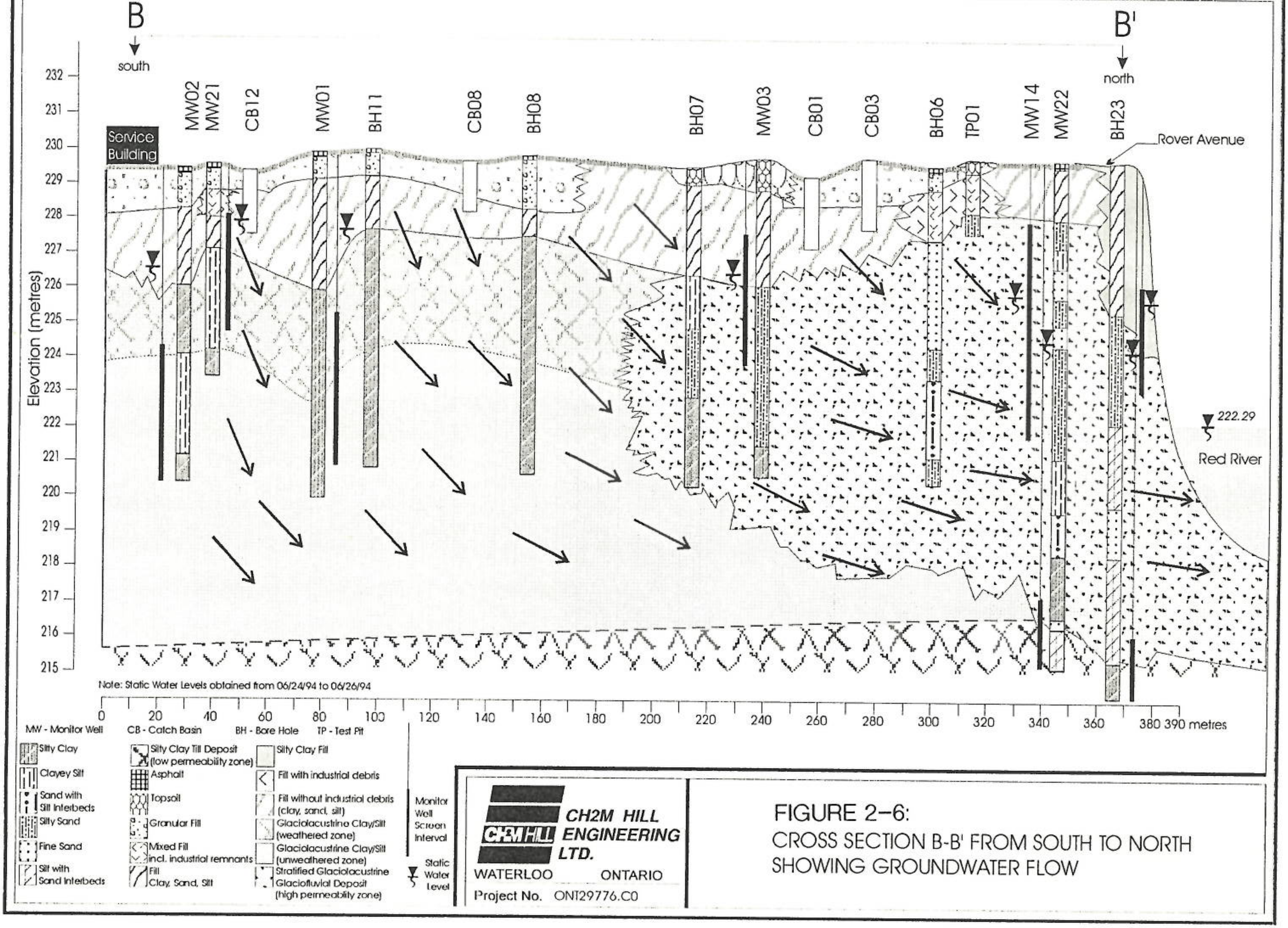


FIGURE 2-5
WATER LEVEL CONTOUR PLAN
JUNE, 1994



CH2M HILL ENGINEERING LTD.
WATERLOO ONTARIO
Project No. ONT29776.C0

FIGURE 2–6:
CROSS SECTION B-B' FROM SOUTH TO NORTH
SHOWING GROUNDWATER FLOW

Table 2.2
Hydraulic Conductivity Measurements

Well Location	Test Type	Dominant Soil Type	Hydraulic Conductivity (m/s)
MW01 (South End)	Bail	Silty clay (weathered and unweathered zone)	1.4×10^{-06}
MW21 (South End)	Bail	Clayey silt and sandy silt fill	6.7×10^{-08}
MW23A (North End)	Bail	Silty clay with the occasional sand fragment	1.1×10^{-05} [1]
MW23B (North End)	Bail	Fine sandy silt with silty clay and fine sand interbeds Silty clay fill	3.4×10^{-05} [1]
MW24A (North End)	Bail	Silty clay with the occasional sand fragment	8.8×10^{-05} [1]
MW24B (North End)	Slug	Medium to coarse sand with some silty clay seams	1.6×10^{-03}
MW24C (North End)	Bail	Fine sandy silt with silty clay and fine sand interbeds Silty clay fill	1.6×10^{-04} [1]

[1] Geometric mean of the measured hydraulic conductivities in the north section of the study area is 7.2 x 10^{-5} m/s

Note: Testing completed at MW24B was made difficult because of the small diameter of the well. CH2M HILL does not believe the soil type and hydraulic conductivity was generally representative of the medium in this area so it was not used in calculating the geometric mean.

higher permeability materials close to the Red River. The following are estimates used in the calculation of groundwater flux to the river:

- Representative hydraulic conductivity (K) of 7.2×10^{-5} m/s for subsurface materials located at the north end of the study area
- Average hydraulic gradient (i) of 0.016 m/m extending north from the operations building towards the Red River
- Saturated thickness of 8.0 metres and a width of 90 metres across the north section of site
- Porosity of 0.30 (30 percent) typical of the soils present

The saturated thickness of the aquifer was based on the water level elevation of 225.67 metres at MW23B in June 1994 and the elevation of the surface of the grey silty clay of 217.52 metres intercepted at MW24A. The result was rounded to 8.0 metres.

Darcy's Law ($Q = nKIA$) was used to calculate the groundwater flux to the Red River. Groundwater flow to the north results in an estimated discharge of 15 L/min to the Red River under normal conditions. The above-mentioned result translates to a discharge of 2.5×10^{-4} m^3/s. As a basis for comparison, the average daily flows in the Red River at Lockport vary from less than 100 m^3/sec to almost 800 m^3/sec, 5 orders of magnitude less (Manitoba Environment, 1991).

The groundwater velocity directed toward the river ranges from 0.5 to 2.8 metres/day in the north section of the site (assuming 30 percent porosity).

Water levels in the south end of the site suggest interaction of the groundwater with the bedding material around the USTs based on the water level at MW02 which has remained significantly lower than the levels in the other wells in the area. However, the measurement at MW02 may also reflect the water level in the native material suggesting that the groundwater in the fill material in the vicinity of the USTs and storm sewer is perched. MW21, MW18 and MW01 identified the direction of groundwater flow toward to Red River across the south end of the site. MW02 was excluded from the groundwater contour plan.

If the hydraulic gradient of 0.016 m/m is used along with the hydraulic conductivities identified at MW01 and MW21, the groundwater velocity at the south end of the site would range from 0.03 to 0.68 metres/year. The hydraulic conductivity results obtained at MW01 and MW21 were representative for the materials in this area.

Chemical and Field Monitoring Results

Laboratory analysis reports for both soil and groundwater are provided in Appendix C.

Soil Analyses

Quality Assurance/Quality Control (QA/QC)

The field QA/QC program consisted of the use of duplicate analysis as a measure of laboratory precision, as described in the Phase I report. The laboratory QA/QC program follows standard laboratory procedures and included a laboratory blank, a method spike and recovery surrogates. The results of these analyses are summarized in Table 2.3.

The duplicate soil sample at MW23A (11.43 to 12.19 metres) identified some variation in analysis but generally remained in the same concentration range for BTEX and PAHs. The results for the PAHs reflect the difficulty that exists in creating exact duplicates in the field during sampling.

The laboratory blank indicates that no contamination was induced during the sample extraction or analysis. The recovery surrogates for the laboratory blank and the method spike were at acceptable levels.

The recovery surrogates for BTEX were identified at an acceptable level. As expected for the PAH analyses, the d8-naphthalene recovery levels were considerably lower than the levels of the d12-chrysene because of its volatile nature. The low recovery levels sometimes suggest that the sample analysis has been biased lower than actually exists in the field. For MW23A (6.1 to 6.9 metres) which contains elevated PAHs, the surrogates were not recovered due to the required dilution of the sample. However, this does not suggest that the results are inconclusive at this location.

The results of the QA/QC program have provided a reasonable level of confidence for the results obtained for the soil samples.

Soil Results

The Phase II soil characterization included analysis of organic compounds at two new borehole locations north of Centra Gas's property boundary, adjacent to the Red River. Results from Phase I activities have not been included in Table 2.3 for comparison as none of the same locations were analyzed in Phase II.

As discussed in the Phase I report, the CCME "ABC" criteria are the primary criteria to which the results have been compared (CCME, 1989). In soils, the Level C criteria indicate the concentration above which remediation should be completed, some other form of mitigation should be implemented, or the land use should be changed. Levels above the "B" value indicate that contamination is present and that further investigation is warranted.

Table 2.3
Comparison of Chemical Analysis of Soil Samples to Available Criteria

Sample Location	MW23A	MW23A	MW23A (Dup)	MW23A	MW24A	Lab Blank	Method Spike	CRITERIA				
Sample Depth (m)	6.1 to 6.9	11.4 to 12.2	11.4 to 12.2	14.5 to 15.2	13.0 to 13.7			CCME "ABC" FOR COAL GASIFICATION SITES			CCME INTERIM REMEDIATION	
Field Classification	VC	TC	TC	NC	NC							
SOIL DEPOSIT	SGL/GF	SGL/GF	SGL/GF	SILTY CLAY TILL	SGL/GF							
Sample Date	06/08/94	06/08/94	06/08/94	06/08/94	06/10/94	06/08/94	06/08/94	A	B	C	Residential Parkland	Commercial/ Industrial
Laboratory No.	07092–02	07092–03	07092–05	07092–04	07092–01	9407092	9407092					
PAH's (ng/g)												
Naphthalene	1460000	167	643	13.7	27.1	<0.88	58%	100	5,000	50,000	5,000	50,000
Acenaphthylene	348000	4.14	<0.9	<0.9	3.21	<0.9	82%	– –	– –	– –	– –	– –
Acenaphthene	29400	<1.12	<1.12	<1.12	<1.12	<1.12	71%	– –	– –	– –	– –	– –
Fluorene	143000	<2.4	<2.4	<2.4	<2.4	<2.4	77%	– –	– –	– –	– –	– –
Phenanthrene	522000	6.98	<3.6	6.95	5.32	<3.6	85%	100	5,000	50,000	5,000	50,000
Anthracene	142000	<1.6	<1.6	<1.6	<1.6	<1.6	80%	– –	– –	– –	– –	– –
Fluoranthene	285000	6.38	<1.18	<1.18	6.36	<1.18	103%	– –	– –	– –	– –	– –
Pyrene	344000	7.42	<1.98	<1.98	7.19	<1.98	93%	100	10,000	100,000	10,000	100,000
Benzo (a) anthracene	154000	<0.88	<0.88	<0.88	13	<0.88	141%	100	1,000	10,000	1,000	10,000
Chrysene	106000	<1	<1	<1	<1	<1	96%	– –	– –	– –	– –	– –
Benzo (b) fluoranthene	81700	<1.94	<1.94	<1.94	<1.94	<1.94	131%	100	1,000	10,000	1,000	10,000
Benzo (k) fluoranthene	71200	<2.2	<2.2	<2.2	<2.2	<2.2	113%	100	1,000	10,000	1,000	10,000
Benzo (a) pyrene	173000	<1.42	*297ng/g	<1.42	*297ng/g	<1.42	131%	100	1,000	10,000	1,000	10,000
Indeno (1,2,3–cd) pyrene	102000	<1.42	<1.42	<1.42	<1.42	<1.42	117%	100	1,000	10,000	1,000	10,000
Dibenzo (a,h) anthracene	18900	<1.86	<1.86	<1.86	<1.86	<1.86	94%	100	1,000	10,000	1,000	10,000
Benzo (ghi) perylene	95300	<1.74	<1.74	<1.74	7.02	<1.74	95%	– –	– –	– –	– –	– –
D8–Naphthalene (Recovery Surrogate)	NR	32%	61%	51%	48%	67%	56%	– –	– –	– –	– –	– –
D12–Chrysene (Recovery Surrogate)	NR	99%	83%	85%	92%	84%	87%	– –	– –	– –	– –	– –
BTEX (ng/g)												
Benzene	<80	<0.58	<0.58	<0.58	18.2	<0.58	95%	– –	– –	– –	500	5,000
Toluene	260	<0.8	<0.8	2.48	<3	<0.8	94%	– –	– –	– –	3,000	30,000
m & p Xylene	13700	3.22	<0.59	<0.59	48.5	<0.59	95%	– –	– –	– –	5,000	50,000
Ethyl benzene	4425	5.93	2.03	1.08	14.7	<0.39	89%	– –	– –	– –	5,000	50,000
o–Xylene	9185	2.44	<0.42	<0.42	42.9	<0.42	97%	– –	– –	– –	5,000	50,000
D6–Benzene (Recovery Surrogate)	112%	93%	117%	93%	111%	103%	101%	– –	– –	– –	– –	– –
D10–Ethylbenzene (Recovery Surrogate	93%	80%	73%	89%	104%	102%	94%	– –	– –	– –	– –	– –
Total Solids	75%	76%	75%	91%	64%			– –	– –	– –	– –	– –

Notes:

Dup – Duplicate sample
MHCPS – Manitoba Hazardous Classification for Petroleum Soils
*297 ng/g – Benzo(a)pyrene was not detected, however, a similar compound possibly an isomer, was present at 297 ng/g quantitated against benzo(a)pyrene
SGL/GF –STRATIFIED GLACIOLACUSTRINE/GLACIOFLUVIAL DEPOSIT

CCME – Canadian Environmental Quality Criteria for Contaminated Sites
– – Guideline not available
▨ Exceeds at least one criteria

Analyzed by Canviro Analytical Laboratories Ltd. (CALL)
Results reported on a dry weight basis

Field Contamination Classification

NC – No contamination
TC – Trace contamination
VC – Visual contamination
C(noVC) – Contaminated but no visual evidence

The Level A criteria are based on analytical detection limits.

The CCME Interim Remediation Criteria (CCME remediation criteria) for commercial/industrial land use have also been used for comparison purposes. The CCME remediation criteria for residential/parkland land use have also been presented in support of the results.

The results of the analysis at MW23A (6.1 to 6.9 metres) were consistent with the VC (visual contamination) field classification. The PAH parameters exceeded the CCME "C" criteria and the CCME remediation criteria for commercial/industrial land use. The highest concentration of benzo(a)pyrene identified during Phase I and II investigations resulted at MW23A (6.1 to 6.9 metres). The concentration level of the PAHs at MW23A (6.1 to 6.9 metres) were in the same range identified at BH06 (6.9 to 8.2 metres) in Phase I activities. Both m&p-xylene and o-xylene exceeded the CCME remediation criteria for residential land use but were lower than the commercial criteria.

At MW23A (11.4 to 12.2 metres) as well as the duplicate sample, only a marginal exceedance of the CCME "A" criteria was identified for naphthalene. No other parameters exceeded available criteria. These results were consistent with the TC field classification.

At MW23A (14.5 to 15.2 metres) and MW24A (13 to 13.8 metres), no criteria were exceeded for PAH or BTEX constituents. The results were consistent with the NC field classification.

In summary, the most elevated PAH and BTEX constituents were identified at shallower depths between 6 and 8 metres along the bank of the Red River. At depths of 11 metres and down, trace to no contamination was identified. The most significant result was the high level PAHs identified along the bank of the river, north of BH06, MW14 and MW22 where elevated PAHs have been identified.

Groundwater Analyses

Quality Assurance/Quality Control

The QA/QC results for groundwater are presented in Tables 2.4 and 2.5. Only results associated with Round Nos. 2 and 3 are presented in the tables. The results of the laboratory blank analyses indicate that non-detectable levels were observed for all chemicals analyzed except for naphthalene which was detected at low concentrations in Round No. 3 (Table 2.5). The results suggest that the laboratory provided representative analysis and that no laboratory contamination occurred.

The recovery of method spikes would be 100 percent under ideal conditions but this is rarely true due to losses during analysis. Method spikes above 75 percent were typically reported in Round Nos. 2 and 3. Values lower than 75 percent suggest that the results are biased lower than actually exists.

Table 2.4
Comparison of Chemical Analysis of Groundwater Samples to Available Criteria (Inorganics)

Page 1 of 2

			Located near UST's							Located near UST's			
Sample Name	MW01	MW01	MW02	MW02	MW03	MW05	MW12	MW14	MW14	MW18	MW18	MW21	MW22
Sample Date	10/04/93	06/26/94	10/24/93	06/26/94	06/26/94	06/26/94	06/26/94	10/04/93	06/26/94	10/04/93	06/26/94	06/26/94	10/04/93
Laboratory No.	10224–01	07005–11	10319–02	07005–13	07005–09	07005–04	07005–06	10224–05	07005–08	10226–01	07005–10	07006–01	10224–07
Round No.	1	2	1	2	2	2	2	1	2	1	2	2	1
Metals (mg/L)													
Aluminum	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1
Boron	0.39	0.43		0.57	0.21	0.18	0.12	0.1	0.14		0.23	0.29	0.28
Barium	0.15	0.22		0.26	0.18	0.26	0.24	0.15	0.23		0.03	0.13	0.17
Beryllium	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005
Cadmium	<0.00008	0.00042		0.00016	0.00023	0.0001	0.0001	0.00016	0.00012		0.00055	0.00017	<0.00008
Calcium	220	173		199	132	270	152	250	223		302	114	97.1
Chromium	<0.0042	<0.00037		<0.00037	<0.00037	<0.00037	<0.00037	<0.0042	<0.00037		<0.00037	<0.00037	<0.0042
Cobalt	<0.0013	<0.09		<0.09	<0.09	<0.09	<0.09	<0.0013	<0.09		<0.09	<0.09	<0.0013
Copper	<0.02	<0.02		<0.02	<0.02	0.03	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02
Iron	0.22	3.69		5.49	3.29	11.2	2.08	0.22	3.53		0.72	2.02	0.54
Lead	<0.0006	<0.002	<0.0006	<0.002	<0.002	<0.002	<0.002	<0.0006	<0.002	<0.0006	<0.002	0.0015	<0.0006
Magnesium	154	125		116	79.9	158	91.6	121	140		199	163	52.3
Manganese	3.24	3.2		4.19	2.61	4.66	5.38	5.72	4.14		6.03	2.36	0.25
Vanadium	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01
Zinc	<0.01	0.02		0.04	1.08	0.21	<0.01	<0.01	0.03		<0.01	0.04	<0.01
Nickel	<0.0012	<0.0012		<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012		<0.0012	<0.0012	<0.0012
Phosphorus	<0.32	<0.32		<0.32	<0.32	<0.32	<0.32	0.86	<0.32		<0.32	<0.32	1.21
Silver	<0.00003	<0.00003		<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003		<0.00003	<0.00003	<0.00003
Strontium	1.28	1.28		1.27	0.44	1.16	0.98	0.73	0.82		1.04	0.92	0.6
Sodium	97.9	115		116	54.4	68.1	73	49.5	74.7		73.9	92.6	53.2
Molybdenum	<0.04	<0.04		<0.04	<0.04	<0.04	<0.04	<0.04	<0.04		<0.04	<0.04	<0.04
Titanium	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01
Zirconium	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01
Thallium		<0.002		<0.002	<0.002	<0.002	<0.002		<0.002		<0.002	<0.002	
Arsenic	0.017							0.08					<0.005
Other (mg/L)													
Total Cyanide	0.425							10.9					0.049
Ammonia (as Nitrogen)	1.6							3.3					2.1
TKN	3.2							8.1					2.7

Notes:

Dup – Duplicate
< – Less than Method Detection Limit
NA – Not applicable
UST – Underground Storage Tank
INT – Due to high copper in sample GFAA could not be performed

* – Potentially labelled incorrectly during sampling

Guidelines

CDWG – Canadian Drinking Water Guidelines
WHO – World Health Organization
CCME – Canadian Environmental Quality Criteria for Contaminated Sites

–– – Guideline not available
▨ Analysis exceeds at least one guideline value

Analyzed by Canviro Analytical Laboratories Ltd. (CALL)

Table 2.4 (cont'd)
Comparison of Chemical Analysis of Groundwater Samples to Available Criteria (Inorganics)

Page 2 of 2

Sample Name Sample Date Laboratory No. Round No.	MW22 (Dup) 10/04/93 10224–08 1	MW22 06/26/94 07005–12 2	MW23A * 06/27/94 07005–02 2	MW23B 06/26/94 07005–03 2	MW24A 06/26/94 07005–07 2	MW24A (Dup) 06/26/94 07005–01 2	MW24C 06/26/94 07005–05 2	MW24B 08/13/94 08256–08 3	CRITERIA CDWG	 WHO	 CCME Remediation (Drinking Water)	 CCME Remediation (Aquatic Life)
Metals (mg/L)												
Aluminum	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	--	--	--	0.005
Boron	0.29	0.3	0.3	0.24	0.26	0.17	0.19	0.17	5	--	5	--
Barium	0.17	0.28	0.08	0.08	0.13	0.17	0.19	0.52	1	--	1	--
Beryllium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	--	--	--	--
Cadmium	<0.00008	0.00013	<0.032(INT)	<0.00008	0.00011	0.00013	<0.00008	<0.00008	0.005	--	0.005	0.0002
Calcium	94.8	92.8	63.7	391	71.5	110	270	175	--	--	--	--
Chromium	<0.0042	<0.00037	0.02	<0.00037	<0.00037	<0.00037	<0.00037	<0.02	0.05	--	0.05	0.002–0.02
Cobalt	<0.0013	<0.09	<0.09(INT)	<0.09	<0.09	<0.09	<0.09	<0.09	--	--	--	--
Copper	<0.02	<0.02	880	<0.02	<0.02	<0.02	0.03	<0.02	1	1	1	0.002–0.004
Iron	0.55	5.56	0.14	17	1.14	3.01	31.3	8.69	0.3	0.3	0.3	0.3
Lead	<0.0006	<0.002	<0.1(INT)	<0.002	<0.002	<0.002	<0.002	<0.0006	0.01	0.01	0.01	0.001–0.007
Magnesium	51	49	44.9	222	44	63.1	210	91.6	--	--	--	--
Manganese	0.26	0.12	0.1	9.77	0.12	2.47	4.31	1.64	0.05	0.1	0.05	--
Vanadium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	--	--	--	--
Zinc	<0.01	0.02	8.82	0.15	0.07	0.15	<0.01	<0.01	5	3	5	0.03
Nickel	<0.0012	<0.0012	<0.03(INT)	<0.0012	<0.0012	<0.0012	<0.0012	<0.03	--	0.02	--	0.025–0.150
Phosphorus	<0.32	<0.32	<0.32	<0.32	<0.32	<0.32	<0.32	<0.32	--	--	--	--
Silver	<0.00003	<0.00003	<0.02(INT)	<0.00003	<0.00003	<0.00003	<0.00003	<0.02	--	--	--	0.0001
Strontium	0.6	0.65	0.46	1.45	0.54	0.42	1.38	0.97	--	--	--	--
Sodium	49.5	55.6	103	58.2	54.4	23.9	61.1	42.2	200	--	200	--
Molybdenum	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	--	--	--	--
Titanium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	--	--	--	--
Zirconium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	--	--	--	--
Thallium		<0.002	NA	<0.002	<0.002	<0.002	<0.002		--	--	--	--
Arsenic	<0.005								0.05	--	0.025	0.05
									--	--	--	--
Other (mg/L)									--	--	--	--
Total Cyanide	0.045								0.2	--	0.2	--
Ammonia (as Nitrogen)	2								--	--	--	1.37–2.2
TKN	3								--	--	--	--

Notes:

Dup – Duplicate
< – Less than Method Detection Limit
NA – Not applicable
UST – Underground Storage Tank
INT – Due to high copper in sample GFAA could not be performed

* – Potentially labelled incorrectly during sampling

Analyzed by Canviro Analytical Laboratories Ltd. (CALL)

Guidelines

CDWG – Canadian Drinking Water Guidelines
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-- – Guideline not available
▨ Analysis exceeds at least one guideline value

Table 2.5
Comparison of Chemical Analysis of Groundwater Samples to Available Criteria (Organics)

Page 1 of 4

			Located close to USTs									Guideline								
Sample Name	MW01	MW01	MW02	MW02	MW02	MW03	MW03	MW03	MW05	MW05	MW05	CCME "ABC" FOR COAL GASIFICATION SITES			CDWG	WHO	ALBERTA MUST		CCME REMEDIATION	
Sample Date	10/04/93	06/26/94	10/04/93	10/24/93	06/26/94	10/04/93	06/26/94	08/13/94	10/04/93	06/26/94	08/13/94									
Laboratory No.	10224-01	07005-11	10224-02	10319-02(10319-02)	07005-13	10224-03	07005-09	08256-01	10224-06	07005-04	08256-02									
Round No.	1	2	1	1	2	1	2	3	1	2	3	A	B	C			Level II	Level III	Drinking Water	Aquatic Life
PAH's (ppb)																				
Naphthalene	0.044	0.457	2.63		0.831	3150	13400	6650	1.3	8390	2.43	0.2	2	20	--	--	--	--	--	--
Acenaphthylene	0.021	0.024	0.368		0.12	561	428	351	69	97.8	19.4	--	--	--	--	--	--	--	--	--
Acenaphthene	<0.008	<0.008	0.086		0.066	18.9	14.6	12.6	36.8	32.9	13.3	--	--	--	--	--	--	--	--	--
Fluorene	<0.004	<0.004	0.251		0.177	80.6	39.1	36	4.49	4.68	0.395	--	--	--	--	--	--	--	--	--
Phenanthrene	0.031	<0.007	0.251		0.25	306	48.4	43.2	9.06	6.82	0.297	0.2	2	20	--	--	--	--	--	--
Anthracene	0.012	<0.008	0.042		0.069	60.6	14.5	16.3	1.87	1.34	0.251	--	--	--	--	--	--	--	--	--
Fluoranthene	0.014	<0.006	0.072		0.135	81.8	10.9	14.7	1.41	0.869	1.11	--	--	--	--	--	--	--	--	--
Pyrene	0.018	<0.004	0.092		0.159	117	15	20.4	1.65	0.863	1.49	0.2	2	20	--	--	--	--	--	--
Benzo (a) anthracene	<0.005	<0.005	<0.005		0.057	20.9	6.38	6.04	0.347	0.111	0.44	0.01	0.1	1	--	--	--	--	--	--
Chrysene	<0.007	<0.007	<0.007		0.041	16.1	3.97	6.14	0.341	0.082	0.331	--	--	--	--	--	--	--	--	--
Benzo (b) fluoranthene	<0.007	<0.007	<0.007		<0.007	36.6(COM)	4.41	3.23	0.173	0.101(COM	0.243	0.01	0.1	1	--	--	--	--	--	--
Benzo (k) fluoranthene	<0.007	<0.007	<0.007		<0.007	COM	3.21	5.58	0.207	COM	0.165	0.01	0.1	1	--	--	--	--	--	--
Benzo (a) pyrene	<0.006	<0.006	<0.006		0.061	25.8	7.88	6.92	0.312	0.063	0.312	0.01	0.1	1	0.01	0.7	--	--	0.01	--
Indeno (1,2,3-cd) pyrene	<0.011	<0.011	<0.011		0.038	14.8	5.57	4.93	0.209	0.015	0.261	0.01	0.1	1	--	--	--	--	--	--
Dibenzo (a,h) anthracene	<0.008	<0.008	<0.008		<0.008	<0.8	0.908	0.78	<0.008	<0.008	0.043	0.01	0.1	1	--	--	--	--	--	--
Benzo (ghi) perylene	<0.009	<0.009	<0.009		0.028	10.6	4.57	5.14	0.175	0.026	0.164	--	--	--	--	--	--	--	--	--
Perylene	<0.006(NS)		<0.006(NS)			<0.6(NS)			0.08(NS)			--	--	--	--	--	--	--	--	--
Benzo (j) fluoranthene	<0.007(NS)		<0.007(NS)			COM/NS			<0.007(NS)			--	--	--	--	--	--	--	--	--
Benzo (e) pyrene	<0.006(NS)		<0.006(NS)			13.6(NS)			0.198(NS)			--	--	--	--	--	--	--	--	--
D8-Naphthalene (Rec. Surrogate)	74%	65%	96%		68%	NR	NR*	NR	54%	39%	53%									
D12-Chrysene (Rec. Surrogate)	108%	90%	112%		86%	NR	95%	83%	93%	86%	58%									
BTEX(ppb)																				
Benzene	<0.11	<0.55	14.3		<0.55	3710	5140	2930	684	980	1160	--	--	--	5	10	50	250	5	300
Toluene	<0.16	<0.8	<1.6		<0.8	740	350	244	<16	<16	<50	--	--	--	24	700	40000	100000	24	300
m & p Xylene	0.31	<0.6	<1.2		<0.6	1760	870	1212	215	225	418	--	--	--	300	500	5000	20000	300	--
Ethyl benzene	<0.08	<0.4	<0.8		<0.4	300	770	<50	427	30	427	--	--	--	2.4	300	10000	50000	2.4	700
o-Xylene	0.16	<0.4	277		<0.4	770	<8	1013	232	275	520	--	--	--	300	500	5000	20000	300	
D6-Benzene (Rec. Surrogate)	72%	110%	128%		77%	103%	107%	99%	107%	95%	98%									
D10-Ethylbenzene (Rec. Surrogate)	104%	112%	98%		31%(INT)	102%	99%	95%	94%	79%	98%									
Phenolics(ug/L)	3	<0.8	51		8.4	230	140	65	42	46		--	--	--	--	--	--	--	--	1
TPH(ppm)																				
Total Volatile Hydrocarbon				NA(nosed)\0.27(withsed)								--	--	--	--	--	--	--	--	--
Total Semi-Volatile Hydrocarbon				0.04(nosed)\0.06(withsed)								--	--	--	--	--	--	--	--	--
Total Petroleum Hydrocarbon				0.04(nosed)\0.33(withsed)								--	--	--	--	--	50	200	--	--

Notes:

Dup – Duplicate sample
NA – Not applicable
< – Less than MDL
UST – Underground Storage Tank
Com – Combined result identified for benzo(b), (j) and (k) fluoranthene
(0.04/0.06) – No sediment/with sediment
NS – NO SPIKE
NR – NO RECOVERY

Analyzed by Canviro Analytical Laboratories Ltd. (CALL)

Guidelines:
CDWG – Canadian Drinking Water Guidelines
WHO – World Health Organization
CCME – Canadian Environmental Quality Criteria for Contaminated Sites

Note: i) Values exceeding CCME "B" or "C" criteria were identified.

Values exceeding the CCME "A" criteria and not the CCME "B" or "C" criteria were not identified. The CCME "A" criteria was not applicable to the present or past use of this site

ii) Alberta MUST Criteria only applies to locations near USTs

-- – Guideline not available
▨ Analysis exceeds at least one guideline value

Table 2.5
Comparison of Chemical Analysis of Groundwater Samples to Available Criteria (Organics) cont'd

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						Located close to the USTs					Guideline								
Sample Name	MW12	MW12	MW12	MW14	MW14	MW18	MW18	MW18	MW21	MW22	CCME "ABC" FOR COAL GASIFICATION SITES			CDWG	WHO	ALBERTA MUST		CCME REMEDIATION	
Sample Date	10/04/93	06/26/94	08/13/94	10/24/93 & 10/04/93	06/26/94	10/04/93	06/26/94	08/13/94	06/26/94	10/04/93									
Laboratory No.	10224-04	07005-06	08256-03	10318-01 & 10224-05	07005-08	10226-01	07005-10	08256-04	07006-01	10224-17									
Round No.	1	2	3	1	2	1	2	3	2	1	A	B	C			Level II	Level III	Drinking Water	Aquatic Life
PAH's (ppb)																			
Naphthalene	7.81	39.4	6.09	3330	15614		2.43	5.47	0.03	11.1	0.2	2	20	--	--	--	--	--	--
Acenaphthylene	0.197	0.079	<0.004	92.6	368		0.07	0.071	0.032	91.9	--	--	--	--	--	--	--	--	--
Acenaphthene	0.868	0.74	0.638	4.48	48.4		0.066	0.057	0.174	45.5	--	--	--	--	--	--	--	--	--
Fluorene	0.871	0.27	<0.004	12.7	44.1		0.082	0.06	0.36	65.9	--	--	--	--	--	--	--	--	--
Phenanthrene	0.467	0.021	0.027	26.6	81.9		0.041	0.016	<0.007	213	0.2	2	20	--	--	--	--	--	--
Anthracene	0.148	0.022	0.03	5.09	20.3		0.045	0.042	<0.008	34.5	--	--	--	--	--	--	--	--	--
Fluoranthene	0.169	0.063	0.013	4.86	31.4		0.068	0.038	<0.006	44.8	--	--	--	--	--	--	--	--	--
Pyrene	0.184	0.089	0.04	5.96	42.7		0.039	0.024	<0.004	49.8	0.2	2	20	--	--	--	--	--	--
Benzo (a) anthracene	0.027	<0.005	<0.005	0.829	7.07		<0.005	0.011	<0.005	6.72	0.01	0.1	1	--	--	--	--	--	--
Chrysene	0.03	<0.007	<0.007	0.829	9.55		<0.007	<0.007	<0.007	8.88	--	--	--	--	--	--	--	--	--
Benzo (b) fluoranthene	<0.007	<0.007	<0.007	0.87(COM)	11.5		<0.007	<0.007	<0.007	7.29(COM)	0.01	0.1	1	--	--	--	--	--	--
Benzo (k) fluoranthene	<0.007	<0.007	<0.007	COM	8.35		<0.007	<0.007	<0.007	COM	0.01	0.1	1	--	--	--	--	--	--
Benzo (a) pyrene	<0.006	<0.006	<0.006	0.662	20.1		<0.006	<0.006	<0.006	7.72	0.01	0.1	1	0.01	0.7	--	--	0.01	--
Indeno (1,2,3-cd) pyrene	<0.011	<0.011	<0.011	0.353	14.9		<0.011	<0.011	<0.011	<1.1	0.01	0.1	1	--	--	--	--	--	--
Dibenzo (a,h) anthracene	<0.008	<0.008	<0.008	0.032	2.27		<0.008	<0.008	<0.008	<0.8	0.01	0.1	1	--	--	--	--	--	--
Benzo (ghi) perylene	<0.009	<0.009	<0.009	0.355	13.8		<0.009	<0.009	<0.009	<0.9	--	--	--	--	--	--	--	--	--
Perylene	<0.006(NS)									2.58(NS)	--	--	--	--	--	--	--	--	--
Benzo (j) fluoranthene	<0.007(NS)									COM/NS	--	--	--	--	--	--	--	--	--
Benzo (e) pyrene	<0.006(NS)									8.02(NS)	--	--	--	--	--	--	--	--	--
D8-Naphthalene (Rec. Surrogate)	62%	54%	58%	NR	NR*		66%	58%	68%	NR									
D12-Chrysene (Rec. Surrogate)	92%	83%	59%	84%	NR**		97%	59%	74%	NR									
BTEX(ppb)																			
Benzene	<1.1	5.43	<5	53300	94930	<11	2080	1363	<0.55	1280	--	--	--	5	10	50	250	5	300
Toluene	<1.6	<0.8	<5	8570	10700	<16	<16	<50	<0.8	<16	--	--	--	24	700	40000	100000	24	300
m & p Xylene	1.2	13.6	<5	2810	5800	<12	550	843	38.4	135	--	--	--	300	500	5000	20000	300	--
Ethyl benzene	1.4	1.31	<5	2930	<800	<8	1130	<50	<0.4	<8	--	--	--	2.4	300	10000	50000	2.4	700
o-Xylene	39.1	45.2	49	1330	<800	136	<8	297	<0.4	46	--	--	--	300	500	5000	20000	300	
D6-Benzene (Rec. Surrogate)	103%	105%	98%	80%	100%	58%	105%	90%	23(INT)%	89%									
D10-Ethylbenzene (Rec. Surrogate)	99%	111%	107%	99%	98%	79%	103%	82%	89%	107%									
Phenolics(ug/L)	10	12		1840	1500	5.8	25	23	52	22	--	--	--	--	--	--	--	--	1
TPH(ppm)																			
Total Volatile Hydrocarbon						0.86					--	--	--	--	--	--	--	--	--
Total Semi-Volatile Hydrocarbon						0.06					--	--	--	--	--	--	--	--	--
Total Petroleum Hydrocarbon						0.92					--	--	--	--	--	50	200	--	--

Notes:

Dup – Duplicate sample
NA – Not applicable
< – Less than MDL
UST – Underground Storage Tank
Com – Combined result identified for benzo(b), (j) and (k) fluoranthene
(0.04/0.06) – No sediment/with sediment
NS – NO SPIKE
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Note: I) Values exceeding CCME "B" or "C" criteria were identified.

Values exceeding the CCME "A" criteria and not the CCME "B" or "C" criteria were not identified. The CCME "A" criteria was not applicable to the present or past use of this site

II) Alberta MUST Criteria only applies to locations near USTs

-- – Guideline not available
▨ Analysis exceeds at least one guideline value

Table 2.5
Comparison of Chemical Analysis of Groundwater Samples to Available Criteria (Organics) cont'd

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Sample Name	MW22 (Dup)	MW22	MW23A	MW23A (Dup)	MW23A	MW23A (Dup)	MW23B	MW23B	MW24A	Guideline								
Sample Date	10/04/93	06/26/94	06/27/94	06/26/94	08/13/94	08/13/94	06/26/94	08/13/94	06/26/94	CCME "ABC" FOR COAL GASIFICATION SITES			CDWG	WHO	ALBERTA MUST		CCME REMEDIATION	
Laboratory No.	10224-08	07005-12	07005-02	07005-01	08256-06	08256-10	07005-03	08256-05	07005-07									
Round No.	1	2	2	2	3	3	2	3	2	A	B	C			Level II	Level III	Drinking Water	Aquatic Life
PAH's (ppb)																		
Naphthalene	9.5	13600	0.436	0.353	0.488	0.109	22800	12400	0.399	0.2	2	20	--	--	--	--	--	--
Acenaphthylene	73	1590	1.12	0.88	1.21	0.071	1450	741	0.162	--	--	--	--	--	--	--	--	--
Acenaphthene	44.5	276	0.156	0.131	0.041	<0.008	138	54.3	0.14	--	--	--	--	--	--	--	--	--
Fluorene	60.1	486	0.414	0.366	0.077	<0.004	573	203	<0.004	--	--	--	--	--	--	--	--	--
Phenanthrene	168	1960	0.689	0.492	0.401	0.017	2200	603	0.064	0.2	2	20	--	--	--	--	--	--
Anthracene	37.8	504	0.609	0.506	0.299	0.01	636	191	0.021	--	--	--	--	--	--	--	--	--
Fluoranthene	54.4	850	2.25	1.93	0.554	<0.006	960	242	0.069	--	--	--	--	--	--	--	--	--
Pyrene	62.5	1110	7.75	6.53	3.39	0.292	1170	330	0.081	0.2	2	20	--	--	--	--	--	--
Benzo (a) anthracene	6.65	167	3.42	2.72	0.761	<0.005	509	90.6	<0.005	0.01	0.1	1	--	--	--	--	--	--
Chrysene	11.9	206	2.3	1.92	0.913	<0.007	364	101	<0.007	--	--	--	--	--	--	--	--	--
Benzo (b) fluoranthene	<0.7	218(COM)	1.55	1.06	0.632	<0.007	296	63.3	<0.007	0.01	0.1	1	--	--	--	--	--	--
Benzo (k) fluoranthene	<0.7	COM	1.36	1.15	0.798	<0.007	191	56.4	<0.007	0.01	0.1	1	--	--	--	--	--	--
Benzo (a) pyrene	6.34	165	3.17	2.5	1.42	<0.006	517	98.4	<0.006	0.01	0.1	1	0.01	0.7	--	--	0.01	--
Indeno (1,2,3-cd) pyrene	<1.1	60.9	1.91	0.123	0.692	<0.011	289	45.3	<0.011	0.01	0.1	1	--	--	--	--	--	--
Dibenzo (a,h) anthracene	<0.8	<8	0.277	0.096	0.112	<0.008	72.2	7.23	<0.008	0.01	0.1	1	--	--	--	--	--	--
Benzo (ghi) perylene	<0.9	64	1.78	1.36	0.758	<0.009	277	51.9	<0.009	--	--	--	--	--	--	--	--	--
Perylene	3.59(NS)									--	--	--	--	--	--	--	--	--
Benzo (j) fluoranthene	<0.7(NS)									--	--	--	--	--	--	--	--	--
Benzo (e) pyrene	10.7(NS)									--	--	--	--	--	--	--	--	--
D8-Naphthalene (Rec. Surrogate)	NR	NR	58%	62%	76%	56%	NR	NR	57%									
D12-Chrysene (Rec. Surrogate)	NR	NR	71%	70%	93%	63%	NR	NR	76%									
BTEX(ppb)																		
Benzene	573	2280	<0.55	<0.55	<0.5	<0.5	10320	7710	<0.55	--	--	--	5	10	50	250	5	300
Toluene	11.4	380	<0.8	<0.8	<0.5	<0.5	<16	<50	<0.8	--	--	--	24	700	40000	100000	24	300
m & p Xylene	18.7	335	<0.6	<0.6	<0.5	<0.5	725	1215	<0.6	--	--	--	300	500	5000	20000	300	--
Ethyl benzene	<0.8	490	<0.4	<0.4	<0.5	<0.5	520	<50	<0.4	--	--	--	2.4	300	10000	50000	2.4	700
o-Xylene	7.6	<8	<0.4	<0.4	<0.5	<0.5	<8	1340	<0.4	--	--	--	300	500	5000	20000	300	
D6-Benzene (Rec. Surrogate)	77%	108%	97%	91%	96%	76%	112%	95%	100%									
D10-Ethylbenzene (Rec. Surrogate)	90%	98%	93%	91%	95%	92%	101%	91%	109%									
Phenolics(ug/L)	26	16	1.6	1.6	3	2	67	210	<0.8	--	--	--	--	--	--	--	--	1
TPH(ppm)																		
Total Volatile Hydrocarbon										--	--	--	--	--	--	--	--	--
Total Semi-Volatile Hydrocarbon										--	--	--	--	--	--	--	--	--
Total Petroleum Hydrocarbon										--	--	--	--	--	50	200	--	--

Notes:

Dup – Duplicate sample
NA – Not applicable
< – Less than MDL
UST – Underground Storage Tank
Com – Combined result identified for benzo(b), (j) and (k) fluoranthene
(0.04/0.06) – No sediment/with sediment
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Values exceeding the CCME "A" criteria and not the CCME "B" or "C" criteria were not identified. The CCME "A" criteria was not applicable to the present or past use of this site

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Table 2.5
Comparison of Chemical Analysis of Groundwater Samples to Available Criteria (Organics) -- cont'd

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Sample Name	MW24A	MW24B	MW24C	MW24C	Trip Blank	Lab Blank	Lab Blank	Method Spike	Method Spike	Guideline								
Sample Date	08/13/94	08/13/94	06/26/94	08/13/94	08/13/94	06/26/94	08/13/94	06/26/94	08/13/94	CCME "ABC" FOR COAL GASIFICATION SITES			CDWG	WHO	ALBERTA MUST		CCME REMEDIATION	
Laboratory No.	08256-07	08256-08	07005-05	08256-09	08256-11	9407005	9408256	9407005	9408256									
Round No.	3	3	2	3	3	2	3	2	3	A	B	C			Level II	Level III	Drinking Water	Aquatic Life
PAH's (ppb)																		
Naphthalene	0.018	0.084	3090	3030	0.037	<0.004	0.009	69%	63%	0.2	2	20	--	--	--	--	--	--
Acenaphthylene	0.195	2.06	47	73.4	0.035	<0.004	<0.004	84%	76%	--	--	--	--	--	--	--	--	--
Acenaphthene	0.023	0.888	20.9	26.5	<0.008	<0.008	<0.008	77%	69%	--	--	--	--	--	--	--	--	--
Fluorene	0.023	0.555	6.6	11	<0.004	<0.004	<0.004	81%	78%	--	--	--	--	--	--	--	--	--
Phenanthrene	0.036	0.039	13	18.7	0.012	<0.007	<0.007	87%	82%	0.2	2	20	--	--	--	--	--	--
Anthracene	0.02	0.159	2.54	6.68	<0.008	<0.008	<0.008	78%	79%	--	--	--	--	--	--	--	--	--
Fluoranthene	0.057	0.148	3.09	2.64	<0.006	<0.006	<0.006	96%	75%	--	--	--	--	--	--	--	--	--
Pyrene	0.077	0.162	3.65	3.21	<0.004	<0.004	<0.004	89%	75%	0.2	2	20	--	--	--	--	--	--
Benzo (a) anthracene	<0.005	<0.005	0.86	0.258	<0.005	<0.005	<0.005	110%	75%	0.01	0.1	1	--	--	--	--	--	--
Chrysene	<0.007	<0.007	0.612	0.203	<0.007	<0.007	<0.007	97%	73%	--	--	--	--	--	--	--	--	--
Benzo (b) fluoranthene	<0.007	<0.007	0.331	0.066	<0.007	<0.007	<0.007	93%	68%	0.01	0.1	1	--	--	--	--	--	--
Benzo (k) fluoranthene	<0.007	<0.007	0.328	0.066	<0.007	<0.007	<0.007	95%	67%	0.01	0.1	1	--	--	--	--	--	--
Benzo (a) pyrene	<0.006	<0.006	0.752	0.116	<0.006	<0.006	<0.006	93%	59%	0.01	0.1	1	0.01	0.7	--	--	0.01	--
Indeno (1,2,3-cd) pyrene	<0.011	<0.011	0.403	0.055	<0.011	<0.011	<0.011	78%	59%	0.01	0.1	1	--	--	--	--	--	--
Dibenzo (a,h) anthracene	<0.008	<0.008	<0.008	0.011	<0.008	<0.008	<0.008	72%	60%	0.01	0.1	1	--	--	--	--	--	--
Benzo (ghi) perylene	<0.009	<0.009	0.421	0.042	<0.009	<0.009	<0.009	81%	57%	--	--	--	--	--	--	--	--	--
Perylene										--	--	--	--	--	--	--	--	--
Benzo (j) fluoranthene										--	--	--	--	--	--	--	--	--
Benzo (e) pyrene										--	--	--	--	--	--	--	--	--
D8-Naphthalene (Rec. Surrogate)	55%	56%	48%	66%	72%	64%	62%	68%	51%									
D12-Chrysene (Rec. Surrogate)	67%	60%	76%	58%	62%	67%	61%	87%	70%									
BTEX(ppb)																		
Benzene	<0.5	105	6270	5080	<0.5	<0.55	<0.5	90%	103%	--	--	--	5	10	50	250	5	300
Toluene	<0.5	<5	70	<50	<0.5	<0.8	<0.5	93%	109%	--	--	--	24	700	40000	100000	24	300
m & p Xylene	<0.5	49	340	335	<0.5	<0.6	<0.5	91%	103%	--	--	--	300	500	5000	20000	300	--
Ethyl benzene	<0.5	<5	310	915	<0.5	<0.4	<0.5	98%	106%	--	--	--	2.4	300	10000	50000	2.4	700
o-Xylene	<0.5	53.5	255	285	<0.5	<0.4	<0.5	98%	99%	--	--	--	300	500	5000	20000	300	
D6-Benzene (Rec. Surrogate)	78%	97%	111%	94%	100%	84%	101%	103%	98%									
D10-Ethylbenzene (Rec. Surrogate)	89%	92%	102%	94%	90%	80%	98%	112%	103%									
Phenolics(ug/L)	3.6	28	56	350	<0.8					--	--	--	--	--	--	--	--	1
TPH(ppm)																		
Total Volatile Hydrocarbon										--	--	--	--	--	--	--	--	--
Total Semi-Volatile Hydrocarbon										--	--	--	--	--	--	--	--	--
Total Petroleum Hydrocarbon										--	--	--	--	--	50	200	--	--

Notes:

Dup - Duplicate sample
NA - Not applicable
< - Less than MDL
UST - Underground Storage Tank
Com - Combined result identified for benzo(b), (j) and (k) fluoranthene
(0.04/0.06) - No sediment/with sediment
NS - NO SPIKE
NR - NO RECOVERY

Guidelines:
CDWG - Canadian Drinking Water Guidelines
WHO - World Health Organization
CCME - Canadian Environmental Quality Criteria for Contaminated Sites

Note: I) Values exceeding CCME "B" or "C" criteria were identified.

Values exceeding the CCME "A" criteria and not the CCME "B" or "C" criteria were not identified. The CCME "A" criteria was not applicable to the present or past use of this site

II) Alberta MUST Criteria only applies to locations near USTs

-- - Guideline not available
▨ Analysis exceeds at least one guideline value

Analyzed by Canviro Analytical Laboratories Ltd. (CALL)

Deuterated surrogate recoveries should be close to 100 percent under ideal conditions. Generally, the deuterated surrogate recoveries for PAHs tend to be much less than those associated with the BTEX analysis. Any values significantly below 100 percent indicate that the reported concentrations may be below actual concentrations and they are likely biased on the low side. The deuterated surrogate recoveries were in the range which is typical for the types of analyses performed and indicate no need for concern in interpreting the results.

Duplicate samples provide an indication of laboratory precision and reproducibility. Duplicate samples for organics analysis were prepared at MW23A for Round Nos. 2 and 3. A duplicate sample for inorganics was collected in Round No. 2 at MW24A. Comparison of the duplicate sample for organics in Round No. 2 suggests an acceptable level of precision was obtained. PAHs, BTEX and phenolics all compared well between the two samples. The duplicate for inorganics at MW24A also identified an acceptable level of precision. A poor comparison was identified at MW23A for PAHs in Round No. 3 for the duplicate sample indicating questionable reliability in the lab results. The reproducibility and precision was low for this duplicate PAH sample; however, the BTEX and phenolics identified an acceptable level of comparison at MW23A in Round No. 3.

A trip blank was prepared for Round No. 3 sampling activities. The purpose of the trip blank is to identify any potential sample bias that may occur during transportation from the site to the laboratory due primarily to airborne contaminants. From a review of the results, three of the lighter weight PAHs (i.e. naphthalene, acenaphthylene and phenanthrene) were identified in the trip blank sample. This suggests that samples with significant PAH concentrations stored in the same transportation container may have caused some low level bias to the other samples likely through airborne contamination.

Groundwater Results

Results of chemical analyses for groundwater samples are presented in Table 2.4 for inorganic chemicals, Table 2.5 for organic chemicals, and Table 2.6 for indicator analysis. Tables 2.4 and 2.5 for inorganic and organic chemicals, respectively, provide a comparison of the chemical results collected since the initiation of Phase I. Sample results exceeding at least one of the reference criteria are shaded to assist in interpretation. The discussion of the inorganic and organic results that follows is presented according to the following areas:

- South End of Site
- North End of Site
- Offsite Area (Adjacent to the Red River)

Indicator Analyses. As in Phase I, indicator analyses were performed in the field as indicators of overall groundwater quality in Round Nos. 2 and 3. The analyses performed included electrical conductance, pH, temperature, and redox potential. A physical description is provided for the groundwater sampled at each location. The results of these analyses are provided in Table 2.6.

Table 2.6
Summary of Groundwater Indicator Results From Phase II Field Monitoring

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Monitor Well Location	Cumulative Volume Purged (Litres)	pH	Electrical Conductivity (μS/cm)	Redox Potential (mvolts)	Sample Temperature (degree celsius)	Comments
ROUND NO. 2						
Purging Period: 06/26/94						
MW-01	2	--	--	--	--	Clear to slightly turbid, no odour or sheen
	22	6.7	1431	156	10.5	Clear and no colour
	42	6.8	1335	122	9.7	Clear and no colour
Purging Period: 06/24/94 to 06/26/94						
MW-02	23	6.8	1535	21	10.5	Dark grey with sweet odour
	30	6.8	1596	53	11.5	Dark grey with sweet odour
	37	6.8	1525	119	8.5	Dark grey with sweet odour
Purging Period: 06/24/94 to 06/26/94						
MW-03	18	6.9	1432	141	11.7	Brown, slight sheen & no odour
	34	6.9	1496	177	12.8	Sheen, naphthalene odour, turbid
	48	7	1500	140	12	Sheen, naphthalene odour, turbid
Purging Period: 06/25/94 to 06/26/94						
MW-05	32	6.9	1765	15	11.5	Sheen, naphthalene odour, turbid
	56	6.9	1704	75	9.7	Sheen, naphthalene odour, turbid
	79	7	1657	105	10.7	Sheen, naphthalene odour, turbid
Purging Period: 06/24/94 to 06/26/94						
MW-12	19	6.9	1349	11	9.8	Naphthalene odour, turbid
	38	6.8	1314	107	10.5	Naphthalene odour, turbid
	55	6.9	1233	134	9.2	Naphthalene odour, turbid
Purging Period: 06/25/94 to 06/26/94						
MW-14	26	7	1416	-51	12.9	Moderate odour, turbid & grey
	49	7	1434	30	10.9	Moderate odour, turbid & grey
	68	7.1	1452	117	11.2	Moderate odour, turbid & grey
Purging Period: 06/24/94 to 06/26/94						
MW-18	50	6.6	1725	232	7.5	Turbid & no odour
	90	6.6	1829	202	9	Turbid & no odour
	120	6.6	1612	178	8	Less turbid & no odour
Purging Period: 06/26/94						
MW-21	5	--	--	--	--	Clear, no colour & no odour
	17	7.1	1865	179	8.6	Clear, no colour & no odour
Purging Period: 06/24/94 to 06/25/94						
MW-22	12	--	--	--	--	Pure tar (300ml), strong odour
	62	--	--	--	--	Pure tar, strong odour (product retained)
	94	7	904	25	10.2	Pure tar, strong odour
Purging Period: 06/16/94 to 06/26/94						
MW-23A	29	7.8	530	60	13.7	Sheen, grey, fine sand & moderate odour
	34	7.7	714	5	13.2	Sheen, grey & moderate odour
	57	7.3	701	103	11	Slight sheen, grey, turbid and moderate odour
Purging Period: 06/16/94 to 06/26/94						
MW-23B	32	6.7	1847	70	14.6	Strong odour, sheen, black
	60	6.7	1796	76	14.4	As above with fine sand (less sheen)
	76	6.6	1596	58	11	
Purging Period: 06/12/94 to 06/26/94						
MW-24A	48	--	--	--	--	Faint odour with fine sand
	68	--	--	--	--	
	88	7.4	832	-4	12.1	Faint odour, grey & turbid
	118	7.3	776	103	11.9	Faint odour, grey & silty
Purging Period: 06/12/94 to 06/26/94						
MW-24B	30	7.3	838	-8	14.2	Moderate odour, grey
	80	7.2	1079	-18	13.9	Moderate odour, grey
	120	7.1	1231	-17	14.9	Moderate odour, grey. cleaning up
Purging Period: 06/16/94 to 06/24/94						
MW-24C	60	--	--	--	--	Strong odour, fine sand & sheen
	80	--	--	--	--	Strong odour, fine sand & sheen
	100	7	1756	-81	11.7	Strong odour, turbid & grey
	120	7	1882	-66	13.2	Strong odour, turbid & grey
	150	6.9	1597	-92	10.9	Strong odour, turbid, grey & silty
ROUND NO. 3						
Purging Period: 08/13/94						
MW-03	17	6.9	1600	174	11.2	yellow, odour
	33	--	--	--	--	--
	50	--	--	--	--	--
MW-05	26	6.9	1631	-83	10.0	dark brown, strong odour
	43	--	--	--	--	--
	62	--	--	--	--	--
MW-12	19	6.8	1444	40	9.5	yellow, odour
	30	--	--	--	--	--
	57	--	--	--	--	--
MW-18	30	6.4	1961	173	10.3	cloudy
	60	--	--	--	--	--
	90	--	--	--	--	--
MW-23A	30	7.5	854	16	11.1	odour, light grey, silty
	90	--	--	--	--	--
MW-23B	23	6.6	1641	-53	10.7	strong odour, sheen
	43	--	--	--	--	--
	62	--	--	--	--	--
MW-24A	30	7.2	898	86	11.6	dark grey, silty
	90	--	--	--	--	grey, silty
MW-24B	30	6.9	1778	-117	11.1	strong odour, yellowish
	90	--	--	--	--	cloudy, yellow
MW-24C	30	7.2	1297	78	11	dark grey, odour
	60	--	--	--	--	--
	90	--	--	--	--	--

The electrical conductance (EC) measurements generally ranged from 1400 to 1800 μS/cm in Round No. 2 and 1300 to 1600 μS/cm in Round No. 3. The average EC value observed at the site was approximately 1400 μS/cm. There were some exceptions to this across the site. The deeper monitoring well locations such as MW22, MW23A & MW24A identified EC values below the average (700 to 900 μS/cm) which was consistent with results from Phase I sampling activities. These results indicate different groundwater quality in these depth intervals.

The pH values were close to neutral across the site as identified in Round Nos. 2 and 3. The pH values ranged from 6.6 to 7.8 in Round No. 2 and 6.4 to 7.5 in Round No. 3. The average across the site was approximately 7. Temperature values remained relatively consistent although some variation did exist. The average groundwater temperature for the two rounds was approximately 11 degrees celsius.

As observed in Phase I, redox values identified variation at each location monitored which is typical with these measurements. Because of this, little emphasis has been placed on this information. In Round No. 2, the redox values ranged from 10 to 150 mV and in Round No. 3 ranged from approximately 40 to 174 mV for most of the monitoring wells measured. Some reduction in atmospheric oxygen has probably occurred in the zone above the water table based on these measurements. The negative measurements observed at MW24B and MW24C suggest the presence of an oxygen-depleted environment or instrumental error. As indicated in the Phase I report (CH2M HILL, 1994), the low redox values identified at depth are consistent with the electrochemical evolution sequence in groundwater.

The most notable observation identified during completion of the field measurements was that a tarry liquid substance with a strong naphthalene odour was identified during sampling at MW22. This monitoring zone is situated at the top of the silty clay till at approximately 14 metres below ground surface.

Inorganics. The criteria available for comparison of the inorganic results are the Canadian Drinking Water Guideline (CDWG), the World Health Organization Criteria (WHO), the CCME Remediation Criteria for drinking water and the CCME Remediation Criteria for protection of aquatic life. Although these criteria are not directly applicable to the site as the water beneath the site is not being used for drinking water purposes and aquatic life is not being exposed to it, the criteria are used because they provide a reference point to identify chemicals requiring further attention.

Locations where results have been described in the Phase I report (CH2M HILL, 1994) are provided in Table 2.4 but are discussed here for comparison only if additional analyses were completed.

South End of Site. Iron and manganese were above the drinking water and aquatic guidelines at MW01, MW02, MW18 and MW21. The only exception to this was in Round No. 1 at MW01 where iron was below the drinking water guideline. These chemicals often occur naturally in groundwater and do not indicate a cause for concern as the guidelines are associated with aesthetics rather than health.

Cadmium was observed marginally above the aquatic guideline at MW18 in Round No. 2. Lead and zinc were also marginally above the aquatic guideline at MW21 in Round No. 2. The concentrations marginally above the aquatic guideline in the south end of the site do not pose a concern.

The lead results at MW02, MW18 and MW21 in the vicinity of the USTs do not exceed the Alberta Level I criteria of 0.05 mg/L (Alberta MUST criteria).

<u>North End of Site.</u> Iron and manganese concentrations exceed the drinking water and aquatic guidelines at MW03, MW05, MW12, MW14 and MW22. The only exception was the iron result at MW14 in Round No. 1, which did not exceed available criteria.

Zinc marginally exceeded the aquatic guideline at MW03, MW05 and MW14.

No significant exceedances for inorganic constituents were identified in this section of the site.

<u>Offsite (Adjacent of the Red River).</u> Iron and manganese were above the drinking water and aquatic guidelines at MW23A, MW23B, MW24A, MW24B and MW24C. As mentioned above, the chemicals do not indicate a cause for concern although some of the more elevated results may indicate microbial degradation of PAH residues.

The most significant inorganic exceedance has occurred at MW23A (deep well). Chromium, copper and zinc were observed at levels above the drinking water and aquatic guidelines. The copper result greatly exceeds the available guidelines. Inorganic species have a low mobility in the groundwater and typically adhere to soil particles or in some cases precipitate out of solution. Because of their low mobility in groundwater, elevated copper levels would be expected at shallower depths at MW23B rather than at greater depths at MW23A. A question remains whether or not MW23A and MW23B were labelled incorrectly during sample collection. Resampling for analysis of inorganic constituents would be necessary at MW23A and MW23B to resolve this inconsistency.

Zinc marginally exceeded the aquatic guideline at MW23B and MW24A. Copper marginally exceeded the aquatic guideline at MW24C.

With the exception of the elevated chromium, zinc and copper levels at MW23A, the analysis of inorganic constituents downgradient of the Centra Gas property has resulted in little cause for concern. Confirmation of the results at MW23A and MW23B would provide verification whether these elevated results are at shallow or deeper depths. At shallower depths, a greater potential exists for these constituents to discharge into the Red River and potentially affect in aquatic organisms.

Organic Chemicals. More detail concerning the various criteria used for evaluation of the results has been provided in the Phase I investigation report (CH2M HILL, 1994). A brief summary of the criteria has been provided for convenience below. The main criteria used for the evaluation of PAH results are the CCME (1989) criteria which are specific to PAHs. Criteria are provided for three levels of PAHs: Levels A, B, and C. Level A criteria is the least important for comparison with Levels B and C being the primary focus for evaluation.

The criteria used to assess BTEX results include the Alberta MUST criteria as well as drinking water and aquatic life guidelines. The Alberta MUST criteria, although not directly applicable, are the best measure of the significance of the results. The drinking water criteria and aquatic life values have also been included for comparison.

The results of the organic analyses are presented in Table 2.5.

South End of Site. There are no significant exceedances of organic constituents at the south end of the site as shown in Table 2.5. The results at MW01 from Round No. 2 did not exceed the available criteria. Phenols, which were observed to be slightly elevated above the criteria in Round No. 1, did not exceed the criteria in Round No. 2. Naphthalene and acenaphthylene were detected at low concentrations in Round No. 2.

In the vicinity of the USTs, MW02 and MW18 were resampled at least once following the Phase I investigation. MW21 could only be sampled once during Phases I and II due to slow groundwater recovery rates. At MW21, phenols were present at levels that exceed the Alberta Level I criteria and the CCME Remediation Criteria for protection of aquatic life. PAHs and BTEX constituents were not identified above the available criteria.

At MW02, results from Round No. 1 analyses identified only a small number of exceedances. Naphthalene only marginally exceeded the Level B CCME criteria. Benzene exceeded the Alberta Level I criteria but was less than Level II criteria. Phenols were present at levels which exceeded the Alberta Level I criteria and the CCME Remediation Criteria for protection of aquatic life. In Round No. 1, TPH exceeded the Alberta Level I criteria at MW02 but only marginally. The results from Round No. 2 were similar to Round No. 1 or identified a slight decrease in concentration for the constituents analyzed at MW02. Phenols only marginally exceeded the CCME Remediation Criteria for protection of aquatic life in Round No. 2. The phenols concentration decreased from 51 to 8.4 μg/L between the two rounds of analyses. No other parameters exceeded available criteria at MW02 in Round No. 2.

At MW18, phenols were detected at measurable levels in Round No. 1 which exceeded the Alberta Level I criteria and the CCME Remediation Criteria for protection of aquatic life. TPH marginally exceeded the Alberta Level I criteria at MW18. In Round Nos. 2 and 3, the results were more elevated for BTEX and phenols compared to Round No. 1. The most significant exceedance occurred for benzene in both Round Nos. 2 and 3. Benzene exceeded the CCME Remediation Criteria for drinking water and the Alberta Level III criteria. No other BTEX constituents exceeded the Alberta Level II or III criteria. The

CCME Remediation Criteria for drinking water was exceeded for benzene and m&p-xylene in both Round Nos. 2 and 3. Ethyl benzene exceeded this criteria in Round No. 2 but was not detected above measurable levels in Round No. 3. Phenol results from Round Nos. 2 and 3 increased in concentration from Round No. 1 and exceeded the CCME Remediation Criteria for protection of aquatic life. Naphthalene was the only PAH compound to exceed the CCME Level B criteria in both Round Nos. 2 and 3.

In general, very little groundwater contamination was identified in the south section of the site in association with the former coal gasification plant. The most significant observations were identified in the vicinity of the USTs close to the storm sewer system at MW18. It is possible that potential leakage or over spillage from the former USTs has accumulated along the sewer backfill based on elevated BTEX concentrations at MW18. Only marginal PAH contamination occurred at MW18 suggesting that the source was likely associated with the former USTs. Since 1993, the USTs have been pumped of any remaining petroleum fuel and are presently inactive onsite.

North End of Site. In reviewing the analytical results (Table 2.3), MW03, MW14 and MW22 in the northwest part of the site were identified as exceeding Level C values for PAHs in Round Nos. 1 and 2 as well as Round No. 3 for MW03 only. Both MW14 and MW22 identified increases in concentrations in Round No. 2 suggesting that a source of coal tar may be located close to these wells. The concentrations of PAHs are significant at MW22 as this well is located 14 metres below ground surface above the silty clay till. At MW03, naphthalene was the only PAH to significantly increase in concentration in Round Nos. 2 and 3. All other PAHs at MW03 decreased in concentration in Round Nos. 2 and 3. The Alberta Level III criteria for benzene was exceeded for all sample rounds at the above-mentioned locations. The Alberta Level II criteria for m&p-xylene was exceeded at MW14 in Round No. 2. At the MW03, MW14 and MW22 for all sample rounds, BTEX generally exceeded the CCME Remediation Criteria for drinking water and protection of aquatic life including the WHO and CDWG criteria. At MW03, MW14 and MW22 for all sample rounds, phenols exceeded the CCME Remediation Criteria for protection of aquatic life.

Water quality at MW05, at the northeast corner of the site, had similar trends for the three sample rounds. Chemical constituents were generally at lower concentrations at MW05 compared to MW03, MW14 and MW22 in the northwest corner. For PAHs, most constituents exceeded the Level B criteria. In Round No. 2, naphthalene greatly exceeded the Level C criteria which was not consistent with the other sample rounds. The Alberta Level III criteria for benzene was exceeded at MW05 in Round Nos. 1, 2 and 3. One or more of the BTEX constituents at MW05 exceeded the CCME Remediation Criteria for drinking water and protection of aquatic life including the WHO and CDWG criteria. Phenols exceeded the CCME Remediation Criteria for all sample rounds.

Water quality at MW12 at the eastern property line was identified generally above the Level B criteria for most parameters and the criteria for naphthalene only. Phenols were observed above the CCME Remediation Criteria for protection of aquatic life. Benzene only marginally exceeded the CDWG and CCME Remediation Criteria for drinking water in Round No. 2. The concentration identified at MW12 for the various constituents was much lower than locations close to the north property boundary.

In summary, the groundwater at the north end of the site has been degraded by activities associated with the former coal gasification plant. MW03, MW14 and MW22 identify exceedances of available criteria. MW05 and MW12 also identify groundwater degradation but to a much lesser extent.

Offsite Area (Adjacent to the Red River). The results completed beyond the property boundary of the Centra Gas site, along the bank of the Red River, have identified a number of exceedances which are provided in Table 2.3.

At MW24A (deep well) no exceedances were identified for PAH and BTEX compounds in Round No. 2 and 3. Only a marginal exceedance occurred for phenols from comparison to the CCME Remediation Criteria for protection of aquatic life. MW24B (located at shallower depth) did not exceed Level B values for PAH compounds. The CCME Remediation Criteria for drinking water, the CDWG, and the WHO criteria were exceeded for benzene at MW24B in Round No. 3. Also the benzene result at MW24B exceeded the Alberta Level II criteria.

MW24C (shallowest well) identified exceedances for PAHs, BTEX and phenols in both Round Nos. 2 and 3. Naphthalene exceeded the Level C criteria and all other PAHs with criteria exceeded the Level B values. The only exception to this was for benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-cd)pyrene which did not exceed the Level B criteria in Round No. 3. For the other constituents analyzed, the results between the two rounds at MW24C remained in a similar range except for ethyl benzene and phenols which significantly increased in concentration. Benzene was the only parameter that exceeded the Alberta Level III criteria. The CCME Remediation Criteria for protection of aquatic life was exceeded for benzene in both Round Nos. 2 and 3. This criteria was also exceeded for ethyl benzene in Round No. 3.

MW23A (deep well located north of MW22) identified exceedances in both Round Nos. 2 and 3. The results remained in the same range with the majority of constituents showing a decrease in concentration in Round No. 3. The same PAHs in Round Nos. 2 and 3 exceeded the Level B criteria. BTEX did not exceed available criteria at MW23A. The CCME Remediation Criteria for protection of aquatic life was only marginally exceeded for phenols at MW23A in the two rounds.

MW23B identified the most elevated concentrations of PAHs and BTEX north of the Centra Gas property boundary. Although a decrease in concentrations was observed between Round Nos. 2 and 3 for the majority of constituents, the same exceedances were evident with the exception of ethyl benzene and o-xylene. The nine PAHs with criteria all exceeded the Level C values in both rounds at MW23B. Benzene, m&p-xylene, and ethyl benzene exceeded the CCME Remediation Criteria for drinking water, the CDWG, and the WHO criteria in Round No. 2. In Round No. 3, benzene, m&p-xylene, and o-xylene exceeded the above-mentioned criteria at MW23B. Benzene was the only parameter to exceed the Alberta Level III criteria at MW23B. Phenols exceeded the CCME Remediation Criteria for protection of aquatic life in both rounds at MW23B.

From a review of this information, it was observed that the most significant offsite condition is located north of MW14 and MW22, adjacent to the Red River. Results at MW23A identified some degradation of groundwater but to a much lesser degree compared to MW23B, located at shallow depth. Of the five wells sampled offsite, MW23B identified the most elevated concentrations for both PAH and BTEX compounds. All PAHs with criteria exceeded the Level C values at MW23B.

Only minor degradation of groundwater has been identified at MW24A and MW24B with no PAHs exceeding any of the available criteria. At MW24C at shallow depth, impacts of the former coal gasification plant were identified based on elevated PAH, BTEX and phenolic constituents in the groundwater. The shallow groundwater results at MW24C were less elevated compared to results identified at MW23B also located at shallow depth.

The water quality at these offsite monitoring locations is indicative of groundwater flowing to the Red River.

The calculated groundwater flow rates, combined with the length of time since the residues were placed in the subsurface, suggest that many of the more mobile dissolved chemicals would have reached the river at some earlier point in time. This suggests that the loading of many dissolved contaminants from the site is more likely than not decreasing with time.

In concluding the interpretation of soil and groundwater information, it is re-emphasized that groundwater is not used for a drinking water supply here and is unlikely to be in the future. An examination of possible impacts on the Red River was undertaken as part of this project, and these results are provided in Sections 4 and 5 of this report.

Section 3

Sewer Inspection and Sampling

Sewer inspection and sampling were included in the Phase II program for the following reasons:

- Sewer elevations are close to that of the water table in some areas of the site. Sewers and/or sewer backfill have been found to act as pathways for contaminant migration at many industrial sites. Cracks in the sewers or leakage at pipe joints can result in infiltration or exfiltration from the sewers. Sewer backfill is typically a granular material which can act as a conduit for migration of residues.

- Interviews with persons familiar with the historical operation of the facility indicated some evidence of gas plant residues had been observed in the sewers beyond the property. Sewers have been modified with time and sewers which at one time contained residues may or may not be in use or exist today.

Methodology

Sewer lines along roadways surrounding the Centra Gas property were initially inspected as part of Phase I of this investigation. It was then found that the combined sewers along the surrounding roadways did not accumulate a significant quantity of sediment and that water and gas quality in the sewers would be the main area of focus for the Phase II investigation.

Sewers were inspected on June 23, 1994 to confirm their tributary origins, to observe physical structure, and to measure organic vapour and oxygen concentrations within the sewer lines. Field notes are presented in Table 3.1 and the locations of the combined sewer manholes inspected are shown on Figure 3-1.

Four sewer manholes were chosen to determine the composition of the sewer gas and water. The manholes chosen were selected based on their location relative to tributaries from the site, proximity to the water table, and results of the preliminary screening measurements. Gas and water samples were taken for analysis by a laboratory. Both gas and water samples were taken at the same locations including one upgradient background location.

Gas samples were taken from four selected locations (CS-1, CS-2, CS-3 and CS-7) for analysis of PAH and BTEX compounds on July 26, 1994. The samples were taken throughout a two-hour period (approximately) within each sample location. Gas samples

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Table 3.1
Sewer Inspection and Air Sampling Data

Location Number	Location Description	Depth to Water (m)	Flow Direction	Oxygen Concentration	Organic Vapour Concentration	Odour Detected	PAH Sample Volume (litres)	BTEX Sample Volume (litres)
CS 1	Rover Ave., west Disraeli overpass	3.6	west to east	normal	0 ppm	septic	332	33.2
CS 2	Rover Ave., east side of Disraeli overpass	3.7	south to east	normal	0 ppm	septic	240	24
CS 3	Rover and Anabella St.	4.2	west to east	normal	5 ppm	septic	294	29.4
CS 4	Anabella St. near Power Plant entrance	2.7	none	normal	0 ppm	septic	--	--
CS 5	159 Annabella St.	2.2	south & southwest to north	normal	0 ppm	septic	--	--
CS 6	Gladstone and Sutherland Ave.	3.15	north and west to south	normal	0 ppm	none	--	--
CS 7	Glandstone near Centra Parking lot exit	2.65	east &south to north	normal	0 ppm	none	294	29.4
CS 8	2.0 m South on MH# 7	2.6	east to north	normal	0 ppm	none	--	--
CS 9	Gladstone at Disraeli off ramp	2.75 (dry)	none	normal	0 ppm	none	--	--
CS 10	Sutherland and Anabella	1.35	none	normal	0 ppm	none	--	--

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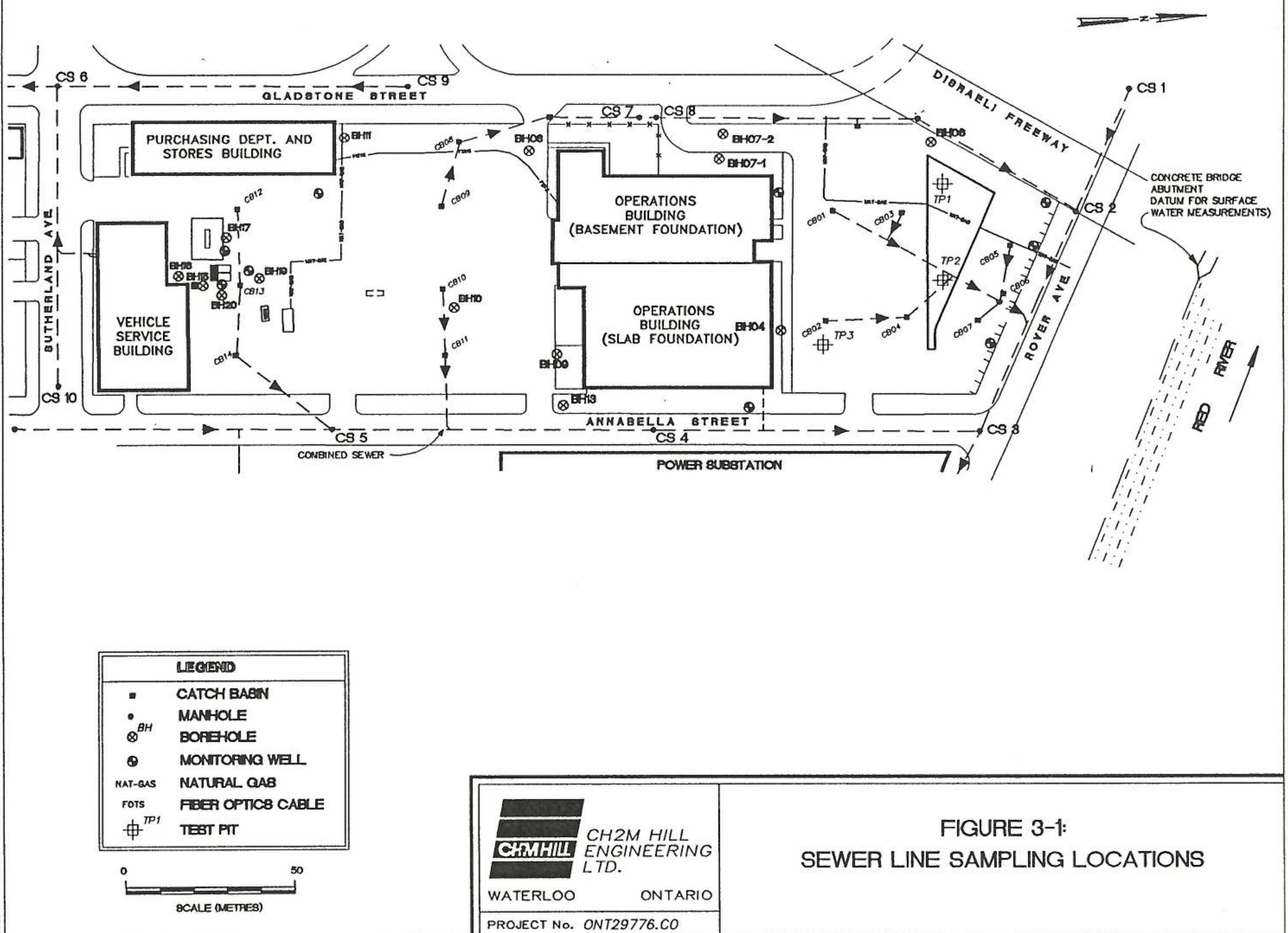

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FIGURE 3-1:
SEWER LINE SAMPLING LOCATIONS

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were drawn from the sewer lines at a point approximately 0.5 m from the base of the catch basin. Sampling protocols were similar to those used during indoor air sampling conducted in the Phase I investigation. All pump flow rates were calibrated prior to sampling. Samples were capped, wrapped in tinfoil and stored in a cooler with ice immediately following each sampling event and during shipment to the laboratory. Sample volumes are presented in Table 3.1.

Four water samples were also taken to determine PAH and BTEX concentration. Samples were taken with a pole jar assembly to preclude the need to enter the sewers. All water samples were immediately placed in labelled jars and shipped to the lab in coolers with ice packs.

Results

Gas

Gas samples from the manholes were analyzed by A and L Canada Laboratories East, Inc. and interpretation of results was provided by Industrial Hygiene and Environmental Advisory Services Inc., both of London, Ontario. Laboratory analysis for PAHs was performed using NIOSH 5575 and BTEX was analyzed by Gas Chromatograph. Laboratory analysis reports are provided in Appendix D.

Of the analysis performed for PAHs and BTEX compounds, only one compound, xylene, was found above the detection limits (Appendix D). Xylene concentrations were marginally above the detection limit of 0.5 μg/charcoal tube. Concentrations were calculated to range from 0.034 to 0.067 mg/m^3 (<0.015 ppm), which is below the Time Weighted Average (TWA) exposure criteria for xylene of 434 mg/m^3 or 100 ppm (American Conference of Governmental Industrial Hygienists, 1992). Concentrations of other BTEX compounds and PAH compounds were below the instrument limit of 0.5 μg/charcoal tube and 0.001 mg/charcoal tube, respectively.

Water

The results of water analysis in the combined sewers around the site are provided in Table 3.2. Sample location CS1 is upstream (i.e. to the west) of the site and is indicative of background concentrations before the sewer water reaches the site. (Note: Sewers along the river here flow eastward, opposite to the river which flows predominantly west.) Background sewer water quality contains several PAH and BTEX chemicals at relatively low levels. These results indicate that low levels of chemicals characteristic of gas plant residues are entering the sewers upstream of the site and are not attributable to any residues present on the Centra Gas site.

Comparing the other analyses to the background concentration indicates that concentrations do not increase across the site by a significant margin. Most concentrations remain stable

Table 3.2
Comparison of Chemical Analysis of Sewer Water to Available Criteria

Sample Name	CS 1	CS 2	CS 3	CS 7	Trip Blank	Lab Blank	Rinseate	Guidelines						
Sample Date	06/26/94	06/26/94	06/26/94	06/26/94	06/26/94	06/26/94	06/26/94	CCME "ABC" FOR COAL GASIFICATION SITES			CDWG	WHO	CCME REMEDIATION	
Laboratory No.	07006–1	07006–03	07006–04	07006–05	07006–06		07006–06	A	B	C			Groundwater	Aquatic Life
PAH's (ppb)														
Naphthalene	0.922	2	1.71	0.105	<0.004	<0.004		0.2	2	20				
Acenaphthylene	0.027	<0.004	<0.004	0.022	<0.004	<0.004								
Acenaphthene	0.074	<0.008	1.53	0.095	<0.008	<0.008								
Fluorene	<0.004	<0.004	0.069	0.039	<0.004	<0.004								
Phenanthrene	0.15	0.111	0.139	<0.007	<0.007	<0.007		0.2	2	20				
Anthracene	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008								
Fluoranthene	0.055	0.036	0.046	0.033	<0.006	<0.006								
Pyrene	0.045	0.029	0.034	0.03	<0.004	<0.004		0.2	2	20				
Benzo (a) anthracene	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		0.01	0.1	1				
Chrysene	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007								
Benzo (b) fluoranthene	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007		0.01	0.1	1				
Benzo (k) fluoranthene	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007		0.01	0.1	1				
Benzo (a) pyrene	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006		0.01	0.1	1	0.01	0.7	0.01	
Indeno (1,2,3–cd) pyrene	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011		0.01	0.1	1				
Dibenzo (a,h) anthracene	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008		0.01	0.1	1				
Benzo (ghi) perylene	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009								
D8–Naphthalene (Recovery Surrogate)	64%	53%	66%	59%	68%	83%								
D12–Chrysene (Recovery Surrogate)	75%	77%	89%	89%	90%	65%								
BTEX (ppb)														
Benzene	<0.55	<0.55	<0.55	<0.55		<0.55	<0.55				5	10	5	300
Toluene	7.8	6.55	7.95	3.84		<0.8	<0.8				24	700	24	300
m & p Xylene	<0.6	<0.6	<0.6	<0.6		<0.6	<0.6				300	500	300	
Ethyl benzene	<0.4	<0.4	<0.4	<0.4		<0.4	<0.4				2.4	300	2.4	700
o–Xylene	<0.4	<0.4	<0.4	<0.4		<0.4	<0.4				300	500	300	
D6–Benzene (Recovery Surrogate)	100%	100%	103%	96%		104%	101%							
D10–Ethylbenzene (Recovery Surrogate)	98%	98%	97%	99%		101%	94%							

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or do not vary significantly. This indicates that there is no measurable impact on sewer water quality due to infiltration of groundwater exposed to residues in the subsurface.

It was concluded that no significant impacts were apparent on either the sewer water or gas quality in the sewers immediately surrounding the former gas plant property. This suggests that there is little potential for migration along the sewers to offsite receptors and that no further attention need be directed at investigating this potential pathway.

Section 4

Water and Sediment Quality Assessment in the Red River

Water and sediment sampling were conducted in the Red River adjacent to Centra Gas's Sutherland Avenue facility as part of Phase II of the EHSA. The assessment was conducted due to the proximity of the site to the river, the presence of by-products above the CCME level C criteria at the property boundary in Phase I and because the river was identified as a potential receptor of by-products which needed to be investigated. The objectives of the water and sediment quality assessment were:

- To determine if any evidence of by-products could be detected in the river above ambient levels
- To determine the significance of any by-products relative to applicable guidelines, etc.

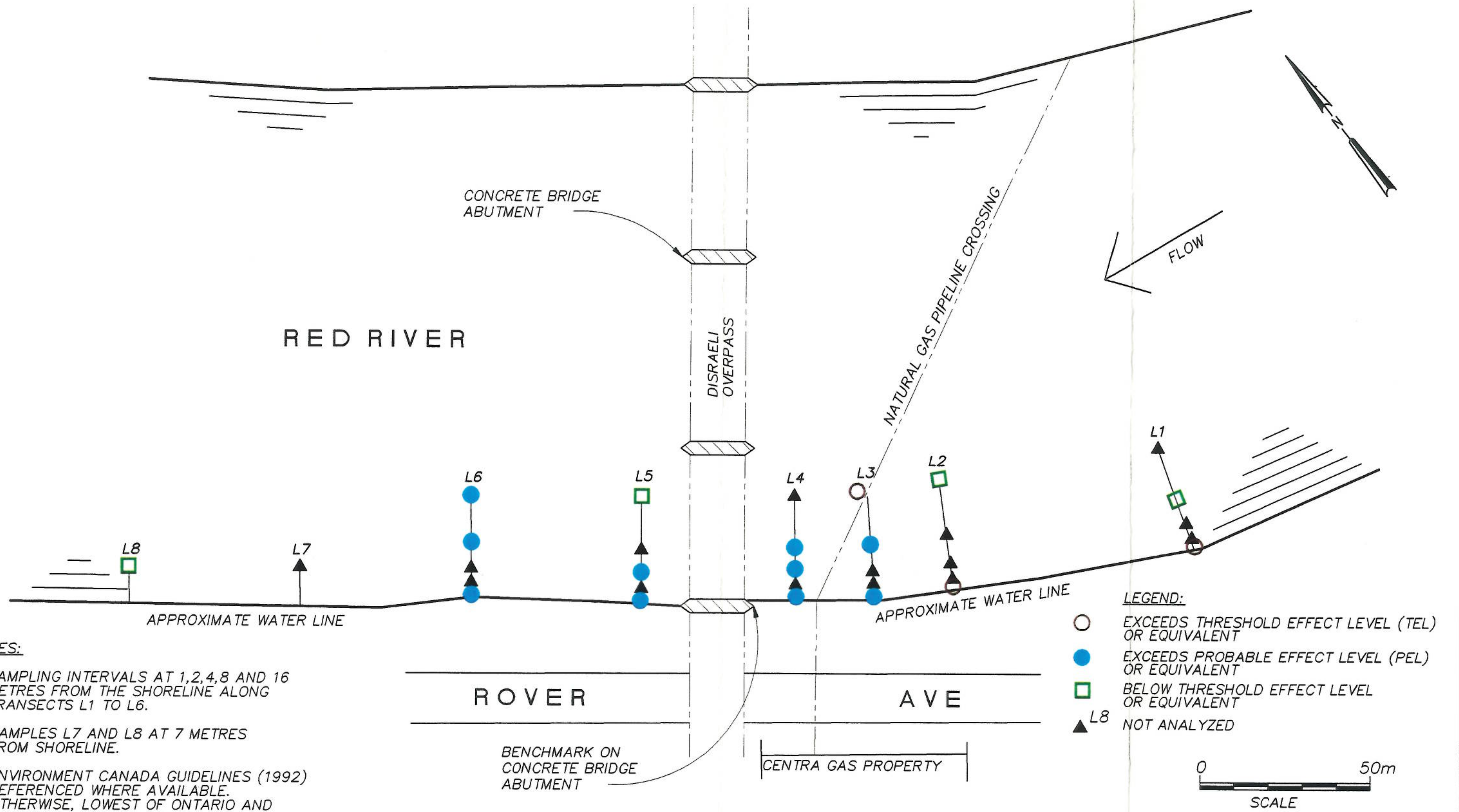
Sampling Locations

A total of 32 sediment and 10 water samples were collected along the south shore of the Red River in late March, 1994 (March 17 to 20). Sediment samples were collected along eight transects oriented perpendicular to the shoreline. Three transects (L2, L3 and L4) were located adjacent to the Centra Gas site, one was located upstream (L1), and four were located downstream. Sediment samples were collected at intervals of 1, 2, 4, 8 and 16 metres from the shoreline along transects L1 to L6. At transects L7 and L8, samples were collected only at seven metres from the shoreline. Sediment sampling locations are shown in Figure 4-1.

Water samples were collected at a distance of 7 metres from the shore at all transects. Water samples were also collected at all five locations along transect L4 adjacent to the Centra Gas site.

Sampling Methodology

All sampling was conducted from the surface of the ice by first creating a hole through the ice with an ice auger. Sediment samples were collected by two methods. The main emphasis of sediment sampling was on shallow river bottom sediment and therefore most samples (26 of 32) were collected from the upper 0.5 to 1.0 metre of sediment. These shallow samples were collected using a conventional split spoon sampler driven with portable drilling equipment (i.e. Pionjar drill).



LEGEND:

- ○ EXCEEDS THRESHOLD EFFECT LEVEL (TEL) OR EQUIVALENT
- ● EXCEEDS PROBABLE EFFECT LEVEL (PEL) OR EQUIVALENT
- □ BELOW THRESHOLD EFFECT LEVEL OR EQUIVALENT
- ▲ L8 NOT ANALYZED

NOTES:

1. SAMPLING INTERVALS AT 1,2,4,8 AND 16 METRES FROM THE SHORELINE ALONG TRANSECTS L1 TO L6.
2. SAMPLES L7 AND L8 AT 7 METRES FROM SHORELINE.
3. ENVIRONMENT CANADA GUIDELINES (1992) REFERENCED WHERE AVAILABLE. OTHERWISE, LOWEST OF ONTARIO AND QUEBEC GUIDELINES USED.
4. CHEMICAL ANALYSIS OF SHALLOW SEDIMENT (TYPICALLY < 0.8m) USED TO COMPILE THIS FIGURE.

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FIGURE 4-1:
SEDIMENT SAMPLE LOCATIONS IN THE RIVER INDICATING ANALYTICAL RESULTS

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Deeper samples were collected at 6 of the 32 locations to assess sediment quality versus depth. These samples were collected using a vibratory sampling method in which samples are collected directly into a clear Lexan tube for storage and inspection. Deeper samples were collected up to 3.3 metres into the sediment. Deep samples were collected at one metre from shore at transects L1 to L6 (i.e. sample locations L1-1 to L6-1).

All shallow sediments were examined in the field to provide geologic descriptions and to identify evidence of contamination. These observations were used to guide the sampling program and to determine its areal extent. Deeper samples were retained in the Lexan sleeves to be examined at a later date in CH2M HILL's field operations facility. The sediment sampling logs containing information on the sampling depth, sample description, evidence of contamination and a field classification are included in Appendix E.

Water samples were collected by lowering a jar and stopper assembly to approximately 0.5 metres from the river bottom. These samples were considered to be representative of water quality in the river above the sediments at that location.

All samples were placed in sample bottles (except for the deep cores) and kept in a cooler with ice until they reached the laboratory. Upon reaching the laboratory, all samples were stored under refrigerated conditions pending chemical analysis.

Evaluation Criteria

Sediment

The province of Manitoba has not developed guidelines for sediment quality to date. Manitoba Environment has indicated that they adopt federal guidelines in the absence of provincial guidelines. Environment Canada is in the process of developing sediment quality guidelines for fresh water sediments at this time. Release of the guidelines is not anticipated until at least December of this year. In the interim, Environment Canada is planning to release assessment guidelines which are expected to be similar to the final guidelines but have not undergone peer review. A draft copy of these guidelines was released in September 1994 (Environment Canada, 1994).

Sediment quality guidelines have been developed in other provinces over the last few years and these guidelines have been the secondary guidelines considered in the evaluation. Guidelines from Quebec (unpublished, 1992) and Ontario (MOEE, 1993) were referenced in this evaluation.

The Environment Canada draft assessment guidelines contains two assessment values:

- Threshold Effect Level (TEL) - The concentration below which adverse effects are expected to occur rarely

- Probable Effect Level (PEL) - The level above which adverse effects are expected to occur frequently

The Ontario and Quebec guidelines typically identify three thresholds indicating increasing levels of effect, as follows:

- No Effect Level (NEL)/No Effect Threshold (NET) - This is the level at which no adverse effect on water quality, fish or benthic organisms can be detected.
- Lowest Effect Level (LEL)/Minimum Effect Threshold (MET) - Some adverse effect can be detected at this level. No effects on the majority of benthic organisms are expected. Effects are typically marginal and further investigation may be required.
- Severe Effect Level (SEL)/Toxic Effect Threshold - This level indicates heavily polluted sediment that is likely to affect the health of sediment dwelling organisms. At this level of contamination, a management plan is often required.

Sediment quality guidelines referenced in this report are provided in Table 4.1.

Water

Surface water quality guidelines have been developed for many parameters in Manitoba. However, they have not been developed for the chemicals that are indicative of by-products from coal gasification. A similar situation exists for the federal government and the other provinces. CH2M HILL has compiled available water quality criteria which, although they may not be directly applicable to surface water quality, provide a reference for evaluation of the river water analysis. These criteria were compiled in Phase I and are included in Table 4.2 with the results of river water samples.

Chemical Analysis

Quality Assurance/Quality Control (QA/QC)

The field QA/QC program consisted of the use of duplicate analysis as a measure of laboratory precision, as described in the Phase I report. The lab QA/QC program follows standard laboratory procedures for analysis of blanks, duplicates, and standards, etc.

The duplicate analysis for the sediment samples was conducted on sample L4-15-T and was called Dup-01. This analysis is tabulated in Table 4.1 and indicates good agreement between the two analyses and no cause for concern.

Table 4.1
Comparison of Chemical Analysis of River Sediment to Available Criteria

Page 1 of 4

	L01–01T	L01–15T	L02–01T	L02–32T	L03–01T	L03–01B	L03–15T	TEL (EC, 1994)	PEL (EC, 1994)	NET (Quebec)	MET (Quebec)	TET (Quebec)	LEL (Ontario)	SEL (Ontario)
Sample Date	03/18/94	03/18/94	03/18/94	03/18/94	03/18/94	03/18/94	03/18/94							
Laboratory No.	04007–1	04007–2	04007–3	04007–4	04007–6	04007–5	04007–7							
Field Classification	TC	NC	NC/TC	NC	TC	NC	NC							
PAH's (ng/g) = ppb														
Naphthalene	555	35.8	1,020	<0.88	864	1,270	41.4			20	400	570		
Acenaphthylene	3.85	<0.9	1.43	<0.9	20	11.6	51.1			10				
Acenaphthene	24.7	<1.12	44.9	<1.12	729	77.1	67.4			10				
Fluorene	34.3	<2.4	21.3	<2.4	481	35.4	82.9			10			190	1520
Phenanthrene	219	12.5	158	<3.6	2,470	239	699	41.9	514.9	50	400	760	560	9025
Anthracene	48.1	1.78	31	<1.6	422	84.2	234			20			220	3515
Fluoranthene	236	11.6	66.9	<1.18	947	195	959	111.3	2354.9	110	600	1900	750	9690
Pyrene	213	9.52	59.9	<1.98	948	163	1,290	53	875	60	700	950	490	8075
Benzo (a) anthracene	291	3.09	8.96	<0.88	374	53	370	31.7	384.7	50	400	475	320	14060
Chrysene	91.4	5.2	12.3	<1	220	61.8	278	57.1	861.7	100	600	760	340	4370
Benzo (b) fluoranthene	48.6	<1.94	3.39	<1.94	170	24.4	133			300			240	12730
Benzo (k) fluoranthene	53.5	<2.2	6.05	<2.2	171	44.9	117			300			240	12730
Benzo (a) pyrene	77.6	<1.42	6.91	<1.42	337	48.8	371	31.9	782	55	500	665	370	13680
Indeno (1,2,3–cd) pyrene	43.9	<1.42	2.16	<1.42	169	24.8	234			70			200	3040
Dibenzo (a,h) anthracene	<1.86	<1.86	<1.86	<1.86	14	<1.86	23.8			5			60	1235
Benzo (ghi) perylene	50.2	<1.74	2.92	<1.74	134	24.9	221			100			170	3040
Perylene	Det (no value)	Det (no value)	Det (no value)		Det (no value)	Det (no value)	Det (no value)							
Total PAH	**1990.15**	**79.49**	**1289.7**	**0**	**8470**	**2357.9**	**5172.6**						4,000	95000
D8–Naphthalene (Recovery Surrogate)	97%	129%	105%	89%	90%	113%	61%							
D12–Chrysene (Recovery Surrogate)	97%	131%	102%	95%	74%	99%	74%							
OTHER														
Total Solids	75%	70%	0.8%	77%	70%	69%	69%							
Total Organic Carbon	0.87%	1.27%	0.44%	<0.28%	1.1%	1.12%	0.8%							

Notes:

EC, 1994 – Interim Sediment Quality Assessment Values (Draft), Soil and Sediment Quality Section, Guidelines Division September, 1994

TEL – Threshold Effect Level
PEL – Probable Effect Level

Quebec: Criteres Interimaires pour l'evaluation de la qualite des sediments du Saint–Laurent, 1992. Environnement Canada at Ministere de l'Environnement du Quebec. Environment Canada contact Rene Rochon 514–283–0676

NET – No Effect Threshold
MET – Minimum Effect Threshold
TET – Toxic Effect Threshold

Ontario: D. Persaud, R. Jaagumagi, & A. Hayton. 1992 Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of Environment Contact: Rein Jaagumagi 416–323–4929

LEL – Lowest Effect Level
SEL – Severe Effect Level
Ontario – NOEL not calculated due to insufficient data/no suitable method

British Columbia: N.K. Nagpal, 1993. Ambient Water Quality Criteria for Polycyclic Aromatic Hydrocarbons (PAHs). Water Quality Branch, Ministry of Environment, Lands and Parks, Province of British Columbia. Contact: Beverly Baker 202–260–7037

SQC – Sediment Quality Criteria
SQO – Sediment Quality Objective for the specified site

1234	Concentration > PEL (lowest of TET or SEL used if no PEL)
▨	TEL < Concentation < PEL (lowest of MET or LEL used if no TEL, PEL based on above)

Guideline normalized to an average TOC of 0.95% excluding anomalously high TOC results for L4–7T and L5–1T

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Table 4.1
Comparison of Chemical Analysis of River Sediment to Available Criteria

	L03-32T	L04-01T	L04-01B	L04-07T	L04-15T	L04-15T (Dup)	L05-01T	TEL (EC, 1994)	PEL (EC, 1994)	NET (Quebec)	MET (Quebec)	TET (Quebec)	LEL (Ontario)	SEL (Ontario)
Sample Date	03/18/94	03/18/94	03/18/94	03/18/94	03/18/94	03/18/94	03/18/94							
Laboratory No.	04007-8	04007-10	04007-9	04007-11	04007-12									
Field Classification	TC	TC	NC	VC	VC	VC	VC							
PAH's (ng/g) = ppb														
Naphthalene	76.9	4,540	467	6,660,000	22,100	21,100	4,130,000			20	400	570		
Acenaphthylene	8.78	28.4	1.91	873,000	1,090	1,050	163,000			10				
Acenaphthene	24.7	1740	10.8	931,000	11,900	11,200	909,000			10				
Fluorene	24.4	794	7.56	1,050,000	4,680	4,820	595,000			10			190	1520
Phenanthrene	128	2,410	60.4	3,990,000	22,300	22,000	2,610,000	41.9	514.9	50	400	760	560	9025
Anthracene	26.3	599	27.4	1,350,000	7,210	7,140	704,000			20			220	3515
Fluoranthene	91.5	1,030	52.2	2,530,000	14,600	14,100	1,660,000	111.3	2354.9	110	600	1900	750	9690
Pyrene	68.7	1,220	39.8	1,830,000	14,100	13,500	1,250,000	53	875	60	700	950	490	8075
Benzo (a) anthracene	26.1	301	19.7	805,000	4,680	4,690	528,000	31.7	384.7	50	400	475	320	14060
Chrysene	21.2	292	15.6	727,000	4,440	4,430	458,000	57.1	861.7	100	600	760	340	4370
Benzo (b) fluoranthene	14	118	10.4	571,000	2,160	2,390	322,000			300			240	12730
Benzo (k) fluoranthene	14.6	226	6.86	477,000	3,190	3,090	343,000			300			240	12730
Benzo (a) pyrene	16.9	346	20.5	814,000	4,630	4,660	512,000	31.9	782	55	500	665	370	13680
Indeno (1,2,3-cd) pyrene	12.7	141	8	502,000	2,040	2,140	271,000			70			200	3040
Dibenzo (a,h) anthracene	<1.86	14.7	<1.86	69,500	223	245	35,700			5			60	1235
Benzo (ghi) perylene	12.6	174	2.11	421,000	2,180	2,170	247,000			100			170	3040
Perylene	Det (no value)	Det (no value)	Det (no value)	Det (no value)	Det (no value)	Det (no value)	Det (no value)							
Total PAH	567.38	13974.1	750.24	23600500	118193	118725	14738033						4,000	95000
D8-Naphthalene (Recovery Surrogate)	73%	85%	92%	NR	34%	38%	NR							
D12-Chrysene (Recovery Surrogate)	91%	103%	106%	NR	83%	81%	NR							
OTHER														
Total Solids	81%	62%	78%	70%	60%	63%	71%							
Total Organic Carbon	0.69%	1.24%	0.37%	18.6%	1.98%	1.85%	20.6%							

Notes:

EC, 1994 – Interim Sediment Quality Assessment Values (Draft),
Soil and Sediment Quality Section, Guidelines Division
September, 1994

TEL – Threshold Effect Level
PEL – Probable Effect Level

Quebec: Criteres Intermaires pour l'evaluation de la qualite des
sediments du Saint-Laurent, 1992. Environnement Canada
at Ministere de l'Environnement du Quebec. Environment
Canada contact Rene Rochon 514-283-0676

NET – No Effect Threshold
MET – Minimum Effect Threshold
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Ontario: D. Persaud, R. Jaagumagi, & A. Hayton. 1992
Guidelines for the protection and management of aquatic
sediment quality in Ontario. Ontario Ministry of Environment
Contact: Rein Jaagumagi 416-323-4929

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Water Quality Branch, Ministry of Environment, Lands and
Parks, Province of British Columbia. Contact:
Beverly Baker 202-280-7037

SQC – Sediment Quality Criteria
SQO – Sediment Quality Objective for the specified site

1234 Concentration > PEL
(lowest of TET or SEL used if no PEL)

▨ TEL < Concentation < PEL
(lowest of MET or LEL used if no TEL, PEL based on above)

Guideline normalized to an average TOC of 0.95% excluding anomalously high
TOC results for L4-7T and L5-1T

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Table 4.1
Comparison of Chemical Analysis of River Sediment to Available Criteria

	L05-01B	L05-07	L05-32T	L06-01T	L06-01B	L06-15	L06-32	L08-01T	TEL (EC, 1994)	PEL (EC, 1994)	NET (Quebec)	MET (Quebec)	TET (Quebec)	LEL (Ontario)	SEL (Ontario)
Sample Date	03/18/94	05/02/94	03/18/94	03/18/94	03/18/94	05/02/94	05/02/94	03/18/94							
Laboratory No.		05011-2	04007-16	04007-17	04007-18	05011-3	05011-1	04007-19							
Field Classification	TC	TC	NC	NC/TC/VC	NC	NC/TC	NC/TC	NC							
PAH's (ng/g) = ppb															
Naphthalene	1,910	799	33.1	1,060	1,370	1,600	12,900	8.05			20	400	570		
Acenaphthylene	194	730	5.18	62.4	15.7	285	608	1.4			10				
Acenaphthene	1,090	2,350	6.82	362	103	960	5,650	534			10				
Fluorene	731	2,070	6.42	270	39.7	885	4,040	108			10			190	1520
Phenanthrene	2,840	10,800	23.5	1,290	226	4,670	14,900	20.6	41.9	514.9	50	400	760	560	9025
Anthracene	791	2,950	6.15	510	65.6	1,410	3,970	4.11			20			220	3515
Fluoranthene	1,650	10,300	18.6	838	202	4,950	9,280	3.43	111.3	2354.9	110	600	1900	750	9690
Pyrene	1,350	8,580	15.5	761	177	3,780	7,280	3.76	53	875	60	700	950	490	8075
Benzo (a) anthracene	537	5,040	4.62	288	61	2,260	4,200	<0.88	31.7	384.7	50	400	475	320	14060
Chrysene	487	3,550	7.07	268	70	1,640	3,060	<1	57.1	861.7	100	600	760	340	4370
Benzo (b) fluoranthene	420	4,360	7.02	184	37.9	1,780	3,440	<1.94			300			240	12730
Benzo (k) fluoranthene	409	3,030	4.92	151	61.1	1,340	2,640	<2.2			300			240	12730
Benzo (a) pyrene	614	5,310	6.29	333	72.1	2,290	4,480	<1.42	31.9	782	55	500	665	370	13680
Indeno (1,2,3-cd) pyrene	471	3,910	6.06	219	47.1	1,680	3,232	<1.42			70			200	3040
Dibenzo (a,h) anthracene	56.6	708	<1.86	21.6	<1.86	325	504	<1.86			5			60	1235
Benzo (ghi) perylene	427	2,700	5.72	209	44.5	1,140	2,280	<1.74			100			170	3040
Perylene	Det (no value)		Det (no value)	Det (no value)	Det (no value)										
Total PAH	13977.6	67187	156.97	6847	2592.7	30995	82484	683.35						4,000	95000
D8-Naphthalene (Recovery Surrogate)	92%	58%	85%	81%	108%	56%	54%	102%							
D12-Chrysene (Recovery Surrogate)	101%	100%	102%	102%	112%	86%	92%	107%							
OTHER															
Total Solids	77%	77%	79%	63%	72%	67%	78%	61%							
Total Organic Carbon	0.57%	0.69%	0.41%	0.57%	<0.28%	1.21%	2.15%	1.48%							

Notes:

EC, 1994 – Interim Sediment Quality Assessment Values (Draft),
Soil and Sediment Quality Section, Guidelines Division
September, 1994

TEL – Threshold Effect Level
PEL – Probable Effect Level

Quebec: Criteres interimaires pour l'evaluation de la qualite des sediments du Saint-Laurent, 1992. Environnement Canada at Ministere de l'Environnement du Quebec. Environment Canada contact Rene Rochon 514-283-0676

NET – No Effect Threshold
MET – Minimum Effect Threshold
TET – Toxic Effect Threshold

Ontario: D. Persaud, R. Jaagumagi, & A. Hayton. 1992
Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of Environment
Contact: Rein Jaagumagi 416-323-4928

LEL – Lowest Effect Level
SEL – Severe Effect Level
Ontario – NOEL not calcualted due to insufficient data/no suitable method

British Columbia: N.K. Nagpal, 1993. Ambient Water Quality Criteria for Polycyclic Aromatic Hydrocarbons (PAHs). Water Quality Branch, Ministry of Environment, Lands and Parks, Province of British Columbia. Contact:
Beverly Baker 202-280-7037

SQC – Sediment Quality Criteria
SQO – Sediment Quality Objective for the specified site

1234	Concentration > PEL (lowest of TET or SEL used if no PEL)
▨	TEL < Concentation < PEL (lowest of MET or LEL used if no TEL, PEL based on above)

Guideline normalized to an average TOC of 0.95% excluding anomalously high TOC results for L4-7T and L5-1T

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Table 4.1
Comparison of Chemical Analysis of River Sediment to Available Criteria

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	Lab Blank	Lab Blank	Method Spike	Method Spike	TEL (EC, 1994)	PEL (EC, 1994)	NET (Quebec)	MET (Quebec)	TET (Quebec)	LEL (Ontario)	SEL (Ontario)
Sample Date	03/18/94	03/18/94	03/18/94	03/18/94							
Laboratory No.											
Field Classification											
PAH's (ng/g) = ppb											
Naphthalene	<.088	<.088	118%	94%			20	400	570		
Acenaphthylene	<0.9	<0.9	115%	94%			10				
Acenaphthene	<1.12	<1.12	115%	92%			10				
Fluorene	<2.4	<2.4	115%	93%			10			190	1520
Phenanthrene	<3.6	<3.6	111%	98%	41.9	514.9	50	400	760	560	9025
Anthracene	<1.6	<1.6	111%	93%			20			220	3515
Fluoranthene	<1.18	<1.18	107%	91%	111.3	2354.9	110	600	1900	750	9690
Pyrene	<1.98	<1.98	111%	92%	53	875	60	700	950	490	8075
Benzo (a) anthracene	<0.88	<0.88	95%	90%	31.7	384.7	50	400	475	320	14060
Chrysene	<1	<1	105%	94%	57.1	861.7	100	600	760	340	4370
Benzo (b) fluoranthene	<1.94	<1.94	104%	83%			300			240	12730
Benzo (k) fluoranthene	<2.2	<2.2	115%	90%			300			240	12730
Benzo (a) pyrene	<1.42	<1.42	106%	83%	31.9	782	55	500	665	370	13680
Indeno (1,2,3-cd) pyrene	<1.42	<1.42	105%	73%			70			200	3040
Dibenzo (a,h) anthracene	<1.86	<1.86	107%	72%			5			60	1235
Benzo (ghi) perylene	<1.74	<1.74	122%	80%			100			170	3040
Perylene											
Total PAH										4,000	95000
D8-Naphthalene (Recovery Surrogate)	129%	88%	118%	84%							
D12-Chrysene (Recovery Surrogate)	97%	62%	99%	82%							
OTHER											
Total Solids											
Total Organic Carbon											

Notes:

EC, 1994 – Interim Sediment Quality Assessment Values (Draft),
Soil and Sediment Quality Section, Guidelines Division
September, 1994

TEL – Threshold Effect Level
PEL – Probable Effect Level

Quebec: Criteres intermaires pour l'evaluation de la qualite des sediments du Saint-Laurent, 1992. Environnement Canada at Ministere de l'Environnement du Quebec. Environment Canada contact Rene Rochon 514-283-0676

NET – No Effect Threshold
MET – Minimum Effect Threshold
TET – Toxic Effect Threshold

Ontario: D. Persaud, R. Jaagumagi, & A. Hayton. 1992
Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of Environment
Contact: Rein Jaagumagi 416-323-4928

LEL – Lowest Effect Level
SEL – Severe Effect Level
Ontario – NOEL not calcualted due to insufficient data/no suitable method

British Columbia: N.K. Nagpal, 1993. Ambient Water Quality Criteria for Polycyclic Aromatic Hydrocarbons (PAHs).
Water Quality Branch, Ministry of Environment, Lands and Parks, Province of British Columbia. Contact:
Beverly Baker 202-260-7037

SQC – Sediment Quality Criteria
SQO – Sediment Quality Objective for the specified site

1234 ▨ Concentration > PEL
(lowest of TET or SEL used if no PEL)

▨ TEL < Concentation < PEL
(lowest of MET or LEL used if no TEL, PEL based on above)

Guideline normalized to an average TOC of 0.95% excluding anomalously high TOC results for L4-7T and L5-1T

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Table 4.2
Comparison of Chemical Analysis of Surface Water Samples to Available Criteria (Organics)

Sample Name	L01-07	L02-07	L04-01	L04-03	L04-15	L04-15 (Dup)	L05-07	L07-07	Lab Blank	Method Spike	Guidelines					
Sample Date	03/20/94	03/20/94	03/20/94	03/20/94	03/20/94	03/20/94	03/20/94	03/20/94	03/20/94	03/20/94	CCME "ABC" FOR COAL GASIFICATION SITES			CDWG	WHO	CCME REMEDIATIO
Laboratory No.	03269-02	03269-03	03269-04	03269-05	03269-06	03269-01	03269-07	03269-08			A	B	C			Groundwater
PAH's(ppb)																
Naphthalene	0.006	0.005	0.004	0.004	0.006	0.004	0.005	<0.004	0.006	98%	0.2	2	20			
Acenaphthylene	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	102%						
Acenaphthene	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	100%						
Fluorene	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	101%						
Phenanthrene	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	99%	0.2	2	20			
Anthracene	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	97%						
Fluoranthene	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	95%						
Pyrene	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	96%	0.2	2	20			
Benzo (a) anthracene	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	79%	0.01	0.1	1			
Chrysene	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	91%						
Benzo (b) fluoranthene	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	82%	0.01	0.1	1			
Benzo (k) fluoranthene	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	84%	0.01	0.1	1			
Benzo (a) pyrene	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	74%	0.01	0.1	1	0.01	0.7	0.01
Indeno (1,2,3-cd) pyrene	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	80%	0.01	0.1	1			
Dibenzo (a,h) anthracene	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	82%	0.01	0.1	1			
Benzo (ghi) perylene	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	84%						
D12-Chrysene (Recovery Surrogate)	82%	76%	77%	84%	77%	77%	74%	67%	83%	86%						
D8-Naphthalene (Recovery Surrogate)	106%	102%	102%	110%	101%	91%	103%	98%	132%	111%						

Note: No exceedance of criteria

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The duplicate analysis for the water analysis was conducted on L4-15 and was called Dup-01. This analysis is tabulated in Table 4.2 and indicates comparable results. The lab blank had naphthalene detected at a concentration of 0.006 ppb. This indicates that the naphthalene detected at this or lower concentrations in samples from the river is probably an artifact of lab analysis and not due to naphthalene in the river.

Sediment

Sediment samples were submitted for analysis based on the field classification of the samples. Not all samples were analyzed, only those necessary to delineate the areal and vertical extent of by-products. Initially, 19 samples including one duplicate were analyzed. Ontario (1993) guidelines were used in the initial assessment of these data as the Environment Canada guidelines were not available at the time. After review of these results, an additional 3 samples were analyzed to provide a more complete delineation of sediment quality relative to these guidelines. A summary of the sample characteristics for samples submitted for laboratory analysis is provided in Table 4.3.

The results of sediment analysis are provided in Table 4.1 along with the applicable criteria. Some of the criteria are dependent on the total organic carbon (TOC) levels in the sediment. These criteria have been adjusted to reflect the average TOC level of 0.95 percent in the sediment analyzed.

Sediment quality was evaluated by comparison to the evaluation criteria discussed previously as well as to the background conditions defined in the river sediments in this study. Background conditions were based on sediment quality at Line 1, as defined by analysis for L1-01T and L01-15T. In one of the two background samples, the Probable Effect Level (PEL) was exceeded. In the second sample (L1-15T), 7 of 17 PAH compounds were detected but all were below the evaluation criteria. Total PAH concentrations varied from 79.49 to 1990.15 ppb. These analyses suggest that low levels of PAHs occur in the river, possibly as a result of upstream sources not related to the former manufactured gas plant. Other sources of data on sediment quality from further upstream could not be identified for confirmation of this observation.

Lateral Delineation

A total of 18 chemical analyses were conducted to delineate the areal extent of shallow sediment quality (typically less than 0.8 m.). Of these analyses, one was a duplicate sample and two others were to determine background concentrations (discussed previously). The results of chemical analysis of sediments is presented in Table 4.1 and laboratory reports are included in Appendix E.

Chemical analysis indicates that 11 of the 15 locations exceed the least stringent Environment Canada sediment quality criteria (i.e. PEL), or the least stringent criteria from another jurisdiction. The remaining four samples were at or below background levels.

Table 4.3
Red River Sediment Samples Submitted for Laboratory Analysis

Sample Location	Sample Depth Below Ice Surface (m)	Sample Description	Evidence of Contamination	Field Classification
L1-1T	1 TO 3.2*	SILT SEDIMENT, DARK GREY	BLACK STAINING, FAINT NAPHTHALENE ODOUR	TC
L1-15T	3.7 TO 4.3	CLAY, DARK GREY, TRENDING TO FINE, MEDIUM AND COARSE SAND SEDIMENT, TILL AT	NO ODOUR OR STAINING	NC
L2-1T	1.2 TO 4.2*	SILT SEDIMENT, DARK GREY	NO ODOUR OR STAINING	NC/TC
L2-32T	3.8 TO 4.6	FINE GRAINED GREY SAND TO 4.0 M, LIGHT GREY SILTY TILL	NO ODOUR OR STAINING	NC
L3-1B	2.1 TO 3.1*	SILTY CLAY, DARK GREY	NO ODOUR OR STAINING	NC
L3-1T	0.8 TO 1.9*	FINE SAND AND SILT SEDIMENT, DARK GREY	FAINT NAPHTHALENE ODOUR, NO STAINING	TC
L3-15T	2.9 TO 3.7	SILT SEDIMENT, DARK GREY, COHESIVE	NO ODOUR OR STAINING	NC
L3-32T	3.8 TO 4.6	MEDIUM FINE SAND AND SILT	SOME BLACK STAINING, NAPHTHALENE ODOUR	TC
L4-1B	3.7 TO 4.7*	CLAY, DARK GREY	NO ODOUR OR STAINING	NC
L4-1T	1.7 TO 2.8*	FINE SAND AND SILT SEDIMENT, OCCASIONAL GRAVEL	NAPHTHALENE ODOUR, NO STAINING	TC
L4-7T	3.1 TO 3.8	SILT SEDIMENT, SANDY, SOME GRAVEL AT SURFACE	STRONG NAPHTHALENE ODOUR, SHEEN, VISIBLE TAR	VC
L4-15T	3.7 TO 4.4	SILT SEDIMENT, WOOD FRAGMENTS AND ORGANICS AT SURFACE	BLACK STAINING AND STRONG NAPHTHALENE ODOUR	VC
L5-1T+	1.7 TO 1.9*	SILT SEDIMENT WITH FINE SAND SEAMS, VISIBLE TAR, ORGANIC FIBRES	NAPHTHALENE ODOUR, BLACK STAINING	VC
	1.9 TO 3.2*	FINE SAND AND SILT, COHESIVE, LIGHT AND DARK GREY	STRONG NAPHTHALENE ODOUR, NO STAINING	VC
L5-1B	3.2 TO 4.7*	SILTY CLAY, DARK GREY	STRONG NAPHTHALENE ODOUR, NO STAINING	TC
L5-7	2.7 TO 3.5	MEDIUM GRAINED FINE SAND	SOME BLACK STAINING AND NAPHTHALENE ODOUR	TC
L5-32T	4.4 TO 5.2	SAND, BROWN, MEDIUM GRAINED	NO ODOUR OR STAINING	NC
L6-1T+	1.5 TO 1.65*	SAND AND GRAVEL, SOME SILT, DARK GREY, NO ODOUR	NO ODOUR, SOME BLACK STAINING	NC/TC
	1.65 TO 1.75*	FINE SAND AND SILT SEDIMENT	STRONG NAPHTHALENE ODOUR, NO STAINING	VC
	1.75 TO 2*	FINE AND MEDIUM GRAINED SAND, LIGHT BROWN	FAINT NAPHTHALENE ODOUR	TC
	2 TO 3*	GREY CLAY MATRIX WITH COARSE GRAINED SAND AND GRAVEL THROUGHOUT	NO ODOUR OR STAINING	NC
L6-1B	3 TO 4.5*	SILTY CLAY, DARK GREY, SOME LIGHT GREY SILT POCKETS THROUGHOUT	NO ODOUR OR STAINING	NC
L6-15	2.7 TO 3.5	BLACK GRAINED SAND AND COARSE GRAVEL, OVERLYING LIGHT GREY CLAY WITH MANY SHELLS	NAPHTHALENE ODOUR IN SAND AND GRAVEL, NO ODOUR OR STAINING IN CLAY	TC/NC
L6-32	4.3 TO 5.0	MEDIUM BROWN SAND OVER BLACK STAINED FINE SAND AND SILT OVER LIGHT GREY CLAY WITH SHELLS	NAPHTHALENE ODOUR IN SILT, NO STAINING OR ODOUR ABOVE OR BELOW	TC/NC
L8-1T	3.05 TO 3.66	SILT SEDIMENT, DARK GREY, COHESIVE	NO ODOUR OR STAINING	NC

NOTES:

VC - VISUAL EVIDENCE OF CONTAMINATION
TC- OLFACTORY EVIDENCE OF CONTAMINATION
NC - NO EVIDENCE OF CONTAMINATION
THE ICE SURFACE ELEVATION WAS 222.18 M (ASL) DURING FIELD SURVEY
LINE ONE (L1) WAS APPROXIMATELY 130 M UPGRADIENT OF THE CENTRA GAS PROPERTY
LINE 2, 3, AND 4 ARE ADJACENT TO THE CENTRA GAS PROPERTY
LINE 5,6,7, AND 8 ARE DOWNGRADIENT OF THE CENTRA GAS PROPERTY

*DEPTH INTERVAL ESTIMATED DUE TO IMCOMPLETE CORE RECOVERY
+SAMPLES L5-1T AND L6-1T WERE COMPOSITED OVER MORE THAN ONE DEPTH INTERVAL

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Of the samples above the least stringent criteria, two contained concentrations of PAHs above 1 percent. Sample L5-01T contained 1.5 percent and sample L4-07T contained 2.4 percent PAHs. Visual examination of these samples identified the presence of tarry residues and both samples contained strong naphthalene odours. All other samples analyzed contained much lower levels of residues, in the fraction of a percent range.

The results of the comparison of chemical analysis to evaluation criteria were shown on a plan of the sediment sampling area (Figure 4-1). It is evident from this figure that a zone of PAHs above the PEL (or equivalent) is present starting adjacent to the former coal gasification facility and close to the shore. The zone of residues above this criteria extends downstream and out further into the river. Samples upstream and downstream of this zone contain background levels of residues, bounding the zone on all sides.

The analytical results, combined with evidence of contamination observations and the field classification were used to further delineate the extent of the residues. The assimilation of this information is presented on Figure 4-2. Through examination of the correlation between lab analysis and field classification, it was concluded that any samples with a "NC" or no contamination classification were most likely indicative of background conditions. Any samples with a NC/TC, TC or VC field classification were indicative of residues at concentrations above the probable effect level (PEL). This zone is approximately 300 m in length along the shoreline, and extends at least 30 m into the river at Line 6.

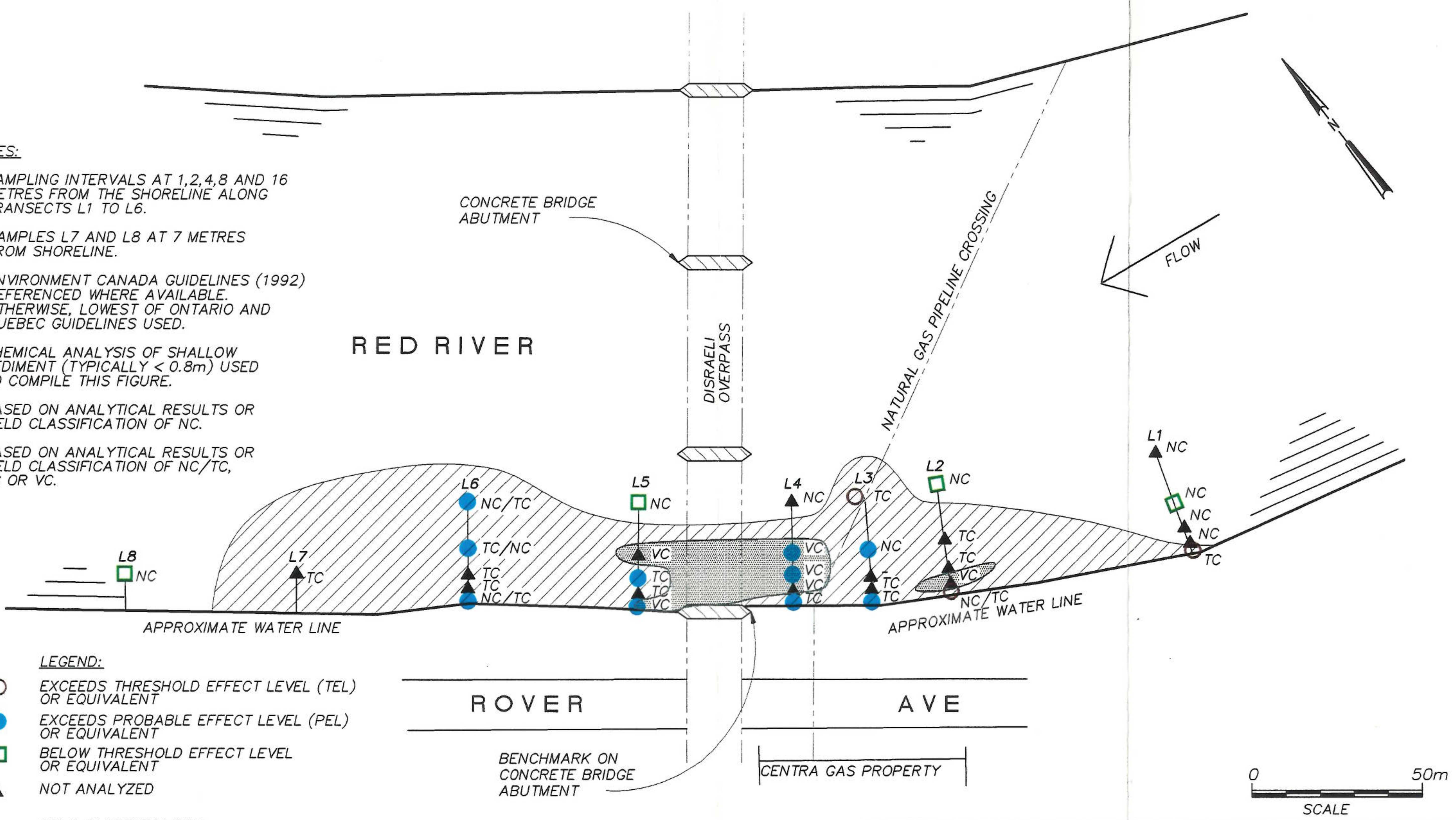
A second zone was also delineated which contains higher concentrations of PAHs and either visual evidence of tarry material or strong naphthalene odours. This zone is smaller than the zone with above-background concentrations. The zone containing residues with strong odours and/or visible tar is approximately 50 m in length and 25 m in width. It is located slightly downstream of the former manufactured gas plant and extends an equal distance upstream and downstream of the Disraeli Overpass.

These results indicate that a localized area of above-background residue levels, of approximately 9000 square metres, exists in the sediment adjacent to and downstream of the former manufactured gas plant. A second area with higher levels of by-products exists within this zone and is estimated to cover approximately 1250 square metres.

Vertical Delineation

At four of the sampling locations (L3-01, L4-01, L5-01 and L6-01), both shallow and deep samples were analyzed to provide an indication of the distribution of residues with depth. The deeper sediment/soil type at all of these locations was consistent and consisted of dark grey silty clay. Some uncertainty exists with regard to the actual depth from which these samples were collected due to incomplete core recovery. It was assumed that the deeper samples at each of these locations came from 1.5 to 3.0 m below the surface of the sediment. These sediments may originate from as little as 0.6 to 1.0 m below the sediment surface.

06/OCT/94



NOTES:

1. SAMPLING INTERVALS AT 1,2,4,8 AND 16 METRES FROM THE SHORELINE ALONG TRANSECTS L1 TO L6.
2. SAMPLES L7 AND L8 AT 7 METRES FROM SHORELINE.
3. ENVIRONMENT CANADA GUIDELINES (1992) REFERENCED WHERE AVAILABLE. OTHERWISE, LOWEST OF ONTARIO AND QUEBEC GUIDELINES USED.
4. CHEMICAL ANALYSIS OF SHALLOW SEDIMENT (TYPICALLY < 0.8m) USED TO COMPILE THIS FIGURE.
5. BASED ON ANALYTICAL RESULTS OR FIELD CLASSIFICATION OF NC.
6. BASED ON ANALYTICAL RESULTS OR FIELD CLASSIFICATION OF NC/TC, TC OR VC.

LEGEND:

○	EXCEEDS THRESHOLD EFFECT LEVEL (TEL) OR EQUIVALENT
●	EXCEEDS PROBABLE EFFECT LEVEL (PEL) OR EQUIVALENT
□	BELOW THRESHOLD EFFECT LEVEL OR EQUIVALENT
▲	NOT ANALYZED

FIELD CLASSIFICATION

NC, TC, VC ▨	ESTIMATED EXTENT OF PAHs > BACKGROUND CONCENTRATIONS. (5)
▒	ESTIMATED EXTENT OF RESIDUES WITH STRONG ODOURS AND/OR VISIBLE TAR. (6)

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FIGURE 4-2:
ESTIMATED EXTENT OF
SEDIMENTS CONTAINING RESIDUES

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The chemical analyses were compared to the background sediment analyses for samples collected at Line 1 (L1-01T and L01-15T). Two of the four deeper samples contained concentrations of PAHs that were comparable to background concentrations. The fourth sample from L5-01B contained PAHs at concentrations above background as well as above the TEL and the PEL. Sample L5-01B was located below one of the two samples containing the highest concentrations of residues. The sample from L3-01B contained one parameter above the PEL criteria.

All of the deeper samples contained lower concentrations than the overlying shallow samples. The analysis of deeper sediments and comparison with the shallower analysis suggest that the most significant concentrations of residues are restricted to the shallow sediments, located in the upper 0.8 to 1.5 m.

Water

A total of eight water samples were submitted for analysis of PAHs including one duplicate (Table 4.2). No PAHs were detected above the laboratory detection limits in any of the samples submitted for analysis.

Benzo(a)pyrene [B(a)P] is the main PAH chemical which has had water quality guidelines developed, albeit for drinking water purposes. The B(a)P concentration is often used as an indication of PAH contamination. The Canadian Drinking Water Guideline for B(a)P is 0.001 ppb (1 ppt). The analytical detection limit for this parameter is 0.006 ppb. No samples analyzed contained B(a)P above 0.006 ppb.

Discussion of Results

The results of river water analysis found no detectable levels of PAHs in the river indicating that no evidence of by-products exists in the water column. It suggests that the PAHs are bound to the organic carbon in the sediment and that they are not present at levels of concern in the dissolved phase. Exposure of aquatic life to dissolved PAHs was concluded to be an unlikely source of significant impact. Other exposure pathways include:

- Direct ingestion of PAHs in sediment by sediment-dwelling organisms
- Subsequent ingestion of sediment-dwelling organisms by species higher in the food chain
- Direct ingestion of re-suspended sediment by bottom-feeding aquatic life other than sediment dwellers
- Erosion of contaminated sediments resulting in exposure to downstream water users or aquatic life

Section 5

Biological Testing Program

A laboratory biological testing program was developed to provide an initial assessment of the impact on aquatic life in the Red River due to the presence of by-products of coal gasification as identified in Section 4. The program was aimed at identifying whether potential impacts due to degraded sediment quality could be defined. The program was designed to determine if residues have a measurable impact on the benthic (sediment-dwelling) community, resulting in acute or chronic toxicity to selected test species and whether measurable bioaccumulation of residues occurs in aquatic life tissue. The program developed was based primarily on laboratory assessment of field samples to provide an indication of impacts. In situ monitoring (i.e. in the river) was not conducted as part of this program.

Sampling Locations

Sediment samples were collected in three areas as follows:

- **Reference Control.** Sample collected at location L1-15 as shown on Figure 4-1. This location is located upstream of the site and at a location where chemical analysis of sediment indicates that sediment quality is indicative of background conditions.

- **Moderately Affected Sediment.** Samples were collected at location L4-1 (test sediment #1) located in area which exceeded the background concentrations and the PEL. This sample contained moderate levels of residues based on the chemical analysis reported in Section 4.

- **Highly Affected Sediment.** Sample collection was initiated near L4-7 in the area where chemical analysis indicated that sediments were above the SEL. However, repeated sampling in this area could not obtain samples due to the coarse nature of the bottom sediments. Instead, a sample was collected from L4-15 where black staining and strong odours were observed and chemical analysis indicated total PAH concentrations were higher than L4-1 by a factor of approximately 10. However, the sample contained significantly lower concentrations (by a factor of 200) than sample L4-7 which contained the highest level of residues detected in this assessment.

Sampling Methodology

Samples were collected on June 22 and 23, 1994. All sediment samples were collected using a Ponar dredge with a capacity of 2 litres. Sampling was conducted from a boat and the position of the boat was maintained above the sampling location to facilitate repeat sampling.

Sediment samples for characterization of benthic community required that samples be collected in triplicate at each sample location. The one-litre samples were preserved in 10 percent formalin and stored on ice during shipment to the laboratory.

Samples collected for sediment toxicity testing required numerous repetitions to provide the 10 litres of sediment required for testing. Samples were placed in 10-litre food grade bags, placed in coolers with ice and shipped to the laboratory immediately after sampling. Samples were then refrigerated pending laboratory testing.

Sampling for benthos was problematic due to interferences caused by debris on the river bottom. This led to variable and sometimes no sample recovery. Therefore the benthic samples retrieved are not representative of a defined surface area of river bottom.

A summary of the sediment sampling performed and the descriptions of the samples obtained is provided in Table 5.1.

Testing Procedures

All biological testing was subcontracted to a recognized and qualified biological testing company called Integrated Explorations Environmental Research Consultants of Guelph, Ontario. In the laboratory report, sample L4-1 is mistakenly referenced as L4-7. Discussion of these results has been corrected in this section.

Chronic Toxicity Testing

Chronic toxicity testing was conducted according to the Ontario Ministry of the Environment and Energy (MOEE) developed procedure entitled "Laboratory Sediment Biological Testing Protocol" dated August 1992 (MOEE, 1992). Three species of test organisms were exposed to each of four sediment types (three from the Red River and one negative control from which the organisms were cultured). The experiments were conducted in triplicate except for sample L4-15 which could only be conducted in duplicate due to the limited amount of sample available.

Table 5.1
Sediment Sampling Field Data (June 22 and 23, 1994)

Sample Number	Benthic Sample Preservation	Benthic Sample Volume	Toxicity Sample Preservation	Sample Volume	Sample Date	Toxicity Sample Time	Soil Type	Evidence of Contamination	Other Notes or Observations
L4-1	5.6 to 7.4%	3 x 1 litre	- dark, cool, no headspace - formaldehyde	10 litres	June 22, 1994	11:50	- silt sediment, black	- black staining and naphthalene odour	- sample not obtainable from L4-7 due to coarse grained sediments
L4-15	5.6 to 7.4%	3 x 1 litre	- dark, cool, no headspace - formaldehyde	10 litres	June 22, 1994	15:00	- coarse sand to muck	- some visible tar, strong naphthalene odour, black staining	- attempts to sample L3-15 and L6-15 were unsuccessful
L1-15	5.6 to 7.4%	3 x 1 litre	- dark, cool, no headspace - formaldehyde	10 litres	June 23, 1994	9:30	- silt sediment, grey, some stones, metal, twigs	- natural odour, no staining	- upgradient background sample

Bioaccumulation Studies

Analysis of one of the three test species for the chronic toxicity tests, the fathead minnows, was conducted as an indication of bioaccumulation. The fathead minnows are the only test species which are large enough to provide sufficient mass for a tissue analysis. Fish tissue from replicate samples for each of the four sediment types were composited and analyzed for PAHs.

Benthic Community Characterization

Characterization of benthos revealed low numbers and diversity of organisms in all sediment samples. This may reflect poor river sediment quality on a larger scale but may also be an artifact of difficult sediment sampling characteristics. It was necessary to composite the replicates from each location to provide some indication of the benthic community characteristics.

Results

Chronic Toxicity Testing

The results of chronic toxicity are provided in the laboratory test report provided in Appendix F and summarized in this section. Sample L4-1 did not exhibit toxicity characteristics that were significantly different from the reference control (L1-15) or the negative control based on either mortality rates or length and weight measurements. This suggests that the concentrations present in sample L4-1 are not sufficiently high to result in adverse impacts to aquatic life based on the conditions of this test. No mitigative measures are warranted in areas with similar concentrations of PAHs.

In sample L4-15, higher mortality was observed than in the other samples. The mean mortality was 30 percent, 35 percent, and 100 percent for fathead minnows, mayfly nymphs and chironomids, respectively, in L4-15. In the other samples, it was 13.3 percent, 3.3 percent and 17.8 percent or less, respectively, for the same species. This occurred in both replicates of L4-15 for all three test species.

Non-test species were also enumerated during the testing. Oligochaetes were the only indigenous species identified. The numbers of oligochaetes found in each of the samples, as summarized in the report in Appendix F, indicate that these species were not present in the sample from L4-15. Oligochaetes were present in similar numbers in both the reference control and sample L4-1.

The results at L4-15 indicate that samples with this concentration or higher have an adverse impact on aquatic life for the conditions under which the test was performed. It is noted that these tests are conducted under laboratory test conditions which may be more extreme than actually occurs in the river. Prior to determining if any mitigative measure is warranted, further information would be required.

Bioaccumulation Studies

Tissue analysis results from the composite samples of fathead minnows used in the chronic toxicity test are provided in Table 5.2.

All tissue analysis contained PAHs. The negative control sample, from fathead minnows exposed to sediments from a site where some of the test organisms were cultured, contained total PAHs of 76.4 ppb. This indicates that some level of PAHs is expected in all tissue samples but that it is not necessarily indicative of a pollution source.

The reference control [L1-15(A/B,B/B)] from the Red River contained total PAHs of 274.07 ppb. This indicates that PAHs in fish exposed to background sediment in the Red River are likely to be above the level found in the negative control. This is consistent with the presence of PAHs in background sediment above the TEL, as discussed previously.

Total PAHs in tissue from sample L4-1(A/B/C), an area indicative of above-background PAH levels in sediment, is characterized by total PAHs in tissue below that found in the reference control (L1-15). These results suggest that bioaccumulation of PAHs in fish tissue is not significantly different from background or other sediments with PAH levels similar to L4-1.

In sample L4-15(A/B/C), total PAHs are in excess of two orders of magnitude above background indicating ingestion of PAHs by fathead minnows. These above-background levels may be indicative of the confined conditions under which the tests were performed and may be overly conservative relative to in situ conditions. The results also reflect whole body analysis, and may have contained ingested sediment not PAHs in actual tissue.

Benthic Community Characteristics

The benthic community analysis is summarized in Table 5.3. It had been anticipated that this analysis would provide a measure of the impact of residues based on the characteristics of the benthic community. The number of species found is too low to provide a statistically reliable indication of adverse impacts. However, the analysis did provide some interesting results. The number and diversity of species at L1-15, the background conditions, was low indicating that benthos may be affected by upstream sources of pollution not related to the former manufactured gas plant. This observation was supported by the chemical analysis of sediment at this location that found background levels above the TEL. Alternatively, it could suggest that the residues from the gas plant extend slightly upstream to this vicinity.

Comparison of the sampling locations within the zone of above background PAHs to background indicated that the sample (L4-15) with the highest levels of residues had the

Table 5.2
Tissue Analysis of PAHs in Fathead Minnows from Chronic Toxicity Tests

	L4−15A/B & L4−15B/C Composite	L1−15A/B & L1−15B/C Composite	L4−1A/B & L4−1B/C Composite	Neg CTRL A/B & Neg CTRL B/C Composite
Sample Date	10/03/94	10/03/94	10/03/94	10/03/94
Laboratory No.	94−09316−01	94−09316−02	94−09316−03	94−09316−04
PAH's (ng/g) = ppb				
Naphthalene	743	40.6	18.9	21.1
Acenaphthylene	1110	3.93	3	2.19
Acenaphthene	673	35.5	15.5	13.5
Fluorene	716	28	7.06	5.4
Phenanthrene	5360	113	31.3	14.9
Anthracene	3070	4.18	5.23	<3.2
Fluoranthene	5740	19.8	9.94	3.27
Pyrene	3070	16.6	12.4	<3.96
Benzo (a) anthracene	2470	<1.76	<1.76	<1.76
Chrysene	2410	<2.00	<2.00	<2.00
Benzo (b) fluoranthene	4288*	<3.88	<3.88	<3.88
Benzo (k) fluoranthene	*	<4.4	<4.4	<4.4
Benzo (a) pyrene	2270	<2.84	<2.84	<2.84
Indeno (1,2,3−cd) pyrene	1400	<2.84	<2.84	<2.84
Dibenzo (a,h) anthracene	313	<3.72	<3.72	<3.72
Benzo (ghi) perylene	1130	<3.48	<3.48	<3.48
Perylene				
Total PAH	**34763**	**274.07**	**115.79**	**76.4**
D8−Naphthalene (Recovery Surrogate)	32	34	39	50
D12−Chrysene (Recovery Surrogate)	70	56	56	53

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Table 5.3
Sediment Invertebrate Analysis

Sample Number	Number of Species/Sample Location		
	L-4-1	L-4-15	L-1-15
Mollusca			
Sphaerdae			
Sphaerium		4	8
Insects			
Ephemeroptera			
Hexagenia	1	1	
Trichoptera			
Hydropsychidae			
Cheumatopsyche		2	
Chironomidae			
Chironominae			
Harnischia	2	8	8
Cryptochironomus	1		
Polypedilum	1		
Chironomus	2		
Tanypodinae			
ablabesmyia	3	1	
Oligochaeta			
Enchytraeidae	1	17	30
Tubificidae			
immature, no hair setae		8	3
immature, with hair setae		10	13
Limnodrilus hoffmeisteri		2	5

Notes:

1. Collected June 22 - 23, 1994
2. Total contents of sample screened through 500 micron mesh.

most diverse population of invertebrates. L4-15 contained many of the same species as at L1-15, both of which originated from similar depths of water and an equal distance from shore. Sample L4-15 contained predominantly silt whereas L1-15 contained clay with some sand. Sample L4-1, contains a very different distribution of species compared to the other two samples. This is likely due to the shallow water environment at this location.

Prior to determining if any mitigative measure is warranted, further information would be required.

Section 6
Baseline Human Health Risk Assessment

Overview

This section provides an evaluation of potential risks to human health presented by chemicals detected in surface and subsurface soil and groundwater at the Centra Gas property. A brief summary of the site background pertinent to this risk assessment is provided below, followed by a discussion of the scope and organization of the risk assessment.

Site Background

The Centra Gas site is located in a residential and commercial/industrial neighbourhood. The site has been divided into three areas (I, II and III) characterized by different mixes and levels of residues. Figure 6-1 shows the site (including all three areas) and surrounding.

- **Area I** is the north section of the site and extends from approximately the midpoint of the operations building to Rover Avenue with the Red River located just beyond the road. Paved roads surround the area on the north, west and east sides. An overpass (Disraeli Freeway) is located at the northwest corner of the property. A Power Substation building is located to the east. Area II is located to the south. The area was used primarily for coal and coke storage. Several organic compounds including PAHs, VOCs, and petroleum hydrocarbons, and various inorganic constituents have been detected in both subsurface soil and groundwater. The area is currently an asphalt covered parking lot to the north of the operations building with a central grassed area and strips of grass on the perimeter of the building and property. The estimated size of Area I is approximately 10,000 m^2.

- **Area II** is the central section of the site and extends from Area I to the south to the start of the purchasing department and stores building. This area has fewer sampling locations than Area I. The area is bordered by roads on the west and east sides. Beyond the roads, a grassed area is located beside the expressway to the west, and a power substation building is located to the east. Areas I and III border the area to the north and south respectively. As with Area I, several organic and inorganic compounds were detected in this area but at generally at lower concentrations than Area I. The area is currently an asphalt parking lot to the south of the operations building with strips of grassed areas on the east and west side. The estimated size of Area II is approximately 7,850 m^2.

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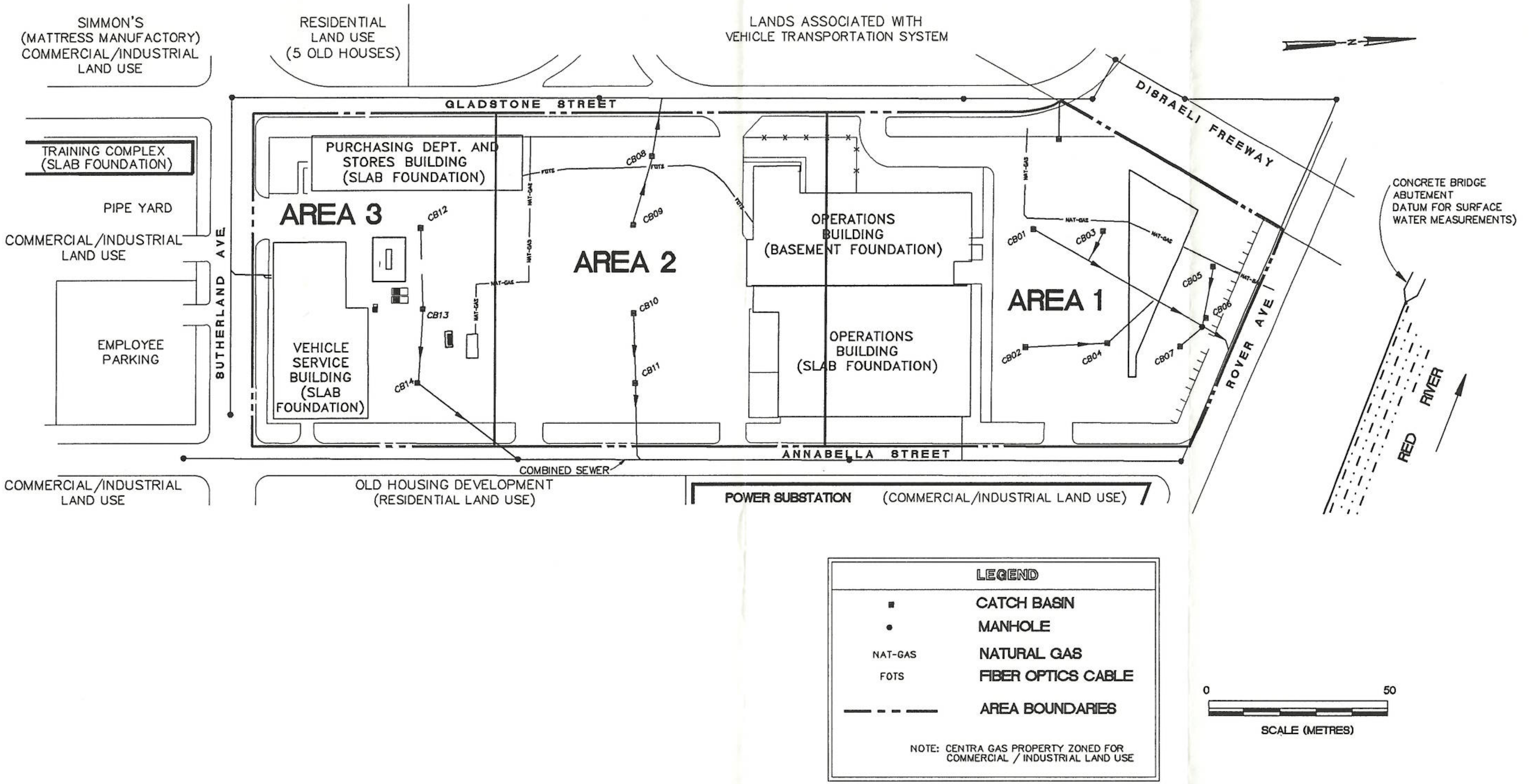

CH2M HILL
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PROJECT No. ONT29776.C0

FIGURE 6-1
SITE PLAN SHOWING RISK ASSESSMENT
AREAS OF CENTRA GAS FACILITY

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- **Area III** is the south section of the site and extends to Sutherland Avenue. This area includes the Vehicle Service Building and Purchasing Dept. and Stores Building. Both of these buildings are single storey and do not have basements. This area contains three underground storage tanks (2 gasoline and 1 waste oil) which are currently out of service. The area is bordered to the east and west by residential housing, to the north by Area II and to the south by Sutherland Avenue with further commercial/industrial land use beyond the road. The contaminants detected in this area are BTEX, PAHs and petroleum hydrocarbons. The concentrations in Area III are considerably lower than in Areas I and II. As with Areas I and II, this area is asphalted with some perimeter grassed areas. The estimated size of this area is 5,800 m^2.

Scope of the Risk Assessment

A baseline risk assessment was completed to address the three areas of the Centra Gas site. As a baseline risk assessment, human health risks were estimated based on current site conditions, assuming that no corrective actions will take place.

There are no strict guidelines or legislation for performing risk assessments in Manitoba or across Canada. This risk assessment was performed using generally accepted scientific practices and principles. Fate and transport modelling of contaminants was assisted with the aid of a program known as AERIS (Aid for Evaluating the Redevelopment of Industrial Sites). Other general methodology used by the U.S. EPA was also incorporated into the assessment as necessary.

Methodology of the Human Health Risk Assessment

The human health risks were estimated using a four-step process:

- **Identification of chemicals of potential concern (COPC).** Chemical results from site investigation activities were evaluated as part of the human health risk assessment using screening criteria to identify COPC. Chemicals retained following this evaluation were the focus of subsequent evaluation in the risk assessment.

- **Exposure assessment.** Pathways by which exposure could occur were identified; for exposure pathways that were both complete and plausible, potential receptors and exposure parameters such as exposure frequency and duration were characterized.

- **Toxicity assessment.** Quantitative risk values, including slope factors and reference dose values, were identified and used to assess health effects associated with exposure to the COPC.

- **Risk characterization.** Information from the toxicity and exposure assessments was integrated for the estimation of potential risks to human health, including both noncancerous and cancerous health effects associated with human contact under the evaluated exposure scenarios. An expert system computer software model known as AERIS was used for the risk characterization to calculate the dose by inhalation and ingestion to a receptor.

  A total exposure hazard index (TEHI) for the site was established by adding individual hazard indices for each contaminant and for each exposure pathway. For carcinogens, a risk level was calculated based on the received dose and the cancer slope factor for that contaminant.

The final step in the risk assessment summarizes the basic assumptions and the uncertainties associated with the data, methodology, and values used in the risk estimations.

Overall, for the Centra Gas site, complete exposure pathways (i.e. where a receptor can come into contact with site chemicals) were evaluated for risks due to chemicals at the site. Intake was estimated using site-specific information whenever possible; otherwise health-protective assumptions were used.

Several assumptions were used in preparing the risk assessment, including:

- Potential future remedial actions at the Centra Gas site were not considered in estimating risk.
- This risk assessment is based on data collected by CH2M HILL during the 1993 and 1994 field studies.
- Chemical concentrations were considered constant over time, although migration and degradation of some COPC may be anticipated to occur with time.
- It was assumed that exposure remains constant over the exposure periods assessed (i.e. intake levels are constant).

Finally, soil sample results representing dry weight concentrations were used for the purposes of the risk assessment.

Identification of Chemicals of Potential Concern

Chemicals detected from each area of the Centra Gas site (Areas I, II, and III) were reviewed for selection as a chemical of potential concern (COPC) for this risk assessment. Chemicals of potential concern were selected based on the following criteria:

- Chemicals that were frequently detected (generally greater than 5 to 10 percent) in the soil or groundwater samples.
- Chemicals that were associated with current or historical site activities.
- Concentrations that exceeded federal or provincial criteria, or literature values.
- Relative toxicity and mobility in the environment.

The results of the subsurface investigation are summarized in the Phase I: Site Investigation Report and in previous sections of this Phase II: Detailed Site Characterization Report.

Soil quality was found to be degraded to levels above the CCME Level C criteria for PAHs at the north, west, and east sides of the property in Phase I and found to extend offsite to the north in Phase II. Groundwater quality was found to be degraded to levels above the CCME Level C criteria for PAHs and to levels above the Alberta Level III criteria for BTEX up to and beyond the north property line. Soil quality is also degraded at the south portion of the property for both organics and inorganics; however, the areas where residues exist is much more localized to shallow depths compared to the north portion of the site.

Soil and groundwater samples from Areas I, II and III were analyzed for PAHs, BTEX, phenolics, TPH (volatile and semi-volatile) and 14 inorganic chemicals.

Concentrations above the screening criteria for PAHs, BTEX and phenolics were detected at select locations in Area I. Boron, lead, arsenic, vanadium and zinc exceeded the CCME Interim Assessment Criteria at selected locations, however they were below the CCME Interim Remediation Land Use Criteria for Residential/Parkland (with the exception of boron which does not have a published value). The inorganic parameters have not been included in the risk assessment because they were detected below the CCME Interim Remediation Land Use Criteria. BTEX compounds have also been excluded from the risk assessment because they are not present in the soil to any appreciable amount. They are present in the groundwater at higher levels at the north property boundary. However, the north boundary is downgradient of the site away from onsite and offsite buildings. TPH has not been included in the risk assessment since dose criteria is unavailable for this parameter and it would be difficult to quantify the risks associated with TPH. PAHs have been retained for the risk assessment. Although assessment or remediation criteria does not exist for many of the PAHs, toxicity dose information is available for some of the PAHs. Therefore, 13 PAHs have been retained for the risk assessment. Acenaphthylene, Benzo(g,h,i)perylene and Phenanthrene have not been retained for the analysis since they are not classifiable as to human carcinogenicity and there are no available U.S. EPA IRIS toxicity effects data for these compounds. All of the probable human carcinogens have been retained. Toxicity information for those compounds which are not listed in IRIS was obtained from the CA Department of Toxic Substances Control (CDTSC).

Based on similar reasons, only the 13 PAHs have been retained for the risk assessment of Areas II and III where concentrations are typically lower for all parameters than Area I.

Fate and Transport of PAHs

The fate and transport of a chemical is characterized by its physical and chemical properties. Water solubility predicts the amount of a chemical that will dissolve in water. Soil sorption coefficient (K_{oc}) predicts the ratio of chemical mass that will adsorb to soil versus the mass that will dissolve in water. The vapour pressure of a chemical can indicate the likelihood that a chemical will volatilize (e.g., from surface soil); chemicals with high vapour pressures like benzene are expected to readily volatilize from surface soils. The Henry's Law constant for a chemical indicates the likelihood that a chemical will volatilize from the water phase to the vapour phase; chemicals with high Henry's Law Constants like benzene are expected to volatilize readily from surface water. The log octanol-water partition coefficient (log K_{ow}) describes the partitioning of a chemical between water and organic phases such as fats and oils; log K_{ow} can be used to predict the likelihood that a chemical will partition from water to biota. The physical and environmental parameters described are presented in Table 6.1 for the organic contaminants of concern at the Centra Gas site and include water solubility, K_{oc}, vapour pressure, Henry's Law constant, and the log K_{ow}.

PAHs were the group of chemicals most frequently detected in samples collected from the Centra Gas site. PAHs were detected in subsurface soil and groundwater samples from Area I, II and III. PAHs are hydrophobic and preferentially adsorb to soil, depending on the amount of organic carbon present. Migration through groundwater is low relative to groundwater flow rates.

PAHs are environmentally stable, particularly in sediments. The stability of individual PAHs is related to the number of aromatic rings per structure and the arrangement of those rings. Compounds with rings fused in steps are the most stable (e.g., chrysene) while those in a linear arrangement are the least stable (anthracene). Degradation of these compounds occur slowly through microbial degradation in soils and photo-degradation in shallow surface water and air.

Air

Photochemical oxidation and sorption to particles that settle to the ground dominate the atmospheric fate of PAHs. PAHs in the vapour phase (e.g., naphthalene, phenanthrene) are primarily removed through photochemical reactions. The rate of reaction is decreased when PAHs are adsorbed to atmospheric particulates like soot. However, smog stimulates PAH degradation because of strong oxidizing agents such as ozone and singlet oxygen. Larger PAHs such as benzo[a]pyrene are removed from the atmosphere primarily through settling and precipitation. The photodegradation half-life for PAHs has been estimated at

Table 6.1
Physical Chemical Properties of Chemicals of Potential Concern

Name	No. of Rings per Structure	CAS No.	Molecular Weight (g/mol)	Water Solubility (mg/L)	VP (Pa)	Henry's Law Constant (atm-m^3/mole)	Log K_{oc}	Log K_{ow}
POLYNUCLEAR AROMATIC HYDROCARBONS								
Acenaphthene	3	83-32-9	154	3.9	2.07E-01	9.20E-05	3.66	3.92
Acenaphthylene	3	208-96-8	152	3.93	3.87	1.48E-03	3.40	3.70
Anthracene	3	120-12-7	178	0.045	2.6E-02	1.02E-03	4.41	4.45
Benzo(a)anthracene	4	56-55-3	228	0.0057	2.93E-06	1.16E-06	6.14	5.61
Benzo(b)fluoranthene	5	205-99-2	252	0.014	6.7E-05	1.19E-05	5.74	6.06
Benzo(k)fluoranthene	5	207-8-9	252	0.0043	7.6E-05	3.94E-05	5.74	6.06
Benzo(g,h,i)perylene	6	191-24-2	276	0.0007	1.00E-08	5.34E-08	6.20	6.51
Benzo(a)pyrene	5	50-32-8	252	0.0038	7.5E-07	1.55E-06	6.74	6.06
Chrysene	4	218-1-9	228	0.0018	8.4E-07	1.05E-06	5.30	5.61
Dibenzo(a,h)anthracene	5	53-70-3	278	0.0005	1.00E-08	7.33E-08	6.52	6.80
Fluoranthene	4	206-44-0	202	0.26	6.67E-04	6.46E-06	4.58	5.22
Fluorene	3	86-73-7	116	1.94	1.4	6.42E-05	3.86	4.18
Indeno(1,2,3-c,d)pyrene	6	193-39-5	276	0.00053	1.00E-08	6.86E-08	6.20	6.50
Naphthalene	2	91-20-3	128	31.7	10.9	4.80E-04	3.10	3.37
Phenanthrene	3	85-01-8	178	1.00	9.0E-02	1.59E-04	4.15	4.46
Pyrene	4	129-00-0	202	0.148	8.86E-04	5.04E-06	4.92	5.17

Source: AERIS, 1991 and U.S. EPA.

less than one day. The presence of several PAHs together can either accelerate or inhibit the photo-degradation process, depending on the specific PAHs present.

PAHs are generally not considered volatile and therefore are not expected to significantly volatilize from water. PAHs have low Henry's Law Constants indicating limited volatilization from water (Table 6.1). Volatilization from soil to air will be limited because PAHs have high K_{oc} values, tending to adsorb strongly to soil. For risk assessment purposes, the EPA has characterized volatile chemicals as those having a Henry's Law constant of $1x10^{-5}$ atm-m^3/mole or greater, and a molecular weight of less than 200 g/mole. Using this guidance, only four of the 16 PAH analytes are considered as potentially volatile: acenaphthylene, anthracene, naphthalene, and phenanthrene. Since there are no U.S. EPA reference doses for acenaphthylene and phenanthrene and since both of these compounds are not considered human carcinogens they were not included in the risk assessment.

Water

PAHs present in onsite groundwater tend to be those with four or fewer rings. Transport to groundwater of PAHs with four or more rings is expected to be very limited since those PAHs have high octanol-water partition coefficients (K_{ow}) and low water solubilities.

The primary fate of PAHs in onsite groundwater is soil adsorption and aerobic microbial degradation. The rate of degradation is slow, however, due to the limited availability of oxygen.

Soil

Soil and sediments become the final sink for PAHs unless they are biologically degraded or are returned to the air or water by disturbance. Surface soil concentrations tend to be proportional to air concentrations, because of settling of PAHs from combustion releases, unless there has been direct introduction into soil. PAH degradation in surface soil is due to degradation by microbial degradation, photodegradation, or plant uptake. At the sediment-water interface, smaller PAHs (fewer rings, lower molecular-weight) continue to be microbially and photochemically degraded, but degradation of higher molecular-weight PAHs is greatly slowed. After the PAHs reach the subsurface sediment, they are less likely to degrade and can remain unaltered for years. PAHs bound to sediment have a half-life of 5 to 10 years.

Sorption of PAHs is greatest in soils with high organic content. Soil moisture, soil type, temperature, Ph, and the chemical characteristics of the adsorbing chemical also affect the adsorption interaction. Studies using pyrene and dibenzo[a,h]anthracene have shown correlations of increasing adsorption with increasing soil organic content and decreasing soil particle size (greater total surface area for adsorption). Further, the bioavailability of PAHs sorbed to soil (i.e. the availability of PAHs to be desorbed from soil and taken up by biota) was compared with the availability of PAHs when chemically extracted using solvents. It was found that significantly more PAHs are available by chemical extraction than are bioavailable, and that bioavailability decreases with increasing time of PAH contact with sediments.

Exposure Assessment

The exposure assessment identifies the scenarios in which people could possibly come into contact with COPC at the Centra Gas site under both current and plausible future site use conditions. This section describes potential receptors and selects potential exposure pathways to be retained for evaluation. The methodology used to estimate carcinogenic and noncarcinogenic risk and the exposure assumptions for the retained exposure pathways are also presented.

Summary of Physical Setting and Land Use

The Centra Gas site is located in a mixed residential, commercial and industrial area. Area I is located furthest from the residential developments. It is bordered by Rover Avenue and the Red River to the north, a power substation building to the east, Gladstone Street and Disraeli Freeway to the west and the operations buildings to the south. Area II is bordered by residential housing to the east and west, the operations buildings to the north (Area I) and parking to the south. Area III is bordered by residential housing to the east and west, parking to the north (Area II) and commercial industrial buildings and parking as well as Sutherland Avenue to the south.

Potentially Exposed Populations

This subsection identifies receptor groups who could possibly be exposed to COPC associated with the Centra Gas site. Both current and future plausible receptors are described.

Current Potential Onsite Receptors

Potential current onsite receptors include Centra Gas and contracted workers, and trespassers.

The onsite workers consist of office personnel, truck drivers and maintenance/operational crew members. The maximum time spent by an employee on the site is assumed at 8 hours/day indoors and 1 hour/day outdoors in the summer and winter. Two hours/day outdoors and 4 hours/day indoors on weekends in the summer and 1 hour/day outdoors and 4 hours/day indoors on weekends in the winter. The balance of an employee's time is assumed to be spent away from the site.

Area I potential receptors are primarily office and operational staff located in the operations building. There are approximately 70 people in these buildings. Area II includes this office staff because of the overlap with Area I and extends to the truck compound and warehouse and stores buildings. The warehouse and stores building has approximately 10 people working in this facility. Area III is primarily the garage or service building and houses approximately 20 maintenance staff. Service vehicle operators are onsite for approximately 10 - 20 percent of the time of an office employee.

There is low potential for trespassers at each area since the compound is fenced and the security staff prevent unauthorized visitors. Site-specific visitor and trespasser frequency were not evaluated as these were assumed to be lower frequency potential receptors.

Current Potential Offsite Receptors

Offsite receptors could potentially include workers, pedestrians, and offsite residents. Workers employed by businesses surrounding the site may include employees. Residents are located to the east and west of Areas II and III. The potential for vapour migration along sewer lines or backfill was evaluated and found negative results for sewer water and gas analysis (Section 3). While the baseline human health risk assessment focused solely on onsite workers, an offsite risk assessment was not carried out for three main rasons:

- The results of offsite sewer sampling were negative
- The onsite risk assessment suggested risks were within acceptable levels
- There is a lack of data on the factors required to determine offsite risks

Future Potential Onsite and Offsite Receptors

Plausible future onsite receptors are limited to the worker population. The Centra Gas site is located in an area zoned industrial. The land use is not expected to change and Centra Gas intends to continue to own the property.

Future offsite receptors could include local workers at bordering properties, offsite residents, and pedestrians.

Initial Screening of Potential Pathways

An exposure pathway is the means by which a person (a receptor) may come in contact with COPC from the Centra Gas site. A complete exposure pathway has five elements:

- A source of chemical released to the environment
- A mechanism for release of the source (e.g. wind transporting soil)
- An environmental transport medium (e.g. air)
- An exposure point (e.g. a workplace)
- A feasible route of exposure (e.g. inhalation)

Exposure may occur when chemicals migrate or are physically moved from the site to an exposure point (i.e. a location where receptors can come in contact with chemicals), or when a receptor comes in direct contact with the source material containing the COPC. An exposure pathway is complete (i.e. there is exposure) if a receptor takes in chemical constituents through ingestion, inhalation, or dermal absorption (contact with the skin).

Possible pathways of exposure to COPC by receptors on and near the Centra Gas site are discussed in this section. Pathways that are incomplete (i.e. there can be no exposure) or are not plausible are not retained for the risk assessment; rationale for these eliminated pathways is presented.

Surface soil is covered with asphalt, preventing exposure to current workers and trespassers, and preventing transport to offsite workers, residents, and pedestrians. Therefore, surface soil exposure pathways (i.e. dermal contact, ingestion, particulate inhalation) for these receptors will not be retained. Surface soil exposure pathways for future onsite workers and residents, and offsite workers, residents and pedestrians have also been excluded since Centra Gas intends to keep ownership of the property and the contaminated material is located at depth on the site.

Current onsite workers may be exposed to subsurface soil via dermal contact, ingestion, or inhalation while digging or working in a trench. To protect current workers from this sort of exposure, Centra Gas must take the necessary health and safety precautions. Centra Gas will need to inform contractors of site conditions prior to their performing excavation activities and will require them to comply with Centra Gas guidelines. There is a potential for future workers to be exposed to COPC in subsurface soil during digging or excavation activities, however, the duration of exposure would be considerably less than onsite workers. Secondly, because of the safety measures a Centra Gas employee or contractor would take during excavation of the subsurface soil, this receptor will not be considered further in this assessment.

Current or future onsite office workers could potentially be exposed if volatile COPC diffused from the subsurface soil into building basements. CH2M HILL has conducted indoor air monitoring and no COPC were detected for the conditions in existence on that sampling day. However, this exposure pathway will be retained for evaluation of potential worker exposure in the current building to corroborate this result. Future onsite workers may also possibly be exposed to volatile COPCs that diffuse from subsurface soil or groundwater through the foundation. Future onsite residential exposure is unlikely based on land use and will therefore it will not be retained as a pathway for analysis.

Current and future offsite receptors (workers, residents, or pedestrians) have no mechanism for exposure to subsurface soil by direct contact, ingestion or particulate inhalation and therefore these exposure pathways will not be retained. Exposure to offsite receptors by vapour migration into basement homes was not evaluated for the reasons stated previously.

Currently, local groundwater is not used for water supply onsite or offsite; therefore, no complete pathways exist for current onsite or offsite receptors. These pathways will not be retained.

Summary of Exposure Pathways to be Retained

In summary, Areas I, II, and III are covered with asphalt or soil cover/vegetation in areas preventing exposure to current workers and trespassers, and preventing certain transport pathways to offsite workers, residents, and pedestrians. Therefore, surface soil exposure pathways (i.e. dermal contact, ingestion, particulate inhalation) for these receptors will not be retained. The only exposure pathway considered for current and future onsite workers is exposure via inhalation of vapours through basements exposed to COPC through inhalation of vapours.

Methodology for Exposure Estimation

This section summarizes the methodology and exposure factors used to quantify exposure. Exposure, or chemical intake, is defined as the product of: chemical concentration in the source material, times, the amount of intake (or source material the body contacts)

$$\text{Exposure} = \text{Chemical Concentration} * \text{Intake}$$

Five basic factors are used to estimate intake: exposure frequency (days/year), exposure duration (total years), exposure rate, body weight, and averaging time (associated with the period of exposure and effects).

Exposure can be described by the following general equation:

$$\text{Exposure} = \frac{\text{Concentration} * \text{Contact Rate} * \text{Exposure Frequency} * \text{Exposure Duration}}{\text{Body Weight} * \text{AveragingTime}}$$

In this assessment, exposure (or intake) is normalized for time and body weight and is expressed in milligrams of chemical per kilogram of body weight, per day (mg/kg-day).

Exposure Estimation for Carcinogens

The intake of a chemical evaluated for carcinogenic health effects is averaged over an entire lifespan (i.e. lifetime average chemical intake) of 70 years. For carcinogens, 70 years is referred to as the averaging time. The selection of an averaging time that spans a lifetime is based on U.S. EPA guidance: "The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime" (U.S. EPA, 1989a). By convention (U.S. EPA, 1989a), a "typical" individual with a lifetime average body weight of 70 kg is assumed.

Exposure Estimation for Noncarcinogenic Effects

The intake of chemicals evaluated for noncancerous health effects uses an averaging time based on the estimated period of exposure for any given exposure setting. The noncarcinogenic risk is evaluated for a target receptor (i.e. group within a potentially exposed population with the greatest potential exposure, that is the group that receives the highest dose or intake of a chemical based on an exposure per kilogram of body weight per day).

Exposure Concentrations and Factors

In calculating exposure, the chemical concentration used to represent the source media was based on either measured concentration (e.g., subsurface soil) or modelled concentrations (e.g., air concentrations). Volatile chemical concentrations in air, used to evaluate the potential for inhalation of volatile chemicals transported through the foundation of a home or facility building, were estimated using COPC measured in onsite subsurface soil and/or groundwater. The methods used to determine chemical concentrations for these exposure scenarios are further described below.

Potential volatile chemical (gas) concentrations within the onsite building were estimated by incorporating calculated soil-gas concentrations into equations that calculate the flux of the gas through a building foundation. Soil-gas concentrations were estimated for each area from subsurface soil and groundwater concentrations for volatile organic chemicals, using soil-water partition coefficients (K_{oc}) and Henry's Law constants. A summary of the maximum and average soil concentrations of all PAHs measured from Areas I, II and III are provided in Table 6.2. It is noted that the soil concentrations in Areas I and II are approximately 1000 times or more greater than the soil concentrations measured in Area III. This observation will be of importance when comparing the risks associated with each area. The measured concentrations from each sampling location used to calculate the averages are provided in Appendix G.

Soil-gas flux from soil pore space to air inside a building was calculated using Fick's first law of diffusion.

The receptor's average daily dose from inhaling vapours is estimated using the equation:

$$N_v = \frac{Q_v C_v F_v B_v}{\left(365\frac{d}{y}\right) BW} \qquad \text{(AERIS®, 1991)}$$

where N_v = daily dose from inhaled vapours (mg/kg-bw/d)
Q_v = quantity of air inhaled hourly (m^3/h)
C_v = concentration of chemical in air (mg/m^3)
F_v = hours in one year receptor is onsite (h/yr)
B_v = bioavailability of chemical in inhaled vapours (unitless)
BW = body weight of receptor (kg)

Exposure Assumptions Used to Quantify Risk

Scenarios involving exposure to site COPC are described below. Whenever possible, specific activity patterns and characteristics of each receptor group were used in the

Table 6.2: PAH Soil Concentrations

PAH's (ppm)	Area I (2.5–10.6 m)		Area II (1.0–7.0 m)		Area III (1.3–4.7 m)	
	Avg. Conc	Max. Conc	Avg. Conc	Max. Conc	Avg. Conc	Max. Conc
Acenaphthene	10.57	38.1	8.5	25.5	0.017	0.063
Acenaphthylene	278.07	1460	24.93	74.8	0.014	0.047
Anthracene	51.11	160	41	123	0.048	0.183
Benzo (a) anthracene	92.89	381	57.34	172	0.022	0.004
Benzo (a) pyrene	110.2	479	44.67	134	0.01	0.003
Benzo (b) fluoranthene	78.34	390	39.34	118	0.02	0.07
Benzo (k) fluoranthene	88.92	283	92.1	92.1	0.003	2.2
Benzo (ghi) perylene	56.76	257	21.5	64.5	0.005	0.013
Chrysene	76.53	292	43.67	131	0.018	0.065
Dibenzo (a,h) anthracene	11.24	53.4	5.9	17.7	0.002	0.002
Fluoranthene	189.84	762	128.34	385	0.14	0.532
Fluorene	47.1	170	55.33	166	0.19	0.735
Indeno (1,2,3–cd) pyrene	79.69	342	32.77	98.3	0.006	0.018
Naphthalene	444.03	1560	258	774	0.32	0.843
Phenanthrene	174.83	627	207.67	623	0.61	2.43
Pyrene	147.67	629	93.34	280	0.094	0.363

exposure assessment calculations. Otherwise, AERIS, CDTSC or U.S. EPA default values were used to characterize a receptor group.

An onsite worker may possibly be exposed to chemical constituents in air resulting from the transport of PAHs from subsurface soil through the foundation of a building. The rate of inhalation for a worker was assumed to be 1.0 m^3/hr (AERIS, 1991). For Area I it is assumed that the worker is in a building with a total volume of 21,600 m^3. The dimensions of the basement are approximately 69 x 57 x 3 m. The duration of exposure was described in the previous section entitled 'Current Onsite Receptors'.

Individual chemicals will volatilize at different rates. The air exchange rate for the office building was assumed to be 2 events/hr in the summer and 1 event/hr in the winter (AERIS, 1991).

Toxicity Assessment

The toxicity assessment is comprised of two general steps: hazard identification, the process of determining what adverse health effects, if any, can result from exposure to a particular chemical; and toxicity evaluation, which quantitatively examines the relationship between the level of exposure and the incidence of adverse health effects in the exposed population.

Hazard Identification

For the purpose of this risk assessment, human health effects are divided into two broad categories: cancer and noncancer effects. Although the chemicals have been divided into these categories, both types of effects are associated with some chemicals.

Carcinogenic Effects

The U.S. EPA has developed a carcinogen classification scheme (U.S. EPA, 1986a) using a weight-of-evidence approach to classify the likelihood of a chemical being a human carcinogen. Information considered in developing the classification includes studies on the association between human cancer incidence and exposure, and long-term animal studies under controlled laboratory conditions. Other supporting evidence considered includes short-term tests for genotoxicity, metabolic and pharmacokinetic properties, toxicological effects other than cancer, structure-activity relationships, and the physical/chemical properties of the chemical.

Seven of the COPC included in this risk assessment are classified as human carcinogens (Class A), or probable human carcinogens (Classes B1 and B2), by the U.S. EPA Carcinogen Assessment Group. These include seven PAHs [benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene]. These chemicals and their U.S. EPA classifications are presented in Table 6.3.

Noncancer Effects

Noncancer health effects include a variety of toxic effects on body systems such as renal toxicity (toxicity to the kidney) and central nervous system disorders. They fall into two basic categories: those that occur after acute exposure and those that occur after chronic exposure. Acute toxicity occurs after a short exposure, and the effects are typically observed within 1 to 7 days. Chronic toxicity can occur after short or longer (continuous or intermittent) exposures, with effects seen weeks, months, or years after the initial exposure.

Chemicals causing noncancerous effects, in contrast to carcinogens, are assumed to exhibit a toxicity threshold. That is, there is some level of exposure that can be tolerated by the organism without causing an observed health effect. The toxicity threshold is the point at which an organism's detoxification mechanisms are no longer wholly effective, allowing a toxic effect to be manifested. A chemical's toxic potential in humans is estimated following a review of toxic effects noted in short-term (acute) animal studies, long-term (chronic) animal studies, and epidemiological investigations.

Toxicity Profiles

Summary toxicity profiles for the COPC are presented in Appendix H. The profiles describe four categories of potential toxic effects: acute toxicity, chronic toxicity, carcinogenicity, and other effects.

Toxicity Values

Toxicity values take the form of reference doses (RfDs) or slope factors (SFs), which provide a quantitative expression of available dose-response relationship information for a chemical. Toxicity values were obtained from several sources for this risk assessment. The primary source was the U.S. EPA's Integrated Risk Information System (IRIS) database (U.S. EPA, 1992a). IRIS is the U.S. EPA's repository of agency-wide verified toxicity values. DTSC cancer potency factors were also used when available. Interim toxicity values as presented in the Health Effects Assessment Summary Tables (HEAST) (U.S. EPA, 1992b, 1992c) were used as a secondary source.

Reference Dose

The toxicity value used to evaluate the dose-response relationship for noncancerous effects is the RfD. The U.S. EPA RfD Work Group (U.S. EPA, 1988a) defines RfDs in the following manner:

Table 6.3
Carcinogenic Classification and Critical Toxicity Values for COPC

Chemicals	Oral Cancer Effects			Oral Noncancer Effects		Inhalation Cancer Effects			Inhalation Noncancer Effects	
	Slope Factor (mg/kg-day)-1	Weight of Evidence[a]	Source	Chronic Reference Dose (mg/kg-day)	Source	Slope Factor (mg/kg-day)-1	Weight of Evidence	Source	Chronic Reference Dose (mg/kg-day)-1	Source
Polynuclear Aromatic Hydrocarbons										
Acenaphthene	-	-	-	0.06	IRIS	-	-	-	-	-
Anthracene	-	D	IRIS	0.3	IRIS	-	D	IRIS	-	-
Benzo(a)anthracene	0.73^b	B2	CDTSC	0.00057	CDTSC	0.61^b	B2	IRIS	-	-
Benzo(a)pyrene	7.3^b	B2	IRIS	0.00057	CDTSC	6.1^b	B2	IRIS	-	-
Benzo(b)fluoranthene	0.73^b	B2	CDTSC	0.00057	CDTSC	0.61^b	B2	IRIS	-	-
Benzo(k)fluoranthene	0.073^b	B2	CDTSC	0.00057	CDTSC	0.061^b	B2	IRIS	-	-
Chrysene	0.0073^b	B2	CDTSC	0.00057	CDTSC	0.0061^b	B2	IRIS	-	-
Dibenzo(a,h)anthracene	7.3^b	B2	CDTSC	0.00057	CDTSC	6.1^b	B2	IRIS	-	-
Fluoranthene	-	D	IRIS	0.04	IRIS	-	D	IRIS	-	-
Fluorene	-	D	IRIS	0.04	HEAST	-	D	IRIS	-	-
Indeno(1,2,3-cd)pyrene	0.73^b	B2	CDTSC	0.00057	CDTSC	0.61^b	B2	-	-	-
Naphthalene	-	D	IRIS	0.004	HEAST	-	D	IRIS	-	-
Pyrene	-	D	IRIS	0.03	IRIS	-	D	IRIS	-	-

[a] Weight of Evidence Classifications:

[b] This value represents the EPA slope factor.

A Human carcinogen
B1 Probable human carcinogen; limited human data are available.
B2 Probable human carcinogen; sufficient evidence in animals but inadequate evidence in humans.
D Not classifiable as to human carcinogenicity.

Notes:
IRIS = Integrated Risk Information Systems, U.S. EPA 1992a. Accessed August 1992.
CDTSC = CA Department of Toxic Substances Control, 1991.
HEAST = Health Effects Assessment Summary Tables, U.S. EPA, 1992b, 1992c.

> In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfD is generally expressed in units of milligram per kilogram of body weight per day (mg/kg-day).

RFDs used in this assessment are summarized in Table 6.3. A RfD of 0.00057 mg/kg-day was used to evaluate the noncarcinogenic health effects for those PAHs not having IRIS values. This value was developed by CA Department of Toxic Substances Control and is based on 20 μg/l PAHs in water and 2 $\mu g/m^3$ PAHs in air. This is an acceptable action level which corresponds to a 10^{-6} human health risk or a hazard index of 1, when converted to an intake rate (assuming residential exposure factors) is 0.00057 mg/kg-day for the inhalation pathway.

Slope Factor

The slope factor is defined as the upper 95th percent confidence limit on the slope of the dose-response curve, fitted to a given model (e.g., linear multi-stage model). Slope factors are presented in units of the inverse of milligrams of chemical per kilogram of body weight per day $(mg/kg\text{-}day)^{-1}$. The slope factors used in this assessment are summarized in Table 6.3.

The data used for estimating the dose-response relationship and therefore the slope factor for carcinogens are taken from lifetime animal studies or human occupational or epidemiologic studies. Risk at low exposure levels is difficult to determine directly, either by animal experiments or by epidemiologic studies (U.S. EPA, 1984). Therefore, it is assumed that if a carcinogenic response occurs at the dose levels used in the study, then a response will occur at all lower doses. Slope factors are then based on the assumptions that any degree of exposure leads to some degree of risk, and cancer risk is, therefore, probabilistic. The approach used by the U.S. EPA to estimate the carcinogenic slope factor from animal studies or human data assumes a dose-response relationship with no threshold. There is conservatism built into the U.S. EPA's approach through the use of uncertainty factors; the greater the uncertainty in the results of the toxicology studies or the risk extrapolation process (e.g., estimating the response in man based on the response in animals), the greater the uncertainty factor and therefore the more conservative the slope factor.

Cancer risks from PAHs were estimated using HEAST of EPA-ECAO slope factors.

Whenever possible, inhalation-specific slope factors and reference doses were used in estimating human health risks. All of the carcinogenic PAHs have inhalation-specific reference doses but none of the non-carcinogenic PAHs have inhalation-specific reference doses. Therefore, oral reference doses were used as inhalation reference doses.

Human Health Risk Characterization

In this section, exposure scenarios retained for quantitation are evaluated for carcinogenic and noncarcinogenic risks. Estimated excess lifetime cancer risk and hazard indices are presented, and summarized by pathway. Qualitatively addressed pathways are also discussed.

Risk Estimation

This section summarizes the approach used in developing the human health risk estimates.

Carcinogenic Effects

The potential for carcinogenic effects was evaluated by estimating the excess lifetime cancer risk for each exposure scenario. Excess lifetime cancer risk is the incremental increase in the probability of developing cancer during one's lifetime over the background probability of developing cancer (i.e. if no exposure to site COPC occurred). For example, a 1×10^{-6} excess lifetime cancer risk means that for every 1 million people exposed to the carcinogenic COPC throughout their lifetimes (which is typically assumed to be 70 years), the average incidence of cancer is estimated to increase by one extra case of cancer over the background rate. Because of the methods followed by the California DTSC and the U.S. EPA in estimating cancer slope factors, the excess lifetime cancer risks estimated in the assessment should be regarded as upper bounds on the potential cancer risks rather than accurate representations of true cancer risks. The actual risk may be significantly lower.

Although synergistic or antagonistic interactions might occur, there is insufficient information in the toxicological literature to predict the effects of such interactions. Therefore, consistent with U.S. EPA guidelines on chemical mixtures (U.S. EPA, 1986d), carcinogenic risks were treated as additive in the assessment within a route of exposure and between exposure routes.

The Excess Lifetime Cancer Risk for each exposure pathway is calculated using the equation:

$$ELCR_{ij} = CDI_{ij} \times CSF_{ij}$$

where $ELCR_{ij}$ = a unitless probability of an individual developing cancer as a result of exposure pathway from chemical i

CDI_{ij} = chronic daily intake averaged over 70 years (mg/kg - day) for chemical i with exposure pathway j;

CSF_{ij} = cancer slope factor $(\text{mg/kg - day})^{-1}$

The Total Exposure Excess Lifetime Cancer Risk (TEELCR) was calculated by adding the risk for each exposure pathway;

If the total exposure excess lifetime cancer risk is greater than 1×10^{-6} (U.S.EPA), then risk management should be considered.

Noncarcinogenic Effects

To assess the potential for noncarcinogenic effects posed by the COPC, the "hazard index" approach was used. The hazard index is the sum of the hazard quotients, the ratios of the daily intakes of individual chemicals to their reference doses. If the estimated daily intake for any single chemical is greater than its reference dose, the hazard quotient will exceed one. When a hazard quotient exceeds unity, it indicates a potential transition from acceptable to unacceptable exposure levels and suggests that there might be a potential health effect (U.S. EPA, 1989a).

The hazard index, the sum of the hazard quotients, for a mixture of chemicals can exceed one even if the intake of no single chemical exceeds its reference dose. In this situation, the chemicals in the mixture may be segregated by similar effects (e.g., target organs) to further evaluate the potential health risks.

Non-carcinogenic hazard quotients are calculated for each contaminant of concern for each exposure pathway using the equation:

$$HQ_{ij} = \frac{CDI_{ij}}{RfD_{ij}}$$

where CDI_{ij} = chronic daily intake for exposure pathway j for chemical i;
RfD_{ij} = reference dose for exposure pathway for chemical ij for chemical i
HQ_{ij} = non-carcinogenic hazard quotient for chemical i at exposure pathway j

Since risks are considered additive (US.EPA) a hazard index is calculated for each exposure pathway j for all contaminants using the equation:

$$HI_j = \Sigma \frac{CDI_{ij}}{RfD_{ij}} = \Sigma\, HQ_{ij}$$

where HI_j = hazard index for exposure pathway j

A total exposure hazard index is then calculated by adding all exposure pathway hazard indexes using the equation:

$$HI = \Sigma HI_j$$

where HI = total exposure hazard index for site

If the total exposure hazard index for the site is greater than 1, then risk management should be considered. For this study only one exposure pathways is of interest.

Estimating Risks-Quantitative Assessment

Area I

A summary of the calculated noncancer and cancer risk results for the adult worker scenario for Area I are provided in Tables 6.4-and 6.5. The AERIS model computer data is provided in Appendix I.

In this initial baseline assessment, Area I was selected for evaluation since it had the highest concentrations of soil and groundwater contamination. Based on these results, some conclusions can be made regarding the risks associated with Areas II and III.

Vapour inhalation exposure pathway risks (noncancerous and cancerous) were calculated for each COPC present in surface soil, subsurface soil or groundwater. Risks for individual chemicals were then added to estimate the multichemical risk (carcinogenic) or hazard index for this exposure pathway. The following discussion summarizes the individual and multichemical calculated risks for this exposure pathway.

The hazard index for the adult worker scenario is 0.3 based on an exposure calculated using the average soil concentration for each COPC from Area I and U.S. EPA and California DTSC reference doses (refer to Table 6.4). Using the maximum soil concentration measure in Area I, the HI was 1.0. The hazard indices for both soil concentrations are at or below the hazard index level of 1 and are within accepted levels.

Naphthalene had the most significant contribution to the HI results. The hazard quotient for naphthalene is approximately 98 percent of the hazard index.

The excess lifetime cancer risk for the adult worker scenario is 1.6×10^{-8} based on average soil concentrations and 7.2×10^{-8} based on maximum soil concentrations and using USEPA and U.S. EPA cancer slope factors (refer to Table 6.5). The estimated risks are well below the accepted risk value of 1×10^{-6} and was primarily due to benzo (b) fluoranthene.

Areas II and III

From Area I's assessment, we can conclude that the calculated risks for the adult worker scenario for this area as well as Areas II and III (since PAH soil concentrations in these areas are typically below Area I concentrations) are within guideline accepted values (i.e. a Hazard Index of I and a risk value of less than 1×10^{-6}). In particular, the average and maximum concentrations of naphthalene in Area I are approximately twice that of Area II and more than a thousand times greater than Area III. Therefore, further modelling of Areas II and III for the adult worker scenario is not warranted.

Table 6.4: Area I – Noncancer Risk Results for Adult Worker Scenario

PAH's (ppm)	Area I Adult CDI		RfD	Area I HQ = CDI/RfD	
	Avg. Conc	Max. Conc		Avg. Conc	Max. Conc
Acenaphthene	1.4E−06	5.0E−06	0.06	0.000023	0.000084
Anthracene	0.000043	0.000135	0.3	0.000144	0.000451
Benzo (a) anthracene	5.8E−10	2.4E−09	0.00057	1.0E−06	4.2E−06
Benzo (a) pyrene	8.7E−10	3.8E−09	1.6E−07	0.005468	0.023763
Benzo (b) fluoranthene	1.3E−08	6.3E−08	0.00057	0.000022	0.00011
Benzo (k) fluoranthene	4.7E−08	1.5E−07	0.00057	0.000083	0.000265
Chrysene	3.0E−09	1.1E−08	0.00057	5.3E−06	0.00002
Dibenzo (a,h) anthracene	1.4E−12	6.6E−12	0.00057	2.4E−09	1.2E−08
Fluoranthene	1.9E−07	7.7E−07	0.04	4.8E−06	0.000019
Fluorene	0.000057	0.000207	0.04	0.001435	0.005178
Indeno (1,2,3−cd) pyrene	1.9E−11	8.3E−11	0.00057	3.4E−08	1.5E−07
Naphthalene	0.001144	0.004019	0.004	0.286	1.00475
Pyrene	1.6E−07	6.7E−07	0.03	5.3E−06	0.000022
Hazard Index = Summation of HQ				0.293191	1.034666

Table 6.5: Area I – Cancer Risk Results for Adult Worker Scenario

PAH's (ppm)	Area I Adult CDI		SF	Area I RISK=CDI*SF	
	Avg. Conc	Max. Conc		Avg. Conc	Max. Conc
Benzo (a) anthracene	5.8E−10	2.4E−09	0.61	3.5E−10	1.5E−09
Benzo (a) pyrene	8.7E−10	3.8E−09	6.1	5.3E−09	2.3E−08
Benzo (b) fluoranthene	1.3E−08	6.3E−08	0.61	7.7E−09	3.8E−08
Benzo (k) fluoranthene	4.7E−08	1.5E−07	0.061	2.9E−09	9.2E−09
Chrysene	3.0E−09	1.1E−08	0.0061	1.8E−11	7.0E−11
Dibenzo (a,h) anthracene	1.4E−12	6.6E−12	6.1	8.5E−12	4.0E−11
Indeno (1,2,3−cd) pyrene	1.9E−11	8.3E−11	0.61	1.2E−11	5.0E−11
Total Excess Lifetime Cancer Risk				1.6E−08	7.2E−08

Comparison of Modelled and Measured Air Exposure Concentrations to Ambient Air Quality Criteria and Time Weighted Averages

Naphthalene has been identified as the primary chemical of interest based on the modelled risk assessment. Using the assessment results, we can calculate the concentration of chemical in air (mg/m^3) in the basement of buildings. Naphthalene concentrations were estimated to be 0.01 x 10^{-3} mg/m^3 and 0.04 x 10^{-3} mg/m^3 based on average and maximum soil concentrations, respectively.

The modelled exposure concentrations are well below the time weighted average exposure value for naphthalene of 52 mg/m^3 for the adult worker scenario. The ambient air quality criteria in Ontario for naphthalene is 22.5 μg/m^3 (0.0225 mg/m^3) based on a 24-hour period. For the adult worker scenario assessed, the estimated concentrations are below the ambient air quality criteria.

From Phase I, measured air concentrations in the Centra Gas building showed naphthalene to be below the average detection limit of 5.3 x 10^{-6} mg/m^3. This value is well below the modelled exposure concentations, the time weighted average exposure concentrations and ambient air quality criteria for the adult worker scenario.

Uncertainties

Uncertainties in this risk assessment include uncertainties in the risk assessment process in general (i.e. the toxicological database), specific uncertainties in characterizing the site, and uncertainties associated with describing exposure.

Specifically, the risk assessment is subject to uncertainty from a variety of sources, including:

- Sampling and analysis
- Exposure estimation
- Toxicological data

Uncertainty associated with sampling and analysis includes the inherent variability (standard error) in the analysis, representativeness of the samples, sampling errors, and heterogeneity of the sample matrix. Although the QA/QC program used serves to reduce these uncertainties, it cannot eliminate all errors associated with sampling and analysis. In this assessment, samples were collected in a manner considered to have the greatest likelihood of being affected by past site uses. This sampling method can lead to an over-estimate of risk.

Risk results for Area III will be much lower than Areas I and II. Therefore, these risk results overestimate the risks for the entire site (i.e. Areas I, II and III together).

Sample analysis was limited to chemicals typically found at coal gasification plants sites and associated with the underground petroleum storage tanks. BTEX were the only VOCs measured in the soil, therefore, risks due to other VOCs could not be estimated. Exposure point concentrations were assumed to remain constant with time.

Exposure estimations were based on human activity patterns reported in the AERIS manual (AERIS, 1991), on knowledge of Centra Gas personnel, and on professional judgment. These values may over- or underestimate actual exposure periods.

The toxicological database was also a source of uncertainty. They include extrapolation from high to low doses and from animals to humans; species differences in uptake, metabolism, and organ distribution; species differences in target-site susceptibility; and human population variability with respect to diet, environment, activity patterns, and cultural factors.

Several chemicals were not assessed in quantitatively analyzed pathways because appropriate toxicity values were not available. Elevated levels of acenaphthylene, benzo (ghi) perylene and phenanthrene were detected in the subsurface soil. Because toxicity values were not found in the U.S. EPA toxicology databases for these three constituents and they do not exhibit human carcinogenicity, the health risks attributable to these chemicals were not assessed.

Finally, inhalation toxicity values were not available for any of the COPC; therefore, oral toxicity values were used. Use of these oral values may result in an over or underestimation of risk.

Summary

The purpose of this human health risk assessment was to identify potential sources of risk at the Centra Gas site to assist in making appropriate recommendations for remediation, as needed. This summary presents the estimated risks and attempts to provide a context within which these risks can be used.

The Centra Gas site was a former coal gasification plant. Consequently, samples from the site were analyzed for primarily PAHs and other chemicals typically found in coal gasification residues (e.g. BTEX) as well as several inorganic chemicals. Based on detection frequency, current or historical site activities, concentration exceedances of reference criteria and/or known chemical toxicity and mobility, certain PAHs were selected for the risk assessment.

Within the exposure assessment, plausible pathways were identified; those pathways with very limited likelihood were not retained. Based on this assessment, the only receptors and exposure pathway were current and future onsite workers potentially exposed through basement foundations via vapour inhalation. While the baseline human health risk assessment focused solely on onsite workers, an offsite risk assessment was not carried out for three main rasons:

- The results of offsite sewer sampling were negative
- The onsite risk assessment suggested risks were within acceptable levels
- There is a lack of data on factors required to determine offsite risks

Exposure assumptions were selected to be protective of human health, addressing the majority of the population being characterized. When possible, information that characterized the site was used. When site-specific information was not available, default values from AERIS and the U.S. EPA were used.

Toxicity information for the chemicals of potential concern was taken from IRIS, HEAST and ECAO databases and the California DTSC available data.

Risks were estimated using the exposure assumptions and toxicity values previously described. For Area I, the estimated excess lifetime cancer risks from vapour inhalation for the adult worker was between 1.6×10^{-8} and 7.2×10^{-8}, 14 to 63 times less than the accepted threshold of 1×10^{-6}. Based on measured soil concentrations from Areas II and III it was concluded that the adult worker scenario would result in even lower risk than in Area I for these areas.

The hazard indices for the adult worker scenario were calculated to be at (based on maximum soil concentrations) or below (based on average soil concentration) 1 for Area I at values of 1.0 and 0.3, respectively. Based on the lower measured soil concentrations in Areas II and III, these areas would have an even lower hazard index than Area I.

The Phase I measured naphthalene air concentrations in the Centra Gas building are well below the modelled concentrations, the time weighted average and ambient air quality criteria for the adult worker scenarios.

Because of uncertainties associated with risk calculation values, conservative assumptions were used. As a result, the estimated carcinogenic and noncarcinogenic risks presented here are expected to be higher than the actual risks.

Section 7
Conclusions

The conclusions reached in completing Phase II of the EHSA are as follows:

- Residues were found to extend offsite to the north across Rover Avenue in both soil and groundwater at concentrations exceeding the level above which the Canadian Council of Ministers of the Environment (CCME) recommend action is required to mitigate adverse impacts.

- Repeat sampling of monitoring wells installed in Phase I confirmed earlier groundwater quality results.

- Groundwater flow was confirmed to be to the north towards the Red River, at an estimated lateral groundwater flow rate of 0.5 to 2.8 m/day. This results in an estimated flux to the river of 2.5×10^{-4} m^3/sec (15 L/min) which is a factor of approximately 100,000 lower than the flow in the Red River (100 m^3/sec to 800 m^3/sec).

- Residues are believed to be contained at depth by a clayey till deposit of low permeability soil encountered at approximately 15 m below grade, although the reported presence of fissures at shallow depths in the Winnipeg area may reduce the amount of containment provided.

- No impacts from gas plant residues were detected in the sewers around the Sutherland Avenue facility based on analysis of sewer water and gas.

- Visual, olfactory and chemical characterization of sediments in the Red River identified:

    - An area of approximately 9000 square metres containing residues that are predicted to cause an adverse impact on aquatic life, based on comparison to draft Environment Canada Probable Effect Level (PEL) guidelines

    - An area of approximately 1250 square metres (which overlaps the zone described above) and characterized by higher residue concentrations and other visual evidence of tarry materials or strong naphthalene odours

    - The most significant concentrations of residues are restricted to the upper 0.8 to 1.5 m of sediment

- Residues found in soil were:
    - found to extend offsite to the north toward the Red River
    - exist at their highest concentration between 6 and 8 metres deep
    - more prolific in the northwest portion of the site (onsite and offsite)
    - at low to negligible levels below 11 metres in depth
    - highest at a depth which corresponds to the river bottom, and
    - likely the source of residues in the river sediments

- Although degraded groundwater is likely flowing to the Red River, analysis of water samples from the Red River found no evidence of residuals in the water, indicating that residues are adsorbed to the river sediments or diluted, and are unlikely to affect aquatic life through consumption of water alone.

- A preliminary biological testing program found that only sediments containing higher levels of residues and exhibiting visual evidence of tarry residues or strong naphthalene odours (1250 m^2):
    - were chronically toxic, based on mortality, to 3 aquatic species tested under "worst case" laboratory conditions
    - resulted in tissue concentrations above background levels in fathead minnows used for "worst case" laboratory chronic toxicity

- The remaining sediments not included above but above background and the probable effect level (PEL) did not exhibit chronic toxicity or tissue concentrations significantly different from background.

- Biological and chemical testing suggests that low levels of residues may be present upstream of the former manufactured gas plant due to other sources.

- A preliminary benthic survey suggests low numbers and diversity of species, both adjacent to and upstream of the former gas plant site.

- The area of sediment quality above background but with no evidence of strong odours and\or visual tar (estimated 9000 m^2) was typical of sites where thorough biological assessments were conducted to determine if significant adverse impacts had occurred and whether remediation was warranted.

- The chemicals of potential concern considered for the baseline human health risk assessment were based on:
    - detection frequency in soil and groundwater
    - current or historical site activities
    - concentration exceedances of reference criteria and/or

  - known chemical toxicity and mobility for specific PAHs

- The receptors and exposure pathway required for the risk assessment were current and future onsite workers potentially exposed via the vapour inhalation route in building basements that may receive PAH vapours. While the baseline human health risk assessment focused solely on onsite workers, an offsite risk assessment was not carried out for three main reasons:

  - The results of offsite sewer sampling were negative
  - The onsite risk assessment suggested risks were within acceptable levels, and
  - There is a lack of data on factors required to determine offsite risks

- Inhalation risks were estimated for PAH vapours entering the onsite operations building in Area I. Risk was well below the accepted criteria (i.e. 1×10^{-6} for carcinogens or a hazard index of 1 for non-carcinogens). Based on these results, no human health risks exist from inhalation of gaseous PAHs by workers in current or future buildings, supporting previous air sampling results from Phase I.

- The estimated risk in Areas II and III was well below the accepted criteria for both carcinogens and non-carcinogens in the worker exposure scenario.

- The results of Phases I and II should be discussed with the appropriate regulatory agencies to determine what further actions, if any, may be warranted.

Section 8

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