C.0463

Centra Gas

Centra Gas Manitoba Inc.
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October 21, 1996

Manitoba Department of Environment
Building 2, 139 Tuxedo Avenue,
Winnipeg, Manitoba
R3N 0H6

Attention: Mr. Edwin Yee, Manager, Contaminated Sites Dangerous Goods Section

Subject: Sutherland Avenue Manufactured Gas Plant Site Proposed Remedial Action Plan

Dear Mr. Yee:

As a follow up to our September 5th meeting and Manitoba Environment's interest in addressing the groundwater - river sediment interface issue, please find attached an evaluation of remedial options which have been considered in addressing this issue, (Attachment A).

For the various reasons outlined in Agra Earth and Environmental's assessment of options, Centra Gas Manitoba is prepared to accept and implement the bioremediation project as outlined in Attachments A and B. Our intention would be to begin setting up for a pilot test later this year and evaluate results in 1997 which, if successful, would lead to full scale implementation in the north half of the Sutherland property sometime in late 1997 or early 1998.

Centra Gas wishes to determine if this option addresses the concern Manitoba Environment has with respect to the groundwater - river sediment interface and whether this remedial option if successful, would lead to delisting the site from the province's Contaminated Sites Registry when fully implemented in the north half of the Sutherland property.

I apologize for the delay in providing you with our review and recommendation.

Yours sincerely;

Andrew Galarnyk
Manager Facilities, Risk and Environmental Affairs

RECEIVED
OCT 23 1996
DANGEROUS GOODS

D. Brett
M. Kast
H. Pankratz

I\era\remact.let.
21/10/96

ATTACHMENT A

C.0163

AGRA
Earth & Environmental

AGRA Earth &
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October 15, 1996
Project No. WX-04010

Centra Gas Manitoba Inc.
444 St. Mary Avenue
Winnipeg, Manitoba
R3C 3T2

Attention: Mr. Andy Galarnyk

Dear Sir:

**RE: GROUNDWATER REMEDIATION
SUTHERLAND AVENUE OPERATIONS BUILDING
WINNIPEG, MANITOBA**

1.0 INTRODUCTION

Further to your request, AGRA Earth & Environmental Limited (AEE) is pleased to provide information on the viability of initiating containment and remediation of the shallow groundwater beneath the site prior to natural discharge to the Red River. Over the past one or two decades, technologies for the treatment of contaminated groundwater at industrial sites have involved the removal of the contaminated groundwater combined with above ground treatment either by physical, chemical or biological treatment processes. More recently, various in situ remediation techniques have been developed that promise to be more cost effective in the remediation of contaminated groundwater. Furthermore, these techniques have the added advantage of limiting or even excluding the transfer of the contaminants from one media to another (e.g. from the groundwater regime to the atmosphere) and the transfer of the contaminants from one location to another (e.g. from the impacted site to a treatment site.).

ML bed? (No)

It is AEE's understanding that Centra Gas is aware of other options for managing the environmental risk that may be associated with the site. The purpose of this letter is to investigate the feasibility and to provide a first order capital cost estimate for the remediation of the contaminated groundwater beneath the site prior to natural discharge from the site into the Red River. As part of your request, the hydrogeological characterization of the site, as presented in CH2M HILL ENGINEERING LTD.'s Phase II Detailed Site Characterization report, was also reviewed.

2.0 BACKGROUND

CH2M HILL ENGINEERING LTD. was commissioned by Centra Gas Manitoba Inc. to complete an Environmental, Health and Safety Assessment of the Sutherland Avenue Operations Facility. Phase I, issued in draft form in April 1994, presented the preliminary site characteristics. Phase II, issued in draft form in January 1995, presented detailed site characteristics.

It is beyond the scope of this letter to present a detailed summary of the findings of the two reports. Briefly, however, residual concentrations of polycyclic aromatic hydrocarbons (PAH's) and BTEX components were detected in the subgrade soils and river bottom sediments located adjacent to the site. The same constituents were dissolved in the shallow groundwater beneath the site.

As part of Phase II, a human health risk assessment was conducted with the receptors being the Centra Gas Sutherland Avenue workforce. The risk assessment indicated that the workforce was exposed to less than a one in a million additional life time cancer risk. Laboratory-based biological testing, indicative of "worst case" conditions, indicated that the most highly contaminated river bottom sediments were toxic to several species of aquatic life (flathead minnows, mayfly nymphs and chironomids). However, due to the large flow rate in the river there was no evidence of dissolved concentrations of PAH and BTEX constituents in river water sampled adjacent to the site.

eff ... dilution prior to receptor

I dont feel that the entire saturated zone soils beneath the entire site can be considered as representative of uniform flow (as in figs in report)

3.0 HYDROGEOLOGICAL DATA REVIEW

3.1 Introduction

CH2M HILL ENGINEERING LTD. presented results for hydraulic conductivities in their draft Phase II ESA. The hydraulic conductivity values ranged over 5 orders of magnitude across the site from 1.6 X 10^{-3} m/s at the north end of the site (MW24B) to 6.7 X 10^{-8} m/s at the south end of the site (MW21). The geometric mean of the measured hydraulic conductivities in the north area of the site was reported to be 7.2 X 10^{-5} m/s. A mean value for hydraulic conductivity was not presented for the south end of the site. AEE was not able to verify the hydraulic conductivity values as the field data was not available for review.

CH2M HILL also presented estimates of the horizontal hydraulic gradient for the shallow water table; the groundwater flux; and, the groundwater velocity. In recalculating these values, AEE used the geometric mean of the hydraulic conductivity for the north end of the site (i.e. 7.2 X 10^{-5} m/s).

10^{-5} m/sec
10^{-3} cm/sec
generally 10^{-4} cm/sec is OK for effective RAP using groundwater dil[ution]/extraction & in-situ Bio-

The hydrogeological charac. of the south end clayey silts and silty clays should be ignored and this sediment body considered a point source. Thus, the formation of concern for g.w. migration is the north end sandy deposits which are in contact with the "source area". ∴ K of 10^{-5} m/s (10^{-3} cm/s) applies. worse-case of K = 10^{-3} m/s (10^{-1} cm/s)

Assume 0.02 m/m for Nord granular Zone (from MW-03 to MW-22)

3.2 Hydraulic Gradient

CH2M HILL reported an average hydraulic gradient (i) of 0.016 m/m from the Operations Building north to the Red River. AEE obtained a value of 0.009 for the zone between MW03 (north side of the Operations Building) and MW23B (Rover Avenue). A similar gradient was calculated for the zone between MW20 (Vehicle Service Building) and MW03.

3.3 Groundwater Flux

The groundwater flux (Q) across the north end of the site into the Red River may be calculated using Darcy's Law. CH2M HILL reported a calculated flux of 2.5×10^{-4} m^3/s (15 L/min.) using a hydraulic gradient value of 0.016. AEE's calculation of the groundwater flux, using a hydraulic gradient value of 0.009, was determined to be 4.7×10^{-4} m^3/s (28 L/min.). For most practical purposes, the two values are in agreement.

3.4 Groundwater Seepage Velocity

CH2M HILL calculated the groundwater velocity directed toward the Red River. It is not clear from the report if this represented the specific discharge (also known as the discharge velocity or the Darcian velocity) which is calculated from Darcy's Law or if it represents the average linear velocity (also known as the seepage velocity). The average linear velocity (V_x) is calculated by including a term for the effective porosity in the Darcy equation. The specific discharge is an apparent velocity whereas the average linear velocity is the rate at which the water actually moves through the porous media.

CH2M HILL reported a groundwater velocity [high] at the north end of the site ranging from 0.5 to 2.8 m/day (or from 180 to 1020 m/year). At the south end of the site, their reported value ranged from 0.03 to 0.68 m/year. It may be assumed that the range of reported velocities was related to the 5 orders of magnitude variation in hydraulic conductivity values calculated for the site.

AEE calculated a value for the average linear velocity, V_x, using Darcy's Law and a value for the effective porosity. The effective porosity is always somewhat lower than the porosity, which CH2M HILL reported as being 0.3. AEE assumed an effective porosity value of 0.2 after consulting literature values for similar materials. This resulted in an average linear velocity value of 0.25 m/day or 91 m/year.

Side of caution would use the > V_L of 2.8 m/day. Seems high for non-uniform geologic conditions present.

3.5 Water Balance Estimate

CH2M HILL did not provide a water balance estimate for the site. A water balance accounts for both inflow volumes (e.g. infiltration of precipitation) and outflows (e.g. primarily discharge into the Red River). AEE performed a rough estimate of the inflows to the local groundwater system and compared the estimate to the calculated groundwater flux (28 L/min.).

Assume $K = 7 \times 10^{-5}$ m/s
$i = 0.02$ m/m
$n = 0.3$

$V_L = Ki/n$
$V_L = (7 \times 10^{-5})(0.02)/.3$
$= 5 \times 10^{-6} \approx 150$ m/yr

mean of CH2M 180 m/yr
AGRA 91 m/yr
= 135 ≈ 150 m/yr

The site is located on the north side of a peninsula of land (Point Douglas) which is surrounded on three sides by the Red River. In the vicinity of the site the width of the peninsula is about 800 m. It was assumed that the site forms part of a 400 m long by 90 m wide strip of land that discharges groundwater into the Red River at the north end of the site. Much of the water that enters this rectangular strip of land is contributed from either rain water or melted snow. The contribution of the latter is believed to be small due to frozen ground conditions and due to snow clearing operations at the site. The strip of land also probably receives subsurface flows from contiguous areas to the west.

The total mean precipitation for Winnipeg is approximately 535 mm, of which 404 mm is in the form of rain. Most of the site is either covered with pavement or occupied by buildings. Paved areas typically result in between 70% to 95% of the rainfall running off of the site into land drainage catch basins. For a paved site in Winnipeg this would result in between 20 mm to 121 mm of rain water infiltration every year. This compares favourably with a back calculated recharge rate of 87 mm per year if the calculated discharge rate of 28 L/min. is distributed over the 400 m by 90 m strip of land surface described above.

The purpose of completing an estimate of the water balance was to determine the validity of the groundwater flux calculation. The groundwater flux estimation, as determined from application of Darcy's Law, falls within the range of values that would be expected from the water balance calculation.

4.0 TREATMENT TECHNOLOGIES

4.1 Introduction

It is beyond the scope of this letter to present a detailed discussion of the available treatment technologies that have been applied to remediate the groundwater beneath former coal gas and other industrial sites. However, a general indication of several of these options will be discussed in this section. The three techniques that will be discussed include: source removal/containment; pump and treat systems; and, in situ bioremediation techniques. The strengths and weaknesses of each as applied to the site will be presented along with some relative cost projections. The volume of groundwater to be treated would be on the order of 30 L/min. Could you get this ~~for~~ pump & treat?

Prior to implementation of a suitable remedial technology, approval from Manitoba Environment (ME) would be required. Normally the procedure is to submit a remedial action plan to ME for consideration.

4.2 Source Removal/Containment

Where substantial concentrations of residual hydrocarbons can be identified in a particular area, a commonly applied remedial strategy is to remove these "hot spots" from the subsurface, or, alternatively, to isolate them in situ so as to limit further spread of the contaminants. The contamination may exist as either free (liquid) product or as elevated residual contamination in the soil mass at or below the saturation concentration. All liquids or soils removed from the subsurface may be treated either on-site or off site prior to final disposal.

It is AEE's understanding from a review of the site assessment studies that accumulations of free phase liquid contaminants have not been identified in the subsurface at the Sutherland Avenue site. In addition, the residual soil contamination appears to be widely distributed throughout the subsurface at relatively low to moderate concentrations. These observations combined with the developed and active nature of the site may limit the application of source removal or containment as remedial strategies.

Containment, using low permeability slurry walls, grout curtains, high-density polyethylene (HDPE) membranes or sealable joint sheet piles, has been used to restrict advective transport of solutes from a discrete and clearly definable contaminant source area. In some cases the barrier method has been used to direct the contaminated groundwater through a subsurface treatment zone(s) where biotic and/or abiotic processes operate to reduce dissolved contaminant concentrations.

At the Sutherland Avenue site, restriction of the horizontal flow paths may result in unacceptable consequences. The subsurface hydraulic regime will be forced to adjust to the installation of a low permeability barrier, with the possible consequence that the water table may rise above the base of buried structures such as sewer lines, weeping tiles and the newly installed elevator shaft. The CH2M HILL reports indicate that there is little evidence that the PAH components, which are more dense than water, have penetrated the unweathered lacustrine clay located at depth beneath the site. Uncertainties presently exist as to the potential for impact on the movement of the contaminants if a vertical barrier were to be installed. Although the bedrock aquifer is not currently used as a source of potable water it is used for other economic purposes (e.g. cooling and processing water). Finally, all low permeability barriers are subject to the movement of contaminants across the barrier under the influence of diffusive fluxes. Diffusion acts independently of advective flow, therefore, the permeability of the barrier will not impact on the rate of mass flux across the barrier under a concentration gradient.

Not necessarily at 28L/min (assume 400x90 strip) combined with downgradient "dewatering" treatment via -trench -wells -drains

S.O.S toe drainage collection in a landfill.

4.3 Pump and Treat

Since the 1970's almost all groundwater remediation at contaminated sites in North America has been based on groundwater extraction from wells or drains, usually accompanied by treatment of the extracted water prior to disposal either on site (injection wells) or off site (eg.

to the sanitary sewer). Extraction often results in an initial decrease in contaminant concentrations in the extracted water, followed by a levelling off of dissolved concentrations and, sometimes a gradual decline that is expected to continue over decades. In such cases, the goal of reaching health and/or ecologically based remediation standards is often remote and the ultimate cost of cleanup very high due to the ongoing operational and maintenance costs.

Extraction schemes can be reasonably efficient at removing organic contaminants from the more permeable zones (e.g. sands and gravel) in the subsurface. However, the less permeable silt and clay rich zones, located both within and adjacent to the granular materials described above, contain substantial quantities of absorbed contaminants. Due to the fine grained nature of these deposits it is not possible to flush the contaminants from the silts and clays as is possible with granular deposits. However, when the extraction systems are shut down contaminants will continue to be released from the fine grained sediments. The released constituents will build up in the dissolved phase within the granular deposits often to the point of exceeding various remedial standards. The North American experience has been that at very few sites has the groundwater been remediated successfully using pump and treat technology despite the expenditure of large sums of money.

At the Sutherland site, groundwater control would require the installation of two or three extraction wells at the north end of the site. The actual number required would depend on the well performance and available drawdown. It is anticipated that the extracted water could not meet the discharge criteria for the City sewer bylaw without undergoing on-site treatment prior to disposal. It may be possible to inject the water upgradient and on-site with minimal treatment such as the use of air sparging tanks. Groundwater modelling would be advised to select optimum locations for extraction and injection wells (or infiltration trenches).

better yet a collection trench

up gradient but still in north end granular deposit zone.

The ex situ treatment technologies most applicable to dissolved PAH and BTEX concentrations in groundwater include the use of air sparging tanks, air stripping (packed) towers and granular activated carbon (GAC) barrels. The application of all three technologies may be required to meet the City sewer bylaw. Due to the range of contaminants dissolved in the groundwater, the design of the most appropriate treatment technology may require the completion of a treatability study. Bench scale treatability tests are often done at no charge by the equipment supplier. In some cases a pilot test may be required to optimise equipment selection and chemical requirements. Pilot tests are also used to identify potential operating problems, such as scale buildup, sludge bulking and post-precipitates so that corrective action can be taken before initiation of full scale operations.

OR off site trucking!

4.4 In situ Bioremediation

In response to the high costs and operational problems associated with the traditional pump and treat systems, various in situ (subsurface) bioremediation schemes have been implemented in recent years. Some of these systems are "passive" in that groundwater extraction is not required; in other systems extraction may form part of the strategy.

Intrinsic (natural) bioremediation has been detected at many sites. The microorganisms naturally present in the soil are frequently capable of degrading organic contaminants. Unfortunately, absolute evidence of intrinsic bioremediation is often difficult to obtain due to the varied metabolic processes that may be responsible and the relatively low rates of remediation in oxygen deficient environments. Also, the processes move towards completion over a very long time frame.

Not sure that IB can provide effective time frame w.r.t. river impact

The intensity of intrinsic aerobic bioremediation may be enhanced by providing microorganisms with a source of oxygen. The primary methods of getting additional supplies of oxygen into the subsurface and below the water table include air sparging; the addition of hydrogen peroxide; and, the use of oxygen release compounds (ORC), such as magnesium ~~di~~peroxide. It should be pointed out that elevation of the subsurface oxygen concentrations could result in suppression of intrinsic anaerobic bioremediation processes, which although much slower than aerobic processes, are sometimes more effective for some recalcitrant compounds.

In situ bioremediation could be enhanced at the north end of the Sutherland Avenue site to limit the off site migration of dissolved PAH and BTEX constituents. Oxygen could be added to the subsurface along a line across the width of the site using a row of air sparging wells; to an interceptor trench in which air is forced through a slotted horizontal PVC pipe using an air compressor; or , from a row of monitoring wells containing sleeves of material impregnated with ORC.

System selection would be based on a comparison of the capital and annual operational and maintenance costs. Air sparging systems require fewer wells but the systems require ongoing maintenance and energy inputs when compared to the use of ORC. Most ORC require replacement every 4 to 6 months. On site structures like roads, buildings and underground utilities will also impact on system selection. Installation of either system would require the disposal and remediation of contaminated borehole cuttings at an off site treatment facility.

BUT will O_2 augmentation sufficiently enhance biomass capability to degrade PAH (esp. Benzo(a)pyrene) to target levels?

5.0 CONCLUSIONS

AEE personnel reviewed the Phase I and Phase II site assessment reports prepared by CH2M HILL ENGINEERING LTD. on the subject site. AEE also reviewed in-house case histories and various published articles on the remediation of hydrocarbons, including PAH's, using in situ bioremediation techniques.

Several methods of treating the dissolved PAH and BTEX constituents in the groundwater were reviewed. Pump and treat systems are an established treatment option but they have not proven to be cost effective for many groundwater remediation projects, especially for those sites with fine grained soils and complex organic contaminants. The application of in situ bioremediation is generally less costly to initiate and maintain than a pump and treat system. Most in-situ bioremediation systems require the addition of oxygen below the water table using such established methods as air sparging wells or a horizontal sparging pipe or the use of hydrogen peroxide or oxygen release compound installed in a row of closely spaced monitoring wells.

6.0 RECOMMENDATIONS

AEE has the following recommendations:

1. Submission of groundwater samples obtained from the monitoring wells to one or more suppliers of water treatment equipment for the completion of treatability tests and sizing of an ex situ treatment system.

2. Obtain cost estimates from a supplier for satisfying oxygen demands using ORC. ?

3. Water samples from the existing monitoring wells should be submitted and analyzed for parameters selected specifically to indicate the presence and type of intrinsic bioremediation active beneath the site. Most of these parameters would not have been reported in the site assessment reports. The parameters to be analyzed would include dissolved oxygen (DO), sulphate, iron, nitrate, methane and bicarbonate. The microbial populations in the groundwater should be classified and quantified from several locations across the site.

   Generally don't reflect substrate biomass!

4. Conduct an enhanced bioremediation pilot study. This may include selectively adding oxygen (hydrogen peroxide) and nutrients to some of the monitoring wells on a trial basis to observe if dissolved naphthalene concentrations decrease. The addition of cultured microorganisms could be considered to observe possible impacts on more recalcitrant PAH components.

7.0 CLOSURE

Thank you for this opportunity to provide Centra Gas with this general design and costing information. AEE would be pleased to review the scope of work and associated costs once additional details are known. If you have any questions, please contact this office.

Yours truly,

AGRA Earth & Environmental Limited

Robert Matthews, P. Geol.
Senior Hydrogeologist

Harley Pankratz, P. Eng.
Manager, Winnipeg Operations

Reviewed by,
Paul Glen, P. Eng.

PH3/4010L3A.RNM

ATTACHMENT B

C-0463

AGRA
Earth & Environmental

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October 15, 1996
Project No. WX-04010

Centra Gas Manitoba Inc.
444 St. Mary Avenue
Winnipeg, Manitoba
R3C 3T2

Attention: Mr. Andy Galarnyk

Dear Sir:

**RE: INTRINSIC BIOREMEDIATION
SUTHERLAND AVENUE OPERATIONS FACILITY
WINNIPEG, MANITOBA**

1.0 INTRODUCTION

Further to your request, AGRA Earth & Environmental Limited (AEE) is pleased to provide information on the viability of stimulating ambient natural bioremediation of the shallow groundwater beneath the site prior to natural discharge to the Red River. The first step would be to obtain direct and/or indirect evidence to substantiate that natural bioremediation is active in the subsurface. The next step would be to initiate specific actions to stimulate the natural processes.

It is AEE's understanding that Centra Gas is aware of other options for managing the environmental risk that may be associated with the site. The purpose of this letter is to provide a first order cost estimate to collect evidence for the existence of natural bioremediation processes (also called intrinsic bioremediation) and the cost to conduct a feasibility trial and associated bench scale testing for stimulating intrinsic bioremediation processes beneath the site.

Budget figures for each phase of the work are presented in Table 1.

2.0 INTRINSIC BIOREMEDIATION

2.1 Introduction

Intrinsic bioremediation is the use of ambient bioremediation processes to remove low levels of dissolved organics, including petroleum hydrocarbons such as polycyclic aromatic hydrocarbons (PAH's) and monocyclic aromatic hydrocarbons (MAH's). MAH's include benzene, ethylbenzene, toluene and xylenes (BTEX). Natural bioremediation has been used both intentionally and inadvertently as a means to control migration of dissolved organics.

Intrinsic bioremediation has two main uses at contaminated sites. One is to control the leaching of contaminants from untreated or residual sources. In many cases intrinsic remediation can adequately reduce the risk of groundwater impact due to leaching of residual contamination (i.e. immobile liquids located below the water table). The other use is to control and mitigate low-level dissolved plumes.

Prior to discussing ways to "prove" that intrinsic bioremediation is active at the site and, subsequently, how to stimulate the natural processes, a brief explanation of the chemistry will be presented in the next section.

2.2 Chemical Processes

Not necessarily for PH cmpds.

The breakdown of petroleum hydrocarbons (electron donors) into the benign end products of carbon dioxide and water requires the presence of electron acceptors and available nutrients. Electron acceptors include oxygen; nitrate/nitrite; sulphate; iron (Fe^{+3}); and, Manganese (Mn^{+4}). Of these electron acceptors, oxygen is the most readily available, being replenished by natural recharge processes. Sulphate, iron and manganese also occur naturally but depend on the site and regional hydrogeochemistry. The predominate sources of nitrate are anthropogenic activities such as agricultural fertilization.

The redox conditions (aerobic versus anaerobic) determine which of the electron acceptors are active. Oxygen is consumed first but once depleted anaerobic conditions prevail and nitrate, sulphate and the other electron acceptors are consumed in order of their redox potentials.

3.0 EVALUATION OF EXISTING CONDITIONS

3.1 Introduction

The proper use of intrinsic remediation requires monitoring and evaluation to determine that natural biodegradation is occurring. At a minimum, the monitoring should document that PAH and BTEX compounds are decreasing at a rate that exceeds what would be expected from normal dispersion and dilution. Biodegradation is also indicated by the consumption of electron acceptors (oxygen, sulphate, iron and nitrate) or the presence of by-products (reduced iron, sulphide, methane, carbon dioxide and bicarbonate). Consumption of electron acceptors or the buildup of by-products should be evaluated by comparing their concentrations across the site.

In addition, general indicators of environmental conditions favourable to degradation should be measured. These general indicators include Ph, temperature, redox potential, the presence of a viable microbial (heterotrophic) community, and the presence of low levels of nutrients (nitrogen, phosphorus, potassium or N,P K). Establishing the presence and efficacy of intrinsic remediation is based on the weight of evidence as the literature on the subject clearly indicates there have been very few projects that have directly and unequivocally demonstrated the occurrence of in situ bioremediation in aquifers (as opposed to the laboratory where inputs and outputs can be controlled and monitored).

3.2 Baseline Hydrogeochemical Program

It is proposed that a baseline groundwater sampling and analytical program be completed to demonstrate the presence, or absence, of the natural biodegradation processes on-site. The wells were last sampled by CH2M HILL in June, 1994. As the condition of the well casings is unknown, prior to initiating the program each monitoring well would be located; accessibility for sampling purposes confirmed; and, the casing lids would be painted to facilitate identification during the winter months.

CH2M HILL presented the results of several rounds of groundwater sampling and chemical analyses in the two reports that CH2M HILL prepared on the site. The analytical program primarily focused on the dissolved hydrocarbon (electron donors) concentrations and the dissolved metal concentrations. The baseline hydrochemical characterization will supply data to evaluate the occurrence of natural biodegradation. It is proposed that the dissolved hydrocarbon concentrations not be assessed again at this time.

In advance to conducting the sampling program, three casing volumes of water will be purged from each of the 14 monitoring wells. The purge water will be stored on-site in covered barrels. It may be possible to dispose of the water at the City of Winnipeg North End Pollution Control Centre subsequent to laboratory characterization. If the City is unable to accept the purge water, the services of a commercial waste disposal company (e.g. Laidlaw) will have to be hired to transport the water to an out of province disposal facility.

Subsequent to purging the monitoring wells, several physical parameters will be measured on-site. These parameters include Ph, temperature, dissolved oxygen concentrations and possibly, redox potential. Alternatively, dissolved oxygen will be fixed on-site and determined in the laboratory.

Following the completion of the above phase, water samples will be extracted from each of the wells and submitted for laboratory analyses of: standard (heterotrophic) plate counts; detailed salinity analyses (which includes some of the nutrient parameters); and, dissolved inorganic carbon (DIC).

Not sure plate counts on water are indicative as it is the sediments that generally host the biomass.

As PAH are highly hydrophobic, any PAH-degraders will likely also be tight to soil/PAH compounds. and tight to soil particles

4.0 FEASIBILITY TEST - INTRINSIC BIOREMEDIATION

4.1 Introduction

The natural attenuation of petroleum hydrocarbon contaminants in groundwater systems depends largely on ambient rates of microbial degradation processes. Natural bioremediation may be enhanced to be used as a viable form of groundwater remediation.

Enhancement of the natural processes normally entails the addition of oxygen and, in some cases, nutrients. Generally, "engineered" microbes are not added for in-situ projects and where the natural biota includes hydrocarbon degraders. These constituents may be added to existing wells and the effects monitored both at the same wells that receive the additions and at down gradient wells. However, methods for evaluating in-situ rates of microbial degradation processes are problematic. This is due to the fact that in the field it is difficult to separate the effects of microbial processes from abiotic processes such as hydrodynamic dispersion and sorption. Therefore, it is proposed that an integrated field and laboratory feasibility study be conducted to determine the required oxygen and nutrient additions.

It is proposed that the field trials would be conducted at MW05; MW14; MW22; MW23A; MW23B; MW24A; MW24B; and MW24C. The bench scale treatability testing would be done at AEE's Portland, Oregon location.

4.2 Field Trial

It is proposed that an oxygen source will be added to the 3 upgradient monitoring wells (MW05; MW14; and, MW22). The oxygen source will be either hydrogen peroxide or a commercial oxygen release compound (ORC). Both of these oxygen sources are relatively expensive, however, for the purposes of completing the feasibility test, the costs will be considerably lower than using compressed air to sparge the wells.

The dissolved oxygen and selected indicator parameter concentrations will be measured after one month of operation and each subsequent month thereafter in both the receiving wells and in the 5 down gradient wells (ie. MW23A; MW23B; MW24A; MW24B; and, MW24C). After dissolved oxygen breakthrough is observed at the down gradient wells, the petroleum hydrocarbon concentrations will be determined in groundwater samples obtained from the down gradient wells. Nutrients will not be added to the receiving wells until completion of the bench scale testing and until oxygen breakthrough has been confirmed at the down gradient wells.

A request for quotation will be submitted to a supplier of ORC to obtain a firm estimate of the cost to provide oxygen to the subsurface for the duration of the feasibility test.

Indicator parameters will be determined on a monthly basis. The dissolved PAH concentrations, to be determined after oxygen breakthrough has been confirmed.

4.3 Bench Scale Testing

Bench scale laboratory testing is required to determine the optimum rates for oxygen and nutrient additions. A bacterial growth rate analyses will be conducted to determine if hydrocarbon degradation rates increase with the addition of oxygen alone, and with the addition of oxygen in combination with nutrients. The half-life of each of the PAH constituents will be determined under the various amendment (i.e. oxygen/nutrient) scenarios.

The amount of oxygen and nutrients required to effect enhanced microbial activity will be determined. Concurrently, the rate of contaminant reduction will be analyzed.

4.4 Recalcitrant Hydrocarbons

The more complex PAH molecules may prove to be resistant to intrinsic biodegradation. The general rule is that the greater the molecular complexity of the organic compound, the more recalcitrant the pollutant. The feasibility testing should indicate which PAH compounds are recalcitrant.

Additional bench scale testing may be required to determine if these fractions could be degraded by varying the input parameters (i.e. oxygen, nutrients and surfactants) or by increasing the time frame. The feasibility of using commercially available "Superbugs" could also be assessed in the laboratory setting.

4.5 Additional Boreholes

There may be a requirement to install two 4-inch wells near the north property line along Rover Avenue to facilitate the installation of the ORC. The requirement for these wells will be discussed with the supplier of the ORC product prior to initiating the project.

5.0 CONCLUSIONS

Once the site hydrochemical conditions have been assessed and the feasibility testing completed, the optimal remediation option or combination of options can be selected from the available technologies. An initial estimate of the type of system that is likely to prove effective would include the installation of an air sparging fence (i.e. remediation zone) along the Rover Avenue site boundary. The sparging fence will most likely require the installation of a line of dedicated sparge well points across the north end of the site. The sparge well points would be manifolded below grade and connected an appropriately sized air compressor. The existing monitoring wells would be maintained for their present purpose as PVC monitoring wells are generally not suitable for conversion to sparge wells. Finally, for fully operational projects, sparging is generally a more economical means of supplying oxygen to the subsurface. and more efficient in terms of O_2 utiliz. vs supplied.

Other technologies may be required in combination with the sparge system. If excess volatile organic compounds (VOC's) are created by the sparge system, a vapour extracting system may be required to vent the VOC's to the atmosphere to prevent their accumulation in underground structures. Depending on the results of the feasibility testing, nutrient enhancement may be required. Some systems make use of down gradient pumping wells and re-injection of the extracted water upgradient in an infiltration trench. One advantage of this approach, besides controlling off site movement of groundwater, is that enhanced biodegradation may be induced across a wider area of the site.

6.0 CLOSURE

Thank you for this opportunity to provide Centra Gas with this general design and budgeting information. If you have any questions, please contact this office.

Yours truly,

AGRA Earth & Environmental Limited

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