1.0 PROJECT DESCRIPTION

Knox Evangelical Free Church and Strathcona Library are heritage-listed buildings, built between 1910 and 1925, located in Strathcona Old Town, south-central Edmonton. A 1950s vintage underground storage tank, formerly used to refuel City buses, was the source of an extensive diesel fuel release. Diesel product and dissolved hydrocarbons were detected on the water table, at about seven metres depth, under the majority of the Knox Church (Figure 1), continuing south across a City road and under the north portion of the Strathcona Library (Figure 2).

Members of the public using the Church and Library were potentially at risk from diesel on the water table under both buildings and nearby apartment building residents were also potentially at future risk from groundwater-transported dissolved hydrocarbons. Capture of the diesel fuel and halting groundwater-transported dissolved hydrocarbons were warranted for the diesel product, soil and the groundwater not complying with Alberta regulatory quality standards.

Following site assessment in 2003 to 2005, clean up commenced in March 2006. Three PVC extraction wells over 100 metres long, were constructed by horizontal drilling, 0.5 metres below the water table elevation, under both heritage buildings to enable vacuum extraction of water table liquids and subsoil vapour across the diesel product area and outer fringe of dissolved-phase hydrocarbon. End-of-well vacuum sensors transmit data to the extraction system controller for maintaining optimal vacuum along the full length of each well. Extracted liquids are treated prior to sewer release for compliance with City of
Edmonton combined sewer standards and the extracted vapours (off-gases) are incinerated by a catalytic oxidizer, which has been mostly self-sustaining without the need for significant make-up gas to maintain operation.

Extraction treatment and vapour incineration are monitored by a data acquisition system and programmable logic controller that sends data via satellite to a web server for office-based monitoring and optimization. Current projections indicate that the diesel capture objective will be attained within a year of operation. As an added-value benefit, the extraction system is also capable of modification in the event that additional clean up is needed to meet Provincial soil and groundwater quality standards.

Challenges facing the main objectives of capturing diesel fuel and halting dissolved hydrocarbon movement was the implementation of clean up in an inner-city urban environment with multiple stakeholders with respect to property ownership and usage within and around the clean up area. In addition, extensive subsurface utilities were present and it was necessary to integrate the clean up construction in the context of other construction work immediately in the same area.

Key stakeholders involved with this project included:

- Knox Church
- The City of Edmonton:
  - Community Services
  - Drainage Services
  - Library Board
  - Property Management
  - Transportation and Streets
- Edmonton Radial Railway Society (leased from The City Edmonton and Province of Alberta)
- Edmonton International Fringe Theatre Festival
- Old Strathcona Foundation

Figure 3: Extraction System Operated During The Edmonton International Fringe Festival
In August 2006 Without Notice
Involvement of these stakeholders at an early stage was important to the successful initiation of clean up involving on-site stakeholder meetings. Protection of the environment at all clean up stages was also an important aspect of the design of the extraction system including the provision of water treatment utilizing on-site water quality control, which was monitored by EBA Engineering Consultants Ltd. (EBA).

Site remediation was initiated in March 2006 involving water quality laboratory testing for compliance with The City of Edmonton sewer use bylaw, and also monitoring for potential fugitive hydrocarbon vapours and odours to ensure protection of the nearby apartment and residential area. All groundwater and soil testing was conducted by the project analytical laboratory.

2.0 SCOPE OF REMEDIATION PROJECT

Laboratory analyses revealed that the majority of soil hydrocarbons were in the carbon fraction range typical of diesel fuel (C_{10} to C_{15}), although there were also some indications of gasoline fuel content. Site assessment was conducted between 2003 and 2005 to delineate areas of diesel product, impacted groundwater and soil.

The diesel product created a potential concern for the health of members of the public using the Church and Library, as they were potential receptors of volatile hydrocarbons via the inhalation pathway. Dissolved hydrocarbon was also detected in groundwater moving downgradient (northwest) from the diesel source, toward apartment buildings and residential properties, creating similar human health concerns for these residents (Figure 4b). Finally, there was a potential for contamination to reach the North Saskatchewan River, under natural groundwater gradients.
Other assessment work was conducted during 2005 to evaluate the clean up site as a candidate for diesel product and groundwater extraction using vacuum technologies (Figures 5a and 5b).

### 3.0 REMEDIATION PLANNING AND RISK MANAGEMENT

A remediation options comparison was conducted by EBA, and based on the site assessment and characterization of hydrocarbon presence, it was determined that the optimal subsurface option to capture diesel product and also restore groundwater and soil quality was multi-phase vacuum remediation.
Multi-phase (liquids and vapour) vacuum extraction was researched by EBA and discussions held with a specialist remediation contractor to evaluate the concept of using horizontal extraction wells in place of vertical or inclined wells. Multi-phase extraction is a proven technology for fuel product and contaminated groundwater when used in conjunction with vertical extraction wells that cope with seasonal water table movement, by adjustment to match a fall or rise in the water table. Horizontal extraction wells however, being constructed with intake screens at constant elevation, are subject to two major problems: as water tables fall, wells become dewatered and stranded above the water table and, as water tables rise, wells become excessively submerged. The latter creates a well "dead-heading" condition in which the vacuum is insufficient to lift groundwater because of excessive water column depth and extraction ceases. A solution to the latter problem was developed by the eventual project contractor which was considered sufficiently promising that EBA presented a comparison study between vertical and horizontal multi-phase extraction to The City of Edmonton that evaluated the risks of horizontal multi-phase extraction - after this review, The City requested EBA to proceed with implementation.

4.0 PROJECT IMPLEMENTATION

The prospect of using horizontal extraction wells was appealing in that it avoided site disturbance other than at the well ends, which was of significant benefit to the 84 Avenue right-of-way which was undergoing curb-to-curb upgrading and beautification of the frontage of the newly renovated Fringe Theatre building (TransAlta Arts Barns).

Horizontal wells are easier to keep in operation through winter as they are effectively self-winterized and protected against freezing, with only the upper terminal ends requiring frost protection. Well "dead heading" risks were addressed by the innovative installation of pneumatic pump-out tubing inside each extraction well that flushed the well contents with a timed pneumatic pulse for resumption of multi-phase extraction. Although this introduced a small degree of pump-and-treat to the remediation approach, the overall groundwater extraction and treatment rate remained less than 50 Lpm.

Figure 6: Horizontal Drilling Rig

Figure 7: Drill Bit Tracking During Drilling
Horizontal directional drilling (HDD) has traditionally been applied in the petroleum production sector, electric installations, telecommunications, sewer lines. More recently, horizontal drilling has been applied to environmental wells (Figure 6) for groundwater and soil remediation enabling water table liquids to be extracted over distances three to five times that compared to vertically-installed extraction wells. Advanced tracking features enable the drilling bit telemetry to be tracked on surface (Figures 7 and 8) and relayed to the driller’s control console (Figure 9).

5.0 PROJECT QUALITY CONTROL

During well construction, continuous tracking of the drill bit location and depth was maintained by the remediation contractor to within tolerance established by EBA for vertical alignment with the top of the water table. As-built drawings were produced by the contractor on completion of well construction and supplied to the City for incorporation into the cadastral base of documented underground infrastructure.

A start-up program was developed by EBA in which the extraction system was started and all treated water was diverted to a vacuum-truck for off-site commercial disposal. Samples of the treated water were collected and to ensure the groundwater treatment system performance was in compliance with City combined sewer release limits for hydrocarbons (Figure 10).

The hydrocarbon vapour concentrations of vapour extracted from the subsurface and also from water treatment equipment is electronically measured so that the catalytic oxidizer (Figure 11) can either be self-sustaining or uses supplied natural gas to ensure destruction of all off-gases. The temperature of the oxidizer is electronically monitored and alarm limits ensure that if the temperature outside the limits for optimal off-gas destruction, all extraction equipment is automatically deactivated.
Although relatively limited amounts of groundwater are extracted by multi-phase extraction compared to a pump-and-treat, there is still a risk of ground settlement. The City coordinated a pre-construction survey of the Church and Library foundations involving attachment of brass markers so that elevations could be checked by the project surveyor (Hamilton & Olsen Surveys Ltd.). On-going surveys have not detected any settlement of the brass markers to-date.

6.0 PROJECT IMPLEMENTATION DIFFICULTIES

Construction of the extraction wells was completed during November 2005 and the extraction system was commissioned in March 2006. The extraction system construction had to also contend with other construction work within and immediately around the clean up area, including:

- Strathcona Library Addition and Restoration
- 84 Street Upgrading and Beautification
- Dr. Wilbert McIntyre Park Upgrading

The initial foundation design for the Strathcona Library addition involved the use of augered cast-in-place concrete piles to bedrock, thereby presenting numerous obstructions to drilling horizontal wells. The east extraction well layout was therefore configured to avoid each pile; the Library architect later changed the addition foundation design because of pile construction difficulties.

Drilling difficulties were encountered by the remediation contractor in the form of zones of coarse gravel and cobble which required one well to be restarted five times. Cross-sections of the drilling alignment were developed by EBA to maintain safe clearances from Church and Library foundations, utilities, etc., although as two wells were being drilled, minor surface “breakouts” of the xanthum gum-based drilling
mud occurred outside the Library, and one seepage occurred inside the Library basement which was being renovated at the time (Figure 12a).

Figures 12a and 12b: Drilling Mud Seepage in Library and Composition (Xanthum Gum)

The drilling mud “breakouts” were of limited volume and cleaned up in a short time. Biodegradability and inert chemical properties of the drilling mud were a condition of its use and therefore it did not pose a risk to the construction workers inside the Library or to the general public.

7.0 COMMUNITY BENEFITS

At stakeholder meetings in 2005, a temporary shutdown of extraction was requested to coincide with the annual Edmonton International Fringe Festival (The Fringe) held during August, as the event is centred on the Fringe Theatre and Knox Church properties (Figure 13) and Dr. Wilbert McIntyre Park south of the Library. Between August 16 and 27, 2006, The Fringe attracted over 500,000 visitors, yet the earlier concerns for excessive noise, nuisance or problematic hydrocarbon odours were not realized and operation of the extraction system was allowed to continue without interruption.

The August Fringe Festival was also a peak time for the Edmonton Radial Railway Society which operates the High Level Street car using part of the former bus barns to house historical street cars which travel past the extraction system (Figure 14). The extraction system had been provided with privacy fencing which reduced its profile to members of the public using the High level Street car and so that it did not attract undue attention or complaints.
Figure 13: Knox Church and 84 Avenue During The Fringe Festival (August 2006)

Figure 14: High Level Street Car at Temporary Platform Adjacent to Extraction System (Right)