Reclamation of a contaminated utility corridor, Surrey, BC

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Abstract: Remediation of service station properties contaminated with hydrocarbons has become common in North America. Remediation generally involves the removal or in situ treatment of contaminated soils. Often the region of contamination intersects a utility corridor either servicing the property or passing close by. Utility corridors present an opportunity for accelerated contaminant migration on or off site due to the high permeability of the utility trench backfill material. Hydrocarbons can travel great distances along utility corridors and may cause significant offsite contamination. Remediated soils on site risk re-contamination due to back-migration of the contaminant along the utility corridor. It becomes necessary to create a barrier between the cleaned environment and the remaining contaminated utility corridor.

A recent project in the City of Surrey, BC involved the remediation of a property by means of removal of the contaminated soils and replacement with clean granular fills. A large utility corridor hosting a 100 mm diameter gas line, 150 mm diameter feeder water main and a 400 mm diameter sanitary sewer bisected the site and proved to be a conduit for migration of contaminant off site. Remediation of the site and utility corridor could not extend beyond the edge of a major roadway to the south. Completion of the project required the placement of a barrier to prevent the contaminant from returning onto the site via the utility corridor.

A shoring system was designed to support the roadway adjacent to the property where the utility corridor egresses the site. Excavation was conducted to the full depth of the utility corridor including the utility bedding materials and into the native clayey silt soils. A plug of engineered low permeability backfill was placed and compacted around the utilities. The design of the engineered fill accommodated the requirement for a low permeability, workable, batchable, compactable mix that could be re-excavated in the future to provide access for future utility installation. A series of mixes were batched and tested for both strength and permeability in order to optimize the design and economy of the engineered backfill. The utility corridor was located beneath a lane right-of-way and thus the engineered backfill required adequate strength to support the roadway and prevent large or differential settlements. The design takes into account the potential for minor settlements and changes in groundwater conditions that may have led to cracking of a cementitious mixture.

Introduction

The subject site is located in the Cloverdale area of Surrey BC. The site is bordered to the south and east by city roadways. The eastern portion of the site was a former petroleum company service station, decommissioned over 10 years ago. The western part of the site was formerly occupied by a commercial / industrial operation which has also been decommissioned. The properties were separated by what was historically a north–south municipal right-of-way. In a property swap with the City of Surrey, the site owner acquired the municipal right-of-way in exchange for frontage along the municipal roadway to the south. This resulted in a single owner, contiguous site. An environmental assessment of the site indicated hydrocarbon contamination as a result of the former service station operation. Development plans for the site required targeted onsite remediation.

While undertaking targeted onsite remediation, in Fall / Winter 2000 it was determined that the utility corridor beneath the north-south right-of-way provided a preferred pathway for off site migration of water borne hydrocarbon contamination. This corridor also allowed the potential for post remediation flow of contamination back on to the site.

The objective of the project was twofold: a) remove hydrocarbon contaminated soil from the site and b) provide a clean trench corridor along the perimeter of the site to accommodate installation of a Telus fibre optic conduit. The scope of work was modified on an ongoing basis to accommodate site specific issues that were not identified prior to undertaking work on the project.

In order to accommodate the installation of the utility conduit, timing became a major driving issue behind the approach from the design, operation and construction points of view.

Soil Stratigraphy

The site soils consist of a desiccated organic crust underlain by very soft clayey silt deposits to a depth of 4 to 5 metres. Below the clayey silts are suspected to be peat soils and or very soft silts which are typical for the area. The groundwater at the site varies between 1.2 and 1.5 m in depth. The majority of the construction as described took place within the utility corridor and was conducted in placed granular fills typical of utility bedding. The edges and the base of the final excavation extended into the native clay silt soils. A site plan is provided in Fig 1.

Within the existing north-south utility corridor three services were identified. The services included a 125 mm diameter BC Gas natural gas line, a 150 mm diameter municipal water service and a 350 mm diameter sanitary sewer service. The utility inverts varied in depth from 1.1 m to approximately 3.7 m below ground surface.

As part of a previous contract a low strength concrete barrier wall was placed within the existing utility corridor. The wall was intended to form an aquitard or 'plug' of low permeability material that acts to inhibit hydraulic flow. The plug was installed to the full width (approximately 6 m) and depth (approximately 3.5 m) of the utility corridor and was situated about 6 m north of the south property line.

Environmental Assessment

The site was a former petroleum company service station decommissioned over 10 years ago. A number of subsurface assessments involving test pitting, borehole and monitoring well installations aimed at identifying the presence of soil / groundwater contamination, have been carried out since site closure. Representative soil and groundwater samples were submitted for laboratory analysis of potential contaminants of concern: benzene, toluene, ethylbenzene, xylene (BTEX), polycyclic aromatic hydrocarbons (PAH), extractable petroleum hydrocarbons (EPHs) and metals. These analytes were chosen based on the historical uses of the site.

Although hot spots of elevated hydrocarbon concentration were identified on site, none of the in situ samples collected along the intended Telus utility trench alignment were found to have the selected analytes in concentrations exceeding Commercial Site Use standards as per the BC Contaminated Site Regulation (CSR). The presence of BTEX was identified. BTEX in comparable concentrations has been found to affect subsurface utilities and it was therefore decided to undertake targeted remedial excavation to provide a clean corridor for utility installation. Metals and PAHs were found not to be of concern onsite. As the work progressed areas of elevated BTEX concentrations were identified and excavated as necessary.

The fluctuation of the groundwater table may create a smear zone of contaminant within the soil strata. This smear zone can have a detrimental effect upon soil engineering properties. Often the hydrocarbon contaminant can degrade the organic fraction of the soil and create weakened zones tending along the natural bedding planes of the soil. These weakened zones can present preferred failure planes that may significantly reduce slope stability.

Past experience by utility operators indicates that hydrocarbon infiltration into the communications conduits can have surprising and detrimental affects. The hydrocarbon impacts can include degradation of plastic or bituminous coatings, seals, pitting of fiber optic cable and n pit the fibers and seriously damage the material with a significant reduction in fiber performance.

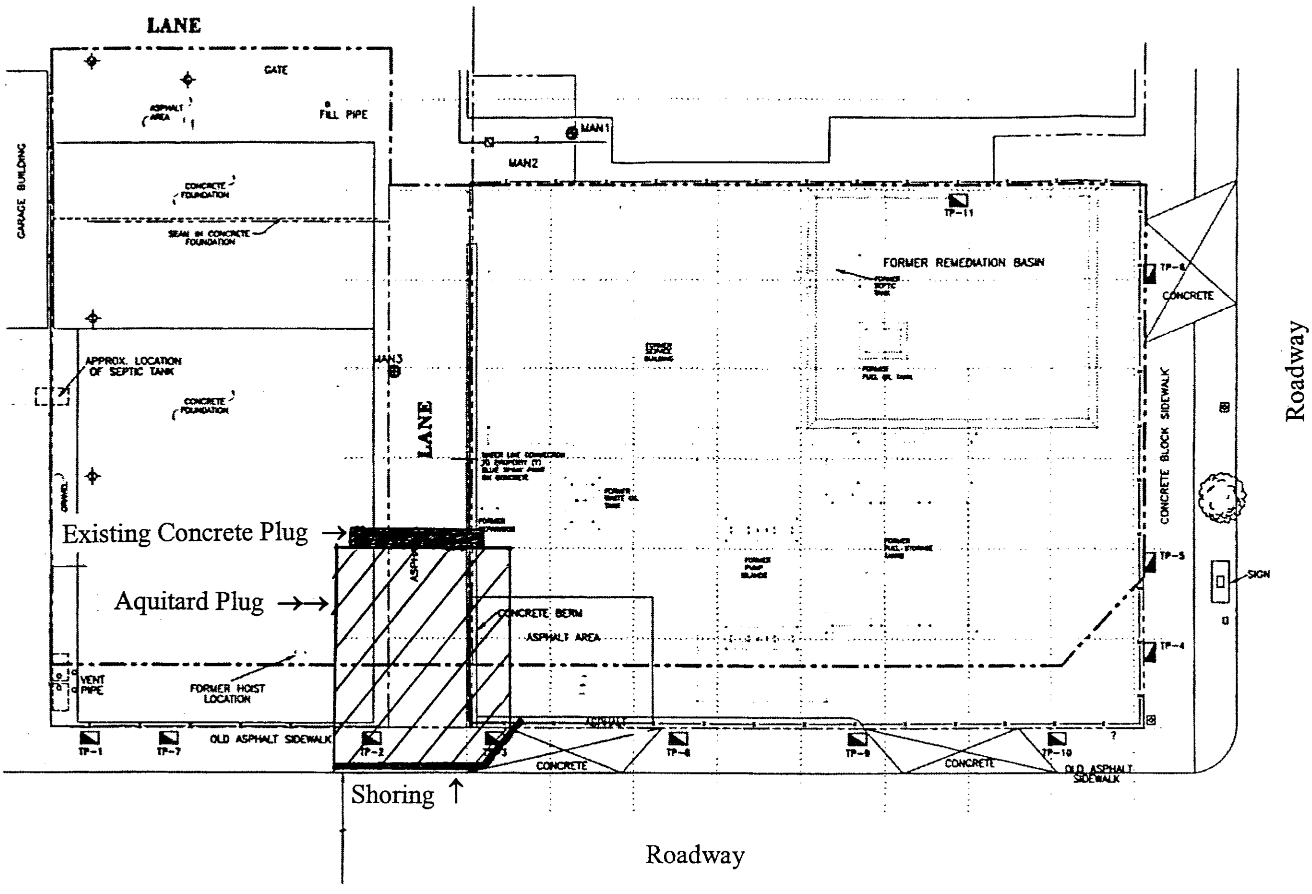
Design Rationale

Overall the soil stratigraphy was deemed to be suitable for open excavation using temporary slopes at maximum slopes of up to 1 horizontal to 1 vertical, within the maximum depth of excavation of about 3.8 m. In areas where hydrocarbon or other analytes were found in high quantities the slopes were to be reduced. This permitted the open excavation and removal of contaminated site soils along the proposed east-west Telus utility corridor north of the arterial roadway. The excavation was designed using 1 to 1 side slopes with the placement of a polyethylene barrier between the remaining contaminated site soils and the replacement clean fills.

Mid-way through the project it was identified that the utility corridor beneath the former north-south municipal right-of-way provided a preferential pathway for contaminant flow off the site. Within the area of the existing utility corridor the contaminant concentrations were not initially indicated to be higher than in the native clayey silt soils. However, within the smear zone (the natural range of fluctuation of the phreatic surface) a thin layer of highly concentrated hydrocarbons was present. The condition of the existing concrete barrier wall and the utilities as they passed through the wall were not known. It was the intention of the previous designers that the plug be removed at a later date when the corridor north of the plug was to be remediated.

The design team determined that an aquitard should be installed at the property boundary at the south end of the utility corridor to prevent the north-south bilateral flow of hydrocarbon contamination through this pathway. This would reduce the potential for recontamination (onsite) and minimize the potential of the contamination spreading off site. In addition, the removal of the entire utility corridor material between the roadway and the existing concrete barrier (6 m north of the south property line) was determined to offer the most economical solution when considering the required future remediation of the site. As part of the future remediation it was anticipated that the excavation to remove the north concrete barrier would require excavation below the underside of the deepest utility (sanitary sewer). In order to accommodate the removal of the existing concrete barrier the new aquitard should be designed to stand vertical at a minimum excavation depth of 3.9 m.

Fig 1. Site Plan



Therefore the design for the proposed aquitard included a vertical excavation at the south and north faces of the utility corridor. This required the design of a shoring system to retain a combination of utility trench backfill materials and the native soft clayey silt soils along the property line to the south immediately adjacent to the arterial roadway. As well the shoring system was required to retain the concrete plug to the north during excavation to the limit of the utility trench bedding.

Further a number of client, City of Surrey and site-specific criteria influenced the geometry and materials selected for the aquitard design. These parameters dictated that the aquitard and the aquitard material must:

a) be of low hydraulic conductivity to adequately prevent flow of contamination off / on the site.

b) be repairable and self-healing. The aquitard is placed over normally consolidated soft clay silt soils with a high groundwater table. The overall site is subject to settlement due to development or fluctuation in the groundwater regime in the surrounding area. In anticipation of probable differential settlements and induced cracking, the material must be designed to heal itself upon re-hydration.
c) be excavatable. The City of Surrey specified that since the aquitard would be encasing municipal utilities, it must be workable / excavatable to allow for ongoing utility maintenance.

d) not present a risk of damage to the utilities upon settlement. The aquitard had to be constructed of a flexible, elastic material that would not damage the utilities upon settlement.

e) be constructed of a material that would provide a structurally sound base for the municipal roadway and future construction activity. In order to eliminate any restrictions on future site development plans, any material used in the construction of the aquitard must be structurally sound, and

f) be workable for the contractor to deliver, handle, place and compact efficiently in the field. In order to maintain site and construction efficiencies the aquitard material must be simple to place, and to modify in the field.

Historically aquitards have been constructed of low strength concrete or controlled density fills (as specified in the MMCD document), which was not acceptable in this application. The primary reason for this is the brittle nature of low strength concrete and the difficulty presented in working in and around utilities once encased within hardened concrete. Low strength concrete and controlled density fills suffer cracking under differential settlements and are not self-healing. In addition they create 'hard points' where the concrete wall borders upon native soils.

The material designed and ultimately used on the site met the above criteria and accommodated the requirements of both the client (site owner) and the City of Surrey. The design of the aquitard material required the investigation of constructability, performance, cost and engineering properties. A placed aquitard was determined to be the most feasible method of installation after consideration of the orientation and complexity of the utility trench works. The three main utilities traveled in a north-south orientation within the corridor and a proposed fourth utility consisting of a Telus fiber optic conduit was planned to traverse the corridor in an east-west direction, see fig 4.

Aquitard Material Design

The results of a literature search indicated sand and bentonite mixtures were capable of attaining very low permeability while maintaining workability in terms of engineering properties and placement. Typical sand and bentonite mixtures varied in bentonite content between 8 and 16 % by dry mass.

The literature indicates that both hydraulic conductivity and engineering properties of sand and bentonite mixtures are affected by the hydration level of the bentonite prior to placement and compaction. Minimum hydraulic conductivity appears to be achieved at a hydration between 13 and 15.8 %, for sand and bentonite mixtures with 8% bentonite by mass (Stoicescu et al, 1996 and Huag and Wong, 1992). Huag and Wong noted that there was a small decrease in hydraulic conductivity at water contents between 5.9% and 15.8%, from 6.5E-9 cm/sec to 1.4 E-9 cm/sec, respectively. They further suggested that for the low permeability obtained during their testing the molding water content did not appear to be a critical factor in achieving the desired level of hydraulic conductivity. Through the testing process where full hydration (or saturation) of the samples occurred a final water content higher than the molding water content was achieved. Generally the final water content of the samples after permeability testing was between 17 and 19%.

Optimum engineering performance (compactability and workability) appears to be achieved at a water content between 8 and 14 % (Haug and Wong, 1992 and this study). Thus the design of a sand and bentonite aquitard material may be optimised for constructability as opposed to molding water content and still achieve very low hydraulic conductivity.

Little information was available in the literature providing grain size distribution of the sand substrate into which the bentonite fraction was mixed. Generally the researchers used a uniformly graded sand. The selection of sand by the researchers was perceived to be a function of repeatability and not a desire to minimise sample permeability. Common sense dictated a well graded sand material would provide improved performance over a uniformly graded product.

In order to establish an aquitard material specification a series of samples were designed, prepared and subjected to grain size, permeability and density testing. Table 1 provides a list of the samples and their contents. Concrete sand with a grain size distribution from coarse to very fine sand was selected for the base substrate. Concrete sand is washed and thus little to no silt size particles were present. The mixes included various fractions of sand, bentonite, Portland Type 10 cement and fly ash. Subsequent to the initial round of testing (RD series) further testing was conducted (series Q) using bentonite and unwashed sand with a silt fraction of 10 %, with very favourable results.

The mixes were batched at the Lafarge Cement Research and Development Laboratory facility in Richmond, BC. The specified design water contents were in the 15 to 18 % range. Generally the water contents were decreased

Table 1. Aquitard Sample Mix Designs as Tested in the Laboratory for Permeability.

Mix No	Portland Type 10 kg	Bentonite kg	Concrete Sand kg	Cyclone Sand kg	Fly Ash kg	Water kg	322N* Grams
RD 00 221	0.75	4.80	43.50	0.00	0.00	29.50	0
RD 00 225	0.75	3.00	40.50	0.00	0.00	12.00	0
RD 00 226	0.00	2.25	43.50	0.00	1.50	10.50	0
RD 00 228	4.50	0.75	43.50	0.00	0.00	2.54	0
RD 00 229	1.20	0.30	42.12	13.50	4.20	5.33	13.5
Q 00 1	0.00	4.35	0.00	40.50	0.00	8.70	0
Q 00 3	0.00	6.04	0.00	38.50	0.00	10.88	0

Each sample yielded approximately 30 litres of product
* water reduction agent

during the batching process to facilitate workability. Stickiness of the mixes proved to be problematic from the onset. The bentonite fraction had a tendency to absorb most of the water. If the dry fraction of the samples were not adequately mixed prior to adding the water the bentonite had a tendency to absorb all the available water and ball up. This prevented further mixing with the sand matrix even under high agitation in the laboratory concrete mixer. It was quickly determined that the dry ingredients should be mixed well prior to the addition of any water. If too much water was added the bentonite in the mixes tended to become adhesive and remain stuck to the fins of the mixer. Use of the laboratory mixer proved to be fortuitous because it provided an excellent indicator of the behaviour of the material in the concrete truck drum that was the preferred method of delivery. The batch plant and concrete truck delivery method was selected as it was deemed to provide the highest quality control in terms of batching the materials and ensuring adequate mixing prior to placement. The challenges associated with workability led to the re assessment of the preferred water content of the mixes, which at first was directed at minimizing the hydraulic conductivity of the material. Thus the in the field the design water content was lowered from 15 % to 8 % in most of the production batches delivered to site.

Aquitard Sample Testing

Testing was conducted at the University of Western Ontario Geotechnical Research Centre in London, Ontario and at Surfex BC Ltd. labs in Coquitlam, BC. Initially permeability testing was specified to be conducted using a constant head, triaxial cell, flexible wall permeability test method. Problems with sample preparation and a reduction in the project schedule required a change in the permeability test method to a simple constant head rigid wall method conforming to ASTM D2434. The schedule was further reduced to require the selection of an aquitard mix design prior to the completion of the permeability testing (despite the mobilisation of two testing laboratories to conduct the work). Mix design RD 00 226, providing a laboratory hydraulic conductivity of less than 1.0 E-8 cm/sec was selected for use in the fieldwork. The selection was based on perceived workability, strength and the low laboratory hydraulic conductivity. The design was selected to be repeatable in large quantities, placeable and compactable. During construction the laboratory work was continued and completed. The results of the laboratory testing, provided in Table 2 indicate that the selected material did not provide the lowest tested permeability, however, it did meet the requirements of the client, the City of Surrey and the designers.

Table 2. Aquitard Test Sample Permeability Test Results.

Mix No	Description Consistency	Proctor Density	Test Method	Hydraulic Conductivity K cm/sec	
RD 00 221	Soft	90	Rigid wall, constant head	1.0 E-4	
RD 00 225	Stiff	94	Triaxial flex wall, constant head	2.0 E-6	
RD 00 226	**Stiff**	**95**	**Rigid wall, falling head**	**1.49 E-8**	**Ave 5 tests**
RD 00 228	Hard	96	Triaxial flex wall, constant head	1.3 E-7	
RD 00 228	Hard	96	Rigid wall, variable head	2.3 E-7	
RD 00 228	Hard	96	Triaxial flex wall, constant head	1.7 E-7	
RD 00 229	Hard	100	Rigid wall, constant head	2.0 E-3	Ave 4 tests
Q 00 1	Stiff	91	Rigid wall, constant head	2.38 E-7	Ave 4 tests
Q 00 1	Stiff	96	Rigid wall, constant head	2.20 E-7	Ave 4 tests
Q 00 3	Stiff	91	Rigid wall, constant head	1.04 E-8	Ave 4 tests
Q 00 3	Stiff	96	Rigid wall, constant head	4.36 E-9	Ave 4 tests

Construction Procedure and Method

The initial objective of the remediation work was to remove contaminated soil along the north and east property boundaries. A major utility provider was scheduled to install a utilities conduit and the client was co-operating in providing a clean corridor for the installation.

Of particular concern was the excavation of the east-west trench through the north-south right-of-way which occurred along the southern property boundary, see fig. 1. As per geotechnical recommendation, the trench was excavated maintaining, a maximum 1:1 slope on the sidewalls. The expected depth of excavation was approximately 2.7 metres. The top of the southern slope of the excavation coincided with the property line, which was also the north edge of the city roadway. Once the soil was excavated, a polyethylene liner was placed along the northern face of the excavation to provide a low permeability separation between the remediated trench and the site. The trench was then backfilled with imported clean fill material. To provide ongoing water control within the trench, sumps were placed at 10 metre intervals along the length of the excavation. These sumps were constructed of 0.30 m diameter heavy gauge PVC pipe bedded into drain rock.

During the initial construction procedure it was determined that the soil at the intersection of the proposed east- west trench and the north-south utility corridor alignment would be removed and replaced with an aquitard to the vertical face of the property boundary.

The aquitard was installed at the south property boundary to a depth of approximately 3.9 m. The width of the base of the utility corridor was approximately 2 m. The 1: 1 side slopes determined the top of cut width. Installation allowed for complete encasement of the utilities and engagement of the native clayey silt soils. In order to maximize contaminated soil removal a vertical cut to the design depth was conducted along the southern property line along the edge of the city roadway. An engineered shoring system was designed and installed to facilitate the vertical cut, prevent undermining of the adjacent roadway and provide a safe work area, see figs 2, 3 and 4. The existing concrete barrier wall provided the static support for the south shoring wall and determined the northern extent of the aquitard plug.

With the shoring installed the excavation exposed all the utilities for a length of approximately 6 meters. Where necessary the utilities were mechanically supported from the shoring bracing above.

Prior to commencement of the aquitard placement a test load of four cubic metres was received on site to determine the ease of bathing the material, site workability and to provide samples for Proctor compaction test control and permeability testing. This enabled higher quality assurance during mass delivery to the site, once aquitard placement commenced. The issues impacting workability centered around material moisture content. Increasing the water content (or pre-hydration of the bentonite fraction) created a very 'sticky' mix. This limited the potential field compaction and rendered the material difficult to remove from the ready mix truck as the material stuck to the fins of the drum. Modifications to the batched water content of the material were required as the placement progressed.

Fig 2. Shoring and utilities plan.

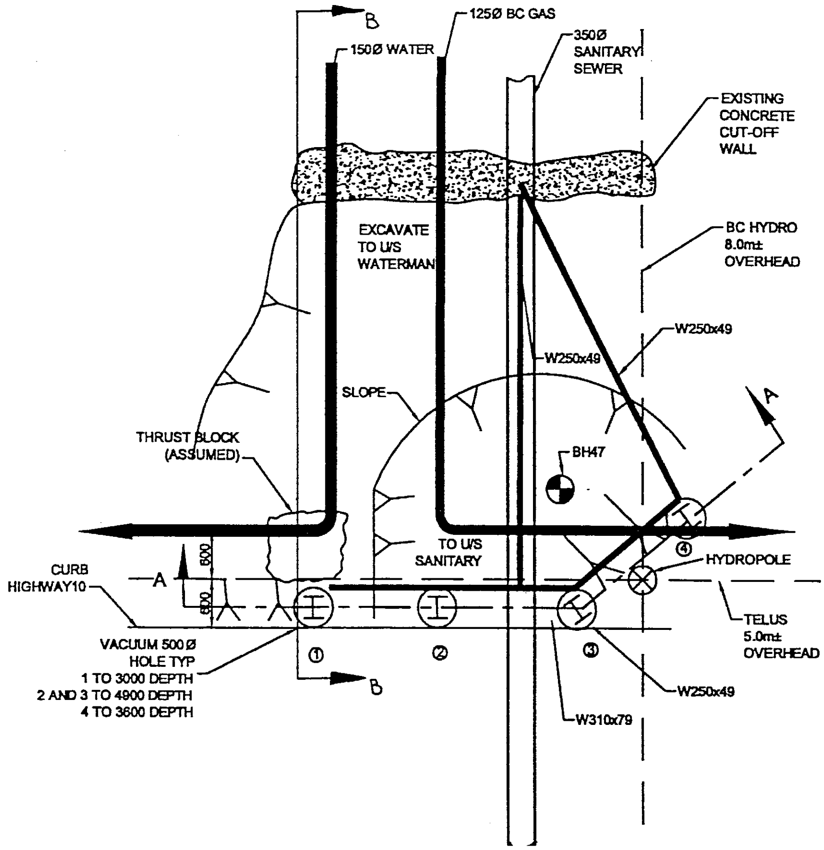


Fig 3. Section A-A Shoring and utilities.

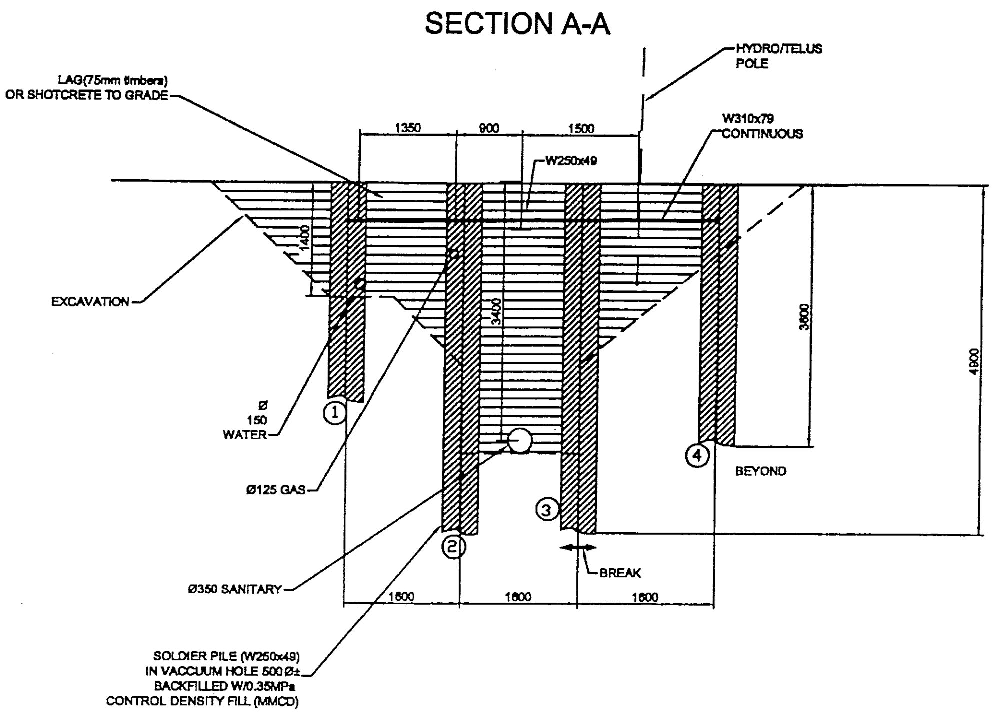
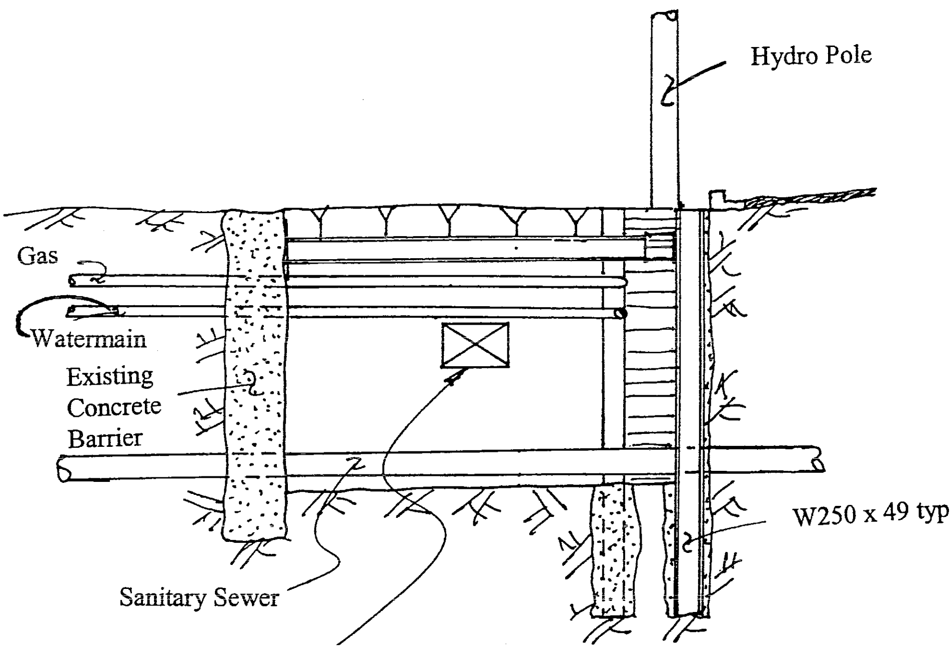


Fig 4. Section B-B Shoring and utilities.



The aquitard material was delivered to site pre mixed and the water content adjusted on site, as necessary. The aquitard material was plate compacted to 95 % Standard Proctor Dry Density in lifts of approximately 250 mm. Field density testing was conducted throughout the backfilling procedure with results ranging from 96 to 103 % of Standard Proctor Dry Density controls. Field testing to establish in situ permeability is planned for the site. No as-placed permeability results are available at the time of writing. Although relatively easy to place and compact the aquitard material did not flow and therefore hand placement was required for the complete encasement of the utilities. However, the excavatable, and self healing characteristics of the material made it superior to low strength concrete.

In order to ensure the adequate performance of the aquitard adjacent to the north concrete barrier wall where future excavation would require a vertical face a placement system was devised to include the use of a geogrid. A geogrid product was specified to be placed at 1 m depth intervals and extend horizontally for a distance of up to 3.5 m.

Temporary Shoring

When the construction method was determined the City of Surrey and the Ministry of Transportation and Highways (MoTH) were approached to determine lane closure and traffic rerouting requirements. The adjacent roadway is a major artery for the City of Surrey which restricted lane closures to weekends only: 8:00 P.M. Friday to 6:00 A.M. Monday. Professional traffic control personnel were hired to assist in designing the traffic management plan and to assist in carrying out the plan during construction. The installation of an engineered shoring system allowed for: a) vertical cut excavation face, b) prevention of undermining the adjacent roadway, and c) ongoing operation of the adjacent roadway with, at most, restricted traffic flow patterns during non peak flow intervals.

It was decided that the shoring and aquitard installation would take place commencing at 8:00 P.M. on a Friday. Contingency plans were put in place to have crew available on a 24 hrs / day basis, if required, to meet the time restrictions placed on the project.

The shoring system was designed to be installed in a minimum amount of time, permit immediate ingress of construction workers and rapid conduction and completion of the works. A soldier pile and lagging system was selected because it permitted rapid, controlled installation of the shoring with minimum disturbance and of exposure of the native soils. The soldier pile and lagging system was designed to be braced against the exiting concrete barrier wall to the north. This permitted installation of a stiff shoring system that did not require movement to mobilise resistance. A temporary overnight lane closure permitted the installation of the soldier piles using a hole cat excavator. Four MPa concrete toes were placed for HP 310 x 79 piles that extended up to 2.0 m below the excavation base. Timber lagging was selected because it permits the installation of clean sand and geo-fabric behind the facing. This permits the free draining of groundwater through the sand and between the lagging boards to prevent the build up of hydraulic head behind the shoring while minimising loss of fines.

A waler and brace system was installed above the utilities The north concrete barrier wall provided a convenient structurally sound barrier to brace the south shoring installation eliminating the requirement for soil anchors. The braces were placed directly over the utilities to provide a convenient hanger system and protect the utilities from damage during excavation. The timber lagging system is convenient because it permits continuous work to be conducted to grade as opposed to shotcrete material that must achieve strength between vertical lifts and panels.

Conclusions

Client and City of Surrey mandates created a unique opportunity to provide land reclamation and development of innovative techniques to protect the environment. The problem of utility corridors providing high conductivity pathways for contaminant migration has been encountered at many sites in the lower mainland. The potential for contamination of neighbouring sites and even sites long distances away are high, leading to potentially prohibitive clean up costs. The installation of aquitard barriers leading into and out of potentially contaminated sites, or as a defensive measure against contaminant migration onto a clean property is becoming a necessary consideration. The aquitard constructed at this site indicates that installation of an aquitard plug may be conducted efficiently and economically as part of routine remediation works.

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