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ST HELENS CANAL
FEASIBILITY STUDY
VOLUME 3
TECHNICAL APPENDIX - GEOTECHNICS

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CONTENTS
VOLUME 3 : TECHNICAL APPENDIX - GEOTECHNICS

CONTENTS
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1.0 INTRODUCTION

WS Atkins were commissioned by Warrington Borough Council on behalf of a group of authorities and organisations to investigate and report on the feasibility of restoring the St Helens Canal to navigation throughout its length from Spike Island, Widnes to the various feeder branches in St Helens.

The Feasibility Study Report is contained within six volumes:

Volume 1	Main Technical Report
Volume 2	Technical Appendix - Structures
Volume 3	Technical Appendix - Geotechnics
Volume 4	Technical Appendix - Planning and Ecology
Volume 5	Technical Appendix - Restoration Proposals Drawings
Volume 6	Executive Summary

This volume, Technical Appendix - Geotechnics, presents the findings of:

- a desk study into the ground conditions likely to be encountered along the route of the canal
- the site investigations undertaken on the in-water and infilled sections of the canal
- the laboratory testing to examine the silt and fill material for contamination.

Trial pit, borehole and silt sampling locations have been defined using national grid references. Two OS Sheet Reference Plans are appended to this document to assist in the identification of these locations.

Chainages are based on zero chainage at Widnes Lock.

2.0 GEOLOGY

2.1 Introduction

This section of the report describes the solid and superficial geology along the route of the canal (sections A to N inclusive). The information reported is taken from the British Geological Survey published Lancashire sheets 101 and 108, 1:10560 scale and sheets 84 and 97, 1:50000 scale.

2.2 Solid Geology

The greater portion of the canal, from the Mersey Estuary to above Earlstown is underlain by Permo-Triassic Sandstone. Northward from about chainage 18675, between Penkford Road Bridge and Engine Lock, the bedrock comprises the Carboniferous Coal Measures which contain a number of once productive seams.

2.3 Superficial Deposits

The superficial deposits along the route of the Sankey Canal can be divided into four main groups. The spatial distribution of these groups is presented in Table A, and a description of each of the soil groups is given below. Table A also indicates the soil group which is inferred to underlie the surface material. This is done as an aid to understanding the possible construction of the canal. For example, in the upper reaches of the canal at chainages greater than 15000m the alignment follows very closely the boundary between the Alluvium and Boulder Clay. The thickness of Alluvium along such an alignment is likely to be very small and, over most of its depth, the canal is probably constructed predominantly within the clays.

Material	Chainage (m)	Directly Underlain by
Shirdley Hill Sands	5200 - 5850 6184 - 6331 6394 - 6911	Alluvium (Estuarine)
Alluvium (Estuarine)	0 - 5200 5850 - 6184 6331 - 6394 6911 - 7047 7885 - 8155	Boulder Clay
Alluvium (River)	8155 - 9910 15185 - 20600 20684 - BB800 20684 - GB350 24275 - 25151	Boulder Clay
Alluvium (River)	9910 - 10425 10890 - 11400 11965 - 12683 13695 - 13795 14355 - 15185	Fluvioglacial (River Terrace)
Fluvio-glacial Sands and Gravels	7047 - 7885 10425 - 10890 11400 - 11965 12685 - 13695 13795 - 14355	Boulder Clay
Boulder Clay	20600 - 20684 22750 - 24275	-

Table A - Distribution of Superficial Deposits

Shirdley Hill Sands

The Shirdley Hill sands are a post glacial deposit comprising wind blown fine grained sands, similar in character to sand dune deposits. The sands are generally uniformly graded with traces of vegetable matter and thin peat horizons. The deposit in the area generally varies in thickness between 0.6m and 1.2m, however, thicknesses in the order of 2.4m are known to occur in the vicinity of Sankey Bridges.

Alluvium

Generally the alluvium is characterised by marked compositional variation both vertically and horizontally consisting of interbedded layers of organic clays, silts sands and gravels. The alluvium in the literature is divided into two units, marine or estuarine and fluvial or river deposits. The essential difference between the two lies with the clay content. The marine alluvium generally comprises an upper layer known as 'Slutch' and a lower loam deposit. The Slutch consists primarily of organic clay which predominates in tidal marsh areas. The loam consists of an inter mixture of clay, silt and sand and would have been deposited in areas where the current flows were stronger. In the tributary valleys, such as the Sankey Brook, the Slutch is intermingled in the zone of tidal influence with the freshwater or fluvial alluvium.

The freshwater alluvium comprises generally an interbedded sequence of soft clays, silts and sands. The thickness of this deposit can be extremely variable with up to 11.0m occurring in the Sankey Brook valley adjacent to the M62 motorway.

Fluvio-glacial Sand and Gravel

The fluvio-glacial sands and gravels comprise generally of a series of fine sands interleaved with gravels. Local variation will occur with the deposit becoming more fine grained consisting of silty to very silty slightly gravelly sand to slightly silty sandy gravel. Thin bands generally less than 1m in thickness of sandy gravelly clays do occur irregularly throughout the deposit. The vertical extent of these deposits are variable with thicknesses reported to vary between 0.5m and 5.0m.

Boulder Clay

The Boulder Clay forms a very extensive deposit along the line of the canal underlying the shallower superficial materials. The clay comprises a silty to sandy, gravelly, low to medium plasticity clay. Boulders and cobbles are present, although, the available data suggests that their occurrence is relatively limited.

2.4 Ground Investigation

The ground investigation consisted, primarily, of some fifty-two trial pits excavated on the line of the canal where it has been infilled, to ascertain the nature and depth of the fill material and the degree of contamination. These were supplemented by six boreholes drilled in pairs, one on the canal alignment one outside, to establish the depth of the canal, thickness of silt and the natural strata alongside the canal.

2.5 Conclusions

An understanding of the superficial deposits and underlying strata along the route of the canal is relevant to the estimation of leakage and of water demand and, also, to establishing the need of the restored canal to be lined.

Only a limited amount of information was obtained directly from the site investigation on the natural ground conditions through which the canal was constructed.

Such conclusions as can be drawn at this stage are based, therefore, primarily on a desk study of the geological survey sheets and are necessarily of a general nature.

These conclusions would need to confirmed at the detail design stage by ground investigations for the restoration of the canal track, remedial works to existing structures and the design of new structures.

Widnes to Sankey Bridges

This 8km section is adjacent to the Mersey Estuary and is all presently in water, though heavily silted in places. For most of its length, about 6km, the canal route is through marine or estuarine alluvium where it overlies boulder clay. For about 0.8km between Whittle Brook and Sankey Brook fluvio glacial sands and gravels overlay the boulder clay and in three sections between Fiddlers Ferry and Whittle Brook, totalling about 1.3km, windblown sand overlies the marine alluvium.

The underlying boulder clay can be considered to be an impermeable layer, though it may contain permeable, thin bands or lenses of sand and gravel. The alluvium can be highly variable and could be reasonably impermeable except where there is an appreciable sand content.

The fluvio glacial sands and gravels and the wind blown sand can be expected to be highly permeable and it is likely, therefore, that in these areas the canal would have been constructed with some form of lining or clay core within the banks.

Silt within the canal will permeate into coarser material and into joints and cracks in walls and thus, over time, will form a very effective seal to assist in the containment of water.

Sankey Bridges to Hey Lock

This 7km section lies within the lower Sankey Valley, which is formed of fluvio glacial sands and gravels overlying boulder clay, with river alluvium along the original course of the Sankey Brook.

The canal remains in water at both ends but some 2km have been used to form a new channel for Sankey Brook and a further 2km have been infilled.

Where the canal alignment is close to the original course of the brook, it lies on alluvium overlying either boulder clay (about 1.7km) or sands and gravels (about 2.6km).

Elsewhere, for about 2.6km in total, the canal lies directly on the fluvio glacial sands and gravels. Additionally, over some lengths the canal is bordered by deposits of wind blown sand.

Except where clay was exposed in the formation, it is possible that the canal was constructed with some form of lining or clay core within the banks.

Hey Lock to St Helens

This section, covering some 11km including the branches, lies within the upper Sankey Valley and the valleys of its tributaries, Black Brook and Rainford Brook.

The Blackbrook Branch and short lengths of the Pocket Nook branch totalling some 5km remain in water, a further 2km act as 'main river' channels for Black Brook and Rainford Brook and some 4km have been infilled.

With the exception of a short length below Old Double Locks and most of the Pocket Nook Branch which lie directly on boulder clay, this section of the canal is routed through the alluvium which overlies the boulder clay. For most of this length the canal appears to be at the boundary between the alluvium and boulder clay and the canal may have been constructed with its formation on the clay and the canal bank on the downhill (watercourse) side may have contained a clay liner or core.

Ground Water

With the canal originally proposed as a river navigation and constructed through alluvium, sands and gravels, ground water levels could be expected to be high. The measurements taken on site, see section 3.4.5 for the results, suggest that ground water levels along the infilled sections that were investigated are between 2m and 3m below ground level ie. above canal bed level.

It is understood from former British Waterways staff that the St Helens Canal was not generally lined with puddled clay. This may be because substantial lengths of the canal were constructed through relatively thin layers of permeable material overlying boulder clay, on which the canal was founded.

When the canal was constructed through permeable ground it may have been lined to contain water or, if inflow rates were high, it may have been left unlined so that the canal could be replenished by ground water. The choice would have depended on the relationship between canal pound levels and sustainable ground water levels.

As an alternative to lining the whole canal bed, the banks may have been constructed up from the underlying boulder clay, where this is at shallow depth, and provided with a clay core. In side-long ground, where the canal follows the contours, a clay core in the bank on the downhill side only would allow the canal to intercept the flow of groundwater. It is known, for example, that this form of construction was adopted for the Bridgewater Canal.

3.0 CONTAMINATION

3.1 Introduction

This section presents the findings of an investigation to assess the degree of contamination present in the canal. For this purpose the canal can be divided into two categories, the in-water sections and the infilled sections.

Previous investigations have been carried out along sections of the canal, these are reviewed and the findings discussed in the context of this investigation.

Factual information is presented on the sampling strategy, methodology and analytical data obtained as part of this survey, in addition to an interpretation of the test results in the context of current UK guidance.

3.2 Regulatory Controls

To assist in an understanding of the issues involved it may be helpful to outline the present legal framework in the context of contaminated land.

Traditionally, issues relating to soil contamination have been controlled through the planning system where land is developed on a fit for purpose basis. In its simplest form the UK approach requires land that is to be used for sensitive end uses, such as residential development, to be restored to a higher standard than that designated for an insensitive use, such as car parking.

Guidance on the appraisal of potentially contaminated land is provided by the Department of the Environment's Interdepartmental Committee for the Redevelopment of Contaminated Land (ICRCL) who have produced a number of guidance papers, the key document being ICRCL Guidance Note 59/83, second edition July 1987, entitled 'Guidance on the Assessment and Redevelopment of Contaminated Land'. This document provides reference values, or trigger concentrations, for contaminants in soil for certain forms of development.

Powers embodied in the National Rivers Authority (NRA) through the Water Resources Act 1991, and local authority environmental health departments and waste regulation authorities (WRA's) through the Environmental Protection Act 1990, can be used in instances where site contamination could have a detrimental impact upon "controlled waters" and the environment.

Following the enactment of the Environmental Act 1995, there is also a duty on local authorities to identify land within their areas which is causing or is likely to cause, harm to the environment. When such land is identified, and the harm being caused is considered to be "significant", the local authority has a duty to serve a remediation notice on the party causing the contamination, or the landowner, or the occupier, or all three. Guidance on the definition of "significant contamination" is currently in preparation and it is likely that the principal criterion will be human health; potential damage to ecosystems will be disregarded unless "significant". Although the full implications of the Act are yet to be tested, the legislation does not appear to have altered the position regarding liabilities, but has the effect of consolidating powers available through earlier statutory controls. However, it should be noted that the 1995 Act extends to land which is 'likely to cause' harm as well as that which is already causing harm.

It should be borne in mind that in addition to the above, employers have responsibilities under the Health and Safety at Work Act 1974 to safeguard the welfare of their employees. This has obvious implications with regard to those engaged in earthworks activities handing potentially contaminated material.

In addition to the above statutory powers, civil action can be a powerful means of control against contaminated site owners and/or occupiers whose land has impacts upon adjacent property or occupied under, for example nuisance actions.

A new Landfill Tax, which was announced in the Budget in November 1995, is due to operate from October 1996 at a rate of £2 per tonne for inactive wastes and £7 per tonne for active wastes. *Following a debate in Parliament in January, it is understood that the Government propose to exempt dredgings from the Landfill Tax but the exact wording of the exemption is not yet available.*

3.3 <u>In-Water Sections</u>

The sections of the canal that are currently in-water are:

1. Widnes Lock (chainage 00) to Bewsey Lock (chainage 10460).

2. Newton Brook (chainage 14635) to Bradley Lock (chainage 16375). This section is sub-divided by Hey Lock (chainage 15185).

3. Penkford Road Bridge (chainage 17675).

4. Blackbrook Branch, from Old Double Locks (chainage 20695) to the terminus (chainage BB 800).

5. Park Road (chainage 2175) to Gerrards Bridge (chainage GB 640).

6. Pocket Nook branch from New Double Lock (chainage 22750) to Safeway car park (chainage 24750) St Helens. Note parts of this section are infilled or culverted but for convenience it will be treated as one section, as water continuity has been maintained.

3.3.1 Review of Existing Data

Two reports have been made available to us that address water quality and the contamination of silt in the in-water section of the canal.

The first report was undertaken in December 1983 by the Environmental Advisory Unit of Liverpool University. It covers the section of the canal from Hey Lock, Newton le Willows to St Helens town centre. It examines water quality, canal sediment and fill pollutants, the current biological value of the canal and whether chemical methods of weed control are available and appropriate.

The investigation comprised 20no. water samples and 19no. sediment or fill samples along the examined length. All samples were tested for lead, zinc, copper, cadmium and nickel, with water samples also tested for pH and electrical conductivity. The report concludes that the water quality in the canal was adequate to good, apart from the 'St Helens Industry' section which needs improvement.

The second report also by the Environmental Advisory Unit of Liverpool University, was undertaken in January 1990 and assessed the sediment and water quality of the Pocket Nook branch of the canal.

A total of 10no. sediment samples and 6no. water samples were submitted for chemical analysis. The analysis comprised lead, cadmium, zinc, copper, nickel, arsenic, mercury, chlorides, cyanides, acid soluble sulphates and phenols. Concentrations of mineral oils and toluene extractable material were investigated in samples that appeared to contain hydrocarbons. In addition, water samples were tested for BOD, COD, total coliforms, E coli, faecal coliforms and salmonella in the laboratory. Field measurements were made of pH, temperature, electrical conductivity, dissolved oxygen and suspended solids.

The report concluded that water quality analyses indicated that the waters were relatively free of chemical contaminants, but that in some sections of the canal there was an elevated microbiological content. Sediments comprised generally of black fine amorphous silts with a thickness of approximately 0.4m. Chemical analysis of the sediments found then to contain 'very high levels' of heavy metals, including lead and zinc, and sulphate. 'Elevated levels' of arsenic, copper and cadmium were present also.

3.3.2 Sampling Methodology

Sampling of the silt in the in-water stretches of the canal was undertaken by Exploration Associates. The samples were taken, where possible, from the bed of the canal using a benthic grab sampler dropped from a boat. Where this was not possible the sample was taken by throwing the sampler from the bankside as far as possible into the channel.

The water depth at each sampling location was recorded and each sample described to BS 5950. This information, along with sampling location plans, can be found in Appendix 1.

The frequency of sampling was approximately every 250m, along the length of the canal. Small disturbed (jar) samples were taken from each location and delivered to Inchape Testing Services, St Helens for laboratory testing purposes. The suite of analytical parameters was as follows:

- polynuclear aromatic hydrocarbons
- phenols
- solvent (toluene) extractable material
- arsenic
- boron (water soluble)
- cadmium
- chromium
- copper (total and available)
- lead
- mercury
- nickel (total and available)
- selenium
- zinc (total and available)
- total sulphates
- water soluble sulphate

- sulphides
- free cyanides
- pH

Subsequent tests for leachability were undertaken, to NRA specifications, on selected samples for:

- leachable sulphide
- leachable arsenic
- leachable boron
- leachable cadmium
- leachable chromium
- leachable copper
- leachable lead
- leachable mercury
- leachable nickel
- leachable selenium
- leachable zinc

All analytical test results are presented in Section 4.

3.3.3 Chemical Analysis Results

A total of 67no. sediment samples were collected from 6no. in-water sections of the canal. The results of the chemical analysis of these samples have been compared with the range of contaminants quoted by Greater Manchester Waste Regulation Authority (GMWRA) in their soil classification guidelines. These guidelines, which give five different classes ranging from Class A (uncontaminated) to Class E (unusually heavily contaminated), are designed principally to assess the suitability of soils for waste disposal to landfill. Similar guidelines are utilised by the majority of Waste Regulation Authorities. A soil class is determined by the level of the worst case contaminant. With regard to the phytotoxic metals (copper, nickel and zinc), the GMWRA guidelines contain concentration ranges for available rather than total metal concentrations. Therefore, in the first instance, we have used the available metal concentrations in our assessment.

Section 1 - Spike Island to Bewsey Lock

A total of 43no. sediment samples were collected from this section of the canal. The depth of water in the canal varied from 0.35m to 1.6m, but generally was 1.0m or greater.

The majority of the samples comprised grey to black silts and clayey silts, generally with abundant vegetable matter. Samples 1, 2, 23, 25, 28 and 31 are comprised of clayey sands and Sample 24 was a sandy coarse gravel. All samples were Class C (contaminated) or worse, with 29no. samples Class D (heavily contaminated) and 10no. samples Class E.

In all cases samples falling into Class E did so on account of a sulphide concentration in excess of 500 mg/kg. The maximum concentration of sulphide, 3000 mg/kg, was detected in sample 7. This concentration exceeds the maximum for Class E of 2,500 mg/kg. The sulphide concentration in a further 30no. samples indicated Class C or Class D.

The concentration of arsenic in 35no. samples indicated Class D, with a further 8no. samples indicating Class C. Cadmium concentrations indicating Class C or worse were found in 30no. samples, of which 5no. are Class D. A majority of samples were Class C on account of boron concentrations, and Class C or D on account of total sulphate concentrations. Available zinc concentrations indicated Class D in 6no. samples and Class C in 8no. samples.

Generally, the remaining analytical parameters were of Class B (slightly contaminated) or better, with the occasional Class C for phenol, lead, mercury and selenium. A concentration of mercury indicating Class C was measured in samples 7, 8, 9 and 10, all of which were collected from a stretch of the canal to the south of the ICI works at Widnes. Similarly, Class C concentrations of selenium were measured in the samples from a stretch of canal to the south of Fiddlers Ferry Power Station.

A total of 5no. samples (2, 7, 21, 37 and 41) from the in-water stretch of the canal between Spike Island and Bewsey Lock were submitted for leachability tests. Generally, the analytical parameters were below their laboratory detection limits.

Section 2 - Newton Brook to Bradley Lock

A total of 7no. sediment samples, 44 to 50, were collected from this in-water stretch of the canal. The depth of the water column overlying the sediment varied from 0.7m to 1.6m.

Apart from sample 44 which was a sample of a silty coarse gravel, all the samples were of a grey or black silt with occasional fine gravel. Sample 47 contained abundant vegetable matter, with some vegetable matter in sample 50.

All samples were Class C or worse, with 5no. samples Class D and 1no. sample Class E. With the exception of sample 47, the classification is due to the sulphide and arsenic concentrations. Sample 47 was Class D due to the concentration of total sulphate. Cadmium concentration were generally Class B, C or D. The majority of the other analytical parameters were Class B or better. No samples from this stretch of the canal were submitted for leachability tests.

Section 3 - Penkford Road Bridge

A total of 2no. samples, 51 and 52, were collected from the in-water stretch adjacent to Penkford Bridge. The depths of the water column was 0.4m and 0.8m respectively. Both were samples of a black silt with abundant vegetable matter. Sample 52 was Class E due to a sulphide concentration of 2300 mg/kg; the concentrations of total sulphate and arsenic were Class D, with all other parameters Class B or better. Sample 51 was Class D due to a total sulphate concentration of 26600 mg/kg; all other analytical parameters were Class B or better.

Section 4 - Black Brook Branch

A total of 3no. samples, 53 to 55, were collected from the Blackbrook Branch of the canal. The depth of the overlying water column varied from 0.3m to 0.6m. Samples 54 and 55 comprised of a black clayey silt with occasional vegetable matter. Sample 53 was a dark grey sandy silt with occasional vegetable matter.

Sample 53 was Class E due to an arsenic concentration of 7820 mg/kg. Class C concentrations were measured also for total sulphate, sulphide, boron, lead, mercury and selenium. The classification of the other two samples was due to their sulphide concentrations.

Sample 53 was submitted for a leachability test. The arsenic concentration in the resultant leachate was 0.4 mg/l, which is negligible compared to the total concentration. Generally the concentrations of the other parameters were below the laboratory detection limits.

Section 5 - Park Road to Gerrards Bridge

A total of 7no. samples, 56 to 62, were collected from the in-water stretch of the canal between Park Road and Gerrards Bridge. The depth of the overlying water column varied from 0.1m to 0.5m.

Samples 56, 57, 58 and 62 were black silts with vegetable matter. Sample 58 had a slight oily sheen. Samples 59, 60 and 61 comprised grey silty sands with occasional gravel. Coal fragments were present in sample 60.

The samples from this stretch of the canal were all Class C at best, with 3no. Class D and 1no. Class E. Sample 56 was Class E due to a sulphide concentration of 550 mg/kg. The other samples were Class C or D with regard to their sulphide or arsenic concentrations. Generally all other parameters were Class B or better. No samples from this in-water stretch of the canal were submitted for leachability tests.

Section 6 - Pocket Nook Branch

A total of 5no. samples, namely 63 to 67, were collected from the Pocket Nook Branch of the canal. The depth of the overlying water column varied from 0.6m to 1.5m, with the exception of the location of sample 67, which was collected from the base of a dry canal.

Samples 63, 65 and 67 comprised silts with some gravel and vegetable matter. Sample 64 was a dark grey to black silty sand with occasional gravel and vegetable matter. Sample 66 was a coarse gravel with occasional pockets of a dark grey/black silt.

Of the 5no. samples, 2no. were Class E and 3no. were Class D. All samples were Class D or worse due to their arsenic concentration, with Class C or D concentrations present for total sulphate, sulphide, cadmium, lead, mercury, selenium or zinc. Additionally, sample 66 was Class E due to a lead concentration of 6960 mg/kg.

Sample 66 was submitted for leachability analysis. Apart from a sulphate concentration of 43 mg/l, all parameters, including arsenic and lead, were below the laboratory detection limits.

3.3.4 Lime Stabilisation Tests

The drying and subsequent disposal of contaminated silt dredged or excavated from the canal could impose a serious constraint on the restoration of the canal through the high cost of transportation, tipping charges and, potentially, also the proposed Landfill Tax.

Quicklime (calcium oxide) has long been used for drying out waterlogged sites and this technique has been adapted and updated so that lime stabilisation of clay soils is acceptable within the DTp Specification for Highway Works. Lime stabilised clay soils have also been used for the reconstruction of canal embankments.

In addition to the drying action, through hydration and evaporation, the lime causes a permanent change in soil structure that reduces it susceptibility to moisture and which is not subject to reversal. In clay soils there is also a pozzolanic reaction which increases the long term strength of the material. Where silt predominates the pozzolanic action will be reduced with a smaller gain in strength. Nevertheless, the possibility of transforming a wet, contaminated silt into a material capable of compaction and even, maybe, suitable for use as a canal lining material is an attractive proposition.

To assess if this was likely to be an achievable prospect, a preliminary programme of lime stabilisation testing was commissioned as described below.

Testing Programme

Twelve silt samples were taken from near Bradley Lock (Chainage 16375) and tested in the laboratory to determine the atterberg limits, moisture content, pH, sulphate content and particle size distribution.

The samples were then mixed, at their natural moisture content, with lime and with OPC or PFA or bentonite in varying proportions as indicated below:

Sample	1	2% lime	
	2	4% lime	
	3	8% lime	
	4	2% lime	4% OPC
	5	4% lime	8% OPC
	6/13	8% lime	16% OPC
	7	2% lime	8% PFA
	8	4% lime	16% PFA
	9	8% lime	24% PFA
	10	2% lime	4% Bentonite
	11	4% lime	8% Bentonite
	12	8% lime	16% Bentonite

PFA from Fiddlers Ferry Power Station was used as it is the nearest source to the site. After mixing, the material was compacted into moulds and left to cure for seven days to allow the pozzolanic reaction and subsequent strength gain to take place.

When the curing period was complete the following geotechnical testing was undertaken on each sample to ascertain the strength and suitability of the material for earthworks:

Moisture content
Standard compaction
Moisture condition value (MCV)
Hand shear vane

Based on the results of these tests, three samples were then selected for permeability testing to determine their suitability as a lining material.

Results

From the atterberg limit particle size distribution tests on the original samples it is possible to classify the material according to BS 5930 (1981). Code of Practice for Site Investigations. Most samples classify as extremely high or very high plasticity clays, with the following exceptions; Sample 3 is an extremely high plasticity silt and Samples 5 and 12 are intermediate plasticity clays.

These classifications are confirmed by the particle size distribution curves which show that all samples (except Sample 1) have a fines content (percentage passing a 63 mm sieve) of 35% or above. Sample 1 has 34% and is likely to act in the same way as the remainder of the samples.

After stabilisation most samples showed a significant decrease in moisture content and a resultant increase in strength and workability. The exception was Sample 7 which showed an unexplained 4% increase in moisture content.

Otherwise, moisture content in the samples decreased by between 2% (Sample 10) and 33% (Sample 8).

Two of the samples (No 6/13 and 12) exhibited properties that were considered acceptable for earthworks ie MCV greater than 8.5 and a maximum dry density in excess of 1.5 Mg/m^3. These values will allow easy placement and tracking of vehicles over the material once placed.

These two samples were tested for permeability along with Sample 3 for comparison with a material considered too wet to be a suitable earthworks material.

The permeability testing was carried out in accordance with BS 1377 in a constant head permeameter. The permeability of the samples was as follows:

Sample No	Additives	Permeability
3	8% lime	6×10^{-7} m/s
6/13	8% lime 16% OPC	3×10^{-8} m/s
12	8% lime 16% Bentonite	4×10^{-10} m/s

It should be noted that typical values used for landfill site liners, where permeability is the primary concern, are 10^{-8} to 10^{-9} m/s. Samples 6/13 and 12 have permeability values better those required for landfill site liners and, therefore, could well be suitable for lining the canal.

The additive mixture could be adjusted to achieve the desired permeability, consistent with workability and at an economic cost.

3.4 Infilled Sections

The infilled section of the canal can be divided into the sections detailed below.

1. Bewsey Lock (chainage 10460) to Newton Brook (chainage 14635).

2. Hey Lock (chainage 15185).

3. Bradley Lock (chainage 16375) to Penkford Road Bridge (chainage 17675).

4. Penkford Road Bridge (chainage 17675) to Old Double Lock (chainage 20695).

5. Old Double Lock (chainage 20695) to Park Road (chainage 21275).

3.4.1 Review of Existing Data

In 1983 the Environmental Advisory Unit, University of Liverpool, undertook a survey of the St Helens Canal between St Helens and Hey Lock, Newton-le-Willows. This include the analysis of a limited number of fill samples collected from the infilled section of canal between Sankey Viaduct and Clough Brook. A total of 5no. samples were analysed for total lead, zinc, copper, cadmium and nickel, and the results compared with the relevant ICRCL guidelines. They concluded that with the exception of one sample, the fill did not appear to be contaminated.

Dames and Moore carried out, on behalf of the NRA, an investigation of an infilled section of the canal adjacent to Sankey Industrial Estate. This also included a review of an earlier investigation of the adjoining Bradley Wharf Section, which had found elevated concentrations of arsenic, cadmium, selenium and polyaromatic hydrocarbons (PAH), when compared with ICRCL guidelines. The investigation carried out by Dames and Moore analysed 10no. samples, collected from 6no. trial pits, for total petroleum hydrocarbons (TPH), phenol, PAHs, pH, metals, cyanide, sulphate and sulphide.

All concentrations were below the relevant ICRCL guideline concentrations and the Dutch Intervention Values. Additionally, the results were compared with the Greater London Council Guidelines for classification of contaminated land. (These were the basis for the GMWRA waste classification guidelines). This showed that although the majority of the fill along this section could be classified as uncontaminated to slightly contaminated, inside the Bradley Wharf area arsenic, cadmium and selenium concentrations would lead to classifications of heavily contaminated to unusually contaminated.

In 1994 Warrington Borough Council collected a number of surface and subsurface samples from the infilled section of the canal to the north of Alder Lane. Comparison with ICRCL guidelines indicated elevated concentrations of arsenic, boron, copper and zinc.

3.4.2 Sampling Methodology

The infilled sections of the canal were investigated by excavating a series of trial pits along the infilled length at 100m intervals. In locations where trial pitting was not possible due to access or other restrictions probe holes were drilled to determine the nature of fill materials. A total of 6no. boreholes were drilled, in pairs, one inside and one outside the infilled area, to define the surrounding ground conditions and the base of the canal silt materials. Piezometers were installed in 3no. boreholes (BH2, 4, 6) to define the surrounding groundwater regime. Trial pit, probe hole and borehole logs are presented along with location plans in Appendix 2.

Samples were taken from the trial pits were delivered to Inchcape Testing Services, St Helens for laboratory testing purposes. The suite of analytical parameters was as follows:

- coal tar derivatives
- phenols
- solvent (toluene) extractable material
- arsenic
- boron (water soluble)
- cadmium
- chromium
- copper (total and available)
- lead
- mercury
- nickel (total and available)
- selenium
- zinc (total and available)
- total sulphates

- water soluble sulphates
- sulphides
- free cyanide
- pH

Subsequent tests for leachability were undertaken to NRA specification on selected samples for:

- leachable sulphides
- leachable arsenic
- leachable boron
- leachable cadmium
- leachable chromium
- leachable copper
- leachable lead
- leachable mercury
- leachable nickel
- leachable selenium
- leachable zinc

All analytical test results are presented in Section 4.

3.4.3 Ground Conditions

Section 1 - Bewsey Lock (chainage 10460) to Newton Brook (chainage 14635)

The investigation into this section comprised 22no. trial pits (TP1 to TP22), 4no. boreholes (BH1 to BH4), and a single probehole (PH6). Sankey Brook flows in the old canal channel along the lower part of this section and, so, this length was not investigated.

The ground conditions encountered are described below. Logs for all the exploratory holes are attached in Section 3.

Chainage 12095 - 12245

Trial pits TP1 and TP2 and borehole BH1 revealed a red brown or brown sand fill with bricks, stones and concrete between 0.5m and 2.7m thick with canal silt materials, predominantly black brown clayey silts, below. Depth to natural ground was between 2.4 and 3.3m, with the black silty sand (TP1) or grey black silty clay (TP2) below.

Chainage 12245 - 14585

Trial pits TP3 to TP21 and BH3 found that ground conditions along this chainage comprised, between 0.4m and 2.9m (generally around 1m), of mostly sand fill with mud, clay, stones, bricks, concrete and wood in places, overlying refuse fill comprising plastic bags, wood, tin cans, sand, bricks and polystyrene (probably domestic refuse). The base of this material varied between 1.9m and at least 3.9m below existing ground level (bgl), overlying soft sandy silts. Underlying natural materials comprised grey silty sands or soft to firm silty clays at around 2.5m bgl.

A single trial pit (TP8) showed no refuse fill, but instead a layer of brick fill with a sand matrix 0.8m thick overlying a firm yellow brown clay fill 0.6m thick.

Chainage 14585 - 14635

The final trial pit in this section (TP22) found 1.1m of red brown sand fill overlying soft black silt from 1.1m to 1.7m bgl overlying a soft grey clayey silt from 1.7m to at least 3.7m bgl. This is probably excavated material from the Newton Brook crossing.

Section 2 - Hey Lock (chainage 15185)

Hey Lock was investigated using a single probe hole (PH6). This revealed 4.5m of brick and clay fill overlying soft red brown clay fill between 4.5 and 5.0m bgl. The hole terminated at 5.0m on a sandstone obstruction possibly the base of the lock chamber.

Section 3 - Bradley Lock (chainage 16375) to Penkford Road Bridge (chainage 17675)

Investigation in this section comprised 8no. trial pits (TP23 to TP30), 4no. probe holes (PH1 to PH4) and 2no. boreholes (BH5 to BH6). The ground conditions encountered are described below.

Chainage 16375 - 17025

Generally trial pits TP23 to TP30 encountered 0.1m to 0.4m of sandy topsoil fill, overlying fill material, comprising brown sand with bricks and stones or orange brown clay, to between 0.5 and 1.8m bgl. Below the fill was a soft grey black silt (canal silt) to 1.7m to 3.8m bgl, which was overlying a firm silty clay to at least 4.0m bgl. Variations to this were TP26, in which a band of amorphous silty peat was found below the silt at 3.4m to at least 3.9m bgl, and TP27, in which a brown silty sand was encountered below the silt at 2.1m to at least 3.1m bgl.

Chainage 17025 - 17675

Borehole BH5 and probe holes PH1 to PH4 encountered fill materials to between 1.0m and 3.0m bgl and comprised sand, clay, ash, clinker, wood, concrete and in one probe hole (PH2) peat. An overlying layer of topsoil was encountered only in BH5 and PH1. Underlying the fill was a layer of grey or black clayey silt or silty clay to between 3.5m and 4.25m bgl.

Natural materials beneath the silt comprised either loose brown sand to between 3.75m and 6.0m or a stiff brown clay to at least 5.0m.

Section 4 - Penkford Road Bridge (chainage 17675) to Old Double Lock (chainage 20695)

Investigation in this section comprised 18no. trial pits (TP31-48). The ground conditions encountered are described below.

Chainage 17675 - 17875

Trial pits TP31 and TP32 showed no correlation with other boreholes in this section. TP31 encountered wet black brown organic silty fill to 0.3m, clayey sand fill to 0.7m, grey sandy silt to 1.5m, overlying clayey sand to at least 2.8m. TP32 comprised orange brown sand fill with wood and lumps of clay to at least 4.2m.

Chainage 17875 - 18175

Trial pits TP33 to TP36 generally comprised 0.5m of brown sandy topsoil overlying a soft friable clay fill to between 1.0m and 1.5m. A layer of soft grey black silt was encountered between 1.5m and at least 1.9m bgl. Trial pit TP36 proved a layer of clay from 3.5m to at least 3.7m bgl. This length of the canal reportedly flowed between embankments, which are no longer present. The fill material is likely to be embankment material that was pushed into the canal channel during decommissioning works.

Chainage 18175 - 18475

Trial pits TP37 to TP39 comprised 0.1m of sandy topsoil fill overlying grey and brown stoney sandy clayey ash and cinder fill to between 0.7m and 2.6m bgl. Underlying the fill was soft grey black silt (canal deposits) to at least 3.0m -4.0m bgl.

Chainage 18475 - 18575

The trial pit at this location (TP40) encountered a 0.3m layer of dry grey friable silt overlying soft black silt to at least 2.0m. The pit was abandoned at this depth due to collapse.

Chainage 18575 - 19845

Trial pits TP41 to TP48 encountered grey silty stoney sand fill with bricks between 1.0 and 3.3m bgl. Occasionally overlain by a 0.2m thick layer of a sandy (TP44) or peaty (TP46) topsoil. Beneath the fill was a soft grey or black silt (canal deposits) to at least 3.8m bgl. Only one trial pit (TP47) proved natural ground, soft to firm brown sandy clay from 2.7m to at least 3.5m bgl. For the remainder of this section (chainage 18175 - 20695) Black Brook flows along the canal channel therefore no investigation was possible.

Section 5 - Old Double Lock (chainage 20695) to Park Road (chainage 21275)

This section was investigated by 4no. trial pits (TP49 to TP52). However, only TP49 detected any evidence of the canal, the others were excavated to the south of the original route of the canal because at this point the former channel crosses rugby pitches making excavations impossible without causing unacceptable damage.

Trial pit TP49 encountered a sandy topsoil (0.1m thick) overlying a gravelly sand fill to 1.5m (probably a drainage layer for the sports field), overlying a red sandy gravel and clinker fill to 2.6m, and a soft black silt (canal deposits) to 3.2m. Natural ground was encountered at 3.2m in the form of an orange brown sand to 3.4m below which was a brown sand to at least 3.8m.

Trial pits TP50 to TP52 are not relevant to the study as noted above but for completeness logs are included in Section 3.

3.4.4 Chemical Analysis Results

A total of 89no. solid samples, from the 52no. trial pits excavated in the infilled sections of the canal, were submitted for chemical analysis.

The results of this analysis have been compared initially with the GMWRA guidelines for classification of waste types.

Section 1 - Bewsey Lock to Newton Brook

Chainage 12905 to 12245

Trial pits TP1 and TP2 were excavated along this length from which 3no. samples were submitted for chemical analysis.

Sample TP2 2.6, a black silty sand, was Class C due to an arsenic concentration of 138 mg/kg, together with Class C concentrations for total sulphate, boron and mercury. The remaining samples from this chainage were Class B or better.

Chainage 12245 to 14585

Trial pits TP3 to TP21 were excavated along this length, from which 21no. samples were submitted for chemical analysis. A total of 19no. of the samples were Class C or worse.

The majority of the samples analysed from this length were samples of a sandy refuse fill, often containing plastic, wood, metal, stones, paper etc. These samples are generally Class C or Class D, due to total sulphate, sulphide, arsenic, boron and cadmium concentrations. Samples TP3 2.0m and TP6 1.5m were Class E, due to a sulphide concentration of 640 mg/kg and an arsenic concentration of 536 mg/kg respectively. Sample TP3 2.0m was submitted for a leachability test, which apart from a boron concentration of 0.3 mg/l and a sulphate concentration of 230 mg/l, was below the laboratory detection limit for all other analytical parameters. A sample of ash and cinders, TP15 2.7m, was Class D due to a total sulphate concentration of 43700 mg/kg and an arsenic concentration of 110 mg/kg.

Samples of a silty clay (TP9 1.6m, TP13 4.0m and TP6 3.8m), which generally underlies the refuse fill, were Class B to Class D. Likewise, samples of sand fill (TP8 0.5m, TP18 0.6m and TP9 0.6m), which generally overlies the refuse fill, were Class B, Class D and Class C respectively. The Class D classification for TP18 0.6m was due to a total sulphate concentration of 21900 mg/kg and a cadmium concentration of 29 mg/kg. A leachability test on this sample gave a concentration in the derived leachate of 866 mg/l for sulphate but a cadmium concentration below the laboratory detection limit.

Chainage 14588 to 14635

A sample TP22 0.7m, of a red brown sand fill, from the only trial pit excavated in this length, was Class A for all parameters.

Section 2 - Hey Lock

Chainage 15185

No trial pits were excavated along this length.

Section 3 - Bradley Lock to Old Double Lock

Chainage 16375 - 17525

Trial pits TP23 to TP30 were excavated along this length, and a total of 10no. samples submitted for chemical analysis.

The majority of the samples analysed comprised a brown sand fill, often with bricks and stones. Generally these samples were Class D or worse, on account of arsenic, sulphide and sulphate concentration. Samples TP23 0.6m and TP30 0.6m were Class E due to arsenic concentrations of 531 mg/kg and 1168 mg/kg. Sample TP23 0.6m was submitted for a leachability test. The arsenic concentration in the derived leachate were below the laboratory detection limit. A sample of a clay fill, TP25 1.2m, was Class C due to an arsenic concentration of 50 mg/kg.

A sample of a black silt, TP27 0.2m, was Class D due to sulphate and sulphide concentrations. A sample of a silty peat, TP26 3.5m, was Class C due to a boron concentration of 5 mg/kg, with all other parameters being Class B or better.

Chainage 17025 to 17675

No trial pits were excavated along this length.

Section 4 - Penkford Road Bridge to Old Double Lock

Chainage 17675m to 17875m

Trial pits TP31 and TP32 were excavated along this length.

A sample of a brown clayey sand fill, TP31 0.6m, was Class E due to an arsenic concentration of 1168 mg/kg and Class C due to sulphide and selenium. This sample was submitted for a leachability test, with the arsenic concentration in the derived leachate being below the laboratory detection limit.

A sample of an orange sand fill, TP32 3.0m, was Class D due to an arsenic concentration of 157 mg/kg, with all other parameters Class B or better. Sample TP32 3.0m, a brown sand fill was Class A for all parameters.

Chainage 17875 to 1875

Trial pits TP33 to TP36 were excavated along this length with a total of 4no. samples submitted for chemical analysis.

The 3no. samples were Class C or worse, principally due to arsenic concentrations. Sample TP33 0.8m, a friable brown clay fill, was Class A for all parameters.

Chainage 18175 to 18472

Trial pits TP37 to TP39 were excavated along this length, with a total of 3no. samples submitted for chemical analysis.

All samples were Class D or worse. Sample TP37 2.8m was Class D due to an arsenic concentration of 404 mg/kg, with a Class C concentration of selenium of 4.8 mg/kg. TP39 2.0m was Class E due to a mercury concentration of 3.6 mg/kg.

Chainage 18475 to 18375

Trial pit TP40 was excavated along this length. Sample TP40 1.0m, a soft black silt, was Class D due to an arsenic concentration of 122 mg/kg, with all remaining parameters being Class B or better.

Chainage 18575 to 19845

Trial pits TP41 to TP48 were excavated along this length with 8no. samples being submitted for chemical analysis.

A sample of a sand fill TP48 0.9m was Class E due to an arsenic concentration of 2161 mg/kg, with a Class D concentration for total sulphate and Class C concentrations for cadmium, mercury and selenium. Other samples of a sand fill, TP42 1.3m, TP43 2.5m and TP45 1.0m, were Class C due to total sulphate concentrations, with all other parameters Class A.

All other samples, 1 No of a sand fill, 1 No of a silty fill and 1 No of a grey silt were class A.

Section 5 - Old Double Lock to Park Road

Trial pits TP49 to TP52 were excavated along this length of chainage, with 4no. samples submitted for analysis.

3 No out of the 4 No samples were Class E. Sample TP50 2.0m, a sandy clay fill, was Class E due to a sulphate concentration of 117000 mg/kg and an arsenic concentration of 1427 mg/kg. Sample TP52 1.1m, a sand fill with ash, was Class E due to arsenic, cadmium and lead concentrations of 1144mg/kg, 76 mg/kg and 31730 mg/kg respectively. Sample TP49 1.8m, a clinker fill, was Class E due to arsenic and lead concentrations of 3284 mg/kg and 20130 mg/kg respectively. All three of these samples also contained Class D concentrations for various parameters. Sample TP50 2.0m was submitted for a leachability test. The derived leachate had a sulphate concentration of 1066 mg/kg, with all other parameters below the analytical detection limit.

Sample TP51 3.0m, a sand fill, was Class D due to a pH of 11.8 and a total sulphate concentration of 70300 mg/kg.

3.4.5 Piezometer Results

Piezometer tubing was installed in 3no. out of the 6no. boreholes drilled along the infilled sections of the canal. These were BH2 and BH4, located in the Bewsey Lock to Newton Brook length, and BH6, located in the Bradley Lock to Penkford Road Bridge length. Two piezometers, with tip depths of 4.1m (shallow) and 6.0m (deep) were installed in BH2. Only one piezometer was installed in each of BH4 and BH6, with a tip depth of 4.0m in each borehole.

Water levels were measured on 5no. occasions over the period 29 August to 27 October 1995. The results are given in Table 1 in Appendix 2 and show that groundwater was found to be between 2m and 3m below ground level. Generally, water levels were fairly constant within individual piezometers, varying over a maximum range of 32mm. The difference between the shallow and deep piezometers in BH2 was in the approximate range 15mm to 20mm over the majority of the monitoring period.

3.5 Adjacent Land Uses

The St Helens Canal was constructed to provide a means of transporting raw materials to and manufactured goods from the developing industrial areas of the St Helens and Warrington. The construction of the canal providing further impetus for industrial development along its length. Amongst the goods carried along the canal were coal mined around St Helens, and copper and iron ores for smelting works and foundries located towards the St Helens end of the canal. Such materials, if lost during transportation, would have led to the contamination of the canal, and accumulation of contamination in the silts on the bed of the canal.

At its Widnes end, the canal passes through an area associated historically with the development of the chemical industrial, in particular the production of soap and alkali (sodium carbonate). The area of Cuerdley Marsh and other low lying areas around Widnes, were used for the disposal of chemical wastes from these industries. Similarly, wastes generated by the various industries located elsewhere along the length of the canal are likely to have been deposited adjacent to the canal. An example of this is the alkali wastes from Musprats Vitriol (sulphuric acid) works, which were located near to Bradley Lock. Additionally, it is known that areas adjacent to the canal are known of have been used for the disposal of domestic and municipal wastes and for the deposition of dredgings from the canal.

Thus it is probable that the canal is bordered by contaminated land along the majority of its length. Any contaminants leached out of these areas, may well have migrated into the canal itself.

Amongst present day land uses with the potential for contamination of the canal are the industries located on the industrial estates based on Tan House Lane/Gorsey Lane, Widnes and to the south of Liverpool Road in Sankey Bridges. Lagoons for the settling of pulverised fuel ash (PFA) from Fiddlers Ferry Power Station are located in the area between the canal and the River Mersey.

The areas immediately to the south of the canal, approximately between Fiddlers Ferry Lock and Sankey Lock is occupied by Gatewarth Landfill site. Although no longer operational, this was a major Cheshire County Council landfill site accepting a wide variety of wastes including special wastes, sludges and liquids, and is known to be generating both leachate and landfill gas both of which could potentially migrate towards the canal.

3.6 Conclusions

The history of the canal and its adjacent land use suggests strongly that contamination will have entered the canal, resulting in the contamination of the water body and the accumulation of contaminants in the silt at the base of the canal.

In-Water Sections

The results of the silt sampling from the in-water lengths of the canal indicates the presence of contaminants within the silt, particularly sulphide and arsenic.

Overall, with regard to the GMWRA guidelines, the majority of silt samples collected from the canal are Class D, with occasional Class C, and can be considered to be contaminated generally by sulphate, sulphide, arsenic, boron and cadmium. The leachability tests carried out indicate that, generally, the soluble fractions of these contaminants are negligible.

Total concentrations of the phytotoxic metals (copper, nickel and zinc) can be compared with the guidelines contained in ICRCL 59/83, which quotes threshold trigger concentrations above which these metals can be considered to have a deleterious effect on plant growth. For copper and zinc, virtually all of the sediment samples exceed these concentrations. However, for nickel only 2no. out of 67 no. samples exceed the threshold concentration.

Additionally, dissolved copper is one of the more toxic metals in respect of aquatic life, being considered highly toxic to crustacea, molluscs and fish in the range 0.3 to 10.0 mg/litre (regardless of other chemical factors eg. pH, hardness). For coarse fish, a copper concentration of 0.5 mg/litre would typically result in 50% fish kill over a period of 4 days. Thus any disturbance of the sediments, or changes to water chemistry, which lead to increased concentrations of dissolved copper would be potentially harmful to aquatic life.

With regard to the future fate of the sediments, if they are dredged from the canal, they will require disposal at a suitably licensed landfill site. If the sediments are allowed to remain in-situ, the limited leachability tests that we have carried out suggest that the contamination within the sediments should not adversely effect water quality due to leaching back into solution. However, any disturbance of the sediments which results in sediment being suspended in the water body would result in a deterioration in water quality.

Infilled Sections

Generally, the materials present in the infilled lengths of the canal can be considered to fall into two types;

i. reworked materials of natural origin ie. sands, clays and silts,
ii. anthropogenic waste materials ie. ash, domestic refuse

The latter type of fill materials are particularly prevalent between chainages 12245m to 14585m.

The contaminants present in the reworked natural materials were generally sulphate and arsenic. In addition the anthropogenic wastes contained sulphide, boron and other metals.

With only a few exceptions the fill of both types can be classified as contaminated (Class C) to unusually heavily contaminated (Class E). Therefore following excavation this material will require disposal at a suitably licensed landfill site, and would not be suitable for use for landscaping purposes along the canal banks.

3.7 Recommendations

Given the length of the canal and the fact that the sampling programme, of both silt and fill materials, was only intended as a scoping exercise, we do not consider that it would be appropriate to classify given lengths of chainage for disposal purposes. However, the information gained should provide a suitable starting point for discussions with the relevant Waste Regulation Authorities and potential waste disposal sites, regarding the acceptability for disposal of excavated material, and of any further ongoing sampling required during excavation. Ultimately decisions regarding the acceptability of excavated/dredged materials is the responsibility of the relevant Waste Regulation Authority.

Although a few samples are unusually heavily contaminated (Class E), the concentrations do not appear to be sufficient to present any major risk to workers engaged in the excavation. Therefore in terms of health and safety, the main precautions necessary would be normal good hygiene and safety practices, including the wearing of overalls, protective footwear and gloves. Extra precautions would involve control of dust generation, and the monitoring of any excavations for hazardous gases, both prior to any entry, and whilst any work is in progress.

The general principles set out in the Health and Safety Executive's document entitled "Protection of Workers and the General Public During the Development of Contaminated Land" should be adopted for such works.