Environmental Protection
Draft Report

UNITED MINES LANDFILL
APPRAISAL OF THE DISPOSAL OF WASTE FROM FALMOUTH DOCKS TIP

December 1993
GW03/0040/01

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EXECUTIVE SUMMARY

South West Water plc propose to develop a new STW on part of an old waste tip at Falmouth Docks (FDT). They intend to remove 26,000m^3 of inert, domestic and industrial waste which contains small amounts of toxic wastes including PCBs and organotin. United Mines Landfill (UML), close to Falmouth, is the only landfill site in Cornwall which may accept the waste. The NRA are concerned that the site does not operate on containment principles and is therefore not suitable for the disposal of toxic wastes. In order to support this position the NRA have undertaken a limited investigation of UML and impact appraisal.

Relevant legislation and guidance provided by; site licensing, EC Groundwater Directive, NRA Groundwater Protection Policy, and DoE guidance has been reviewed. This indicates that PCBs cannot be disposed at UML within the Site Licence. Other List 1 substances (including organotin) specified within the EC Groundwater Directive, can only be deposited if the Directive is followed.

The site investigation of FDT identified two layers of waste. Only the top more contaminated layer will be removed. This contains elevated levels of List 1 substances including; organotin, PCBs, coal tars, mineral oils and mercury. A very approximate assessment of the total amount of these contaminants identifies 2 kg of organotin and 50 kg of PCBs.

An assessment of the input of List 1 substances to UML has been made. This considers the likely presence of a wide range of List 1 substances including PCBs at low levels. Approximately 7 tonnes of organotin has been deposited at UML compared with 4 tonnes at FDT.

A very limited programme of sampling monitoring points associated with UML was undertaken. Organotin including trace levels of tributyltin was identified beneath the site and triphenyltin also at trace levels at Wheal Jane. No other significant levels of organic contaminants were identified although groundwater monitoring boreholes may not be monitoring the site effectively.

Groundwater levels beneath the site indicate the bulk of leachate generated (approximately 166,000m^3/annum) drains to Wheal Jane being diluted by an average of 1:36. Wheal Jane and the County Adit drain to the Carnon River and eventually into the Carrick Roads. A small proportion may drain via the County Adit and there is potential for perched leachate levels to drain to the Hicks Mill catchment.

The investigation has identified a potential for organotin to drain from UML into underlying groundwaters and drain to Wheal Jane and the Carnon River. This is of particular concern to any longterm Wheal Jane treatment scheme and protection of the Carrick Roads. The additional loading of organotin from the FDT waste is estimated to be approximately half that present in UML. Additional monitoring, together with an understanding of leachate drainage is required in order to assess the impact of the FDT waste.

The following recommendations are made for disposal of the FDT waste at UML:-

* PCB contaminated wastes cannot be disposed within the current Site Licence.
* Organotin contaminated wastes should not be disposed unless it can be shown that the EC Groundwater Directive will not be breached.
* There are no objections to the disposal of the other FDT waste, as identified, within the conditions of the Site Licence.

1. INTRODUCTION

This report has been compiled by contract staff working on behalf of the Groundwater Quality Officer of the National Rivers Authority, South Western Region. The report is presented to the Pollution Control Planner to support a paper to Management Team.

1.1 Background

As part of the "Clean Sweep" programme of sewage discharge improvements, South West Water plc (SWW) propose to develop a new STW at Falmouth.

The proposed site occupies part of a waste tip used by Falmouth Docks since the 1940s. SWW's preferred option for development requires excavation of approximately 26,000 m^3 of waste with disposal to United Mines Landfill (UML) at St. Day. The location of Falmouth Docks Tip (FDT) and UML is shown in Figure 1. The waste is a mixture of domestic waste, general industrial and commercial docks waste including shot blasting grits. It contains a wide range of organic and metal contaminants including organotin, PCBs, coal tars, mineral oils and mercury. SWW have approached Cornwall Waste Regulation Authority (CWRA) to seek their agreement for disposal at UML.

The UML site has recently been relicensed as part of the vesting of County Environmental Services (CES), the Local Authority Waste Disposal Company. CWRA have consulted with the NRA as statutory consultees on licence conditions. In line with the EC Groundwater Directive the NRA have objected to the inclusion of certain toxic wastes within the licence, due to the dilute and disperse nature of the landfill and potential risks presented to any future Wheal Jane treatment system. In particular, the NRA is objecting to the disposal of shot blast waste contaminated with organotin from Falmouth Docks which currently is disposed at the site.

In line with NRA objections to the disposal of toxic waste at UML the NRA are currently objecting to the disposal of the contaminated wastes from the FDT waste.

1.2 Objective

In order to support an objection to the disposal of the FDT waste at UML the NRA have undertaken an impact appraisal. The objective of the appraisal is to review the impact on the water environment of List 1 contaminants# already deposited at UML, and to consider any additional impact deposit of the FDT waste may cause.

Note: reference to List 1 compounds in this document refers to List 1 compounds as defined within the EC Groundwater Directive relevant to contaminants present in the FDT waste, unless otherwise specified.

1.3 Scope

The appraisal has been targeted to address the suitability of UML to accept the FDT waste. It does not consider the overall impact of UML on the water environment, or alternative options for site development or waste disposal.

In order to ensure the STW scheme is not delayed a limited period of three weeks has been available for the assessment work. The scope of works have been identified to meet the time restraints.

* Review of relevant legislation, waste management guidance and policies.

* Characterisation of the FDT waste from SWW site investigation findings.

* Assessment of the existing and potential impact of UML to the water environment from List 1 substances.

* Assessment of additional future impact for the disposal of FDT waste at UML.

* Recommendations for FDT waste disposal.

2. LEGISLATION BACKGROUND

A brief review of legislation, guidance and policy relevant to the disposal of the FDT waste is presented. The main areas of interest are; Site Licensing, EC Groundwater Directive, the NRA Groundwater Protection Policy, and DoE Guidance.

2.1 Site Licensing

UML was operated by Cornwall County Council Waste Disposal Authority under a resolution R4 (ref.1) dated 10 March 1977 until 1991. The site was then operated by a shadow LAWDC under a reviewed transition resolution. In September 1993 County Environmental Services was vested and a Waste Disposal Licence WM/2/2/111 (ref.2) has recently been issued. The Waste Disposal Licence will become a Waste Management Licence upon implementation of part II of the Environmental Protection Act programmed for 1 May 1994.

Cornwall County Council Resolution

The Resolution identifies standard conditions for a working plan, site preparation and works, and site operation. Relevant conditions include:

* It allows waste categories; domestic, commercial, industrial (including toxic and difficult), and liquid.

* Any well shaft, adit or springs within the site or its vicinity to be identified and watercourses on the site to be diverted, culverted or otherwise protected.

* A record to be kept of the types and quantities of toxic or difficult waste deposited.

* An alternative supply to be provided if any water source becomes contaminated as a result of tipping operations.

Current Waste Disposal Site Licence

The NRA are statutory consultees for Site Licence applications. Commenting on the United Downs Licence the NRA objected to the inclusion of waste categories D and F "unless the nature of such wastes as they arise from specified waste streams are shown subject to satisfactory safeguards to present no risk to ground or surface waters".

The Site Licence drawn-up by CWRA includes a number of conditions relating to types and quantities of waste, site preparation and works, site operation, environmental protection and monitoring and records. Conditions relevant to this assessment are discussed below:-

Waste Categories

The site is licensed to accept waste categories A to F (which includes most wastes from inert through to toxic) up to a maximum of 1,000 tonnes/day, 260,000 tonnes per year. Categories D - difficult wastes and F - toxic wastes are limited. Category G wastes are prohibited. The schedules listing conditions and limitations for Categories D, F and G are at Appendix 1. These have been drawn up by CWRA with reference to relevant Waste Management Papers and guidance from the DoE. In particular, the licence requires the EC Groundwater Directive (80/68/EEC) to be implemented restricting wastes accepted. Table 2.1 provides a summary of waste category restrictions relevant to the contaminants present in FDT waste.

Site Operation

Leachate produced within the site shall be controlled, treated and disposed of in accordance with the Leachate Management Scheme. As far as is reasonably practical, there shall be no drainage of leachate from the site other than to the existing drainage paths which lead to the Mount Wellington Adit, and associated adits to the north east of the site. An assessment of the present and future water balance to be undertaken within 4 weeks of the issue of the licence.

Leachate treatment to be by irrigation to land designated for such purposes. Suitability of land to be determined by an assessment. A contingency plan to be available should the treatment system result in pollution of surface waters.

Environmental Protection and Monitoring

The site licence requires an environmental monitoring plan to be provided 8 weeks following issue of the licence. The monitoring plan to undertake a number of assessments and identify monitoring programmes for; surface water, groundwater, leachate, leachate irrigation/recirculation, landfill gas, meteorological conditions and other monitoring. An environmental audit of monitoring data is required on an annual basis presented to CWRA.

Conditions are included within the licence (4.2.5 and 4.2.6) requiring the WRA and NRA to be notified immediately of any indication that pollution of surface or groundwaters occurs. Groundwater pollution to be identified relevant to the mine water contamination present. The licence holder to be responsible for carrying out all work necessary to alleviate any pollution caused by the waste site.

TABLE 2.1 Waste Category Restrictions and Prohibitions Relevant to FDTW

Category D - Difficult Wastes.		
Metals	-	Cadmium and mercury not in breach of EC Groundwater Directive.
		Mercury not >100 mg/kg organic mercury. Heavy metals not >50 kg/week except for contaminated soils acceptable as Category A.
Fuels, Oils and greases	-	only to landfill where other disposal means are not feasible.
	-	not >2.5 kg/tonnes of domestic waste, 0.6 tonnes daily, 100 tonnes per annum.
Oil Water mixes	-	not >0.4 kg/tonne of domestic waste.
Petrol, paraffin and derv	-	only in small quantities.
Tar and paint wastes	-	dry waste not to exceed $10m^3$ daily.
Any waste which would render leachate produced within the site unsuitable for treatment and disposal by the stated method.		
Any waste in Category G.		
Category F - Toxic Wastes		
50 litres or 50 kg soild weekly, 1250 litres of liquid or 1250 kg solid per annum providing wastes do not exceed Waste Management Paper guidance. WRA to be consulted where clarification required.		
Any waste which would render leachate produced within the site unsuitable for treatment and disposal by the stated method.		
Any waste contained in waste Category G.		
Category G - Prohibited Wastes		
Material which must not be disposed of by landfill.		
Polyhalogenated biphenyls and other substance having similar ecological consequences eg. PCBs.		
Substances which would result in infringement of EC Groundwater Directive. This includes organotin compounds.		

2.2 EC Groundwater Directive (80/68/EEC)

Under the Directive (ref.8) Member States are required to:-

* Prevent substances in List I from entering groundwater.

* Limit the discharge of List II substances into groundwater so as to avoid pollution.

The Directive applies to all usable groundwaters, whether or not they are developed for water supply. Exceptions to the Directive are:-

* discharges found to contain substances in List I or List II in a quantity and concentration so small as to obviate any future danger of deterioration in the quality of the receiving water.

* discharges of List I substance into groundwater which is found to be permanently unsuitable for other uses provided that other aquatic systems or ecosystems cannot be polluted by these substances and mineral exploitation is not impeded.

DoE Circular 20/90 October 1990 (ref.5) provided further guidance on implementation of the Groundwater Directive. The main guidance changes are:

* Further guidance on the classification of List I and List II chemicals.

* Classification of groundwaters to include water in the unsaturated zone.

As a result of the revised advice, WDA's were to review those disposal licences for landfill sites involving the disposal of wastes containing substances within List I of the Groundwater Directive. WDA's were required to seek the advice of the NRA as to the effect these sites may have on groundwater.

Where the NRA advises that discharges from a landfill site are liable to affect groundwater adversely and that such water is not permanently unusable, then the disposal licence should be reviewed.

2.3 NRA Groundwater Protection Policy

The NRA's Groundwater Protection Policy published in December 1992 (ref.14) provides policy objectives with respect to different types of threat to groundwater resources. Under Waste Disposal to Land the NRA requires all new domestic, commercial and industrial wastes on major or minor aquifers to be operated with engineered containment and with operational safeguards.

The NRA will also seek to ensure that adequate provision is made within a site licence for monitoring to protect controlled waters. Adequate provision must be made for long term maintenance and monitoring of leachate control and disposal system and for the integrity of any cap, basal or sides.

Regular liaison between the NRA and WRA is sought in reviewing waste licences and the NRA will advise the WRA on the surrender of a licence.

2.4 DoE Guidance

DoE guidance is published within Waste Management Papers (ref.6,7) and Circulars. Guidance on the co-disposal of difficult and toxic wastes is currently being reviewed. Current interpretation is perhaps best summarised by the reply by Jan Granow, DoE Wastes Technical Division to a letter from Mr O V Slater, Head of West Yorkshire WRA requesting guidance on "Disposal of Waste Containing List 1 Substances". This is a personal interpretation and not official guidance by the DoE.

The letter includes the following points:

* WRAs are implied as the competent Authority to ensure that waste licences are drawn to adequately protect controlled waters.

* At present the NRA is the competent Authority for implementation of the EC Groundwater Directive. After the Regulations are enforced in May 1994 it appears that the WRA will become the competent Authority for discharges associated with Landfills.

* The approach taken by the Groundwater Protection Policy is supported by the DoE. That is, the degree of containment depends on the vulnerability of controlled waters.

* Household and commercial wastes will inevitably contain List 1/Red List substances but are treated as being sufficiently polluting in other respects to merit containment in the majority of hydrogeological situations. So where wastes are known to contain List I/Red List substances and, as such are classified as special wastes, they should be assigned to a contained landfill.

* It is suggested that a contained landfill, close to the water table would be unacceptable for List 1 substances.

* Some type of an assessment of the impact of List 1 substances is required, including some calculation of leakage quantities and rates from a contained site and the effect of the unsaturated zone on the concentrations likely to reach the groundwater.

* In relation to depositing List 1/Red List wastes, loading rates should take account of the effect of these wastes on other wastes and the dilution provided by the rest of the fill and the Environmental Quality standard for the substance in the potential receiving water.

The DoE is hoping to produce revised guidance on Co-disposal before long.

A draft of Waste Management Paper No. 6 - PCB Treatment and Disposal Methods states that Landfill is not an acceptable method for disposing of PCB wastes other than in exceptional and limited cases involving very slightly contaminated material.

2.5 Relevance to United Mines Landfill

The recently issued site licence allows most of the List 1 contaminants identified in FDT waste to be accepted at UML providing the EC Groundwater Directive is complied with. In particular, organotin is only acceptable if it doesn't enter groundwaters. PCB contaminated wastes are not acceptable even though older household waste within the site is likely to contain measurable levels.

The mine waters beneath UML are generally not suitable for drinking without extensive treatment and no groundwater sources are present within the vicinity. In order for these waters to be exempt from application of the EC Groundwater Directive they must be permanently unsuitable for other uses and not impact on other aquatic systems or ecosystems. Whilst these waters may be unsuitable for other uses they discharge to the River Carnon and eventually Restronguet Creek and the Carrick Roads which are sensitive aquatic systems. Therefore, in the absence of further information the EC Groundwater Directive is considered to apply to groundwaters beneath UML.

UML is underlain by a minor aquifer. The site was designed and operated for more than 20 years prior to the Groundwater Protection Policy. It does not operate on a containment basis and there are limited leachate collection and treatment works.

The licence conditions reflect NRA, EC and official DoE guidance. Acceptance of List 1 substances is dependant upon the hydrogeological setting of the landfill. However, a cautious approach would normally suggest that where wastes are identified to contain significant levels of List 1 substances they should be only disposed at contained sites.

3. INVESTIGATION OF FALMOUTH DOCKS TIP WASTE

3.1 Site Investigation Findings

Ground conditions at the site have been assessed by Posford Duvivier Consulting Engineers on behalf of SWW (ref.11). They have undertaken an extensive two phase intrusive site investigation. The investigation aimed to characterise the geotechnical properties and extent of contamination of the landfill waste.

Boreholes confirmed between 9 and 12.5m of made ground overlying slate bedrock. Two distinct layers of made ground have been identified as shown in Table 3.1.

TABLE 3.1 Waste Description

	Thickness(m)	Description
Upper Layer	4.5 - 5.0	MADE GROUND - loose light to dark brown sandy silty clay with angular slate gravel, metals, cable, timber, rope, plastics, glass, fabrics, electrical fittings, paint and oil cans, bagged domestic refuse and fertilizer sacks.
Lower Layer	8	MADE GROUND - dense grey fine to coarse angular weathered mudstone/slate gravel in a firm grey brown silty clay matrix (reworked slate) with isolated pockets or layers of loose black sand to grey ash (blast grit) and minor quantities of industrial and domestic refuse.

The investigation confirmed the predominantly dry nature of the tip material. Shallow seepage of oily water representing perched leachate levels are recorded on some trial pit logs. Boreholes identify the interface of the waste with the original rock beach at sea level. Water levels monitored reflect the tidal flushing in the base of the waste. This will have resulted in considerable leaching of contaminants from the base of the wastes.

Soil and water samples were analysed for a wide range of inorganic and organic determinands which included organotin (speciation only carried out on water samples), PCBs, metals (including mercury), coal tar derivatives, mineral oils, and toluene extractable matter.

The investigation identified that the lower layer is predominantly well consolidated uncontaminated soils and rock waste. Pockets of shot blast material and other wastes are present. The upper layer is poorly consolidated general wastes containing a wide range of contaminants.

For geotechnical and contamination purposes SWW propose to remove only the top layer of waste to UDL. The lower layer will remain on site with minimal disturbance.

3.2 Characterisation of the Upper Layer

The analytical results have been compared with two sets of published reference standards; the Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL-ref.10); and Dutch Criteria Index for Assessing Soil and Groundwater Contamination (DUTCH). These guidelines are used to provide an indication of contamination to aid evaluation of a site, but they have no legislative status.

ICRCL guide levels have been devised principally for public health protection. They provide no standards for protection of waters. The Dutch guidelines do provide standards for protection of groundwaters as well as soils. However, they relate to protection of the Dutch shallow aquifers and are therefore more stringent than is often appropriate in a UK context.

The analytical results are presented in Appendix 2. The table has been shaded where a parameter exceeds the relevant ICRCL threshold for hard cover or the Dutch Level C standard. Dutch level C is the assessment value above which the pollutant should be treated.

The table shows that a number of trace metals and organic substances are substantially above action levels. Since UML is located within an area of metalliferous mining the high metal levels within the waste are not of concern. However, the organics identified are significant and are discussed below.

Table 3.2 summarises and evaluates organic contaminant levels in the upper 4.5m of waste.

TABLE 3.2 Comparison of Contaminant Levels

CONTAMINANT	MAXIMUM LEVEL mg/kg	GUIDELINE ICRCL (hard cover) mg/kg	GUIDELINE DUTCH 'Level C' mg/kg	% SAMPLES EXCEEDING ICRCL/DUTCH GUIDELINES
Organotin	0.48	NS*	NS*	77
PCB	19.7	NS	10	7
Mercury	36.6	20	10	6
Coal Tar Derivatives	200000	1000	NS	55
Mineral Oil	52751	NS	5000	5
TEM	31900	NS**	NS**	10

NS - Not specified
* - Taken as > laboratory detection limits.
** - Taken as > 10000 mg/kg

In assessing the level of contamination of a site analytical results should not be averaged and hot spots of contamination investigated further. However, in order to attempt to quantify the amount of exotic contaminants within the wastes for disposal purposes, Posford Duvivier have interpretated their investigation results to calculate approximate mean levels of the "exotic" contaminants. They have assumed an excavation volume of 26,000 m^3 and a unit mass of waste as 2000 kg/m^3, and ignored unrepresentative values. Table 3.3 lists contaminant levels. The methodology and assumptions are included in Appendix 3.

TABLE 3.3 Estimation of Contamination Total Mass in Waste

Contaminants	No. of Analysis	Det. Limit (mg/kg)	Range of Conc. (mg/kg)	Average Conc. (mg/kg)	Total Cont. in Waste (kg)
Organotin	28	0.003	<0.003-0.48	0.043	2
PCB	52	0.001	<0.001-19.7	0.999	52
Coal Tars	21	10	<10-9240	1268.6	65,970
Mineral Oils	66	0.1	<0.1-12796.7	491.8	25,573
Mercury	66	0.5	<0.5-36.6	2.12	110
Toluene Extract	66	10	<10-37,763	1370.4	71,263
				TOTAL	169,874 kg

These figures must be used with caution. For instance, a large volume of asbestos waste is understood to have been disposed but only a small part of which was located by the site investigation. It should also be noted that the averaged contaminant levels are skewed due to one or more very high concentrations particularly for TEM, mineral oil and coal tar derivatives. No speciation of total organotin was carried out.

A tentative segregation of contaminants within the waste can be made. PCBs were identified in the north of the site and are interpreted by Posford Duvivier to be associated with free oils draining between the upper and lower layer interface. Metal contamination is pervasive throughout the waste. The highest mercury levels are identified in the north of the site. Hydrocarbon and organotin contaminants, although widespread appear to be concentrated as hot spots associated with zones of a particular waste type e.g. blasting grit or oil drums.

4 INVESTIGATION OF UNITED MINES WASTE DISPOSAL SITE

4.1 Background

Site History

The area now forming UML was one of the most intensively mined areas of Cornwall in the 18th and 19th Centuries (ref.4). Approximately 50 shafts have been identified within the site boundary associated with extensive stopes and other mining features. An arsenic works operated on part of the site.

Prior to the second World War the site is understood to have been a race track and during the War the Americans used an area adjacent to the site as an army base. Apparently mine shafts in the area were a convenient dumping point for army waste. Also according to mining references the site was open cast mined down to depths of 10 to 20 metres at this time.

The site was first used as a tip on a regular basis in the 1970's by Cornwall County Council. Waste control is understood to have been haphazard and no waste acceptance records have been obtained.

Waste controls were introduced in 1979 when the first Watchman was put on the gate.

The weighbridge was installed four years ago and strict waste inspection procedures enforced.

Waste Records

No waste records have been obtained for disposal prior to 1992. Between September 1992 and August 1993 the following volumes of waste were disposed at UML.

	Tonnes
Inert soils etc.	3,707
Construction	91,243
Industrial	40
Domestic Waste	165,791
Asbestos	197
Clinical	101
Total	261,079

The asbestos waste figure also includes category F any toxic liquid wastes accepted. Following discussion with CES and CWRA personnel the total amounts of toxic wastes accepted are considered to be less than the licensed quantity of 50 kg per week, 1250 kg of substances per year.

Input of List 1 Compounds

List 1 compounds will have been disposed at UML within its Resolution as difficult and special wastes and also within the "black bags" and skips as domestic wastes.

Due to the small proportion of licensed special wastes to domestic wastes accepted, it is likely that the majority of List 1 substances within the waste at UML arise from within "domestic" waste.

DoE research published within Waste Management Papers identifies waste and leachate from typical domestic waste sites to contain the contaminants identified in the FDT waste at the following levels:

Organotin	Site dependent
PCBs	7 mg/l in leachate from 1970's waste insignificant in present waste
Mercury	2g/tonnes in waste
Coal Tar	No references
Mineral Oils	10 mg/l in leachates

Falmouth Docks produce a large amount of shot blast waste contaminated with organotin paint fragments. Prior to 1987 it is understood that this waste would have been disposed at FDT. Since 1987 this material has been taken to UML.

Dock records reviewed by the CWRA show that between 1978 and 1987 approximately 20,000 tonnes were disposed at FDT. Since 1987 approximately 35,000 tonnes of shot blast waste was disposed at UML.

The CWRA review estimated typical paint contamination to be about 2% by weight. Within the paint the active ingredient of organotin is up to 5%.

Falmouth Docks also consider that only about 20% of the shot blast waste is contaminated with organotin paints, although levels would have been higher in waste from the 1970's and 1980's.

Based on the above information the amount of organotin in each landfill is as follows:

FDT - 20,000 tonnes shot blast waste - 4 tonnes organotin.
UML - 35,000 tonnes shot blast waste - 7 tonnes organotin.

The investigation of FDT waste identified a total organotin amount of approximately 0.002 tonnes. The organotin in FDT waste is between 7 and 15 years old and will have degraded and been leached. However, perhaps the wide disparity between amounts disposed and those identified illustrates the difficulty in making comparisons.

The DoE are currently commissioning a research project to ascertain the composition of leachates at sites throughout the Country. This is due for publication next spring. However, a summary of Red List analysis from 30 landfill leachates is at Appendix 4. These show the variability of substances within leachate from site to site. They also emphasise that most landfills accepting only domestic waste will contain some List 1/Red List substances.

4.2 Water Quality Investigation

Fieldwork Programme

Within the projects short timescale a limited programme of fieldwork investigation was undertaken at and surrounding UML on the 30 November and 1 December 1993. The main objective was to try and identify the impact of UML on controlled waters with respect to the List 1 contaminants present in the FDT waste.

The fieldwork included:

* Walkover survey of the site guided by CES personnel.
* Sampling of 9 groundwater boreholes and 3 streams.
* Measurement of groundwater levels in boreholes.
* Review of leachate drainage and treatment system.
* Sampling of leachate sump and collection of leachate for Wheal Jane bench tests.

Collection of a further 8 stream and adit water samples was undertaken by the Wheal Jane Project Team on two occasions, 25 October and 30 November 1993.

Sampling locations are shown in Figure 2.

Leachate Samples

A single leachate sump is present at the southern end of the site. It collects only a small proportion of the leachate generated by the site. The samples of leachate collected were very dilute indicating surface water was also being collected by the leachate drain.

Borehole Samples

There are 19 boreholes surrounding UML of which 2 are blocked. No records for drilling logs or borehole completions have been obtained. Due to the extensive mining throughout the area the boreholes are not considered to provide an effective means of monitoring the groundwater quality surrounding the site. Even with a comprehensive mining survey it is likely to prove impossible to assess the relevance of each borehole to the complex groundwater regime beneath the site.

Given the concerns of obtaining representative groundwater samples, and the short fieldwork programme only 9 of the boreholes were sampled (BH's W1, W4, W5, W6, W7, W8, W13, W14 and W17). They were selected by reviewing previous chemical sampling data provided by CES choosing the most contaminated boreholes and an even distribution around the site.

The boreholes are completed with 100mm diameter casing preventing the effective use of the Waterra sampling system. Due to the depth of boreholes and unknown logs/completion etc. a limited purge sampling programme was considered acceptable. 20 litres of water was purged using the CES bailer prior to a sample being taken with a clean NRA bailer.

Surface Water Ditch Samples

Surface water streams are present along the western and eastern boundaries of the site. They drain to the Hicks Mill Stream. A sample was taken of the western stream adjacent to the leachate sump (S3). Two samples of the eastern stream were taken from above the road crossing, one from the main surface water ditch (S4B) and the other from a side stream which drains an adit?/fields to the south east of the landfill (S4A).

Mine Samples

Samples were taken from No. 2 shaft at Wheal Jane (after addition of lime), at Nangiles Adit Portal in the Wheal Jane system and at the County Adit portal.

Watercourse Samples

Samples were taken from the Carnon River at Twelveheads (above the County Adit), Bissoe Bridge (below Nangiles Adit) and Devoran Bridge (mouth of the Carnon River). Samples were also taken of the Hicks Mill and Hale Mills Streams.

Sample Analysis

All samples were analysed by the NRA's Exeter Laboratory.

A standard sanitary/metals suite was specified to establish the general water quality around and beneath UML.

An organics suite was also included to establish whether List 1 substances are being leached from the site, and to assess the fate of these compounds within the local groundwater/mine water drainage systems. In particular, samples were analysed for organotin with speciation to identify levels of tributyltin (TBT), dibutyltin (DBT), monobutyltin (MBT) and triphenyltin (TPT). Also analysis of PCBs and a general suite of organics by GCMS was undertaken.

The samples collected from Wheal Jane and the Carnon Valley were only analysed for organics. Samples collected on the 25 October 1993 were not analysed for PCBs.

4.3 Water Quality Results

A summary of water quality results for the UML site is shown in Figure 3 and for the Wheal Jane area in Figure 4. Water quality data is at Appendix 5.

Leachate

The sample is not considered to be representative of the bulk of the leachate generated by the site. The analytical results are typical of a weak diluted leachate with elevated EC, ammonia, BOD and metals. No organotin compounds were identified, although a PCB congener was detected at 2 ng/l. Several organic compounds were identified using GCMS analysis. The compounds are listed in Appendix 5.

Groundwater

The groundwater sample analyses have been compared with the EC Drinking Water Directive. These specify maximum admissible concentrations (MAC) for different chemical determinands.

The pH is acidic in all the groundwater samples ranging between 3.1 and 6, exceeding MAC levels in 6 of the 8 boreholes. EC is at background (350 μs/cm) throughout with the exception of boreholes W6 (1160 μs/cm) and W8 (1130 μs/cm) which are at nearly four times background. Metals are elevated in all samples but particularly in boreholes W6 and W8 with levels of Ni (up to 1.7 mg/l), Fe (72 mg/l), Zn (109 mg/l), and Al (80 mg/l). The Cd level in borehole W6 (250 μg/l) is 50 times the MAC standard. Significant levels of inorganic contamination was not identified indicating that the boreholes may not be monitoring the mine waters into which the bulk of the leachate is draining.

Organotin compounds were identified at boreholes W13 and W14. 16 ng/l of TBT and 281 ng/l of DBT was measured at borehole W13 and 88 ng/l of DBT and 90 ng/l of MBT was measured at borehole W14. All other organotin compounds were below detection limit. Other organic substances were identified by GCMS in boreholes W6, W13 and W14 at trace levels, less than 2 μg/l. No PCBs were detected.

Surface Water Ditches

Both the surface water ditches along the eastern and western boundaries of the site were uncontaminated. The western stream sampled at S3 had slightly elevated ammonia (0.48 mg/l) and conductivity (419 μs/cm) but was otherwise of good quality. The eastern stream sampled at S4 A and B was inorganically clean, but 54 ng/l of MBT was identified. Trace levels of solvents were identified in both streams.

Mine Adits/Pumped Shafts

30 November samples: TPT was identified at 13 ng/l (at detection limit) in Shaft No. 2. No other organotin compounds were identified. GCMS identified trace levels of other organic compounds at No. 2 Shaft. No PCBs were identified.

25 October samples: No organotin compounds were identified in any of the mine discharges. Trace levels of alcohols were identified at Nangiles Adit and No. 2 Shaft. No PCBs analysis was carried out.

Watercourses

30 November samples: No organotin compounds were detected within the watercourse samples. GCMS identified trace levels of organic compounds and throughout the catchment at up to 10 μg/l. A PCB congener was identified at 1.6 ng/l in the River Carnon at Devoran.

25 October samples: No organotin compounds were detected within the watercourse samples. GCMS identified trace levels of organic compounds within the Carnon Catchment below Twelveheads up to 4 μg/l. Analysis for PCBs was not undertaken.

4.4 Leachate Drainage

Waste disposal has been occurring at UML since the 1970's and only relatively recently has the landfill design included any provision for leachate collection and treatment.

A leachate drain is present along the western boundary of the site draining to a leachate sump. Leachate is pumped from the sump and spray irrigated over an area of restored landfill in the north western corner of the site (see Figure 5). However, this leachate drainage and treatment system only picks up a small amount of the leachate generated by the site. An approximate water balance calculation undertaken by consultants for CES indicates that UML generates about 166,000 m^3 of leachate per year. The leachate drainage system collects approximately 14,000 m^3 per year the majority of which also eventually drains into underlying mine workings.

Therefore, it is clear that UML is not a containment site. Leachate drainage may occur to:-

* Underlying Mine Workings - Wheal Jane/County Adit.
* Perched groundwaters draining to the Hicks Mill Catchment.
* Breakout to surface water ditches draining to the Hicks Mill Stream.

Discussion of these drainage routes follows:

Leachate Drainage via Underlying Mine Workings

UML is underlain by abandoned workings of the United Mines Sett. These workings are on a WSW-ENE lode system which extends up to 6km in length. The lodes have been extensively worked and many of the individual mines are interconnected underground with common mine drainage. A schematic diagram showing relevant mine features and drainage is included as Figure 5.

At the end of its active underground mining phase, United Mines was drained via a branch of the County Adit system which discharges to the Carnon River below Twelveheads. Standing water levels in the mine after abandonment are believed to have been about 32m AOD (ref.4).

NRA investigations in the area after the closure of Wheal Jane Mine suggested that the County Adit crosscut branch which drained United Mines was blocked by a rockfall about 200-300m south of Coads shaft at an elevation of about 24m AOD. County Adit invert level for the United Mines workings was estimated to be approximately 24-25m AOD (ref.13).

The more recent development of Wheal Jane and Mount Wellington Mines in the 1970's and 1980's changed the established drainage pattern in the adjacent abandoned workings. Much of the United Mines sett was dewatered by the Wheal Jane/Mount Wellington pumps. By the time Wheal Jane closed in 1991, all three mines were interconnected.

The recovered water level in Wheal Jane is currently held at about 16m AOD by an NRA pumping/treatment operation. Water pumped from No. 2 Shaft at Wheal Jane discharges to the River Carnon at Bissoe Bridge after treatment. In the event of heavy rainfall or pump failure, discharge of mine water occurs directly to the River Carnon via Nangiles Adit.

All the mine shafts on the United Mines site have been capped since the closure of Wheal Jane and no direct observation of mine water levels below the site has been possible. Borehole water levels measured during the NRA investigation in November 1993 suggest the groundwater beneath the majority of the site is at a similar level to Wheal Jane i.e. 16-18m AOD. See Figure 5. Figure 6 shows the annual fluctuation in groundwater level in some of these boreholes. Therefore for the majority of the year groundwater levels are well below the 24-25m AOD invert level required for drainage along the County Adit.

Groundwater levels monitored to the south and west of the site are slightly higher ranging between 20 and 27m AOD (with the exception of W5 and W7). These may be higher due to the natural ground or mine systems being less well connected with the main United Workings resulting in a hydraulic gradient. In general, they still remain below the level of the County Adit.

However, although the County Adit is above the water level within United Mines it is possible that some surface drainage, including leachate will be preferentially drained to the County Adit. Due to the large areas of stoped workings and extent of connection between levels it is estimated that only a small proportion of leachate drains to the County Adit. Considerable further hydrogeological investigation work would be required to properly identify the drainage routes.

Leachate drainage into the main United Workings will be substantially diluted by mine waters. It will emerge at Wheal Jane via the pumps in No. 2 Shaft or at Nangiles Adit Portal discharging into the Carnon River.

As a very approximate estimate if all UML leachate drains to Wheal Jane 166,000 m^3 leachate will be diluted by 6,000,000 m^3 mine water or a dilution of 1:36 on an annual basis.

Leachate drainage into the County Adit must drain through a suspected blockage down to the portal at Twelveheads discharging into the Carnon River. The average annual flow in the County Adit is similar to the discharge from Wheal Jane. If all UML leachate drains down the County Adit a similar dilution of 1:36 is estimated.

Perched Groundwater draining to the Hicks Mill Catchment

The southern part of UML may not be underlain by the main United Mine workings. Leachate in this area could drain through shallow drainage systems emerging to the Hicks Mill Stream.

Groundwater levels recorded in boreholes along the southern boundary of the site are between 20 and 27m AOD. Whilst this is above levels measured in boreholes to the north it is well below the valley base at approximately 45m AOD.

However, there remains the possibility of shallow leachate drainage to the Hicks Mill Stream which requires detailed investigation.

Breakout to Surface Water Ditches

This is controlled by the management of the site. Sample results indicate that there is no significant breakout of leachate to surface water ditches at the present time.

5. IMPACT APPRAISAL

5.1 Assessment of United Mines Landfill

The following assessment can be made:-

* The leachate from UML is likely to contain small quantities of List 1 substances including organotin.

* The site is not contained and leachate drains into the underlying mine workings. The leachate system only collects a small proportion of leachate generated by the site.

* No representative sampling points are currently available for leachate generated within the deposited wastes or groundwaters on major drainage pathways in the vicinity of the site.

* The dilute leachate sample analysed from the collection sump is not considered representative of leachate produced by the site. Therefore, it is not possible to assess the attenuation of contaminants within the landfill site or the discharge of List 1 substances into underlying groundwaters.

* Sampling of groundwaters and surface water ditches showed organic substances to be largely absent with the exception of organotin (including TBT). In the absence of further information the EC Groundwater Directive is considered to apply to groundwaters beneath UML.

* It is possible that contaminants detected within monitoring boreholes surrounding UML may not arise from leachate generated by UML. There are numerous shafts in the vicinity of the site which have been backfilled with flytip waste, some of which will leach List 1 substances.

* "Perched" leachate drainage or breakout to surface water ditches draining to the Hicks Mill Stream is possible, although there is no supporting evidence. The Hicks Mill Stream is of good water quality not significantly affected by mining discharges. There are no migratory fish due to the poor quality of the Carnon River downstream. The stream runs through a number of residential gardens and has general recreational interests. No leachate was identified draining to surface water ditches.

* Leachate drainage routes within the mine workings is unknown, although it is postulated that the majority of leachate will emerge to Wheal Jane, the remainder draining to the County Adit. The leachate will be diluted by approximately 1:36.

* Leachate draining to Wheal Jane is at present pumped and treated by the NRA funded mine water treatment operation. Samples showed no significant levels of organics, although an organotin (TPT) was identified at the detection limit. TPT is derived from antifouling paints or agricultural fungicides. UML is one possible source. Approximately 8 million pounds is being spent on the present treatment system and a pilot scheme to identify a long term treatment system. This may include biological treatment which may be affected by low levels of exotic organics. The Wheal Jane Project Team are presently assessing the potential impact.

* Leachate draining to the County Adit will emerge to the Carnon River at Twelveheads. The County Adit discharges metal rich water which may eventually be treated by a long term system with the Wheal Jane discharge. The presence of organics must not jeopardise the possible treatment system. In particular, TBT or TPT and its toxicity at very low levels is of particular concern.

* The Carnon River, into which leachate most likely drains, is a poor quality river rich in metals. It is devoid of fish although its biological water quality is generally good. If the discharges from Wheal Jane and the County Adit are treated in the future the Carnon River must be protected from organic contaminants. The EQS for TBT and TPT in freshwaters is 20ng/l.

* The Carnon River drains into Restronguet Creek, the Carrick Roads and the Fal Estuary. These estuarine waters have a number of uses which require protection. The EQS for TBT and TPT in salt water is 2ng/l and 8ng/l respectively.

5.2 Comparison of Falmouth Docks Tip Waste with United Mines Landfill Waste

The following assessment can be made:-

* FDT waste was generated from waste arising at Falmouth Docks between 1970 and 1987. After 1987 this waste stream was deposited at UML. It is likely the earlier docks wastes had higher levels of List 1 substances, especially PCBs than later docks waste, but in general similar wastes to FDT waste have historically been accepted at UML.

* Best estimates suggests approximately twice the amount of organotin waste has been disposed at UML than FDT. FDT investigations identified only 2 kg of organotin. No assessment of the speciation of organotin is possible. Any comparison in the levels of organotin within the two sites must be treated with caution since degradation and leaching will be site dependent.

* PCBs have been identified at a mean concentration of 1 mg/kg within FDT waste with an estimated total quantity of 50 kg. Typical leachates from 1970's waste contain 7mg/l. Therefore, whilst PCBs are present they are not unusually high for waste tips of this age. The level of PCBs within UML is difficult to predict. Older wastes may have significant levels, but levels in modern waste are expected to be insignificant. 2 ng/l was identified in the leachate sump.

* The oils present within FDT waste are also likely to be present in significant quantities in UML from marine oil spills, black bags etc.

* The origin of the coal tars present in FDT waste is not known. Coal tars may be present in UML from gas works waste, although no records have been obtained.

* The elevated levels of trace metals within FDT waste are not of concern due to the metalliferous mining setting of UML.

* Mercury wastes have only been identified in the northern corner of FDT at concentrations up to 37mg/kg. The concentration in UML may be expected to be an average of 2g/kg.

5.3 Additional Impact of United Mines Landfill by the Disposal of the Falmouth Docks Tip Waste

The following assessment is made:

General Wastes

* Disposal of 26,000 m^3, approximately 52,000 tonnes of general domestic, industrial, commercial and inert waste represents approximately 20% of the total annual waste accepted at UML.

* The high proportion of inert and semi inert wastes to domestic waste will result in a weaker than average leachate generated.

* The elevated metal contaminants within the waste will not impact upon groundwaters due to high "natural" background levels.

PCB Wastes

* The absence of tipping records and waste controls in the early years of waste disposal at UML makes it impossible to predict the additional impact of 50kg of PCBs. However, PCBs are generally not easily leached and levels in the FDT waste are likely to be below those within old waste already present in UML.

Organotin Wastes

* TBT has been identified in an isolated sample beneath the site and TPT has been identified at Wheal Jane No. 2 Shaft. They are both below the EQS for freshwaters and have not been detected in watercourses. DBT and MBT are considered much less toxic to the aquatic environment than TBT or TPT.

* As a theoretical calculation ,if it is assumed that all the 2 kg of organotin identified in FDT waste is TBT, and also that this leaches with no further attenuation or degradation over a period of one year then:-

  2kg TBT would be diluted by 166,000m^3 of leachate = 12ug/l

  If it is further assumed that this drains to Wheal Jane with no further degradation, then:-

  at 1:36 dilution Wheal Jane discharge = 344ng/l

  The EQS for freshwater is 20ng/l and for salt water 2ng/l

  In practice, TBT is easily degraded by photochemical, chemical and biodegradative processes. The half life of TBT in aerobic soils is 105-140 days and in anaerobic soils 815 days (ref.12). Some evidence of this is seen in the analytical results which show much higher levels of the degradation products, DBT and MBT in the groundwater adjacent to the site than TBT.

* Additional monitoring of representative sampling points is required together with an understanding of leachate drainage away from the site. Only then will it be possible to reasonably assess the level of TBT degradation and therefore the impact of additional wastes.

Oil Waste

* Providing the wastes are well distributed within the site the additional oils will not result in an additional threat.

Coal Tar Wastes

* The additional threat from disposal of the coal tars cannot be assessed. However, given the relatively low concentrations present in FDT waste and the large volumes of domestic waste disposed at UML they are not considered to present a significant additional threat.

Mercury Wastes

* The small amount of mercury waste within FDT waste is not considered to present a significant additional threat at UML.

6. CONCLUSIONS AND RECOMMENDATIONS

* Falmouth Docks Tip (FDT) waste is slightly contaminated with PCBs. Average levels are below those which would be expected in a domestic landfill containing 1970s waste. United Mines Landfill (UML) Waste Disposal Licence does not allow PCBs to be accepted within the site.

* Wastes containing organotin and other List 1 substances are acceptable at UML providing their disposal does not result in the site contravening the EC Groundwater Directive and disposal is in accordance with Site Licence conditions.

* The EC Groundwater Directive is considered to apply to the disposal of wastes at UML.

* The limited sampling investigation undertaken by the NRA identified organotin including tributyltin (TBT) compounds in the groundwater adjacent to the site. GCMS analysis identified other List 1 compounds were at trace levels or below. If the organotin is draining from the site at significant levels then the EC Groundwater Directive is being breached.

* The amount of organotin within the FDT waste maybe significant dependant upon its degradation within the landfill and mine drainage system. This can only be assessed following additional monitoring of representative sampling points.

* The leachate and groundwater sampling points surrounding the site are not considered to allow the impact of the site to be effectively monitored. The hydrogeological setting of the site is such that in practice effective monitoring may not be possible.

* The leachate drainage beneath the site is poorly understood. The majority of leachate is considered to flow through mine workings to Wheal Jane. Leachate may also drain via the County Adit and potentially in shallow perched groundwaters to the Hicks Mill Catchment.

* Only 2 sets of samples from adit and shaft discharges have been analysed for organics. Triphenyltin (TPT) has been identified in Wheal Jane No. 2 Shaft on one occasion. Other exotic organics have been identified at low levels. UML is only one possible source of the contamination.

* A long term biological treatment system is planned for discharges from Wheal Jane and possibly the County Adit. There is potential for TBT/TPT contaminated wastes disposed at UML to result in TBT/TPT contamination at Wheal Jane. Considerable dilution and degradation would be expected.

* No organotin contamination has been identified within watercourses. A range of other exotic organics have been identified throughout the catchment at low levels. These may be from a variety of sources.

Recommendations for Disposal of Falmouth Docks Tip Wastes

This report supports the following recommendations:-

* Wastes contaminated with measurable levels of PCB cannot be disposed at United Mines Landfill unless the Waste Disposal Licence is modified.

* Wastes containing organotin species tributyltin or triphenyltin contamination should not be disposed at United Mines Landfill unless it can be demonstrated that the EC Groundwater Directive will not be breached.

* There are no objections to the disposal of other wastes (as identified) at United Mines Landfill providing they are deposited within the conditions of the Waste Disposal Licence.

* It is recognised that PCB and TBT contaminated waste is present at low levels throughout Falmouth Docks Tip and it may prove impractical to separate from the bulk of the wastes. If this is correct the waste should not be disposed at United Mines Landfill unless the above concerns are overcome.

* Discussion is required between Cornwall Waste Regulation Authority, County Environmental Services, and the NRA to identify representative sampling points to allow the impact of the site to be effectively monitored.

7. REFERENCES

1. Cornwall County Council Waste Disposal Resolution (R4) - 10 March 1977 - United Mines Refuse Disposal Site, St. Day.

2. Cornwall Mining Services June 1991 - United Downs Waste Disposal Site. Preliminary Mine and Groundwater Assessment.

3. Cornwall Waste Regulation Authority - Waste Disposal Licence No. 2/111 United Mines Landfill Site.

4. Dines H.G. 1956 - The Metalliferous Mining Region of South West Region. HMSO London.

5. DoE Circular 20/90 - 1990.

6. DoE - Waste Management Papers No. 26. 1986.

7. DoE - Waste Management Paper No. 6. Draft 1993.

8. EC Directive on Protection of Groundwater Against Pollution Caused by Certain Dangerous Substances (80/68/EEC) 1982.

9. EC Directive relating to the Quality of Water Intended for Human Consumption (80/778 EEC) DoE 1982.

10. Inter Departmental Committee on the Redevelopment of Contaminated Land No. 59/83 July 1987.

11. JWH Engineering Geologists November 1993 - Falmouth Land Site Investigation - Report No. 1480.

12. Lund M.A. Date unknown - The Disposal of TBT Wastes to Land - AEA Technology, Harwell.

13. Marcus Hodges Environment July 1991 - Wheal Jane Hydrogeological Impact Assessment.

14. National Rivers Authority Dec. 1992 - Policy and Practice for the Protection of Groundwaters.

15. WRc 1988 - Proposed Environmental Quality Standards for List II Substances in Water Organotins - TR255.

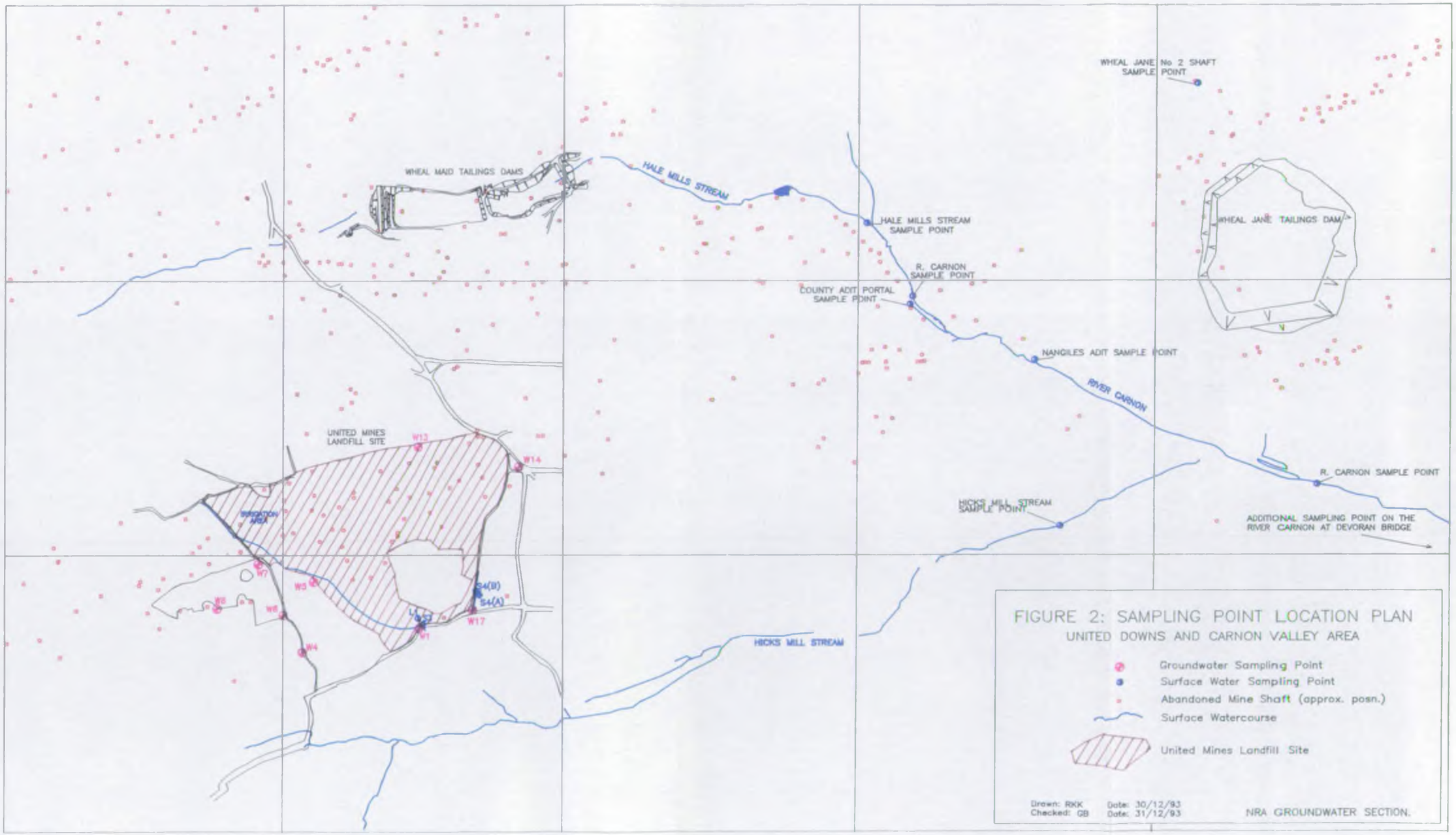
FIGURE 1: WASTE SITES LOCATION PLAN

- FALMOUTH DOCKS TIP
- UNITED MINES LANDFILL
- WHEAL JANE SITE

SCALE: 1:50 000

Drawn: RKK Date: 30/12/93
Checked: GB Date: 31/12/93

NRA GROUNDWATER SECTION.


WHEAL MAID TAILINGS DAMS
HALE MILLS STREAM
HALE MILLS STREAM SAMPLE POINT
R. CARNON SAMPLE POINT
COUNTY ADIT PORTAL SAMPLE POINT
NANGILES ADIT SAMPLE POINT
RIVER CARNON
WHEAL JANE No 2 SHAFT SAMPLE POINT
WHEAL JANE TAILINGS DAM
UNITED MINES LANDFILL SITE
W12
W13
W14
W15
W16
W17
W1
W2
W3
W4
W5
W6
W7
S4(B)
S4(A)
HICKS MILL STREAM
HICKS MILL STREAM SAMPLE POINT
R. CARNON SAMPLE POINT
ADDITIONAL SAMPLING POINT ON THE RIVER CARNON AT DEVORAN BRIDGE
FIGURE 2: SAMPLING POINT LOCATION PLAN
UNITED DOWNS AND CARNON VALLEY AREA
Groundwater Sampling Point
Surface Water Sampling Point
Abandoned Mine Shaft (approx. posn.)
Surface Watercourse
United Mines Landfill Site
Drawn: RKK Date: 30/12/93
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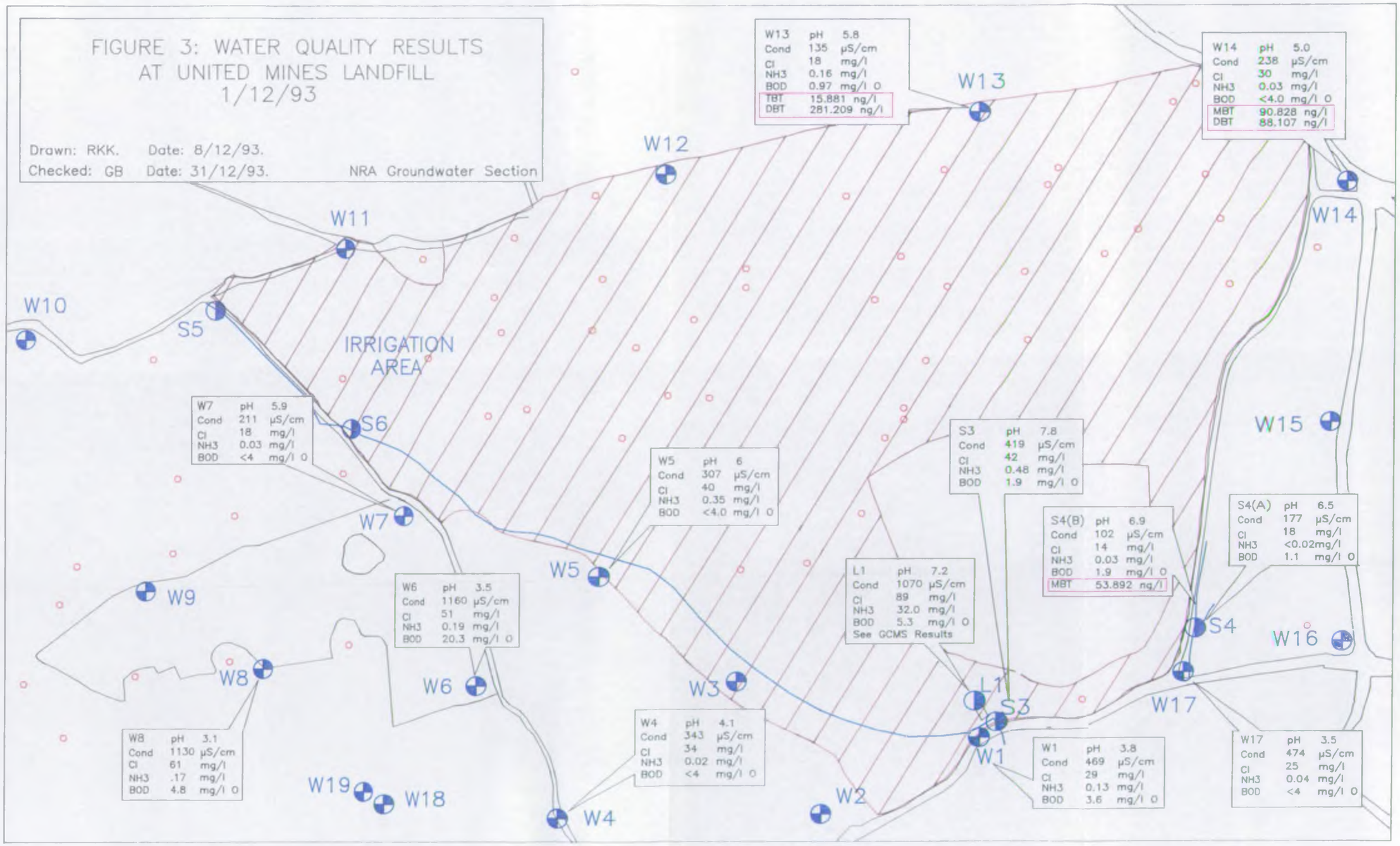
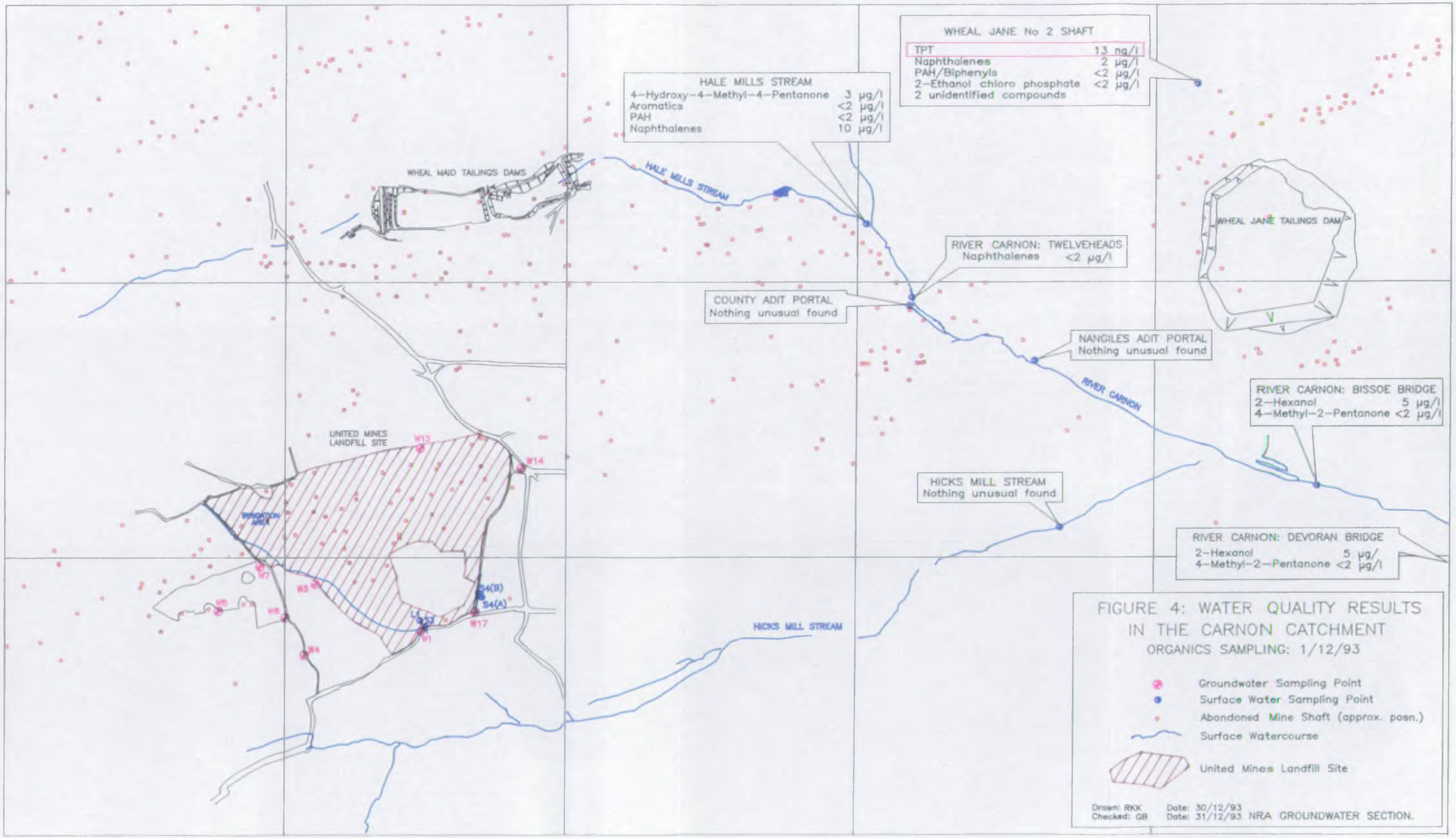
NRA GROUNDWATER SECTION.

FIGURE 3: WATER QUALITY RESULTS AT UNITED MINES LANDFILL 1/12/93

Drawn: RKK. Date: 8/12/93.
Checked: GB Date: 31/12/93. NRA Groundwater Section




WHEAL JANE No 2 SHAFT
TPT 13 ng/l
Naphthalenes 2 µg/l
PAH/Biphenyls <2 µg/l
2-Ethanol chloro phosphate <2 µg/l
2 unidentified compounds
HALE MILLS STREAM
4-Hydroxy-4-Methyl-4-Pentanone 3 µg/l
Aromatics <2 µg/l
PAH <2 µg/l
Naphthalenes 10 µg/l
WHEAL MAID TAILINGS DAMS
HALE MILLS STREAM
RIVER CARNON: TWELVEHEADS
Naphthalenes <2 µg/l
COUNTY ADIT PORTAL
Nothing unusual found
WHEAL JANE TAILINGS DAM
NANGILES ADIT PORTAL
Nothing unusual found
RIVER CARNON
RIVER CARNON: BISSOE BRIDGE
2-Hexanol 5 µg/l
4-Methyl-2-Pentanone <2 µg/l
UNITED MINES LANDFILL SITE
W13
W14
IRRIGATION AREA
W7
W6
W5
W4
W3
W1
S4(B)
S4(A)
W17
HICKS MILL STREAM
HICKS MILL STREAM
Nothing unusual found
RIVER CARNON: DEVORAN BRIDGE
2-Hexanol 5 µg/
4-Methyl-2-Pentanone <2 µg/l
FIGURE 4: WATER QUALITY RESULTS IN THE CARNON CATCHMENT
ORGANICS SAMPLING: 1/12/93
Groundwater Sampling Point
Surface Water Sampling Point
Abandoned Mine Shaft (approx. posn.)
Surface Watercourse
United Mines Landfill Site
Drawn: RKK Date: 30/12/93
Checked: GB Date: 31/12/93 NRA GROUNDWATER SECTION.

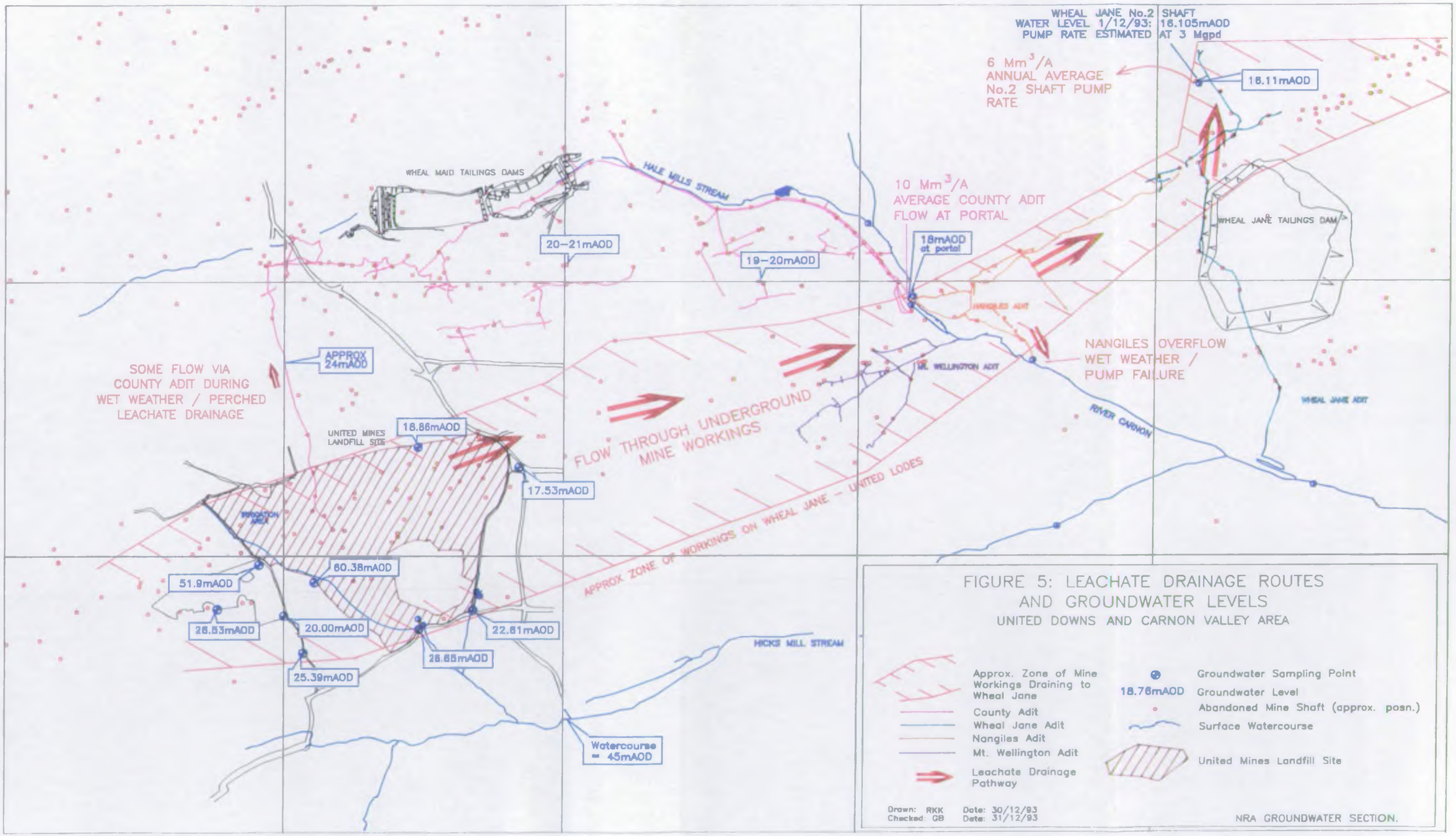


FIGURE 5: LEACHATE DRAINAGE ROUTES AND GROUNDWATER LEVELS

UNITED DOWNS AND CARNON VALLEY AREA

- Approx. Zone of Mine Workings Draining to Wheal Jane
- County Adit
- Wheal Jane Adit
- Nangiles Adit
- Mt. Wellington Adit
- Leachate Drainage Pathway
- Groundwater Sampling Point
- 18.76mAOD Groundwater Level
- Abandoned Mine Shaft (approx. posn.)
- Surface Watercourse
- United Mines Landfill Site

Drawn: RKK Date: 30/12/93
Checked: GB Date: 31/12/93

NRA GROUNDWATER SECTION.

Figure 6: Groundwater Hydrographs