Investigation into the remediation of the contaminated site at Mapua

Soil technical annex

Contents

Soil remediation

Soil remediation has been a principal element of the works at Mapua. Extensive excavation, classification, Mechano-Chemical Dehalogenation (MCD) treatment, validation and backfilling have been undertaken across the site. This technical annex, which is largely based on a draft validation report, discusses evidence for the success of soil treatment, considering remedial criteria, destruction efficiency, and uncertainty in analytical results. It further examines several issues relating to ground works:

- duration and cost of the works
- post-treatment blending of soils
- use of copper sulphate as a process reagent
- completeness of analytical suites
- import of a small volume of contaminated soil from a nearby site.

Validation reporting

The Ministry for the Environment (MfE) has supplied the Parliamentary Commissioner for the Environment (PCE) with a copy of the draft site validation report dated September 2007.[1] PCE was advised that this is the most recent draft. MfE advises that the final draft is near completion (letter 9 July 2008).

This draft validation report is some way from being complete. It contains the following sections:

- Introduction and background
- Remediation methodology
- Validation sampling (some gaps in text)
- Analysis of validation sampling data (a chapter discussing methods of data analysis; some gaps in text)
- Validation analyses – ‘clean’ residential material, commercial stockpiled material, FCC East site (these chapters only partially complete)
- Validation analyses – exported material, East marine sediments, FCC Landfill site, West marine sediments, FCC West site, private residential property, groundwater quality (chapter headings only)
- Quality assurance and quality control (some gaps in text)

[1] Site validation report for the former Fruitgrowers Chemical Company Site, Mapua, Sinclair Knight Merz (SKM) for MfE, version 7, project AE03255, 19 September 2007.

- Compliance with resource consents (chapter heading only)
- Discussion and conclusion (chapter headings only)
- References (chapter heading only).

Some data are also appended to the draft validation report. Contents of apparently complete parts of the text are paraphrased below. We stress that this is an early draft report only, and that this summary must not be taken as necessarily representing the final conclusions.

The draft validation report states that approximately 8,000 samples were analysed during the works, a substantial increase over the 1,000 initially envisaged by the original contractor, Thiess. These include:

- sampling to assess OCP content of excavated and imported soils, and of wastes sent off site
- validation sampling from walls and floors of excavations. The average sampling density is stated to be four samples per 112 m^3 of excavation.
- validation sampling from treated soils, at a rate of one composite sample per day, or approximately one sample per 25 m^3 of treated soil.

Most soil samples were analysed only for the principal contaminants of concern (DDX and ADL) with other contaminants being analysed at a lower frequency. Sampling, analysis and recordkeeping procedures appear to be generally thorough. However, contrary to the site auditor's requirement, quality assurance/quality control (QA/QC) samples were not taken during works, so a sampling programme undertaken after completion was substituted.

For soils used as residential fill material, approximately 10 percent of samples exceeded the residential criterion for DDX (and very occasionally ADL), but overall the 95 percent upper confidence bounds to the means (UCL_{95} statistics) were below the criteria.

For MCD-treated fines, and for the oversize fraction, approximately 10 percent of the samples exceeded the commercial criteria for DDX and/or ADL, and two samples exceeded the criterion for copper, but UCL_{95} statistics are all below acceptance criteria.

It appears that the FCC East Area has met remedial objectives, but no conclusion is yet drawn in respect of the FCC West or Landfill Areas, or coastal sediments.

Data quality

QA/QC analysis in the draft validation report indicates that intra-laboratory precision, as measured by relative percent difference in blind replicate analysis of split samples from commercial zoned soils, was poor for samples appearing to contain less than 50 mg kg^{-1} DDX. This is well above the 5 mg kg^{-1} criterion for residential-zoned soils. This raises a concern that the analytical laboratory used during the works might not have been able to reliably determine whether soil samples met residential criteria. If this were the case, then it would be difficult for the site auditor to determine whether the FCC West Area is suitable for residential use.

Sediments

Before remedial works started, investigations had shown that sediments on both the east (Mapua Channel) and west (Waimea Inlet) foreshores of the Mapua site would not meet sediment acceptance criteria set in the resource consent, especially for DDX. These were therefore excavated (in May 2005 and April 2006 respectively), stabilised with 5 percent to 7 percent Portland cement, and used as fill material in both the FCC East and FCC West Areas. The excavations were reinstated with ‘clean’ imported gravel.

Some validation samples were collected from the excavated material, and some were collected from the bases and walls of the excavation. As the purpose of the excavation was to remove sediment that was unlikely to meet acceptance criteria, but leave material that was likely to be acceptable, concentrations of contaminants should have been quite different in samples of excavated material, than in samples of sediment remaining *in situ*. However, it appears that the draft validation report combines both datasets when assessing the excavated material. This approach may have been taken in order to make up for the number of samples actually collected from the excavated Mapua Channel sediments, which is less than required to meet the target sampling frequency for residential fill material, but this is not considered appropriate.

A few samples of sediments excavated from both Mapua Channel and Waimea Inlet do not meet the residential acceptance criteria for DDX. However, the draft validation report shows that UCL_{95} statistics for DDX are below criteria, and suggests that mixing during stabilisation will have acted to eliminate hotspots. This appears to be a reasonable approach.

The draft validation report does not yet assess samples from sediments remaining *in situ* against sediment acceptance criteria, but it is clear from Tables 13 and 14 (pp. 53-54) that some samples are well above criteria for DDX.

Additionally, an investigation for MfE in May 2007[2] found that DDX concentrations in sediments on both foreshores did not meet sediment acceptance criteria, and decreased with distance from the site. Considering creek and marine water sampling results collected, that investigation suggested that sediments had been recontaminated by runoff and surface water discharge from the site.

Tasman District Council (TDC) undertook sampling of surface sediments and edible invertebrates (mud snails *Amphibola crenata* or, on the east beach, topshells *Diloma subrostrata*) in April to June 2007 and in October 2007. Again, sediments were found not to meet acceptance criteria, with DDX concentrations up to 16 mg kg^{-1} on the western site in early 2007, although the highest concentration in October was only 0.24 mg kg^{-1} (after the removal of the contaminated sediments). Composite samples

[2] Groundwater and sediment investigation report, former Fruitgrowers Chemical Company site, Mapua, CH2M Hill Australia Pty Ltd for MfE, August 2007

of invertebrates contained up to 51 mg kg^{-1} DDX in early 2007, 73 mg kg^{-1} DDX and 2.2 mg kg^{-1} dieldrin in October. These concentrations are higher than in a Landcare survey in 2002, before remediation.[3]

Considering these findings, and an incident on 16 August 2007 when wash water from the treatment plant was discharged into the stormwater drain (refer Water Technical Annex), TDC requested further sampling and remediation of the western sediments via the Compliance Officer's report of September 2007. In October 2007, TDC itself undertook further sediment excavation and validation on the western foreshore of the Mapua site, including further samples of marine biota. No further information has yet been received from TDC in regard to these works.

At the request of the Nelson Marlborough District Health Board, the New Zealand Food Safety Authority advised TDC in September 2007 that consumption of even a small number of snails could exceed acceptable daily intake limits for OCPs. The Nelson Medical Officer of Health then wrote to TDC later that month, and again in January 2008 and February 2008, to request that TDC put up warning signs to prevent the collection of shellfish from the area, and undertake further monitoring at 6-month intervals. TDC put up warning signs on 4 March 2008 and have undertaken the next six-monthly sampling round. TDC advises (4 July 2008) that the latest results show that DDX and ADL concentrations in the snails have reduced by up to 30 times from the previous round.

Technical points:

- The validation report should contain relevant internal quality assurance data from the analytical laboratory.

- The validation report must discuss uncertainty in validation sampling results, and hence indicate the degree of confidence in conclusions as to whether remedial targets for residential zones have been met.

- Validation samples from sediments remaining in situ should not be treated as representative of excavated material. Only validation samples collected from excavated sediments should be used for assessing them as fill materials.

- It appears that sediment quality on both foreshores of the Mapua site failed to meet acceptance criteria, and that invertebrates on the western foreshore are not fit for human consumption. Further investigation and remedial work appeared necessary. It appears that this is being undertaken by TDC. TDC should provide details and findings to the site auditor.

[3] Investigation of Organochlorine Contamination in Biota and Sediment Collected from Mudflats Adjacent to the Fruit Chemical Company (FCC) Site at Mapua, Landcare Research for TDC, 2002.

Efficacy of MCD treatment

The draft Validation Report appears to show the MCD process applied at Mapua to have successfully destroyed DDX and ADL to an extent that meets site-specific acceptance criteria for commercial use. If this result is confirmed, this is a good outcome for the new technology.

While commercial soil acceptance criteria for DDX and ADL appear to have generally been met, the draft validation report does not yet state whether the desired project destruction and removal efficiency was met. Section 5.4 of the Assessment of Environmental Effects (AEE)[4] stated:

> "A critical component to the remediation of the site is the determination of the Destruction / Removal Efficiency (DRE), which is the percentage destruction of organochlorine contaminants in treated soil. This value is to be calculated and agreed with TDC prior to the commencement of the Stage 3 works, based on the results of the MCD plant demonstration and Proof of Performance Trial. Results of demonstration trials undertaken to date indicate that the DRE will fall within a likely range of 90-95% for total DDX.
>
> Thiess and TDC will agree the target DRE that is achievable for the material that is to be treated during the Stage 3 works. The works will be planned and executed so that the target DRE is achieved during the remediation works completed as Stage 3 of the contract."

The primary objective of a DRE is to ensure that soil acceptance criteria are primarily met by soil treatment**.** Additionally, acceptance criteria generally indicate concentrations of contaminant that are believed, at the time, to present an acceptable risk to the environment, but:

- such concentrations are not generally indicative of a desirable soil quality
- a remediated site that contains residual contaminants at concentrations just below acceptance criteria can readily be rendered contaminated again by any further discharge of the same contaminants
- if many sites within a catchment contain residuals of a contaminant, even if each is individually suitable for future use, overall, environmental degradation may result (diffuse source pollution phenomena).

For these reasons, provision for a reasonably achievable project DRE, over and above a requirement to meet soil acceptance criteria, is inherently preferable. (Because soil treatments generally exhibit diminishing returns, it is not reasonable or cost-effective to require remediation to a very high DRE or to concentrations well below risk-based criteria.)

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[4] FCC Mapua Site Remediation: Assessment of Environmental Effects, reference 18777.004, Tonkin and Taylor Ltd for Thiess Services Pty Ltd, May 2003.

Unfortunately, the proposed method of calculating the overall DRE was not clearly specified, and there were lengthy discussions during the works as to exactly how it should be determined. A preferred solution was eventually reached with the help of the site auditor. Among other considerations, this solution takes into account the off-site destruction (in Germany) of a small amount of very highly DDX-contaminated waste, which appears quite appropriate as the associated contaminants are clearly no longer present on site.

EDL's Close-out Report to MfE[5] estimated that soil passed through the MCD plant during the works contained a total of 21,177 kg of DDX and ADL. In addition, approximately 45 kg of pesticide was sent off-site for destruction. The output treated soil was estimated to contain a total of 2,588 kg of pesticide. Therefore the DRE was approximately 87.8 percent, assuming the DDX and ADL content of the untreated coarse fraction to be negligible throughout. Calculated destruction efficiencies for individual batches of soil were often greater than 90 percent, but were as low as approximately 20 percent (batches of 17–20 June 2005 and 21–30 June 2005).

On 5 December 2006, MfE wrote to EDL to vary the contractual target DRE down to 80 percent. The justification for this step is unclear. The variation letter indicates that achieving the 90 percent target in soils that were only moderately contaminated was proving difficult. However, this does not seem to be an extenuating circumstance, because the 90 percent target was for overall DRE, not for individual batches; and because highly contaminated soils contained more DDX and ADL than moderately contaminated soils, they contribute more to the overall DRE.

Technical point:

- The validation report should provide a final calculated overall DRE, and a detailed discussion, including an explanation of the reduction of the contractual requirement to 80 percent DRE during the works.

Time and money

The duration and cost of the Mapua works exceeded initial expectations. Section 5.11 of the AEE advised that:

> "Based on the above normal operating hours only for the MCD treatment plant, it is expected that treatment will be completed within 14.3 months. Plant disestablishment and final site reinstatement is expected to be completed within another 7 weeks. Therefore, based on estimated volumes and treatment plant operation during normal hours only, it is anticipated that the works will take approximately 18 months from commencement to final site validation."

Based on site management meetings and monthly reports, site works began in early September 2004, and treatment finished in early August 2007, with earthworks continuing to the end of that year. Landscaping and minor drains and car-park works

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[5] Close-out report: requirement under Part C1 Technical Specification No. 23, EDL to the Engineer to the Contract (MWH), 8 September 2007

did not end until April 2008. The works therefore took approximately twice as long as envisaged.

The draft validation report states that the MCD reactor achieved a mean throughput of 5 tonnes/hour when in production, significantly better than the target of 3 tonnes/hour advanced in the AEE. Nonetheless, the EDL Close-out Report shows that 8084 m^3 of soil was treated in 584 working days between 1 February 2005 (records before this date are unclear) and 21 July 2007. This works out at 13.8 m^3/day or 83 m^3/week, a shortfall of 23 percent from the target of 108 m^3/week set in EDL's contract. These figures do not include 55 days recorded as undertaking rework or 90 days recorded as "plant down", which, if included, would reduce the averaged work week production to 67 m^3, a 38 percent shortfall. Therefore, if hourly throughput during production was better than expected, the reactor must have been idle more often than it was working. Site management meeting minutes indicate numerous issues that caused treatment to halt, including mechanical failures and excessive moisture content in excavated soil, especially early in the project.

The AEE estimated (section 5.4) that 22,235 m^3 of contaminated material would require excavation, of which 6,161 m^3 would require MCD treatment (an allowance was originally made for up to 6,650 m^3), and the remainder would be acceptable for the less sensitive commercial use. In the event, based on the final volume balance diagram (version C16), more than 38,000 m^3 of contaminated material was excavated, a 70 percent increase. The 8,000 m^3 treated represents a 30 percent increase over the initial estimate (NB: the figure of 10,600 m^3 shown on the volume balance diagram includes the coarse fractions separated out before MCD treatment).

PCE has been advised that as-built drawings for the Mapua site are not yet available, so we have been unable to determine where excavation has been more extensive than initially predicted. There were also some unexpected finds of buried drums and other highly pesticide-contaminated material, particularly along the southern boundary of the residential-zoned FCC West Area.

The site management meeting minutes of February 2007 comment that the highest concentrations of DDT (29 percent by dry weight) were encountered in the top 1 m of cell N10, in the southwest of the FCC West Area. The meeting minutes of September 2006 report that "a large solid waste pit of pesticides was uncovered" in the south of FCC West. (These may refer to the same finding.) Referring to the AEE, it does not appear that either of these hotspots was identified before the works.

Contamination conditions before works were established with reference to a number of intrusive investigations, including Bioresearchers (1993), Woodward-Clyde (1994),[6] GES (2001), Thiess (2002), and T&T (2005).[7]

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[6] Soil and groundwater investigation, Mapua, Woodward-Clyde (NZ) Ltd for Bell Gully Buddle Weir, April 1994.

[7] Report on baseline soil and groundwater sampling, Mapua, Nelson, Tonkin & Taylor Ltd for MfE, draft dated March 2005.

Although we have not sighted the Bioresearchers, GES or Thiess investigation reports, it appears from reviews in T&T (2005) and from Woodward-Clyde (1996)[8] that benchmarking was largely restricted to shallow soils. The T&T (2005) report details sampling of surface soils (0–0.1 m below ground level (bgl)) at 20 locations around the site, and states that the Thiess (2002) investigation sampled only shallow soils at depths of 0–0.5 m bgl. The AEE states that it relied principally on the Woodward-Clyde (1994) investigation, which included analysis of 52 samples from 0–0.5 m bgl in the FCC West and East Areas (but none in the Landfill Area), and just seven samples from greater depth. Section 4.1 of the AEE concluded that:

> "In general, the concentration of organochlorine pesticides was found to decrease with depth. However there were some exceptions, particularly in the 1-2 m depth range, where contamination at depth significantly exceeded concentrations in the upper strata…"

The evidence of Richard Mander-Jones for Thiess at the resource consent hearing, dated 19 August 2003, includes results of grid sampling comprising 150 samples for DDX from FCC West, and 180 from FCC East. Many of these were from shallow depths but some were from depths down to 3 m bgl. Again results for the Landfill Area were not provided, and sampling at depth appears to have been targeted toward areas where previous investigations had collected samples. Some locations, such as grid squares J9-J12 on FCC West, or L23–L25 on FCC East, were found to have DDX concentrations below 5 mg/kg in samples from 0–0.5 m bgl, but >200 mg/kg in soils from greater depth. This shows that a lack of contamination at surface did not always mean a lack of contamination at depth.

It appears likely that sampling was sparse below 0.5 m bgl and in the Landfill Area, even though there were some indications that concentrations could increase with depth; that this contributed to underestimation of the volume requiring excavation, and hence to increased time and cost for the works.

It is common to have a preliminary investigation to assess the general condition of the site, followed by one or more supplementary investigations.[9] At Mapua at least five partial ground investigations were undertaken, yet the volume of soils to be excavated still appears to have been substantially underestimated.

Nonetheless, it is not unusual for contaminated sites to be heterogeneous and for unexpected finds to be made during remediation, regardless of how thorough sampling is. As demonstrated in this project by overruns of 70 percent in excavated contaminated material, and 30 percent in treated contaminated material, it is prudent to make substantial allowances for increased volumes in time and cost budgets. TDC has also suggested (email 4 July 2008) that some soil assessed as residential may have had to be reassessed as commercial because it was cross-contaminated during works.

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[8] Mapua site remediation: assessment of environmental effects, Woodward-Clyde (NZ) Ltd for TDC, October 1996.

[9] *Site investigation and analysis of soils: contaminated land management guideline No. 5,* Ministry for the Environment, 2004

The increase in volume of contaminated soil also meant a shortfall in soil suitable for use in the 0.5 m thick cover layer provided across the site. Version C16 of the volume balance diagram indicates that more than 12,000 m^3 of topsoil, clay and gravel was imported. As a consequence, finished site levels also had to be raised. Had this shortfall been predicted, it is possible that measures could have been taken to avoid the cost and labour of importing material, such as reducing the thickness of the clean cover layer, which was a 'belt-and-braces' protective measure over and above contaminant removal.

MfE has advised PCE that its initial budget for the remedial works was approximately $6 million. The current budget was advised to be approximately $12 million. MfE has not advised any reason for this overrun, which does not seem to be explained simply by the increase in volumes of soil excavated. MfE noted that nearly $2 million has so far gone to monitoring; as noted above, approximately eight times more samples were analysed than initially envisaged.

Post-treatment blending

As discussed in sections 5.2.2 and 7.1.2 of the draft validation report, two batches of soil treated before July 2005, totalling approximately 400 m^3, were found not to meet the soil acceptance criterion for DDX. It is not clear whether the 90 percent DRE target was met for these materials. These unacceptable soils were then blended with approximately 820 m^3 of less-contaminated treated soils so that the final blended product did meet the criterion.

According to an email from EMS to MfE dated 13 March 2005, this blending was to be a "one time only" exception, and the reason for permitting it was that

> "…the Contractor, faced with the expenses and production time of over 5 months of operations with scattered results, is struggling to maintain solvency and any hope of "catching" up to where they should be with their production schedule."

Yet a second blending event occurred some time after 23 July 2005. Time should have been less of a factor on this occasion, as the site management minutes for 5 May and 2 June 2005 state that EDL was "on target with the programme" (the 14 July meeting minutes do not clearly state whether or not the works were on schedule).

The AEE stated unequivocally (section 5.2) that:

> "The minimum requirements of the remediation include… [that] contaminated soils must not be blended or diluted with soil containing lower concentrations of contamination (other than the mixing which will obviously occur in a cell-by-cell excavation)…"

Moreover EDL's contract with MfE stated that:

> "24.2(c): Subject to the conditions of clauses 26.6 and 26.7 of this Technical Specification, contaminated soils must not be blended or diluted with soil containing lower concentrations of contamination to make the material acceptable for off-site disposal or for retention on any part of the Site.

> 26.6: There shall be no blending of soils or sediments for the purposes of reducing contaminant concentrations below target soil acceptance criteria and thereby avoiding the need to treat soils
>
> 26.7: Blending of soils or sediments may be carried out for the purposes of improving the homogeneity of physical and chemical characteristics for the purposes of improving treatment efficiency."

It is true that the treatment process necessarily contains an element of mixing through excavating, screening, drying, treating and recombining. Nonetheless, it remains the case that on two occasions material was blended for the specific purpose of reducing concentrations below criteria. This appears to be a departure from the proposed method of work and the works contract.

There is no obvious reason why these soils could not have been re-treated to meet the DDX criterion, which was met in the Proof of Performance trial and in the remainder of the works. At the time, the works appear to have been on schedule, and there was (at that stage) plenty of time for overrun in the resource consent. Hence the principal driver appears to have been avoidance of re-treatment costs.

It is not clear how the two blending events were authorised, as the issue does not appear to have been brought up in site management meetings. The minutes of the Peer Review Panel meeting on 6 April 2005, at which the site auditor and the TDC Compliance Officer were present, mention that some soils were being blended to meet criteria. It does not appear that there was any detailed discussion. There is nothing in the corresponding Compliance Reports (June and August 2005) and no enforcement action appears to have been taken. TDC indicates (email 4 July 2008) it was unaware of the second blending event.

Technical points:

- The validation report should account for the discrepancy between projected and final volumes of soil to be excavated and treated.
- Considering the two blending events, since acceptance criteria were met and the soils in question cannot readily be located or re-treated, no further remedial works in respect of these blended soils are recommended.

Use of copper sulphate as a process reagent

The MCD process, as operated by EDL, used a proprietary mixture of reagents to enhance treatment. Some of these reagents, notably granulated slag (a source of metal oxides), are considered potentially hazardous chemicals if stored or used in sufficient quantity. As such, the works required resource consent as a hazardous facility under rule 16.7 of the Tasman Resource Management Plan (TRMP), as discussed in sections 6 and 8.8 of the AEE for the remedial works.[10] This was covered by consent RM030521.

[10] FCC Mapua Site Remediation: Assessment of Environmental Effects, Tonkin & Taylor Ltd for Thiess Pty Ltd, May 2003.

Site management meeting minutes show that, at some time between the Proof of Performance test and April 2005, the granulated slag was replaced by copper sulphate [ferrous sulphate was also referred to, but does not appear to have been used]. The AEE referred only to use of granulated slag. This substitution may therefore not have met condition 17 of consent RM030521, which directed that works "shall be carried out in general accordance with" the AEE. Diammonium phosphate was also added to the reagent mixture around this time.

PCE has asked EDL to provide information on actual use of copper sulphate, but has not received a response at this time. Based on a spreadsheet showing reagent usage, as supplied to PCE by MfE, approximately 53 tonnes of copper sulphate were added to treated soils during that part of the works between May 2005 and May 2007, at a rate varying from month to month, in the range 0.2-0.7 percent w/w. There will also have been some use of copper sulphate outside this period, especially in early 2005. From information in the draft validation report, based on validation sampling from treated soil, the overall average is unlikely to have been more than 0.7 percent w/w copper sulphate.[11]

The Environmental Risk Management Authority (ERMA) has classified copper sulphate[12] as acutely ecotoxic (Hazardous Substances and New Organisms category 9.1A). It therefore poses a substantially greater hazard than granulated slag, which was considered to be a "low" hazard to both human health and the environment under the AEE. Under the Hazardous Facility Screening Process (HFSP) prescribed by the TRMP, a new use of more than 360 kg[13] of copper sulphate in a commercial area would require land use consent.

The MfE Remedial Action Plan[14] acknowledges that land use consent may be required before storage or handling of hazardous substances, but no further consent application was made in respect of copper sulphate. The MfE Remedial Action Plan does not appear to recognise the particular ecotoxicity issues associated with copper sulphate.

Conditions 9 and 12 of consent RM030521 required the Remedial Action Plan to be approved by the site auditor and TDC's Compliance Co-ordinator. PCE has not sighted any documentation to show that either the original Thiess Remedial Action Plan or MfE's updated version was formally approved. MfE has advised (letter 9 July

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[11] As an approximate calculation, 9,175 m^3 soil treated after July 2005, at a density of 1.6 T/m^3, makes 15,600 T. The USD_{95} for copper in this soil was 1,923 mg/kg ($n = 58$), implies 30 T of copper, or 120 T as copper sulphate, which is approximately 0.7% by weight. However, use of the USD_{95} is likely to overestimate actual usage, and this calculation does not correct for background concentration.

[12] Hazardous Substances (Pesticides) Transfer Notice 2004 and Hazardous Substances (Chemicals) Transfer Notice 2006 as amended.

[13] TRMP, Schedule 16.7B: environment base quantity 1 tonne per Table 2, adjustment factors FE1 = 3 for a solid, FE3 = 0.3 for use per Table 3. Consent Status Index 0.4 for commercial site, Figure 16.7A.

[14] Amendments to Remedial Action Plan and Site Work Plans: Fruitgrowers Chemical Company Mapua Site, Ministry for the Environment, August 2007. See Work Plan 11 Hazardous and Waste Substances Management, version 2, 6 March 2007.

2008) that it did not supply its Remedial Action Plan to the site auditor or TDC until October 2007, after soil treatment was complete. MfE further comments that the consent required only that the Remedial Action Plan be submitted, not approved, before works commenced. However, this sequence of events meant there was no opportunity to approve any substantive differences between the two Remedial Action Plans, such as the use of new reagents, or to address any matter that might not have met with approval, until well after it had happened. This greatly dilutes the effectiveness of the approval process.

The site auditor expressed concern at the use of copper sulphate as a reagent at the site management meeting of 7 April 2005. The meeting minutes show that

> "It was requested that a full disclosure of the additives included in the process and their respective actions and potential by-products be obtained. [The EDL managing director] responded that he would… provide us with the information.
>
> [The EDL managing director] stated that they are backing out [sic] the copper sulphate usage… the use of quartz sand has provided excellent results and would further allow them to eliminate the copper sulphate…
>
> [MWH] asked EDL what were the amounts of additive quantities to the plant. EDL will provide with each daily log a listing of reagents… This will then be summarized by EDL in the monthly report…"

The minutes of the site management meeting on 5 May 2005 further show that:

> The Engineer to the Contract "…indicated that EDL needs to provide information beforehand on changes or additions to reagents used in the treatment process. All operations must comply with the consents and be approved by the site auditor in advance. We needed to know what reagents are being added in advance… [the site auditor] should be approving these changes. If [the EDL Project Manager] isn't providing this information he is violating the contract and consent conditions. [The EDL Technical Advisor] will undertake to communicate with [the site auditor] about the past changes."

PCE has a copy of a reply email from the site auditor to EDL dated 16 May 2005 that includes the following comments:

> "…Copper is highly toxic to marine organisms… In addition to effects on marine organisms, it is possible that if copper levels are significantly increased, then they could also give rise to a human health effect and limit the development of the site.
>
> We understood from our discussions last year that the concentrations of copper… would be in the range 49-760 mg/kg… it was also suggested at the time that the concentrations may reduce from these…
>
> It is of concern if the concentrations increase, and, in general, it is important that the concentrations be maintained at as low levels as possible. The very high concentrations of copper as occurred during the work earlier this year is

> of definite concern, and is likely to preclude the disposal of the treated soil at the site."

Despite this advice, there does not appear to have been any follow-up in subsequent site management meetings. The Peer Review Panel were evidently aware of the issue, as the meeting minutes of 2 August 2005 includes the comment that "in the soil the only metal that was high was copper (from reagents)" – but there was no discussion or recommendation. In May 2006 the site auditor again raised the issue with MfE:[15]

> "copper concentrations in treated soil… are much higher than had been reported in June 2004, when the Thiess [Remedial Action Plan] was reviewed, and have not been reduced to levels that EDL suggested at the time might be possible… we suggest that you… consult with EDL to determine if reduced concentrations of reagents can [be] used in the further treatment, as inferred in previous discussions…"

Nonetheless, the use of copper sulphate appears to have continued throughout the remedial works. It does not appear that any enforcement action was ever taken, either under the works contract or through RMA processes, to regulate use of this reagent. TDC indicate (email 4 July 2008) that it was aware of correspondence between the site auditor and MfE and EDL, but was not aware that the site auditor's advice had not been taken.

Copper in treated soils

Before remedial works started, the site auditor set soil acceptance criteria for copper of 2,000 mg/kg in open space use, and 5,000 mg/kg in commercial use. These are Australian generic (Tier I) environmental guideline values for these end uses, Health-based Investigation Levels (HIL).[16]

In the AEE, in the site auditor's statement to the consent hearing, and in the resource consents (attachment 1 to each consent) it was stated that, where Australian environmental guideline values were used as acceptance criteria, the lower of the HIL and the Ecological Investigation Level (EIL) had been selected. This was not true for copper where the EIL is 100 mg/kg, much more stringent than either of the HIL, although "it is acknowledged that the EILs for an urban setting have not been derived to protect nominated ecological values and are somewhat arbitrary" (section 3.2 of the HIL guidance document).

The draft validation report shows that, in 58 analyses of copper in MCD-treated fines, two samples exceeded the higher human health-based acceptance criterion of 5,000 mg/kg for commercial areas, while the 95 percent upper confidence bound to the mean (95 percent UCL) was 1,920 mg/kg. It also shows that the 95 percent UCL for copper in 31 "QA/QC" samples from the commercial zoned FCC East Area was

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[15] Letter from GHD to Ministry for the Environment, GHD reference 31/12747/116879, 22 May 2006.

[16] Guidelines on investigation levels for soil and groundwater, [Australian] National Environmental Protection Council (NEPC), Assessment of Site Contamination Schedule B1, 1999

410 mg/kg. Although treated fines were also placed on the Landfill Area, zoned open space, it does not appear that any QA/QC sampling was done in this area.

The site auditor's statement to the consent hearing (paragraph 40) advises that: "The use of published criteria simplifies the assessment and validation process, but requires caution to ensure that the published criteria are appropriate for the situation at hand. The auditing process provides a check at various points in the process that such issues are considered and are not overlooked". PCE considers that there were (and remain) ample grounds for deriving a site-specific criterion for copper that is protective of the estuarine environment, instead of using a generic criterion for the protection of human health:

- A copper compound known to be acutely toxic to aquatic organisms was being used in tonne quantities on site.
- Two validation samples had exceeded selected generic criteria.
- The limiting pathway for the principal contaminants of concern (DDX and ADL) was, in most circumstances, discharge to the estuary.

For open-space use, where planting is likely, it may also be appropriate to consider the protection of plant life. International[17] environmental guideline values for copper that take phytotoxicity into account are also comparatively low. For example, the Canadian soil quality guideline (SQG) in parkland use is 63 mg/kg[18] while the UK "Soil Code"[19] suggests a maximum permissible concentration of 80-200 mg/kg (depending on soil acidity) in amended agricultural soils.

Of potentially greater concern, given the aquatic toxicity of copper, it is also possible that copper from treated soils has reached the estuary through runoff, windblown dust or migration in groundwater. Validation samples of marine sediments were not analysed for copper.

It is possible that the MCD process has also acted to reduce the risk posed by metals such as copper in treated soils. Soils passing through the reactor are significantly comminuted by mechanical impact, greatly increasing the effective surface area of soil particles and hence providing more metal binding sites. Decreased particle size

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[17] Following Contaminated land management guidelines No. 2: Hierarchy and application in New Zealand of environmental guideline values, Ministry for the Environment, 2007, it would be preferable to use New Zealand risk-based guideline values. However, the phytotoxicity threshold for copper of 130 mg/kg given in the relevant New Zealand guideline, Health and environmental guidelines for selected timber treatment chemicals, Ministry of Health/ Ministry for the Environment, 1997, is taken from a UK guidance document, Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL) circular 59/87, which was withdrawn due to lack of scientific basis by the UK Environment Agency in 2001.

[18] Canadian Environmental Quality Guidelines, Canadian Council of Ministers for the Environment, 2006.

[19] Code of good agricultural practice for the protection of soil, [UK] Ministry of Agriculture, Fisheries and Food / Welsh Office, Agricultural Department, 1998.

would also be expected to reduce the hydraulic conductivity of the soil. The addition of phosphate (as diammonium phosphate) as a process reagent provides a binding phase for heavy metals generally (see, for example, UK EA (2000)[20], USEPA (2007)[21]). The organic residue following MCD treatment may also have metal complexing properties. All these factors would act to reduce the leachability, hence mobility and probably bioavailability, of copper and other metals in treated soils. The phosphate additive would also help to buffer soils against any change in acidity that might otherwise occur subsequently, which is useful since heavy metal leachability is generally greatly increased at low pH. However, any such ameliorative effect of the MCD process remains to be demonstrated.

In summary, treated soils were amended with an average of approximately 0.5 percent w/w copper sulphate without any scrutiny through a consent process, even though this appears to be required under the TRMP. The significant hazard posed to aquatic environments by copper compounds was never formally recognised in project documentation. Although EDL indicated that copper usage could be minimised or eliminated, and the site auditor recommended on at least three occasions that this would be desirable, records show that it was used throughout the works.

Technical points:

- EDL should provide MfE, the site auditor and PCE with daily usage records of copper sulphate for the whole of the Mapua project.
- The site auditor should determine appropriate site-specific acceptance criteria for copper in soil and sediments at the Mapua site.
- Validation data should be collected to determine the actual concentrations of copper in treated soils in
  - open space zoned areas of the site
  - marine sediments adjacent to the site.
- The final validation report should discuss the addition of copper to site soils and sediments, the resulting copper concentrations, and any implications for the environment or future site use.
- Leachability studies may now be advisable to determine the mobility of copper in MCD-treated soil. It would be preferable if such studies sought to assess the effects of comminution and addition of phosphate on copper fate and transport in these soils.

[20] Remediation of Toxic Metal Pollution in Soil Using Bone Meal, UK Environment Agency R&D Technical Report P234, 2000.

[21] Framework for Metals Risk Assessment, United States Environmental Protection Agency, Risk Assessment Forum, Washington, DC; EPA 120/R-07/001, 2007.

Contaminants other than DDX and ADL

Contaminants of potential concern

In 1992, Woodward-Clyde[22] conducted a site audit including interviews with former FCC employees. This audit produced a list of more than 80 biocides stored and manufactured at the Mapua site, including estimates of typical annual quantities. These included:

- sulphur
- organochlorine pesticides (OCPs) and herbicides, particularly DDT, dieldrin and lindane
- organophosphorus pesticides, particularly malathion, and also including substantial quantities of azinphos-methyl, chlorpyrifos, diazinon, fenitrothion, fensulfothion, phosmet and disulfoton.
- nitrogen-containing pesticides, particularly chlorthiamid and captan
- triazine herbicides, particularly amitrole, atrazine and simazine
- heavy metal-based pesticides such as lead arsenate and other arsenicals (stored but not produced), and organomercury pesticides, principally phenylmercury acetate. [Organotin antifouling agents are referred to in the text of the Woodward-Clyde (1992) report, but it is not made clear whether or not they could have been present at Mapua.]

Details of the site history were also outlined. It appeared that land reclamation to the east and west of the site largely took place between 1958 and 1969. During this time, organomercury pesticides, dieldrin and lindane, and then DDT were phased out. It appears likely that these phase-outs would have presented waste disposal issues. As discussed above, there were one or two substantial burials of DDT wastes in the south of the FCC West Area. A low point, 'Lake Tas', on the FCC East Area, was also in-filled using site waste in the late 1950s. It cannot be ruled out that reclamation, i.e. the Landfill Area, had also contained OCP or organomercury wastes from the site; it was used for disposal of a variety of industrial and household waste. There was also a report of a spill of the triazine herbicide amitrole on FCC East in 1975.

Nonetheless, ground investigations at the Mapua site included relatively few analyses for contaminants other than the primary concerns, DDX and ADL. As discussed above, sampling was relatively sparse in the Landfill Area, and at depth. Despite the anecdotal evidence of a spill of amitrole, no sample was ever analysed for it, probably because there does not appear to be any New Zealand laboratory that can do this analysis.

Traces of many biocides were detected in the T&T (2005) baseline investigation, which analysed 20 surface soil samples from around the Mapua site, and groundwater

[22] Fruitgrowers Chemical Company, Mapua: Site audit report. Woodward-Clyde (NZ) Ltd, 1992.

samples from six perimeter monitoring wells, for a very broad suite of analytes. These included azinphos-methyl (up to 28 mg/kg), atrazine and simazine. There were also traces of some compounds not on the Woodward-Clyde (1992) list, including pentachlorophenol, hexazinone, 2,4-D and 2,4,5-T.

Stormwater sample analyses from the Mapua site in 1984-1987 cited by Woodward-Clyde (1996) detected the organophosphate pesticides chlorpyrifos and azinphos-methyl, and occasionally coumaphos, isazophos and phosalone.

The January 2007 groundwater monitoring report by ChemSearch, University of Otago, for MfE (refer Chapter 3) includes broad suites of pesticides and herbicides. Compounds detected in samples from 21 January 2007 again include traces of atrazine and simazine, azinphos-methyl and chlorpyrifos, hexazinone and others.

Soil samples were regularly analysed for arsenic and mercury during both investigation and remediation, although at rather lower frequency than DDX and ADL. The following arsenic and mercury results are presented in the draft validation report or previous work:

- six samples from the former Mintech site in the northeast of the FCC East Area, within the Bioresearchers (1993) investigation
- 59 samples, principally of shallow soils and excluding the Landfill Area, within the Woodward-Clyde (1994) investigation
- 20 analyses of surface soils across the site, within the T&T (2005) baseline investigation
- 79 analyses of MCD-treated fines (approximately one per every four samples, or approximately one sample per every 150 tonnes)
- 15 samples of residential category soil from the FCC East Area
- 31 samples of excavated marine sediments
- 27 QA/QC samples from the FCC East Area.

(More analyses appear to have been undertaken, including samples of material excavated from the FCC West and Landfill Areas, and validation samples from excavations, but these are not yet presented in the draft validation report.)

Across all these results, it appears that maximum concentrations encountered were 48 mg/kg arsenic and 1.3 mg/kg mercury. While these are above site residential acceptance criteria of 30 mg/kg and 1 mg/kg respectively, almost all these results meet those criteria.

From the same sources of samples there were at least 187 analyses for endosulfan and polychlorinated biphenyls (PCBs). Only traces of these compounds were detected, with respective maxima of 0.056 mg/kg endosulfan and 0.4 mg/kg total PCB.

PCE engaged Graham Environmental Consulting Ltd (GECL) to assess the potential range of contaminants that may have been present in soils at the FCC Mapua site, and hence the potential nature of discharges to air from the treatment process. Its report[23] is attached as Appendix A of the Air Technical Review. GECL found that the majority of biocides stored and handled at the Mapua site are expected to have limited half-lives in soil, which is consistent with the low concentrations found in the few relevant soil and groundwater samples. Further, the MCD process is expected to reactively decompose most organic compounds, and hence if residual organophosphorus or organonitrogen pesticides were present in soils sent for MCD treatment, concentrations in those soils should now be much reduced.

Soil breakdown rates do not apply to concentrated wastes, especially if contained in drums or the like, so biocides in such forms could still have been present at the time of the remedial works. However, it appears that drummed wastes were disposed of off-site whenever they were excavated. The draft validation report does not detail how much material was sent to landfill or overseas, or whether this could have included wastes from pesticides other than DDX and ADL.

By contrast, OCPs are long-lived and poorly soluble, which is why DDX and ADL, as OCPs, have persisted in site soils even though their use was discontinued in the 1960s. Similarly, the metallic elements in heavy metal pesticides cannot be broken down, so those compounds should be even more persistent. Thus, given the widespread occurrence of DDX and ADL across the Mapua site, and the long-standing production of organomercury pesticides at the site (albeit apparently in much smaller quantities than the OCPs), it is surprising that mercury was not also widespread. Indeed high concentrations of heavy metals were never detected. Arsenic appears only to have been handled, rather than produced at the site, so a virtual absence of elevated arsenic results is less surprising.

Because sampling for mercury has been sparse compared to sampling for DDX and ADL, there is a correspondingly greater potential for undetected ‘hotspots’ of mercury. If such hotspots were unknowingly excavated as part of the remedial earthworks, then as those soils were handled, some mixing will have occurred and concentrations will have been diluted. But remedial works might also have mobilised these metals in the forms of soil-derived dust, treatment plant stack emissions or leachate. As for copper, phosphate added to MCD-treated soils would be expected to bind inorganic mercury, but the parent organomercury compounds might not be immobilised.

Dechlorination products

The GECL review also raises the possibility that degradation intermediates including chlorinated aromatic hydrocarbons, dioxins, furans, phenolics, aromatic amines and nitrogen-containing heterocycles, polycyclic aromatic hydrocarbons (PAH) and nitro-PAH might be present in treated soils, especially if subjected to excessive heat during drying.

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[23] Assessment of possible releases from the Mapua plant during soil processing, Graham Environmental Consulting Ltd for Parliamentary Commissioner for the Environment, February 2008.

In developing the MCD process, it appears that EDL has relied heavily on work by Tristan Bellingham, a doctoral student at Auckland University. Bellingham's thesis[24] was submitted in August 2006, by which time works were well advanced. Based on Bellingham's analysis, which PCE has not attempted to verify, bench scale milling of Mapua soil and of model soils spiked with DDT produced small quantities of a wide range of chlorinated intermediates including DDD and DDE.

Actual concentrations of chemical intermediates resulting from MCD remediation of Mapua soils, either those postulated by GECL or identified by Bellingham, do not appear to have been determined either in the Proof of Perfomance report[25] or in validation samples from treated fines.

The January 2007 groundwater monitoring report by ChemSearch, University of Otago, for MfE (refer Water Technical Annex) indicates that the volatile organic compound chlorobenzene has frequently been detected in samples from three on-site monitoring wells, at up to 0.13 mg/L. Bellingham's thesis lists chlorobenzene among the positively identified byproducts when DDT on quartz sand is destroyed by milling. As chlorobenzene could be produced from cleavage of either chlorophenyl unit from any DDX molecule, it is possible that this is an intermediate resulting from MCD remediation. However, as chlorobenzene was also detected in two of the same wells in the T&T (2005) baseline investigation, before any MCD treatment had occurred, there must be other reasons for its presence, perhaps including natural microbial DDX breakdown or historical use as a solvent.

Of the other MCD byproducts listed by Bellingham:

- benzene and toluene were also detected in January 2007 groundwater monitoring, but have other potential sources such as petrol
- 4-chlorotoluene was not detected
- all others were not included in the analytical suites employed.

Treated fines were occasionally tested for PAH content; in 17 analyses of treated fines, the maximum total PAH was 2.2 mg/kg. This is below New Zealand guidelines for representative individual PAH in soils in commercial land use, and therefore is unlikely to indicate a significant environmental risk.

Suitability of marine sediments as fill materials

In addition to the pesticides discussed in the GECL report, residual salinity in marine sediments stabilised and used for fill materials, apparently in both the commercial FCC East and residential FCC West Areas, according to the draft Validation Report,

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[24] The mechanochemical remediation of persistent organic pollutants and other organic compounds in contaminated soils, Ph.D. thesis, Tristan Bellingham, Auckland University of Technology, August 2006.

[25] FCC Remediation, Mapua: Proof of Performance report, Thiess Services NSW, 2004.

might affect plant life or groundwater quality. No soil acceptance criteria have been set for salinity in site soils.

Asbestos

The Thiess investigation of 2001 included testing of 14 samples from the Landfill Area for asbestos. No asbestos fibres were identified in any of these samples.

Technical recommendations:

- The validation report should address, and the site auditor should consider, whether there is sufficient data to assess whether the Site was (or is) impacted by contaminants other than DDX and ADL, especially mercury compounds; or whether more validation data should be collected.

- Further studies are advisable to identify the nature, concentration and potential environmental impact of intermediate compounds in real MCD-treated, pesticide-contaminated soils, especially chlorobenzene. It would have been preferable if this had been done as part of the Mapua Proof of Performance trial.

Import of contaminated material

TDC has advised PCE (email 28 February 2008) that a small volume of contaminated soil was brought onto the Mapua site from another source:

> "84 m^3 came onto the East site, it was "commercial" as tested for OCPs, and it was mixed into the East, we assume into SG20 near Tahi / Aranui Rd which was active at the time. There were 12 samples analysed when it was *in situ* the Inlet dump and we have copies of those lab results. Only DDX present and average 92 ppm. It wasn't tested for metals, etc. because the source of it was a pallet load of sacks of pink DDT, buried in the sand dunes. It would have been subjected to the site auditor's QA/QC samples taken later."

There is no specific proviso against importing contaminated fill material in the conditions of consent, although condition 10(j)vi of consent RM030521 describes sampling requirements to ensure that a fill material meets acceptance criteria. Only one location in subgrade SG20 was sampled during the QA/QC investigation, and there is no indication as to where exactly this imported material was buried.

This import of contaminated material is not recorded in the final volume balance diagram (version C16), or in the draft validation report, nor have we found any reference to it in site management meetings, Peer Review Panel meetings or monthly project reports. A letter from TDC to MfE dated 22 May 2006 indicates that "two skips" of this soil were treated via the MCD process. MfE responded by letter on 21 June 2006, to accept the remaining 60 m^3 onto the Mapua site.

TDC advises that there was no resource consent covering removal of the material from the originating site, nor does it believe that one was necessary (email TDC to PCE, 28 February 2008).

There is some sense in dealing with OCP contaminated soil from another FCC site via the Mapua site remediation. But it does not appear that there was any effective control over this process. While TDC advises it has extensive files on this material, the matter should have been addressed in Mapua project documentation.

Technical point:

- The site validation report should discuss this import of contaminated soil, and it should be clearly shown on the volume balance diagram.

Glossary and acronyms

2,4-D	An organochlorine pesticide
2,4,5-T	Trichlorophenoxyacetic acid; an herbicide
4-chlorotoluene	An organic synthetic liquid
abatement notice	A formal order, issued by a regional council or local territorial authority, requiring compliance with resource consent conditions within the time specified in the notice
activated carbon	An amorphous form of carbon. Its chemical nature, high surface area and porosity make it an ideal medium for the removal of organic pollutants from liquid or gas streams.
ADL	A collective term for aldrin, dieldrin and lindane, three organochlorine pesticides
adsorbed	Gathering of gas, liquid or a dissolved substance on a surface in a condensed layer
AECS	Air Emissions Control System
AEE	Assessment of Environmental Effects: a report outlining the effects that a proposed activity might have on the environment, required under the RMA for resource consent applications
aerosol sampler	Device used to collect samples, which are analysed for specific liquid or solid particles in the air
AES Ltd.	Air quality and environmental consultants
aldrin	An organochlorine pesticide
amitrol	A triazine herbicide
ammoniacal nitrogen	Nitrogen combined with hydrogen
analytical suite	The compounds found within a sample by chemical analysis
aquifer	Any geological formation containing or conducting groundwater
aromatic amines	Nitrogenous hydrocarbons attached directly or indirectly to benzene rings
arsenical compounds	Arsenic bonded with various other elements
atrazine	A triazine herbicide
azinphos-methyl	An organophosphate pesticide
backfill (verb)	The restoration of excavated gravel or earth against a structure or back into a hole
backfill (noun)	The gravel or dirt that is replaced into a hole or against a structure
back pressure	The resistance to the flow of gas through the exhaust
ball mill	A grinder for reducing hard materials to powder, where the grinding is carried out by the pounding and rolling of ceramic or steel balls within a cylinder
benzene	An aromatic hydrocarbon
bgl	Below ground level
bio-availability	The degree to which, or the rate to which, a substance is absorbed or becomes available within the body

biocides	A chemical agent, such as pesticides, capable of killing living organisms
Bioresearchers	Environmental and biological consultants
blind replicate analysis	Two separate samples are collected from a single sample location, stored in separate containers and submitted for analysis to the laboratory as two separate samples for quality control purposes.
breakdown products	Product resulting from a chemical breaking apart into smaller pieces
bund wall	A wall erected to prevent the escape of stored liquids into the surrounding environment
byproduct	A product produced during the production of something else
cadmium	A heavy metal
capping	Placement of a covering (cap) of one or more layers of sand, silt, rock or synthetic fabric over an established layer of contaminated earth. This cap is designed to prevent pollutants from migrating into surrounding waters by providing a physical and chemical seal.
captan	A nitrogen-containing pesticide
carbon filter	A filter employing activated carbon to remove particles from the air
Ceres Pacific	An historic owner of the Fruitgrowers Chemical Company (FCC)
CH2M Hill	Environmental and engineering consultants
ChemSearch	An environmental and analytical laboratory
chlorinated aromatic hydrocarbons	Hydrocarbons in which a number of hydrogen atoms have been substituted by chlorine atoms.
chlorobenzene	A volatile organic compound
chlorophenoxyacetic acid herbicides	A class of pesticides that mimic plant hormones
chlorothiamid	A nitrogen-containing pesticide
chlorpyrifos	An organophosphate pesticide
clay bunding	Construction of a bund wall using clay
cleanup	Remediation of a contaminated site
cleavage	The breaking of chemical bonds
Close-out Report	A report compiled at the end of a project, which determines if the expectations established as the project outcome were met
CMPS&F	Environmental consultants
containment	The process of keeping hazardous wastes confined to a particular location, so as to prevent their accidental release into the surrounding environment
contaminated land	Land identified as posing a significant possibility of significant harm to human health or the environment due to substances present in, or under, the ground
copper compounds	Copper bonded with various other elements

copper sulphate	A copper salt
coumaphos	An organophosphate pesticide
cut-off wall	A collar (metal, concrete etc.) placed around a culvert to prevent water flowing around the outside of the culvert.
daily intake levels	Recommended acceptable intake levels of various chemicals into the human body
DAP	diammonium phosphate
DDD	A breakdown product of DDT
DDE	A breakdown product of DDT
DDT	An organochlorine pesticide
DDX	The sum of DDT and its primary breakdown products
dehalogenation	The reduction or removal of halogens from a chemical compound. Halogens are various non-metallic elements that readily combine with metals. Halogenated compounds are more likely to be toxic.
de novo	Latin: to make anew
desorbed	To remove condensate from a surface upon which a gas, liquid or dissolved substance has been adsorbed
destruction efficiency target	The agreed percentage destruction of OCP contaminants in treated soil; also known as the Destruction / Removal Efficiency (DRE) target
diazinon	An organophosphate pesticide
dieldrin	An organochlorine pesticide
diffuse source pollution	Pollution arising from diffuse areas in a catchment, as opposed to a point source
dioxin	Any of a group of toxic chlorinated compounds known chemically as dibenzo-p-dioxins. They are produced as a by-product of chemical production or combustion and are widespread pollutants in the environment.
discharge stack	A walled enclosure extending upward to direct exhaust air vertically away from fans
disulfoton	An organophosphate pesticide
down-gradient	Areas in an aquifer with lower water levels
DRE	Destruction / Removal Efficiency (see destruction efficiency target)
drier	A device used to heat and dry the contaminated soil
dry weight	The weight of a chemical divided by the weight of the dried material that once contained it.
East Area	The eastern area of the Mapua contaminated site
ecotoxic	Substances that may present immediate or delayed risks to one or more parts of the environment
EDL	Environmental Decontamination Limited
Egis Consulting	An environmental consultancy
EIL	Ecological Investigation Level

elemental sulphur	A chemical that is a very strong acidification agent
EMS	Effective Management Service Limited
endosulfan	An organochlorine pesticide
enforcement order	An order issued by the Environment Court requiring a consent holder to comply with resource consent conditions within the time specified in the order
entrained	Carried along in a current
ERMA	Environmental Risk Management Authority
estuarine	Found in estuaries (the mouth of a river)
eutrophication	The process by which a body of water acquires a high concentration of plant nutrients, especially nitrates or phosphates, resulting in algae growth and depletion of dissolved oxygen in the water. This natural process can be greatly accelerated by human activities.
FCC	Fruitgrowers Chemical Company
FCC East	Eastern part of the Mapua contaminated site.
FCC West	Western part of the Mapua contaminated site.
fenitrothion	An organophosphate pesticide
fensulfothion	An organophosphate pesticide
fines	Fine fragments, as of crushed rock
French drains	A perforated pipe placed in a gravel-filled pit, where liquid is poured into the drain and then permeates through into gravel
fugitive emissions	Emissions not caught by a capture system (due to factors such as equipment leaks, evaporative processes and/or wind)
furans	One of a group of colourless, volatile, heterocyclic organic compounds
GECL	Graham Environmental Consulting Ltd
GES	Consultants
groundwater	All water which is below the surface of the ground in a saturated zone and in direct contact with the subsoil
half-lives	The time required for the amount of a substance to reduce to one half of its initial value when the rate of decay is exponential
heavy metals	Metallic elements with high atomic weights or density, such as mercury, cadmium, arsenic and lead. Many heavy metals are toxic and, since they do not easily break down, tend to accumulate in the food chain.
herbicide	Any pesticide used to destroy or inhibit plant growth
heterocycles	Cyclic compounds where carbon is substituted by other elements
hexazinone	A triazine herbicide
HFSP	Hazardous Facility Screening Process
HIL	Health-based Investigation Level
hotspots	Localised areas where the concentration of contaminants is high relative to the surrounding area

hydraulic conductivity	A measure of the capacity for a rock or soil to transmit water; generally has the units of cm/sec
hydrocarbons	Organic compounds that contain only carbon and hydrogen
ICRCL	Interdepartmental Committee on the Redevelopment of Contaminated land
impoundment pond	An area with bunding, designed to prevent the escape of stored liquids into the surrounding environment
in situ	Latin: present at the site, in place. Refers here to the treatment of hazardous waste on site, without removing them to another location.
intermediates	Biomolecules that have no specific end use, but are involved in the production of other chemical products that do have a clearly defined end use
isazophos	An organophosphate pesticide
kg	kilogram
landfill	A site used for the disposal of solid waste
leachable	Able to be removed by the action of a percolating liquid
lead arsenate	A heavy-metal based pesticide
Lime and Marble	A mineral processing company, later known as Mintech
lindane	An organochlorine pesticide
low-lying areas	Areas of land lower than the surrounding area, into which water tends to accumulate
malathion	An organophosphate pesticide
Manco Environmental Ltd.	Manufacturer, importer and distributor of waste collection equipment; associate company of EDL
MCD	Mechano-Chemical Dehalogenation
metabolites	A substance that is the product of biological (metabolic) changes to a chemical
MfE	Ministry for the Environment
mg	milligram
micron	1/1,000 of a millimetre or 1/1,000,000 of a metre
microniser	Device designed to reduce a substance to particles that are only a few microns in diameter
Mintech	A mineral processing company, formerly known as Lime and Marble
mobilised	To liberate or move material in the environment.
MoH	Ministry of Health
MWH	Montgomery Watson Harza Limited
National Environmental Standard	Tool provided for by the RMA; used to set nationwide standards for the state of a national resource
Nelson Marlborough District Health Board (NMDHB)	An organisation established to protect, promote and improve the health and independence of the population in the Nelson-Marlborough District
nitro-PAH	Nitro-polycyclic aromatic hydrocarbons

OCPs	organochlorine pesticides
organics	Natural organic materials of waste or non-waste origin, including petroleum products, pesticides, herbicides, solvents, and chemicals from decaying plants and animals
organochoride pesticides	Synthetic organic compounds containing chlorine; also known as chlorinated hydrocarbons. Includes pesticides such as DDT, aldrin, dieldrin and lindane. Found to be toxic to non-target species, persist in the environment, and have a propensity to accumulate in the food chain.
organomercury compounds	Mercury bonded with carbon; organic mercury compounds are also called organomercurials
organonitrogen pesticides	A group of organic compounds consisting of nitrogen bonded with carbon
organophosphate	A group of organic compounds consisting of phosphorus bonded with carbon. Organophosphate pesticides break down rapidly when exposed to sunlight, air and soil.
organotin antifouling agencies	Chemical compounds based on tin with hydrocarbon substituents, used to prevent biological growth on treated surfaces
PAH	polycyclic aromatic hydrocarbons
paraquat	An organochlorine pesticide
particulates	Sum of all microscopic liquid and solid particles, of human and natural origin, that remain suspended in a medium such as air for some time. Particulate matter may be in the form of fog, fumes, dust, soot or fly ash.
PCBs	polychlorinated biphenyls
PCE	Parliamentary Commissioner for the Environment
pesticide	Chemicals used to kill, control, repel or mitigate any pest; includes herbicides (to control weeds and plants), insecticides (to control insects), fungicides (to control fungi), rodenticides (to control rodents) and germicides (to control bacteria)
pentachlorophenol	A chemical, also known as PCP, historically used as an anti-sapstain fungicide for short-term protection of sawn timber surfaces
phenolics	A class of aromatic compounds in which one or more hydroxyl groups are attached directly to benzene rings
phenoxy herbicides	A group of herbicides derived from phenoxy-acetic acid
phenylmercury acetate	An organomercury pesticide
phosalone	An organophosphate pesticide
phosmet	An organophosphate pesticide
phytotoxicity	Toxic effects on plants
PM_{10}	Particulate matter classified as 'coarse and fine' based on the size of their aerodynamic particles
polychlorinated biphenyls	A class of chemical compounds containing benzene and chlorine atoms. Some are used for pesticides and fire-resistant coatings.
polycyclic aromatic	A group of organic compounds composed of several benzene

hydrocarbons	rings
ppm	parts per million; units of mass of a contaminant per million units of total mass
PUF	polyurethane foam sampler
pug mill	A device that mixes and grinds clay or other materials to a desired texture, using rotating paddles or blades
QA/QC samples	Quality assurance / Quality Control samples
rainfall recharge	The process of adding water to an aquifer
reagent	A substance used to react with another substance
remediation	The clean-up or mitigation of risks from contaminants in soil
resource consent	Permission granted by a consent authority for an activity that might affect the environment and is not permitted ‘as of right’ in a District or Regional Plan
RMA	Resource Management Act 1991
rotary-type drier	A mixing apparatus using rotation, as opposed to other options such as kneading, pulverising or stirring
Royal Forest and Bird Protection Society of New Zealand Inc.	An environmental lobby group
run-off	That element of precipitation that finds its way into streams and rivers
simazine	A triazine herbicide
site reinstatement	Reinstating a site to a former condition
slag	Waste product formed from the heating of ore in a furnace
soakhole	An excavated pit where holes have been driven into the rock and then covered over, without being filled, so that stormwater can drain into the ground
soil acceptance criteria	Soil guideline values defining the levels of contaminants that are not considered to pose an unacceptable risk to human health or the environment
soil drier	A device used to heat and dry the contaminated soil
spike tests	Identification of the amount of pesticides remaining on a sampler after extended use through the use of radioactively labelled samples
split samples	Samples divided into two or more portions; assists measurement of the precision of handling, shipping, storage, preparation and/or analysis
stack emissions	Emissions to the atmosphere from a chimney or stack
stormwater	Precipitation that accumulates in natural and/or constructed storage and drainage systems during and immediately following a storm event
stormwater drains	Openings leading to underground pipes or open ditches for carrying surface run-off
T&T	Tonkin & Taylor, environmental and engineering consultants
TDC	Tasman District Council

Thiess Services	A specialist remediation contractor
THI	Total Hazard Index
toluene	An organic solvent; a colourless liquid of the aromatic group of petroleum hydrocarbons
triazines	A group of herbicides typically used on field crops; they have a relatively high solubility and slower degradation time compared to other types of herbicide.
TRMP	Tasman Resource Management Plan
TSPs	Total Suspended Particulates
UCL_{95}	95% upper confidence bound to the mean
up-gradient	Areas in an aquifer with higher water levels
upper strata	Upper layers of material in sedimentary rock.
Validation Report	A site validation report; assesses the results of post-remediation testing against clean-up criteria for a contaminated site.
validation sampling	Testing of field samples to validate that objectives have been achieved
venturi	A short tube with a constricted throat used to determine fluid pressures and velocities by measurement of differential pressures generated at the throat as a fluid traverses the tube
venturi scrubber	An air pollution control device in which the liquid injected at the throat is used to scrub particulate matter from the gas flowing through the tube
volatile organics	Organic compounds that will evaporate into the air naturally from water
West Area	The western area of the Mapua contaminated site
Woodward-Clyde (NZ) Ltd.	Environmental consultants, now known as URS Corporation New Zealand
w/w	weight/weight; the percent concentration of a solute in a solution, by weight