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FINLAY, NINA,CATHERINE

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Using Water Treatment Residual to immobilise lead for *in situ* remediation of contaminated soil

Nina C. Finlay

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the degree of Doctor of Philosophy

School of Engineering and Computing Sciences
Durham University

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Abstract

The potential for using waste materials to provide a sustainable means of remediating contaminated land is being explored. Water treatment residual (WTR) is a waste product generated by drinking-water treatment facilities worldwide and is commonly disposed of by landfill. However, its chemical composition highlights its potential as a sorbent of contaminants found in the environment. In this thesis, WTR was assessed in terms of its potential to immobilise lead (Pb), a common toxic contaminant found in the environment, in order to investigate its suitability as an *in situ* amendment in contaminated soil.

Aluminium-based and iron-based WTRs were sampled from water treatment works in north east England and characterised in terms of their bulk composition to gain an insight into the nature of this waste product and the variation that exists in their physicochemical properties. WTRs are predominantly composed of natural organic matter (NOM) and Fe or Al in oxyhydroxide form. Al-based WTRs contained 10-21% Al and 13-26% carbon; Fe-based WTRs contained 25-37% Fe and 13-27% carbon. Detailed characterisation of Fe-based Broken Scar WTR revealed that ferrihydrite was the dominant mineral form, with the material comprising ~70 wt% ferrihydrite finely intermixed with ~23 wt% NOM. WTR is considered as an organo-mineral composite with low surface area (4.1 m^2/g) and microporous structure. The strong interactions between the NOM and mineral components are considered to protect both parties from degradation and create a relatively stable matrix which is able to function as an adsorbent over a range of environmental conditions.

The Fe-based WTR was highly effective at adsorbing Pb(II) from aqueous solution (max sorption capacity 139 mg/g). Pb sorption exhibited biphasic kinetics where initially fast sorption gave way to slow sorption, which was considered to be controlled by intraparticle diffusion into the microporous matrix of the organo-mineral composite. Pb sorption to WTR was highly pH dependent although it was capable of functioning as a sorbent over a wide pH range. Comparison of nine different WTRs revealed that all WTRs had a high Pb sorption capacity. In general, the sorption capacity of the Fe-WTRs was higher than that of the Al-WTRs.

Experiments were conducted to compare the sorption characteristics of WTR to that of its end-member components, ferrihydrite and humic acid (as a proxy for the NOM component). WTR

exhibited a lower sorption capacity in comparison to humic acid (200 mg/g) and ferrihydrite (170 mg/g). The sorption edge of WTR closely reflected that of ferrihydrite across the whole pH regime (pH 3-7), implying that WTR sorption behaviour is dominated by its Fe oxyhydroxide component. It is considered that the strong associations between the organic and mineral components in WTR that stabilise the composite are also responsible for reducing its reactivity. The organo-mineral composite nature of WTR may provide benefits in terms of long-term immobilisation of contaminants.

The ability of WTR to immobilise Pb and Arsenic (As) from real contaminated soil was investigated through plant growth trials. Soil amendments included wet WTR, dried WTR, compost and dried WTR-compost combinations. In general, all amendments improved plant growth and some treatments reduced metal uptake from the contaminated soil, indicating the amendments reduced contaminant bioavailability. Wet WTR treatments were more effective than dry WTR amendments at reducing plant uptake, and combination treatments yielded the most improved plant growth. The WTR had greater effect on reducing As uptake than Pb. Higher mobility of As may promote greater interaction between this contaminant and the amendment. Equally, wet WTR and compost may achieve greater reduction in contaminant uptake than dry WTR as a result of greater physical interaction, since humic and Fe components in compost and wet WTR may be more readily leached and redistributed within the soil matrix. This suggests that contact is the critical factor in this remediation strategy. Overall, these findings show that WTR has high potential to act as an immobiliser of Pb and other contaminants, for use in soil remediation. The key challenge for this *in situ* stabilisation method is likely to be achieving sufficient mixing for adequate interaction between the contaminants and the amendments.

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Declaration

No part of this thesis has previously been submitted by myself for a degree at this or any other University. Where material has been generated though joint work, the work of others has been indicated.

Nina C. Finlay

Durham University

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1. **Introduction**

1.1 Regeneration of Brownfield Using Sustainable Technology

This PhD project was undertaken as part of a wider multidisciplinary project called ROBUST: Regeneration of Brownfield Using Sustainable Technologies. ROBUST was a five-year (2009-2014), EPSRC funded project between the School of Engineering & Computing Sciences and the Institute of Hazard, Risk & Resilience housed in the Geography Department at Durham University. The project investigated scientific and social aspects of brownfield land and its regeneration. The 'Sustainable Technologies' in ROBUST involved looking at 'waste' products from industry as a means of remediating contaminated soil, which is the focus of this thesis. As well as developing remediation technologies, ROBUST explores the wider issue that is *regenerating* brownfield land back into usable space for the benefit of local communities.

Brownfield land in the UK is land that has previously been developed, and as a result of its former use, may have real or perceived contamination problems. Previously developed land is defined as 'that which is or was occupied by a permanent structure, including the curtilage of the developed land and any associated fixed surface infrastructure' excluding agricultural or forestry buildings (DCLG, 2010). Brownfield regeneration is recognised for its part in promoting environmental improvement, greenfield preservation, and economic and social regeneration of communities. Regeneration of brownfield land in the UK was widely undertaken after a target was set in 1998 for 60% of new housing developments to take place on brownfield land by 2008, a target which was exceeded 8 years ahead of schedule (CLG, 2008). However, not all brownfield land is suitable for such redevelopment. 'Low-value' brownfield land is taken to mean land that is of little interest for property development purposes. The cost for local authorities to bring such land back into beneficial use is often too high to be viable; as a result these sites often lie derelict within the heart of communities, causing blight on the landscape and a potential negative impact on community health, well-being and local economies (Kaufman and Cloutier, 2006).

The benefit of transforming low-value urban brownfield land into high quality public space as part of social regeneration programmes could be considerable (De Sousa, 2003). Indeed, a recent study conducted by ROBUST researchers has shown that there is an association between brownfield land and poor health (Bambra et al., 2014). A wealth of literature emphasises the positive role of public open areas and greenspaces in the promotion of health and well-being of communities (Croucher et al., 2008).

The UK applies a risk-based approach to the identification, assessment, management and redevelopment of contaminated brownfield land. Local authorities are required to investigate potentially contaminated sites and remediate, where necessary, under Part 2A of the Environmental Protection Act 1990. Part 2A applies to cases of contamination where:

- significant harm is being caused; or
- there is significant possibility of significant harm being caused; or
- pollution of controlled waters (such as rivers or groundwater) is being, or is likely to be caused.

In order to determine whether significant harm is being caused or whether there is a possibility of such harm, site specific risk assessments are used. Under Part 2A, potential risks of contaminated land are assessed through the pollutant linkage model. The key elements of a pollutant linkage are defined as (EnvironmentAgency, 2009) :

- A **contaminant** - a substance that is in, on or under the land and has the potential to cause harm;
- A **receptor** - something that could be adversely affected by a contaminant, such as people;
- A **pathway** - a route or means by which a receptor can be exposed to, or affected by, a contaminant.

Each of these elements can exist independently; they create a risk only where they are linked together. So for a risk to exist, there must be contaminants present in, on or under the land in a form and quantity that poses a hazard, and one or more pathways by which they might significantly harm people, the environment, or property; or significantly pollute controlled waters (DEFRA, 2012).

The Contaminated Land Exposure Assessment (CLEA) Model 2002 was developed by the Department for Environment, Food and Rural Affairs (DEFRA) and the Environment Agency (EA) to assess the risk to human health from contaminated soils. Soil Guideline Values (SGVs), which are derived from the CLEA model, are scientifically based generic assessment criteria that can be used to simplify the assessment of human health risks arising from long-term and on-site exposure to chemical contamination in soil (EnvironmentAgency, 2009). They are guidelines on the level of long-term human exposure to individual chemical in soil that are tolerable or pose a minimal risk to human health. SGVs represent "trigger levels", concentrations above which, **may** pose a possibility of significant harm to human health. The CLEA software estimates exposure to chemicals from soil sources through the following pathways (EnvironmentAgency, 2009):

- Ingestion of contaminated soil, indoor dust and homegrown/allotment grown produce;
- Absorption of the contaminant through the skin from soil and indoor dust;
- Inhalation of the contaminated dust and vapour from indoor and outdoor air.

SGVs are derived for three different generic land use scenarios: residential, allotment, and commercial. Further, more detailed, site-specific information is then used to determine whether unacceptable risks to human health are present, including determining whether the SGV values are appropriate based upon the soil condition at the site e.g. different organic matter contents and determining bioaccessibility of contaminants. Following the assessment, remediation options can be appraised for their suitability to return the land into a state which is 'suitable for use'. The statutory guidance for Part 2A states that the broad aim of remediation should be (DEFRA, 2012):

a) To remove identified significant contaminant linkages, or to permanently disrupt them to ensure they are no longer significant and that risks are reduced to below an unacceptable level; and/or
b) To take reasonable measures to remedy harm or pollution that has been caused by a significant contaminant linkage.

1.2 Sustainable Remediation

The concept of sustainable development is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland et al., 1987). A sustainable activity is one that achieves a balance of economic viability and environmental and social impacts. Remediation practitioners are increasingly facing pressures to conduct environmental remediation in a sustainable manner. This is partly because remediation operations are themselves associated with adverse environmental effects (e.g. secondary environmental emission). More importantly key stakeholders as well as society as a whole are demanding “sustainability” in the current sustainable development movement (Hou and Al-Tabbaa, 2014).

Remediation technologies are generally categorised as:

- ***In situ***: remedial activities taking place in the subsurface, without excavation of the contaminated soil or abstraction of groundwater;
- ***Ex situ***: remedial actions applied to excavated soil, or the treatments of contaminated waters or gaseous emissions that take place at the surface; or
- **Civil engineering-based methods**: includes containment measures such as barriers and cover systems; excavation/abstraction measures such as pump and treat, and landfill.

Traditionally, the most common approach to remediation of contaminated land is excavation followed by landfilling with clean soil. However, this is an environmentally disruptive and increasingly expensive strategy. In a contaminated land remediation report generated by DEFRA in 2010, a 2009 UK-wide survey of technology vendors revealed the following proportions of different remediation methods used: *in situ* 40.3%, ex situ 3.3%, and civil engineering-based 56.4% (DEFRA, 2010a). There is increasing emphasis in the contaminated land and remediation research sectors to improve remediation practices and become more sustainable, delivering more cost effective, environmentally and socially acceptable technologies that reduce our reliance on excavation to landfill, and protect our increasingly valued natural resource, soil (DEFRA, 2010a).

Of the three categories, *in situ* remediation techniques may be considered as the most sustainable because they can avoid excessive environmental impacts, costs and disruption. *In situ* remediation can be categorised into:

1) Physical/Chemical treatment technologies
2) Biological treatment technologies
3) Thermal treatment technologies

Contaminated soils are often complex in nature, in terms of site characteristics, subsurface conditions, type and extent of contamination, and the fact that the soil may be contaminated with a "cocktail" of pollutants. Each *in situ* technology has benefits and limitations, and often several remediation techniques are required to contamination to acceptable levels. A summary of some *in situ* treatment technologies are outlined in Table 1-1, Table 1-2 and Table 1-3 (EUGRIS; USEPA, 2006):

Table 1-1: Examples of *in situ* physical/chemical technologies

IN SITU PHYSICAL/CHEMICAL TREATMENTS Physical and/or chemical reactions in the contaminated medium destroy, transform, separate or contain the contamination. Physical processes cause a phase transfer of pollutants. Chemical processes transform the chemical structure of the pollutants.	
Chemical Oxidation/ Reduction	Applicable to inorganic and organic contaminants. Addition of oxidants/reductants causing redox reactions to chemically convert contaminants into less toxic compounds that are more stable, immobile of inert. ✓ Established technology X Has been applied more widely in groundwater remediation, dependent upon specific soil conditions and chemical properties of the contaminant
Stabilisation/ Solidification	Generally applicable to inorganics, some radionuclides and organic compounds. The use of binders/additives to reduce the mobility of contaminants through chemical and/or physical means. ✓ Relatively low cost, simple technique X Pollutants are not destroyed or removed, volume of final mass may be higher than original contaminated soil, depth of contaminants may limit applicability, treatability studies may be required to determine applicability
Soil Vapour Extraction	Applicable to volatile organic and inorganic contaminants. A vacuum is applied to induce a controlled subsurface air flow to remove volatile compounds from the vadose zone to the surface for treatment. ✓ Extensively used technology, requires little attention during operation X High organic matter content limits contaminant volatilisation, requires off-gas and exhaust air treatment system
Electrokinetic remediation	Applicable to heavy metals, anions and polar organics. Pollutants are removed from the soil by electric/electrochemical processes whereby charged species are drawn to electrodes. ✓ Can potentially remove high levels of metal contaminants in soil X Impacted by heterogeneities in the soil, application typically results in widespread acidification of the treated site, still classed as a developing technology
Soil flushing	Applicable to inorganics and some organics. Extracting solutions are flushed through the soil to capture contaminants. ✓ Effective for a rapid clean-up of newly deposited contaminants (e.g. accidental spill) X Developing technology, only useful if flushing solutions can be contained and recaptured, requires above ground treatment of recovered fluids, low permeability/ heterogeneous soils difficult to treat.

Table 1-2: Examples of *in situ* biological technologies

IN SITU BIOLOGICAL TREATMENTS Contaminants are microbially degraded into innocuous substances such as water, CO_2, fatty acids and biomass	
Bioventing	Applicable to aerobically biodegradeable organic compounds. Provision of oxygen to stimulate the naturally occurring soil microorganisms to degrade contaminants. ✓ Uses readily available and easily installed equipment, requires short treatment times, cost competitive X High contaminant concentrations may be toxic to microorganisms, depends on soil conditions
Phytoremediation	Applicable to inorganic and organic contaminants. Plants are used to remove, transfer, stabilise and destroy contaminants in soil. ✓ Low cost, low-tech method X May not be suitable for large scale implementation, plant residues may need to be dealt with as hazardous waste
Monitored natural attenuation	Applicable to biodegradeable organic compounds Contaminants undergo degradation and mineralization using natural subsurface processes. ✓ Passive, low cost, less generation or transfer of wastes X Long time scales, may not achieve required clean-up levels, not effective for high contaminant concentrations
Bioremediation	Applicable to biodegradeable organic compounds. Addition of microorganisms or nutrients to the soil to accelerate natural biodegradation processes. ✓ Minimal disturbance to site operations, cost competitive X High contaminant concentrations may be toxic to microorganisms, low permeability soils are difficult to treat

Table 1-3: Examples of *in situ* thermal technologies

IN SITU THERMAL TREATMENTS Thermal processes use heat to increase volatility to burn, decompose, destroy or melt the contaminants	
Soil vapour extraction thermally enhanced	Uses electrical heating or hot air-steam injection to increase the volatilisation rate of semi-volatile contaminants ✓ Applicable to organic contaminants, readily available equipment for onsite/offsite treatment X Highly dependent upon specific soil conditions and chemical properties of the contaminated media, requires a suitable off-gas treatment system, relatively high cost
Vitrification	Applicable to organics, inorganics and radionuclides. Soil is subjected high temperature to cause it to melt and form a glass when cool, normally destroying organics and trapping inorganics. ✓ Effective technology to immobilise heavy metals X Destructive process, soil can no longer support agricultural use, emissions of dust/particulates during operations, relatively high cost

Stabilisation is a remediation technology that is based on the application of organic and inorganic amendments to contaminated soil. The use of soil amendments has become a promising alternative to other techniques due to its simplicity, low cost and ability to immobilise or transform various types of contaminant with reported high effectiveness (Tica et al., 2011). The reaction between the reagents and the soil matrix reduces the mobility of contaminants. It relies on efficient mixing of the reagents with the soil, which is typically conducted by mechanical mixing, using mixing augers or rotavators (DEFRA, 2010a). For stabilisation of metal contaminated soil, the aim of an amendment is to immobilise the metal(loids) by changing their speciation, into a form which is less readily leachable and bioavailable.

Stabilisation as a remediation strategy has not been widely accepted in the past because it does not decrease the total metal concentration in the soil, and the majority of national guidelines for remediation are based on total metal concentrations. However, over recent years with the development of standard extraction procedures to measure bioavailability and bioaccessibility, regulatory agencies are beginning to adopt a more realistic approach to risk based assessment for setting target criteria for the cleanup of contaminated land (Hartley et al., 2004). Stabilisation and immobilisation are used interchangeably in this thesis.

There is extensive literature on the use of soil amendments for stabilisation and immobilisation of metals, and many reviews exist on the subject. Stabilisation of contaminants can be achieved by amendments able to adsorb, complex or (co)precipitate trace elements. The amendments decrease trace element leaching and their bioavailability by inducing various sorption processes: adsorption to mineral surfaces, formation of stable complexes with organic ligands, surface precipitation and ion exchange, as well as precipitation as salt and co-precipitation (Kumpiene et al., 2008). Organic materials such as activated carbon, calcium- and phosphate-based products such as gypsum (CaSO4.2H20), quicklime (CaO) and calcium phosphate (Ca3(PO4)2), zeolites, clays and oxides of manganese, iron and aluminium, are all effective immobilisers of various potential toxic elements (PTEs) (Udeigwe et al., 2011). Because of their low cost and availability, natural materials such as chitosan, zeolites and clays; industrial by-products such as steel slag, fly ash, oxides and red mud; and agricultural by-products such as compost, lignin, sawdust, straw, manures and sewage sludge have been trialled as contaminant stabilisation amendments (Kumpiene et al., 2008).

1.3 The Use of Water Treatment Residual in Sustainable Remediation

The potential for using a ‘waste’ material to provide a sustainable means of remediating contaminated land, though immobilisation, is explored in this thesis. In collaboration with Northumbrian Water Ltd (NWL) a waste product known as **water treatment residual** (WTR) was identified. WTR is a by-product generated by drinking-water treatment facilities worldwide and is commonly disposed of by landfill. It is a sludge-based waste which is produced during water purification as a consequence of the coagulation process. WTRs are known to contain high quantities of coagulating iron (Fe) or aluminium (Al) (hydr)oxides and coagulated **natural organic matter** (NOM). Its chemical composition highlights its potential as a sorbent of contaminants such as **potentially toxic elements** (PTEs) and also as a soil substitute. It is therefore considered that WTR may be suitable for use as an *in situ* amendment to PTE-contaminated land.

So far, the literature has largely focussed on WTR as a sorbent of the oxyanion phosphorus (P) for potential control of nutrient-rich runoff and pollution prevention in downstream waters, including in the USA (Agyin-Birikorang et al., 2009; Makris et al., 2005a), Ireland (Babatunde et al., 2009) and China (Wang et al., 2012). Largely following on from this work, WTR was found to have a high capacity to immobilise the oxyanion, arsenic (Makris et al., 2006; Nagar et al., 2009; Sarkar et al., 2007a). In comparison, relatively little is known about WTRs ability to function as a sorbent of cation contaminants, such as mercury (Hovsepyan and Bonzongo, 2009), selenium (Ippolito et al., 2009b), cadmium, copper, nickel, lead and zinc (Chiang et al., 2012) and chromium (Nielsen et al., 2011).

This study focuses on the potential for WTR to act as an adsorbent of the potentially toxic element, lead (Pb). Lead was selected for this investigation because it is widely found as an anthropogenic contaminant in the environment. This is particularly the case in north east England, where mining in the North Pennines and the associated heavy industry of the past has left a legacy of contaminated environments.

Lead is a well known toxic heavy metal which adversely affects the health of many biological species. Lead does not appear to be necessary or beneficial to the body and no “safe” level of exposure has been found (Flora et al., 2012). It is known to affect the central nervous, hematopoietic, hepatic and renal systems, producing serious disorders. Lead is known to impact the mental and behavioural development of children. Fetuses and young children are at particular risk to neurological effects of lead because the developing nervous system absorbs a higher fraction of lead (Flora et al., 2012). Exposure to lead can occur through various sources such as leaded petrol, batteries, lead containing pipes or lead-based solder in water supply systems, and has been used in many different industrial processes such as lead smelting, coal combustion, paint production textiles manufacturing, tanneries, etc. Acute toxicity through occupational exposure is fairly uncommon whereas chronic toxicity is much more common and occurs at blood lead levels of about 40-60 µg/dL (Flora et al., 2012). The World Health Organisation guideline drinking water standard for lead is 10 µg/L; above 0.05 mg/L in drinking water, Pb(II) is a potent neurotoxic metal (WHO, 2011).

1.4 WTR Disposal

There are considerable concerns over the disposal of WTR, its associated costs and environmental impact. Regulation governing its disposal varies by country; in some cases recycling to land is permitted, whereas in others the only disposal option is landfill. The costs of handling and disposing of the enormous sludge quantities account for a significant part of the overall operating costs of WTWs, with such costs only likely to increase due to increasingly stringent environmental regulations (Babatunde and Zhao, 2007).

Estimates of the quantity of WTR produced per annum are sparse in the literature. A review paper complied by Babatunde and Zhao (2007) presented production estimates of several million dry tonnes p.a. from Europe in 2004, and 15,000 dry tonnes p.a. from Ireland in 2006, both of which were predicted to double by the next decade. A recent report by Water UK Standards (2014) stated that production of waterworks sludge in the UK was approximately 131,000 tonnes dry solids per annum, consisting of 44% alum coagulant sludge, 32% ferric coagulant sludge, 18.5% softening sludge, 4.5% natural (slow sand) sludge and 1% ‘other’ sludge. Of all the waterworks sludge produced, 75,980 tonnes p.a. was disposed of to landfill, 37,990 tonnes p.a. to sewage treatment and the rest via minor disposal routes, including agricultural land and beneficial uses such as soil conditioners and brick/cement production. Treatment and disposal of the coagulant-based sludges (total of 99,560 tonnes p.a.) is reported to present the greatest challenge to the water industry (Water UK Standards, 2014).

1.4.1 WTR disposal in Scotland

In Scotland, waste disposal is governed by the Waste Management Licensing (Scotland) Regulations 2011. Some activities involving waste materials are exempt from licensing if they meet requirements detailed in the Regulations. Although an activity may be exempt from waste management licensing, it is still subject to statutory controls to prevent environmental pollution and harm to human health. Sludges from water clarification, which includes WTR (European Waste Catalogue code: 19 09 02) are exempt from waste management licensing for:

a) The treatment of land for agricultural benefit or ecological improvement;
b) The reclamation or improvement of land.

Benefit to agriculture or ecological improvement is assessed through criteria such as: addition of plant nutrients; addition of organic matter which improves the soil water holding capacity or porosity, stability, tilth and workability; addition of liming material; the restoration or creation of wildlife habitats. SEPA (Scottish Environment Protection Agency) require a benefit statement for the proposed land spreading to assess/permit land spreading based on soil type, risk to the environment, etc on a case-by-case basis.

Alternatively, WTR is disposed of to landfill, which is regulated by the EU Landfill Directive (Council Directive 1999/31/EC). The costs associated with WTR disposal are on average £110-£130 per tonne for landfill and £50-£75 per tonne for land restoration (pers comm., B. Mulholland, Scottish Water).

In Scotland, the majority of all WTR is alum-based, with only a few sites using ferric as a coagulant. Table 1-4 below presents production figures and approximate disposal costs of WTR from Scottish Water in 2014-2015.

Table 1-4: WTR production figures from Scottish Water, 2014 - 2015

Scottish Water Al-WTR Outlet	WTR produced (wet tonnes) 2014-15	Proportion to outlet (%)	Approximate Cost (£)
Landfill	21182	68.5	2,540,000
Land reclamation	9727	31.5	700,000
Total	30909		3,240,000

Application rates of WTR permitted for land spreading vary greatly depending on the area and the benefit statement presented to SEPA. For land reclamation purposes, exemptions have allowed applications of up to 900 t/Ha; for agriculture, exemptions would typically be in the region of 5 - 60 t/Ha (pers comm., B. Mulholland, Scottish Water, 2015). In comparison, biosolids recycling to land is typically 20-25 t/Ha, based on nutrient additions (e.g. nitrogen, phosphorus, potassium), potentially toxic element (PTE) additions, soil pH and soil type.

1.4.2 WTR disposal in England and Wales

In England and Wales, waste disposal is governed by the Environmental Permitting (England and Wales) Regulations 2010. The treatment of WTR at a water treatment works (WTW) is covered by a waste exemption (T20) which allows up to 10,000 tonnes per annum to be treated by water removal, or it can be imported into a waste water treatment works under a different waste exemption (T21), to be treated in combination with waste water sludge (www.gov.uk).

In terms of waste disposal, exempted materials are allowed to be spread to benefit agricultural land (U10 waste exemption) and non-agricultural land (U11 waste exemption), however under these regulations, WTR is not exempt. In order to spread WTR to land, a permit is therefore required from the Environment Agency (EA). The permit is granted for a specific deployment for each farm. This is a specific quantity allowed to be used over a 12 month period and has to be applied for by a FACTS registered expert (or equivalent), taking into account factors such as soil type, crop type, local environmental risks and so on (EnvironmentAgency, 2013). Other disposal routes are into a sewage treatment works (T21 waste exemption), or landfill. In England, landfill is currently £80 per tonne, excluding a gate fee (pers comm., E. Higgins, NWL Ltd, 2015).

1.4.3 WTR in North East England

Northumbrian Water Ltd (NWL) owns and operates the WTWs in the north east of England, providing water to 2.7 million people in an area covering 9,400 km^2 which encompasses the major population centres of Tyneside, Wearside and Teesside, as well as large rural areas in Northumberland and County Durham. 95% of the drinking water produced by NWL is derived from rivers and reservoirs and the other 5% from boreholes and aquifers, generating 1.15 billion litres of drinking water per day (www.nwl.co.uk).

WTR production figures from Northumbrian Water, 2010-2015 (pers comm., L. Dennis & E. Higgins, NWL Ltd, 2015) are presented below in Table 1-5.

Table 1-5: WTR production figures from Northumbrian Water Ltd, 2010 - 2015

WTR type	Total WTR produced (wet tonnes)	Ferric-WTR (%)	Alum-WTR (%)	Alum/Ferric mix-WTR (%)	Disposal route
2010-11	69666	80	13.5	6.5	Recycled to others' land
2011-12	64871	78.4	13.9	7.7	
2012-13	62871	76.4	16	7.6	
2013-14	55966	72.1	14.7	13.2	
2014-15	61235	67.2	17.8	15	

The table shows that WTR generated by NWL is typically recycled to other's land by means of site specific deployment permits. Application rates vary but recently have been up to 125 t/Ha in non-nitrate vulnerable zones. In comparison, biosolids application rates are typically less than 20 tonnes/Ha, largely because of their much higher nitrogen content (pers comm., E. Higgins, NWL Ltd, 2015).

In the UK, relatively little research has been done into sustainable recycling options for WTR. In this regard, the ROBUST project in collaboration with Northumbrian Water, identified WTR as a waste stream which merited further attention.

1.5 Aims and Objectives

The overall aim of this project was to establish the capacity of WTR to immobilise Pb, and hence to establish its suitability as an *in situ* amendment in contaminated soil. This was achieved by the following objectives:

1) Characterisation of WTRs in north east England, with the aim of assessing their physicochemical composition;
2) Detailed examination of WTR in terms of its morphology and mineralogy with the aim of understanding its stability for use in the environment, and its potential sorbent properties;
3) Assess the capacity of WTR to adsorb Pb from aqueous solution as a function of environmental parameters such as pH, ionic strength, solution concentration and contact time;
4) Investigate the sorption behaviour of WTR in comparison to its end-member components to gain an insight into the factors controlling Pb sorption to WTR;
5) Investigate the capacity for WTR to immobilise PTEs (Pb and As) in real contaminated soil through a plant growth and element uptake study.

1.6 Scope and structure of thesis

This thesis presents research conducted to assess the potential for using WTR to immobilise Pb for *in situ* remediation of contaminated soil. This thesis is structured as follows:

- **This chapter** introduces the topics of contaminated land, sustainable remediation, the waste product WTR and its disposal, to provide the background behind the research project.
- **Chapter 2** provides a description of the processes involved in the generation of WTR. It then presents research into the bulk composition of WTRs sampled from north east England.
- **Chapter 3** presents a detailed examination of the physiochemical characteristics, mineralogy and morphology of a single iron-based WTR which will then be the focus of subsequent chapters.
- **Chapter 4** investigates Pb sorption to WTR by means of batch sorption experiments to establish its capacity as an adsorbent of Pb.
- **Chapter 5** presents a short-term plant trial conducted with WTR amendments in real contaminated soil with the aim of assessing its potential as an *in situ* soil amendment.
- **Chapter 6** concludes the research and suggests further work.

2. Composition of WTRs from North East England

2.1 Introduction

This chapter investigates the physicochemical characteristics of water treatment residuals (WTRs) in north east England with respect to their potential as an amendment for contaminated soil. In this section, the background to WTR production is discussed and the objectives of the study are outlined.

2.1.1 Drinking water treatment

The UK water industry treats and supplies more than 16 billion litres of drinking water per day to domestic and commercial customers (Water UK). It is one of the most regulated and tested products on the market. Within the EU, the European Drinking Water Directive (Council Directive 98/83/EC) sets drinking water quality standards. In the UK, regional water companies (shown in Figure 2-1) who are responsible for the production and supply of safe drinking water are regulated by the Drinking Water Inspectorates in Northern Ireland, England and Wales, and the Drinking Water Quality Regulator in Scotland.

Two-thirds of the raw water comes from surface sources (rivers, streams and reservoirs) and one third from groundwater (aquifers) (Water UK), with surface water dominating the NE drinking water industry.

A vast range of physical, chemical and microbiological measures must be met to satisfy drinking water quality standards, such as suspended solids, potentially toxic elements (PTEs), organic compounds, pathogenic bacteria and protozoan parasites. Consequently, drinking water treatment involves a number of processes which are often extensive and complex.

Figure 2-1: Map of water service suppliers (Water UK, 2007)

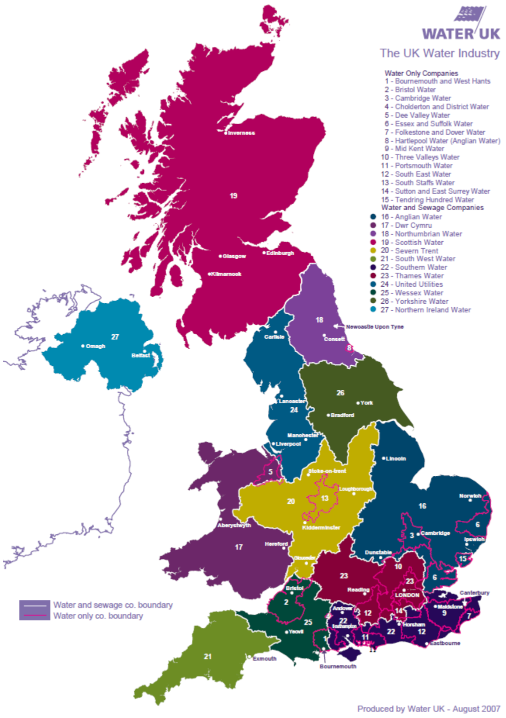


Figure 2-2: Drinking Water Treatment Works Flow Diagram

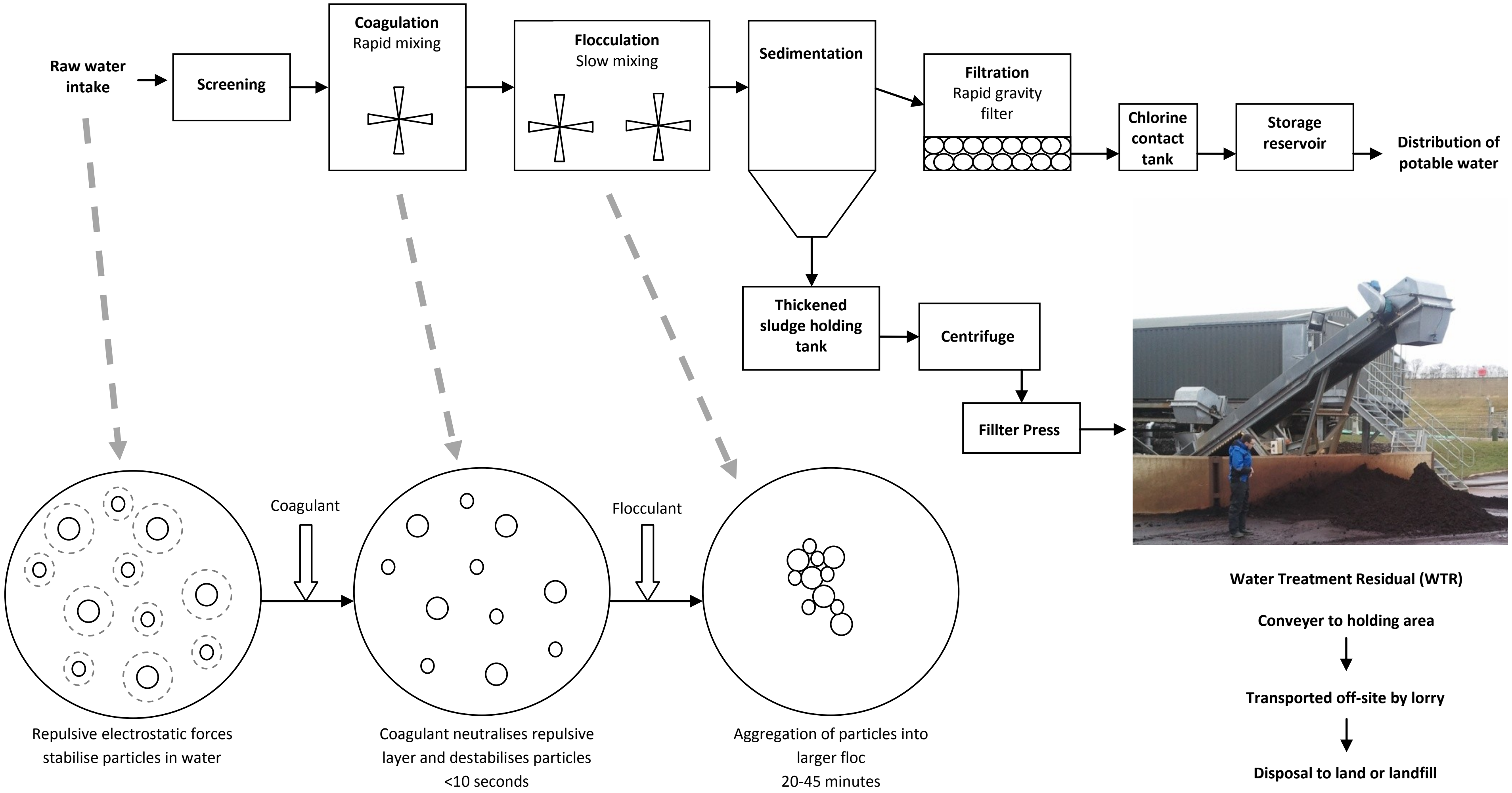


Figure 2-3: Coagulation and flocculation mechanism. Adapted from MVH (2005)

Figure 2-2 illustrates the typical procedure for treating municipal drinking water. It involves a series of mechanical and chemical steps to remove debris, particulate matter and dissolved constituents from the raw water before it is treated with disinfectant chemicals and distributed to customers. As a result of these treatment processes a number of waste products are generated, the most significant of which (in terms of mass produced) is called water treatment residual (WTR). As WTR is the focus of this study, the details of how and why it is formed are discussed below.

2.1.2 Raw water

Raw water in the NE comes from surface water sources and can contain suspended particles (>1 µm), colloidal particles (0.001 to 1 µm) and dissolved constituents (<0.001 µm), of inorganic and organic origin. Inorganic mineral components include weathering products from rocks and soils such as metal oxides and clays which can be present as colloids as well as sand and silt-size fractions. Natural organic components, collectively known as natural organic matter (NOM), may have entered the water source by surface runoff or exist in the water itself. The chemical composition of raw water varies significantly as a result of the geology, topography, land use, climate and hydrology of the water catchment area. Table 2-1 presents some of the major chemical components of natural surface waters.

Table 2-1: Major chemical components of natural waters

Cations	Anions	Colloidal	Suspended solids
Ca^{2+}	HCO^-	Organic matter	NOM
Fe^{2+}	$H_2BO_3^-$	Clays	Clay
Mg^{2+}	CO_3^{2-}	SiO_2	Silt
Mn^{2+}	F^-	Fe_2O_3	Sand
K^+	OH^-	Al_2O_3	
Na^+	NO_3^-	MnO_2	
Zn^+	NO_2^-		
NH_4^+	PO_4^-		
Trace metals	H_3SiO_4		
	SO_4^{2-}		
	HS^-		

(Crittenden et al., 2005)

Natural Organic Matter (NOM)

Natural organic matter (NOM) is a complex mixture of organic compounds present in all natural waters, arising from the decomposition of floral and faunal materials. The organic components from these materials (such as carbohydrates, amino acids and lignin) vary in their reactivity and are broken down by microorganisms at different rates. Microbial respiration releases some of the carbon from these compounds as CO_2 whilst the rest is incorporated into the microbial biomass or transformed into stable, macromolecular compounds known as humic substances, in a process known as humification. The process of humification is not well understood and several concepts exist to describe the pathways of formation of the dark coloured, heterogeneous organic compounds known as humic substances (Piccolo, 2001; Stevenson, 1994; Swift, 1999).

In the traditional theory of humification, it is thought that easily decomposable material releases low molecular weight compounds (such as phenolic and amino acids) which react and polymerise, whereas the more resistant organic material (such as lignin) that only partially degrades can react with low molecular weight compounds. Both of these pathways result in the formation of humic material which consists of complex, polymeric aliphatic and aromatic compounds of varying composition and molecular size and is known as the ‘polymeric model’ (Stevenson, 1994). However, more recently the concept of ‘supramolecular association’ has emerged, in which many relatively small and chemically diverse organic molecules form clusters linked by hydrogen bonds and hydrophobic interactions. The clusters are arranged in a micellar structure in which hydrophilic exterior regions shield hydrophobic interiors (Sutton and Sposito, 2005).

NOM consists of the parent materials in various stages of decomposition and humification. In this study NOM is taken to include humic and non-humic material, as described in Figure 2-4. The non-humic fraction comprises identifiable compounds such as carbohydrates, proteins and lignin.

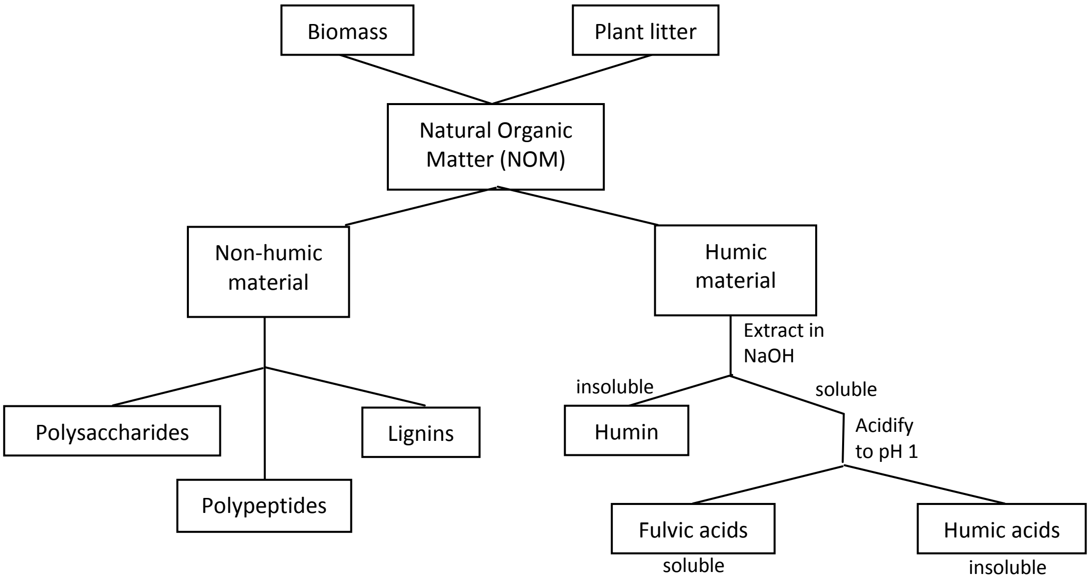


Figure 2-4: Classification scheme of natural organic matter. Adapted from McBride (1994) and Brady and Weil (1999)

Humic substances have traditionally been fractionated into subgroups based on their solubility in NaOH and their subsequent solubility and insolubility in acid solutions (Stevenson, 1994). This operationally defined scheme (Figure 2-4) broadly separates substances with different chemical properties: humin and humic acid have high molecular weights (> 10,000 Da), higher carbon content, are darker in colour and less reactive than fulvic acids which are the more soluble, acidic, low molecular weight fraction (< 10,000 Da) with higher oxygen content owing to a greater number of carboxylic and phenolic groups. It is thought that the less reactive humic acid forms the backbone of the humic material, while the more reactive fulvic acid makes up the side chains. The carbon stabilised as humic substances is resistant to microbial degradation and persists in the environment for prolonged periods of time; the half-life of fulvic acids can be 10 to 50 years while the half-life of humic acid is generally measured in centuries (Brady and Weil, 1996).

The complex heterogeneous nature of humic material makes it very difficult to characterise individual components (Baldock and Nelson, 2000) but it is known to contain a variety of functional groups such as carboxylic, phenolic, amine, carbonyl and sulfydral. A hypothetical structure is presented in Figure 2-5 which highlights the randomly condensed aromatic rings and the important carboxylic and phenolic functional groups (Duan and Gregory, 2003).

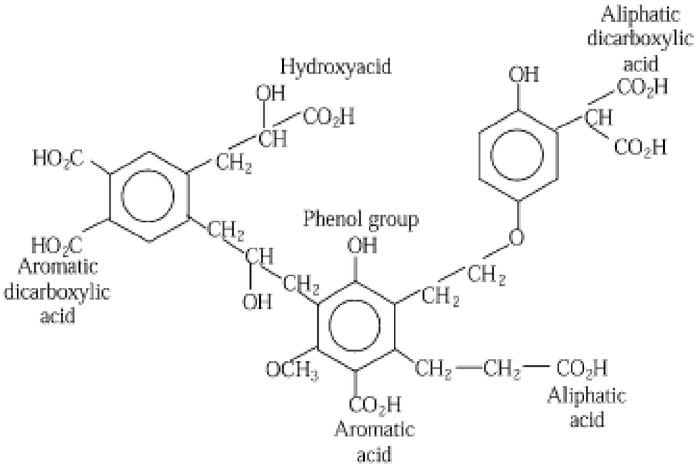


Figure 2-5: Hypothetical molecular structure of humic acid. From Duan & Gregory (2003).

It is thought that the abundance of carboxylic and phenolic functional groups on the humic polymer is responsible for its overall nature (McBride, 1994). Both of these organic acids dissociate by reaction with a base to give negatively charged functional groups (Equation 1 and 2) As a result, humic material always has a negative charge, the magnitude of which varies with pH.

$$\text{R-COOH} \leftrightarrow \text{R-COO}^- + \text{H}^+ \qquad \text{Equation 1}$$

$$\text{R-OH} \leftrightarrow \text{R-O}^- + \text{H}^+ \qquad \text{Equation 2}$$

The NOM present in natural waters consists of both hydrophobic and hydrophilic components. The hydrophobic fraction primarily consists of humic substances whereas the hydrophilic fraction of NOM is mainly composed of aliphatic carbon and nitrogenous compounds such as carbohydrates and proteins (Matilainen et al., 2010). The hydrophobic fraction (humic substances) constitutes the major fraction of aquatic NOM, accounting for 50 to 75% of the total organic carbon (TOC) content in natural waters (Thurman, 1985).

Total organic carbon (TOC) is the sum of particulate organic carbon (POC) and dissolved organic carbon (DOC). The operational definition of DOC is organic carbon that can pass through a 0.45 µm filter, although this can clearly include colloidal carbon as well. Colloidal organic carbon is approximately 10% of the DOC and is considered to be largely comprised of a humic acid fraction, with larger molecular weight and fewer carboxylic and hydroxyl groups than the fulvic acid fraction (Thurman, 1985).

NOM represents the most significant component for removal in water treatment. It presents several issues for the drinking water industry, including: negative effect on water quality due to colour, taste, and odour; increased coagulant and disinfectant dose requirements; promoted biological growth in distribution systems; increased levels of complexed heavy metals and adsorbed organic pollutants, and the formation of disinfection by-products which have been found to be carcinogenic (Jacangelo et al., 1995; Matilainen et al., 2011; Richardson et al., 2007). The quantity and quality of the NOM in surface waters depends on the local climate, geology and topography (Fabris et al., 2008) as well as seasonal variation (Sharp et al., 2006a; Wei et al., 2008). Additionally, increasing concentrations of DOC in surface waters has been observed worldwide over the past 20 years (Delpla et al., 2009; Evans et al., 2005), presenting further challenges for the water industry. It is believed that climate change (temperature and precipitation) and a decline in acid deposition may be responsible for this trend (Delpla et al., 2009).

In natural waters, the majority of both inorganic and organic substances carry a negative surface charge; Table 2-2 shows that most components exhibit a point of zero charge (PZC) that is below neutral pH, and are therefore typically present as negatively charged particles in natural water systems.

Table 2-2: pH_{pzc} of common natural water particulates

Type of Particle	Point of Zero Charge, pH_{pzc}
$Al(OH)_3$	7.5-8.5
Al_2O_3	9.1
$Fe(OH)_3$	8.5
MnO_2	2-4.5
SiO_2	2-3.5
Kaolinite	3.3 - 4.6
Montmorillonite	2.5
$CaCO_3$	8-9
Algae	3-5
Bacteria	2-4
Humic acid	3

(Crittenden et al., 2005)

The repulsive force of the negatively charged particles holds them in a relatively stable suspension in raw water for long periods of time. Since it would take too long for the particles to settle out by sedimentation alone, water treatment facilities use coagulation and flocculation processes to aid the removal of suspended and dissolved material from raw water.

2.1.3 Coagulation and flocculation

In water treatment, a coagulant is a chemical which neutralises negative charges and destabilises the suspended, colloidal and dissolved matter such that it is able to aggregate into slightly larger particles called microflocs. Rapid mixing is required to disperse the coagulant and promote particle collisions. Following coagulation, a gentle mixing stage facilitates flocculation, whereby the microflocs collide and bond to produce larger flocs. A flocculant is a chemical which may be added to aid the aggregation process by producing stronger, larger flocs. The subsequent flocs can then be removed by separation procedures such as sedimentation and filtration. Figure 2-3 illustrates the coagulation-flocculation process.

Coagulation

Coagulants are usually hydrolysing metal salts, the most common of which are listed in Table 2-3 alongside the most common flocculants.

Table 2-3: Common coagulant and flocculant chemicals

Coagulants	Flocculant
Aluminium sulphate (Alum): $Al_2(SO_4)_3.14H_2O$	Polyacrylamides
Prehydrolysed alum (PAS): $Al_a(OH)_b(Cl)_c(SO4)_d$	Polydiallyldimethyl ammonium chloride (poly-DADMAC)
Ferric sulphate: $Fe_2(SO_4)_3.9H_20$	Sodium alginate
Ferric chloride: $FeCl_3.6H_2O$	Starch derivatives

Initially when a salt of Al(III) or Fe(III) is added to water, it dissociates to yield trivalent Al^{3+} and Fe^{3+}, for example:

$$Fe_2(SO_4)_3 \leftrightarrow 2Fe^{3+} + 3SO_4^{2-} \qquad \text{Equation 3}$$

The trivalent ions then hydrate to form aquometal complexes e.g. $Fe(H2O)_6^{3+}$, which pass through a series of hydrolytic reactions giving rise to the formation of a variety of soluble mononuclear and polynuclear species and ultimately the precipitation of the metal hydroxide:

$$Fe(H_2O)_6^{3+} \leftrightarrow [Fe(H_2O)_5(OH)]^{2+} + H^+ \leftrightarrow [Fe(H_2O)_4(OH)_2]^+ + 2H^+ \leftrightarrow [Fe(H_2O)_3(OH)_3] + 3H^+ \qquad \text{Equation 4}$$

These cationic species can destabilise particles by several mechanisms. At low coagulant doses, the soluble metal hydroxide species adsorb onto the surface of negatively charged (inorganic or organic) particulates and help neutralise the negative charge on the fine particles allowing the formation of interparticle bridges. At high coagulant doses, when the Al/Fe salt concentrations exceed saturation indices with respect to the formation of the metal hydroxide, nucleation of the metal oxyhydroxide precipitate occurs on the surface of negatively charged particulates. This leads to growth of the precipitate with entrapment of particles within the amorphous structure. This precipitate can also adsorb dissolved constituents such as DOM (Crittenden et al., 2005).

Each mole of trivalent ion will produce 1 mole of metal hydroxide and 3 moles of hydrogen ion:

$$Fe(H_2O)_6^{3+} \leftrightarrow [Fe(H_2O)_3(OH)_3] + 3H^+ \qquad \text{Equation 5}$$

The hydrogen released in the formation of metal hydroxides will react with the alkalinity of the water:

$$3H^+ + 3(HCO_3^-) \leftrightarrow 3H_2O + 3CO_2 \qquad \text{Equation 6}$$

If the natural alkalinity of the water is insufficient to buffer pH, it may be added to the water in the form of caustic soda (NaOH), lime ($CaOH_2$) or soda ash (Na_2CO_3) (Crittenden et al., 2005).

A number of factors affect the selection and dose of coagulant, including the properties of the coagulant, the chemistry of the raw water including pH, the nature of the particulate load, as well as water temperature.

With respect to pH, the operating region for Al hydroxide precipitation is in a pH range about 5.5 - 7.7 and from about 5 to 8.5 for Fe precipitation. Ferric salt coagulants have a reputation for being more robust operationally because they are less sensitive to pH (Verrelli et al., 2009). However it should be noted that site specific factors unrelated to chemistry are also important, such as the cost of coagulants and appropriate site storage facilities. Ferric coagulants are cheaper but a higher dose is required which produces a more voluminous precipitate. Additionally, the corrosive nature of ferric may restrict its use at some WTWs.

Flocculation

Following particle coagulation, soluble organic polymers are often added to increase the size of the particles (flocculation) in order to enhance the settleability and filterability of flocculated particles. The polymers, which can be anionic, cationic or non-ionic, adsorb onto particles and form bridges between them which increases the size and strength of the floc (Bolto and Gregory, 2007), allowing the particles to settle more quickly according to Stokes' law. Common flocculants are listed in Table 2-3.

Bridging is dependent upon the adsorption of the polymers on the particle surfaces. Adsorption can be in the form of:

a) electrostatic interaction, between polymers and surfaces with opposite surface charges (e.g. cationic polymers on negative surfaces);
b) hydrogen bonding on surfaces such as oxides and silica which have surface hydroxyl groups capable of bonding with amide groups of polyacrylamides for instance;
c) ion binding whereby anionic polymers can adsorb on negatively-charged surfaces despite electrostatic repulsion when there is sufficient concentration of divalent metal ions such as Ca^{2+} which can act as 'bridges' (Bolto and Gregory, 2007).

The most effective bridging polymers are generally linear chains of high molecular weight. Polymer bridging generally produces larger, stronger, more resistant flocs than those formed by metal salts due to the flexibility of the links, which allow for stretching before rupturing occurs. Optimum bridging flocculation occurs at well below complete surface coverage of the particle surface by the polymer. In practical systems, optimum dosages are typically in the order of 1 mg polymer/ g of suspended solids or less (Bolto and Gregory, 2007).

The solids generated from the coagulation and flocculation processes are separated from the liquid phase by sedimentation and dewatered to form the sludge material known as Water Treatment Residual (WTR). Water treatment works produce WTR in the form of sludge or pressed cake depending on the specific plant operating procedures: centrifuges are typically used to separate solids from the bulk solution but in some cases a press is used to compact the sludge into a 'cake' (Figure 2-2).

The physicochemical characteristics of these sludges are directly related to the chemical content of the raw water and the coagulant chemicals. In addition, the site specific procedures employed at each WTW will also affect the composition, since the coagulation and flocculation processes are very sensitive to operating conditions. For instance, coagulant dose and coagulant pH have been found to impact on the composition of the sludge. Such factors have been studied in relation to its dewaterability, since reducing the volume of the waste stream has both environmental and financial benefits. The pH alters the overall solubility of the metal, the speed of the hydrolysis reaction and the precipitate phase favoured to form (Verrelli et al., 2009). Lower pH promotes the slow formation of compact, readily dewaterable aggregates whilst higher pH leads to the increasingly rapid formation of loose, open aggregates that are more difficult to dewater (Verrelli et al., 2009). Equally, low coagulant doses allow slow, reaction-limited cluster aggregation which produces more compact structures. High doses promote rapid, diffusion-limited cluster aggregation which produces less dense precipitates with poorer dewaterability (Verrelli et al., 2009).

2.1.4 Aims and Objectives

In assessing WTR as a potential amendment for contaminated land, its composition must be well understood, both in terms of its adsorbent characteristics, and for its effect on the soil environment.

A number of studies have been carried out on WTR across the world, however there is a distinct lack of studies and characterisation data from the UK. Although the main components of WTR may be fairly standard across the board, with it containing a proportion of NOM, inorganic particulate matter and coagulant, clearly the composition of WTR can vary hugely depending on the factors discussed above. Even within the UK, the composition of WTR may vary significantly depending on regional influences such as local geology, topography, climate and season which will all impact on the raw water quality. Additionally, company-wide policies and site-specific operating procedures such as the types of chemicals used, pH adjustment, mixing times etc, may also influence the characteristics of the WTR produced at a local level. Thus, when investigating potential re-use options, an insight into the potential variability of this waste stream is prudent.

This study aimed to improve our understanding of the composition of WTRs in a UK context by examination of WTRs from the north east region of England. In relation to its re-use potential as a soil amendment for contaminated land, the objectives were to:

- Analyse WTRs sampled from north east England for bulk composition, including physicochemical properties, nutrient and PTE concentrations;
- Investigate temporal and spatial variation in WTR composition from WTRs sampled in north east England;
- Compare the composition of WTRs sampled in north east England with WTRs from other countries using data reported in the literature;
- Compare the PTE concentrations in sampled WTRs with maximum permissible limits for PAS-100 compost and biosolids set under current land spreading regulations.

2.2 Materials and Methods

The materials and methods included in this chapter are also relevant to subsequent chapters and will be referred to throughout the thesis.

2.2.1 WTR sample collection and storage

The purpose of this study was to investigate the composition of WTRs produced in north east England and to assess their variability over time and between water treatment works (WTWs). WTRs were sourced from nine WTWs and collected four times over the course of a year. Northumbrian Water Ltd operate eleven large-scale WTWs of this kind in the north east region, two of which were not included in this study; one disposes of its WTR in the form of a thickened liquid and so was not appropriate to include here; the other was not sampled due to time constraints.

The locations of the WTWs included in this study are presented in Figure 2-6 along with corresponding WTW information in Table 2-4, showing that the WTWs rely on various water sources and catchments. Table 2-4 shows that the WTWs use a variety of coagulant and flocculant combinations.

Figure 2-6: Location of WTWs sampled in NE England

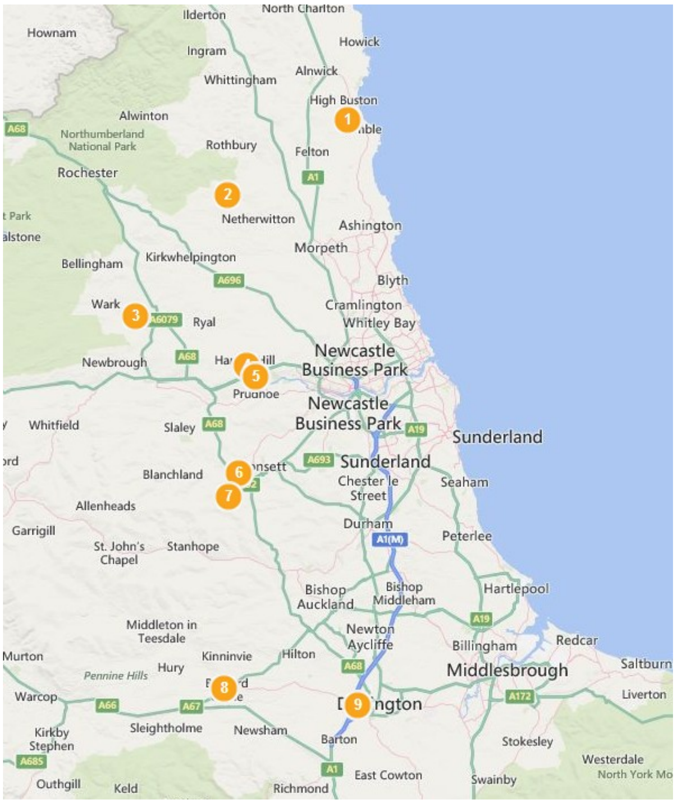


Table 2-4: Water treatment works details

Map no.	WTW	Coagulant	Flocculant	Source	Elevation (m)
1	Warkworth	Alum	Anionic polyacrylamide with sodium acrylite	River	30
2	Fontburn	Ferric	Anionic polyacrylamide	Reservoir	160
3	Gunnerton	Alum	Anionic polyacrylamide with sodium acrylite	Burn	100
4	Whittle Dene	Alum	Anionic polyacrylamide with sodium acrylite	Reservoir	100
5	Horsley	Alum/Ferric	Anionic polyacrylamide	Burn or Reservoir	110
6	Mosswood	Ferric	Anionic polyacrylamide with sodium acrylite + non-ionic potato starch	River	200
7	Honey Hill	Ferric	Anionic polyacrylamide with sodium acrylite + non-ionic potato starch	Reservoirs	320
8	Lartington	Ferric	Anionic polyacrylamide with sodium acrylite	River	220
9	Broken Scar	Ferric	Anionic polyacrylamide with sodium acrylite	River	40

Samples were collected from each WTW in October 2011, January 2012, May 2012 and August 2012 to represent autumn, winter, spring and summer seasons. At each WTW, freshly generated samples of WTR were taken. This differs from the majority of other studies which used aged WTR; the WTRs were typically sampled from holding lagoons where they had been stored for > 1 year (e.g. Makris et al., 2005b). In this study, samples of WTR were taken directly from the conveyer belt (as shown in Figure 2-2) at the end of the production process, and otherwise from the sludge holding area where the WTR was < 2 days old. For each batch of samples, collections were made over the course of 1-5 days. All samples were transported back to the laboratory in sealed rubble sacks where they were then processed and stored accordingly. With the exception of dry solids analysis which was done on the WTRs as received, physicochemical analyses was carried out using dried WTR. Samples were air dried in a darkened fume cupboard on plastic sheeting and then crushed and sieved to <2 mm or as required. All dried samples were stored in screw top polypropylene tubs in the dark prior to use.

2.2.2 General laboratory procedures and chemicals used

Unless otherwise specified, the following instruments and operating conditions were used. Samples were weighed on a Sartorius CP225D analytical balance (220 g x 0.1 mg), A&D GR-200-EC analytical balance (210 g x 0.1 mg) (A&D Instruments, UK), and a Sartorius MC21S micro analytical balance (21 g x 0.001 mg). Solid/liquid samples were shaken using a Yellow line OS 10 Basic orbital shaker (IKA, Germany), and centrifuged using a Hettich Rotanta 460 centrifuge (Hettich Zentrifugen, Germany) at 2500 g (3700 rpm). Samples were filtered with Sartorius Minisart 0.45 µm and 0.2 µm cellulose acetate membrane Luer Lock syringe filters and pipetted with Thermo Scientific Finnpipette pipettes (Fisher Scientific, UK).

Freeze drying for C and N analysis was achieved by freezing samples at -80 °C in a C340 Premium Ultra Low Temperature freezer (New Brunswick Scientific, USA) for at least 24 hours, then drying in a Christ Alpha 1-4 LSC freeze dryer (SciQuip Ltd, UK) for 24 hours. Freeze dried samples were ball milled using a FRITSCH Planetary Mono Mill PULVERISETTE 6 classic line (FRITSCH, Germany), at 500 rpm for 5 mins. Samples were then stored in a desiccator or air-tight container prior to use.

Deionised water (DI) was obtained from a Purite Select Analyst water deioniser (resistance: 14 MΩ.cm) (Purite Ltd, UK) and an ELGA Purelab Ultra Resistance (resistance : 18.2 MΩ.cm) (ELGA Process Water, UK).

2.2.3 Dry solids content and Loss on Ignition (LOI)

Triplicate field moist samples (approx. 5 g) were accurately weighed into ceramic crucibles and dried to constant mass at 105 °C in a drying oven. The dry solids (DS%) content was calculated as a percentage of wet mass:

$$\text{DS (\%)} = \frac{\text{mass of oven dry sample (g)}}{\text{mass of wet sample (g)}} \cdot 100 \qquad \text{Equation 7}$$

The oven dry samples were placed in a muffle furnace at 550 °C for 4 h then cooled in a desiccator to room temperature before recording the final weight. The LOI (loss on ignition) was calculated as a percentage by dry mass:

$$\text{LOI (\%)} = \frac{\text{mass of oven dry sample (g) - mass of ash sample (g)}}{\text{mass of oven dry sample (g)}} \cdot 100 \qquad \text{Equation 8}$$

2.2.4 pH and electrical conductivity (EC)

pH and EC measurements of solid samples were carried out following the ISO 10390 (2005) method. In brief, triplicate 5 mL samples (air-dried and sieved < 2 mm) were measured into 50 mL polypropylene centrifuge tubes. 25 mL DI was added and the suspensions agitated on a reciprocal shaker for 1 h at 150 rpm then left to stand for 2 h +/-1 h. The pH (+/-0.01 pH) and EC (accuracy) of the suspensions was measured. The instruments were calibrated using standard buffer solutions of pH 4.01, 7.01 and 10.01, and EC standard 1413 µS/cm and recalibrated approximately every 20 samples.

2.2.5 Total C and N

Triplicate samples were freeze dried, ball milled, and weighed into tin capsules using a micro balance, followed by flash combustion in a COSTECH 4010 elemental combustions system (ECS 4010). The ECS 4010 was operated in dual reactor mode with a Chromium oxide/ silvered cobalt reactor furnace heated to 950 °C and a reduced copper reduction furnace heated to 650 °C. A 3 m column heated to 70 °C was used for the gas separation followed by TCD detection. The helium flow was set to 95 mL/min and the injected oxygen volume was set to semi-micro mode. Sulfanilamide (COSTECH analytical Ltd) was used to generate a new 5 point calibration at the beginning of every new run. Quality control standards consisting of 1 blank, 1 CRM

(B2150 high organic sediment standard, Elemental Microanalysis Ltd), and 1 solid QC (sulphanilamide) were also included in every run.

2.2.6 Metals in WTRs

Analysis of pseudo-total metal concentrations (Al, As, Ca, Cd, Cr, Cu, Fe, Hg, K, Mg, Mn, Ni, P, Pb and Zn) for the WTR samples was carried out by Northumbrian Water Scientific Services (NWSS) analytical laboratories (North Tyneside, UK). In summary, dried (105 °C), homogenised samples were digested in aqua regia and refluxed for 3 hours on a hotplate. After filtration through a Whatman 541 filter and appropriate dilution, the concentration of the metals was determined by inductively coupled plasma mass spectrometry (ICP-MS) and inductively coupled plasma optical emission spectrometry (ICP-OES) in the case of potassium. Mercury was acid digested using the same method then reduced by stannous chloride to produce mercury vapour which was analysed using cold vapour atomic fluorescence. Blanks, CRMs and spiked samples were run as part of the quality control procedure. One bulk sample was analysed for each WTR. Hg and K were analysed according to in-house methods, whereas the other metals were analysed following UKAS accredited methods. Si wasn't included as part of the suite of elements analysed by NWSS because digestion in hydrofluoric acid is required to dissolve silicates, and this option was not available.

2.3 Results and Discussion

The composition of the nine WTRs are presented below and discussed with regard to the material's potential as a soil amendment. WTR variability is investigated and comparisons are made with other WTRs, with soil and common soil amendments, as well as with regulatory maximum concentration values. The raw WTR characterisation data is presented in Appendix 1.

Table 2-5 presents a range of published values for WTR physicochemical properties that have been reported in the literature; Table 2-6 presents typical PTE concentrations for WTRs reported in the literature. These tables will be referred to throughout the chapter.

Table 2-5: Typical physicochemical properties of WTRs reported in the literature

Reference	Country	Al/Fe-based WTR	pH	EC (uS/cm)	LOI (wt%)	Al (wt%)	Fe (wt%)	C (wt%)	N (wt%)	P (mg/kg)	Mg (mg/kg)
This study	UK	Al	6.5 (5.5-7.2	197 (39-370)	52.7 (39-70)	15.8 (10-21)	1.4 (0.8-2.3)	19.1 (13-26.2)	0.73 (0.52-1.07)	818 (4.0-1527)	1051 (250-2900)
This study	UK	Fe	5.4 (4.1-6.9)	234 (57-405)	46.3 (36-56)	0.4 (0.21-0.88)	29.9 (25-37)	20.3 (13.3-26.6)	0.70 (0.55-0.91)	502 (8.7-1222)	435 (170-1200)
(Chiang et al., 2012)	Belgium	Fe	8.1			1.0	61			2.5	0.25
(Ippolito et al., 2009a)	USA	Al	7.1	1800		5.9	1.45			545	
(Nagar et al., 2009)	USA	Al	5.1	363	33	11.3	1.23	15	0.6		
(Makris et al., 2009)	USA	Al	5.65	450		10.7	0.49	19.8	0.65	2430	
(Makris et al., 2005b) (Makris et al., 2004a)	USA	Al	5.4			9.24	0.62	16.2	0.6	3100	
(Makris et al., 2006)	USA	Al	5.6			8.7	0.46	18.8	0.45	3200	
(Elliott et al., 2002)	USA	Al	5.25		24.1	8.9	0.37	19.1	0.73	2790	117
(Sarkar et al., 2007b)	USA	Al	5.54		46.2	8.71	0.98	18.8	0.5	3539	1252
(Sarkar et al., 2007a)	USA	Al	5.1	363	33	11.3	1.23		0.6		
(Makris et al., 2005b)	USA	Al	7.4			3.7	0.87	3.4	0.3	8000	
(Makris et al., 2005b)	USA	Al	6.8			10.3	2.07	7.6	0.7	8000	
(Makris et al., 2005b)	USA	Al	5.7			8.7	0.57	22.5	1.0	11000	
(Agyin-Birikorang and O'Connor, 2009)	USA	Al	5.1	1.66		15.3	0.5	1.06	0.06	0.3	
(Elliott, 1990)	USA	Al	6.8		33	10.3	2.96	3.0	0.9		
(Babatunde et al., 2009)	Ireland	Al				4.3	0.33			1230	2370
(Kyncl, 2008)	Czech Rep.	Al	7.6		31.6	15	1.88		0.006	20	15600
(Mahdy et al., 2007)	Egypt	Al	7.45	1670	5.7	3.8			0.42	1900	
(Nagar et al., 2009)	USA	Fe	5.4	164	40	0.13	26.8	21	1.0		
(Makris et al., 2007)	USA	Fe	5.5			0.98	25.1	19.6	0.79	2750	
(Makris et al., 2005b) (Makris et al., 2004a)	USA	Fe	6.3			0.98	25.1	14.1	0.8	3200	
(Makris et al., 2006)	USA	Fe	6			0.13	17	19.6	0.78	2700	
(Elliott et al., 2002)	USA	Fe	6.25		35.6	0.85	32.8	15.4	0.94	4360	736
(Sarkar et al., 2007b)	USA	Fe	6.54		47.6	0.1	17.1	19.6	0.8	2671	959
(Sarkar et al., 2007a)	USA	Fe	5.4	164	40	0.13	26.8		1.0		
(Makris et al., 2005b)	USA	Fe	5.6			0.15	31.1	9.4	0.5	3000	
(Makris et al., 2005b)	USA	Fe	3.9			0.22	24.2	20.6	1.1	7000	
(Elliott, 1990)	USA	Fe	6.8		33	2.51	8.35	3.0	0.9		
(Kyncl, 2008)	Czech Rep.	Fe	8		28.8		19.5		0.008	30	13200
(Oliver et al., 2011)	Australia	Fe	7.3			7.23	8.23	5.7	0.61	1339	

*where a range of values have been reported, they are presented in parenthesis

Table 2-6: Typical PTE concentrations in WTRs reported in the literature

Reference	Country	Al/Fe-based WTR	Cu (mg/kg)	Zn (mg/kg)	Ni (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Pb (mg/kg)
This study	UK	Al	22 (13-33)	56 (28-82)	17.3 (10-24)	0.26 (0.2-0.3)	14.7 (6.1-28)	12 (4-17)
This study	UK	Fe	19.4 (7.9-36)	265 (40-1100)	53.8 (22-120)	1.0 (0.3-3.6)	30 (15-39)	60 (5-190)
(Ippolito et al., 2009a)	USA	Al	36	33	6	0.1	8	<0.05
(Sarkar et al., 2007a)	USA	Al	nd	<0.054	<1.62	<0.166	<0.168	<1.092
(Sarkar et al., 2007a)	USA	Fe	nd	<0.054	<1.62	<0.167	<0.168	<1.092
(Elliott, 1990)	USA	Al	171 (135-230)	527 (195-815)	44 (26-65)	1.6 (1-2)	50 (40-60)	204 (47-439)
(Elliott, 1990)	USA	Fe	272 (135-485)	575 (215-865)	136 (33-218)	<1 (<0.1 -2)	269 (62-513)	245 (18-840)
(Kyncl, 2008)	Czech Republic	Al	41	46	18.9	1.04	41	114
(Kyncl, 2008)	Czech Republic	Fe	31	3	12	0.83	37	24

*where a range of values have been reported, they are presented in parenthesis

2.3.1 WTR physicochemical properties

Table 2-7 describes some of the physicochemical properties of the nine WTRs under study. The data is presented as the mean ± the standard deviation from the four samples collected over the course of one year, representing the variability found at each WTW.

Table 2-7: WTR physicochemical properties

WTR	Coag type	WTR form	Dry solids (%)	pH	Electrical conductivity (µS/cm)
Horsley	Al/Fe	Cake	26 ± 2	5.9 ± 0.6	327 ± 53
Gunnerton	Alum	Cake	22 ± 4	5.9 ± 0.3	80 ± 35
Warkworth	Alum	Cake	21 ± 2	6.8 ± 0.3	239 ± 54
Whittle Dene	Alum	Cake	19 ± 2	6.8 ± 0.4	273 ± 75
Broken Scar	Ferric	Sludge	19 ± 2	6.5 ± 0.4	224 ± 57
Fontburn	Ferric	Sludge	17 ± 2	5.0 ± 0.4	231 ± 95
Honey Hill	Ferric	Sludge	17 ± 2	5.0 ± 0.6	224 ± 119
Lartington	Ferric	Sludge	19 ± 2	5.2 ± 0.3	160 ± 93
Mosswood	Ferric	Sludge	20 ± 2	4.7 ± 0.5	239 ± 168
WTR range			15 - 28	4.1 - 7.2	39 - 405

Mean ± standard deviation of 4 samples collected over 1 year.

Despite their solid form and appearance, the table shows that the WTRs are mainly comprised of water, with dry solids content ranging from 15 to 28%. Coagulant-based sludges are inherently difficult to dewater because of the high concentrations of the gelatinous metal hydroxide precipitates, and this range is typical of what such technologies can achieve (Crittenden et al., 2005). Since WTRs are generally disposed of to landfill or spread on land, via transportation by road, their high volumetric water content has serious economic implications for the water treatment industry. However, achieving higher dry solids content would incur uneconomical costs (Crittenden et al., 2005). Similarly, biosolid sludges (from the waste water treatment industry) in the form of digested cake have a dry solids content of around 25% (Defra, 2010b). The results show that there is some inter- and intra-WTW variability in %DS:

there is variation between different WTWs as well as variation in the WTRs from the same WTW.

The WTRs have a slightly acidic pH ranging between pH 4.1 and 7.2, which is similar to values reported in the literature (see Table 2-5). It is thought that the acidity is generated by the coagulant chemicals, since the pH of the raw water feeding into each WTW was pH 7-8 in all cases except for Honey Hill which varied between pH 5 and 8 (see Appendix 2). The Fe-WTRs tend to be more acidic than Al-WTRs, and this can be explained by the acid-generating nature of iron oxyhydroxide formation (see Equation 5). However in most cases the pH falls within the typical circum-neutral soil pH range of 5 to 8.

Conductivities are relatively low, ranging from 39 to 405 µS/cm and are comparable to values in the literature (Babatunde et al., 2009; Dayton and Basta, 2001; Nagar et al., 2009). Although WTRs have a high concentration of iron, aluminium and manganese metal ions, they are evidently not present in a soluble form, nor are there any salinity issues. The EC of WTRs are well below the 4000 µS/cm associated with reduced plant growth due to salinity (Dayton and Basta, 2001).

2.3.2 Chemical composition of WTRs

Table 2-8: Concentrations of major components of dried WTR

WTR	Coag type	Fe (%)	Al (%)	LOI_{550} (%)	Total C (%)	Mn (mg/kg)
Horsley	Al/Fe	13.1 ± 8.0	9.5 ± 3.9	44 ± 3.3	16.7 ± 1.2	1883 ± 2165
Gunnerton	Alum	1.5 ± 0.3	15.8 ± 4.6	66 ± 4.6	25.0 ± 1.6	595 ± 154
Warkworth	Alum	1.7 ± 0.5	15.3 ± 3.6	41 ± 3.0	14.0 ± 0.8	1493 ± 1000
Whittle Dene	Alum	1.1 ± 0.3	16.0 ± 1.6	51 ± 3.6	18.2 ± 1.2	1025 ± 934
Broken Scar	Ferric	34.8 ± 4.5	0.4 ± 0.1	37 ± 1.2	15.4 ± 1.5	1123 ± 175
Fontburn	Ferric	28 ± 0.8	0.2 ± 0.02	49 ± 5.5	22.7 ± 2.9	608 ± 337
Honey Hill	Ferric	29.3 ± 4.2	0.5 ± 0.2	51 ± 2.4	23.4 ± 0.2	1350 ± 289
Lartington	Ferric	29.5 ± 1.9	0.4 ± 0.2	50 ± 5.1	22.4 ± 2.2	953 ± 215
Mosswood	Ferric	28.8 ± 1.7	0.4 ± 0.3	48 ± 2.7	21.4 ± 2.2	1825 ± 665
WTR range		0.8 - 41	0.21 - 21	36 - 70	13 - 26	370 - 5100
Biosolids typical[a]		1.5	0.5	70	40	200[c]
Soils typical[a]		4	7.1	5	3	80-1300

Mean ± standard deviation of 4 samples collected over 1 year
[a] Elliot (1990)
[b] McBride (1994)
[c] Brady & Weil (1996)

Table 2-8 presents the main constituents of WTR, as weight percent of dry solids. It shows that the major components of WTR are organic matter (OM) and iron (Fe) or aluminium (Al) depending on whether the WTW uses a ferric or alum coagulant, respectively. On average, the Al-WTRs contain approximately 15% (n=12, SD=3.1) Al whereas the Fe-WTRs contain approximately 30% Fe (n=20, SD=3.1), confirming that a higher dose of ferric coagulant is required to obtain similar levels of NOM removal in comparison to using alum coagulant. Correspondingly, the literature suggests typical dosages of alum and ferric sulphate range from 10 to 150 mg/L and 10 to 250 mg/L respectively, depending on raw water quality and turbidity (Crittenden et al., 2005).

The majority of Fe and Al in WTR are present as amorphous hydrous metal oxides (Elliott, 1990). Assuming that all the Al and Fe is present as $Al(OH)_3$ and $Fe(OH)_3$ respectively, 15 wt% Al would equate to 43 wt% Al hydroxide and 30 wt% Fe would equate to 57 wt% Fe hydroxide, demonstrating that the metal hydroxides are the largest component of WTR by mass. These Fe and Al concentrations are slightly higher than most of the values found in the literature, which typically report concentrations of 5-10% Al and 17-30% Fe (see Table 2-5).

Table 2-8 also presents the results of total carbon (C) and loss on ignition (LOI) analysis. Due to time and instrument constraints, the WTRs were analysed for total C only. However, a small selection of WTRs were analysed for total and inorganic carbon using a Thermo TOC1200 instrument in order to assess the proportion of inorganic and organic C present. The WTRs were found to contain < 0.1% inorganic C (data not shown). Based on these results, total C was taken to provide a good representation of organic C content in the WTRs.

The WTRs in this study contained C ranging from 13 to 26% and this was assumed to all be organic carbon. High NOM concentrations were not surprising considering that most of the raw water sources originate from upland peat areas. Raw water TOC concentrations vary considerably between WTWs and over time, ranging from 1.4 to 42.0 mg/L (see Appendix 2), and are on average higher than typical surface water concentrations of 1-20 mg/L reported in the literature (Rowell, 1994). The C content of WTRs was more variable between different WTWs than within WTWs over time, suggesting that the NOM concentration depends primarily on the raw water source and the plant operating conditions, including coagulant dose, etc. In addition, the incorporation of organic polymers used as flocculant aids will increase the carbon content of WTRs (Elliot 1990).

A wide range of C contents are reported in the literature (see Table 2-5). Elliot (1990) found that typical TOC values varied from 1.0% to 6.5% across 20 WTR samples taken in the USA, where the typical surface water TOC concentrations of 1 - 15 mg/L were reported. Other published data from the USA shows the TOC content of WTRs reaching 22.5%, presumably from more peaty upland catchments.

Loss on ignition (LOI) is a simple, inexpensive method of estimating the natural organic matter content of soils and sediments. Numerous studies have applied the LOI technique to analyse

WTRs (see Table 2-5). However, it is an operationally defined technique which is known to give inaccurate results in soils which are rich in clays and oxides (Rowell, 1994). Here, LOI results were compared to the total carbon (C) measurements to assess the ability of LOI to provide reasonable estimates of NOM in WTRs.

The WTR LOI_{550} values ranged from 36 to 70%. Plotted against C concentrations, a weak linear correlation was observed ($r^2 = 0.63$). In surface waters the NOM concentration is typically twice that of the TOC concentration (Crittenden et al., 2005) yet in each case, doubling the WTR Total C concentration yielded a substantially lower OM estimate than what the LOI analyses produced. This suggests that LOI is not representative of the OM content in WTRs.

LOI is based on measuring the difference in weight before and after heating the sample to 500-550 °C. Most cellulosic NOM is oxidised to carbon dioxide at these temperatures (Lopez-Capel et al 2005). However, dehydration of clay minerals or metal oxides can also take place between 105 and 550 °C as well as, loss of volatile salts (Heiri et al., 2001). For example, goethite (FeOOH) is dehydrated to haematite (Fe_2O_3) between 280 and 400 °C, thus Rowell (1994) states that LOI is an approximate measure of OM content in sandy soils but may be up to twice the OM content in heavy textured, clayey soils. Given that WTRs are mainly comprised of Fe or Al hydroxides, it is clear that LOI will overestimate its OM content. The same conclusion was reached by Elliot (1990) when the LOI measurement was found to vastly overestimate the OM content in WTR: the average LOI was 33% for WTR samples consisting of an average of 3% TOC.

Evidently, LOI measurements should be avoided when making compositional comparisons between WTRs. In addition, variations in the method used, such as varying exposure times from 1 to 24 h and ignition temperatures from 500 to 550 °C, make it difficult to compare results from different studies (Heiri et al., 2001).

Manganese concentrations were found to range from 370 to 5100 mg/kg which is relatively high since average Mn concentrations in soil are 650 mg/kg (Gilkes and McKenzie, 1988). In areas such as North East England, which are known to contain high levels of dissolved Mn in surface waters, Mn sand or ‘greensand’ filter beds are commonly utilised by WTWs to remove dissolved Mn (Hu et al., 2004). The process involves flash liming to raise the pH of the water in Mn oxide-coated sand filter beds to pH 9 which facilitates the oxidation of soluble Mn(II) to

Mn(III/IV) oxides (McBride, 1994). The Mn sand filter beds are routinely backwashed to clear out the freshly precipitated Mn oxides, and the waste wash water is recycled to the head of the plant (Crittenden et al., 2005). The Mn oxides are then removed by the coagulation/flocculation process, and ultimately end up in the WTR. It is thought that this process contributes to the high Mn content found in the WTRs.

2.3.3 Nutrient elements in WTR

Table 2-9 presents WTR values for some of the most important nutrients required by plants: nitrogen, phosphorus, potassium and magnesium. Samples were analysed for total concentrations of these elements.

Table 2-9: Concentrations of nutrients in WTR

WTR	Total N (%)	C:N	P (mg/kg)	K (mg/kg)	Mg (mg/kg)
Horsley	0.7 ± 0.1	25 ± 2.5	515 ± 342	895 ± 299	698 ± 339
Gunnerton	0.7 ± 0.1	35 ± 3.2	273 ± 187	1348 ± 1705	535 ± 385
Warkworth	0.6 ± 0.1	24 ± 1.2	1287 ± 286	2223 ± 1273	2150 ± 823
Whittle Dene	0.9 ± 0.2	22 ± 5.2	870 ± 188	605 ± 531	473 ± 213
Broken Scar	0.6 ± 0.1	25 ± 2.4	815 ± 310	813 ± 280	600 ± 234
Fontburn	0.7 ± 0.1	34 ± 1.8	412 ± 112	300 ± 195	255 ± 24
Honey Hill	0.7 ± 0.1	32 ± 2.5	352 ± 93	425 ± 231	245 ± 61
Lartington	0.8 ± 0.1	30 ± 0.9	421 ± 127	818 ± 470	408 ± 188
Mosswood	0.8 ± 0.1	27 ± 3.0	472 ± 175	833 ± 565	335 ± 183
WTR range	0.51 - 1.1	15.5 - 39	4.0 - 1528	170 - 3900	170 - 2900
Soil typical[a]	0.02 - 0.5[d]	10	1000	640[c]	
Compost typical[b]	1.2	14-20	3000	4000	3000
Biosolids typical[a]	4	10	25000	3000[b]	2000[b]

Mean ± standard deviation of 4 samples collected over 1 year.
[a] from Elliott (1990)
[b] from Brady & Weil (1996)
c from Rowell (1994)
d from Dayton & Basta (2001)

The total N content ranges from 0.5 - 1.1 % which is within the typical range of values reported in the literature for WTRs (see Table 2-5) and higher than typical soil concentrations of 0.02 - 0.5%. High total N levels in WTR are likely caused by organic constituents such as NOM and algae that are removed from the raw water and concentrated in the WTR (Dayton and Basta, 2001). Additionally, the organic polymer used as a flocculant (e.g. polyacrlyamides) in water treatment will also increase the organic-N content of WTR (Elliott, 1990). Plants require nitrogen to be in an inorganic form (NH_4-N or NO_3-N) for uptake. The organic forms of elements (such as N, P and S) in NOM are transformed into inorganic, plant available forms by a microbially-mediated process called mineralisation (Rowell, 1994). As the carbon-rich matter is broken down, N, P and S are released. The carbon:nitrogen ratio (C:N) therefore controls the proportional transformation of organic-N to inorganic-N and thus the amount of inorganic-N available for plant uptake.

A C:N ratio of around 25 is commonly referred to as the point where mineralisation and immobilisation (the transformation of inorganic-N to organic-N by microbes) are in balance (Pierzynski et al., 2005). A lower C:N ratio promotes mineralisation (net-mineralisation) and a higher C:N ratio promotes immobilisation (net-immobilisation). In soil, stable organic matter has a C:N ratio of 10 to 12; adding materials with very high (>30:1) C:N ratios to soil can cause a rapid increase in microbial biomass and a depletion of plant available N to the point where N deficiency can occur in many plants (Pierzynski et al., 2005). Table 2-9 shows that the C:N ratio of the WTRs range from 15.5 - 39, averaging 28. This suggests that, despite the WTRs containing relatively high levels of N, this material may not necessarily be a useful source of plant available N, and may in some cases cause N depletion. Further analysis is required in order to determine the forms and proportions of N in WTR, including extractions for NH_4-N or NO_3-N and total mineral N.

These results are in agreement with findings published in the literature. Elliot (1990) found WTRs to contain on average 0.9% Total Kjeldahl Nitrogen and only 0.01% NH_3-N. Dayton and Basta (2001) found WTRs to contain on average 0.7% total N and only 0.007% mineral-N. In comparison, the table indicates that compost and biosolids contain higher concentrations of N and it is more easily mineralised (lower C:N ratio).

A wide range of concentrations were found for P (4.0 - 1528 mg/kg), K (170 - 3900 mg/kg) and Mg (170 - 2900 mg/kg), with the majority of the results being similar to or lower than typical soil values. P is often the limiting nutrient for plant growth owing to the very low solubility of phosphate minerals and its strong binding onto particle surfaces (Rowell, 1994). The WTRs were found to contain relatively low concentrations of total P in comparison to other WTR data reported in the literature (Table 2-5) and the typical soil value of 1000 mg/kg. It is well known that the Fe and Al hydroxide components of WTR are strong adsorbents of P (Butkus et al., 1998; Ippolito et al., 2003). The P present in WTR is therefore considered strongly bound, and the lack of labile and soluble forms means that plant available P is very limited. The WTRs high sorption capacity can create P deficiencies in soil and this is reported to be the biggest concern for its application to land (Elliott, 1990). However, Elliot (1990) suggests that this problem can be overcome by effective land management practices, such as the application of extra P fertiliser and selection of appropriate crops (with low P requirement). A large body of literature has investigated the use of WTR in controlling nutrient-rich runoff from agriculture (Agyin-Birikorang et al., 2009; Gallimore et al., 1999; Silveira and O'Connor, 2006) and from wastewater (Babatunde et al., 2009) to prevent pollution of downstream waters. More work investigating the application of WTR in combination with waste products which are high in P, such as compost and biosolids (Agyin-Birikorang et al., 2008; Ippolito et al., 1999; Ippolito et al., 2009a) would be prudent since the literature is fairly limited in this respect. Co-applications may balance the potential leaching of P from nutrient rich solids with P deficiencies from the WTR.

In summary, the data shows that the nutritional composition is relatively low in comparison to compost and biosolids. The elemental concentrations of the WTRs presented above are generally lower or similar to the typical soil range for N, P, K and Mg. In order to determine whether these levels equate to a sufficient plant available nutrient supply, requires further analyses using plant available extraction methods. Small nutrient deficiencies can be satisfied with moderate fertiliser applications. The decreased availability of P is likely to present the biggest impact on soil nutrient status and potentially requires greater management.

2.3.4 Potentially Toxic Elements in WTR

Table 2-10 presents WTR values for common potentially toxic elements (PTEs), along with typical PTE ranges for soil and biosolids, and the limit values for PTE concentrations in compost and biosolids intended for agricultural use, as set out by the BSI PAS 100 Compost Specifications (WRAP, 2011) and the Sewage Sludge Directive 86/278/EEC (EEC, 1986), respectively.

Table 2-10: Concentration of PTEs in WTRs

WTR	**Cd** (mg/kg)	**Cr** (mg/kg)	**Cu** (mg/kg)	**Hg** (mg/kg)	**Ni** (mg/kg)	**Pb** (mg/kg)	**Zn** (mg/kg)
Horsley	0.97 ± 0.85	18.8 ± 6.5	20.8 ± 4.0	0.13 ± 0.05	32 ± 22.2	57.5 ± 9.3	346 ± 297
Gunnerton	0.28 ± 0.05	12 ± 3.7	17 ± 4.3	0.13 ± 0.04	14.5 ± 5.2	13.3 ± 3.0	59.8 ± 17.8
Warkworth	0.25 ± 0.06	22.3 ± 6.1	28.3 ± 3.7	0.09 ± 0.03	21.5 ± 2.1	14.75 ± 2.6	67.8 ± 4.2
Whittle Dene	0.26 ± 0.05	9.8 ± 4.4	19.5 ± 2.7	0.08 ± 0.02	15 ± 3.9	8.4 ± 4.9	39.8 ± 11.2
Broken Scar	0.87 ± 0.16	29.3 ± 6.2	19.3 ± 2.5	0.32 ± 0.24	42 ± 4.2	127 ± 31.0	218 ± 17.1
Fontburn	0.31 ± 0.02	25.0 ± 6.8	9.33 ± 1.3	0.67 ± 0.62	27.5 ± 5.8	18.0 ± 17.0	76.5 ± 31.5
Honey Hill	0.78 ± 0.16	29.5 ± 7.4	17.8 ± 2.6	0.62 ± 0.79	49.3 ± 7.9	31.6 ± 17.8	210 ± 28.3
Lartington	0.72 ± 0.15	31.8 ± 5.6	23.8 ± 3.4	0.18 ± 0.14	52.8 ± 10	25.5 ± 8.6	155 ± 40.4
Mosswood	2.36 ± 1.42	31.5 ± 7.2	26.8 ± 8.3	0.28 ± 0.25	91.5 ± 35.2	85 ± 71.6	665 ± 405
WTR range	0.2 - 3.6	7.8 – 38	7.9 - 36	0.06 - 1.4	10 - 120	5 - 160	28 - 1100
Soil range[a]	0.06 - 1.1	7 – 221	6 - 80	0.02 - 0.41	4 - 55	10 - 84	17 - 125
Biosolids typical[b]	0.1 - 13.6	28 – 509	25 - 2481	0.1 - 2.0	2.6 - 389	8.1 - 850	32 - 2070
BSI PAS 100 Regs[c]	1.5	100	200	1.0	50	200	400
EU Biosolids Regs[d]	20	/	1000	16	300	750	2500

Mean ± standard deviation of 4 samples collected over 1 year.

[a] from McBride (1994)

[b] from Weston-FTA Ltd (1993)

[c] from BSI PAS-100 Specification

[d] from Sewage Sludge Directive 86/278/EEC

underlined = one or more sample exceeds PAS-100 regulations

The average PTE values in WTR can be compared to UK regulatory limits for PTE concentrations in compost and biosolids, both of which are permitted to be spread on land. The biosolids application rate is defined by the permissible annual quantities of PTEs which may be introduced to the soil, and therefore the rate is dependent on the specific biosolids PTE concentrations. BSI PAS 100 quality composts are allowed to be spread on land without an environmental permit, at any application rate. The PAS-100 specifications therefore exert stricter limits than the Sewage Sludge Directive. The WTR values that were found to exceed the BSI PAS 100 limits are underlined in Table 2-10.

The PTE concentrations in the WTRs found in this study are within the range of other published values for WTRs (see Table 2-6) and at the low end of typical biosolids values (Table 2-10). Several WTWs (6 out of the 9) were found to exceed the BSI PAS-100 specification but all values fell below the biosolids regulations. Three WTWs (Horsley, Honey Hill and Mosswood) exceeded the limits for more than one metal, and two WTWs (Mosswood and Lartington) exceeded the limits on more than one occasion. The Nickel limit (50 mg/kg) was exceeded most frequently by the WTRs. Concentrations were found to vary more between WTWs than temporally, with Mosswood WTRs consisting of the highest PTE concentrations of all. Other studies have suggested that the trace metals come predominantly from the coagulant chemicals (Elliott, 1990) but we did not find evidence to support this here, as there were no correlations between the Al/Fe content and PTEs. It should be stated that the catchment for many of the WTWs is dominated by a mining landscape and this is the most likely source of metals such as Pb, Zn, Cd and Mn.

In order to look for patterns in metal concentration in the WTRs, water quality data collected by Northumbrian Water for raw water feeds to each WTW was examined against the WTR data. The hypothesis was that metal loadings in WTR would correlate with metals in raw water over time. However, the available water data was one sample per month (see Appendix 2). Correlations were sought but none could be found using the available data. It is likely that patterns exist but in this case, the lack of samples and alignment of sampling times, as well as the fact that other factors were not taken into account (such as rainfall, residency times), meant that no relationships were found. There may be a mix of factors contributing to the PTE concentrations in WTR and a more detailed investigation would be required to elucidate any trends, which would involve coordinated sampling and analysis of the pure coagulant chemicals, the raw water feed and the WTR.

Current land spreading regulations are based on total PTE concentrations, as given above. However it is also important to understand the partitioning of the metals within a sludge matrix since this information provides an indication of the lability of the PTEs and potential risk of their release into the soil environment. The fractionation of PTEs (including Cd, Cr, Cu, Ni, Pb and Zn) in WTRs was explored by Elliot (1990). Sequential extractions were used to show that >75% of the metals were found in the oxide-bound or residual form, except Cd which was also found in the organically bound fraction in reasonable amounts (38%). Freshly precipitated hydrous oxides have a large capacity to occlude, coprecipitate and sorb divalent metal ions from the surrounding aqueous media. This means that metals that were present in aqueous form in the raw water will tend to be trapped or intermixed within the hydrous oxide solid phase of the WTR as it forms (Elliot, 1990). Less than 6% of each of the metals were found in the exchangeable fraction (1M $MgCl_2$, pH7 extraction), indicating that minimal concentrations of metals will be mobilised under normal soil conditions.

The data above shows that WTRs contain varied concentrations of PTEs but in comparison to biosolids, these levels are relatively low. All of the WTR values fell well below the biosolids regulations and only in limited cases were the WTRs found to exceed the BSP PAS 100 limits. Given that there is no upper limit to application rates of composts which meet the BSI PAS 100 specifications (indicating that they are considered safe to apply to land), suggests that WTRs could also be considered as relatively inert materials from a PTE perspective.

2.4 Conclusions

The aim of this study was to investigate the composition of WTRs in north east England, in order to improve our knowledge and understanding of the characteristics of WTR produced in the UK, and to compare this data to figures reported in the literature from elsewhere.

In terms of its bulk composition, Analysis of the WTRs from north east England shows that their composition was generally within the range of other published values reported worldwide. WTR is set apart from typical soils and biosolids due to its high Al or Fe hydroxide content and high organic matter content. There is some inter- and intra-WTW variability, but for all parameters inter-WTW variability seemed to dominate, with WTR characteristics differing between WTWs more than within WTWs temporally.

The main concerns surrounding land application of WTRs are:

1. Impact on soil fertility: the nutrient status of the WTRs was found to be relatively low suggesting that WTR is unlikely to be considered as a source of plant nutrients. The impact on soil fertility will depend on site specific factors such as soil type, soil quality and WTR application rates. Any potential nutrient deficiencies could be controlled by good land management practice and fertiliser additions.
2. Concentration of PTEs: these were found to be low in comparison to biosolids, and moreover, the PTEs are expected to be immobilised and tightly held within the sludge matrix, suggesting that they will not be readily released into the environment.
3. Impact of high Fe and Al hydroxide content on soil and environment: concerns over WTRs ability to adsorb P and reduce plant availability may be counteracted by good land management practice and applying extra P fertiliser to re-balance any such effects.

The main benefits of applying WTRs to land are considered to be:

1. High organic matter content: organic matter plays a crucial role in maintenance of soil structure. It is thought that the additions of WTR may contribute to improving soil physical properties such as water holding capacity and aggregate strength.
2. High metal hydroxide and organic matter content: Suggests good adsorption potential for PTEs in contaminated soil. This will be explored further in the following chapters.

Further work should include:

- A more detailed study to investigate variation in WTR composition in relation to raw water quality, to draw out patterns and correlations between the composition of the raw water, coagulant dose and WTR;
- Assessment of the plant availability of nutrients;
- Leaching of Fe and Al from WTR under different soil conditions;
- Influence of WTR amendments on soil physical properties;

Ultimately, such further work is required in order to develop specific regulatory guidelines for the safe and effective application of WTR to land. This would help to encourage the productive re-use of WTR.

3. Detailed Characterisation of Broken Scar WTR

3.1 Introduction

In view of establishing WTR's (Water Treatment Residual's) potential as an adsorbent for contaminants in the environment, its physicochemical behaviour as well as its adsorption behaviour were under investigation in this thesis. In Chapter 2, bulk physicochemical analysis was carried out on WTRs sampled in North East England, to gain an initial insight into the composition and extent of variation in WTRs from this region. The bulk composition, nutrient and trace element content of these WTRs was considered with regard to their potential as soil amendments.

Carbon as well as Al or Fe were found in large quantities in all of the WTRs, confirming that they are predominantly composed of the coagulating Al/Fe oxides and the coagulated NOM fraction. Iron oxides, aluminium oxides and NOM are ubiquitous in the natural environment and are all well known for their ability to sorb and sequester PTEs (Potentially Toxic Elements); details of their adsorbent properties are well documented and will be discussed in detail in the following chapter.

Since Fe/Al oxides and NOM are considered to be the largest components of WTR, it holds that WTR should also exhibit adsorbent sorbent capacity. The behaviour of WTR and the extent of its sorption capacity will be directly related to its compositional and structural makeup. It is expected that the WTR's properties will reflect those of its component parts. However, the degree to which they impact its behaviour and the role that the component parts play in creating its sorption capacity will be determined by:

(i) the interaction of these components within WTR in its formation, and
(ii) the influence this has on the morphology, mineralogy and surface properties of the material.

3.1.1 Aims and Objectives

The aim of this chapter was to gain a better understanding of the compositional and structural makeup of WTR by carrying out a detailed examination of its morphology and mineralogy. This was undertaken by means of:

- Scanning electron microscopy and element maps to assess the morphology, porosity and surface composition
- X-ray diffraction to investigate mineralogy
- Selective Fe dissolution extractions
- Surface area analysis

Henceforth in this thesis, a single WTR was selected on which to carry out further investigations. Broken Scar Fe-WTR from the first batch of WTR collections (autumn 2011), was chosen for this purpose on the basis that the majority of Northumbrian Water Ltd WTWs use Fe-based coagulants, of which Broken Scar generates the largest quantity of WTR per annum in North East England (3570 tonnes/yr, dry solids in 2010-2011). WTR was investigated using the techniques described below and discussed in conjunction with findings from the literature.

3.2 Materials and Methods

3.2.1 Sample Selection and Preparation

In several experiments, WTR is compared to its end-member constituents, namely Fe oxide and NOM. Two-line ferrihydrite was considered the most likely Fe oxide phase in Fe-based WTRs because it tends to be the first precipitate that forms from hydrolysis of Fe(III) salt solutions (Schwertmann and Cornell, 2000). It is also one of the least crystalline Fe oxides, often referred to as "hydrous ferric hydroxide (HFO)" or "amorphous iron oxide". Most studies have been unable to detect crystalline Al or Fe mineral phases in WTR, which has led the authors to conclude that WTRs consist of amorphous metal oxyhydroxides (Ippolito et al., 2011).

2-line ferrihydrite was synthesised following the method of Schwertmann and Cornell (2000) by the rapid hydrolysis of Fe(III) salt solution. In a large beaker, 80 g $Fe(NO_3)_3.9H_2O$ (Sigma Aldrich, UK) was dissolved in 1000 mL deionised water (DI) using a magnetic stirrer. Under vigorously stirred conditions, 1.0 M NaOH was added quickly to raise the pH to 7 which induced the formation of a brown precipitate. After settling, the excess water was decanted and the beaker was refilled with fresh DI water. This rinsing procedure was repeated several times over the next 3 days. The suspension was then centrifuged gently with refills of DI until the solution conductivity was less than 50 µS/cm. The precipitate was then left to air dry before being ground to < 63 µm for sorption experiments. A subsample was freeze-dried for XRD and SSA analysis using the methods outlined in Section 2.2.2.

Humic acid (HA)(Sigma Aldrich, UK) was selected to represent the NOM fraction of WTR. NOM is known to be made up of a wide range of humic and non-humic substances, of which the humic substances (hydrophobic fraction) are thought to account for 50 to 75% of the TOC in natural waters (Thurman, 1985). HA is often used to represent the hydrophobic fraction of NOM in laboratory experiments; it was considered appropriate for use as the WTR end-member since it has been found that the hydrophobic, high molecular weight NOM fractions are more efficiently removed from raw water during coagulation treatment than the hydrophilic lower molecular weight fractions (Matilainen et al., 2010; Sharp et al., 2006b), as discussed in Chapter 2. It is important to note that a small proportion of the carbon present in WTR originates from the organic polymer used in the flocculation process. At Broken Scar WTW, the polymer used was Flopam AN913 SEP (pers. comm, L. Dennis, NWL, 2011) which is an anionic copolymer of polyacrylamide and sodium acrylite. In comparison to the NOM, the polymer is present in much smaller quantities. In 2011-2012, the average TOC concentration of the raw water feeding Broken Scar WTW was 10 mg/L (NWL data, Appendix 2); the average dose of Flopam polymer to raw water must not exceed 0.25 mg/L (pers. comm., SNF, 2012). Based on these figures, the amount of added carbon is calculated to be approximately 1 to 2% of the natural carbon. However, by its very nature, the added polymer-based carbon may exert a disproportionately strong influence over the structure and behaviour of WTR, as will be discussed in Section 3.3.7.

All adsorbents were air-dried, ground using a mortar and pestle and sieved to <63 µm prior to use, unless otherwise stated. Samples were stored in the dark in clean screw-top polypropylene tubs at room temperature.

3.2.2 Scanning Electron Microscopy (SEM)

The morphology and surface composition of air-dried, ground (<63 µm) and un-ground (>2 mm) WTR samples were examined by SEM using a Hitachi SU-70 Scanning electron microscope at various magnifications, in secondary-electron and back-scatter modes. Additionally, Pb-sorbed WTR samples at <63 µm were also examined by SEM to look for possible changes to the surface which may have occurred as a result of undergoing sorption, such as precipitation (see Chapter 4).

In order to inhibit surface charging, samples were coated in carbon (Cressington carbon coater 108 carbon/A) when investigating morphology only, and coated in gold-palladium (Cressington sputter coater 108 auto) when investigating surface composition, so that the carbon in the sample could be identified. Qualitative elemental analysis was performed by Electron Dispersive X-ray (EDX) spectroscopy using INCA software (Oxford Instruments).

In addition, a subsample of WTR particles (<2 mm) was made into a thin section to reveal internal features such as porosity. The sample was impregnated with epoxy resin, ground and polished. A 3 mm disk was then cut and polished further by the broad ion beam polishing technique, using a Gatan 691 precision ion polishing system (PIPS). The sample was gold-palladium coated prior to analysis by SEM.

3.2.3 X-Ray Diffraction (XRD)

XRD was used for the determination of mineral phases in the WTR and the synthetic ferrihydrite. It was also used to identify any possible mineral precipitates that had formed on the WTR during the Pb sorption experiments (see Chapter 4).

Randomly orientated, <63 µm particle size, powder samples were prepared on a Si slide changer. XRD was performed on a Bruker AXS D8 Advance powder diffractometer using Cu-Kα radiation from 20 to 80 °2θ with a step-size of 0.02 °2θ. An initial short scan revealed a high level of noise associated with the samples so the scan time was increased to approximately 16 h per run for the WTR and ferrihydrite samples, and approximately 5 h for the Pb-sorbed WTR samples.

3.2.4 Selective Fe extractions

An attempt was made to quantify the amorphous iron oxide and organically-bound iron fractions in WTR using selective dissolution procedures. Selective dissolution procedures have been developed for use in soils to determine specific fractions of soil Fe (Chao and Zhou, 1983). An estimate of “active” or amorphous iron oxides in the WTRs was determined using acid ammonium oxalate (pH3) in darkness (Tamm’s Reagent), and an estimate of the organically-bound Fe was determined using sodium pyrophosphate (pH10) extraction.

Oxalate extractable Fe (est. amorphous Fe oxyhydroxide fraction):

The oxalate extraction was carried out following the method of Loeppert & Inskeep in Methods of Soil Analysis - Part 3 by Sparks et al. (1996) which is a modification of the procedure of Schwertmann (1964) and McKeague and Day (1966).

In triplicate, 500 mg of WTR, previously freeze-dried and ball milled to pass through a 150 µm sieve, was weighed into a 50 mL polypropylene centrifuge tube. In darkness, 30 mL of pH 3.0 ammonium oxalate solution was added to the sample which was then shaken for 2 h on a reciprocating shaker at 150 rpm. After centrifuging for 5 mins at 3700 rpm, the supernate was passed through a 0.2 µm syringe filter, acidified with a few drops of concentrated HNO_3, and stored in the refrigerator prior to analysis by atomic absorption spectroscopy (AAS). The samples were contained in a light proof container as far as possible to minimise photoinduced decomposition of oxalate, which could result in precipitation of Fe.

High concentrations of oxalate can clog the burner head during the nebulisation process in AAS. This was minimised by diluting samples with DI water prior to analysis by AAS, aspirating between samples with DI water, and regularly checking flow rates and the burner head for clogging. Fe was analysed by AAS using a Varian SpectrAA 220FS atomic absorption spectrometer. Fe was determined using an oxidising air/acetylene flame, at 248.3 nm using a 0.2 nm slit width for calibration range 1.0 - 10 ppm, and at 372.0 nm slit, width 0.2 nm, for calibration range 10 - 100 ppm.

Sodium Pyrophosphate extractable Fe (est. organically-bound Fe):

Sodium pyrophosphate extraction was also carried out following the method of Loeppert & Inskeep in Methods of Soil Analysis - Part 3 by Sparks et al. (1996).

250 mg of WTR, previously freeze-dried and ball-milled to pass through a 150 um sieve, was weighed into a 50 mL polypropylene centrifuge tube. 25 mL of pH 10 sodium pyrophosphate solution was added to the sample which was then shaken for 16 h on a reciprocating shaker at 150 rpm. The sample was then centrifuged for 5 mins at 3700 rpm, and the supernate was passed through a 0.2 um syringe filter, acidified with a few drops of concentrated HNO_3, and stored in the refrigerator prior to analysis by AAS using the method stated above.

3.2.5 Specific surface area

Specific surface area determinations of Broken Scar WTR, synthetic ferrihydrite and humic acid were made by N_2 gas adsorption at 77 K using the BET (Brunauer, Emmett and Teller) technique (Brunauer et al., 1938). Freeze dried samples were degassed overnight at 50 °C under a flow of nitrogen prior to analysis on a Micrometrics Tristar 3000 Gas Adsorption Analyser. The specific surface area was calculated according to the BET equation from 5-point plots. BET measurements were performed in duplicate.

3.3 Results and Discussion

3.3.1 Physicochemical properties

Table 3-1: Selected physicochemical properties of Broken Scar WTR

Parameter	Mean Value	Units
pH	6.0	
EC	307	µS/cm
Total C	13.3	%
Total N	0.55	%
Al*	0.22	%
Fe*	41	%
Pb*	88	mg/kg

n = 3

* Pseudo total metals measured by aqua regia digestion, n = 1

The main physicochemical properties of air-dried Broken Scar WTR (autumn collection) are shown in Table 3-1 (method details can be found in Section 3.2). Broken Scar WTR will simply be referred to as "WTR" herein. The key features of this WTR are its circum-neutral pH of 6.0, high C content (13.3 wt.%) and high Fe content (41 wt.%), giving a C:Fe mass ratio of 1:3.1. These C and Fe concentrations are equivalent to WTR containing 10.8 mmoles of C/g WTR and 7.35 mmoles of Fe/g WTR, which gives a C:Fe molar ratio of 1.47:1.

Based on an estimation of the C content of NOM as 58% (Rowell, 1994) and the approximate structural formula for ferrihydrite of $FeOOH \cdot 0.4H_2O$, where Fe content constitutes 58% of the mineral (Hiemstra and Van Riemsdijk, 2009), it can be estimated that the WTR contains approximately 23 wt.% NOM and 70 wt.% Fe oxyhydroxide, with the rest (less than 10%) considered to be comprised of silicates from sand and clay inputs and other trace elements.

Given that the proportion of added polymer-based carbon is calculated to account for approximately 1 to 2 wt.% of the natural carbon present in WTR, the concentration of added polymer-based carbon is expected to constitute less than 0.3 wt.% of WTR's total composition. Clearly the proportion Fe to carbon, and the contribution of polymer-based carbon in WTR, are dependent on the raw water quality, specific plant operating condition and so on, all of which are likely to vary to some degree (Verrelli et al., 2009).

3.3.2 Visual inspection of WTR

Figure 3-1: Photographs of wet (left) and dry (right) WTR

In its fresh state, WTR is a thick, dark brown, fine-textured sludge, the bulk of which is in fact water (80% moisture content in wet solids) (Figure 3-1 (left)). As WTR dries and the bulk of the entrapped water is lost, the sludge shrinks in size forming small clumps or aggregates. These aggregates are dark coloured with rough outer air-exposed surfaces, much like soil aggregates (Figure 3-1 (right)). However the dried material is very brittle, fracturing and breaking apart easily into angular particles to reveal dark, smooth, shiny glass-like surfaces. The physically trapped (non-stoichiometric) water is irreversibly lost upon air-drying, in that the dried WTR does not rehydrate to form a sludge-type consistency again; rather, when immersed in water the aggregates tend to disintegrate into fine particles. Similar behaviour is known for ferrihydrite (Schwertmann and Cornell, 2000) and the same dark, glassy, fine particles were observed in our synthetic ferrihydrite, suggesting that the surface nature of WTR reflects that of its Fe oxyhydroxide component.

3.3.3 Scanning Electron Microscopy (SEM) Analysis

The morphology and surface composition of the Fe-WTR was explored using SEM, EDX and element maps.

Figure 3-2: SEM (secondary electron) images of external surfaces of WTR clasts (>2 mm) at various magnifications

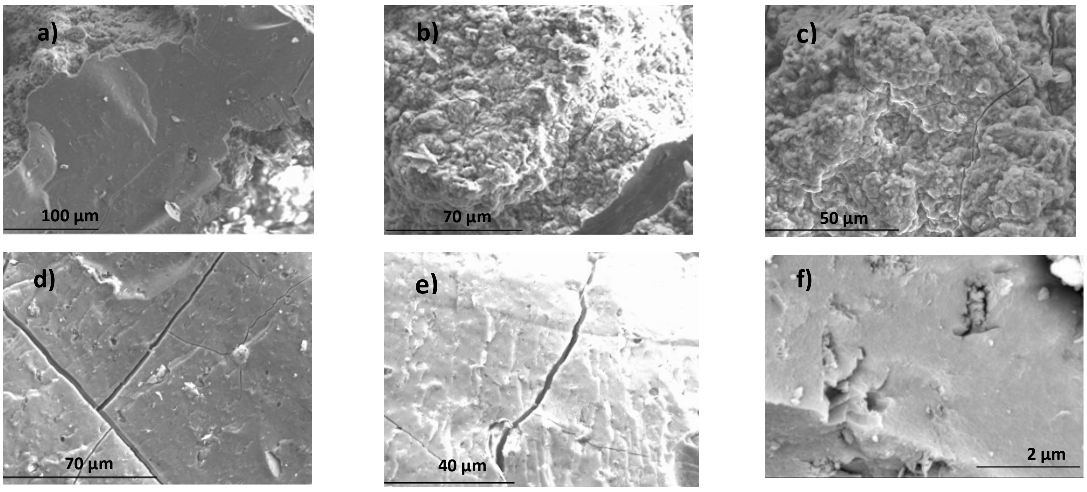
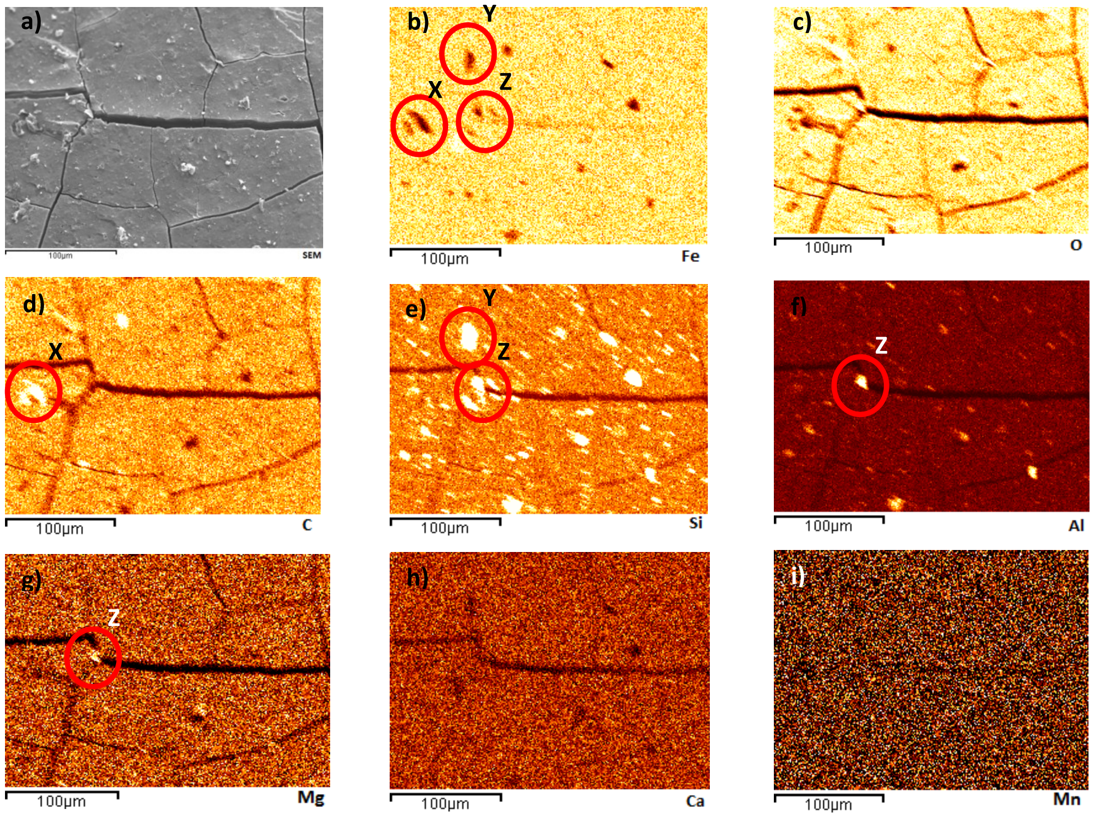


Figure 3-2 presents a representative selection of images of external surfaces of WTR at several magnifications. Figure 3-2 (a) and (b) clearly show the rough outer, air-exposed surfaces and the smooth "inner" surfaces which are exposed when the WTR particles fracture and break apart. In the experimental work where <63 µm particles were used, most of the particles will be created by the breakdown of these larger aggregates, which means that they will predominantly consist of the smooth, "inner" surfaces. The lack of surface roughness of these particles may have implications for its surface area and its adsorption capacity.

These images, particularly those of the smooth surfaces (Figure 3-2 (d) to (f)), reveal that the WTR is relatively homogenous down to 2 µm. This implies that NOM is coprecipitated with the Fe oxyhydroxide homogenously at this scale. The WTR is dissimilar to soil in that soil clasts would typically contain a mixture of mineral grains and organic matter in a range of sizes visible at a larger scale.

Element maps were taken of a selection of WTR surfaces to further assess the degree of compositional homogeneity in the WTR. Figure 3-3 presents the sample area (a) and the corresponding Fe, O, C, Si, Al, Mg, Ca and Mn maps ((b) to (i). In the element maps the lighter the colour, the higher the concentration of the element.

Figure 3-3: Au-Pd coated WTR sample a): SEM image b) - i): corresponding element maps of Fe, O, C, Si, Al, Mg, Ca and Mn, respectively

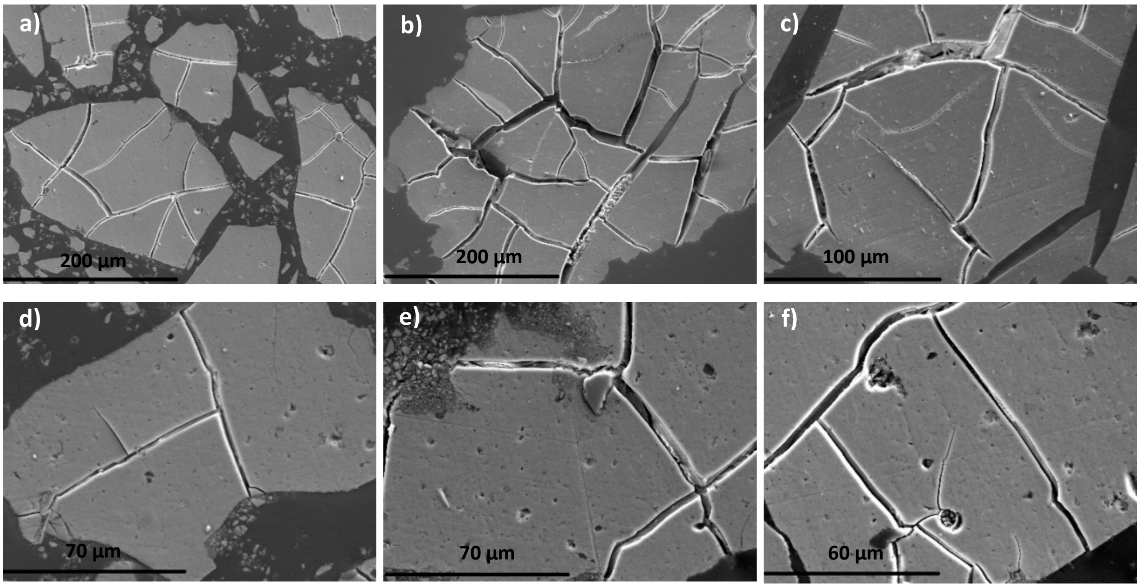


The SEM image (a) presents a smooth, fractured surface with deposits or inclusions of smaller fragments visible on the surface. Examination of the element maps reveals highest concentrations of Fe (b), O (c) and C (d) as expected, which appear to be relatively evenly distributed across the sample, at least at this scale, with only a few brighter C and Fe rich blebs apparent. It is clear that during the coagulation-flocculation process in which the Fe oxide species and organic polymer adsorb and enmesh dissolved and particulate NOM, the Fe becomes thoroughly intermixed with C.

Additionally, the maps clearly identify other elements contained in the sample: the dark spots (low concentrations) in the Fe element map (b) correlate well with hot spots of C (d) (e.g. point X), Si (e) (e.g. points Y and Z) and Al (f) (e.g. point Z). Si appears widely across the sample in spots of variable size, some of which correlate with high Al concentrations, suggesting that the sample contains entrapped silica sand (quartz), as well as aluminosilicate clay particles in some cases. For example, point Z consists of Si, Al and Mg, indicative of a clay. Other dark Fe spots correlate well with hotspots of C (e.g. point X), suggesting that they are comprised of larger fragments of occluded NOM. Images (g), (h) and (i) show relatively low concentrations of Mg, Ca and Mn, respectively. The low concentration of Ca (h) implies that calcium carbonates are not present in significant quantities, consistent with the limited concentrations of inorganic C found in WTRs, as discussed in Section 3.3. EDX point analysis was also performed on several WTR particles which highlighted the predominance of Fe, O and C in WTR (see Appendix 3).

Figure 3-4 presents a selection of SEM images of internal WTR surfaces at various magnifications, taken of ion beam polished thin sections of WTR particles (>2 mm). The images clearly display the angular fragments of variable size and the crumbly, fractural nature of the dried WTR material.

Figure 3-4: a) to f): SEM (secondary electron) images of WTR thin sections



Images (d), (e) and (f) reveal a number of holes and intrusions in the thin sections of less than 10 µm diameter, which are indicative of the presence of some large pores, which may play a role in adsorption. However, based on these images it is not possible to assess the abundance, pore size distribution or connectivity of these pores since porosity is measured on the nanometre scale (macroporosity being >50 nm, mesoporosity 2-50 nm and microporosity <2 nm). Using mercury intrusion porosimetry, Makris et al. (2004a) found that WTRs had a low volume of macropores and a lack of a significant network between them; most of the volume accessed by Hg was in the mesoporous size range. Mesopores and micropores are considered to be especially important in the context of adsorption (Rouquerol et al., 2013), particularly so in the case of WTRs (Makris et al., 2004a) which will be discussed below.

3.3.4 X-Ray Diffraction (XRD) Analysis

Figure 3-5: XRD analysis of Ferrihydrite and WTR

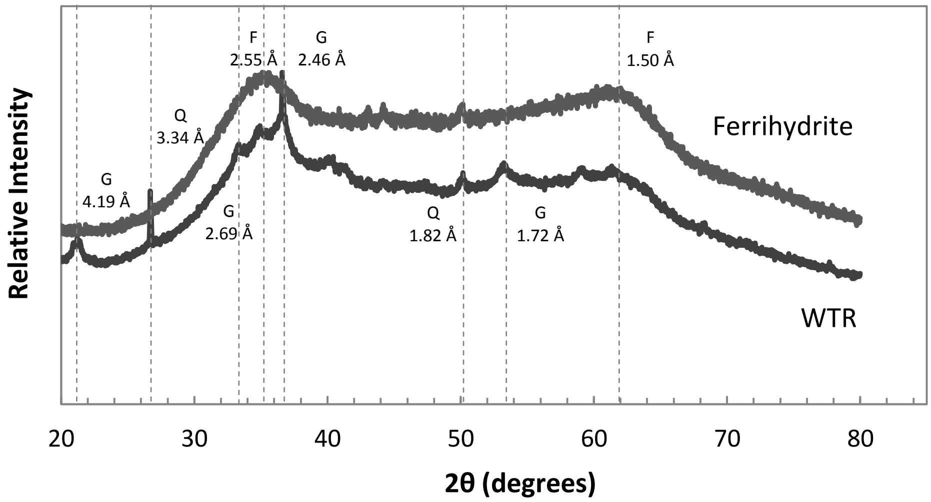


Figure 3-5 presents the X-ray diffraction analysis of the WTR and synthetic ferrihydrite samples. The scans yielded relatively poorly resolved X-ray reflections with high backgrounds due to the large amount of amorphous materials present in the samples, making mineral identification difficult. Nevertheless, the similarities between the two materials are clear: the characteristic 2-line ferrihydrite pattern was observed in both the synthetic ferrihydrite and WTR, with two broad peaks occurring at ~2.55 and 1.50 in Å (Schwertmann and Cornell, 2000). Nielsen et al (2011) and Verrelli et al (2009) also successfully identified the Fe oxide phase of WTR as ferrihydrite. However, most other studies have not observed the characteristic 2-line ferrihydrite peaks in Fe-WTR, simply concluding from indistinct XRD results that Fe is present as amorphous Fe oxyhydroxides (Chiang et al., 2012; Ippolito et al., 2011; Makris et al., 2004a; Makris et al., 2005b; Titshall and Hughes, 2005).

In addition to the characteristic 2-line ferrihydrite pattern, the WTR revealed other peaks which were not present in the pure ferrihydrite scan and so an attempt was made to cross-match these with likely mineral phases using the PDF-4$^+$ 2021 (ICDD) database. This was largely unsuccessful because many of the peaks did not differentiate from the background clearly enough to make certain matches. Nevertheless, some of the peaks may be explained by quartz, based on the peaks detected at 3.34 and 1.82 Å, and goethite based on peaks found at 4.19, 2.69, 2.46 and 1.72 Å, (see Figure 3-5). The presence of quartz (SiO_2) was highly likely since Si was detected in the SEM element maps as distinct blobs (see Figure 3-3 e) and several other studies have reportedly found quartz in WTRs (Chiang et al., 2012; Ippolito et al., 2011; Titshall and Hughes, 2005). Quartz may originate from backwashing of sand filters in the WTW as well as from sand particles removed from the raw water.

Ferrihydrite is a metastable mineral which is known to be a precursor of more crystalline minerals such as Goethite. Goethite (α-FeOOH) is a possible component of WTR since ferrihydrite can transform to goethite in water under ambient conditions, the mechanism of which involves the dissolution of ferrihydrite and re-precipitation of goethite crystals (Schwertmann and Murad, 1983; Schwertmann and Cornell, 2000; Schwertmann et al., 2004). It is possible that a degree of transformation may have occurred during WTR formation or during the time (a period of months) when fresh WTR was stored in plastic bags prior to drying for use in experiments. This is relevant because transformation of metastable minerals to more crystalline forms can reduce the extent and rate of metal sorption (Scheinost et al., 2001). Although the *mechanism* of binding would not differ between ferrihydrite and goethite, the extent and rate of sorption to an amorphous Fe oxyhydroxide such as ferrihydrite would be greater than to the crystalline form, goethite, owing to its greater surface area.

However, it is well documented that the transformation of ferrihydrite to more stable crystalline forms can be inhibited in the presence of sulphate, silicate, phosphate and a range of cations and organics (Baltpurvins et al., 1997; Jang et al., 2003; Schwertmann, 1966), all of which may be present in WTR. In particular, the presence of dissolved organic matter (DOM) has been found to inhibit the transformation of ferrihydrite into more crystalline forms via the formation of coprecipitates, which can affect the crystal order of metastable iron oxides and hinder their transformation into more stable forms (Henneberry et al., 2012; Schwertmann, 1966; Schwertmann et al., 2005). It is therefore possible that the transformation of ferrihydrite has been retarded to some extent by the presence of NOM and other crystalline inhibitors present in the WTR, but not fully blocked, in accordance with the XRD results. Given that XRD analysis is a semi-quantitative technique, we can assume from the relative intensities that ferrihydrite is the dominant mineral phase.

No other crystalline phases were identifiable from the XRD analysis presented above, however other studies have detected aluminosilicate clays, which are known to be removed in the coagulation process (Duan and Gregory, 2003), as well as feldspar and calcite (Chiang et al., 2012; Ippolito et al., 2011; Titshall and Hughes, 2005).

As well as the inhibitory effect of organic compounds on the transformation of ferrihydrite to goethite, organic compounds have also been found to affect the crystallinity of ferrihydrite itself. The impact of coprecipitated organic compounds on ferrihydrite crystallinity has been investigated in numerous studies, yielding different results. Mikutta et al. (2008) and Moon & Peacock (2012) reported that ferrihydrite crystallisation was apparently not affected by Fe(III) precipitation in the presence of extracellular organic compounds, whereas Eusterhues et al. (2008) and Mikutta et al. (2010) observed a systematic XRD peak broadening in the two main ferrihydrite reflexes with increasing C:Fe ratio in coprecipitates, indicative of increasing stacking disorder. Angelico et al. (2014) and Mikutta (2011) also highlighted the role of NOM as an inhibitor of ferrihydrite crystallisation, reporting the importance of the location of phenolic groups in hydroxybenzoic acid moieties in the distortion of ferrihydrite. The concentration and composition of NOM, as well as the conditions for Fe precipitation, have all been found to impact ferrihydrite crystallinity in various cases (Angelico et al., 2014; Eusterhues et al., 2010; Eusterhues et al., 2008; Schwertmann et al., 2005). In comparison to the synthetic ferrihydrite scan, the WTR peaks were less distinct from the background (lower relative intensity), with slightly weaker and broader peaks at 2.55 and 1.55 Å. The comparison between WTR and ferrihydrite is complicated by the presence of the additional sharp peaks in the WTR scan, but overall the differences are clearly small. These results suggest that the presence of NOM in WTR has had a minimal effect on the degree of ferrihydrite crystallisation.

3.3.5 Iron-organic matter associations - WTR as an organo-mineral composite

The WTR contains 13.3 wt.% total carbon and 41 wt.% total Fe. It was estimated earlier in this chapter that if all Fe is present in oxyhydroxide form as ferrihydrite and all C is present in organic matter form, then the WTR contains approximately 23 wt.% NOM and 70 wt.% Fe oxyhydroxide, with the rest (less than 10%) suspected to be comprised of silicates from sand and clay inputs and other trace elements. Given the nature of the water treatment process (where coagulating Fe salts hydrolyse to FeOH species which adsorb and coprecipitate with the organic matter constituents of raw water in order to remove them), we expect that the Fe oxyhydroxides are intimately intermixed with the OM fraction within WTR.

An attempt was made to quantify the Fe oxide phases present in WTR using selective dissolution procedures. Selective dissolution procedures have been developed for use in soils to determine the fractionation of soil Fe. It is well known that such chemical extraction techniques are operationally defined and results should not be interpreted as an accurate measure of a specific fraction of Fe (Sparks et al., 1996). Nevertheless, the oxalate extractable method for quantifying amorphous Fe oxides has been widely adopted by those studying soils and WTRs, and so extractions were trialled on Broken Scar WTR for this study.

An estimate of “active” or amorphous iron oxides in the WTRs was determined using acid ammonium oxalate (pH3) in darkness (Tamm’s Reagent), and an estimate of the organically-bound Fe was determined using sodium pyrophosphate (pH10) extraction. The organically bound Fe fraction is taken to be the Fe oxyhydroxide fraction which is associated with organic matter. The results of the extractions are presented below in Table 3-2. It was hypothesised that if all the Fe in WTR is present as oxyhydroxides which are associated with NOM, then the oxalate extractable Fe and pyrophosphate extractable Fe should account for all the Fe contained in WTR.

Table 3-2: Selectively extractable Fe from WTR

Extraction	Fe (wt.%) in WTR sample ± SD (n=3)
Oxalate-extractable Fe	21.10 ± 0.77
Pyrophosphate-extractable Fe	0.35 ± 0.01
Pyrophosphate-extractable Fe following an oxalate extraction	0.54 ± 0.05

Results show that approximately 21 wt.% Fe in the WTR was oxalate-extractable, 0.35% Fe was extractable with pyrophosphate, and 0.54% Fe was extractable with pyrophosphate following an oxalate extraction. Sparks et al. (1996) state that although ammonium oxalate preferentially dissolves poorly crystalline Fe oxides, it will also extract water-soluble Fe, exchangeable Fe and a fraction of the organically bound Fe. Given that WTR contains 41 wt% total Fe, these results show that only ~50% of the total Fe contained in WTR was extractable by these selective extraction procedures, which are supposed to give a crude estimate of amorphous oxides and organically bound Fe.

This figure is comparable to other findings in the literature for WTR; studies have reported oxalate-extractable Fe concentrations of 64% (Makris et al., 2006), 63% (Makris et al., 2005c) and 45% (Makris et al., 2004a) of total Fe. Figures compiled in a review by Ippolito et al (2011) show oxalate-extractable Fe was on average 50% of total Fe for a range of WTRs studied. None of this literature however, provides and explanation or even a speculation about the 'missing' ~50% Fe.

Here it is hypothesised that, given the nature of the coagulation process, most if not all of the Fe oxyhydroxide will be intimately bound with OM. There may be some "free" Fe oxyhydroxide (concentrated hot spots) as a result of overdosing or inadequate mixing during the coagulation process for instance, but this would represent a relatively small proportion. It is suggested that the strong interactions between the OM and Fe oxyhydroxides, which are intimately mixed in WTR, stabilise the components against breakdown and extraction by the selective extraction techniques employed here. It is suspected that these standard selective extraction procedures release only a proportion of Fe oxyhydroxides bound up with the OM in WTR. It may be that the concentration and composition of the OM and exactly how it associates with the mineral phases determines whether the Fe oxyhydroxide can be extracted or not.

Alternatively, or additionally, a substantial proportion of the Fe may be present in crystalline Fe oxide form such as Goethite which is not targeted by these extraction techniques. However, based on the XRD analysis and as discussed in the XRD section above, it is assumed that ferrihydrite is the dominant mineral phase (owing to the relative peak intensities). Although the WTR was left to air dry for weeks-months which could be enough time for transformations in crystallinity to take place, significant transformations were considered unlikely because OM is known to inhibit crystallisation. There is no simple way to quantify crystalline Fe oxide in WTR. Dithionite extraction is often used to target total “free” iron oxide phases, including crystalline and non-crystalline oxides. The difference between dithionate-extractable Fe and oxalate extractable Fe could provide a measure of the crystalline Fe fraction. However, dithionite is a strong reductant which is capable of reducing all Fe(III) in iron-containing oxides to Fe(II) including those in association with organic carbon. This extraction is therefore not able to distinguish between Fe oxides which are crystalline, and Fe oxides which are strongly associated with OC, whether they are crystalline or not. In fact, in Lalonde’s paper, the citrate-dithionite reduction method was used to determine the amount of organic carbon associated with solid reactive iron phases (Fe oxides) in sediments by dissolving the Fe phases and measuring the organic carbon associated with them. They showed that an average of 20.5% of total organic carbon was directly associated with iron oxide phases in sediments (Lalonde et al., 2012).

In the case of WTR, the crystalline Fe oxide phase is suspected to be relatively small in comparison to the amorphous Fe oxyhydroxide phase, i.e. ferrihydrite (Fh). We can therefore imply from our findings that the amorphous Fe oxyhydroxide which is intimately mixed with OM, is stabilised against breakdown and extraction.

Where mixtures of organic and mineral fractions are associated with each other in this way, they are referred to as “organo-mineral composites”. The existing WTR literature does not describe WTR as an organo-mineral composite. However, a wealth of literature exists on organo-mineral composites (natural and synthetic) which may help to inform us of the nature and characteristics of WTR, and the association of OM and Fh within it.

Natural organo-mineral composites are ubiquitous in soils and sediments within the surface environment. It is well known that a significant proportion of organic carbon is associated with mineral phases in this way (Keil et al., 1994). However, exactly how the organic and mineral components interact in organo-mineral composites is largely unknown. This is currently a hot topic within the field of biogeochemical research since it is becoming increasingly realised that organo-mineral composites play a crucial role in global carbon cycling, carbon sequestration and preservation (Guggenberger and Kaiser, 2003; Johnson et al., 2015; Lalonde et al., 2012). In fact it has been speculated that stabilisation of OM by interactions with mineral matrices may be the single largest factor controlling OM preservation on the Earth’s surface (Keil et al., 1994).

Researchers have found that organic carbon (OC) in sediments and soils which is intimately associated with mineral matrices, through sorption and coprecipitation, is somehow protected against microbial decomposition (Baldock and Skjemstad, 2000; Keil et al., 1994; Saidy et al., 2012). However it is not clear what mechanisms cause this inaccessibility to microbial and enzymatic degradation (Kaiser and Guggenberger, 2000; Lützow et al., 2006).

Some studies suggest physical protection by aggregation with minerals and occlusion at the microstructure level (Kaiser and Guggenberger, 2003; Lützow et al., 2006; Mayer et al., 2004). Occluded OM may be spatially protected against decomposition due to (i) reduced access for microbes and their enzymes; (ii) reduced diffusion of enzymes into the intra-aggregate space; (iii) restricted aerobic decomposition due to reduced diffusion of oxygen. It is therefore primarily the pore network and pore-size distribution that controls these processes (Lützow et al., 2006). Others speculate that in addition to physical entrapment, reactive minerals may induce polymerisation reactions which increase the recalcitrance of the mineral-bound OM (Johnson et al., 2015). Baldock states that the degree and amount of protection offered by such protection mechanisms depends on the chemical and physical properties of the mineral matrix and the morphology and chemical structure of the organic matter (Baldock and Skjemstad, 2000).

Although the literature focuses on carbon stabilisation by the mineral phase, it follows that the sorption/coprecipitation between the OM and mineral components will go some way to protecting both phases from dissolution, as we see in the case of WTR. This is alluded to in the literature, where surface areas of minerals are reportedly significantly reduced by sorption of organic matter. Kaiser and Guggenberger (2000) found that the OM coating of a soil decreased its BET-N_2 specific surface area (SSA), stating that sorbed OM seems to "mask" mineral surfaces by reducing the surface roughness of the minerals (Burford et al., 1964; Feller et al., 1992; Pennell et al., 1995). Kaiser and Guggenberger (Kaiser and Guggenberger, 2003) also found that sorption of OM to mineral matrices reduced the SSA. Their results pointed towards the preferential association of organic matter with micropores, through sorption of OM at reactive sites in or at mouths of micropores, which fills or blocks them. Mayer et al. (2004) suggests that diffusional hindrance in organo-mineral composites, caused by some combination of pore size distribution and tortuosity, will slow access to digestive enzymatic agents and hence protect the organic matter from degradation. Presumably diffusional hindrance would protect the Fe oxide phases too. Therefore, both the masking of reactive oxide surfaces, and physical occlusion/diffusional hindrance effects may explain how the OM helps to protect the Fe mineral.

It is thought that the standard selective extraction procedures used for soils are not appropriate to provide reasonable estimations of amorphous Fe oxide or organically-bound Fe fractions in WTR. Where OM and Fe oxyhydroxides are strongly associated with each other, in organo-mineral composites such as this, it appears that both phases are stabilised against breakdown extraction. The extraction procedures can't extract the Fe because the OM is helping to protect the Fe mineral. Here, it is proposed that the intimate association of the NOM and Fe oxyhydroxide creates a material (WTR) which protects the NOM and Fe components from degradation, at least to some degree.

Based on these findings, and supported by the literature on carbon stabilisation in organo-mineral composites, we speculate that:

1) The NOM contained within WTR may be less reactive and less easily mineralised relative to the individual NOM component, and
2) The ferrihydrite within WTR may be less available (possibly due to masking) and therefore less reactive, relative to the individual ferrihydrite component.

These speculations have implications for WTR's long-term behaviour and effectiveness, both as an adsorbent of contaminants in the environment (which will be investigated in the following chapter), and also potentially as a 'preserver' of the NOM which is associated with it.

Further research and the use of more powerful analytical techniques, such as scanning transmission X-ray microscopy (STXM), are required to evidence the hypotheses stated here. As Kaiser and Guggenberger (2000) state, the rapid improvement of micro- and nanoscale microscopic and spectroscopic techniques is a key factor in gaining a better insight into the localisation of sorbed OM at the mineral surface and into conformational changes of the OM associated with the sorption. In order to advance the understanding of mineral-based OM preservation in soil and sedimentary environments, this is where the field of research is currently being focussed on a wide scale.

3.3.6 Specific Surface Area (SSA) Analysis

Table 3-3: Specific surface areas of ferrihydrite, humic acid and WTR

	BET-N_2 SSA (m^2/g)	Correlation coefficient	Mean BET-N_2 SSA (m^2/g)
Ferrihydrite	282.31 ± 2.88	0.999	280
	276.80 ± 2.78	0.999	
Humic Acid	0.99 ± 0.03	0.998	0.97
	0.96 ± 0.03	0.999	
WTR	4.04 ± 0.08	0.999	4.10
	4.16 ± 0.09	0.999	

The BET method for measuring specific surface area (SSA) is based on the fact that if a gas is brought in contact with an adsorbent at a temperature near the condensation temperature of that gas, the gas molecules can form a monolayer at the surface, from which the surface area can be calculated (Schwertmann and Cornell, 2000). SSA measurements using nitrogen gas as the adsorbent (BET-N_2) were taken of the WTR, ferrihydrite and humic acid and are presented in Table 3-3. The mean SSA for the ferrihydrite was found to be 280 m^2/g, in agreement with values reported in the literature, which typically range from 200 to 350 m^2/g for synthetic 2-

line ferrihydrite (Eggleton and Fitzpatrick, 1988; Jambor and Dutrizac, 1998; Schwertmann and Cornell, 2000). The humic acid yielded a very low surface area of 0.97 m^2/g which is at the lower end of the range of values found in the literature; LeBoeuf and Weber (1997) reported the N_2-SSA of humic acid as 3.95 m^2/g whereas Chiou et al. (1990) found values between 0.61 and 18 m^2/g for various SOM samples. It is necessary to point out that the SSA measurements may be less accurate at such low levels (correlation coefficient for humic acid sample 1 was <0.999); nevertheless the results clearly show that humic acid has the lowest SSA of all the samples analysed.

Given that the WTR is predominantly composed of ferrihydrite and NOM, a surface area reflecting this mix was expected. However, a relatively low SSA of 4.1 m^2/g was found for the WTR. Several studies have observed similar N_2-SSA values in ferrihydrite-OM coprecipitates, which were found to be negatively correlated with C concentration (Eusterhues et al., 2008; Mikutta et al., 2008). These low SSAs have been explained by: (i) a reduced accessibility for N_2 due to the formation of denser aggregates with the associated OM, and/or (ii) by a masking of the mineral surface by OM (Eusterhues et al., 2008). The WTR literature presents similarly low values for N_2-SSA (Makris et al., 2004a; Makris et al., 2004b; Makris et al., 2005b). Accordingly, the Fe-based WTR in the literature that most closely relates to the composition of our WTR (Tampa WTW, Florida, containing ~25% Fe and ~14% C), was reported to have an N_2-SSA of 3.9 m^2/g (Makris et al., 2004a).

Materials such as organic matter are actually known to have high specific surface areas which are created by their microporous structure (De Jonge and Mittelmeijer-Hazeleger, 1996). However, as alluded to above, the BET-N_2 SSA measurement can yield misleadingly low results because N_2 diffusion is restricted in microporous materials. By measuring gas adsorption on molecular sieves, it was found that below a certain temperature, N_2 diffusion is restricted when the pore radius is smaller than around 0.5 nm (Lamond and Marsh, 1964). Consequently an alternative to the BET-N_2 method was established, which utilises CO_2 adsorption and the Dubinin-Ragushkevitch equation to calculate monolayer surface area in microporous media. Although CO_2 is similar in dimension to N_2, the higher temperature (273K) and absolute pressure used in the CO_2-SSA analysis enables the CO_2 molecules to access the micropores (De Jonge and Mittelmeijer-Hazeleger, 1996). Thus, CO_2-SSA is often the method of choice for measuring microporous materials such as activated carbons, polymers and clays (Altin et al., 1999; Garrido et al., 1987). De Jonge et al. (1996) concluded that the amorphous, highly cross-linked structure of humic substances severely restricts N_2 diffusion after observing a large difference between the BET-N_2 surface area (0.89-4.94 m^2/g) and the CO_2 surface area (94-174 m^2/g) of three soil organic matter samples.

Consequently, it was hypothesised by Makris (2004) that the BET-N_2 method did not accurately measure the 'true' surface area of carbon-rich WTRs, which led the author to investigate SSA by CO_2 as well as N_2 for a range of WTRs differing in C contents. The results showed marked differences in SSAs between the two techniques, with CO_2 giving higher SSA measurements in all cases, indicating that organic C in WTRs restricted diffusion and sorption of N_2 to a much greater extent than for CO_2 (Makris et al., 2004a; Makris et al., 2005c). For example, Tampa WTR which had an N_2-SSA of 3.9 m^2/g was found to have a CO_2-SSA of 28 m^2/g. What's more, the degree of difference between the CO_2 and N_2 values was dependent on the C content, showing that N_2-SSA measurements of WTRs are indeed affected by their C concentration. Although CO_2-SSA was not measured in our study due to instrument limitations, it is reasonable to assume that similar results would be obtained.

3.3.7 Porosity

Sorption of substances by microporous solids is commonly a two-step process, in which rapid adsorption to the external surface is followed by slow sorption along surface sites on the micropore wall (Axe and Trivedi, 2002). Accordingly, Makris et al. (2004a, 2004b) on the adsorption of phosphorus to WTRs, proposed that diffusion into micropores was the rate limiting step in the adsorption process. In addition, the shape as well as size of micropores may limit diffusion rates and hinder ions from reaching certain reactive sites, impacting both the kinetics and adsorption capacity.

It is important to consider the contribution of organic carbon originating from the polymer contained in WTR. As described in Chapter 2, dissolved, colloidal and particulate inorganic and organic matter are first destabilised in solution by the addition of a hydrolysing metal salt which neutralises the negative charges and facilitates adsorption and/or coprecipitation with the metal hydroxides to form aggregated particles. Polymeric flocculants are then used to increase the size of the aggregated particles (flocs) and thus improve solid-liquid separation during the sedimentation and filtration steps. The polymers are high molecular weight, longchained linear compounds with a random coil configuration which allows them to adsorb onto the surface of several particles, bridging them together into larger floc. WTR can ultimately be thought of as small particles of Fe oxyhydroxides predominantly bound or coprecipitated with NOM in microflocs which are then bound together by the polymer. The polymer thus creates an additional level of binding that must clearly influence the structure of WTR. It is hypothesised here that the polymer plays an important role in creating a more constrained, heavily cross-linked microporous structure than would otherwise result from the exclusive coprecipitation of NOM and ferrihydrite.

Additionally, as a consequence of the adsorption processes which are fundamental to coagulation and flocculation, a significant proportion of the mineral surface will be masked by the organic compounds that are bound to it, and vice versa, which will further impact the porosity and SSA of WTR. This can be deduced from the literature: the CO_2-SSA value for Tampa WTR reported by Makris et al. (2004) is larger than the N_2 value (28 vs. 3.9 m^2/g) but it is still considerably lower than the SSA measurement for either pure organic matter samples (97-174 m^2/g (CO_2) as measured by De Jonge et al., 1996) or ferrihydrite (>200 m^2/g). This suggests that the WTR has a significantly reduced surface area in comparison to its end members or indeed, to a combination of both of them in an unbound state, albeit that the above mentioned OM samples are not the *actual* NOM component of WTR.

In summary, it is thought that the low N_2-SSA reported for our WTR is brought about by the NOM and polymer fractions, which create a microporous substance that restricts N_2 diffusion. As a result of the organic compounds being adsorbed to the Fe oxyhydroxide surface, it is hypothesised that the pore size, pore connectivity and surface area are all likely to be constrained in WTR more than in a combination of its end members in an unbound state. It is likely that the reactivity and adsorption of PTEs to our WTR will be impacted by these constraints. Nonetheless, adsorption to microporous substances also has favourable implications for the immobilisation of contaminants. It is proposed that micropore-bound contaminants are more likely to resist desorption because the bonding interaction is maximised with the adsorbent surfaces, favouring long-term stability (Makris et al., 2004a). Further research would be needed to understand and quantify the relative contributions of the WTR components using CO_2 SSA analysis and using the *real* organic end-member components of WTR, namely NOM isolated from the raw water, the polymeric flocculant and ferrihydrite.

3.4 Conclusions

Findings from the detailed investigation of Broken Scar Fe-WTR suggest that it is predominantly composed of NOM and Fe oxyhydroxides with smaller contributions (<10%) coming from quartz and clays. Assuming that all the C and Fe are present as NOM and Fe oxide respectively, the Fe-WTR from Broken Scar comprises of ~23 wt.% NOM and ~70 wt.% Fe oxyhydroxides. We estimate that <0.3 wt.% of the carbon contained in the WTR originates from the organic polymer.

The SEM images indicate that, during the water treatment process, the NOM becomes finely intermixed with the Fe oxyhydroxides. Ferrihydrite was identified as the dominant Fe oxyhydroxide phase in WTR by XRD analysis. Although no other iron phases were definitively identified, the XRD scan suggests that goethite may also be present in WTR. The WTR is considered here as an organo-mineral composite. Selective extractions revealed that only 50% of the amorphous Fe oxyhydroxides were released by the dissolution procedure, suggesting that the association between the NOM and Fe oxyhydroxide components protects both components from degradation. This implies that the carbon bound in WTR could remain stabilised in the natural environment for longer than if it were in an unbound state, and also suggests that WTR may be effective as a long-term sorbent material.

The SSA data from both this work and the literature suggest that the WTR may have a reduced specific surface area, and therefore a lower reactivity, in comparison to its pure end-members. It is necessary to consider these findings in relation to the potential for using WTR as an adsorbent for PTEs in the environment. The two main components of WTR, namely ferrihydrite and NOM, are both known to be strong sorbents for PTEs (details of which will be discussed in the following chapter). This suggests that WTR is likely to act as a sorbent for PTEs as well, and that both the NOM and ferrihydrite components may play a role in its sorption behaviour. Clearly, the way in which the end-member components interact and influence the physicochemical behaviour of WTR is important to understand, as this will also affect WTR's capacity as a sorbent.

Based on results from the literature, we surmise that WTR is a microporous material. In comparison to its end members, it is thought that WTR will contain: (i) a constrained pore network (in terms of size and connectivity) due to NOM and polymer fractions occluding and heavily cross-linking oxide particles, and (ii) a proportion of masked reactive surfaces due to NOM and polymer adsorbing to Fe oxides. As a result of masking and a more limited pore network, WTR may exhibit a lower adsorption capacity than that of the combination of its end members in an unbound state. Importantly, on the other hand, the organo-mineral composite nature of WTR may give advantages in terms of stability and ability to function over a wider range of environmental conditions.

WTR will be further investigated in relation to its sorption behaviour in the following chapter. Humic acid (as a proxy for NOM) and ferrihydrite were chosen as most appropriate end-members for WTR, which are used in further laboratory-based experiments discussed in Chapter 4.

In terms of further work on the characterisation of WTR, a better understanding could be gained by comparing the surface properties of WTR with those of the actual NOM end-member and polymer components. The NOM component of WTR comes from the raw water and could be isolated via filtration. Use of analytical techniques such as transmission electron microscopy (TEM) which is able to examine the surface at nm scale, as well as tools which better measure porosity and SSA of microporous substances, may help to provide more conclusive findings. The types and quantities of the Fe phases present in WTR also have important implications for its ability to function as a sorbent and its behaviour in the environment. Further work to quantify this and to elucidate the potential mineral transformations that may occur over time and under different storage conditions is therefore prudent. In the wider field of research, more powerful analytical tools such as X-ray absorption spectroscopy (XAS) are being utilised to probe the mechanisms responsible for the stabilisation of NOM in organo-mineral composites. This information will be directly relevant to understanding the stability of WTR over time, and the processes controlling its behaviour as an adsorbent of contaminants in the environment.

4. **Macroscopic Sorption of Pb onto WTR**

4.1 Introduction

The overarching aim of this thesis was to establish the potential for using WTR as an immobiliser for Pb in contaminated soil. Fundamental to this aim is to establish WTR's sorption capacity for Pb and to understand its sorption behaviour.

Contaminant immobilising amendments act by inducing various sorption processes, including adsorption to mineral surfaces, formation of stable complexes with organic ligands, surface precipitation and ion exchange. The amendments can also cause the contaminants to (co)precipitate as salts. Sorption is the general term for the retention of a substance at a surface. These processes are summarised below (McBride, 1994):

- **Ion exchange** - ions held at a charged surface by electrostatic bonds are replaced by other ions of same charge present in solution. They are held as outer-sphere complexes, which means the ions remain bound by the hydration shell and do not bind directly to the surface. Cation exchange is a major reaction in the natural environment. Cation exchange can occur on three types of surfaces:
    - Aluminosilicate clays - a permanent negative charge on the faces and a pH variable charge on the edge of the clay lattice;
    - Humified organic matter - a mixture of functional groups give rise to both positive and negative charges but the overall charge is negative due to the number of carboxylic and phenolic groups, the magnitude of which varies with pH;
    - Hydrous oxides of Al, Fe, and Mn - have a pH dependent surface charge, positive at low pH and negative at high pH.
- **Adsorption** (also known as surface complexation) - ions and molecules in solution bond directly to specific sites on the surface of a solid phase as inner-sphere complexes (no intervening water molecules). Bonding to the surface is by strong covalent bonds (chemisorption), hydrogen bonds or van der Waals forces. The main surfaces involved are the hydrous oxides. Sorption of metal cations is pH-dependent and is characterized by a narrow pH range where adsorption increases to nearly 100%,

known as the adsorption edge. The sorption edge of a particular element is related to its hydrolysis characteristics.

- **Complexation** - electronegative atoms of functional groups in an organic molecule form a coordinate bond with metal ions from solution by replacing one or more of the water molecules from its hydration shell. Important functional groups in organic matter include: oxygen containing groups (e.g. carboxylate, carbonyl, ether), nitrogen containing groups (e.g. amine, azo), and sulphur containing groups (e.g. thiol, sulphide).
- **Precipitation** - when the concentration of ions in solution exceed a certain critical value, the ions form a compound which precipitates out of solution as a new solid phase. There is a continuum between surface complexation and surface precipitation: at low surface coverages, surface complexation dominates but as surface coverage increases, surface precipitation can occur.

In addition to pH, these processes are influenced by many environmental factors such as redox potential, cation exchange capacity, soil characteristics, competition from other ligands, type and concentration of adsorbent (Sparks, 1995).

Fe oxides and hydroxides consist of hexagonal or cubic close-packed O^{2-} and/or OH^- anions with Fe^{3+} residing in octahedral sites. The arrangement of the Fe octahedral units and the degree to which they share corners (one shared oxygen), edges (two shared oxygens) or faces (three shared oxygens), distinguishes the individual oxide minerals. The most common Fe oxides in the environment are ferrihydrite ($FeOOH.0.4H_2O$) which is poorly-ordered, and goethite (FeOOH) a well-structured mineral, both found in temperate regions, and hematite (αFe_2O_3) a crystalline mineral found in tropical areas (McBride, 1994). Goethite and ferrihydrite are known to have similar local structures, where three O atoms and three OH groups neighbour the ferric ion. However, goethite has long octahedral chains which give it long-range order, whereas ferrihydrite is characterised by much shorted octahedral chains giving rise to low-range order and more edge sites (Trivedi and Axe, 2001). The high density of edge sites and poor crystallinity of ferrihydrite means that it has a large surface area and adsorption capacity for foreign ions. Owing to these characteristics, ferrihydrite is recognised for playing an important role in the transportation and fate of PTEs in the aquatic and soil environments (Jambor and Dutrizac, 1998). Lead has been shown to adsorb onto the surface of iron (oxyhydr)oxides via inner-sphere bidentate edge-sharing complexes (Bargar et al., 1997; Templeton et al., 2003; Trivedi et al., 2003).

Natural organic matter, as discussed in Section 2.1.2, is a complex, largely uncharacterisable, amorphous polymeric material, containing many types of N-, P-, and S-based compounds. Organic matter is responsible for many important function in soil, including: maintenance of good soil pore structure and improved water retention; release of nitrogen, phosphorus, sulphur and trace elements by mineralization; retention of nutrients (e.g. Ca^{2+}, Mg^{2+}, K^{+}, NH_4^{+}, Mn^{2+}, Fe^{3+}, Cu^{2+}) by cation exchange; and adsorption of potentially toxic elements and organics (McBride, 1994).

NOM can act as sorbent of some PTEs through ion exchange, where ions are held non-specifically as weak outer-sphere complexes that are freely exchangeable. Some PTEs can coordinate directly with the functional groups through strong ionic and covalent bonds, as inner-sphere complexes. As well as the properties of the metals themselves, metal selectivity for organic matter depends on a number of factors, including: 1) type of functional group, 2) level or adsorption on the organic matter, 3) pH at which adsorption is measured, 4) ionic strength of the solution in which adsorption is measured (McBride, 1994). Spectroscopic studies have demonstrated that Pb can form inner-sphere complexes with soil humic substances (Xia et al., 1997). Pb sorption has been attributed to the carboxylic and phenolic moieties in peat and humic substances (Liu and Gonzalez, 2000; Qin et al., 2006).

Organo-mineral composites are recognised for their importance in controlling the fate and mobility of trace metals in natural waters, soils and sediments, although limited literature exists on deciphering how the organic and mineral components interact and control the metal sorption processes. A study which looked at Pb retention in organic (leaf compost), mineral (ferrihydrite), and mixed component systems found that Pb sorption was highest in the mineral and mixed systems in comparison to the organic system (Martínez and McBride, 1999). Templeton and co-workers studied the distribution of Pb in bacterial-mineral composites and found the partitioning of Pb(II) between biological and iron oxyhydroxide surfaces was pH-dependent, with more Pb associated with the biofilm at lower pH (<5.5) and more Pb associated with the mineral at higher pH (>6) (Templeton et al., 2003). The role of the end-member components in Pb sorption to WTR is fundamental to understanding how the sorbent would function in the environment, over a range of conditions.

4.1.1 Aims and objectives

WTR has been extensively studied as an adsorbent for anions such as phosphorus (Agyin-Birikorang et al., 2007) and arsenic (Makris et al., 2006) but relatively little attention has been given to its adsorption capacity for cations, in particular trace metals such as Pb. It is necessary to gain an understanding of how Pb interacts with WTR in order to assess its sorbent capabilities, optimise adsorption pathways and design effective *in situ* stabilisation technologies.

The aim of this study was to investigate the sorption behaviour and capacity of WTR for Pb. In this chapter, macroscopic investigations are presented in which batch sorption experiments were used to meet the following objectives:

- Assess the Pb(II) sorption capacity and behaviour of WTR as a function of initial solution concentration, ionic strength, contact time, particle size and pH;
- Compare Pb sorption capacity and behaviour of WTR to ferrihydrite and humic acid in order to investigate the role of the end-member components in Pb sorption to WTR.
- Compare the sorption capacity of all 9 WTRs and determine whether there is a relationship between sorption capacity and WTR composition.

To the author's knowledge this is the first study to carry out a detailed investigation of Pb(II) sorption to WTR. Broken Scar WTR, an Fe-based WTR, was selected for this study.

4.2 Materials and Methods

Samples were prepared as described in Chapter 3. Briefly, all adsorbents were air-dried, ground using a mortar and pestle and sieved to <63 µm prior to use, unless otherwise stated. Samples were stored in the dark in clean screw-top polypropylene tubs at room temperature.

4.2.1 Lead Sorption Experiments

Batch sorption experiments were conducted to determine the effect of various parameters on Pb sorption to WTR, including contact time, initial concentration, particle size and pH. All adsorption experiments were carried out at room temperature (22 ± 2 °C) and a temperature log was kept during the period of experimentation.

Pb(II) stock solutions were prepared at various concentrations from ACS grade $Pb(NO_3)_2$ (≥ 99.0%, Sigma Aldrich, UK), using 0.1 M $NaNO_3$ (Sigma Aldrich, UK) as the background electrolyte. 0.1 M acid and alkali solutions for pH adjustments were made from 1 M HCl and NaOH (Sigma Aldrich, UK), respectively.

Method

Batch sorption experiments were carried out in 50 mL Corning polypropylene centrifuge tubes (Sigma Aldrich, UK) using the following general procedure: adsorption samples were prepared at 10 g/L solid:solution ratio (SSR) by adding the required volume of Pb stock solution to 0.2 g adsorbent in 0.1 M $NaNO_3$. The pH was recorded and adjusted to the required value by the drop-wise addition of 0.1 M NaOH or 0.1 M HCl whilst gently shaking the suspension. Suspensions were shaken at 150 rpm on a reciprocal shaker for the desired contact time, during which the pH was monitored and adjusted when necessary. The final pH was recorded before suspensions were centrifuged (3000 g for 5 mins) and filtered (0.45 µm cellulose acetate syringe filters) into 15 mL Corning polypropylene centrifuge tubes. Samples were acidified to 1% with concentrated HNO_3 and then stored at 4 °C prior to analysis by atomic absorption spectroscopy (Varian SpectrAA 220FS). All adsorption experiments were performed in triplicate. The Pb concentration was recorded in mg/g, i.e. the mass load Pb in solution (mg) per mass of adsorbent (g).

The amount of Pb(II) adsorbed per unit mass of the adsorbent was calculated as q (mg/g), where:

$$q = \frac{\left(C_{initial} - C_{final}\right) V}{M} \qquad (1)$$

Where $C_{initial}$ is the initial concentration of Pb in solution (mg/L), C_{final} is the final concentration of Pb in solution, V is the volume of solution (L) and M is the mass of sample (g).

Investigations were made into Pb(II) sorption capacity and behaviour of WTR as a function of initial solution concentration, ionic strength, contact time, particle size and pH by using the following procedures:

Adsorption isotherm experiments were carried out by varying the initial Pb solution concentrations. Experiments were conducted at pH 5, with a 3 d contact time and SSR of 10 g/L, using Pb(II) concentrations ranging from 10 to 300 mg/g (mg Pb/g adsorbent) in 0.1 M $NaNO_3$.

Experiments were carried out at 0.01, 0.05, 0.1 and 0.5 M $NaNO_3$ to study the effect of ionic strength on Pb sorption, using Pb concentrations of 25 - 200 mg/g at pH 5, 3 d contact time and 10 g/L SSR.

To measure the effect of contact time, experiments were run for 1 h, 2 h, 4 h, 8 h, 1 d, 2 d, 4 d, 7 d, 14 d and 21 d using Pb concentrations of 25 - 200 mg/g in 0.1 M $NaNO_3$, at pH 5 and SSR of 10 g/L.

The effect of pH was studied by conducting experiments at pH 3, 4, 5, 6 and 7 using Pb concentrations of 25 - 200 mg/g, 3 d contact time and SSR of 10 g/L. Suspensions of adsorbent in 0.1 M $NaNO_3$ were adjusted to the required pH prior to addition of Pb(II) stock solution and held at the set pH for the duration of the experiment with drop-wise additions of NaOH or HCl.

Sieve-size fractions of <63 µm, 63 - 250 µm, 250 - 500 µm, 500 µm - 1 mm and 1 - 2 mm were used to study the effect of particle size on Pb sorption. Experiments were carried out at pH 5 in 0.1 M $NaNO_3$ and 3 d contact time and 10 g/L SSR using Pb concentrations of 25 - 200 mg/g.

Experiments using humic acid (Sigma Alrdich, UK), ferrihydrite (synthesised as described by the method in Section 3.2) and all other WTRs were conducted at pH 5 using various Pb concentrations in 0.1 M $NaNO_{3,}$ 3 d contact time and SSR of 10 g/L.

4.2.2 Spectroscopic analysis

Pb and Fe were analysed by atomic absorption spectroscopy (AAS) using a Varian SpectrAA 220FS atomic absorption spectrometer. Pb was determined using an oxidising air/acetylene flame using a 0.2 nm slit width at 217.0 nm for calibration range 0.1 - 10 ppm, and at 261.4 for calibration range 10 - 1000 ppm. Fe was also determined using an oxidising air/acetylene flame using a 0.2 nm slit width at 248.3 nm for calibration range 1.0 - 10 ppm, and at 372.0 nm for calibration range 10 - 100 ppm.

Polished blocks of air-dried unreacted and Pb-sorbed WTR samples were analysed by Electron probe microanalysis (EPMA). Electron probe X-ray mapping was performed on a Jeol 8100 Superprobe (WDS) with an Oxford Instrument Inca system (EDS). Energy spectral data were collected in the 0-20 eV range. Mapping of Fe, O, Pb and Mn was carried out using an accelerating voltage of 15 kV, current 2.5 mA and a beam diameter of 1 μm.

SEM and XRD were also performed on unreacted and Pb-sorbed WTR samples, as described in Chapter 3.

4.2.3 Geochemical modelling

Experimental solution speciation was calculated with PHREEQC v.2 (Parkhurst and Appelo, 1999) using the MINTEQ. v4 database. The experimental conditions and variable chemical parameters such as pH and Pb concentrations were input to calculate saturation indices, which indicate whether mineral phases are in solution or solid phase during the sorption experiments.

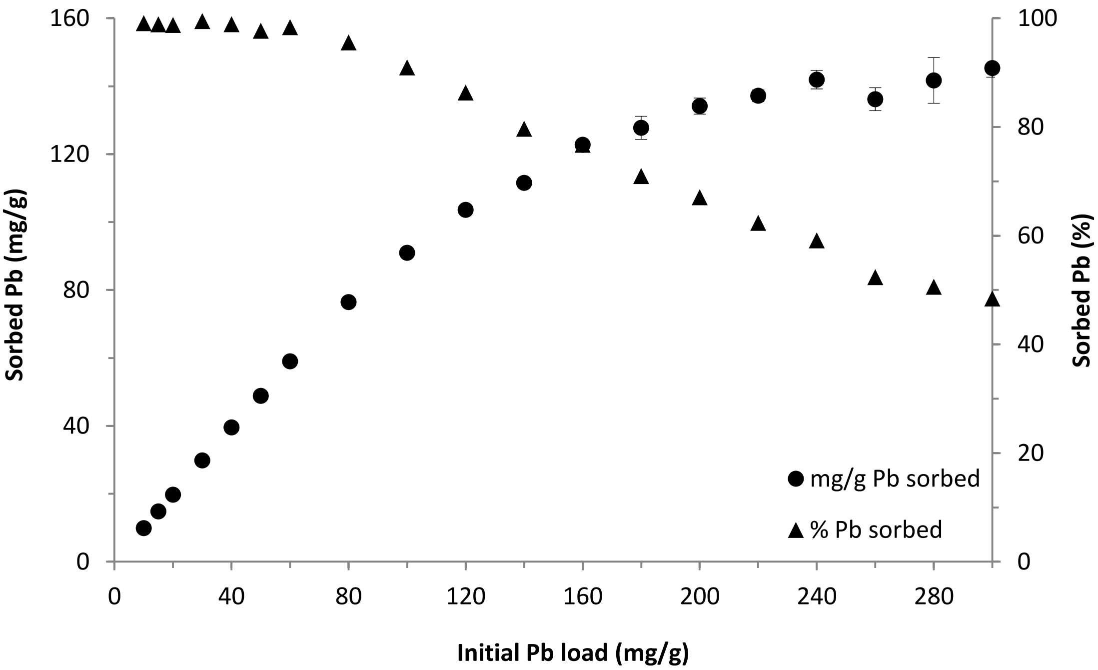
4.3 Results and Discussion

4.3.1 Effect of initial concentration

Figure 4-1 presents the sorption affinity of Pb(II) for WTR as a function of initial concentration, at pH 5 after 3 d contact time. The concentration of Pb(II) is measured in mg/g, i.e. mass of Pb per unit mass of WTR.

The initial Pb concentration along the x-axis shows the maximum Pb load available to be sorbed (mg/g); the left y-axis measures the quantity of Pb actually sorbed in mg/g, and the right y-axis shows the quantity of Pb sorbed expressed as a percentage of initial mass load.

Figure 4-1: Effect of initial concentration on Pb(II) sorption by WTR



Error bars are standard deviation of 3 replicates. Where error bars are not visible, they are smaller than the series symbols.

The graph shows that with increasing initial concentration, the quantity of Pb(II) sorbed increased (left y-axis). The plot also shows a decreasing trend in percentage of Pb(II) sorbed with increasing loading (right y-axis); At lower initial Pb loadings (<80 mg/g), 100% of the Pb was sorbed but at higher initial Pb loadings (>80 mg/g), a lower proportion of the initial Pb load was sorbed. Nevertheless, at these higher Pb loadings, Pb sorption continued to increase;

at a Pb loading of 160 mg/g, 123 mg/g were sorbed, and at a Pb loading of 240 mg/g, 142 mg/g were sorbed. This suggests that a higher concentration gradient facilitates faster sorption.

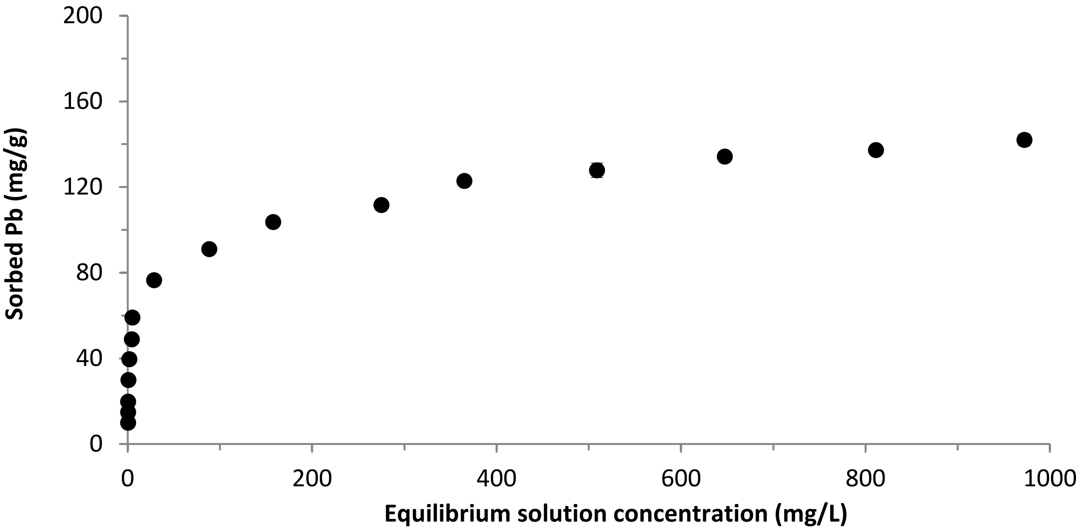
These results suggest that at the lower Pb(II)/WTR ratios, Pb sorption is to high affinity, highly accessible surface sites. As the Pb(II)/WTR ratio increases and the high affinity sites become used up, Pb sorption continues to a lesser extent, with Pb either binding to lower affinity sites or to less (physically) accessible high affinity sites. The gradual flattening of the curve indicates that the sorption sites have become saturated.

Adsorption data are commonly represented by an adsorption isotherm, where the quantity of adsorbate retained by the adsorbent (mg/g) is plotted against the concentration of the adsorbate in solution phase at equilibrium with the solid adsorbent (mg/L), under constant temperature and pH. The shape of the isotherm line suggests (but does not confirm) information about the adsorbate-adsorbent interaction (McBride, 1994). Thus, isotherms can help to provide an insight into the mechanisms governing the removal of a substance from aqueous-phase to solid-phase.

Figure 4-2 presents the sorption isotherm for Pb(II) on WTR. As observed in Figure 4-1, this plot shows the Pb in solution is completely removed at lower concentrations. At higher Pb concentrations the isotherm forms a plateau indicative of the onset of saturation of sites. This plateau is defined as the maximum sorption capacity available on the adsorbent surface (Dzombak, 1990; Trivedi et al., 2003).

It should be noted that the equilibrium solution concentration was taken as the final solution concentration after 3 d contact time. These values cannot be taken as ‘true’ equilibrium concentrations since it was observed in the kinetic experiments that at high Pb loadings, small quantities of Pb continued to be removed from solution over the course of weeks. This will be discussed in more detail later, however since the vast majority of Pb was sorbed after 3 d contact time, final concentration values were considered to be fairly representative of equilibrium concentrations.

Figure 4-2: WTR adsorption isotherm for Pb(II)



Error bars are standard deviation of 3 replicates. Where error bars are not visible, they are smaller than the symbol size.

Based on the initial steep slope and general shape of the curve, this isotherm can be considered as H-type, according to Giles classification (Giles et al., 1960). An H-type curve reflects a very strong adsorbate-adsorbent interaction and is indicative of chemisorption (McBride, 1994). As discussed above, chemisorption involves the formation of strong covalent bonds between the adsorbate molecule and surface functional groups, which means that the bonding is more specific and less reversible than other common sorption mechanisms such as ion exchange. Pb bound to WTR in this way has favourable implications for the use of WTR as a stabilising agent for Pb and other PTEs in contaminated environments. This does not provide any insight into whether Pb sorption is to functional groups belonging to ferrihydrite, organic matter or both.

Adsorption isotherm data can be fitted to equilibrium isotherm models to provide further information on the type of adsorption. A wide variety of isotherm models have been formulated but the most frequently applied for the characterisation of liquid-phase adsorption are the Langmuir and Freundlich models (Foo and Hameed, 2010).

The Langmuir isotherm (Langmuir, 1918) assumes monolayer adsorption onto a finite number of identical surface sites, with no lateral or steric hindrance between the adsorbed molecules (Foo and Hameed, 2010).

The linear form of the Langmuir equation is:

$$\frac{C_e}{q_e} = \frac{1}{q_{max}b} + \frac{C_e}{q_{max}} \qquad (2)$$

Where C_e is the equilibrium concentration (mg/L), q_e is the amount of solute adsorbed at equilibrium per unit mass of adsorbent (mg/g), q_{max} is the maximum adsorption capacity (mg/g) and *b* is the Langmuir constant (L/mg).

The Freundlich isotherm (Freundlich, 1906) can be applied to multilayer adsorption with non-uniform distribution over a heterogeneous surface. The linear form of the Freundlich equation is expressed as:

$$\log q_e = \log K_f + \frac{1}{n}\log C_e \qquad (3)$$

Where K_f is the adsorption capacity (mg/g) and n is the intensity of adsorption, Freundlich constant.

The experimental data were plotted according to the linear Langmuir and Freundlich equations which are presented in Figure 4-3 and Figure 4-4, respectively. Both plots showed a linear relation indicating that the data fit both models reasonably well. However a better fit was made with the Langmuir equation as represented by the higher correlation coefficient (R^2 0.9945 vs. 0.9654), suggesting that the Langmuir equation gives a more adequate explanation of the adsorption process. The Langmuir isotherm refers to homogenous, monolayer adsorption, where each molecule has constant enthalpy and sorption activation energy and all sites possess equal affinity for the adsorbate (Foo and Hameed, 2010). This fit adds credence to chemisorption being the principal Pb(II) binding mechanism in these experiments.

The Langmuir sorption capacity (q_{max}) was calculated to be 139 mg/g. This result (equivalent to 0.68 mmol/g) shows that WTR has a very high sorption capacity for Pb(II), and similar to Chiang et al. (2012) who reported an Fe-WTR Pb(II) sorption capacity of 120 mg/g (0.579 mM/g) under similar experimental conditions. To the author's knowledge, this is thought to be the only other study to have reported Pb(II) sorption capacity for Fe-WTR.

Figure 4-3: Langmuir plot for adsorption of Pb(II) to WTR

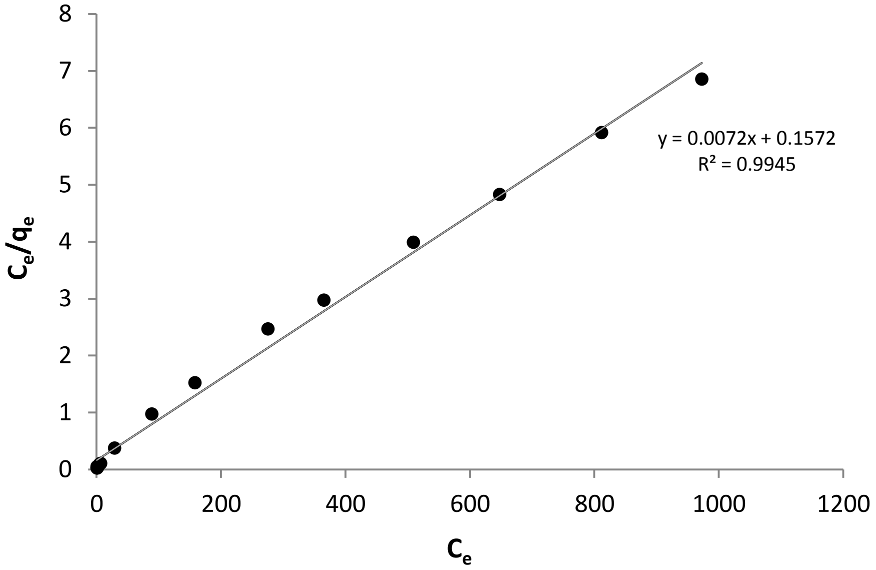
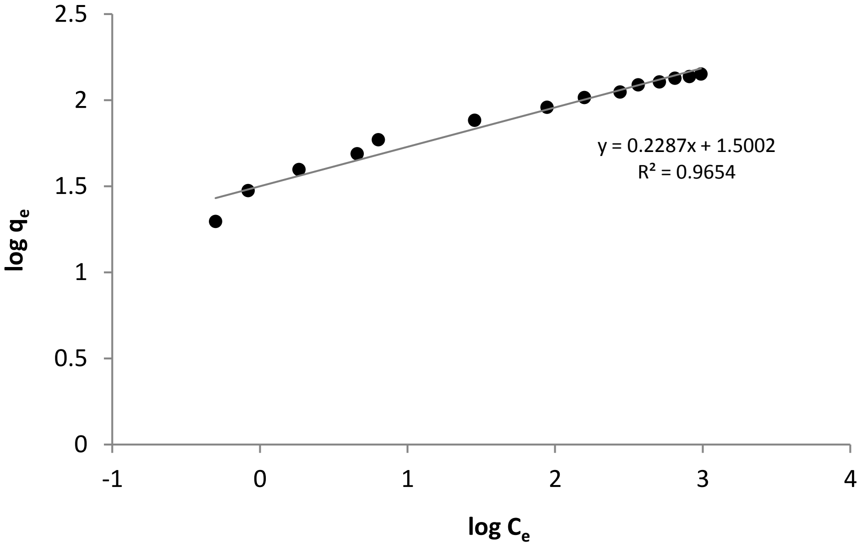


Figure 4-4: Freundlich plot for adsorption of Pb(II) to WTR



4.3.2 Sorption versus Precipitation

It should be noted that Pb(II) solutions of up to very high concentrations (10 - 2500 mg/L) were necessary to observe the plateau of Pb sorption and to draw out the effects of the parameters studied below. However, with higher Pb(II) concentrations there comes an increasing risk of precipitation of new solid Pb phases. Each solid Pb phase has a specific solubility limit or solubility product (K_{so}), which is the maximum concentration at which its constituents remain in solution. If the concentration of Pb in solution exceeds the solubility limit with respect to a particular Pb compound, the Pb can precipitate out of solution as this new solid phase, under the right conditions (e.g. pH, temperature, solution composition). In sorption processes, it can be difficult to differentiate between chemisorption and precipitation; it is often viewed as a continuous process that ranges from chemisorption at the low end of solubility to precipitation at the high end of solubility (McBride, 1994).

Clearly the extent to which Pb is stabilised in a solid phase depends on the mechanism by which it is removed. Chemisorption is generally considered to be most irreversible, whereas the stability/solubility of precipitated phases depends on the type of precipitate that is formed (McBride, 1994). Thus, in discussing the ability of WTR to function as an immobiliser for Pb, it is important to establish whether precipitation is a mechanism which is likely to play a role in the removal of Pb(II) from solution.

PHREEQC was used to carry out solution speciation calculations for likely Pb precipitates, such as Pb hydroxides and carbonates, for the range of solution concentrations used in the batch sorption experiments. The calculations, which are presented in Appendix 4, indicate that solutions containing the highest Pb concentration (200 mg/g Pb loading) approached the solubility limits for Pb hydroxide ($Pb(OH)_2$) (pH 5.5), Cerrusite ($PbCO_3$) (pH 5.7), and Hydrocerrusite ($Pb_3(OH)_2(CO_3)_2$) (pH 5.1). This shows that Pb precipitation may have been induced in the highest [Pb] systems. However, it should be noted that in preparing the batch experiments, care was taken to add the Pb(II) solutions in a slow, dropwise manner to avoid introducing a shock load of Pb. With adsorption occurring instantaneously, the concentration of Pb in solution would therefore always be expected to be less than the actual Pb loading applied.

Additionally, the isotherm does not show characteristic precipitation features in the fact that the isotherm plateaus; the increasing Pb(II) concentrations did not result in a steep upturn in the graph which is the typical effect seen in a system controlled by precipitation (McBride, 1994). These results suggest that adsorption to the WTR surface is the dominant mechanism for Pb removal in our system.

SEM

SEM images are presented below of the external surfaces of WTR particles (<63 µm) which were:

1) Untreated (Figure 4-5);
2) Pb-sorbed at 200 mg/g Pb loading, pH 5 for 3 d (Figure 4-6), and
3) Pb-sorbed at 200 mg/g Pb loading, pH 5 for 14 d (Figure 4-7).

The aim of the analysis was to examine whether there was any noticeable difference in the surface morphology after undergoing sorption, in particular whether Pb precipitates could be observed. In each figure, the upper three images are SEM and the lower three are back-scattered (BS) images. In BS images, heavier elements appear brighter. The BS images can therefore bring out surface compositional features. EDX analysis was taken at points on the surface of each of the particles (see Appendix 3).

In all the figures the SEM images clearly show the relatively smooth surfaces of the WTR particles, which range in size from about 10 to 50 µm. Much smaller particles or clusters of particles are present on the surface of the bulk particles. At a Pb loading of 200 mg/g, around 130 mg/g and 165 mg/g Pb was sorbed after a contact time of 3 d and 14 d, respectively. In comparing the BS images in Figure 4-5, Figure 4-6 and Figure 4-7, the overall brightness of the sample can clearly be seen to increase with increasing Pb load. The brightness can be attributed to the Pb since it is a heavy element in comparison to the other components of WTR. The BS images and EDX analysis (Appendix 3) show that the smaller particles present on the surface are simply finer particles of the same composition as the larger particles i.e. Fe, O and C (in a few cases Si was also detected in the WTR). Analysis of the fine particles in the Pb-treated samples (Appendix 3) indicates that they are enriched in Pb to a similar extent as the bulk surface; Fe, O and Pb were identified at all points. The back scatter images and EDX points show Pb coverage across the entire WTR surface and reveal no obvious zonal Pb enrichment on any of the surfaces. Discrete Pb mineral phase precipitation is also thought to be unlikely based on these findings.

Figure 4-5: WTR un-treated: SEM secondary electron (top) and back-scattered (bottom) images

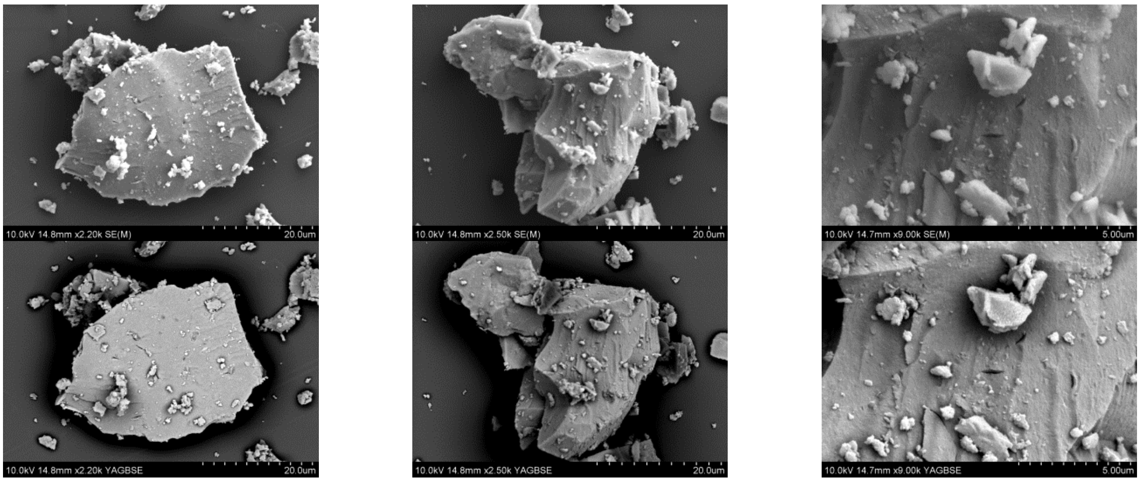


Figure 4-6: WTR with 200mg/g Pb, pH5, 3d: SEM secondary electron (top) and back-scattered (bottom) images

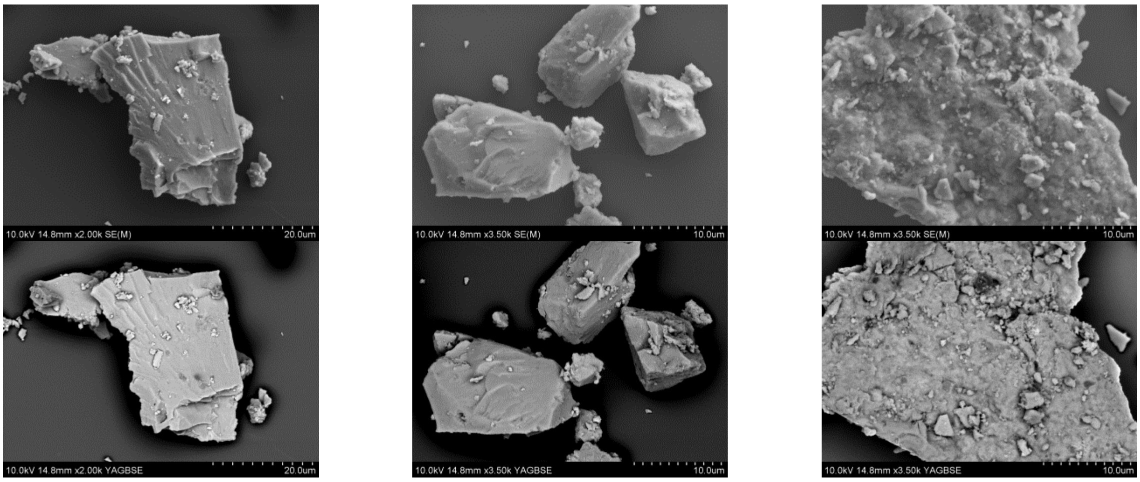
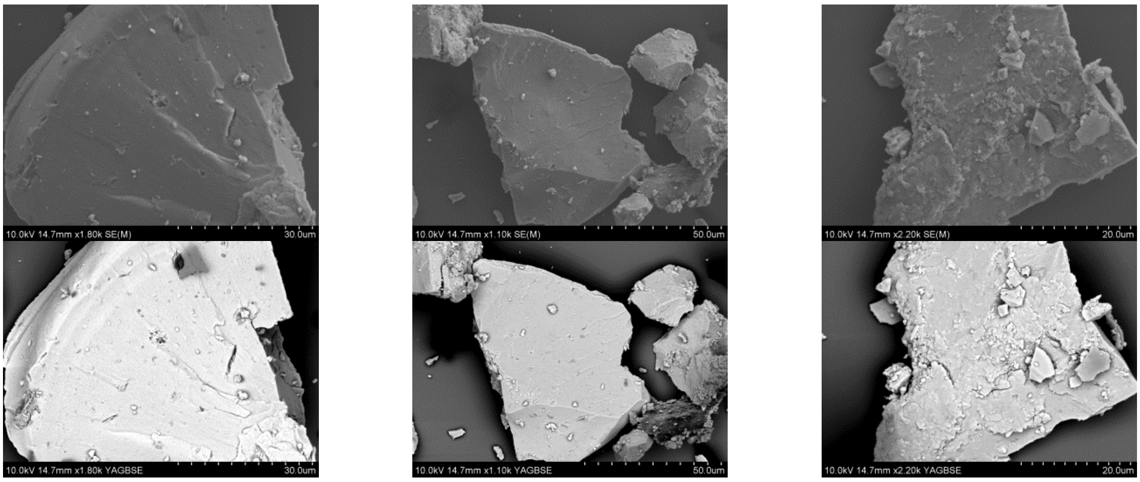


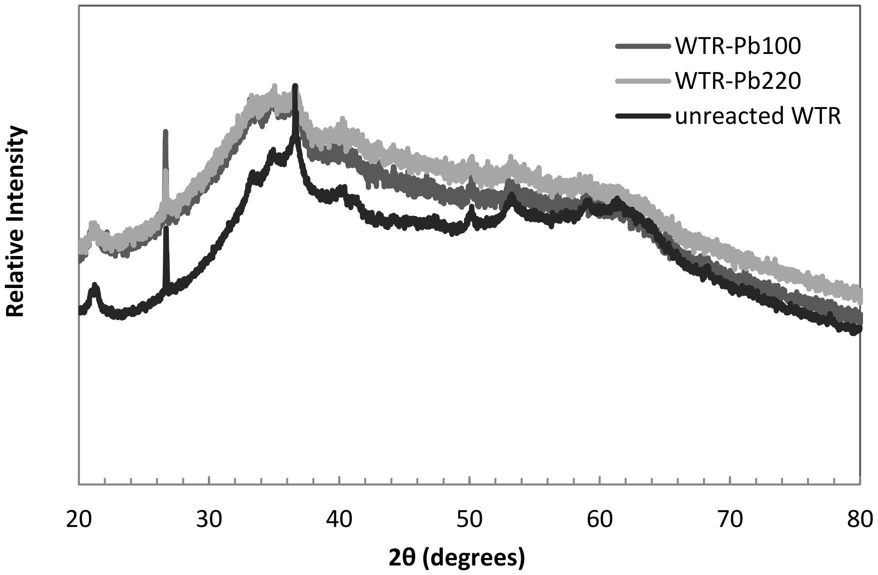
Figure 4-7: WTR with 200mg/g Pb, pH5, 14d: SEM secondary electron (top) and back-scattered (bottom) images



XRD

Additionally, XRD scans were taken of Pb-sorbed WTR particles from the initial concentration experiment. Two samples were scanned which had adsorbed 90 mg/g and 138 mg/g after a 3 d reaction time, from initial Pb loadings of 100 and 220 mg/g, respectively. Scans were run to determine whether there were any changes in the mineralogy as a result of the experiment, specifically, if any Pb precipitate forms could be detected on the Pb-sorbed samples.

Figure 4-8: XRD of Pb-sorbed WTR after 3 d reaction time at different initial Pb loadings (XRD runtime 5h) in comparison to unreacted WTR (XRD runtime 16h)

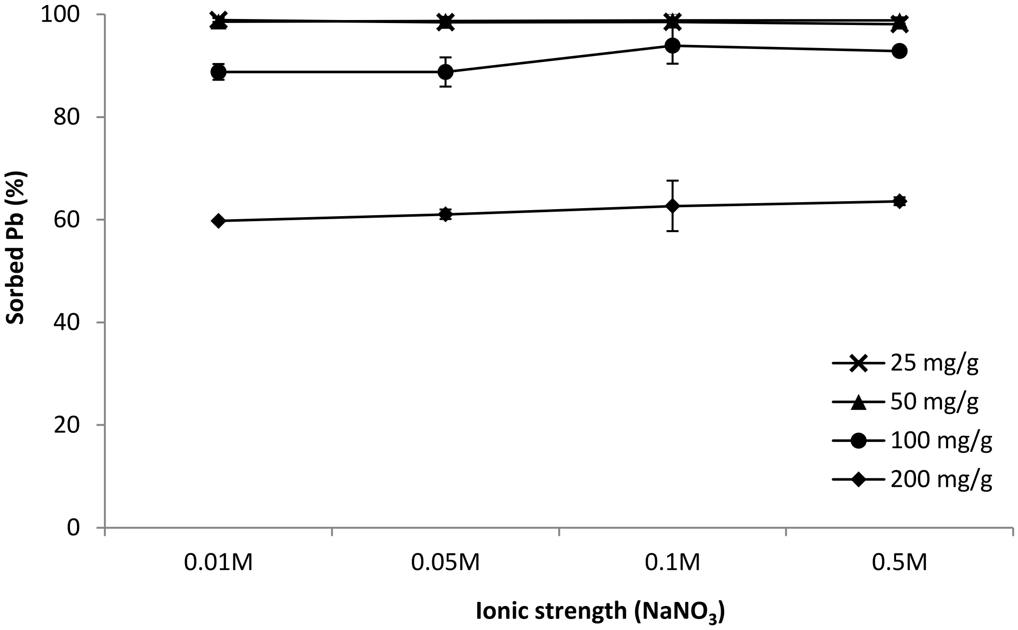


The scans are presented in Figure 4-8, alongside the unreacted WTR (no Pb) which was run previously (Chapter 3) for comparison. The Pb-sorbed WTR scans showed no evidence of Pb hydroxide or carbonate mineral phases. Unfortunately however, the Pb-WTR scans were less well resolved than the previous WTR scan due the shorter scan time that was used (5 h rather than 16 h). This may be the reason for the difference in the sharpness of the peaks. Additionally, the large shoulder and high background resulting from the amorphous nature of WTR may obscure lower intensity peaks coming from other minerals, as discussed previously (see section 3.3.4). The lack of evidence for Pb mineral phases in these XRD scans cannot be taken as proof that they don’t exist. However, taken together, the H-type isotherm, PHREEQC calculations and XRD data all suggest precipitation does not play a major role in Pb removal in this system.

4.3.3 Effect of ionic strength

The effect of ionic strength was investigated by varying the concentration (0.01, 0.05, 0.1 and 0.5 M) of background electrolyte ($NaNO_3$) in a batch sorption experiment at pH 5 for 3 d contact time. The results are presented below in Figure 4-9.

Figure 4-9: Effect of ionic strength



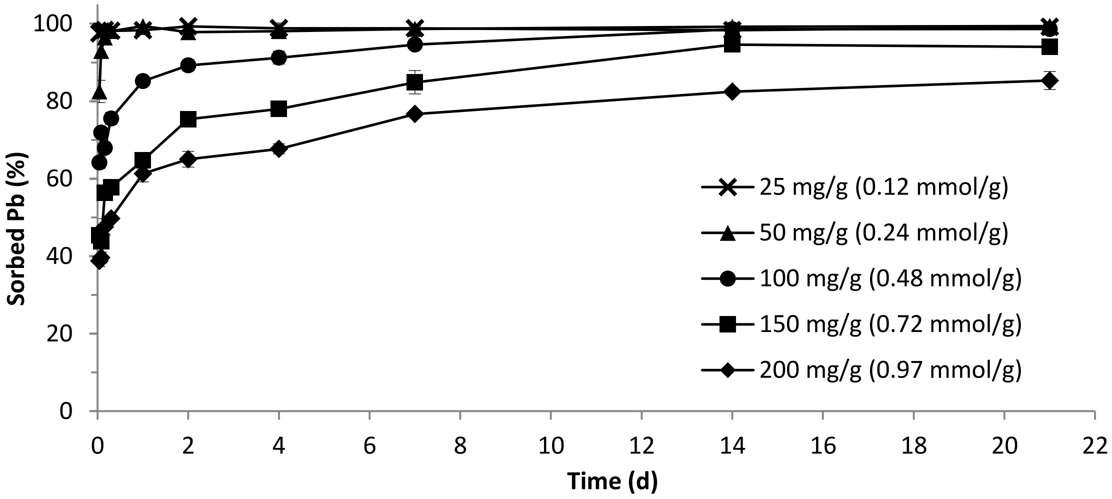
The graph clearly shows that there was no effect of ionic strength on Pb sorption over the test conditions, suggesting no significant competition from the background electrolyte for Pb sorption. This is indicative of Pb binding by chemisorption, through inner-sphere complexation with surface functional groups, rather than by ion exchange (outer-sphere complexation) in which competition would come from other ions in solution (Trivedi et al., 2003). Similarly, Swallow et al. (1980) showed that Pb sorption to hydrous ferric oxide (HFO) was unaffected by ionic strengths ranging from 0.0005 to 0.5 M $NaClO_4$. Trivedi et al. (2003) showed that Pb sorption to Fh did not vary significantly with ionic strengths of 0.001 - 0.1 M $NaNO_3$ over a pH range of 3 to 7, as did Reich et al. (2010) (ionic strength range 0.003 to 0.1 M $NaNO_3$) .

4.3.4 Effect of contact time

The 3-day initial concentration experiment showed that 100% sorption was achieved up to a loading of approx 80 mg/g, and thereafter less efficient removal was achieved, up to an observed 140 mg/g max sorption capacity. The fact that WTR has a high sorption capacity and is able to absorb Pb(II) ions over a wide range of solution concentrations indicates that WTR could be used as an adsorbent of Pb in a range of low to highly contaminated systems. Thus in studying the effect of different solution parameters on Pb sorption herein, a range of initial solution concentrations (Pb loadings) were used so that their effect as a function of initial concentration could also be assessed.

The effect of time and the prediction of kinetics are fundamental to understanding the sorption process and designing Pb removal treatment systems. The effect of contact time on Pb(II) sorption was studied at pH 5 on systems loaded with 25 - 200 mg Pb/g WTR, using <63 µm particle size. Samples were shaken for 1 h up to 21 d in order to assess short to longer term effects. Figure 4-10 shows that Pb sorption is time-dependent, with sorption increasing over time, and that initial concentration greatly affects this kinetic behaviour.

Figure 4-10: Effect of contact time on Pb(II) adsorption



Error bars are standard deviation of 3 replicates. Where error bars are not visible, they are smaller than the symbol size.

It is clear from the graph that a significant fraction of Pb is sorbed within the first hour at all Pb loadings: 24, 40, 64, 68 and 78 mg/g were sorbed from the 25, 50, 100, 150 and 200 mg/g loaded systems, respectively. This also shows that sorption was faster in the systems containing higher initial Pb concentrations: 78 mg/g from the 200 mg/g Pb-loaded system compared to 64 mg/g from the 100 mg/g Pb-loaded system, respectively. This supports the idea that a stronger concentration gradient encourages more rapid migration of Pb(II) ions from solution onto WTR. This is to be expected due to Fick's law: a greater concentration gradient will drive diffusion and interaction between aqueous Pb and the WTR surface.

100% sorption of the 25 mg/g and 50 mg/g Pb loads was achieved rapidly indicating that there are enough high affinity, highly accessible sites on the WTR surface to sorb these quantities of Pb, in line with the above findings on sorption capacity. The shape of the 100, 150 and 200 mg/g curves reveal that the initial fast sorption which occurred within the first 1 h was followed by slower sorption. Between 2 d and 4 d, the plots appeared to level out and it was initially thought that equilibrium had been reached by day 3. However, observations over a longer period of time revealed that Pb sorption continued to increase, albeit more gradually, thereafter. By day 14, the 100 mg/g Pb loaded system reached 100% sorption, the 150 mg/g Pb loaded system reached 140 mg/g after 14 d and remained constant thereafter, whereas the 200 mg/g Pb loaded system continued to sorb Pb gradually from solution for the duration of the experiment, indicating that true equilibrium had not been reached. By day 21, 170 mg/g sorption was achieved in this system, exceeding the previously calculated max sorption capacity.

The observation that rapid sorption gives way to slow sorption demonstrates that Pb has a biphasic pattern of adsorption to WTR. This two-stage kinetic behaviour is commonly observed in rate studies involving trace metals and inorganics at sorbent-water interfaces; a wealth of literature reports biphasic behaviour of Pb for a range of sorbent materials including metal oxides (Strawn et al., 1998; Yiacoumi and Tien, 1995), organic matter (Strawn and Sparks, 2000) and other biosorbents (Gadd, 2009). Typically, very rapid initial sorption occurs for a few minutes, followed by a long period of much slower uptake. The first step is a fast reaction between the bulk aqueous phase and adsorbent external surface sites, including sites in the macropores (Axe and Anderson, 1995). Bulk diffusion and the adsorption reaction are considered to be instantaneous; the effect of transport in the solution is typically eliminated in experimental systems by rapid mixing of the suspensions (Ho et al., 2002; Scheinost et al., 2001), and inner-sphere complexation/ chemisorption is reported to be completed within seconds (Grossl and Sparks, 1995; Hachiya et al., 1984).

The initial rapid Pb(II) sorption phase observed in our experiment (< 1 hour) is therefore likely attributable to chemisorption of Pb to sites on the WTR external surface which are easily accessible. The second stage may take from a few hours to several days, weeks or even months before equilibrium is reached depending on the nature of the metal ion and the adsorbent, and is thought to be largely controlled by diffusion processes (Axe and Anderson, 1995; Axe and Trivedi, 2002; Benjamin and Leckie, 1981; Scheinost et al., 2001).

In microporous materials, the rate-limiting step typically involves diffusion of the metal ion into the hydrated micropores, and is termed intraparticle diffusion (Axe and Anderson, 1995). Axe and Anderson (1995) state that the type of intraparticle diffusion is determined by the area of the diffusion path: when pores are large relative to the diameter of the ion, bulk diffusion through hydrated micropores is possible; when pores are small relative to the size of the ion, transport is limited to solid state diffusion, which is known as surface diffusion. Thus, intraparticle diffusion of ions can occur both in the water and along the surface of the pore. Ion diffusion through an aqueous medium is generally rapid (>mm/s) but it can be several orders of magnitude slower when the water film at a reactive surface is thin and the ion strongly interacts with the surface (Scheinost et al., 2001).

In microporous materials such as amorphous oxides which contain small pores, it has been found that surface diffusion dominates and thus controls the sorption kinetic behaviour (Axe and Trivedi, 2002). Surface diffusivities of various trace metals have been reported to range from 10^{-16} to 10^{-10} cm^2/s in hydrous amorphous oxides of Al, Fe and Mn (Axe and Anderson, 1995; Trivedi and Axe, 2000). Importantly, it has been shown that the same types of sites exist on external surfaces, macropores and micropores. Therefore the mechanism involved in long-term sorption of ions within the micropores of oxides, which can occur via intraparticle diffusion, has been found to be the same mechanism involved in sorption onto external surfaces (Barrow et al., 1989; Trivedi and Axe, 2000; Trivedi et al., 2001).

Numerous studies have reported that intraparticle surface diffusion is the rate-limiting mechanism in the adsorption of trace metals to both oxides and organic matter, and has been found to be responsible for slow sorption stages ranging between days and months (Axe and Trivedi, 2002; Strawn and Sparks, 2000; Willett et al., 1988).

It is suspected that microporous diffusion could explain the slow sorption observed above in Figure 4-10. However, several other mechanisms are also known to cause slow sorption. In the case of both oxides and organic matter, the presence of multi-sorption sites of varying affinity has been found to influence sorption kinetics, since sorption proceeds to the highest affinity sites first, followed by slower sorption to lower affinity sites (Benjamin and Leckie, 1981; Liu and Huang, 2003; Town and Filella, 2002). Another mechanism commonly responsible for slow sorption is precipitation, since it is often a slower process than adsorption (McBride, 1994). As discussed above, surface precipitation may occur in systems that are under-saturated (Strawn et al., 1998; Towle et al., 1997). In many cases, ongoing precipitation has been found to be the cause of long-term sorption; for example slow sorption of Cd to hydrous ferric oxide was attributed to ongoing Cd hydroxide precipitation (Dzombak and Morel, 1986), and nucleation of Ni-Al surface phases was found to explain the slow sorption stage of Ni onto Al oxides and clays (Scheidegger et al., 1998).

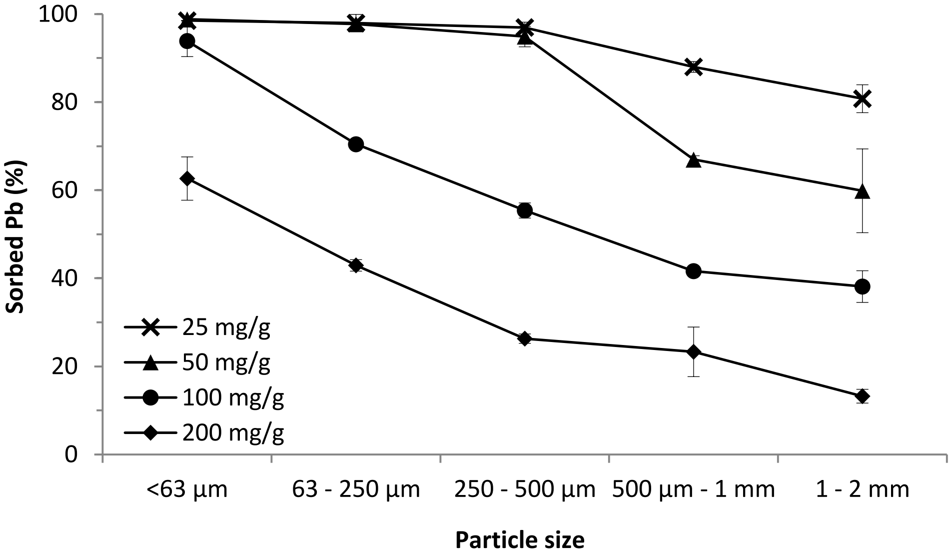
The three main mechanisms for slow sorption are therefore considered to be:

1. Diffusion into micropores of solids followed by sorption on interior sites
2. Sorption to sites of lower affinity
3. Surface precipitation

All three mechanisms are potentially feasible in the Pb-WTR system. WTR is a heterogeneous material containing a mixture of ferrihydrite, NOM and other trace components. As discussed in Chapter 3, both NOM and ferrihydrite components are known to be microporous, and it is proposed that the creation of WTR produces an even more constrained microporous material. It is therefore likely that intraparticle diffusion also influences the sorption kinetics of WTR. Additionally, since both NOM and ferrihydrite components are capable of sorbing Pb and both are known to contain various site types and functional groups differing in reactivity, it is highly possible that several different types of sorption sites of differing affinity are involved in Pb sorption to WTR. In terms of precipitation, although Pb concentrations were maintained below the solubility limits and the findings presented earlier (effect of initial concentration section) suggest that precipitation was not the dominant mechanism for Pb removal, it is still possible that precipitation, including surface nucleation and surface polymerisation, may contribute to long-term sorption.

For a clearer idea of whether intraparticle diffusion is an important mechanism in our system, further experiments were carried out to determine the effect of particle size on Pb sorption. This was investigated after 3 d contact time at pH 5, at several Pb loadings. The results are presented in Figure 4-11.

Figure 4-11: Effect of particle size on Pb(II) sorption to WTR



Error bars are standard deviation of 3 replicates. Where error bars are not visible, they are smaller than the symbol size.

The graph clearly shows that particle size has a strong effect on Pb sorption. Sorption of Pb increases with decreasing particle size and the effect is more pronounced at higher Pb loadings.

A reduction in particle size is likely to have two effects on WTR:

1. Increase the external surface area;
2. Increase the accessibility of the interior of the adsorbent by reducing diffusion path distances

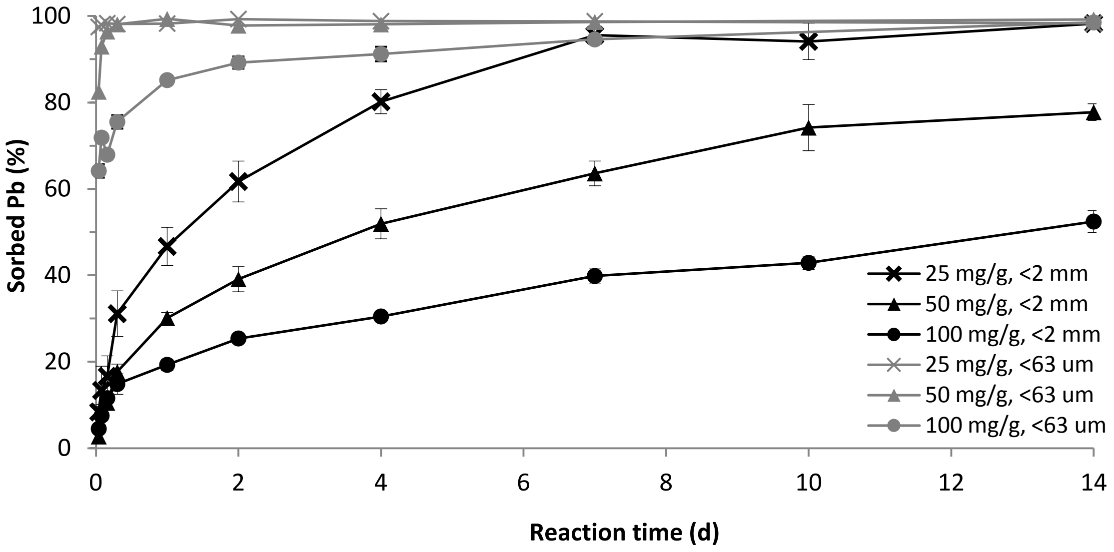
These will have the combined effect of increasing Pb sorption, since the number of external surface sites available for Pb sorption will increase and the rate and extent of Pb sorption in the micropores will also increase. It is therefore likely that both of these contribute to the observed effect shown in Figure 4-11.

The graph also shows that the effect of particle size is more pronounced at higher initial Pb concentrations (Pb loadings). There is a greater percentage difference in Pb sorbed between the largest and smallest particle sizes at higher concentrations because there are proportionally less sites available for sorption at higher Pb concentrations, since more sites have been used up. The fact that the effect of particle size is less pronounced at lower initial Pb concentrations (Pb loadings) suggests that there are closer to being enough available sorption sites across the particle size range.

Ultimately if sorption was allowed to reach ’true’ equilibrium in these systems, it is expected that the adsorption capacity would be similar for all particle size classes, since the Pb ions would eventually diffuse into all available sorption sites. However, within a certain reaction time, more Pb will be sorbed in the smaller particle size system because more reaction sites are more easily accessible. Thus, in the case of microporous adsorbents such as WTR, it is expected that the rate of sorption is most impacted by particle size, which in turn affects the extent of Pb sorption over a given time.

In order to test this hypothesis, a further sorption experiment was undertaken in which the effect of contact time on Pb sorption to <2 mm WTR particles was examined. Figure 4-12 presents the results of this experiment along with results reported previously (in Figure 4-10) for effect of contact time on <63 µm particles (grey lines) at the same Pb-loadings, for comparison.

Figure 4-12: Effect of contact time on Pb(II) sorption to WTR, <2 mm particle size, at pH 5



Error bars are standard deviation of 3 replicates. Where error bars are not visible, they are smaller than the symbol size.

The graph shows the dramatic effect of particle size on Pb sorption over time. In comparison to the <63 µm particle size fraction, Pb sorption to <2 mm particles is considerably slower. A relatively small amount of Pb is sorbed in the first hour: <10% (2 mm fraction) in comparison to >60% (63 µm fraction). This difference shows that there is much less sorption to the external surface sites in <2 mm particles, consistent with larger particles having a smaller external surface area. For the <2 mm particles, the second stage of sorption, i.e. the slow sorption stage, is much more important for Pb removal under all initial Pb concentrations. In larger particles, it is expected that the interior pores are less accessible, and diffusion over a longer distance is required for Pb to reach available sites. The continuous sorption over the course of weeks in the larger size fraction implies that intraparticle diffusion is the rate-limiting process controlling Pb sorption here. The observed effect of particle size suggests that the accessibility of sites is a more important factor than site affinity or surface precipitation. However, this is not to say sorption to lower affinity sites or precipitation over time does not occur; only that diffusion is likely to be the rate-controlling factor.

To investigate the interaction of Pb with the WTR surface further, X-ray microprobe images were taken of a selection of WTR particles of different sizes and at different Pb loadings. The samples were thin-sectioned in order to slice through the particles and look at the interior surfaces. Figure 4-13 is a back-scattered image of untreated WTR, <2 mm particles (scale 1 mm). As with previous images (Section 3.3.3), it shows that the WTR is cracked and fairly uniform. It should be noted that the fractures are a result of cutting through the WTR particle during thin-section preparation; they did not exist during the sorption experiment (the images below show that Pb is not associated with these fractures). The microprobe images in Figure 4-14 show high levels of O and Fe throughout the grain, and no Pb.

Figure 4-13: Back-scattered image of untreated WTR, <2 mm

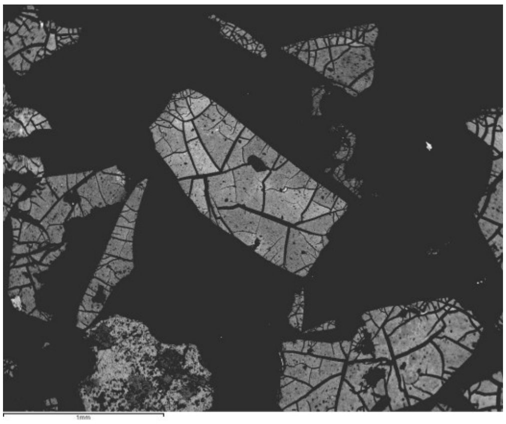


Figure 4-14: X-ray microprobe images of untreated WTR, <2 mm

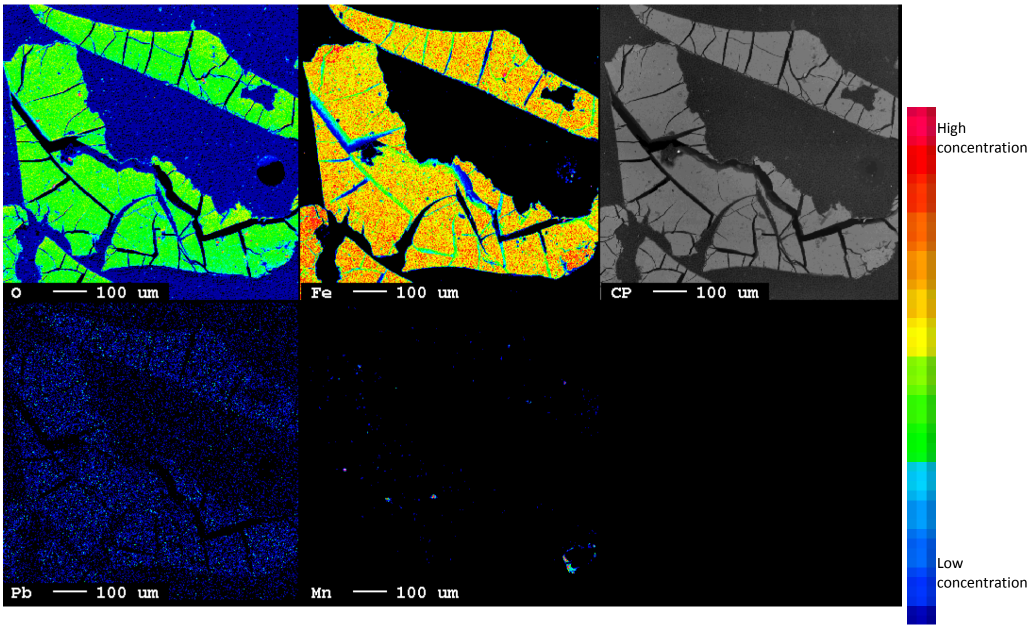


Figure 4-15 shows microprobe images of Pb-sorbed <2 mm WTR particles at low Pb loading (16 mg/g) after 2 d. The image clearly shows that the rims of the particles are enriched in Pb. The Pb is brightest (highest concentration) at the edges of the particle and becomes less so moving in towards the interior. The Pb extends approximately 50-80 µm into the particle.

Figure 4-15: X-ray microprobe images of WTR at low (16 mg/g) Pb loading, <2mm particle size, 2 d

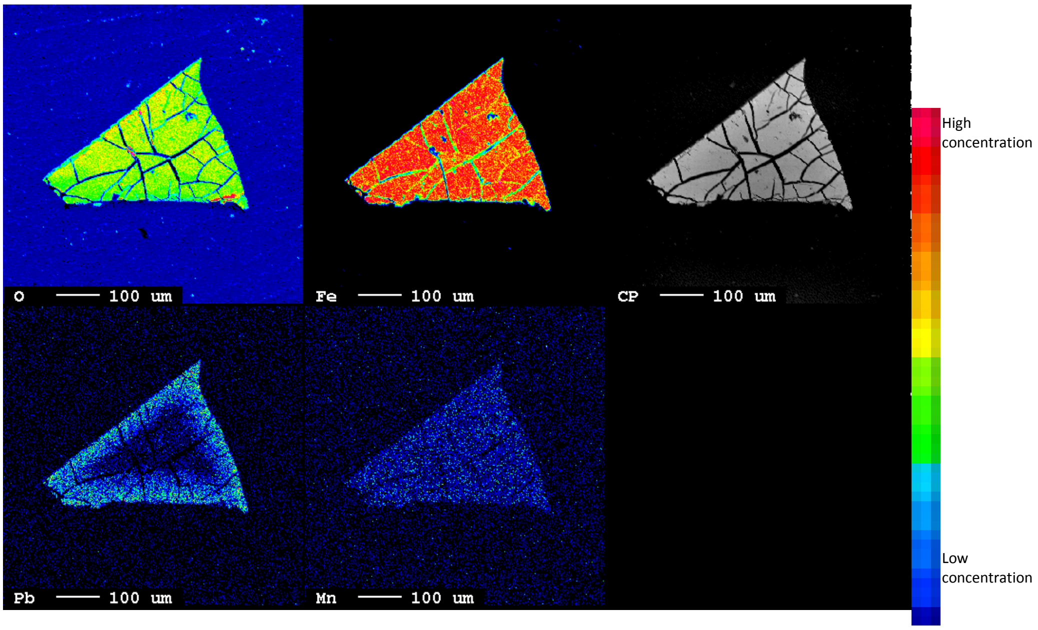


Figure 4-16 and Figure 4-17 present images which were taken of a higher Pb-loaded (100 mg/g) WTR sample for the same particle size and reaction time. Figure 4-16 is the back-scattered image showing some of the grains; scale is 1 mm. The grains have obvious bright rims indicating that the rims are enriched with a heavier element (Pb) than the cores. The smaller particles in the image appear to be enriched throughout. The accompanying microprobe image in Figure 4-17 shows that the rims are very enriched with Pb and that the Pb also extends further into the particle, by more than 100 µm. The smaller particle in the top left-hand corner appears to be more uniformly enriched, showing only slightly less Pb in the centre.

Figure 4-16: Back-scattered image of Pb-sorbed WTR, 100 mg/g Pb loading, <2 mm particle size, 2 d

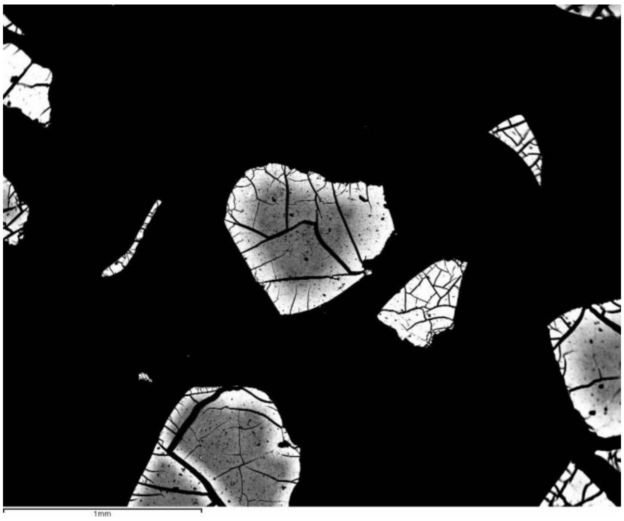
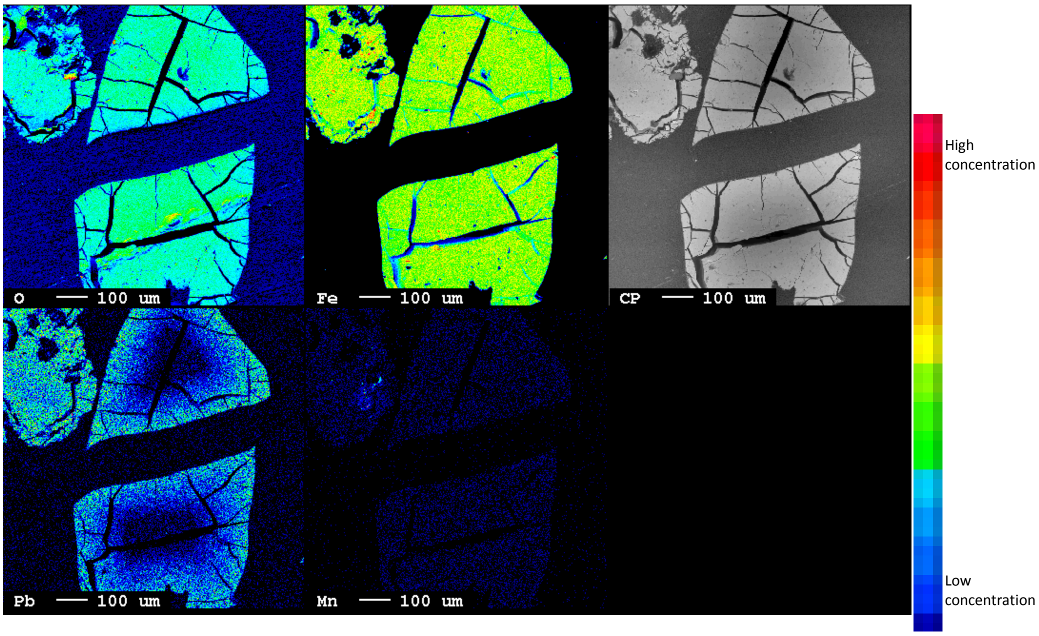


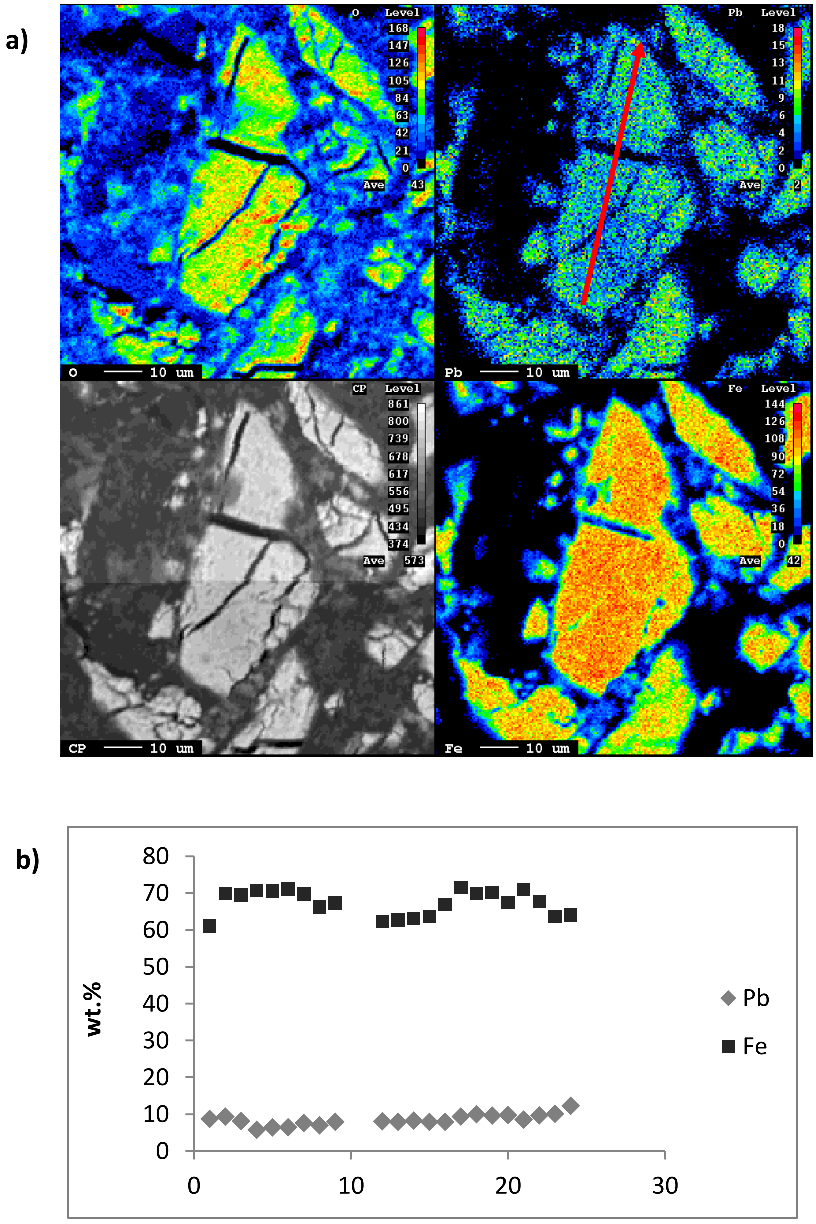
Figure 4-17: X-ray microprobe image of Pb-sorbed WTR, 100 mg/g Pb loading, <2 mm particle size, 2 d



These images clearly show that Pb sorption is occurring within the WTR particles. None of images show a build up of Pb on the exterior of particles which would be indicative of large-scale surface precipitation. With the higher Pb loading, the particles are more enriched and are enriched further into the particle core, again suggesting that Pb diffuses further into the microporous adsorbent in order to access available binding sites. Importantly, these results show that significant diffusion into the adsorbent has occurred within 2 days, giving more weight to the hypothesis that intraparticle diffusion is the rate-limiting mechanism controlling the slow sorption stage from early on in the experiment (hours).

Additionally, microprobe analysis was done on <63 µm particles having undergone Pb sorption at 200 mg/g Pb loading. Figure 4-18 presents microprobe (a) and point analysis (b) of <63 µm Pb-sorbed WTR particles at 200 mg/g loading after 3 d reaction time.

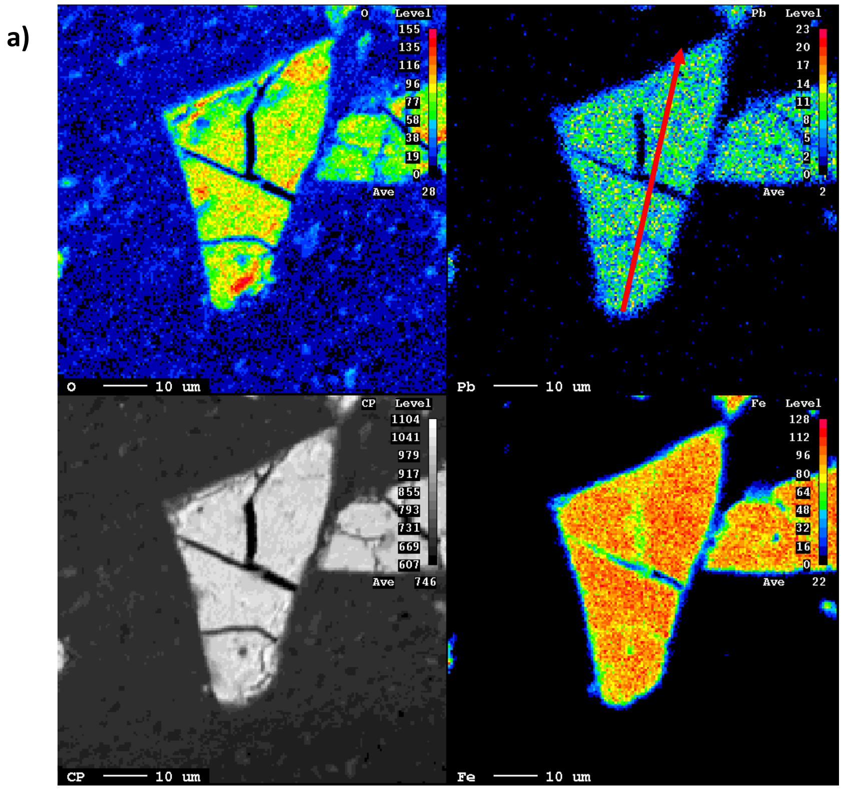
Figure 4-18: X-ray microprobe image (a) and point analysis (b) of Pb-sorbed WTR, 200 mg/g Pb loading, <63 um particle size, 3 d



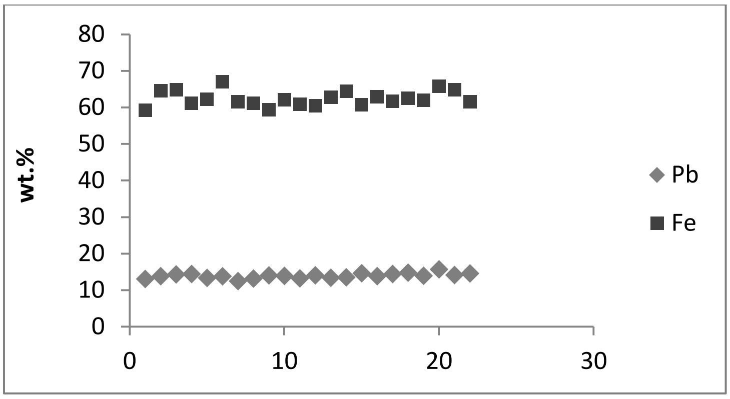
The microprobe image shows that Pb is dispersed throughout the grain, which is less than 60 µm in diameter. This is unsurprising since the Figure 4-17 showed that Pb diffused to a distance of greater than 100 µm. The point analyses (b) taken across the grain as shown by the red arrow in (a) taken from one end of the grain to the other, shows that Pb concentrations are fairly consistent across the grain at around 7-9 wt.% (average 8.5 wt.%), with Pb being slightly higher towards the edges.

From the time graph of <63 µm particles (Figure 4-10), we know that Pb sorption continued in the 3 to 21 d period, albeit at a much slower rate. Given that the microprobe analysis shows that Pb is able to diffuse to a distance of greater than 60 µm within the 3 d period, the question still remains over what controls Pb sorption over the longer term (i.e. weeks) in <63 µm grains. Figure 4-19 presents the microprobe (a) and point analyses across the grain (b), as shown by the red arrow in (a) of <63 µm Pb-sorbed WTR particles at 200 mg/g loading after 21 d.

Figure 4-19: X-ray microprobe image (a) and point analyses (b) of Pb-sorbed WTR, 200 mg/g Pb loading, <63 um particle size, 21 d



b)



The images in Figure 4-19 show that Pb is dispersed throughout the particle more uniformly and that the particle is enriched to a greater extent than in Figure 4-18. In concordance, the point analyses shows that the Pb concentrations are very consistent across the grain and much higher than in the 3 d sample, at an average of 13.9 wt.%. Between day 3 and 21 the amount sorbed increased from ~130 mg/g to ~170 mg/g, so approximately 40 mg/g additional Pb was sorbed over this period. This enrichment along with the apparently more uniform distribution of Pb throughout the particle may point towards intraparticle diffusion as the mechanism controlling slow sorption over this time.

Clearly a range of pores of different shapes and sizes exist within each pore class. Those termed micropores are simply those that are <2 nm in diameter and thus a variety of shapes and sizes of pores may be contained within this category. Pb(II) ions have an ionic diameter of 0.264 nm and hydrated diameter of 0.8 nm (Nightingale, 1959) indicating that they are able to diffuse into micropores but may be restricted in the lower size range. The relatively large pores will be more easily accessed and therefore sorption to these pore surfaces will occur first. Equally, Pb diffusion through the microporous network will be fastest through the most accessible micropores. It is proposed that diffusion of ions into WTR may be hindered in places where pores are smaller or narrower and the pore connectivity is particularly constricted (Makris et al., 2004b). This could result in a bottle-neck effect which reduces the rate of diffusion through such pores, or which forces ions to take longer, more distorted diffusion paths in order to reach accessible pore openings (Makris et al., 2004a). In both cases, a longer reaction time would allow for more micropores to be accessed and filled. The rate of Pb sorption would be expected to tail off as the most accessible reactive sites are taken up and the remaining sorption sites become increasingly more difficult to reach, which is what we observe in our system. Both the reduction in the rate of sorption and the more thorough distribution of Pb throughout the WTR particle over time suggests that intraparticle diffusion into less accessible micropores may be the reason for the observed slow sorption after day 3, in <63 µm particles.

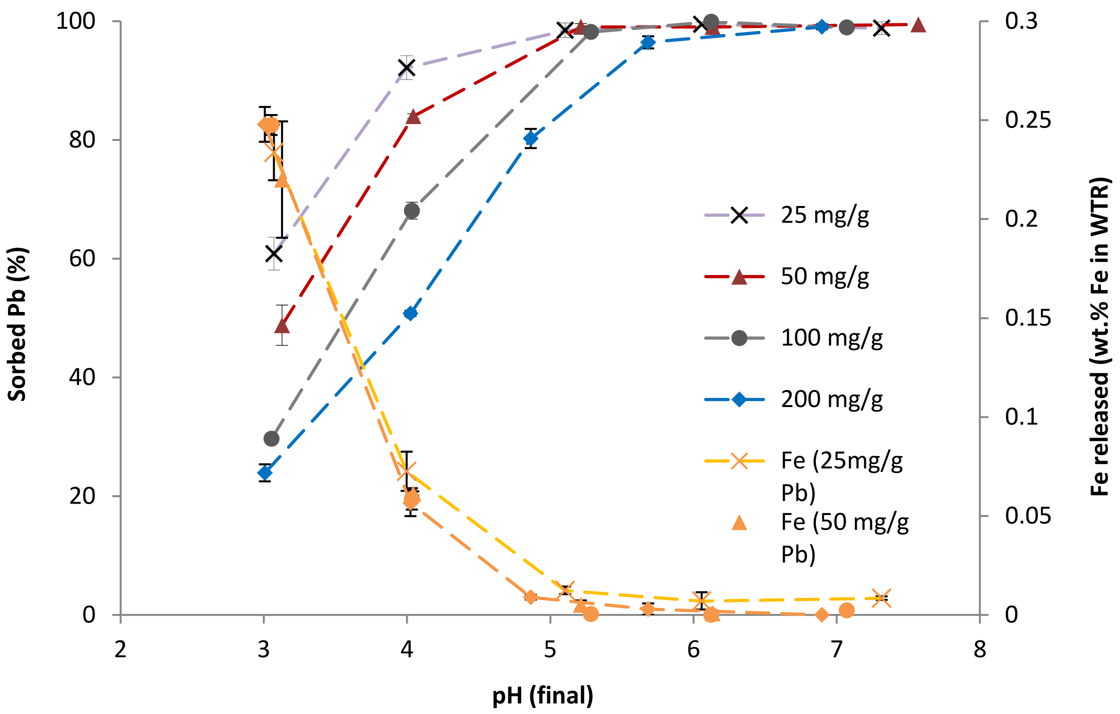
Of the three possibilities discussed (intraparticle diffusion, multi-affinity sites and surface precipitation), intraparticle diffusion is considered to be the most plausible rate-limiting mechanism controlling the slow sorption stages for all particle size fractions, given that both the NOM and ferrihydrite components are microporous in nature, and that the binding and cross-linking between these components during the formation of WTR is expected to result in a range of micropores of different shapes and sizes. It is considered unlikely that all such micropores would be equally accessible to Pb ions. It is therefore unlikely that sorption would become slower only as a result of binding to increasingly lower affinity sites or only as result of precipitation. The apparently more uniform distribution of Pb within WTR over time may indicate that more micropores have been accessed. Thus, whatever the actual mechanism(s) of sorption, intraparticle diffusion may be the most likely rate-limiting step in the slow sorption process.

Intraparticle diffusion into the microporous network of WTR was hypothesised to be responsible for the slow sorption kinetics of phosphate (Makris et al., 2004a; Makris et al., 2004b; Makris et al., 2005b). Makris et al. (2004a) looked at the pore size distribution of Fe-WTR particles that were both treated with P and untreated, using CO_2 gas adsorption data. They found that phosphate sorption shifted the pore size distribution of WTR to larger size micropores and reduced the total micropore volume and CO_2-SSA, suggesting that P had occupied micropores in the range of 0.4-0.8 nm (phosphate ionic diameter ~0.4 nm). As stated by Makris et al. slow sorption into the micropores of the WTR would significantly increase the activation energy of desorption, therefore immobilising sorbed ions in the pores of WTRs and providing long-term stability (Makris et al., 2004b).

4.3.5 Effect of pH

The effect of pH on Pb sorption was explored between pH 3 and 7 at different initial Pb loadings. Fe concentrations were also measured and converted into Fe released as a percentage of total Fe in the WTR sample. The sorption edges are presented in Figure 4-20 alongside the fraction of Fe released from the WTR samples during the experiment. Dissolved Fe was measured to investigate the stability of WTR under different pH conditions.

Figure 4-20: Effect of pH on Pb sorption to WTR



Error bars are standard deviation of 3 replicates. Where error bars are not visible, they are smaller than the symbol size.

The graph clearly shows that Pb sorption is pH dependent. The effect of pH is more pronounced at higher Pb loadings as shown by the steepness of the sorption edges. Similar results were reported by Trivedi et al. (2003) with increasing Pb(II)/ferrihydrite ratio. At pH 3, approximately 60%, 50%, 30% and 24% of the 25, 50, 100 and 200 mg/g Pb-loadings were sorbed respectively, which equates to 15, 24, 30 and 48 mg/g. This shows that although the effect of pH on the proportion of Pb sorbed is more pronounced at higher Pb loadings, the actual quantity of Pb sorbed over the pH range is larger at higher Pb loadings, again suggesting the influence of the concentration gradient as seen with the other experiments. Gustafsson et al. (2011) also present data showing Pb sorption edges shift to higher pH with increasing Pb concentration.

pH has a pronounced influence on the adsorption of metal ions on lots of sorbent materials, both organic and inorganic in nature (Ahmaruzzaman, 2011). The characteristic effect of pH on metal cation sorption can be explained by the fact that at low pH values the H+ ion concentration is higher and therefore protons can compete with the metal ions for surface sites. Additionally, functional groups on the adsorbent surface sites become protonated which increases the electrostatic repulsion between the positively charged metal and the surface of the adsorbent. With increasing pH, functional groups become deprotonated and there is a decrease in positive surface charge which favours adsorption of metal cations (Ahmaruzzaman, 2011; Naiya et al., 2009).

The graph shows that Pb sorption increased to 100% between pH 5 and 6 for all Pb loaded systems. According to the PHREEQC calculations, the onset of Pb precipitation occurs at pH >5.7 and above for Pb hydroxide and Pb carbonate species in the highest Pb-loaded system (200 mg/g). So although Pb sorption would be expected to reach 100% around pH 6 and above, sorption and precipitation cannot be distinguished from each other at these higher pHs.

It was of interest to explore the stability of Pb-sorbed WTR under low pH conditions, where in both soil and water environments this would represent particularly harsh conditions. Findings show that < 0.25% Fe was released from the WTR under acidic conditions (pH3) which fell to < 0.1% at pH 4.0. This quantity clearly represents a very small proportion of the total amount of Fe contained in the WTR. In comparison, Pb(II)/ferrihydrite sorption experiments conducted by Gustafsson et al. (2011) showed more significant dissolution of Fe at low pH: up to 10% of the ferrihydrite dissolved at pH 3.0 which fell to < 1% at pH 3.5.

The fact that limited dissolution of Fe from the WTR occurred under a low pH regime, indicates that the ferrihydrite is fairly stable within the WTR structure. This adds weight to the hypothesis discussed in Chapter 3 that the stability and structural integrity of WTR may be strengthened by the interactions between the NOM and mineral components which may stabilise both parties from degradation. These findings have positive implications for its use as an adsorbent in the environment, both because it is able to function as a sorbent across a wide range of pHs, and also that the WTR particles appear to remain stable over a wide pH range.

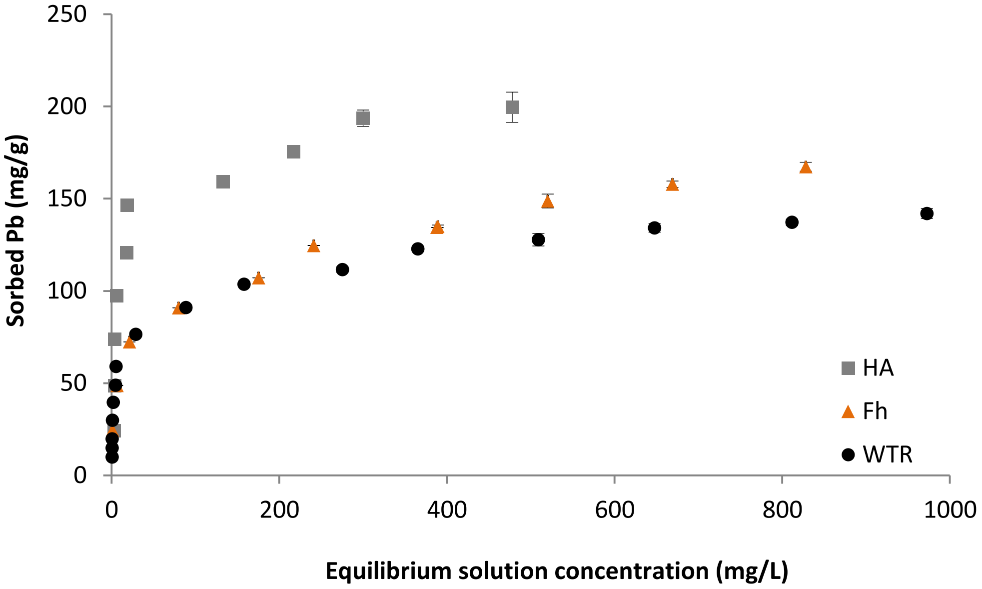
4.3.6 The role of mineral and organic components in Pb sorption to WTR

Pb sorption to WTR was compared to ferrihydrite (Fh) and humic acid (HA) in order to investigate the role that these end-member components play in the sorption behaviour of WTR. By comparing the sorption characteristics of WTR to its end-member components in this way, it may be possible to make deductions about the mechanism(s) controlling Pb sorption to WTR. To the authors knowledge this is the first study to compare WTR's sorption behaviour to that of its end-member components. Since HA and Fh, which are both strong sorbents of Pb, are clearly comprised of different surface functional groups exhibiting different surface charges and site affinities, it is hypothesised that the sorption behaviour of WTR, including its sorption capacity and pH sorption profile, are influenced by both end-member components.

HA has a lower pH_{pzc} (~2.5-3) than Fh (~7.5-8). This means that over the pH range 3-7, the net surface charge on HA is more negative than the net surface charge on Fh and suggests that the HA surface sites would have a greater affinity for metal cations than the Fh. This can be related to its pH_{50}, which is the pH at which 50% of the amount of a given heavy metal is sorbed. It is reported that the lower the pH_{50} the higher the affinity of the metal for the sorbent (Qin et al., 2006; Violante et al., 2003). This suggests that HA would typically exhibit greater sorption capacity than Fh over the pH regime studied (Moon and Peacock, 2011; Zhu et al., 2010). It was hypothesised that the sorption edge of WTR, as a composite of NOM and Fh, would fit somewhere in between the profiles of the two end-members, displaying adsorption which is intermediate to the end-member components.

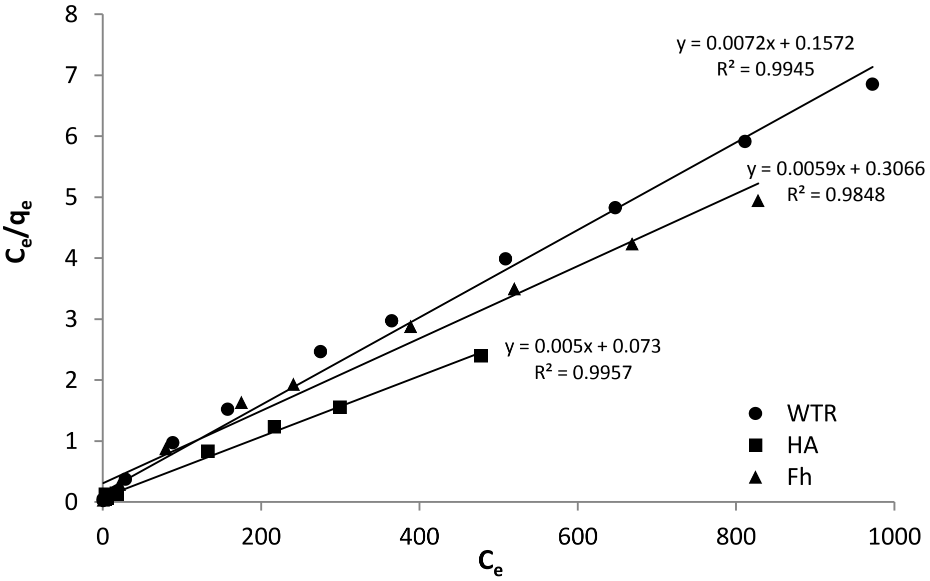
Figure 4-21 presents the Pb(II) sorption isotherm for HA and Fh alongside the WTR isotherm presented earlier. It shows that both HA and Fh isotherms exhibit steep initial curves which gradually plateau. Similarly to WTR, these can be described as H-type isotherms which are indicative of chemisorption (inner-sphere complexation). The WTR and Fh isotherms are clearly very similar whereas the HA isotherm indicates that HA exhibits relatively greater Pb sorption. The experimental data were plotted according to the linear Langmuir equation, shown in Figure 4-22. Using the data from this plot, the Langmuir max sorption capacity values for the three sorbents were calculated and are presented in Table 4-1. The r^2 values show that the data fits well to the Langmuir model.

Figure 4-21: WTR, HA and Fh adsorption isotherms for Pb(II)



Error bars are standard deviation of 3 replicates. Where error bars are not visible, they are smaller than the symbol size.

Figure 4-22: Langmuir plot for adsorption of Pb(II) to WTR, HA and Fh



Error bars are standard deviation of 3 replicates. Where error bars are not visible, they are smaller than the symbol size.

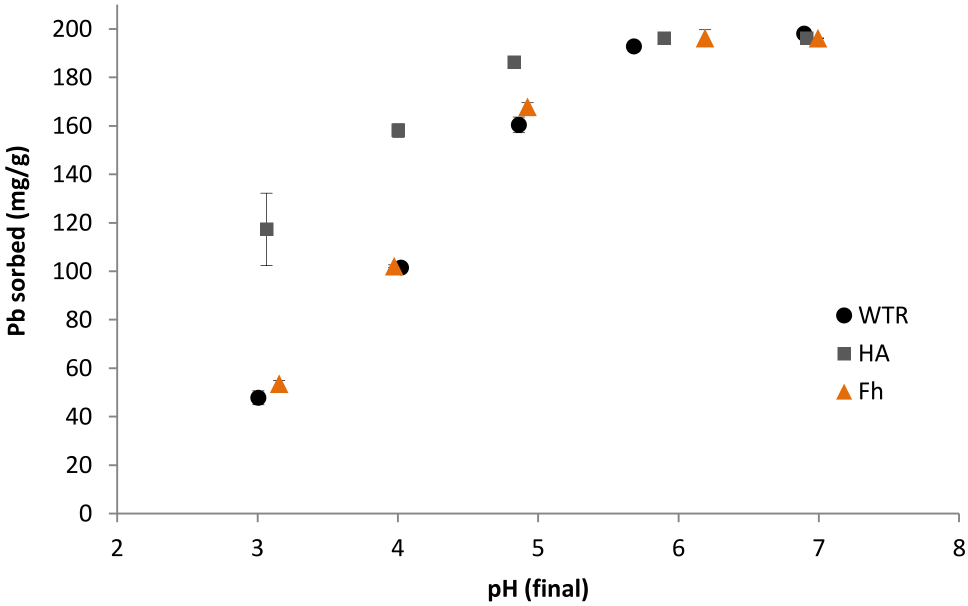
Table 4-1: Pb(II) sorption capacity of WTR, HA and Fh

Sorbent	Langmuir qmax (mg/g)	Correlation coefficient r^2
WTR	139	0.9945
Humic acid	200	0.9848
Ferrihydrite	170	0.9957

The sorption capacities were found to be 200 mg/g for HA, 170 mg/g for Fh, in comparison to 139 mg/g for WTR. Interestingly, this data shows that WTR has a lower sorption capacity than either of its end-member components. This will be discussed further below.

The sorption edges of HA, Fh and WTR were compared over a pH range of 3-7. Figure 4-23 presents the sorption edges, which were carried out at pH 5, 200 mg/g Pb loading for 3d.

Figure 4-23: Effect of pH on Pb sorption to HA, Fh and WTR



Error bars are standard deviation of 3 replicates. Where error bars are not visible, they are smaller than the symbol size.

Firstly, the graph shows that the HA sorption edge exhibits a gradual profile over the pH range studied. This is consistent with other HA studies: Kerndorff and Schnitzer (1980) showed that the pH_{50} for Pb was approximately pH 2.5. Comparably, the profile of our HA sorption edge suggests that pH_{50} would be reached at approximately pH 2.5. This HA sorption edge is also similar to that of other biosorbents such as green algae (pH_{50} of 2.5 and qmax 198.5 mg/g) (Deng et al., 2007). Secondly, the Fh exhibits a sharper sigmoid profile with a pH_{50} of approximately 4.1. This sorption edge fits well within the range observed for most other Fe oxide studies which report a pH_{50} of 4-5 for Pb (Ainsworth et al., 1994; Benjamin and Leckie, 1981; Gadde and Laitinen, 1974; Gustafsson et al., 2011; Reich et al., 2010; Trivedi et al., 2003). Finally, the graph clearly shows that the sorption edge of WTR strongly resembles that of Fh, with no sign of it displaying intermediate sorption between both end-members.

In summary, the data presented in this section shows that:

1) WTR has a reduced Pb sorption capacity in comparison to its end-members;
2) The WTR Pb sorption isotherm closely reflects the Fh sorption isotherm;
3) The WTR sorption edge matches that of Fh.

The fact that WTR has a lower sorption capacity than either of its end-members suggests that the reactivity of the NOM and Fh has been reduced, rather than enhanced, by the way in which these components are associated with each other within the organo-mineral composite.

The fact that the WTR and Fh sorption isotherms are similar and that the WTR sorption edge matches that of Fh is significant because it implies that WTR sorption behaviour is dominated by its Fh component, over the whole pH regime. It appears that Pb sorption was not enhanced in the low pH regime as was previously hypothesised.

Studies looking at metal sorption to organo-ferrihydrite composites report varied results. Many studies have found that metal sorption is influenced by both components in different parts of the pH regime. It has been shown that cation sorption is enhanced on composites at pH's <6 compared with isolated end-member components; this enhanced sorption behaviour is attributed to changes in electrostatic interactions (Moon and Peacock, 2013; Tipping et al., 1983; Vermeer et al., 1999), the presence of additional metal binding sites provided by the humic fraction(Zachara et al., 1994), or new high affinity sites created when the humics sorb to the hydroxide surface (Ali and Dzombak, 1996). For example, Moon and Peacock recently investigated Cu(II) sorption to synthesised *Bacillus subtilus*-ferrihydrite composites. Comparing the Cu(II) sorption edges (pH -3-7) of the composite and its end-member components indicated that the composite sorption profile was similar to Fh in the high pH regime but influenced by the bacteria component in the mid-low pH regime. Using EXAFS spectroscopy they determined that uptake of Cu by the composite was a result of adsorption to both the Fh and *B. Subtilis* fractions. In the low pH regime (pH~4), as much as ~20% of the Cu was bound by carboxyl surface functional groups present on the bacterial fraction, whereas in the upper pH regime inner-sphere complexation to ferrihydrite was the dominant mechanism for Cu sorption (Moon and Peacock, 2011; Moon and Peacock, 2012; Moon and Peacock, 2013). Templeton et al. (2003) examined the retention of Pb by bacteria-goethite composites and assessed the partitioning of Pb between these components using EXAFS. At pH <5.5, at least 50% Pb was associated with the biofilm component; above pH 6, Pb sorption was dominated by goethite. Zhu et al. (2010) looked at Pb sorption to organomineral complexes made by coprecipitating ferrihydrite with oxalate and tartrate. They found that greater amounts of Pb were sorbed onto the organomineral complexes than ferrihydrite (in terms of µmol/m2), and the higher the carbon content, the greater the sorption. They stated that stronger metal sorption to the organomineral complex was due to the presence of organic ligands which provided strong complexing sites and less positive surfaces. Kulczycki et al. (2005) investigated Pb sorption behaviour of *Bacillus subtilis*-Fh and *E-coli*-Fh composites. Contrastingly, they found that the sorption capacity of the bacteria-Fh composites (103.5-141 mg/g) was much reduced in comparison to Fh (277 mg/g). Electrophoretic mobility analysis indicated that the surface properties of ferrihydrite dominated the net surface charge for the composite systems. Based on the fact that the observed sorption capacities of the composites were lower than values predicted upon available site additivity, they implied that a masking of reactive surface sites by attachment had occurred between the bacteria and Fh. Studies which point toward non-additive sorption behaviour of composites speculate that this is due to physiochemical interactions between the surface functional groups present on the mineral and organic fractions, resulting in a reduced number of available sites for sorption and/or altered surface charge on the composites compared to the isolated end-member phases (Kulczycki et al., 2005; Small et al., 1999).

Our results correlate most closely with the findings from Kulczycki et al. (2005), given that WTR sorption behaviour appears to be dominated by its Fh component. As speculated in Chapter 3, the intimate intermixing of the Fe oxide fraction with the organic matter fraction may stabilise both components from degradation to some degree, and reduce their reactivity as a result of the binding and masking of surface sites. Additionally, the WTR may exhibit a more constrained, heavily cross-linked structure with a reduced pore network. Both of these affects would cause a reduction in Pb sorption to WTR in comparison to its end-members. This is supported by the theory that OM can mask the Fh surfaces within organo-mineral composites (Franzblau, 2014; Kaiser and Guggenberger, 2000) therefore reducing the availability of Fh surface sites for metal sorption (Kulczycki et al., 2005; Small et al., 1999).

Clearly other studies have shown that metal sorption to organo-mineral composites is enhanced by the organic component, due to changes in electrostatic interactions (more negative surface charge), the presence of additional metal binding sites, or new high affinity sites created when the humics sorb to the hydroxide surface (Violante et al., 2003). However, none of these effects seem to have influenced Pb sorption in our WTR system.

The question was then considered: Given that HA is seen to exhibit a greater sorption capacity than Fh, why does it appear that the Pb preferentially binds to Fh over NOM in the WTR?

Possible explanations are:

1) The surface functional groups on Fh have much greater chemical affinity for Pb than the surface functional groups on NOM.

This hypothesis is considered unlikely because the HA is seen to exhibit greater sorption capacity than Fh over the entire pH regime, which suggests that the HA functional groups exhibit strong affinity for Pb. However, of course the HA is not the *actual* NOM end-member in WTR. It may be that HA is not representative of the actual NOM component and the NOM WTR may have a lower affinity for Pb sorption than the HA, owing to differences in physiochemical composition. The HA component was chosen as a reasonable proxy for the NOM in WTR because it is has been shown that the water treatment coagulation process more efficiently removes hydrophobic, high molecular mass NOM compounds from raw water than hydrophilic low molecular mass compounds (Matilainen et al., 2010). Clearly though, a true comparison of WTR to its end member components requires the isolated raw water NOM component to be used.

2) The NOM surface sites are relatively unavailable for Pb sorption as a result of its association with the Fh mineral phase in the organo-mineral composite. The strong binding between NOM and Fh surface functional groups may result in:
    a. A reduced number of available OM sites for sorption;
    b. Altered surface charge on OM which reduces its affinity for Pb;
    c. A more constrained porous structure causing spatial inaccessibility between OM and Pb.

This explanation is linked to the hypotheses made in Chapter 3 that OM is stabilised in organo-mineral composites and protected from degradation by the strong association with the Fe oxyhydroxide, which means it is essentially less ‘reactive’ than the isolated OM fraction. Of course, these explanations remain speculative without significant further research.

This information provides important insights into the factors controlling Pb sorption to WTR. In summary, the evidence suggests that WTR sorption characteristics are strongly influenced by the nature of the organo-mineral association, which promotes preferential binding of Pb ions to the Fh component. The findings imply that Pb sorption to WTR is dominated by inner-sphere complexation to Fh. It is speculated that WTR has a lower Pb sorption capacity than its end members as a result of the physiochemical interactions between the surface functional groups present on the mineral and organic fractions, although the mechanisms are not fully understood. These hypotheses could be tested using spectroscopic techniques which would help to elucidate sorption mechanisms at the molecular scale.

4.3.7 Comparison of Pb sorption to all Batch-1 WTRs

Sorption experiments were carried out to compare Pb sorption to all 9 WTRs collected in Autumn 2011 (Batch 1). Since Pb appears to adsorb to the mineral component in WTR, it was hypothesised that there may be a positive correlation between Fe/Al content and Pb sorption capacity and a negative correlation between C content and Pb sorption capacity.

The sorption isotherms are presented below in Figure 4-24. The graph shows that all WTRs display high affinity for Pb. The WTRs appear to display H-type patterns, although several of the WTRs did not reach plateaus, indicating that near-equilibrium had not been reached and that sites had not become fully saturated within the conditions of the experiment. Nevertheless, the data was plotted to the linear Langmuir equation and reasonable fits were obtained. The Langmuir calculated sorption capacities and r^2 values for all WTRs are reported in Table 4-2 alongside their Al/Fe, and C contents. It shows that the max sorption capacities range from 99 mg/g to 169 mg/g with all r^2 values >0.96.

Figure 4-24: Pb sorption isotherms for all WTRs

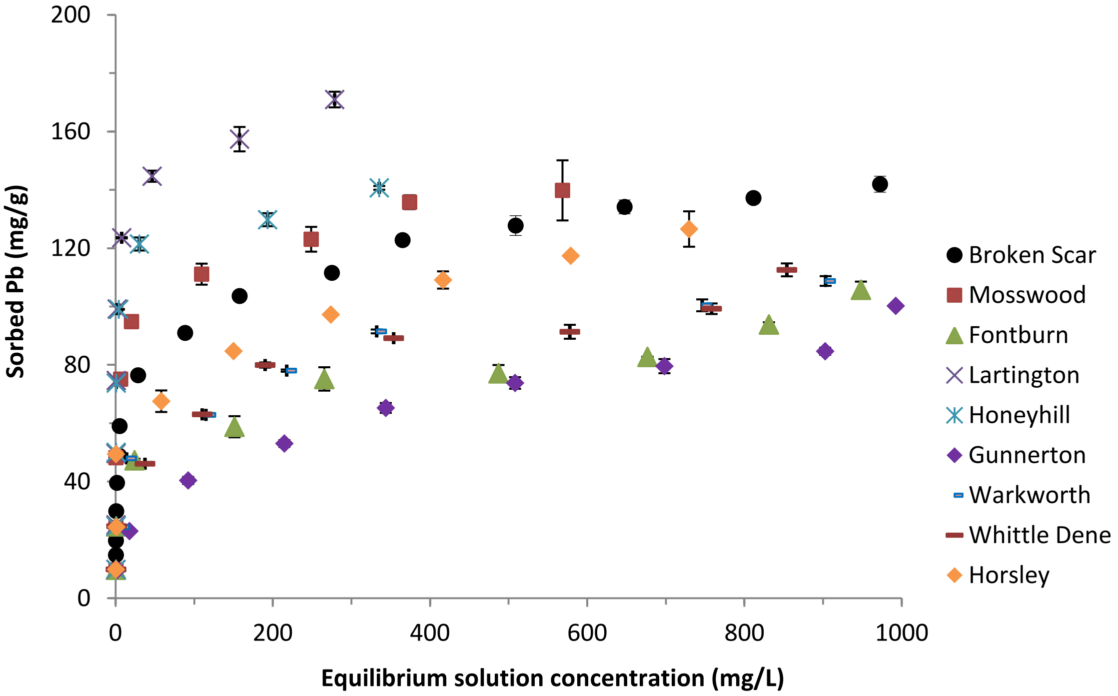


Table 4-2: Bulk composition and Langmuir max sorption capacities for all Batch 1 WTRs

Batch 1 WTRs	Fe or Al-based	Fe/Al content (wt.%)	C content (wt.%)	Langmuir qmax (mg/g)	Correlation coefficient r^2
Broken Scar	Fe	37	13	139	0.9945
Fontburn	Fe	28	21	99	0.968
Honeyhill	Fe	35	24	139	0.9981
Lartington	Fe	31	24	169	0.9978
Mosswood	Fe	31	19	139	0.997
Horsley	Fe/Al	14/6	18	125	0.9857
Gunnerton	Al	15	26	99	0.9613
Warkworth	Al	18	14	109	0.9899
Whittle Dene	Al	15	19	109	0.982

The table shows that in general, Fe WTRs had a higher Pb sorption capacity than Al WTRs. This suggests that Fe oxyhydroxides within WTR are stronger sorbents of Pb than Al oxyhydroxides within WTR. This is consistent with the literature on Pb sorption to hydrous metal oxides, which indicates that in order of affinity for Pb, Mn oxides > Fe oxides > Al oxides (Aualiitia and Pickering, 1987). This result is significant in the context of considering WTRs as an amendment for Pb as it indicates that Fe-WTRs may be more effective. Further work would be required in order to compare Pb sorption behaviour of Al and Fe WTRs in more detail.

The WTRs' sorption capacities were correlated against their respective Al or Fe contents and C contents. However no strong correlations were observed. The table shows that there is no clear link between high Fe/Al content and high sorption capacity.

Clearly though, correlations have been confounded by the underestimation of sorption capacities, given that some of the WTR evidently did not reach near-equilibrium. In order to make a more robust assessment of potential correlations, the experiment would need to be run for longer and with a larger number of WTR samples. Other factors which could influence WTR sorption capacity may include variations in the mineralogy of the oxide phases and composition of the organic matter components, surface charge, SSA, porosity, drying and ageing times, and so on. Clearly the conditions of the water treatment process, such as raw water quality, pH, coagulation and flocculation procedures, mixing times and polyelectrolyte usage, are the main factors responsible for producing this highly variable by-product and which in turn influences WTRs' sorbent properties. A number of parameters may need to be assessed to understand what factors are responsible for 'optimum' sorbent characteristics.

4.3.8 Comparison of WTR Pb sorption capacity to other sorbents from the literature

The sorption capacity of Broken Scar WTR was compared to other potential *in situ* Pb sorbents found in the literature. Pb sorption capacities for a range of inorganic and organic sorbents are presented in Table 4-3.

The table shows that WTR has a relatively high sorption capacity in comparison to various other sorbent materials, particularly to those sorbents which are considered as industrial or agricultural by-products.

Table 4-3: Maximum sorption capacity (qmax) of Broken Scar WTR in comparison to other potential *in situ* Pb sorbents from the literature

Adsorbent	Qmax (mg/g)	Reference
Fe-based WTR	140	This study
Humic Acid	200	This study
Ferrihydrite	170	This study
Fe-based WTR	120	(Chiang et al., 2012)
Ferrihydrite	279	(Kulczycki et al., 2005)
Ferrihydrite	269	(Trivedi et al., 2003)
Mn oxide-coated sand	346	(McCann et al., 2015)
Magnetic alginate beads (Fe nanoparticles)	50	(Idris et al., 2012)
Fly ash	444.7	(Yadav et al., 1987)
Blast furnace slag (Fe)	64	(López-Delgado et al., 1998)
Red mud	64.8	(Gupta et al., 2001)
Red mud	165.8	(Apak et al., 1998)
Activated sludge biomass	58	(Kusvuran et al., 2012)
Soil organic matter	168	(Strawn and Sparks, 2000)
Green algae	198.5	(Deng et al., 2007)
Barley straw	23.2	(Pehlivan et al., 2009)
Grape bagasse	88.6	(Farinella et al., 2008)
Peat	122	(Ho et al., 2002)
Chitosan	16.4	(Huang et al., 1996)
Peanut hull	37.3	(Oliveira et al., 2009)
Granular activated carbon	30	(Reed and Arunachalam, 1994)
Coffee residue	63	(Boudrahem et al., 2009)
Sugar beet pulp	43.5	(Pehlivan et al., 2008)
Black tea waste	129.9	(Lavecchia et al., 2010)
Saw dust activated carbon	46.1	(Sreejalekshmi et al., 2009)
Activated charcoal (bamboo)	53.8	(Lalhruaitluanga et al., 2010)
Rice husk ash	91.7	(Naiya et al., 2009)

It should be noted that direct comparisons of qmax are not straightforward because sorption capacities vary hugely with experimental conditions such as contact, time, temperature and pH.

4.4 Conclusions

WTR exhibited high affinity for Pb, from low to extremely high [Pb(II)] in aqueous solution. The sorption isotherm was classed as 'H-type' which is indicative of a chemisorption (inner-sphere complexation) mechanism. The ionic strength of solution had no effect on Pb sorption further suggesting inner-sphere complexation as opposed to outer-sphere complexation.

Under the experimental conditions of the study, the adsorption capacity was calculated to be 139 mg/g. The sorption capacity of WTR was compared to other potential *in situ* Pb sorbents. This shows that WTR has a relatively high sorption capacity in comparison to various other by-products and sorbent materials. WTR is different

Pb sorption to WTR exhibited biphasic kinetics, where initially fast sorption (mins to hours) was followed by slow sorption (days), characteristic of metal sorption to both organic and oxide phases. Further sorption experiments and X-ray microprobe analysis of the Pb within the WTR grains suggested that intraparticle diffusion plays a dominant role in the slow sorption phase.

The pH experiments showed that Pb sorption is highly pH dependent, although it was capable of functioning as a sorbent over a wide pH range. Minimal Fe dissolution from the WTR occurred, highlighting its structural integrity.

WTR exhibited a lower sorption capacity (139 mg/g) in comparison to HA (200 mg/g) and Fh (170 mg/g). The sorption edge of WTR closely reflected that of Fh across the whole pH regime (pH3-7). This implies that WTR sorption behaviour is dominated by its Fh component. It is thought that WTR sorption characteristics are strongly influenced by the nature of the organo-mineral association. The strong physiochemical interactions between the OM and Fh are suspected to reduce the 'reactivity' of WTR although the mechanisms are not fully understood. Possible explanations include:

a. Binding between OM and Fh surface functional groups reduces the number of sites available for Pb sorption;
b. Some surface sites are spatially inaccessible to Pb due to the constrained, microporous nature of the composite;
c. Altered surface charge affecting surface affinities.

Comparison of all nine batch-1 WTRs revealed that all WTRs had a high Pb sorption capacity. In general, the sorption capacity of the Fe-WTRs was higher than that of the Al-WTRs. Given that the oxyhydroxide component appears to be responsible for Pb sorption in WTR, it was hypothesised that Pb sorption capacity may be related to the oxyhydroxide content, but no correlations were found within the limited sample pool.

Overall, the findings from this study have positive implications for the long-term immobilisation and stability of sorbed Pb contained within WTR. The investigation demonstrates that WTR has potential to function as an adsorbent for Pb in a range of contaminated environments, such as waters, soils and sediments. Given that the aim of this thesis was to investigate the use of WTR to immobilise Pb in contaminated soil, the next logical step was to assess its effectiveness as an adsorbent when it is added to contaminated soil. This will be explored in Chapter 5.

Additional work to further our understanding of WTR's sorption behaviour is suggested below:

- Isolate the actual OM from raw water to use as the WTR organic end-member in comparative sorption studies.
- X-ray absorption spectroscopy to elucidate sorption mechanisms. The actual mechanism(s) of Pb sorption cannot be determined by batch sorption experiments alone. Ultimately, stronger techniques such as EXAFS are required to elucidate sorption mechanisms.
- Further insight into the kinetics of Pb sorption. Also compare the sorption kinetics of WTR with its end-member components to test the hypothesis that WTR comprises a more constrained porous structure that of either Fh or HA which may influence its kinetic sorption behaviour. This should include further porosity and SSA measurements such as CO_2-SSA and pore size distributions, micropore volumes, etc.
- Multi-element sorption experiments to understand WTRs behaviour and capacity to function as a sorbent of a range of PTEs and competition effects.
- Desorption studies, over a range of environmental conditions and time frames to assess the long-term stability of WTR and the long-term immobilisation of Pb bound to WTR.
- Column studies to determine the effectiveness of WTR in removing Pb from continuous flow systems.

5. Plant growth and PTE uptake in contaminated soil amended with WTR treatments

5.1 Introduction

Research described in previous chapters has demonstrated the ability of WTR to immobilise Pb from solution. Pb sorption was examined under various controlled conditions to assess environmental factors which could affect this process, such as pH, initial metal concentration and particle size. The objective of this thesis is to explore the potential for using WTR as an in-situ amendment to immobilise Pb in contaminated soil. After establishing the WTR's ability to immobilise Pb in batch sorption experiments, the next logical step was to examine the effectiveness of WTR when added to real contaminated soil.

The goal of any in-situ remediation technology based on soil amendments is to achieve maximum reduction in contaminant bioavailability by immobilisation in the soil, in order to reduce risks to flora, fauna and human health (Nwachukwu and Pulford, 2009). In this study, bioavailability refers to the fractional uptake of contaminants in soil into human or ecological receptors (Martin and Ruby, 2003). A range of inorganic and organic amendments have been used as soil amendments for potentially toxic element (PTE)-contaminated soil, exploiting various immobilisation mechanisms. For instance, amendments such as phosphate have been used to reduce the solubility of heavy metals by precipitation; lime to raise pH causing precipitation of many PTEs, and a whole suite of sorbent materials such as clay minerals, oxides, zeolites, biochar, composts and other agricultural by-products are used to immobilise contaminants through sorption and chelation reactions (Nwachukwu and Pulford, 2009). Most contaminated soils are polluted with not only one PTE but several, in what is termed multi-element contaminated soil or "cocktail sites". Challenges arise in finding treatment technologies which are capable of immobilising a mixture of metals/metalloids.

PTEs exist in the terrestrial environment in several forms which range in solubility and bioavailability including: dissolved in the soil solution, exchangeable or bound in organic and inorganic components; as structural components of minerals in soils; and precipitated with other soil components (Shahid et al., 2012). The speciation and transformation of PTEs in soils is influenced by a complex mixture of biogeochemical factors such as soil pH, redox potential, SOM and oxide content, soil structure, presence of other cation and anions and microbial activity (Gao, 2007; Gulz et al., 2005; Moreno-Jiménez et al., 2012). Those PTEs retained or transformed into labile forms will be the most mobile and the most biologically available. Thus, speciation of PTEs is recognised as the key factor in controlling the mobility and bioavailability of these contaminants in soils (Beak et al., 2007; Wragg and Cave, 2012).

Various methods exist to assess the bioavailability of PTEs within the soil including bioassays, plant uptake studies, leachability and lysimeter trials, as well as a suite of soil extractions, from simple one-step extractions to more complex sequential extractions and *in vitro* gastrointestinal extractions assessing oral bioaccessibility (Gleyzes et al., 2002; Wragg and Cave, 2012). Bioavailability measurements are challenging due to the complex, dynamic nature of soil systems and the heterogeneous makeup of real contaminated environments, which causes inherent difficulties in identifying specific cause-and-effect relationships (McCann et al., 2015; Naidu et al., 2013).

In this study, plant trials were chosen to assess the effectiveness of WTR treatments to immobilise and reduce the bioavailability of PTEs within a real contaminated soil. A soil heavily contaminated with As (up to ~9000 mg/kg) and Pb (up to ~8000 mg/kg) was used in the trial. This not only allowed us to investigate the effect of WTR treatments on Pb, but also to explore the interaction of WTR with a PTE of different chemical nature, and therefore to assess WTR's ability to sorb PTEs from a multi-element contaminated soil.

Pb and As exhibit very different characteristics and behaviours in the environment. The properties of Pb have been described previously in Chapter 4 in relation to the batch sorption studies. Arsenic is classed as a metalloid which more easily forms oxyanions, and so its non-metal properties dominate. The most common oxidations states of As are +3 (arsenite) and +5 (arsenate). Under aerobic conditions, arsenate is the predominant species, whereas in reducing environments As is found as arsenite, which is more mobile and more toxic than arsenate (Moreno-Jiménez et al., 2012).

The activity of As in soil is largely controlled by reactions with Fe, Mn and Al oxides; soils containing high proportions of Fe are known to have greater retention capacity for arsenate and arsenite (Moreno-Jiménez et al., 2012). Since the exchange surfaces of silicates and OM tend to be negatively charged, they have a greater tendency to retain cations than anions, although As may be held in exchange positions under low pH conditions. Arsenic may also be found in its mineral form largely associated with sulphides, although under aerobic conditions sulphides can be easily oxidised releasing As into the environment (Moreno-Jiménez et al., 2012). Given As is an oxyanion, a rise in pH causes release from exchange positions, often resulting in mobilisation of As in the soil, in contrast to most trace metals' cationic behaviour (Masscheleyn et al., 1991). Inorganic As (arsenate and arsenite) is highly toxic to plants. It is taken up by the phosphate transport system because of the chemical similarity between the P and As oxyanions. It uncouples phosphorylation and inhibits phosphate uptake, interferes with plant metabolic processes inhibiting growth and can lead to plant death (Carbonell et al., 1998; Geng et al., 2006; Meharg and Macnair, 1992).

The differences in As and Pb characteristics mean that is difficult to find appropriate in-situ amendments which can immobilise both contaminants. For instance, raising the pH reduces Pb solubility but increases As solubility, treating with phosphate precipitates Pb but can mobilise As (Gulz et al., 2005). It has been suggested that a combination of amendments may be required for the remediation of multi-element contaminated soils in order to combat these conflicting behaviours (Clemente et al., 2010).

Substantial research has already been conducted looking at the ability of WTR to adsorb As. The literature shows that WTR has a high sorption capacity for As, both from water (Makris et al., 2006; Nagar et al., 2010) and from soil (Nielsen et al., 2011; Sarkar et al., 2007a) and can reduce As bioaccessibility (Nagar et al., 2009; Sarkar et al., 2007b). Spectroscopic studies have been used to examine As sorption mechanisms to WTR and have found that As(III) and (As(V) form strong, inner-sphere surface complexes with the Fe and Al hydroxides in the respective Fe- and Al-based WTRs (Makris et al., 2007; Makris et al., 2009). Based on this information, it is therefore hypothesised that the WTR is capable of adsorbing and immobilising both Pb and As in the contaminated soil.

Since WTR has been found to have a low nutrient status and high P adsorbing capacity, it was decided to include compost treatments in the plant trial, in addition to WTR amendments. Compost is considered as an optimum plant growing medium in terms of nutrients status, structural benefits, WHC and aeration (Brady and Weil, 1996). The compost treatments would be applied singularly and as a combination with WTR.

Compost has also been shown to immobilise heavy metals such as Pb, through sorption to organic matter components and/or due to an induced rise in pH (Farrell et al., 2010; Karami et al., 2011; Nwachukwu and Pulford, 2008; van Herwijnen et al., 2007; Venegas et al., 2015). However, there is conflicting evidence on the effect of compost on soil As. In some cases, a reduction in soluble As and plant uptake from compost amended soils has been attributed to sorption onto organic matter (Cao and Ma, 2004). However, more commonly it has been found that the mobility of As increases as a result of soluble constituents (DOC) of the compost displacing As from binding sites in the soil matrix (Bauer and Blodau, 2006; Clemente et al., 2010; Hartley et al., 2009). In addition to releasing soluble humic and fulvic acids, compost can possess a significant soluble P component. A number of studies have shown that As can be displaced from inorganic and organic binding sites by P as well as fulvic acids (Grafe et al., 2001; Jain and Loeppert, 2000; Wang and Mulligan, 2006).

A short-term greenhouse based pot trial was set up to investigate the effects of the WTR and compost amendments on plant growth and bioavailability of Pb and As.

The objectives were to assess:

(i) The effect of WTR/compost amendments on plant health, using several plant growth measurements;

(ii) The influence of WTR/compost amendments on the mobility and bioavailability of PTEs in the soil, measured by plant uptake of Pb and As.

It was hypothesised that: the WTR treatments may improve plant growth by reducing the availability of Pb and As; the compost treatments may improve plant growth by supplying plant nutrients, improving the soil structure as well as potentially immobilising Pb. The combination of both WTR and compost as a treatment may therefore provide the most improved conditions for plant growth.

5.2 Materials and Methods

An eight-week plant trial was undertaken to measure the effects of plant growth and PTE uptake in contaminated soil amended with WTR and compost treatments. The study involved: (i) the design and set-up of the plant trial experiment; (ii) eight weeks of plant growth measurements; and (iii) analysis of the plant material post-trial, the details all of which are outlined below. The experimental set-up and plant growth measurements were carried out with the aid of Ana Walpole, who used some of the results for her final year MEng project.

5.2.1 Sample Collection and Preparation

The soil selected for the greenhouse experiments was a PTE-contaminated soil from a site in Newcastle upon Tyne, formerly known as St Anthony's Leadworks. The site remains as one of the most contaminated along the River Tyne in North East England, an area of the UK in which heavy mining and industrial activity of the past has left a legacy of contaminated environments (Macklin et al., 1997). The site is located approximately 3 miles east of Newcastle city centre, south of Walker. The site covers approximately 5 ha on the North bank of the River Tyne and makes up the western section of Walker Riverside Park which is a public recreational area (Figure 5-1).

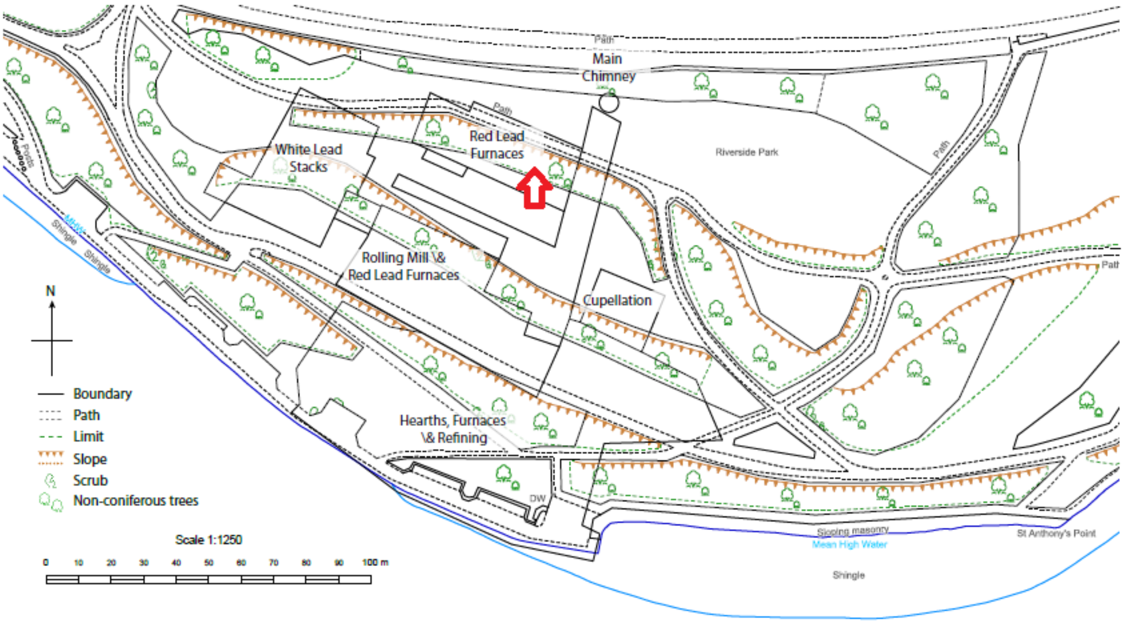
Figure 5-1: Geographic location of Newcastle upon Tyne (left) and aerial view of Walker Riverside Park, formerly St Anthony's Lead works (right) (map adapted from Bing maps, 2015).

The former St Anthony’s Lead Works operated from around mid 1840s to mid 1930s. Pb ore was shipped into the works from mining areas in the North Pennines and elsewhere in the UK and Spain for various types of processing including smelting for the extraction of silver and for the manufacture of white and red lead, sheet and lead pipe (Okorie et al., 2011). It is thought that the disposal of by-products such as slag, dross, dust and wastewater probably occurred on-site in landfills and lagoons (McCann, 2012).

Minimal earth movement is thought to have occurred since the closing of the lead works (Okorie et al., 2011). In the 1960’s the site was landscaped by laying a shallow surface dressing of imported topsoil, which was seeded with grass on the flat terraced areas and planted with woodland on the slopes. Based on historical maps, the site layout remains relatively unchanged (Okorie et al., 2011).

The site currently consists of level grassed areas and steeply-sloping shrubby/wooded areas, as well as paths, a section of road and a carpark. The map of Walker Riverside Park (Figure 5-2) outlines the former lead works processing areas including the location of furnaces, mills and chimneys, etc. The soil contains a mixture of rubble, former building foundations, building materials, ash, clinker, glass, coal and ballast (Okorie et al., 2011), which is most evident in the sloping woodland areas. Although elevated concentrations of PTEs exist across the site, the contamination has been found to be heterogeneous in terms of PTE distribution and concentration. Okorie et al. (2010) analysed 19 samples from different areas of the site and showed the concentrations ranged from 10 - 6502 As, 0.4 - 44 Cd, 70 - 620 Cr, 22 - 680 Cu, 22 - 160 Ni, 174 - 33300 Pb and 123 - 10600 Zn mg/kg, respectively. It is expected that the soil concentrations and mineral forms of the PTEs which are present in different areas of site reflect the specific activity or type of processing that took place there.

Figure 5-2: Walker Riverside Park outlining the location of former St Anthony's Lead Works processing areas (map drawn by Jonathan Asquith, Durham University, based on historical maps and information supplied by Newcastle City Council). Red arrow points to soil sampling area.



The soil was collected in November 2011 from a 9 m^2 area of a shrubby embankment where samples have previously been taken by the Environmental Engineering group at Durham University. The red arrow points to the approximate sampling location in Figure 5-2. The soil was dug from the top 60 cm, and stored in plastic rubble sacks. In the laboratory, the soil was spread out on clean plastic sheeting to air-dry.

Since the soil is known to be heterogeneous with respect to PTE contamination (Okorie et al., 2010), thorough mixing was required in order to achieve relatively homogenous soil samples for use in the experiments. The air-dried soil was crushed and sieved to <4 mm diameter and mixed in the process. Representative soil samples were then taken using the quartering and coning method (Rowell, 1994).

For the amendments, the Fe-rich, Broken Scar WTR (Autumn 2011 batch) was used. This was collected from Northumbrian Water Ltd in November 2011 as detailed in Chapter 2. The compost was supplied from Com-vert Ltd (Alnwick, UK) in November 2011. The compost was generated largely from green garden waste and was PAS-100 certified. Some WTR was used in its fresh wet state (80% water content) which was stored in sealed plastic rubble sacks prior to use. The rest of the WTR and the compost was spread out on clean plastic sheeting to air-dry in the laboratory, then crushed and sieved to <4 mm.

5.2.2 Plant trial set-up

The plant trial was carried out based on a method adapted from Hartley and Lepp (2008). A factorially designed, randomised block trial was set up with the soil from St Anthony's (PTE-soil), which was treated with one- and two-factor treatments as shown in Table 5-1. The single-factor treatments including wet WTR (fresh-state WTR), air-dried WTR and compost were added at 5%, 10%, 25% and 50%, on a dry weight basis. Two-factor treatments included the addition of air-dried WTR and compost in the ratios of 1:1, 1:2 and 2:1 WTR:compost. The two-factor treatments made up total amendment sizes of 5%, 10%, 25% and 50% by dry weight. The mass (g) of material to be added to each pot was calculated based on density and moisture content measurements. The amendments were mixed with the PTE soil thoroughly by hand to achieve homogeneity before filling into 1 kg capacity (16cm diameter) plastic plant pots. Untreated PTE soil as well as compost and wet WTR were used as controls. Each treatment had 4 replicates.

The field water capacity for each soil mixture was estimated in accordance with Rowell (1994) and the pots were initially watered to this value using tap water. The pots were then left to moisten and equilibrate for seven days before seeding.

Winter wheat (*Triticum aestivum* cv. Einstein)(supplied by Nickerson seeds, UK) was selected as the test plant due to its fast growth and disease resistance, and as a commonly grown crop in the UK (Hough et al., 2003; Merrington et al., 1997). Five seeds were sown directly into each pot. The pots were transferred to a lighted greenhouse run by the Biology Department at Durham University, where they were set up in a randomised block design. Conditions were monitored using a temperature/humidity logger (average conditions: 10-30 °C; 25-50 % R.H.; 12 h light daily). Watering was carried out daily or as required. The plant trial was run for eight weeks which allowed sufficient time for wheat shoot growth.

Table 5-1: Plant trial treatments

Treatment		Percentage addition (dry wt.)
One-factor:	Wet WTR Air-dried WTR Compost	5%, 10%, 25%, 50%
Two-factor:	1:1 Air-dried WTR:Compost 1:2 Air-dried WTR:Compost 2:1 Air-dried WTR:Compost	5%, 10%, 25%, 50%
Controls:	St Anthony's Soil (PTE-soil)	100%
	Compost	100%
	Wet WTR	100%

Figure 5-3: Images showing set-up of greenhouse trial

5.2.3 Measuring and harvesting of plant material

The plant growth measurements included: seed emergence, shoot growth, final shoot and root height, and final shoot and root mass. Seedling emergence and the shoot height of each seedling were measured every day over the first two weeks. After two weeks, plants were thinned to leave the two strongest seedlings per pot. Subsequently, the shoot heights of the remaining seedlings were recorded on a weekly basis.

After eight weeks, the plant trial was dismantled. The contents of each pot were removed and the plants were recovered carefully avoiding root damage. The shoots and roots were separated by cutting the base of the plant at the soil surface with a sharp knife. The plants were washed in water and blotted dry with tissue paper. Fresh biomass was recorded along with final shoot and root length. The plant material was then freeze dried to remove all moisture, using the method described in Chapter 2. The dried material was then re-weighed. The soil mixtures were air-dried, sieved to <2 mm and stored in sealed plastic sample bags prior to analysis.

Figure 5-4: Example of dismantling pot experiments and separating plants from soil, post-trial

5.2.4 Analysis of plant material

A selection of shoot and root samples were analysed for PTE and nutrient uptake. These included plants from the PTE-contaminated soil, WTR and compost controls, 10% and 50% single factor treatments and 10% and 50% 1:1 WTR:compost treatment. In each case, plants from two of the four pots were analysed, giving a maximum of 4 plants per treatment. Due to limited plant mass, one analysis was performed on each shoot and root sample. Shoot and root concentrations were therefore taken as the mean of 4 individual plant sample analyses.

The plant material was chopped up with clean stainless steel scissors and ground in a mechanical grinder (coffee grinder) which was cleaned between samples to prevent cross-contamination. The plant samples were then digested using a microwave digestion technique. An accurately weighed sample (up to 100 mg) of finely ground plant material was added to 6 mL hydrogen peroxide and 12 mL concentrated HNO_3 and left to stand overnight. The samples were then microwave digested in a Mars 6 Xpress microwave digestion instrument (CEM, UK), following a method that was specifically created and optimised for this experiment (programme settings: 40 min ramp up to 180 °C, 20 min hold at 180 °C, 10 min cool down). A plant-based certified reference material (Algae IAEA-413 CRM) and a blank acid sample were included in every batch of digests. The digest solutions were then filtered and made up to 50 mL with DI water in polyethylene tubes, and refrigerated at 4 °C prior to analysis. Elemental analysis was carried out by ESG (Environmental Scientific Group, Burton upon Trent, UK) using ICP-OES and ICP-MS.

5.2.5 Soil analysis

The chemical composition of the WTR, St Anthony's soil (PTE soil) and compost, as well as the post-trial soil samples was analysed using X-ray Fluorescence (XRF). XRF was chosen because of its low-cost and speed of analysis which enabled a rapid turnaround of samples. Briefly, air-dried samples were ball-milled according to the method outlined in Chapter 2, then 5 g samples were accurately weighed into vials along with 1 g of binding wax powder (Licowax C Micropowder, Fluxana, Germany) and thoroughly mixed. The samples were then pressed into pellets using a 10 tonne pellet press. The pellets were analysed using a Spectro X-Lab 2000 XRF instrument, alongside standard reference samples. Pellets were made in duplicate for each soil sample.

C and N analysis of the PTE soil and compost was carried out according to the method described in Chapter 2. The pH and electrical conductivity of the soil samples pre- and post-trial were determined using BS EN 10390:2005, as described in Chapter 2.

5.2.6 Statistical analysis

Statistics were carried out in SPSS (IBM SPSS Statistics 20). These included One Sample T-tests to assess statistically significant ($p<0.05$) differences in shoot height and plant biomass for all test conditions. Multivariate ANOVAs using a Helmert contrast were run to assess the statistical significance of element uptake and transfer coefficients for treatment conditions (wet WTR, dry WTR, compost and 1:1 treatments) compared to the control condition (PTE soil), and to test for significant differences ($p<0.05$) between element uptake and different treatment levels (% additions) for each condition.

5.3 Results and Discussion

5.3.1 Physicochemical properties of soil and amendments

The physicochemical properties of the PTE soil, WTR and compost are outlined in Table 5-2 below. The values for the nutrients and PTEs are total elemental concentrations, as measured by XRF.

Table 5-2: Physicochemical properties of soil, WTR and compost

		PTE-soil	WTR	Compost
pH		6.6	6.0	7.4
EC	µS/cm	220	310	1700
C	%	4.7	13	15
N	%	0.21	0.55	1.13
Al	%	8.1	0.3	4.1
Fe	%	4.1	41	2.8
Si	%	20.6	0.80	13.5
Ca	%	0.78	0.90	3.24
Mn	mg/kg	350	990	525
K	mg/kg	15240	310	19010
Mg	mg/kg	4500	270	6560
P	mg/kg	407	510	2942
As	mg/kg	8820	5.8	10.4
Pb	mg/kg	6954	88	136
Zn	mg/kg	1987	210	250

Values are mean of 2 replicates

The pH of the soil and the amendments were all within circumneutral range, at pH 6.6, 6.0 and 7.4 for the PTE-soil, WTR and compost, respectively. The compost consisted of the highest electrical conductivity (EC) at 1700 µS/cm, indicative of a high degree of soluble ions. The compost also contains extremely high concentrations of nutrients including Ca, K, Mg, N and P in comparison to the PTE-soil and WTR. Taken together, the high EC and total nutrient concentrations suggest that the compost contains a relatively high proportion of soluble, plant available nutrients. In addition, the compost contains a large proportion of organic carbon in the form of natural organic matter (NOM) which creates good soil structure and water holding capacity (WHC). These physicochemical properties make compost an extremely good plant growing medium (Brady and Weil, 1996).

In comparison to the compost, both the PTE-soil and WTR have low EC values and contain smaller quantities of nutrients, indicating that plant nutrient supply is likely to be more limited. The characteristics of the WTR have been discussed in previous chapters; briefly, the WTR's composition is dominated by high levels of C and Fe which are mainly present in the form of NOM and Fe oxyhydroxide, respectively. The NOM and Fe oxyhydroxide fractions are finely intermixed, and the material's physical behaviour is dominated by its Fe oxide component, as shown in Chapter 4. Once the WTR has been air-dried, the material does not absorb water or re-swell, and does not contain a high proportion of water-soluble elements.

The PTE-soil was found to contain approximately 40% sand, 30% silt and 30% clay (pers. comm. Jonathan Asquith, Durham University, 2014), which categorises this soil as a clay loam according to the UK textural classification scheme (Rowell, 1994). Some generalised properties of fine textured soils such as clay loam include high water holding capacity, poor aeration, high compactability, high ability to store plant nutrients and high resistance to pH change (Brady and Weil, 1996).

The most significant feature of the soil is that it contains extremely high levels of PTEs, including As, Pb and Zn at average concentrations of 8820, 6950 and 1990 mg/kg respectively. The Pb and Zn values fall into the middle of the range of pseudo-total concentrations reported by Okorie et al. (2010), whereas the As concentration exceeds their highest reported value (of 5062 mg/kg). Okorie et al. (2010) classified the St Anthony's site as significantly contaminated based on the high concentration of PTEs that were found in the soil.

Remediation with respect to Pb and As are the focus of this investigation, given that they are present in by far the highest concentrations in the soil. However, as discussed previously, total soil element concentrations do not provide information on the form, fractionation or bioavailability of the PTEs within the soil, and can thus be considered as poor indicators of plant-available fractions.

Previous analysis of soil samples which were taken from the same location by the Environmental Engineering group at Durham University has shown that the major mineral form of Pb and As in the soil is galena (lead(II) sulphide) (pers. comm K. Hudson-Edwards, Birkbeck). Galena was mined heavily in the North Pennines and used as the principle Pb ore at St Anthony's. Various metals including Ag, As and Zn are associated with galena and other sulphide deposits as common impurities found in the North Pennine ore fields (Lord and Morgan, 2003; Young, 1996), and therefore galena is also expected to have been the main source As and Zn to the soil.

In the form of galena, Pb and As are highly immobile since the mineral has very low solubility. Galena is very stable under reducing conditions, however it is thermodynamically unstable upon exposure to ambient conditions, and sulphide can be oxidised to sulphate, releasing Pb ions (Gao, 2007). Under oxidising conditions, galena may be altered to secondary minerals such as lead sulphates (anglesite), carbonates (cerrusite) and phosphates (pyromorphite) depending on the soil matrix geochemistry, i.e. redox potential, pH, CEC, and available anions (Ruby et al., 1994).

Through the on-site processing work at St Anthony's, galena was transformed into a wide range of Pb products, including oxides, carbonates and metallic forms. The soil is therefore likely to have received a mixture of Pb and As products through spillages, dumping of ores and waste materials on site, as well as through dust and ash deposition. Transformation of parent Pb minerals to secondary minerals through biogeochemical weathering and bioturbation will have redistributed the Pb and As in different forms (Gao, 2007), resulting in a degree of partitioning of Pb and As into the pore water, clay, oxide and organic fractions of the soil. A range of forms and fractions of Pb and As exist in the soil matrix at St Anthony's, which have been identified in electron microprobe images (data not shown) (pers. comm. K. Hudson-Edwards, Birkbeck). These fractions vary in toxicity, mobility and bioavailability (Gao, 2007). The mobile and weakly bound fractions of As and Pb are most bioavailable and therefore present the greatest risk to plants and animals.

Given the extremely high concentrations of total As and Pb present in the soil, even a proportionally small bioavailable fraction would yield significant concentrations and produce significant toxicity. These Pb and As fractions have not been quantified in this study, however, the oral bioaccessibility of PTEs from 19 samples of St Anthony's soil was studied by Okorie et al. (2011). They found that the bioaccessible fraction of Pb and As in the soil ranged from 25 to 58% for Pb, and 42 to 64% for As. This finding clearly indicates that a significant proportion of the Pb and As contained in the soil is bioavailable. Okorie et al. concluded that Pb and As posed a significant pollutant risk to humans via the hand to mouth route.

The pHs of the soil mixtures pre- and post-trial are displayed in Figure 5-5 and Figure 5-6 for single-factor and two-factor treatments, respectively. Although there was a relatively small amount of pH variation between treatments, the graphs show some clear trends.

Figure 5-5: pH of single factor treatments pre- and post-trial

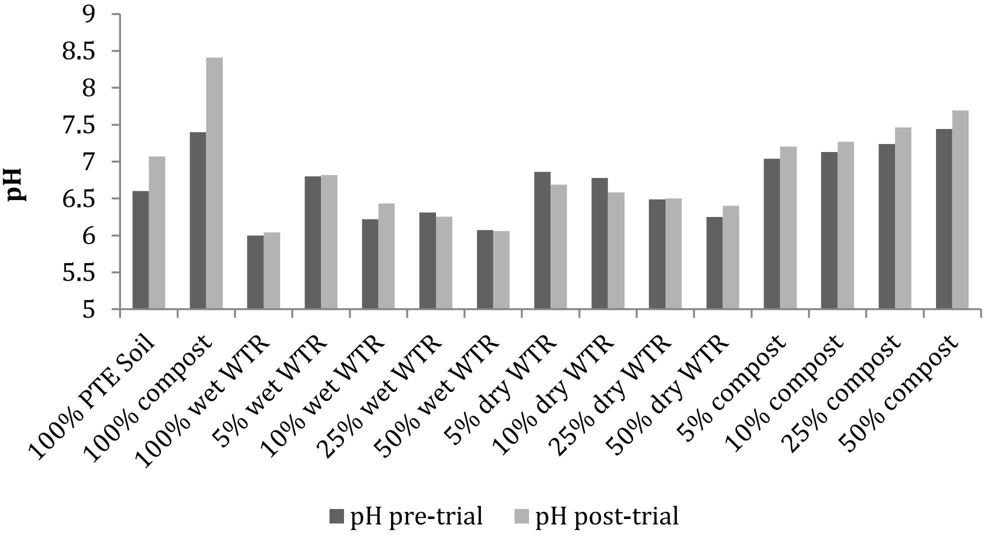


Figure 5-6: pH of two factor treatments pre- and post-trial

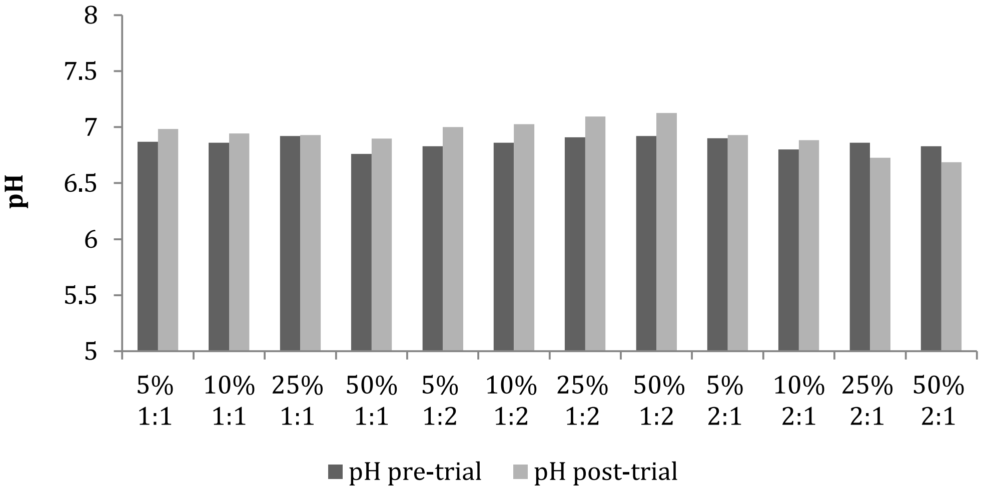


Figure 5-5 shows that the pH of the PTE-soil is approximately centred between the pH's of the WTR and compost, at pH 6.6, 6.0 and 7.4 (pre-trial) respectively. It is clear that the WTR amendments (wet and dry) reduced the soil pH, whereas the compost amendments increased it, both of which were affected linearly with treatment level.

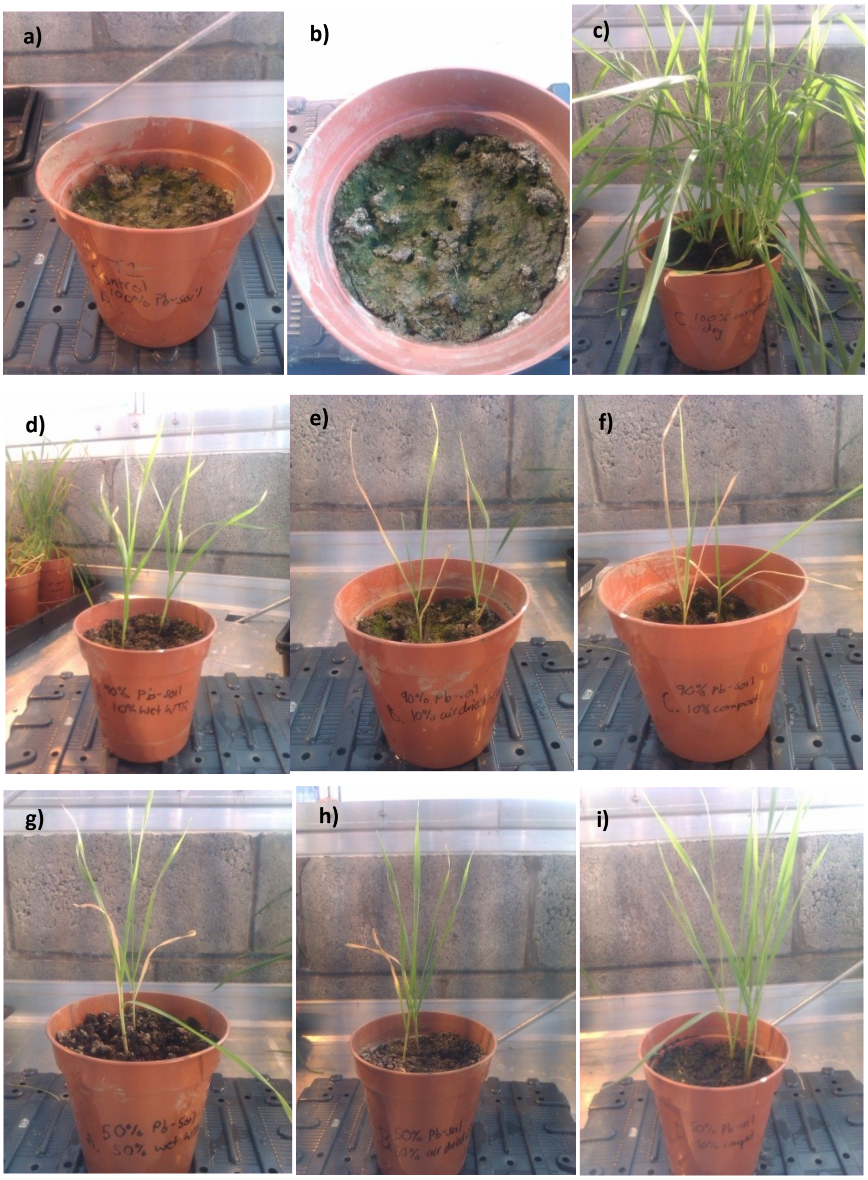
Figure 5-6 shows that the two-factor treatments resulted in minimal change to the original soil pH level. This indicates that pH was counterbalanced by the addition of both the WTR and compost amendments together, resulting in no net change to the pH.

The comparison of pre- and post-trial pHs shows that there was minimal change to pH as a result of the trial, with the exception of the compost control which increased from pH 7.4 to pH 8.4. It is unclear what brought about this change but it is hypothesised that a portion of soluble organic acids may have leached from the compost. Overall, the pHs of the treated soils were all contained within the circumneutral pH range (6.0 to 7.7) suggesting that variations in pH are unlikely to greatly influence the effect of the treatments on plant growth and remediation.

5.3.2 Plant appearance

The size and mass of the wheat plants was found to vary largely with treatment factor and level. As a visual example, a selection of images is presented in Figure 5-7.

Figure 5-7: Selection of plant pot images containing: unamended PTE-soil (a + b); wheat grown in: 100% compost(c); 10% wet WTR (d); 10% dry WTR (e); 10% compost (f); 50% wet WTR (g); 50% dry WTR (h) and 50% compost (i).



Images (a) and (b) illustrate the clayey texture of the PTE-soil. In addition to the extremely high level of PTE contamination known to be present, the images suggest that soil structure was of poor quality for supporting plant growth. The apparent poor soil structure may be attributed to the high proportion of fine particles and relatively small pore size distribution which is inherent in clay soils.

The size, shape and distribution of particles and pores are important factors relating to the ability of soils to support plant life. Depending on size, pores carry out important functions: transmission pores (>50 µm) allow for aeration (movement of O_2 and CO_2), drainage and root penetration; storage pores (0.2-50 µm) store water available for plant use, whereas residual pores (<0.2 µm) hold water so strongly that it is not available to plants (Rowell, 1994). In clay-sized material, the pore system is dominated by residual pores which means that aeration, drainage, plant available water and root penetration are restricted (Rowell, 1994). As a clay loam, the PTE-soil has a relatively low proportion of transmission and storage pores and as a consequence, aeration and drainage may be limited. Additionally, the soil structure may have been degraded during the sample preparation stages; the drying, crushing and sieving is likely to have broken up larger aggregates and caused compaction, exacerbating the drainage and aeration issues.

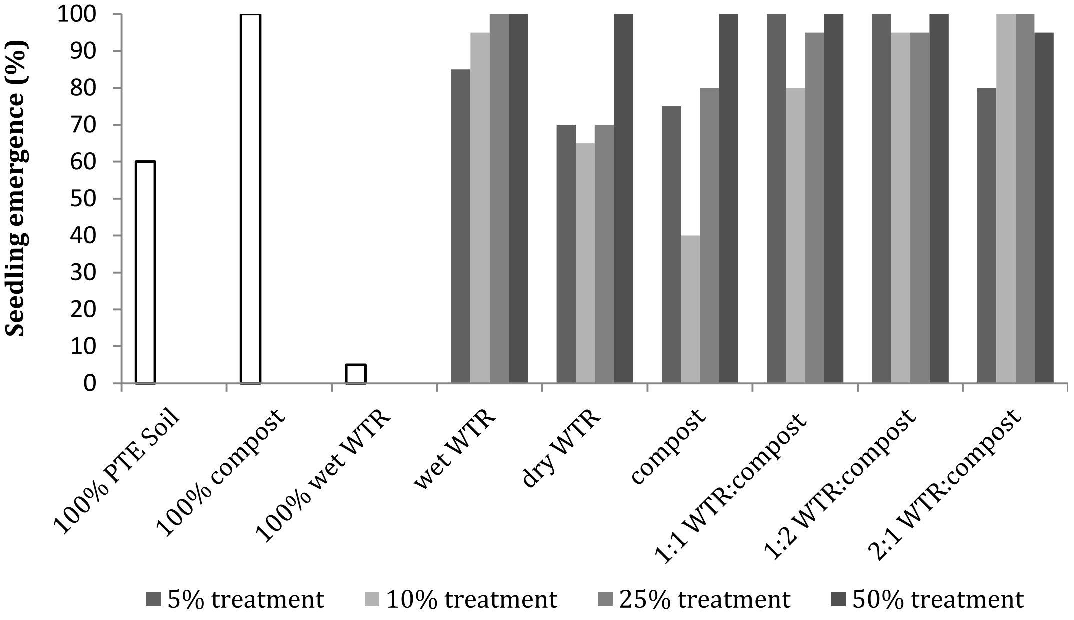
Wheat grown in the unamended PTE-soil was extremely stunted and exhibited a large proportion of chlorotic foliage including yellowish leaves and dead tips, which occurred to a lesser extent in the treated soils. Chlorosis and stunted root and shoot growth are symptoms of PTE toxicity which have been found in wheat as a result of elevated Pb and As concentrations in soil (Li et al., 2007; Liu et al., 2005; Mesmar and Jaber, 1990; Sharma and Dubey, 2005). There were no other signs of discolouration in the plants or any signs of disease. However, in comparison to the healthy and abundant wheat growth in 100% compost (image c), growth in all the amended PTE-soils was clearly suppressed, as highlighted in Figure 5-7.

From these initial observations, it was hypothesised that as well as providing a potential chemical benefit to the soil, the amendments may also provide a physical benefit, by improving aspects of the soil structure. The improvement to soil structure may contribute towards the improved growth in the treated soils by providing more aeration, and water to roots and allowing easier root penetration. However, if the soil structure was solely responsible for improved growth, it may be expected that the compost amendments would result in the best growth overall, since organic matter is of major importance in maintaining soil porosity. This was not the case, as will be described later.

5.3.3 Seedling emergence

The effect of the soil treatments on plant germination was studied by measuring seed emergence. The degree of seedling emergence gives an indication of the suitability of the soil media to support the initial phase of plant growth. Seed germination frequency and early seedling growth are more sensitive to metal toxicity because some plant defence mechanisms have not yet developed, therefore the effects at early stages of plant development can be useful for toxicity assessment (Liu et al., 2007). Seedling emergence was calculated as the number of seedlings that emerged above the soil surface after fourteen days as a proportion of the total number of seeds sown for each treatment (Sirguey et al., 2008).

Figure 5-8: Seedling emergence



*Seedling emergence was taken as a percentage of the total number of seeds sown for each treatment.

The data presented in Figure 5-8 shows that in the compost control, which is considered as the optimum growing medium, seedling emergence was 100%. The rate was considerably lower in the PTE soil (60%) and minimal in the wet WTR control (5%).

The major environmental factors affecting seed germination are phytoxicity, exposure to water, oxygen availability, light and temperature (Kigel, 1995; Kranner and Colville, 2011; Rowell, 1994). Phytoxicity may have had a significant impact on seedling emergence in the PTE-soil, largely generated from the extremely high level of As in the soil, which has been found to inhibit wheat germination (Li et al., 2007; Liu et al., 2005; Liu et al., 2007; Zengin, 2015). There are conflicting reports on the effect of Pb on wheat germination; An (2006) found wheat germination was insensitive to Pb toxicity whereas other studies have measured a significant inhibition due to Pb (Lamhamdi et al., 2011; Munzuroglu and Geckil, 2002; Yang et al., 2010). In addition, the poor structure of the PTE-soil may also impact the germination rate as a result of lack of available water and aeration in the fine-textured soil.

Interestingly, seedling emergence was lowest in the wet WTR control, where only 5% (1 out of 20 seedlings) emerged after 14 d. In this case, the lack of aeration and available water are likely to have had significant impacts. Despite wet WTR containing an extremely high water content (approx. 80%), its thick sludge consistency and homogenous fine texture suggests that its porosity is limited, and therefore that aeration and plant available water may be restricted. With the high water content and lack of air flow, anoxic conditions may be created, all leading to extremely poor conditions for seed germination (Kigel, 1995). This is an important finding when considering the potential for using WTR as a soil substitute, since it suggests that pure wet WTR is not a suitable plant germinating medium.

Despite the above finding, the graph indicates that WTR is able to support seed germination when used as an amendment to soil, since the seed emergence rate was improved from that of pure PTE soil by all the WTR treatments. A seed emergence rate of 85% or greater was achieved using wet WTR treatments whereas the dry WTR treatments improved seed emergence rates to a lesser extent: 70%, 65%, 70% and 100% in the 5%, 10%, 25% and 50% treatments, respectively. The compost amendments also improved seed emergence, except for the 10% compost treatment, which reduced the seed emergence to 40%. In this case 2 pots did not germinate at all but it is unclear why this may have been. The combination treatments also improved seed emergence but with no clear trend. In the 1:1 and 1:2 ratio combinations, 100% seed emergence was achieved in the 5% and 50% treatments whereas in the 2:1 combination, the 10% and 25% treatments gave the highest seed emergence rates (100%).

Overall, seed emergence was higher in the amended PTE-soils than in the unamended soil, suggesting that conditions for seed germination were improved by the addition of the amendments. In all but 3 cases (10% dry WTR, 25% dry WTR and 25% compost), seedling emergence was increased by a larger fraction than the amendment percentage addition, suggesting that the amendments had a positive effect, over and above the dilution factor. The two major factors which are likely to have improved seed emergence are: (i) a reduction in As availability as a result of immobilisation by the WTR, (ii) improvement to the soil structure as a result of compost and WTR additions, increasing aeration and plant available water.

It is noteworthy that when the wet WTR was used as the sole growing medium it did not support seed germination, whereas when it was used as an amendment to the PTE soil, seed germination was greatly improved. This suggests that it may have had a positive effect in reducing the bioavailability of phytotoxic As. It is also possible that although the WTR has a poor structure itself, the addition of wet WTR may have helped to loosen the PTE soil, creating aggregates. Owing to its heavy sludge consistency it was not possible to distribute the wet WTR as fine grains, however the mixture of clumps of WTR within the PTE soil may have created more of a heterogeneous soil structure with more voids, allowing for better air and water flow.

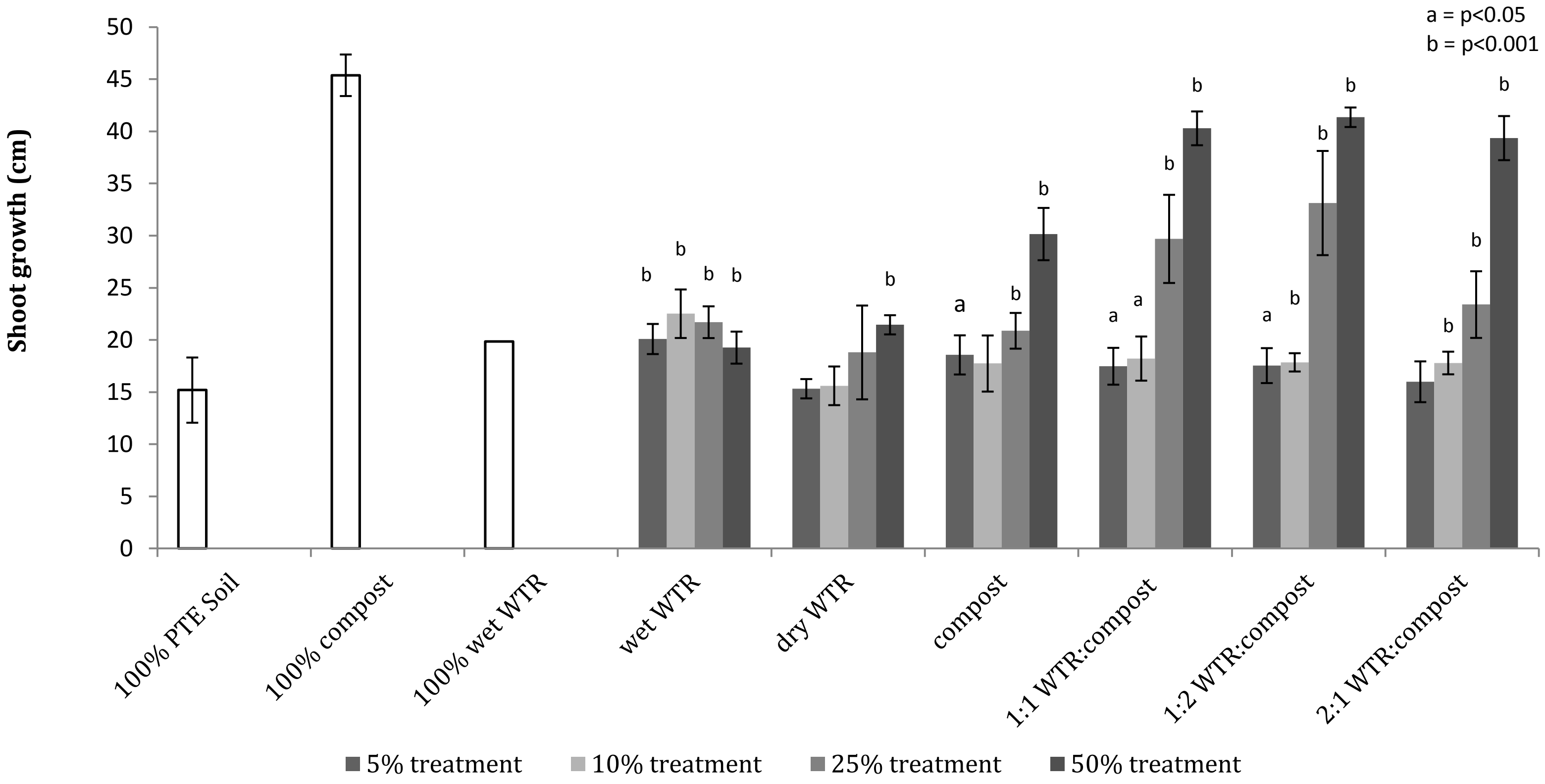
The fact that seedling emergence was improved to a lesser extent by the dried WTR suggests that it may not exert as great an ability to reduce the As bioavailability and/or improve the soil structure as the wet WTR treatments. Given the porous nature of compost and its well-known water-holding and aeration qualities, it would be expected that compost would have the greatest beneficial impact on soil structure. However, it did not improve seed germination to as great an extent as the wet WTR or two-factor amendments. This suggests that improving the soil structure may be less important than reducing phytotoxicity in order to improve germination in the PTE-soil.

5.3.4 Plant growth

Shoot height (length of the longest shoot) and plant biomass are measurements which are commonly used as indicators of plant health, since the extent to which plant growth is stunted is reflected in the height of growing shoots and the mass of the plant. The factors which affect plant growth can be different to those affecting germination (Isselstein et al., 2002), for example nutrient deficiencies and phytotoxicity may become more important. The results from shoot height and plant biomass measurements are presented and discussed below. Since the root and shoot biomass data exhibited similar trends, the total plant biomass (root + shoot mass combined) is presented here.

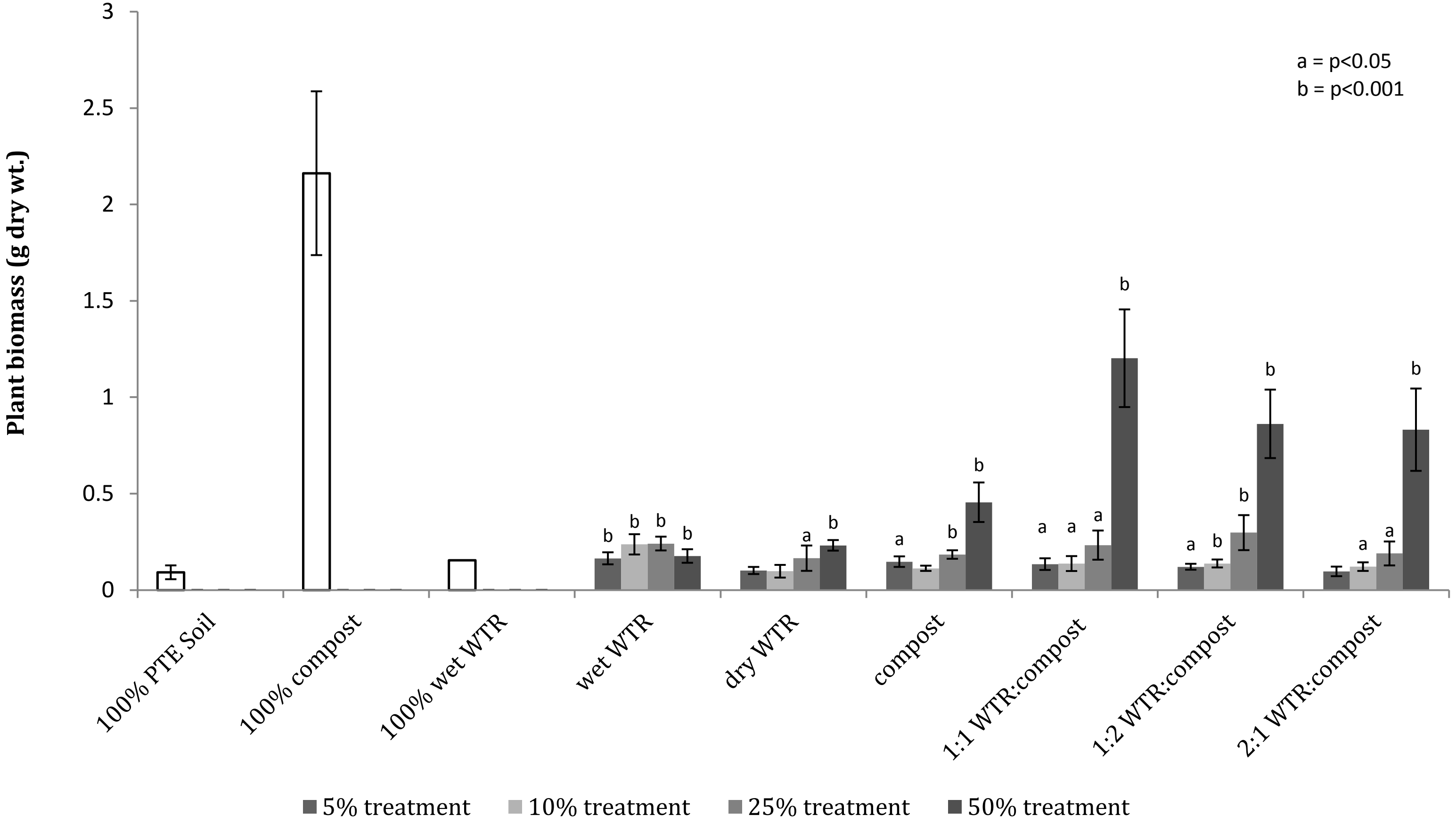
Plant growth measurements were performed on a total of up to 8 seedlings per treatment (two seedlings per pot) depending on the number that emerged in the first 14 days; seedlings that germinated thereafter were not counted. The mean final wheat shoot height (n = 8 (max) ± 1 SD) is presented in Figure 5-9. Graphs of weekly shoot growth can be found in Appendix 5. The mean final wheat plant biomass (n = 8 (max) ± 1 SD) is presented in Figure 5-10.

Figure 5-9: Wheat shoot height after 8-week trial (mean ± SD)*



*A one sample t-test was used to assess the differences between shoot growth in treated soils in comparison to shoot growth in 100% PTE soil. Significant differences are represented by **a** (p<0.05) and **b** (p<0.001). Only one plant sample from 100% wet WTR treatment was available for analysis.

Figure 5-10: Dry plant biomass after 8-week trial (mean ± SD)*



*A one sample t-test was used to assess the differences between plant biomass in treated soils in comparison to plant biomass in 100% PTE soil. Significant differences are represented by **a** (p<0.05) and **b** (p<0.001). Only one plant sample from 100% wet WTR treatment was available for analysis.

Wheat seedlings grown in PTE-soil yielded the lowest amount of growth, with wheat shoots reaching a maximum mean height of 15.2 cm and biomass of 0.09 g. In comparison to the PTE-soil, all treatments resulted in greater growth. Of all treatments, the compost control yielded the best shoot growth (45.4 cm), highlighting the extent of growth that could be achieved under optimum growing conditions, i.e. high nutrient and water availability, good soil structure and no phytotoxic impact. The comparison between PTE-soil and 100% compost clearly reveals that PTE-soil is an extremely poor growing medium, and this may be attributed to the extremely high concentrations of Pb and As present. Both Pb and As have been found to inhibit shoot growth in wheat plants (An, 2006; Garg and Singla, 2011; Geng et al., 2006; Liu et al., 2005; Munzuroglu and Geckil, 2002). Additionally, soil structure effects and nutrient deficiencies may also play a role in stunting growth in the PTE-soil. Dense, clayey soils can inhibit growth due to the soil's resistance to root penetration, poor aeration, slow movement of nutrients and water, build-up of toxic gases and root exudates (Brady and Weil, 1996).

Despite poor germination of wheat in wet WTR, the seedlings which did emerge grew taller (19.9 cm height) than in the PTE-soil (15.2 cm height). This suggests that once seedlings are established, the wet WTR is able to support some level of plant growth, including a supply of available plant nutrients, water and aeration. This is particularly surprising given that aeration was considered to be poor in the thick, sludge-textured, wet WTR. One possibility is that following germination, the channels which are created by growing roots help to break up the homogenous structure and serve as aeration pathways, thus improving aeration at a localised level around the roots. This may be the reason for better than expected plant growth. It is worth noting however, that only one single seedling germinated in the 100% WTR treatment, thus the analysis should be treated with caution. Further growth experiments of wheat in 100% WTR would be required to create a robust data set.

Single Treatment Amendments

The graphs show that all treatments improved plant growth compared to PTE soil, and in general, the growth improved with treatment level. Using a one sample t-test to compare shoot height in treated soils to PTE soil (15.2 cm shoot height) shows that overall, the test conditions significantly improved shoot growth (all $t > 3.6$; all $p < 0.01$) with the exception of 5%, 10%, 25% dry WTR, 10% compost and 5% 2:1 treatments (all $t < 2.3$; all $p > 0.05$). Similarly, the treatments significantly increased plant biomass under all conditions (all $t > 2.7$; all p <

0.05) with the exception of 5%, 10 % dry WTR, 10% compost and 5% 2:1 treatments (all $t < 3.1$; all $p > 0.05$) (see Appendix 6 for SPSS statistical outputs). Interestingly in the case of wet WTR, it was the 10% addition which resulted in the best growth (22.5 cm shoot height). The only single-factor amendment to exceed this height was the 50% compost amendment (30.2 cm shoot height). It is clear from the graphs that plant growth was improved to a lesser extent by the dry WTR amendments.

These findings suggest that wet WTR may be able to reduce Pb and As bioavailability to a greater extent than the dry WTR, but it is also possible that the wet WTR provides additional benefit in terms of improving soil structure, supplying plant available nutrients and water. It remains unclear however, why the optimum WTR treatment was the 10% addition of wet WTR. The 50% compost treatment resulted in substantially better growth in comparison to the other single-factor treatments. As suggested earlier, the addition of compost is likely to significantly improve the soil structure and nutrient status, and may also play a role in immobilising Pb (Karami et al., 2011; Nwachukwu and Pulford, 2008; Nwachukwu and Pulford, 2009). On the other hand, compost may have a detrimental impact on plant growth by increasing As bioavailability within the PTE-soil (Farrell and Jones, 2010; Hartley et al., 2009; Mench et al., 2003). Compost may therefore provide a positive and negative impact on plant growth. The fact that the 50% compost addition resulted in much improved growth compared to the 5%, 10% and 25% additions may indicate that at the 50% addition level, any negative impacts of the compost (i.e. increased As bioavailability) may have been completely outweighed by the positive effects of improved nutrition and/or soil structure. In all cases except for the 50% wet WTR and 5%, 10% and 25% dry WTR treatments, the amendments improved shoot height and plant biomass over and above the dilution factor, indicating that those treatments provided a benefit to plant growth which cannot simply be explained as dilution of the PTE-soil.

Combination Treatment Amendments

It was hypothesised that the main benefit of WTR treatments is likely to be in reducing PTE bioavailability and therefore phytotoxicity, whereas the main benefit of the compost treatment is likely to be in enhancing nutrient availability and/or soil structure. Given that both the compost and WTR treatments improve plant growth suggests that nutrient deficiencies and/or poor soil structure as well as phytotoxicity are all factors affecting plant growth in PTE-soil. It follows that a WTR:compost combination treatment would improve plant growth in an additive fashion, so that a 50% 1:1 combination treatment (which is 25% dry WTR and 25% compost) would improve growth to a similar extent as the sum of the growth improvement given by 25% single-factor dry WTR amendment and the growth improvement given by the 25% single-factor compost amendment.

The graphs show that the combination treatments resulted in the largest improvement to shoot growth and plant biomass, and that all the combination ratios (1:1, 1:2, 2:1) exhibited a similar pattern. At 5% and 10% additions, the growth improvement was roughly additive, whereas the 25% and 50% combination treatments improved growth substantially more than this. For example, the growth improvement achieved by the 50% combination treatment (165% times PTE pot growth) far exceeded the growth improvement of the 25% compost and 25% WTR single-factor treatments combined (61% times PTE pot growth). The shoot height reached a maximum of 33 cm at the 25% level and 41.4 cm at the 50% level in the combination treatments, with the 1:1 and 1:2 combinations achieving the best improvement.

The fact that the combination treatments improved growth more than the single-factor treatments suggests that a treatment which tackles more than one of the potential soil issues (phytotoxicity, soil structure and nutrition) is more beneficial than improving only one of these aspects to a larger degree. At the 25% and 50% addition levels, it is also clear that the act of applying compost and WTR together provided some sort of synergistic benefit to plant growth. In these combination treatments, it is possible that any As which was mobilised by the added compost may have been re-adsorbed by the added WTR. The WTR may counteract the detrimental effect of the compost, allowing the compost to provide an improvement in nutrients and/or soil structure without increasing As phytotoxicity. This may explain the much improved plant growth evident in the combination treatments, and will be discussed further in relation to element uptake.

5.3.5 As, Pb and P uptake in wheat plants

The effect of the WTR and compost amendments on PTE availability in the soil was investigated through plant uptake of As and Pb. Phosphorus (P) uptake was also investigated to gain an insight into the availability of nutrients in amended and unamended PTE-soil and to relate this to the plant growth results. The uptake of As, Pb and P was determined by elemental analysis of shoot samples. Shoot rather than root samples were selected for analysis in order to determine elemental uptake via translocation. This was considered more accurate than using root samples because roots may be contaminated with soil particles, leading to artificially high results. It should be noted that the element uptake data was not normalised for the dilution effect.

As and Pb Uptake

The results of As and Pb uptake in wheat shoots are presented in Figure 5-11 and Figure 5-12, respectively. Firstly in examining PTE uptake, Figure 5-11 and Figure 5-12 show that wheat grown in the unamended PTE-soil contained high concentrations of As and Pb, at an average of 52.7 ± 28.5 mg/kg and 27.8 ± 7.7 mg/kg, respectively. The fact that substantial quantities of As and Pb were taken up by the plants and translocated into the shoots indicates that significant quantities of As and Pb were present in a bioavailable form within the soil. In comparison, there was minimal plant uptake of As (2.1 ± 0.3 mg/kg) and Pb (3.1 ± 1.5 mg/kg) from 100% compost. Surprisingly, the graphs show that there was relatively high uptake of As (11.7 mg/kg) and Pb (14.5 mg/kg) from 100% wet WTR, despite the WTR containing lower As and Pb concentrations than the compost. It is unclear why this may be, but given that it is based on a single shoot sample, the result should be treated with caution.

The As and Pb uptake graphs exhibit similar patterns where in general, the amendments reduced the uptake of As and Pb into wheat shoots. The graphs show that uptake was reduced to a greater extent by the 50% amendments in comparison to the 10% amendments, as would be expected with increasing treatment level.

Figure 5-11: As uptake in wheat shoots (mean ± SD)

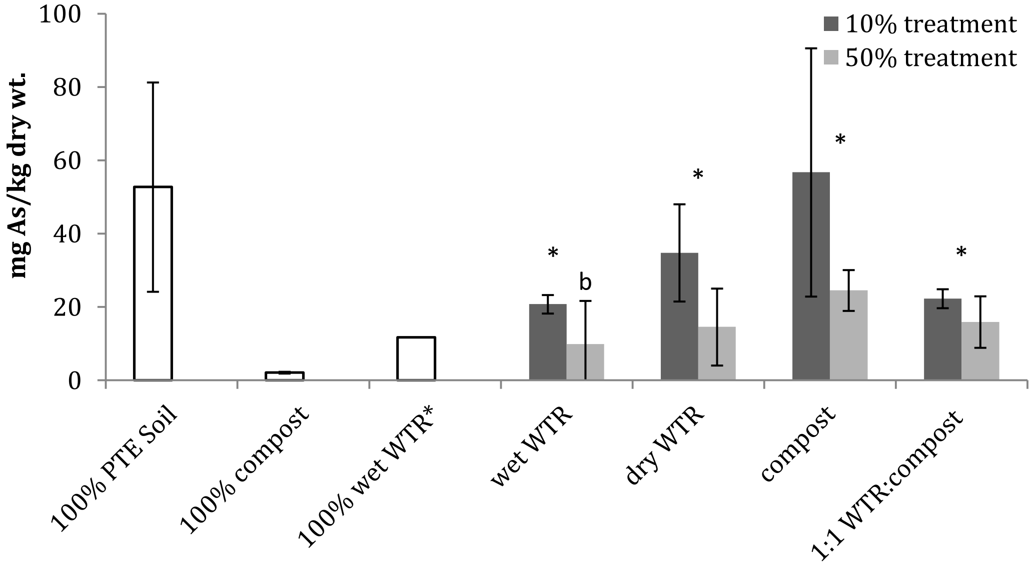
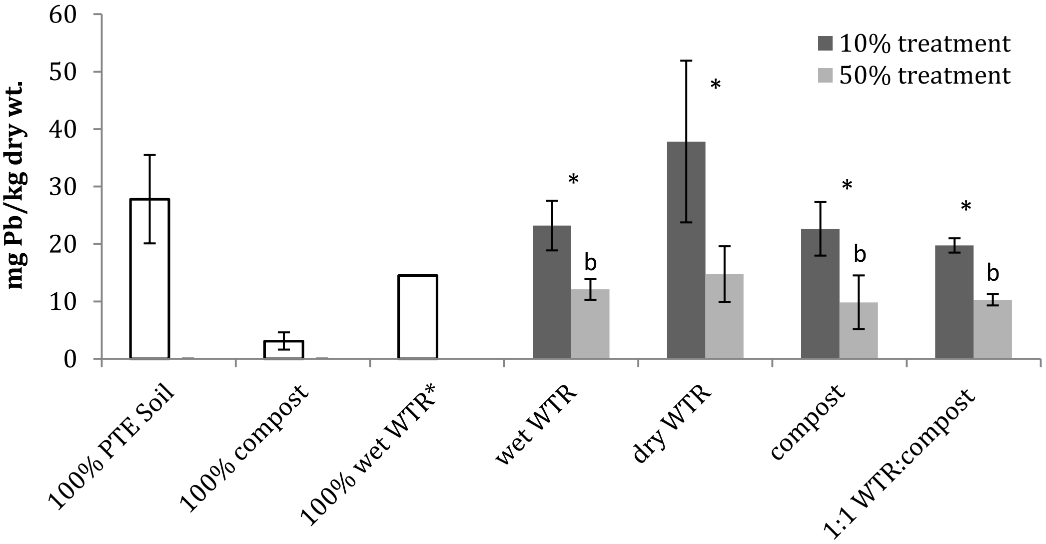


Figure 5-12: Pb uptake in wheat shoots (mean ± SD)



To determine if soil treatment affected element uptake, a multivariate ANOVA was run where As, Pb and P served as dependent variables and treatment condition served as between-group factors. Significant differences are represented by **a** ($p<0.05$) and **b** ($p<0.001$). An additional multivariate ANOVA was run to determine if differences in element uptake occurred between 10% and 50% treatments, where As, Pb and P served as dependent variables, and experimental treatment conditions and treatment level served as between-group factors. Significant differences are represented by * above the columns. Only one plant sample from 100% wet WTR treatment was available for analysis. The statistical outputs are presented in Appendix 6.

The ANOVA analysis showed that there was a significant effect of treatment condition for As ($F(8,27) = 4.52$, $p = 0.001$, $\eta_p^2 = 0.57$) and Pb ($F(8,27) = 8.81$, $p = 0.000$, $\eta_p^2 = 0.72$). The Helmert contrasts for both elements were significant, suggesting that in general the treated soils differed from the PTE soil.

For Arsenic, Bonferroni-corrected pairwise comparisons indicated that the 50% wet WTR treatment (mean = 9.88, SD = 1.81 mg/kg) significantly reduced As uptake in comparison to the PTE soil (mean = 52.7, SD = 28.5 mg/kg) ($p = 0.02$). The 50% dry WTR (mean = 14.6, SD = 1.4 mg/kg) and 50% 1:1 (mean = 15.9, SD = 2.3 mg/kg) treatments tended to reduce As uptake in comparison to the PTE soil (all $0.07 < p < 0.10$). 10% wet WTR (mean = 20.8, SD = 2.5 mg/kg), 10% 1:1 (mean = 22.3, SD = 2.6 mg/kg) and 50% compost (mean = 24.6, SD = 8.1 mg/kg) treatments showed less uptake than the PTE soil, but these failed to reach significance (all $0.28 < p < 0.63$). The 10% dry WTR (mean = 35.0, SD = 13.3 mg/kg) and 10% compost (mean = 56.7, SD = 33.9 mg/kg) treatments were not different from the PTE soil.

For Lead, Bonferroni-corrected pairwise comparisons indicated that the 50% wet WTR (mean = 12.1, SD = 1.8 mg/kg), 50% compost (mean = 9.83, SD = 4.67 mg/kg) and 50% 1:1 (mean = 10.3, SD = 1.0 mg/kg) treatments significantly reduced uptake in comparison to the PTE soil (mean = 27.8, SD = 7.7 mg/kg) (all $p \leq 0.05$). The 50% dry WTR treatment (mean = 14.7, SD = 4.8 mg/kg) showed less uptake than PTE soil but failed to reach significance ($p = 0.23$). The 10% wet WTR (mean = 23.2, SD = 4.3 mg/kg), 10% dry WTR (mean = 37.8, SD = 14.1 mg/kg), 10% compost (mean = 22.6, SD = 4.7 mg/kg) and 10% 1:1 (mean = 19.7, SD = 1.2 mg/kg) treatments were not statistically different from the control.

The graphs show that uptake was reduced to a greater extent by the 50% amendments in comparison to the 10% amendments, as would be expected with increasing treatment level. For As and Pb, the ANOVA test showed that uptake was significantly lower in the 50% treatment than 10% treatment across all conditions.

Single Amendment Treatments

The wet WTR treatments reduced plant uptake of As to a greater extent than Pb: the 10% and 50% wet WTR additions reduced the uptake of As by an average of 61% and 81%, respectively, and Pb by an average of 17% and 57%, respectively. The dry WTR treatments were less effective than the wet WTR treatments at reducing As and Pb uptake: the 10% and 50% dry WTR additions reduced the uptake of As by an average of 34% and 72%, respectively; the 10% dry WTR addition actually resulted in an increased Pb uptake of 36%, and the 50% dry WTR addition reduced uptake by only 47%, which is below the dilution factor. The compost treatments also provided interesting uptake results, performing poorly with respect to reducing As uptake: the 10% compost addition actually increased As uptake by 8%, and the 50% compost addition reduced As uptake by an average of only 53%. The compost performed slightly better than the wet WTR with respect to reducing Pb uptake: the 10% and 50% compost additions reduced the uptake of Pb by an average of 19% and 65%, respectively.

The findings so far suggest that:

i) Dry WTR was ineffective at reducing Pb and As uptake;

ii) Wet WTR was more effective than dry WTR at reducing uptake of As and Pb from the PTE-soil;

iii) WTR was more effective at reducing uptake of As than Pb;

iv) WTR was more effective than compost at reducing uptake of As; and

v) Compost was slightly more effective than wet WTR at reducing uptake of Pb.

The sorption studies described in previous chapters showed that dry WTR has a high sorption capacity for Pb. However, the graphs show that dry WTR was ineffective at reducing Pb uptake from the PTE-soil, suggesting that it was unable to immobilise Pb under the conditions of this plant trial. It is interesting that the wet WTR treatments were able to reduce Pb uptake when the dry WTR was not. A reduction in soil pH which makes Pb more mobile and therefore available for plant uptake may cause this effect, however, the soil pH decreased from 7.0 in the PTE-soil to 6.6 (10% amendment) and 6.4 (50% amendment) in the dry WTR treatments, but decreased to 6.4 (10% amendment) and 6.0 (50% amendment) in the wet WTR treatments. Therefore the change in pH is not likely to explain the difference in performance of the wet and dry WTR treatments. Alternatively, the difference may be based on physical nature of the amendments. The wet WTR may perform better than the dry WTR because wet

WTR has high moisture content and is therefore more voluminous than the dry WTR; this greater surface area is likely to lead to greater contact with contaminants in the PTE-soil. Additionally, given that the WTR was in a wet state, some Fe and humic substances may be leached from the WTR, giving rise to greater distribution of these sorbent constituents and more potential for interaction with the contaminants. Fe that is leached in reduced form could be redistributed and oxidised to Fe oxides elsewhere in the soil matrix, facilitating further sorption and possible co-precipitation reactions. These interactions would enhance immobilisation of Pb and As by the WTR, reducing the plant available concentrations in the soil, leading to less plant uptake.

Results show that the WTR amendments achieved a greater percentage reduction in As uptake in comparison to Pb uptake. Analysis of the soil samples showed that total soil As concentration was 8820 mg/kg and total Pb was 6954 mg/kg (Table 5-2). Okorie et al. (2011) found that there was a strong positive correlation between pseudo-total PTE concentrations and bioaccessible PTE concentrations in St Anthony's soil samples. The gastrointestinal bioaccessible fraction (BAF) ranged from 42-64% for As and 25-58% for Pb. Additionally, within the pH range of the plant trials (pH 6-7.7), it is expected that As would be in a more labile form than Pb. Taken together, this data suggests that there is a larger labile, bioavailable pool of As than Pb in the PTE-soil. Indeed, the plant uptake results show that 53 mg/kg of As and only 28 mg/kg Pb were taken up from the PTE-soil into the wheat shoots. It can be hypothesised that, given there is a larger pool of more labile As in the soil than Pb, the As is more likely to interact with the WTR and become immobilised by it. Thus, presenting as the WTR being a more effective treatment for reducing As uptake than Pb in the plant trials. The lesser effect of the amendment on Pb may be attributed to Pb being present in more stable, less mobile complexes in this soil (Beesley et al., 2010b).

Based on this hypothesis, there are significant challenges in using solid adsorbents to treat relatively immobile soil contaminants. Clearly, due consideration must be paid when applying amendments to deal with multi-element contaminated soils, since sorption to the most available contaminants, both chemically and physically, will dominate.

The fact that the wet WTR and compost performed similarly with respect to reducing Pb uptake suggests that Pb had a relatively equal affinity for the compost and wet WTR. Similarly to wet WTR, humic substances may be leached from the compost and transported through the soil medium, allowing for more interaction with soil contaminants. This again points towards contaminant-amendment interactions being a critical factor in determining the effectiveness of an amendment in soil. The fact that compost appeared less effective at reducing As uptake supports the hypothesis that compost-only amendments are not suitable for immobilising As, and they may even facilitate the mobilisation of soil As. Natural organic matter (NOM) may enhance the release of As from soils into the soil solution, with the main influencing mechanisms being competition for available adsorption sites, formations of aqueous complexes, and/or changes in the redox potential of surface sites and As redox speciation (Wang and Mulligan, 2006). Several studies have reported an increase in As release following compost amendments to contaminated soil. Mench et al. (2003) and Hartley et al. (2009) reported increases in leachable As from compost-amended soils, which was attributed to DOC competing with As for sorption sites. Beesley et al. (2010a) found As concentration in soil pore water to be both a function of pH and DOC. Redman et al. (2002) observed the formation of aqueous complexes of NOM with arsenate and arsenite as well as competition between NOM and As for sorption sites on oxides. However, organic matter may also serve as binding agents, reducing As mobility depending on the characteristics of the organic components (Wang and Mulligan, 2006).

It is also known that since P and As have similar chemical properties, they compete for sorption sites on soil particles (Davenport and Peryea, 1991). P addition to As-contaminated soils has been shown to enhance As release from the soil through competitive anion exchange (Peryea and Kammereck, 1997). Smith et al. (2002) found that introducing P into As-contaminated soil greatly reduced As sorption, particularly in soils low in Fe oxides. These findings suggest that an influx of P into PTE-soil caused by the compost additions may induce a similar As-releasing effect. Additionally, compost amendments can stimulate As release into soil solution as a result of pH rise (Farrell and Jones, 2010). Post-trial pH's were 7.0 in the PTE-soil, 7.2 in 10% compost and 7.7 in 50% compost treatments (Figure 5-5), indicating that a rise in pH may have had some impact on As release.

The evidence suggests that compost may have two conflicting effects on the PTE's mobility: increasing bioavailability through creating soluble complexes (e.g. with low molecular weight components) and immobilisation (through sorption onto insoluble components (e.g. higher molecular weight fractions). The overall effect has been to increase plant available As and reduce plant available Pb, highlighting the different binding mechanisms and affinities at play within the compost for the As oxyanion and the Pb cation.

Clearly the interactions between organic matter components with Pb and As are multiple and complex. Further investigations including soil pore water analysis (e.g. pH, PTE and DOC concentration), compost characterisation (e.g. soluble and insoluble fractions) and spectroscopic analysis of the soil would be required to fully understand the effect of the amendments on the behaviour of the PTE's under study.

Combination Amendment Treatments

Results from the 1:1 dry WTR:compost treatments showed that the 10% and 50% additions reduced the uptake of As by an average of 58% and 70%, respectively, and reduced the uptake of Pb by an average of 29% and 63%, respectively. This indicates that the combination treatment performed similarly to the wet WTR at the 10% level and less effectively at the 50% level with respect to As uptake. The combination treatment was the most effective of all treatments at reducing Pb uptake at the 10% level and performed similarly to compost at the 50% level.

Interestingly, these findings again show that the combination of dry WTR and compost performed better than would be expected from the summation of the single treatment (dry WTR and compost) performances; for instance the 10% 1:1 treatment (5% dry WTR and 5% compost) was more effective at reducing As plant uptake than single treatments of 10% WTR and 10% compost. In the case of As, this suggests that any mobilisation of As that may have occurred as a result of the compost addition is completely counteracted by the addition of WTR, indicating that the WTR may be acting as an adsorbent for the compost-mediated mobilised As.

In the case of Pb, despite the fact that dry WTR was ineffective as a single amendment, the combination treatments of dry WTR and compost reduced plant uptake similarly or more effectively than the singular compost treatments. This again suggests that there is some benefit to applying WTR and compost as a combination. If the WTR is acting as a sorbent for compost-mobilised As, this may free up binding sites on the OM within compost, enabling Pb sorption. Thus the combination treatment may drive As to bind with surface hydroxyl groups of the ferrihydrite in WTR and Pb to bind with OM in the compost.

As and Pb Transfer Coefficients

In order to determine whether the amendments influenced the elemental plant uptake over and above the dilution factor, the As, Pb and P shoot tissue concentration was normalised to the As, Pb and P soil concentration for each treatment. Transfer coefficients (TC) were obtained by dividing the metal concentration in plant tissue (mg/kg) by the metal concentration in the substrate (mg/kg) (Hartley and Lepp, 2008), where the soil concentrations were taken as totals based on XRF results. Treatments which reduce the transfer coefficient relative to the unamended PTE-soil show that they have had a positive impact on reducing the PTE availability to plants. The statistical outputs are presented in Appendix 6. Figure 5-13 and Figure 5-14 present the transfer coefficients for As and Pb, respectively.

ANOVA revealed that there was a main effect of treatment condition, but Helmert contrasts indicated that the As and Pb transfer coefficients in the treated soils were not significantly different from the transfer coefficients in the PTE soil. Pairwise comparisons using Bonferroni correction confirmed that none of the conditions significantly differed from the PTE soil, although the 10% dry treatment generally had a higher Pb transfer coefficient than the PTE soil, but this effect was not close to statistical significance (p = .201).

Although the patterns observed in the TC graphs were similar to the element uptake data, the results show that when the PTE uptake was normalised to the PTE concentration in the treated soils, the treatments did not cause a significant effect. It is expected that differences may become more significant with larger sample numbers since there is relatively high variation between replicates, as indicated by the SD error bars.

Figure 5-13: As transfer coefficients in wheat shoots

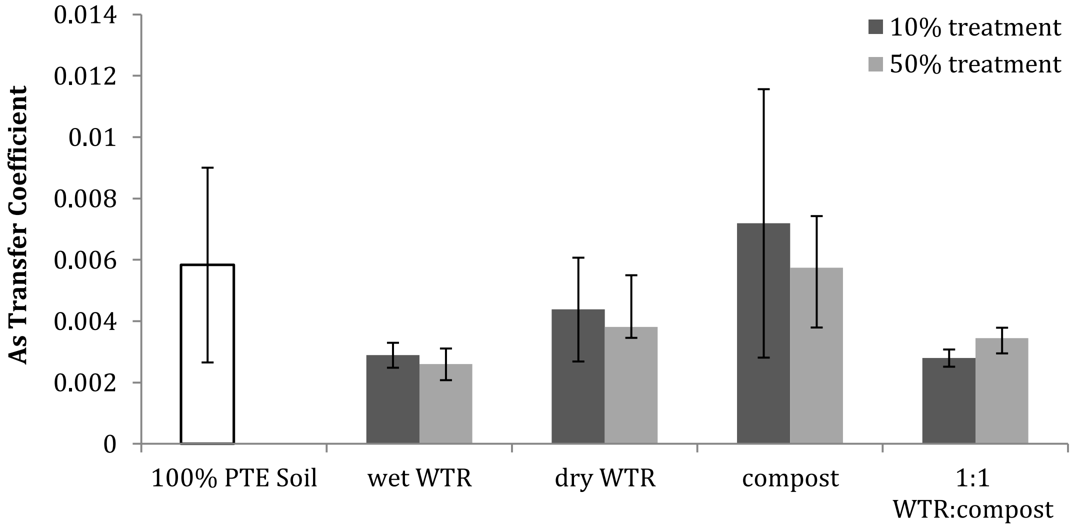
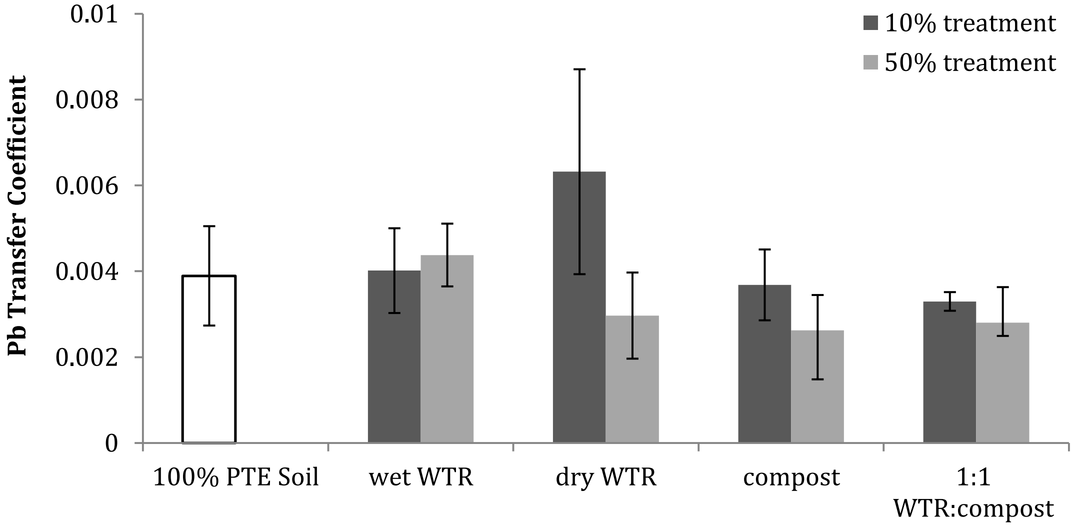


Figure 5-14: Pb transfer coefficients in wheat shoots



To determine if soil treatment affected transfer coefficient of As and Pb, a multivariate ANOVA was run where As and Pb served as dependent variables and treatment condition served as between-group factors. Significant differences are represented by **a** ($p<0.05$) and **b** ($p<0.001$). An additional multivariate ANOVA was run to determine if differences in element uptake occurred between 10% and 50% treatments, where As and Pb served as dependent variables, and experimental treatment conditions and treatment level served as between-group factors. Significant differences are represented by * above the columns. Only one plant sample from 100% wet WTR treatment was available for analysis. The statistical outputs are presented in Appendix 6.

Phosphorus Uptake

Phosphorus (P) uptake was investigated in order to assess P plant availability in unamended and amended PTE-soil, and to relate this to the plant growth measurements. The results of P uptake in wheat shoots are presented in Figure 5-15. P transfer coefficients are presented in Figure 5-16.

Figure 5-15 shows that the P concentration found in wheat shoots grown in 100% compost (mean = 5542, SD = 190 mg/kg) far exceeds the P concentration in all other treatments. Results from the soil analysis (Table 5-2) showed that compost contained the highest total P concentration (2942 mg/kg in compost, 510 mg/kg in WTR and 407 mg/kg in PTE-soil), and the uptake data confirms that a larger proportion of this total P is plant available in comparison to the P in PTE-soil and WTR.

The ANOVA analysis showed that there was a significant effect of treatment condition for P ($F(8,27) = 38.31$, $p = 0.000$, $\eta_p^2 = 0.92$). The Helmert contrast was significant, suggesting that in general the treated soils differed from the PTE soil.

For P uptake, Bonferroni-corrected pairwise comparisons indicated that the 10% wet WTR (mean = 1667, SD = 205 mg/kg), 50% dry WTR (mean = 1705, SD = 213 mg/kg), 50% compost (mean = 1216, SD = 263 mg/kg) and 50% 1:1 (mean = 2744, SD = 646 mg/kg) treatments significantly increased P uptake in the wheat shoots in comparison to the PTE soil (mean = 469, SD = 15 mg/kg) (all $p < 0.02$). The 50% wet WTR (693, SD = 91 mg/kg), 10% dry WTR (mean 476, SD = 136 mg/kg), 10% compost (mean = 474, SD = 38 mg/kg) and 10% 1:1 (mean = 452, SD = 68 mg/kg) treatments were not statistically different from the PTE soil.

Figure 5-15: P uptake in wheat shoots (mean ± SD)

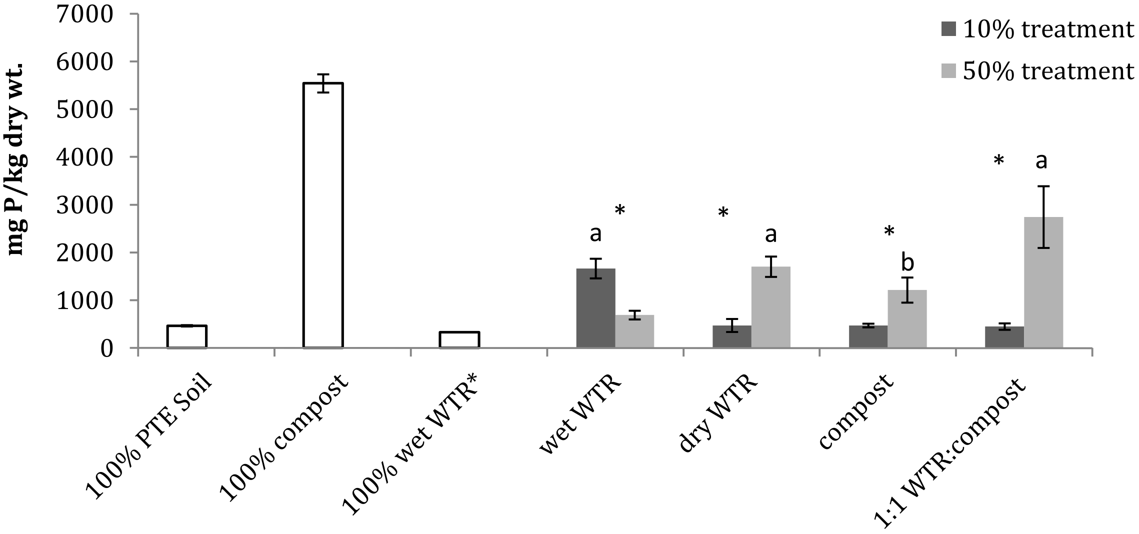
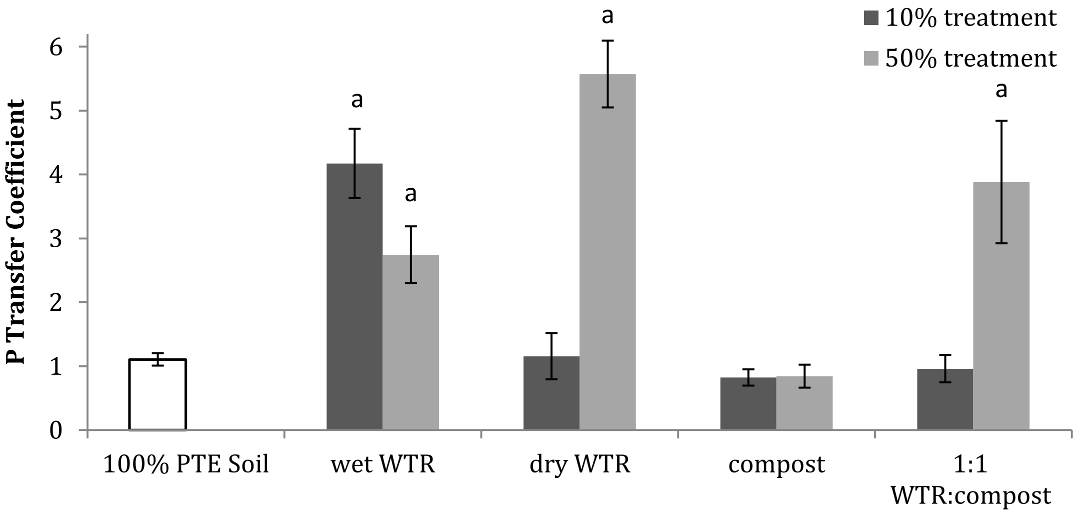


Figure 5-16: P transfer coefficients in wheat shoots



To determine if soil treatment affected element uptake and transfer coefficient, multivariate ANOVAs were run where P served as a dependent variable and treatment condition served as between-group factors. Significant differences are represented by **a** ($p<0.05$) and **b** ($p<0.001$). An additional multivariate ANOVA was run to determine if differences in element uptake occurred between 10% and 50% treatments, where P served as dependent variable, and experimental treatment conditions and treatment level served as between-group factors. Significant differences are represented by * above the columns. Only one plant sample from 100% wet WTR treatment was available for analysis. Appendix 6 presents the statistical outputs.

The data shows that the WTR treatments increased plant uptake of P to a greater extent than the compost treatments. This is surprising because the total P concentration in the WTR (510 mg/kg) was fairly similar to that of the PTE-soil (407 mg/kg), and it is considered highly unlikely that the P in WTR is more plant available than the P in the PTE-soil, given WTR's strong P sorption capacity. Indeed, the literature highlights P deficiency as the most significant issue associated with using WTR as a soil substitute (Dayton and Basta, 2001; Lombi et al., 2010; Mahdy et al., 2007).

Interestingly, the wet and dry WTR results yielded contradictory findings. An independent samples t-test indicated that P uptake from the 10% wet WTR treatment was significantly higher than from the 50% treatment ($t(6) = 8.7$, $p < 0.001$), whereas the opposite was true for the dry WTR; P uptake from the 50% treatments was significantly higher than from the 10% treatments for dry WTR ($t(6) = -9.7$, $p < 0.001$), compost ($t(3.1) = -5.6$, $p = 0.01$) and 1:1 ($t(3.1) = -7.1$, $p = 0.005$) treatments.

In the dry WTR, compost and combination treatments, only the 50% amendments caused a significant increase in P uptake. Although the compost amendments improved P uptake to a small extent, surprisingly, the compost addition did not result in a proportional increase in P uptake, neither at the 10% level nor at the 50% level. The 1:1 combination treatment also yielded interesting results: there was no significant effect at the 10% level, whereas the 50% treatment substantially increased P uptake. Alike to the plant growth results, the 50% combination treatment yielded a greater than additive uptake of P, i.e. the combination treatment produced a higher P uptake than would be expected from the summation of the results from the individual dry WTR and compost treatments. This suggests that the 50% combination treatment may have actually increased the pool of plant available P and accessibility to it.

The P transfer coefficients in wheat shoots (P in plant tissue (mg/kg) divided by total P in soil (mg/kg)) are shown in Figure 5-16. Bonferroni-corrected pairwise comparisons showed that 10% wet WTR, 50% wet WTR, 50% dry WTR and 50% 1:1 treatments resulted in significantly increased P transfer coefficients compared to the PTE soil (all $p \leq 0.001$). No differences were observed for 10% dry WTR, 10% compost, 50% compost and 10% 1:1 treatments compared to the PTE soil. These results substantiate the hypothesis that the WTR is in some way able to enhance the availability of P from the PTE soil.

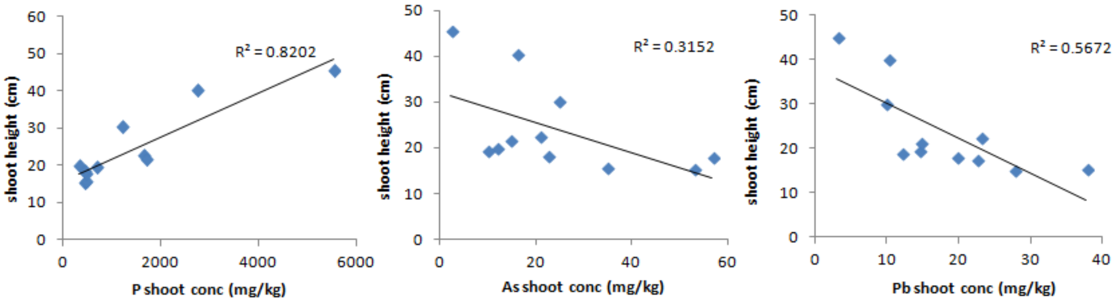
As and P exhibit similar chemical characteristics (tetrahedral geometry, atomic radii, ionization potential, electronegativities) and as such, plants can take up As through the P uptake mechanism, which is why As is particularly phytotoxic (Zhao et al., 2010). With both elements competing for the same mechanism, P uptake could therefore be inhibited in the presence of As. In the case of the PTE-soil, the high As concentration may inhibit P uptake from the soil as a result of competition for sorption sites, through either higher affinity or, more likely, the effect of mass action (Smith et al., 2002), since soil As concentration (8820 mg/kg) far exceeds P concentration (407 mg/kg). Our results so far indicate that the WTR treatments are able to immobilise plant-available As, leading to lower plant uptake of this element. With less plant-available As in the system, P may be less inhibited, therefore facilitating greater P plant uptake. This may be the reason for the apparent increase in plant uptake of P from WTR-amended soils.

Our earlier hypothesis was that the compost treatment may actually promote the mobility of soil-As, increasing the pool available for plant uptake. If this is the case, the compost-mobilised As could further inhibit the uptake of P, to a certain extent counteracting the nutrient benefit supplied by the compost. This may be the reason why the compost treatments did not result in as great an increase in P uptake than might be expected from such a P-rich material.

By use of a combination treatment, it follows that the WTR may be able to adsorb the extra compost-mobilised As, allowing the compost to provide a nutritional benefit without the detrimental increase in available As. This hypothesis may explain why the combination treatments were able to promote greater P uptake and lesser As uptake than the compost amendments alone, and suggests that the combination treatment may provide the greatest improvement to plant growth in PTE-soil.

To assess the association between plant growth and uptake, the plant growth results were correlated with the plant uptake data, which is presented in Figure 5-17.

Figure 5-17: Correlations of plant growth with plant uptake of P, As and Pb



As can be seen from the correlation graphs, shoot height was highly positively correlated with P uptake (R^2 = 0.82), and more weakly negatively correlated with As (R^2 = 0.31) and Pb (R^2 = 0.57) uptake. This suggests that wheat growth was more positively affected by higher P availability than negatively affected by the presence of the contaminants, and therefore that P availability had the most significant impact on plant growth. Nevertheless, the negative correlations do suggest that a reduction in contaminant uptake and therefore phytotoxicity is also important for improving plant growth. The strong plant growth/P-uptake correlation also indicates that it was not simply the addition of compost which improved plant growth, relating back to Figure 5-15 which showed that 10% wet WTR, 50% dry WTR and 50% combination treatments resulted in highest P plant uptake. This supports the hypothesis that the WTR treatments bring about physicochemical changes to the PTE-contaminated soil which improve conditions for plant growth as well as reducing bioavailability of contaminants.

5.4 Conclusions

The purpose of this study was to investigate the effects of the WTR and compost amendments on (i) plant health, measured by various growth indicators, and (ii) mobility and bioavailability of PTEs in the soil, measured by plant uptake of Pb and As.

Overall, it was found that the combination treatments improved growth more than the single-factor treatments. It is suggested that an amendment which tackles more than one of the potential soil issues (phytotoxicity, soil structure and nutrition) is more beneficial than improving only one of these aspects to a larger degree. At the 25% and 50% addition levels, the combination treatments appeared to provide a synergistic benefit to plant growth. It is hypothesised that any As which is mobilised by the compost addition may be re-adsorbed by the WTR, thus counteracting the detrimental effect of the compost, allowing the compost to provide an improvement in nutrients and/or soil structure without increasing As phytotoxicity.

Whilst the wet WTR may have helped to improve the PTE-soil structure by creating a more heterogeneous soil texture, it is suspected that this benefit may be short-lived. As the WTR dries out, this voluminous sludge shrinks and does not rewet or re-swell. The benefit of WTR may therefore change from improving soil structure to increasing particle size distribution over time. As it dries and shrinks it may create voids that allow water movement and aeration. However, the brittle nature of dried WTR particles is likely to result in its disintegration over time if the soil is disrupted, as was observed in the laboratory. This will probably result in the WTR becoming more finely intermixed into the soil over time, but may mean that any soil structure improvements are negated. On the other hand, increasingly fine particles will exhibit greater surface area allowing for improved sorption capacity of WTR over time.

The data indicated that there was no significant effect of treatment conditions on Pb and As transfer coefficients, from contaminated soil to the plants. However, the patterns in transfer coefficients were similar to those in the Pb and As uptake data. The high degree of variation in element concentration between replicates in the soil treatments as well as in the plants (as indicated by the SD error bars) may account for some loss of observed effect. It is expected that differences may become more significant with larger number of replicate samples.

Although there was no significant effect of treatment on Pb and As transfer coefficient, theories were still considered for the effect of treatments on Pb and As plant uptake. The combination treatment may have provided the greatest improvement to plants grown in PTE-soil, but it was unclear whether the combination treatment provided the best solution for immobilising contaminants. Overall, the combination treatments performed best in terms of reducing both Pb and As plant uptake. However, uptake of As was only significantly reduced by the 50% wet WTR treatment. In this case, it was clear that the WTR immobilised the As that was already plant-available within the PTE-soil. The issue with the combination treatment is that the compost may have helped to mobilise additional As which was otherwise not easily available to plants. On one hand, this could be seen as having a detrimental impact, but on the other, it may be beneficial that more As is made available to interact with and become adsorbed by the WTR than would be otherwise, since it could lead to more efficient, and potentially longer term, immobilisation of As.

The uptake results suggest that WTR had a greater effect on reducing As uptake than Pb. This may be attributed to there being a larger, more labile pool of As than Pb, resulting in a higher probability of As interacting with the adsorbent. Although a significant fraction of the Pb may still be bioaccessible, it's relatively limited mobility means that it may not move through pore water and interact with the amendments as readily as the As, pointing towards contact being the critical factor in this remediation strategy. The P transfer coefficient data indicated that the wet WTR, 50% dry WTR and 50% 1:1 treatments significantly increased P uptake in the plant shoots. These results suggest that the WTR was able to enhance availability of P from the PTE soil. This is possibly due to WTR reducing plant-available As, therefore allowing greater P plant uptake, since As is known to compete with P for plant uptake.

Wet WTR achieved greater reduction in PTE uptake than dry WTR, and this may also be due to greater physical interaction, since humic and Fe components of the wet WTR may be leached and redistributed within the soil matrix. Likewise it is hypothesised that compost achieved more significant reduction in Pb plant uptake than the WTR treatments as a result of interaction between mobilised organic matter fractions and Pb. However in this case, the greater Pb impact may also be attributed to Pb having greater affinity for binding sites on compost than the WTR.

In conclusion, only the PTEs which come into direct physical contact, as a result of initially mixing the amendments into the soil or through leaching of the PTEs and/or the amendments, are likely to have a chance of becoming immobilised by the soil amendments. This highlights the challenge in using solid-state, in-situ amendments to treat relatively immobile contaminants in real contaminated soil. In this study, only one soil was used which was extremely heavily contaminated with As and Pb. In soils more moderately contaminated with PTEs, one would expect less interaction between the PTEs and the amendments, meaning that contact would become even more of an important issue and may ultimately show that using a solid amendment to adsorb immobile contaminants is ineffective in such cases.

No treatment was able to completely immobilise the PTEs and prevent accumulation in the plant tissue. However, results were promising given that it was only a short-term (8 week) trial with relatively small number of replicate samples. It is expected that over a longer duration, WTR may exert greater influence, in that as more As and Pb come into contact with the WTR (e.g. through water movement, tillage, bioturbation), more As and Pb will become immobilised, resulting in a greater reduction in bioavailability over time.

Further work

The plant trials described in this chapter have provided interesting initial findings and insight into the potential use of WTR and compost amendments in real contaminated soil, supplementing results from the laboratory-based sorption experiments discussed previously. Some interesting hypotheses have been generated from the plant growth and uptake results. However, an inherent problem when experimenting with real contaminated soil is that it is a relatively uncontrolled system, and there is clearly a complex mix of contributing and confounding factors affecting the results. It is therefore difficult to determine the actual impact of the amendments on the PTE and nutrient mobilisation/immobilisation and plant availability, soil structure, etc. Ultimately, further investigation is required in order to determine the effects of the amendments on these specific aspects and on the soil system as a whole, and to understand whether in-situ WTR/compost amendments could be used as an industry-viable technology.

Further work should include the following:

- Determine the Pb and As sorption capacity and behaviour of WTR and compost in systems containing both Pb and As, by conducting multi-element batch sorption experiments and spectroscopic studies;
- Understand the interaction of the amendments with P and other nutrients, and how this interaction affects their availability;
- Investigate potential competition effects, e.g. from other anions and cations present in the soil;
- Understand the speciation and behaviour of the PTEs in the soil, before and after treatment. This research would be greatly enhanced through in-depth physiochemical assessments of the soils to complement the plant growth trials, including:
    - column, microcosm or lysimeter trials
    - soil extractions, such as bioaccessibility, sequential extractions and pore water analysis
    - spectroscopic analysis;
- Experiments controlling for nutrients to examine only the effects of PTEs on plant growth;
- Establish appropriate applications rates, both in terms of effectiveness and practicality;
- Investigate different mixing procedures, both in terms of effectiveness and feasibility on larger scale;
- Determine effects of the amendments in different soil types and different levels of contamination;
- Understand long-term effects on PTE immobilisation, nutrient status and soil structure, using longer-term pot trials and field trials.

6. Conclusions and Further Work

The overall aim of this project was to assess the capacity of WTR to immobilise Pb, in order to establish its suitability as an *in situ* amendment in contaminated soil. The scope of the work ranged from physicochemical characterisation of WTRs, to the fundamentals of Pb sorption to WTR, and then to assess its effectiveness when applied to real contaminated soil.

6.1 Conclusions

1. Relatively little is known about the composition of WTR that is generated in the UK. The composition of WTRs from nine WTWs in north east England were investigated over the course a year, taking one sample per season from each location. The physicochemical properties of the WTRs were analysed and assessed in comparison to typical soils and biosolids values, and to WTR data reported in the literature from elsewhere. WTR is set apart from typical soils and biosolids due to its high Al or Fe hydroxide content and high organic matter content. The composition of WTRs from north east England was generally within the range of other published values reported worldwide. The results showed that there was some inter- and intra-WTW variability, but for all parameters inter-WTW variability seemed to dominate, with WTR characteristics differing between WTWs more than within WTWs temporally. It is expected that this is due to factors such as raw water quality, plant operating conditions and climate conditions.

2. A more detailed examination of the Fe-based WTR from Broken Scar WTW indicates that it is predominantly composed of NOM and Fe oxyhydroxides with smaller contributions (<10%) coming from quartz and clays. Assuming that all the C and Fe are present as NOM and Fe oxide respectively, the Fe-WTR comprises of ~23 wt.% NOM and ~70 wt.% Fe oxyhydroxides, with ferrihydrite identified as the dominant mineral form. The water treatment coagulation process creates a finely intermixed material of NOM and Fe oxyhydroxide. WTR is considered as an organo-mineral composite with altered physicochemical properties in comparison to its end-member components. SSA-N_2 analysis shows that it has a significantly lower surface area than its ferrihydrite end-member. Findings from this study and the literature indicate that WTR is a microporous material. It is suspected that the strong interactions between the NOM

and oxyhydroxide protect both components from degradation to some degree, much in the same way as organic carbon is found to be stabilised in organo-mineral complexes in the natural environment.

3. Batch sorption experiments revealed that WTR had a strong sorption capacity for Pb. The Langmuir maximum sorption capacity was calculated to be 139 mg/g and the sorption isotherm was indicative of inner-sphere complexation of Pb to WTR. Pb sorption to WTR exhibited biphasic kinetics, where initially fast sorption (seconds to hours) was followed by slow sorption (days), characteristic of metal sorption to both organic and oxide phases. Potential mechanisms for slow sorption were considered: intraparticle diffusion, sorption to sites of lower reactivity and surface nucleation-precipitation. Further sorption experiments and X-ray microprobe analysis of the Pb within the WTR grains suggests that intraparticle diffusion plays a dominant role in the slow sorption phase. Experiments showed that Pb sorption was highly pH dependent, although it was capable of functioning as a sorbent over a wide pH range. Minimal Fe dissolution from the WTR occurred, highlighting its structural stability, even under acidic conditions. Comparison of nine different WTRs revealed that all WTRs had a high Pb sorption capacity. In general, the sorption capacity of the Fe-WTRs was higher than that of the Al-WTRs.

4. The sorption behaviour of WTR was compared to that of humic acid and ferrihydrite with the aim of investigating the role of both end-member components in the Pb sorption process. WTR exhibited a lower sorption capacity in comparison to HA (200 mg/g) and Fh (170 mg/g). The sorption edge of WTR closely reflected that of Fh across the whole pH regime (pH 3-7), implying that WTR sorption behaviour is dominated by its Fh component. It is proposed that the sorption characteristics of WTR are strongly influenced by the interactions between the end-member components within this composite material. In comparison to its end-members, it is hypothesised that WTR may contain: (i) a constrained pore network (in terms of size and connectivity) due to NOM and polymer fractions occluding and heavily cross-linking oxide particles and vice versa, and (ii) a proportion of masked reactive surfaces due to NOM and polymer adsorbing to ferrihydrite. This may explain why WTR exhibits a lower adsorption capacity than that of its end members individually or additively. Importantly, it is

considered that the organo-mineral composite nature of WTR may give advantages in terms of stability and ability to function as a sorbent over a wider range of environmental conditions.

5. Plant growth trials were set up to investigate the effect of WTR amendments on immobilising Pb and As in real contaminated soil. Amendments included wet WTR, dried WTR, compost and dried WTR-compost combinations, at 5, 10, 25 and 50 wt% treatment levels. It was hypothesised that the main benefit of WTR treatments may be to reduce PTE bioavailability and therefore phytotoxicity, whereas the main benefit of the compost treatment may be to enhance nutrient availability and/or soil structure. The impact of the amendments on Pb and As bioavailability was measured through element uptake in wheat shoots. Plant growth measurements were taken as a means of assessing plant health. The trial showed that wheat grown in the PTE-contaminated soil was extremely stunted and exhibited chlorotic foliage. It is thought that this was due to phytotoxic effects, although poor soil structure may also have played a part. In comparison to the PTE-soil, almost all treatments significantly improved plant growth ($p<0.05$) and in general, growth improved with treatment level. Of the single treatment amendments, the 10% wet WTR addition most improved growth. Overall, the 50% combination treatments improved growth most significantly.

   The amendments also affected the uptake of As, Pb and P into wheat shoots. Plant uptake data showed that some treatments had a significant impact on element uptake, however the transfer coefficients (plant concentrations normalised to the soil concentrations) of treated soils were only significantly different from the PTE soil for P. Wet WTR treatments were more effective at reducing Pb and As uptake than the dry WTR treatments. The 50% wet WTR significantly reduced As uptake, whilst the 50% wet WTR, 50% compost and 50% 1:1 combination treatments significantly reduced Pb uptake. The compost treatment was ineffective at reducing As uptake, supporting the hypothesis that compost-only amendments are not suitable for immobilising As, and they may even facilitate the mobilisation of soil As. Interestingly, the findings show that the combination of dry WTR and compost performed better than would be expected from the summation of the single treatment (dry WTR and compost) performances. This suggests that any mobilisation of As that may have occurred as a result of the compost addition is counteracted by the addition of WTR, indicating that the WTR may be acting as an adsorbent for the compost-mediated mobilised As. In the case of Pb, despite the fact that dry WTR was ineffective as a single amendment, the combination treatments of dry WTR and compost reduced plant uptake similarly or more effectively than the singular compost treatments, again suggesting that there may be some benefit to applying WTR and compost as a combination. It is speculated that if the WTR is acting as a sorbent for compost-mobilised As, this may free up binding sites on the OM within compost, enabling Pb sorption to the compost rather than the WTR.

6. The plant uptake results suggest that WTR had a greater effect on reducing As uptake than Pb. This may be attributed to there being a larger, more labile pool of As than Pb, resulting in a higher probability of As interacting with the adsorbent. Although a large fraction of the Pb may still be bioaccessible, it’s relatively limited mobility means that it may not move through pore water and interact with the amendments as readily as the As, pointing towards contact being the critical factor in this remediation strategy. Wet WTR achieved greater reduction in PTE uptake than dry WTR, and this may also be due to greater physical interaction, since humic and Fe components of the wet WTR may be leached and redistributed within the soil matrix. Clearly, only the PTEs which come into direct physical contact, as a result of initially mixing the amendments into the soil or through leaching of the PTEs and/or the amendments, are likely to have a chance of becoming immobilised by the soil amendments. This highlights the challenge in using solid-state, in-situ amendments to treat relatively immobile contaminants in real contaminated soil. Nevertheless, this study produced promising results, based on a short 8-week trial. It is hypothesised that given a longer *in situ* stabilisation period in the natural environment, where soil processes such as water movement, tillage and bioturbation are expected to promote greater interaction between contaminants and adsorbents, that more As and Pb will become immobilised, resulting in a greater reduction in bioavailability over time.

6.2 Further work

This study has provided a detailed insight into the capability of WTR to act as an adsorbent of Pb. and highlights the potential for its use as a sustainable remediation method. Clearly further work is required in order to design an effective, practicable and durable remediation technology for use in the natural environment. Possibilities for further work have been highlighted throughout the thesis. The main are listed below.

- Characterisation of WTRs in relation to raw water quality and water treatment processes, in order to understand the key factors controlling their composition. This may help in understanding the 'optimum' composition for its role as an adsorbent of contaminants in the environment.

- Further characterisation and sorption studies on WTR in comparison to its organic and mineral constituents using the real end-member components would provide a clearer understanding of the factors dominating its behaviour. NOM could be isolated from the raw water for this purpose.
- X-ray absorption spectroscopy to elucidate sorption mechanisms and understanding the key mechanisms controlling the stability of WTR as an organo-mineral composite. The actual mechanism(s) of Pb sorption cannot be determined by batch sorption experiments alone. Ultimately, stronger techniques such as EXAFS are required to elucidate sorption mechanisms.

- Further insight into the kinetics of Pb sorption. Also to compare the sorption kinetics of WTR with its end-member components to test the hypothesis that WTR comprises a more constrained porous structure that of either ferrihydrite or NOM which may influence its kinetic sorption behaviour. This should include further porosity and SSA measurements such as CO_2-SSA and pore size distributions, micropore volumes, etc.

- Multi-element sorption experiments to understand WTRs behaviour and capacity to function as a sorbent of a range of PTEs. Investigate competition effects, particularly between cations and anions such as Pb and As.

- Desorption studies, over a range of environmental conditions and time frames to assess the long-term stability of WTR and the long-term immobilisation of Pb bound to WTR.

- Column studies to determine the effectiveness of WTR in removing Pb from continuous flow systems.

- Understand the long-term effects of WTR amendments on PTE immobilisation, nutrient status and soil structure, using longer-term pot trials and field trials. This should involve establishing appropriate applications rates, both in terms of effectiveness and practicality; investigating different mixing procedures, both in terms of effectiveness and feasibility on larger scale; determining effectiveness of such amendments in different soil types and different levels of contamination.

- More work on designing optimum amendment mixtures, which are capable of immobilising multiple contaminants and also of providing sufficient nutrient status and soil structure to support plant growth. As well as compost, the co-application of biosolids with WTR merits further attention.

- Ultimately, development of specific regulatory guidelines for land applications of WTR in order to encourage productive re-use of WTR.

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Appendix 1 - WTR Characterisation Data

	Autumn		Winter		Spring		Summer	
	BATCH 1		**BATCH 2**		**BATCH 3**		**BATCH 4**	
WTR	**Moisture content (%)**	StDev	**Moisture content (%)**	StDev	**Moisture content (%)**	StDev	**Moisture content (%)**	StDev
Broken Scar	82.341	0.136	83.245	0.116	78.961	0.131	80.661	0.584
Fontburn	85.340	0.166	81.609	1.655	81.243	0.516	85.497	0.117
Gunnerton	80.419	0.539	81.725	0.781	73.563	1.844	76.377	0.702
Honeyhill	81.365	0.062	85.427	0.157	81.835	0.402	83.564	0.328
Horsley	75.990	0.972	71.756	0.723	74.806	0.622	74.222	1.879
Lartington	80.763	0.056	82.384	0.256	78.985	0.178	82.293	0.091
Mosswood	77.519	0.105	78.963	0.207	82.757	0.156	79.794	0.419
Warkworth	78.414	1.608	80.823	0.922	77.518	0.735	80.361	0.762
Whittle Dene	80.657	0.569	80.542	0.541	79.956	0.242	80.957	0.498

	Autumn		Winter		Spring		Summer	
	BATCH 1		**BATCH 2**		**BATCH 3**		**BATCH 4**	
WTR	**LOI (%)**	StDev	**LOI (%)**	StDev	**LOI (%)**	StDev	**LOI (%)**	StDev
Broken Scar	38.586	0.196	36.161	0.435	36.103	0.049	36.989	0.672
Fontburn	49.903	0.397	41.522	3.980	48.187	0.211	54.734	0.209
Gunnerton	65.606	0.300	67.080	2.611	59.204	0.671	70.138	4.995
Honeyhill	54.075	0.128	51.335	0.469	48.814	0.175	49.257	0.507
Horsley	47.792	0.351	40.058	0.692	45.417	0.639	42.782	0.206
Lartington	55.939	0.024	46.222	0.612	44.965	0.081	51.547	0.425
Mosswood	45.602	0.142	46.804	0.577	47.703	0.312	51.783	0.041
Warkworth	44.926	0.461	42.582	1.444	38.682	0.461	39.121	0.572
Whittle Dene	54.347	1.544	53.497	3.604	46.263	0.507	51.304	0.559

	Autumn		Winter		Spring		Summer	
	BATCH 1		**BATCH 2**		**BATCH 3**		**BATCH 4**	
WTR	**pH**	StDev	**pH**	StDev	**pH**	StDev	**pH**	StDev
Broken Scar	5.99	0.11	6.56	0.01	6.42	0.05	6.89	0.02
Fontburn	4.51	0.01	5.42	0.05	5.27	0.07	4.70	0.03
Gunnerton	5.70	0.20	6.12	0.09	6.09	0.08	5.51	0.10
Honeyhill	4.14	0.01	5.33	0.06	4.97	0.04	5.36	0.02
Horsley	5.27	0.02	5.84	0.02	6.76	0.02	5.65	0.01
Lartington	4.80	0.02	5.63	0.03	5.26	0.14	5.13	0.04
Mosswood	4.16	0.04	5.22	0.02	4.39	0.02	5.17	0.03
Warkworth	6.38	0.32	6.98	0.12	6.75	0.02	7.04	0.04
Whittle Dene	6.25	0.08	7.15	0.04	7.07	0.13	6.71	0.09

	Autumn		Winter		Spring		Summer	
	BATCH 1		**BATCH 2**		**BATCH 3**		**BATCH 4**	
WTR	**EC**	StDev	**EC**	StDev	**EC**	StDev	**EC**	StDev
Broken Scar	307.33	27.57	190.47	12.86	210.33	7.57	186.97	6.16
Fontburn	355.33	19.22	146.97	29.56	166.07	2.98	254.00	4.36
Gunnerton	82.23	8.69	39.20	11.00	124.43	0.51	74.30	5.94
Honeyhill	218.67	3.79	167.47	18.58	119.07	4.34	392.33	25.77
Horsley	295.67	7.64	404.67	23.76	291.00	15.72	316.67	9.87
Lartington	173.87	27.99	101.77	13.21	286.67	20.50	79.47	7.55
Mosswood	366.67	32.93	137.87	14.04	396.00	28.00	57.33	6.93
Warkworth	211.67	17.10	318.67	4.04	206.00	4.36	218.67	2.89
Whittle Dene	187.87	14.59	266.67	14.98	370.33	8.50	268.33	16.29

	Autumn		Winter		Spring		Summer	
	BATCH 1		**BATCH 2**		**BATCH 3**		**BATCH 4**	
WTR	**TOT. N**	StDev	**TOT. N**	StDev	**TOT. N**	StDev	**TOT. N**	StDev
Broken Scar	0.5515	0.0042	0.5696	0.0169	0.7156	0.0046	0.6375	0.0034
Fontburn	0.6031	0.0077	0.5853	0.0083	0.6614	0.0194	0.8547	0.0129
Gunnerton	0.7159	0.0150	0.6607	0.0078	0.6863	0.0109	0.8306	0.0365
Honeyhill	0.7211	0.0003	0.6479	0.0261	0.7802	0.0038	0.7616	0.0022
Horsley	0.7207	0.0052	0.5500	0.0046	0.7150	0.0039	0.7106	0.0038
Lartington	0.8055	0.0052	0.6646	0.0146	0.6932	0.0213	0.8370	0.0406
Mosswood	0.7780	0.0007	0.6914	0.0044	0.7497	0.0025	0.9123	0.0215
Warkworth	0.5838	0.0180	0.5156	0.0021	0.6593	0.0076	0.6015	0.0110
Whittle Dene	0.7412	0.0209	0.7250	0.0082	1.0720	0.0041	0.9635	0.0248

	Autumn		Winter		Spring		Summer	
	BATCH 1		**BATCH 2**		**BATCH 3**		**BATCH 4**	
WTR	**TOT. C**	StDev	**TOT. C**	StDev	**TOT. C**	StDev	**TOT. C**	StDev
Broken Scar	13.3071	0.8876	15.7855	0.0889	15.8624	0.1753	16.6886	0.0101
Fontburn	20.8780	0.1245	20.2174	0.5109	22.9921	0.6611	26.5825	0.0689
Gunnerton	25.7609	0.7671	25.4732	1.8186	22.5630	0.3388	26.1647	0.3352
Honeyhill	23.5350	0.8842	23.1590	0.1670	23.3967	0.4014	23.6357	0.0470
Horsley	18.1146	0.0366	15.5229	0.0810	15.9523	0.3951	17.2122	0.1588
Lartington	24.4934	0.0789	20.4541	1.6331	20.4491	0.1960	24.0234	0.1336
Mosswood	18.5617	0.1071	20.9794	0.3413	22.1160	0.4406	23.9319	0.0998
Warkworth	14.3312	0.0919	12.9153	0.4875	14.8320	0.0587	14.0643	0.1132
Whittle Dene	19.3607	0.0876	18.5501	0.0809	16.5868	0.2388	18.3871	0.4491

	Al (%)				Fe (%)			
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
WTR	**BATCH 1**	**BATCH 2**	**BATCH 3**	**BATCH 4**	**BATCH 1**	**BATCH 2**	**BATCH 3**	**BATCH 4**
Broken Scar	0.35	0.53	0.37	0.31	37	32	31	35
Fontburn	0.21	0.28	0.24	0.23	28	27	29	28
Gunnerton	15	21	17	10	1.1	1.7	1.5	1.5
Honeyhill	0.27	0.52	0.8	0.32	35	25	28	29
Horsley	6.1	7.7	15	9.2	14	19	1.5	18
Lartington	0.25	0.72	0.33	0.37	31	27	31	29
Mosswood	0.28	0.88	0.36	0.27	31	27	29	28
Warkworth	18	16	10	17	1.5	1.2	1.8	2.3
Whittle Dene	15	16	16	18	0.83	1	1.4	0.76

	P (mg/kg)				Mg (mg/kg)			
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
WTR	**BATCH 1**	**BATCH 2**	**BATCH 3**	**BATCH 4**	**BATCH 1**	**BATCH 2**	**BATCH 3**	**BATCH 4**
Broken Scar	610.99	1221.98	872.84	654.63	540	750	600	780
Fontburn	375.32	567.35	301.13	405.87	240	280	270	230
Gunnerton	3.97	436.42	340.41	309.86	250	450	340	1100
Honeyhill	427.69	436.42	292.40	253.12	300	290	220	170
Horsley	8.73	698.27	741.91	610.99	1200	460	560	570
Lartington	353.50	610.99	344.77	375.32	250	680	340	360
Mosswood	480.06	698.27	274.94	436.42	270	600	180	290
Warkworth	1527.47	1396.54	872.84	1352.90	1900	1100	2700	2900
Whittle Dene	785.56	829.20	1134.69	829.20	290	450	780	350

	Pb (mg/kg)				Cu (mg/kg)			
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
WTR	**BATCH 1**	**BATCH 2**	**BATCH 3**	**BATCH 4**	**BATCH 1**	**BATCH 2**	**BATCH 3**	**BATCH 4**
Broken Scar	140	160	120	140	18	23	18	18
Fontburn	5	13	43	11	8.8	11	7.9	9.6
Gunnerton	13	16	9.1	15	15	23	13	17
Honeyhill	26	50	9.5	41	20	20	16	15
Horsley	58	54	70	48	24	21	23	15
Lartington	18	36	19	29	21	28	21	25
Mosswood	39	190	40	71	26	36	16	29
Warkworth	15	11	16	17	33	28	24	28
Whittle Dene	4	9.3	15	5.4	17	20	23	18

	Cr (mg/kg)				**Ni (mg/kg)**			
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
WTR	**BATCH 1**	**BATCH 2**	**BATCH 3**	**BATCH 4**	**BATCH 1**	**BATCH 2**	**BATCH 3**	**BATCH 4**
Broken Scar	39	37	28	22	59	45	37	45
Fontburn	27	30	28	15	35	29	24	22
Gunnerton	7.8	14	10	16	10	22	13	13
Honeyhill	36	33	30	19	47	61	45	44
Horsley	18	28	13	16	64	24	27	13
Lartington	32	37	34	24	42	66	50	53
Mosswood	36	38	30	22	95	110	41	120
Warkworth	18	16	28	27	22	19	21	24
Whittle Dene	6.1	9.5	16	7.6	11	16	20	13

	Zn (mg/kg)				**Hg (mg/kg)**			
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
WTR	**BATCH 1**	**BATCH 2**	**BATCH 3**	**BATCH 4**	**BATCH 1**	**BATCH 2**	**BATCH 3**	**BATCH 4**
Broken Scar	210	240	200	220	0.14	0.55	0.49	<0.060
Fontburn	120	79	56	51	0.25	1.4	0.95	<0.060
Gunnerton	64	82	53	40	0.16	0.16	0.12	0.085
Honeyhill	210	250	190	190	0.34	0.15	1.8	0.18
Horsley	770	200	320	95	0.13	0.19	0.15	0.066
Lartington	120	210	130	160	0.12	0.15	0.38	<0.060
Mosswood	550	850	160	1100	0.16	0.27	0.64	<0.060
Warkworth	69	62	68	72	0.084	0.075	0.13	<0.060
Whittle Dene	38	38	55	28	0.089	0.1	0.099	<0.060

	K (mg/kg)				**Mn (mg/kg)**			
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
WTR	**BATCH 1**	**BATCH 2**	**BATCH 3**	**BATCH 4**	**BATCH 1**	**BATCH 2**	**BATCH 3**	**BATCH 4**
Broken Scar	530	1100	1000	620	850	1400	1300	1200
Fontburn	230	210	590	170	1100	540	350	440
Gunnerton	350	560	580	3900	760	680	520	420
Honeyhill	390	410	730	170	1600	1600	1100	1100
Horsley	600	680	1100	1200	5100	730	1200	500
Lartington	330	1400	970	570	680	1000	930	1200
Mosswood	460	1600	910	360	1600	2200	1000	2500
Warkworth	1700	690	3000	3500	2200	2500	550	720
Whittle Dene	320	320	1400	380	1200	370	800	2400

	Cd (mg/kg)			
	Autumn	Winter	Spring	Summer
WTR	**BATCH 1**	**BATCH 2**	**BATCH 3**	**BATCH 4**
Broken Scar	0.8	0.76	0.82	1.1
Fontburn	0.33	0.3	0.29	0.33
Gunnerton	<0.20	0.3	<0.30	<0.30
Honeyhill	0.61	0.92	0.9	0.67
Horsley	2.2	0.46	0.83	0.37
Lartington	0.5	0.83	0.74	0.8
Mosswood	1.6	3.6	0.75	3.5
Warkworth	0.21	<0.20	<0.30	<0.30
Whittle Dene	<0.20	0.21	0.23	<0.30

Appendix 2 - NWL Raw Water Quality Data

Broken Scar WTW raw

Spt Desc	Detdesc	Datetaken	Value	Unitused
Broken Scar WTW Raw- River Tees	Hydrogen ion	01/21/11	7.8	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	02/25/11	7.6	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	03/25/11	8	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	04/22/11	8.3	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	05/20/11	7.5	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	06/24/11	5.9	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	07/22/11	7.3	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	08/26/11	7.6	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	09/23/11	7.4	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	10/21/11	7.5	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	11/25/11	7.8	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	12/23/11	7.3	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	01/06/12	7.2	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	02/17/12	7.8	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	03/16/12	8.1	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	04/06/12	7.7	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	05/04/12	7.8	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	06/01/12	7.8	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	07/06/12	7.3	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	08/17/12	7.4	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	09/07/12	7.6	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	10/05/12	7.4	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	11/16/12	7.6	pH Value
Broken Scar WTW Raw- River Tees	Hydrogen ion	12/07/12	7.7	pH Value
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	01/21/11	220	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	02/25/11	180	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	03/25/11	260	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	04/22/11	240	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	05/20/11	140	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	06/24/11	200	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	07/22/11	91	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	08/26/11	140	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	09/23/11	99	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	10/21/11	120	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	11/25/11	110	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	12/23/11	100	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	01/06/12	150	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	02/17/12	150	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	03/16/12	180	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	04/06/12	250	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	05/04/12	250	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	06/01/12	210	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	07/06/12	130	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	08/17/12	150	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	09/07/12	180	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	10/05/12	150	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	11/16/12	160	uS/cm
Broken Scar WTW Raw- River Tees	Conductivity 20 Deg. C	12/07/12	230	uS/cm
Broken Scar WTW Raw- River Tees	Turbidity	01/21/11	1.9	NTU

Broken Scar WTW Raw- River Tees	Turbidity	02/25/11	3	NTU
Broken Scar WTW Raw- River Tees	Turbidity	03/25/11	1.8	NTU
Broken Scar WTW Raw- River Tees	Turbidity	04/22/11	3.4	NTU
Broken Scar WTW Raw- River Tees	Turbidity	05/20/11	2.7	NTU
Broken Scar WTW Raw- River Tees	Turbidity	06/24/11	53	NTU
Broken Scar WTW Raw- River Tees	Turbidity	07/22/11	4.2	NTU
Broken Scar WTW Raw- River Tees	Turbidity	08/26/11	1.5	NTU
Broken Scar WTW Raw- River Tees	Turbidity	09/23/11	1.7	NTU
Broken Scar WTW Raw- River Tees	Turbidity	10/21/11	1.5	NTU
Broken Scar WTW Raw- River Tees	Turbidity	11/25/11	4.1	NTU
Broken Scar WTW Raw- River Tees	Turbidity	12/23/11	6.4	NTU
Broken Scar WTW Raw- River Tees	Turbidity	01/06/12	4.7	NTU
Broken Scar WTW Raw- River Tees	Turbidity	02/17/12	3.4	NTU
Broken Scar WTW Raw- River Tees	Turbidity	03/16/12	1.3	NTU
Broken Scar WTW Raw- River Tees	Turbidity	04/06/12	1.3	NTU
Broken Scar WTW Raw- River Tees	Turbidity	05/04/12	2.6	NTU
Broken Scar WTW Raw- River Tees	Turbidity	06/01/12	1.4	NTU
Broken Scar WTW Raw- River Tees	Turbidity	07/06/12	16	NTU
Broken Scar WTW Raw- River Tees	Turbidity	08/17/12	5.5	NTU
Broken Scar WTW Raw- River Tees	Turbidity	09/07/12	1.1	NTU
Broken Scar WTW Raw- River Tees	Turbidity	10/05/12	3.3	NTU
Broken Scar WTW Raw- River Tees	Turbidity	11/16/12	1.8	NTU
Broken Scar WTW Raw- River Tees	Turbidity	12/07/12	4.3	NTU
Broken Scar WTW Raw- River Tees	Colour Filtered	01/21/11	42	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	02/25/11	61	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	03/25/11	32	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	04/22/11	32	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	05/20/11	70	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	06/24/11	5.2	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	07/22/11	170	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	08/26/11	81	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	09/23/11	120	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	10/21/11	100	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	11/25/11	150	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	12/23/11	69	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	01/06/12	59	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	02/17/12	58	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	03/16/12	49	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	04/06/12	46	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	05/04/12	44	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	06/01/12	43	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	07/06/12	150	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	08/17/12	150	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	09/07/12	76	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	10/05/12	100	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	11/16/12	89	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Colour Filtered	12/07/12	63	mg/l Pt/Co scal
Broken Scar WTW Raw- River Tees	Temperature Deg. C	01/21/11	4.3	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	02/25/11	0.4	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	03/25/11	10.6	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	03/27/11	7.1	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	04/22/11	13.5	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	05/20/11	14.8	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	06/24/11	10.8	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	07/22/11	14.5	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	08/26/11	15.7	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	09/23/11	14.7	Deg. C

Broken Scar WTW Raw- River Tees	Temperature Deg. C	10/21/11	11.1	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	11/25/11	11.2	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	12/23/11	10.3	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	01/06/12	8.7	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	02/17/12	8.1	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	03/16/12	12.1	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	04/06/12	8.3	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	05/04/12	11.2	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	06/01/12	15.4	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	07/06/12	16.2	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	08/17/12	17.4	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	09/07/12	17.3	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	10/05/12	14.6	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	11/16/12	11.9	Deg. C
Broken Scar WTW Raw- River Tees	Temperature Deg. C	12/07/12	6.2	Deg. C
Broken Scar WTW Raw- River Tees	Total Organic Carbon	01/07/11	8.1	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	01/14/11	8.6	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	01/21/11	5.6	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	01/28/11	8	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	02/04/11	11	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	02/11/11	6.9	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	02/18/11	7.4	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	02/25/11	7	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	03/04/11	5.4	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	03/11/11	12	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	03/18/11	5.6	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	03/25/11	4.3	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	04/01/11	4.3	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	04/08/11	8.7	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	04/15/11	5.1	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	04/22/11	4.8	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	04/29/11	5	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	05/06/11	5.3	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	05/13/11	5.9	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	05/20/11	8.9	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	05/27/11	8.8	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	06/03/11	7.1	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	06/10/11	6.2	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	06/17/11	8.2	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	06/24/11	18	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	07/01/11	7.8	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	07/08/11	6.5	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	07/15/11	7.9	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	07/22/11	20	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	07/29/11	7.7	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	08/05/11	8	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	08/11/11	21	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	08/19/11	13	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	08/26/11	9.4	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	09/02/11	9.8	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	09/09/11	16	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	09/16/11	12	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	09/23/11	14	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	09/30/11	10	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	10/07/11	18	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	10/14/11	14	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	10/21/11	11	mg/l

Broken Scar WTW Raw- River Tees	Total Organic Carbon	10/28/11	11	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	11/04/11	17	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	11/11/11	11	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	11/18/11	9.7	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	11/25/11	16	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	12/02/11	12	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	12/09/11	9.7	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	12/16/11	7.2	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	12/23/11	7.2	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	12/30/11	8.9	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	01/06/12	6.7	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	01/13/12	5.9	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	01/20/12	6	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	01/27/12	6.9	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	02/03/12	5.3	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	02/10/12	6.2	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	02/17/12	6.9	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	02/24/12	8	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	03/02/12	5.8	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	03/09/12	9.3	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	03/16/12	5.7	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	03/23/12	5.3	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	03/30/12	5.2	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	04/06/12	5.9	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	04/13/12	12	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	04/20/12	11	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	04/27/12	11	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	05/04/12	5.6	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	05/11/12	12	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	05/18/12	5.6	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	05/25/12	5.8	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	06/01/12	5.4	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	06/08/12	8	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	06/15/12	6.5	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	06/22/12	16	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	06/29/12	15	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	07/06/12	18	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	07/13/12	12	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	07/20/12	19	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	07/27/12	7.7	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	08/03/12	16	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	08/10/12	10	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	08/17/12	18	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	08/24/12	14	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	08/31/12	16	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	09/07/12	8.2	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	09/14/12	14	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	09/21/12	11	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	09/28/12	9	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	10/05/12	10	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	10/12/12	12	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	10/19/12	11	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	10/26/12	11	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	11/02/12	11	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	11/09/12	10	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	11/16/12	9.7	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	11/23/12	14	mg/l

Broken Scar WTW Raw- River Tees	Total Organic Carbon	11/30/12	7.5	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	12/07/12	7.7	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	12/14/12	6.3	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	12/21/12	9.2	mg/l
Broken Scar WTW Raw- River Tees	Total Organic Carbon	12/28/12	8.1	mg/l
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	01/21/11	0.015	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	02/25/11	0.015	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	03/25/11	0.013	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	04/22/11	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	05/20/11	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	06/24/11	0.023	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	07/22/11	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	08/26/11	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	09/23/11	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	10/21/11	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	11/25/11	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	12/23/11	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	01/06/12	0.016	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	02/17/12	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	03/16/12	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	04/06/12	0.015	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	05/04/12	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	06/01/12	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	07/06/12	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	08/17/12	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	09/07/12	0.012	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	10/05/12	0.007	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	11/16/12	0.007	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrogen Ammoniacal	12/07/12	0.05	mg/l as NH4
Broken Scar WTW Raw- River Tees	Nitrate	01/21/11	7.9	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	02/25/11	7.1	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	03/25/11	6.3	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	04/22/11	3.6	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	05/20/11	3	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	06/24/11	2.7	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	07/22/11	2.7	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	08/26/11	2.7	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	09/23/11	2.7	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	10/21/11	2.7	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	11/25/11	2.7	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	12/23/11	2.7	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	01/06/12	5.3	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	02/17/12	4.8	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	03/16/12	2.7	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	04/06/12	3.5	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	05/04/12	7.9	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	06/01/12	4.3	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	07/06/12	2.8	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	08/17/12	3.5	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	09/07/12	4	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	10/05/12	3.4	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	11/16/12	2.1	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrate	12/07/12	5.6	mg/l as NO3
Broken Scar WTW Raw- River Tees	Nitrite	01/21/11	0.0072	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	02/25/11	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	03/25/11	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	04/22/11	0.0014	mg/l as NO2

Broken Scar WTW Raw- River Tees	Nitrite	05/20/11	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	06/24/11	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	07/22/11	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	08/26/11	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	09/23/11	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	10/21/11	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	11/25/11	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	12/23/11	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	01/06/12	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	02/17/12	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	03/16/12	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	04/06/12	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	05/04/12	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	06/01/12	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	07/06/12	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	08/17/12	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	09/07/12	0.0014	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	10/05/12	0.0011	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	11/16/12	0.0011	mg/l as NO2
Broken Scar WTW Raw- River Tees	Nitrite	12/07/12	0.0011	mg/l as NO2
Broken Scar WTW Raw- River Tees	Hardness Total	01/21/11	41	mg/l
Broken Scar WTW Raw- River Tees	Hardness Total	02/25/11	33	mg/l
Broken Scar WTW Raw- River Tees	Hardness Total	03/25/11	49	mg/l
Broken Scar WTW Raw- River Tees	Hardness Total	04/22/11	46	mg/l
Broken Scar WTW Raw- River Tees	Hardness Total	05/20/11	29	mg/l
Broken Scar WTW Raw- River Tees	Hardness Total	06/24/11	37	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	07/22/11	17	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	08/26/11	27	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	09/23/11	21	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	10/21/11	25	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	11/25/11	24	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	12/23/11	18	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	01/06/12	28	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	02/17/12	29	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	03/16/12	33	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	04/06/12	39	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	05/04/12	51	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	06/01/12	41	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	07/06/12	26	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	08/17/12	28	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	09/07/12	34	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	10/05/12	30	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	11/16/12	32	mg/l as Ca
Broken Scar WTW Raw- River Tees	Hardness Total	12/07/12	40	mg/l as Ca
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	01/21/11	100	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	02/25/11	68	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	03/25/11	120	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	04/22/11	120	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	05/20/11	47	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	06/24/11	17	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	07/22/11	46	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	08/26/11	64	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	09/23/11	46	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	10/21/11	62	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	11/25/11	57	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	12/23/11	41	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	01/06/12	54	mg/l as HCO3

Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	02/17/12	56	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	03/16/12	74	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	04/06/12	87	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	05/04/12	110	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	06/01/12	90	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	07/06/12	61	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	08/17/12	74	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	09/07/12	100	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	10/05/12	69	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	11/16/12	74	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Alkalinity to pH 4.5 (Total)	12/07/12	87	mg/l as HCO3
Broken Scar WTW Raw- River Tees	Chloride	01/21/11	18	mg/l
Broken Scar WTW Raw- River Tees	Chloride	02/25/11	14	mg/l
Broken Scar WTW Raw- River Tees	Chloride	03/25/11	17	mg/l
Broken Scar WTW Raw- River Tees	Chloride	04/22/11	15	mg/l
Broken Scar WTW Raw- River Tees	Chloride	05/20/11	8.2	mg/l
Broken Scar WTW Raw- River Tees	Chloride	06/24/11	7.3	mg/l
Broken Scar WTW Raw- River Tees	Chloride	07/22/11	7	mg/l
Broken Scar WTW Raw- River Tees	Chloride	08/26/11	8.9	mg/l
Broken Scar WTW Raw- River Tees	Chloride	09/23/11	6.9	mg/l
Broken Scar WTW Raw- River Tees	Chloride	10/21/11	7.7	mg/l
Broken Scar WTW Raw- River Tees	Chloride	11/25/11	7.1	mg/l
Broken Scar WTW Raw- River Tees	Chloride	12/23/11	9.2	mg/l
Broken Scar WTW Raw- River Tees	Chloride	01/06/12	13	mg/l
Broken Scar WTW Raw- River Tees	Chloride	02/17/12	13	mg/l
Broken Scar WTW Raw- River Tees	Chloride	03/16/12	12	mg/l
Broken Scar WTW Raw- River Tees	Chloride	04/06/12	34	mg/l
Broken Scar WTW Raw- River Tees	Chloride	05/04/12	19	mg/l
Broken Scar WTW Raw- River Tees	Chloride	06/01/12	14	mg/l
Broken Scar WTW Raw- River Tees	Chloride	07/06/12	7.8	mg/l
Broken Scar WTW Raw- River Tees	Chloride	08/17/12	9	mg/l
Broken Scar WTW Raw- River Tees	Chloride	09/07/12	9.4	mg/l
Broken Scar WTW Raw- River Tees	Chloride	10/05/12	8.5	mg/l
Broken Scar WTW Raw- River Tees	Chloride	11/16/12	8.4	mg/l
Broken Scar WTW Raw- River Tees	Chloride	12/07/12	26	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	01/21/11	14	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	02/25/11	12	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	03/25/11	17	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	04/22/11	16	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	05/20/11	1.5	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	06/24/11	74	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	07/22/11	0.49	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	08/26/11	0.49	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	09/23/11	0.49	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	10/21/11	0.49	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	11/25/11	0.49	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	12/23/11	0.49	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	01/06/12	4.8	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	02/17/12	11	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	03/16/12	12	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	04/06/12	14	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	05/04/12	19	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	06/01/12	15	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	07/06/12	0.49	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	08/17/12	0.49	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	09/07/12	2.8	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	10/05/12	0.29	mg/l

Broken Scar WTW Raw- River Tees	Sulphate Dissolved	11/16/12	0.29	mg/l
Broken Scar WTW Raw- River Tees	Sulphate Dissolved	12/07/12	14	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	01/21/11	9.7	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	02/25/11	8.2	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	03/25/11	12	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	04/22/11	10	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	05/20/11	6.7	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	06/24/11	5.7	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	07/22/11	5.6	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	08/26/11	6.6	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	09/23/11	5.2	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	10/21/11	5.9	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	11/25/11	5.7	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	12/23/11	6	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	01/06/12	8.5	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	02/17/12	8.1	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	03/16/12	8.7	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	04/06/12	21	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	05/04/12	12	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	06/01/12	9.2	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	07/06/12	6.3	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	08/17/12	6.3	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	09/07/12	6.9	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	10/05/12	5.7	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	11/16/12	6.2	mg/l
Broken Scar WTW Raw- River Tees	Sodium Total	12/07/12	17	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	01/21/11	4.8	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	02/25/11	4.4	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	03/25/11	7.3	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	04/22/11	6.7	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	05/20/11	4.6	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	06/24/11	4.4	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	07/22/11	0.83	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	08/26/11	3.9	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	09/23/11	2.9	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	10/21/11	3.3	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	11/25/11	3.1	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	12/23/11	2.3	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	01/06/12	3.7	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	02/17/12	4.1	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	03/16/12	4.7	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	04/06/12	5.1	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	05/04/12	5.7	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	06/01/12	5.7	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	07/06/12	3.3	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	08/17/12	3.9	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	09/07/12	5	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	10/05/12	3.6	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	11/16/12	4.1	mg/l
Broken Scar WTW Raw- River Tees	Magnesium Total	12/07/12	5.2	mg/l
Broken Scar WTW Raw- River Tees	Calcium Total	01/21/11	33	mg/l
Broken Scar WTW Raw- River Tees	Calcium Total	02/25/11	26	mg/l
Broken Scar WTW Raw- River Tees	Calcium Total	03/25/11	37	mg/l
Broken Scar WTW Raw- River Tees	Calcium Total	04/22/11	35	mg/l
Broken Scar WTW Raw- River Tees	Calcium Total	05/20/11	21	mg/l
Broken Scar WTW Raw- River Tees	Calcium Total	06/24/11	30	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	07/22/11	15	mg/l as Ca

Broken Scar WTW Raw- River Tees	Calcium Total	08/26/11	21	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	09/23/11	17	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	10/21/11	19	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	11/25/11	19	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	12/23/11	14	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	01/06/12	21	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	02/17/12	22	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	03/16/12	26	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	04/06/12	31	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	05/04/12	42	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	06/01/12	31	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	07/06/12	21	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	08/17/12	22	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	09/07/12	26	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	10/05/12	24	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	11/16/12	25	mg/l as Ca
Broken Scar WTW Raw- River Tees	Calcium Total	12/07/12	32	mg/l as Ca
Broken Scar WTW Raw- River Tees	Cadmium Total	01/21/11	0.022	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	02/25/11	0.042	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	03/25/11	0.023	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	04/22/11	0.063	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	05/20/11	0.043	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	06/24/11	0.11	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	07/22/11	0.061	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	08/26/11	0.033	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	09/23/11	0.041	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	10/21/11	0.029	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	11/25/11	0.054	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	12/23/11	0.013	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	01/06/12	0.0081	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	02/17/12	0.023	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	03/16/12	0.033	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	04/06/12	0.025	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	05/04/12	0.031	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	06/01/12	0.047	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	07/06/12	0.094	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	08/17/12	0.044	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	09/07/12	0.016	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	10/05/12	0.027	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	11/16/12	0.011	ug/l
Broken Scar WTW Raw- River Tees	Cadmium Total	12/07/12	0.02	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	01/21/11	90	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	02/25/11	150	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	03/25/11	82	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	04/22/11	150	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	05/20/11	93	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	06/24/11	270	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	07/22/11	200	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	08/26/11	69	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	09/23/11	96	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	10/21/11	90	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	11/25/11	140	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	12/23/11	180	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	01/06/12	250	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	02/17/12	96	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	03/16/12	60	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	04/06/12	43	ug/l

Broken Scar WTW Raw- River Tees	Aluminium Total	05/04/12	200	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	06/01/12	85	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	07/06/12	780	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	08/17/12	180	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	09/07/12	100	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	10/05/12	150	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	11/16/12	64	ug/l
Broken Scar WTW Raw- River Tees	Aluminium Total	12/07/12	180	ug/l
Broken Scar WTW Raw- River Tees	Lead Dissolved	03/27/11	1.1	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	01/21/11	11	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	02/25/11	7.7	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	03/25/11	4.7	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	03/27/11	4.3	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	04/22/11	7.1	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	05/20/11	8.1	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	06/24/11	9	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	07/22/11	14	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	08/26/11	5.3	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	09/23/11	7.4	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	10/21/11	5.1	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	11/25/11	9.1	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	12/23/11	9.1	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	01/06/12	7	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	02/17/12	5	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	03/16/12	4.3	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	04/06/12	2.8	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	05/04/12	6.1	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	06/01/12	7.6	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	07/06/12	28	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	08/17/12	17	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	09/07/12	10	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	10/05/12	9.5	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	11/16/12	5.6	ug/l
Broken Scar WTW Raw- River Tees	Lead Total	12/07/12	3.5	ug/l
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	01/21/11	120	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	02/25/11	28	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	03/25/11	32	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	04/22/11	35	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	05/20/11	46	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	06/24/11	24	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	07/22/11	38	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	08/26/11	36	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	09/23/11	25	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	10/21/11	24	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	11/25/11	41	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	12/23/11	22	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	01/06/12	26	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	02/17/12	26	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	03/16/12	25	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	04/06/12	27	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	05/04/12	38	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	06/01/12	28	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	07/06/12	82	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	08/17/12	48	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	09/07/12	33	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	10/05/12	29	ug/l as P
Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	11/16/12	25	ug/l as P

Broken Scar WTW Raw- River Tees	Phosphorus Total (As P)	12/07/12	42	ug/l as P
Broken Scar WTW Raw- River Tees	Manganese Total	01/21/11	7.3	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	02/25/11	18	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	03/25/11	15	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	04/22/11	62	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	05/20/11	28	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	06/24/11	220	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	07/22/11	25	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	08/26/11	13	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	09/23/11	9.3	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	10/21/11	11	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	11/25/11	23	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	12/23/11	18	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	01/06/12	11	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	02/17/12	7.1	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	03/16/12	13	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	04/06/12	6.4	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	05/04/12	22	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	06/01/12	27	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	07/06/12	47	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	08/17/12	27	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	09/07/12	20	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	10/05/12	20	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	11/16/12	6.8	ug/l
Broken Scar WTW Raw- River Tees	Manganese Total	12/07/12	6.1	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	01/21/11	230	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	02/25/11	350	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	03/25/11	200	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	04/22/11	370	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	05/20/11	340	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	06/24/11	31000	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	07/22/11	730	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	08/26/11	320	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	09/23/11	540	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	10/21/11	440	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	11/25/11	830	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	12/23/11	600	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	01/06/12	350	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	02/17/12	540	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	03/16/12	220	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	04/06/12	180	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	05/04/12	330	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	06/01/12	270	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	07/06/12	1100	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	08/17/12	770	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	09/07/12	380	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	10/05/12	520	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	11/16/12	360	ug/l
Broken Scar WTW Raw- River Tees	Iron Total	12/07/12	350	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	01/21/11	1.6	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	02/25/11	1.2	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	03/25/11	1.1	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	04/22/11	1.1	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	05/20/11	1.4	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	06/24/11	10	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	07/22/11	1.9	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	08/26/11	1.1	ug/l

Broken Scar WTW Raw- River Tees	Nickel Total	09/23/11	1.3	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	10/21/11	1.2	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	11/25/11	1.5	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	12/23/11	0.9	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	01/06/12	1.3	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	02/17/12	0.92	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	03/16/12	0.64	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	04/06/12	0.63	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	05/04/12	0.75	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	06/01/12	1	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	07/06/12	2.6	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	08/17/12	1.6	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	09/07/12	1.1	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	10/05/12	1.3	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	11/16/12	0.78	ug/l
Broken Scar WTW Raw- River Tees	Nickel Total	12/07/12	0.84	ug/l

Fontburn WTW raw

Spt Desc	Detdesc	Datetaken	Value	Unitused
Fontburn WTW raw - reservoir	Hydrogen ion	01/13/11	7.1	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	02/17/11	7.1	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	03/17/11	7.3	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	04/14/11	7.6	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	05/19/11	7.6	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	06/16/11	7.5	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	07/14/11	7.5	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	08/18/11	6.9	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	09/15/11	7.8	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	10/13/11	7.6	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	11/17/11	7.4	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	12/15/11	7.8	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	01/04/12	7.5	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	02/01/12	7.5	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	03/07/12	7.6	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	04/04/12	7.6	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	05/02/12	7.3	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	06/06/12	7.2	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	07/04/12	6.8	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	08/01/12	7.5	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	09/05/12	7.2	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	10/03/12	6.9	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	11/08/12	7.3	pH Value
Fontburn WTW raw - reservoir	Hydrogen ion	12/05/12	7.6	pH Value
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	01/13/11	120	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	02/17/11	90	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	03/17/11	98	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	04/14/11	110	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	05/19/11	120	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	06/16/11	140	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	07/14/11	140	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	08/18/11	100	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	09/15/11	120	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	10/13/11	130	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	11/17/11	140	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	12/15/11	130	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	01/04/12	120	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	02/01/12	130	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	03/07/12	130	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	04/04/12	150	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	05/02/12	110	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	06/06/12	100	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	07/04/12	96	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	08/01/12	100	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	09/05/12	100	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	10/03/12	82	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	11/08/12	90	uS/cm
Fontburn WTW raw - reservoir	Conductivity 20 Deg. C	12/05/12	83	uS/cm
Fontburn WTW raw - reservoir	Turbidity	01/13/11	9.1	NTU
Fontburn WTW raw - reservoir	Turbidity	02/17/11	3.7	NTU
Fontburn WTW raw - reservoir	Turbidity	03/17/11	2.6	NTU
Fontburn WTW raw - reservoir	Turbidity	04/14/11	2.8	NTU
Fontburn WTW raw - reservoir	Turbidity	05/19/11	2.5	NTU
Fontburn WTW raw - reservoir	Turbidity	06/16/11	5	NTU

Fontburn WTW raw - reservoir	Turbidity	07/14/11	2.2	NTU
Fontburn WTW raw - reservoir	Turbidity	08/18/11	1.9	NTU
Fontburn WTW raw - reservoir	Turbidity	09/15/11	2.9	NTU
Fontburn WTW raw - reservoir	Turbidity	10/13/11	3.1	NTU
Fontburn WTW raw - reservoir	Turbidity	11/17/11	3.8	NTU
Fontburn WTW raw - reservoir	Turbidity	12/15/11	7	NTU
Fontburn WTW raw - reservoir	Turbidity	01/04/12	5.1	NTU
Fontburn WTW raw - reservoir	Turbidity	02/01/12	3.9	NTU
Fontburn WTW raw - reservoir	Turbidity	03/07/12	3.7	NTU
Fontburn WTW raw - reservoir	Turbidity	04/04/12	3.6	NTU
Fontburn WTW raw - reservoir	Turbidity	05/02/12	5.5	NTU
Fontburn WTW raw - reservoir	Turbidity	06/06/12	2.1	NTU
Fontburn WTW raw - reservoir	Turbidity	07/04/12	2.9	NTU
Fontburn WTW raw - reservoir	Turbidity	08/01/12	2	NTU
Fontburn WTW raw - reservoir	Turbidity	09/05/12	2.9	NTU
Fontburn WTW raw - reservoir	Turbidity	10/03/12	5.3	NTU
Fontburn WTW raw - reservoir	Turbidity	11/08/12	2.8	NTU
Fontburn WTW raw - reservoir	Turbidity	12/05/12	16	NTU
Fontburn WTW raw - reservoir	Colour Filtered	01/13/11	190	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	02/17/11	200	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	03/17/11	190	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	04/14/11	180	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	05/19/11	150	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	06/16/11	130	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	07/14/11	160	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	08/18/11	300	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	09/15/11	230	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	10/13/11	200	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	11/17/11	210	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	12/15/11	240	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	01/04/12	260	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	02/01/12	230	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	03/07/12	200	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	04/04/12	190	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	05/02/12	210	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	06/06/12	180	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	07/04/12	280	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	08/01/12	350	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	09/05/12	380	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	10/03/12	300	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	11/08/12	290	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Colour Filtered	12/05/12	300	mg/l Pt/Co scal
Fontburn WTW raw - reservoir	Temperature Deg. C	01/13/11	4.1	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	02/17/11	3.5	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	03/17/11	4.3	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	04/14/11	9.2	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	05/19/11	11.6	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	06/16/11	10.8	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	07/14/11	15.3	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	08/18/11	16.4	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	09/15/11	12.5	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	10/13/11	11.8	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	11/17/11	8.5	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	12/15/11	3.3	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	01/04/12	3.9	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	02/01/12	2.7	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	03/07/12	5.6	Deg. C

Fontburn WTW raw - reservoir	Temperature Deg. C	04/04/12	7.2	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	05/02/12	8.9	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	06/06/12	10.2	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	07/04/12	12.9	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	08/01/12	11.7	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	09/05/12	9.7	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	10/03/12	10.9	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	11/08/12	10	Deg. C
Fontburn WTW raw - reservoir	Temperature Deg. C	12/05/12	5.4	Deg. C
Fontburn WTW raw - reservoir	Total Organic Carbon	01/06/11	24	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	01/13/11	23	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	01/20/11	24	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	01/27/11	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	02/03/11	24	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	02/10/11	24	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	02/17/11	24	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	02/24/11	24	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	03/03/11	23	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	03/10/11	23	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	03/17/11	23	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	03/24/11	23	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	03/31/11	22	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	04/07/11	20	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	04/14/11	21	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	04/21/11	20	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	04/28/11	20	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	05/05/11	19	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	05/12/11	19	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	05/19/11	18	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	05/26/11	18	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	06/02/11	17	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	06/09/11	17	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	06/16/11	17	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	06/23/11	17	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	06/30/11	18	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	07/07/11	18	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	07/14/11	18	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	07/21/11	33	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	07/28/11	31	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	08/04/11	31	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	08/11/11	35	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	08/18/11	36	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	08/25/11	33	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	09/01/11	29	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	09/08/11	26	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	09/15/11	26	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	09/22/11	27	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	09/29/11	26	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	10/06/11	26	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	10/13/11	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	10/20/11	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	10/27/11	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	11/03/11	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	11/10/11	26	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	11/17/11	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	11/24/11	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	12/01/11	25	mg/l

Fontburn WTW raw - reservoir	Total Organic Carbon	12/08/11	26	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	12/15/11	28	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	12/22/11	27	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	12/29/11	28	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	01/04/12	28	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	01/11/12	26	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	01/18/12	27	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	01/25/12	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	02/01/12	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	02/08/12	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	02/15/12	24	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	02/22/12	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	02/29/12	23	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	03/07/12	24	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	03/14/12	24	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	03/21/12	24	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	03/28/12	24	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	04/04/12	22	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	04/11/12	22	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	04/18/12	22	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	04/25/12	24	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	05/02/12	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	05/09/12	24	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	05/16/12	26	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	05/23/12	26	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	05/30/12	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	06/06/12	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	06/13/12	25	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	06/20/12	28	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	06/27/12	35	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	07/04/12	36	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	07/11/12	37	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	07/18/12	42	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	07/25/12	42	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	08/01/12	39	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	08/08/12	40	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	08/15/12	40	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	08/22/12	41	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	08/29/12	46	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	09/05/12	42	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	09/12/12	39	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	09/19/12	36	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	09/26/12	38	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	10/03/12	35	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	10/10/12	33	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	10/17/12	34	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	10/24/12	33	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	10/31/12	6	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	11/08/12	27	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	11/14/12	33	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	11/21/12	24	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	11/28/12	28	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	12/05/12	0.71	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	12/12/12	32	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	12/19/12	30	mg/l
Fontburn WTW raw - reservoir	Total Organic Carbon	12/28/12	25	mg/l
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	01/13/11	0.012	mg/l as NH4

Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	02/17/11	0.012	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	03/17/11	0.023	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	04/14/11	0.012	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	05/19/11	0.015	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	06/16/11	0.012	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	07/14/11	0.012	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	08/18/11	0.018	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	09/15/11	0.02	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	10/13/11	0.012	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	11/17/11	0.012	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	12/15/11	0.021	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	01/04/12	0.014	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	02/01/12	0.012	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	03/07/12	0.012	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	04/04/12	0.013	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	05/02/12	0.012	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	06/06/12	0.012	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	07/04/12	0.022	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	08/01/12	0.025	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	09/05/12	0.022	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	10/03/12	0.044	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	11/08/12	0.029	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrogen Ammoniacal	12/05/12	0.034	mg/l as NH4
Fontburn WTW raw - reservoir	Nitrate	01/13/11	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	02/17/11	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	03/17/11	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	04/14/11	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	05/19/11	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	06/16/11	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	07/14/11	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	08/18/11	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	09/15/11	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	10/13/11	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	11/17/11	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	12/15/11	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	01/04/12	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	02/01/12	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	03/07/12	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	04/04/12	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	05/02/12	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	06/06/12	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	07/04/12	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	08/01/12	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	09/05/12	2.7	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	10/03/12	0.36	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	11/08/12	1.2	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrate	12/05/12	1.2	mg/l as NO3
Fontburn WTW raw - reservoir	Nitrite	01/13/11	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	02/17/11	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	03/17/11	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	04/14/11	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	05/19/11	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	06/16/11	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	07/14/11	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	08/18/11	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	09/15/11	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	10/13/11	0.0014	mg/l as NO2

Fontburn WTW raw - reservoir	Nitrite	11/17/11	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	12/15/11	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	01/04/12	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	02/01/12	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	03/07/12	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	04/04/12	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	05/02/12	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	06/06/12	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	07/04/12	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	08/01/12	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	09/05/12	0.0014	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	10/03/12	0.0011	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	11/08/12	0.0011	mg/l as NO2
Fontburn WTW raw - reservoir	Nitrite	12/05/12	0.0011	mg/l as NO2
Fontburn WTW raw - reservoir	Hardness Total	01/13/11	24	mg/l
Fontburn WTW raw - reservoir	Hardness Total	02/17/11	18	mg/l
Fontburn WTW raw - reservoir	Hardness Total	03/17/11	20	mg/l
Fontburn WTW raw - reservoir	Hardness Total	04/14/11	22	mg/l
Fontburn WTW raw - reservoir	Hardness Total	05/19/11	24	mg/l
Fontburn WTW raw - reservoir	Hardness Total	06/16/11	28	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	07/14/11	31	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	08/18/11	22	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	09/15/11	27	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	10/13/11	29	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	11/17/11	30	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	12/15/11	29	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	01/04/12	25	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	02/01/12	27	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	03/07/12	28	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	04/04/12	30	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	05/02/12	23	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	06/06/12	22	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	07/04/12	19	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	08/01/12	22	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	09/05/12	22	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	10/03/12	16	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	11/08/12	21	mg/l as Ca
Fontburn WTW raw - reservoir	Hardness Total	12/05/12	17	mg/l as Ca
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	01/13/11	53	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	02/17/11	31	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	03/17/11	35	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	04/14/11	56	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	05/19/11	50	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	06/16/11	45	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	07/14/11	69	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	08/18/11	49	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	09/15/11	67	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	10/13/11	72	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	11/17/11	72	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	12/15/11	66	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	01/04/12	54	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	02/01/12	53	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	03/07/12	59	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	04/04/12	57	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	05/02/12	60	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	06/06/12	41	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	07/04/12	33	mg/l as HCO3

Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	08/01/12	45	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	09/05/12	53	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	10/03/12	33	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	11/08/12	41	mg/l as HCO3
Fontburn WTW raw - reservoir	Alkalinity to pH 4.5 (Total)	12/05/12	34	mg/l as HCO3
Fontburn WTW raw - reservoir	Chloride	01/13/11	9.9	mg/l
Fontburn WTW raw - reservoir	Chloride	02/17/11	9.1	mg/l
Fontburn WTW raw - reservoir	Chloride	03/17/11	8.5	mg/l
Fontburn WTW raw - reservoir	Chloride	04/14/11	8.8	mg/l
Fontburn WTW raw - reservoir	Chloride	05/19/11	10	mg/l
Fontburn WTW raw - reservoir	Chloride	06/16/11	9.4	mg/l
Fontburn WTW raw - reservoir	Chloride	07/14/11	8.6	mg/l
Fontburn WTW raw - reservoir	Chloride	08/18/11	7.7	mg/l
Fontburn WTW raw - reservoir	Chloride	09/15/11	8	mg/l
Fontburn WTW raw - reservoir	Chloride	10/13/11	9	mg/l
Fontburn WTW raw - reservoir	Chloride	11/17/11	8.6	mg/l
Fontburn WTW raw - reservoir	Chloride	12/15/11	8.7	mg/l
Fontburn WTW raw - reservoir	Chloride	01/04/12	9.2	mg/l
Fontburn WTW raw - reservoir	Chloride	02/01/12	12	mg/l
Fontburn WTW raw - reservoir	Chloride	03/07/12	11	mg/l
Fontburn WTW raw - reservoir	Chloride	04/04/12	11	mg/l
Fontburn WTW raw - reservoir	Chloride	05/02/12	11	mg/l
Fontburn WTW raw - reservoir	Chloride	06/06/12	4.7	mg/l
Fontburn WTW raw - reservoir	Chloride	07/04/12	9.4	mg/l
Fontburn WTW raw - reservoir	Chloride	08/01/12	7.5	mg/l
Fontburn WTW raw - reservoir	Chloride	09/05/12	9.7	mg/l
Fontburn WTW raw - reservoir	Chloride	10/03/12	9.7	mg/l
Fontburn WTW raw - reservoir	Chloride	11/08/12	8	mg/l
Fontburn WTW raw - reservoir	Chloride	12/05/12	8.7	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	01/13/11	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	02/17/11	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	03/17/11	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	04/14/11	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	05/19/11	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	06/16/11	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	07/14/11	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	08/18/11	1.6	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	09/15/11	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	10/13/11	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	11/17/11	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	12/15/11	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	01/04/12	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	02/01/12	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	03/07/12	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	04/04/12	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	05/02/12	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	06/06/12	0.49	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	07/04/12	1.9	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	08/01/12	2	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	09/05/12	1.8	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	10/03/12	0.29	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	11/08/12	0.29	mg/l
Fontburn WTW raw - reservoir	Sulphate Dissolved	12/05/12	0.29	mg/l
Fontburn WTW raw - reservoir	Sodium Total	01/13/11	6	mg/l
Fontburn WTW raw - reservoir	Sodium Total	02/17/11	5.5	mg/l
Fontburn WTW raw - reservoir	Sodium Total	03/17/11	5.7	mg/l
Fontburn WTW raw - reservoir	Sodium Total	04/14/11	5.9	mg/l

Fontburn WTW raw - reservoir	Sodium Total	05/19/11	6.1	mg/l
Fontburn WTW raw - reservoir	Sodium Total	06/16/11	5.9	mg/l
Fontburn WTW raw - reservoir	Sodium Total	07/14/11	6.2	mg/l
Fontburn WTW raw - reservoir	Sodium Total	08/18/11	5.5	mg/l
Fontburn WTW raw - reservoir	Sodium Total	09/15/11	5.8	mg/l
Fontburn WTW raw - reservoir	Sodium Total	10/13/11	5.8	mg/l
Fontburn WTW raw - reservoir	Sodium Total	11/17/11	6.1	mg/l
Fontburn WTW raw - reservoir	Sodium Total	12/15/11	6.3	mg/l
Fontburn WTW raw - reservoir	Sodium Total	01/04/12	6.3	mg/l
Fontburn WTW raw - reservoir	Sodium Total	02/01/12	7.3	mg/l
Fontburn WTW raw - reservoir	Sodium Total	03/07/12	6.6	mg/l
Fontburn WTW raw - reservoir	Sodium Total	04/04/12	6.7	mg/l
Fontburn WTW raw - reservoir	Sodium Total	05/02/12	6.8	mg/l
Fontburn WTW raw - reservoir	Sodium Total	06/06/12	6.9	mg/l
Fontburn WTW raw - reservoir	Sodium Total	07/04/12	6.3	mg/l
Fontburn WTW raw - reservoir	Sodium Total	08/01/12	5.6	mg/l
Fontburn WTW raw - reservoir	Sodium Total	09/05/12	5.5	mg/l
Fontburn WTW raw - reservoir	Sodium Total	10/03/12	5.4	mg/l
Fontburn WTW raw - reservoir	Sodium Total	11/08/12	5.4	mg/l
Fontburn WTW raw - reservoir	Sodium Total	12/05/12	4.1	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	01/13/11	3.1	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	02/17/11	2.7	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	03/17/11	2.9	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	04/14/11	2.9	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	05/19/11	2.7	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	06/16/11	4.1	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	07/14/11	3.7	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	08/18/11	2.4	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	09/15/11	3.2	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	10/13/11	4.1	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	11/17/11	3.6	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	12/15/11	3.7	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	01/04/12	3.4	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	02/01/12	3.9	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	03/07/12	3.4	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	04/04/12	3.9	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	05/02/12	3.3	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	06/06/12	3.6	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	07/04/12	2.7	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	08/01/12	3.1	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	09/05/12	3	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	10/03/12	1.9	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	11/08/12	2.9	mg/l
Fontburn WTW raw - reservoir	Magnesium Total	12/05/12	2	mg/l
Fontburn WTW raw - reservoir	Calcium Total	01/13/11	19	mg/l
Fontburn WTW raw - reservoir	Calcium Total	02/17/11	14	mg/l
Fontburn WTW raw - reservoir	Calcium Total	03/17/11	16	mg/l
Fontburn WTW raw - reservoir	Calcium Total	04/14/11	17	mg/l
Fontburn WTW raw - reservoir	Calcium Total	05/19/11	20	mg/l
Fontburn WTW raw - reservoir	Calcium Total	06/16/11	21	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	07/14/11	25	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	08/18/11	18	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	09/15/11	22	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	10/13/11	23	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	11/17/11	24	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	12/15/11	23	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	01/04/12	20	mg/l as Ca

Fontburn WTW raw - reservoir	Calcium Total	02/01/12	21	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	03/07/12	22	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	04/04/12	24	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	05/02/12	17	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	06/06/12	16	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	07/04/12	15	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	08/01/12	17	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	09/05/12	17	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	10/03/12	13	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	11/08/12	16	mg/l as Ca
Fontburn WTW raw - reservoir	Calcium Total	12/05/12	14	mg/l as Ca
Fontburn WTW raw - reservoir	Cadmium Total	01/13/11	0.063	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	02/17/11	0.035	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	03/17/11	0.047	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	04/14/11	0.026	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	05/19/11	0.027	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	06/16/11	0.016	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	07/14/11	0.015	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	08/18/11	0.047	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	09/15/11	0.038	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	10/13/11	0.02	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	11/17/11	0.018	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	12/15/11	0.021	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	01/04/12	0.017	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	02/01/12	0.029	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	03/07/12	0.035	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	04/04/12	0.026	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	05/02/12	0.044	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	06/06/12	0.037	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	07/04/12	0.058	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	08/01/12	0.028	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	09/05/12	0.04	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	10/03/12	0.049	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	11/08/12	0.049	ug/l
Fontburn WTW raw - reservoir	Cadmium Total	12/05/12	0.047	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	01/13/11	360	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	02/17/11	310	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	03/17/11	280	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	04/14/11	230	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	05/19/11	160	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	06/16/11	140	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	07/14/11	110	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	08/18/11	290	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	09/15/11	190	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	10/13/11	170	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	11/17/11	140	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	12/15/11	260	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	01/04/12	290	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	02/01/12	200	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	03/07/12	190	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	04/04/12	170	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	05/02/12	350	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	06/06/12	240	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	07/04/12	370	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	08/01/12	370	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	09/05/12	340	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	10/03/12	370	ug/l

Fontburn WTW raw - reservoir	Aluminium Total	11/08/12	290	ug/l
Fontburn WTW raw - reservoir	Aluminium Total	12/05/12	440	ug/l
Fontburn WTW raw - reservoir	Lead Total	01/13/11	1.4	ug/l
Fontburn WTW raw - reservoir	Lead Total	02/17/11	1.6	ug/l
Fontburn WTW raw - reservoir	Lead Total	03/17/11	0.93	ug/l
Fontburn WTW raw - reservoir	Lead Total	04/14/11	0.54	ug/l
Fontburn WTW raw - reservoir	Lead Total	05/19/11	0.61	ug/l
Fontburn WTW raw - reservoir	Lead Total	06/16/11	0.51	ug/l
Fontburn WTW raw - reservoir	Lead Total	07/14/11	0.55	ug/l
Fontburn WTW raw - reservoir	Lead Total	08/18/11	1.3	ug/l
Fontburn WTW raw - reservoir	Lead Total	09/15/11	0.64	ug/l
Fontburn WTW raw - reservoir	Lead Total	10/13/11	0.59	ug/l
Fontburn WTW raw - reservoir	Lead Total	11/17/11	0.68	ug/l
Fontburn WTW raw - reservoir	Lead Total	12/15/11	0.99	ug/l
Fontburn WTW raw - reservoir	Lead Total	01/04/12	1.2	ug/l
Fontburn WTW raw - reservoir	Lead Total	02/01/12	0.89	ug/l
Fontburn WTW raw - reservoir	Lead Total	03/07/12	0.81	ug/l
Fontburn WTW raw - reservoir	Lead Total	04/04/12	0.68	ug/l
Fontburn WTW raw - reservoir	Lead Total	05/02/12	1.1	ug/l
Fontburn WTW raw - reservoir	Lead Total	06/06/12	0.68	ug/l
Fontburn WTW raw - reservoir	Lead Total	07/04/12	1.5	ug/l
Fontburn WTW raw - reservoir	Lead Total	08/01/12	2.3	ug/l
Fontburn WTW raw - reservoir	Lead Total	09/05/12	1.4	ug/l
Fontburn WTW raw - reservoir	Lead Total	10/03/12	1.5	ug/l
Fontburn WTW raw - reservoir	Lead Total	11/08/12	1	ug/l
Fontburn WTW raw - reservoir	Lead Total	12/05/12	12	ug/l
Fontburn WTW raw - reservoir	Phosphorus Total (As P)	01/13/11	97	ug/l as P
Fontburn WTW raw - reservoir	Phosphorus Total (As P)	04/14/11	25	ug/l as P
Fontburn WTW raw - reservoir	Phosphorus Total (As P)	07/14/11	17	ug/l as P
Fontburn WTW raw - reservoir	Phosphorus Total (As P)	10/13/11	29	ug/l as P
Fontburn WTW raw - reservoir	Phosphorus Total (As P)	01/04/12	42	ug/l as P
Fontburn WTW raw - reservoir	Phosphorus Total (As P)	04/04/12	28	ug/l as P
Fontburn WTW raw - reservoir	Phosphorus Total (As P)	07/04/12	46	ug/l as P
Fontburn WTW raw - reservoir	Phosphorus Total (As P)	10/03/12	49	ug/l as P
Fontburn WTW raw - reservoir	Manganese Total	01/13/11	330	ug/l
Fontburn WTW raw - reservoir	Manganese Total	02/17/11	69	ug/l
Fontburn WTW raw - reservoir	Manganese Total	03/17/11	73	ug/l
Fontburn WTW raw - reservoir	Manganese Total	04/14/11	71	ug/l
Fontburn WTW raw - reservoir	Manganese Total	05/19/11	110	ug/l
Fontburn WTW raw - reservoir	Manganese Total	06/16/11	120	ug/l
Fontburn WTW raw - reservoir	Manganese Total	07/14/11	52	ug/l
Fontburn WTW raw - reservoir	Manganese Total	08/18/11	33	ug/l
Fontburn WTW raw - reservoir	Manganese Total	09/15/11	380	ug/l
Fontburn WTW raw - reservoir	Manganese Total	10/13/11	250	ug/l
Fontburn WTW raw - reservoir	Manganese Total	11/17/11	150	ug/l
Fontburn WTW raw - reservoir	Manganese Total	12/15/11	130	ug/l
Fontburn WTW raw - reservoir	Manganese Total	01/04/12	99	ug/l
Fontburn WTW raw - reservoir	Manganese Total	02/01/12	53	ug/l
Fontburn WTW raw - reservoir	Manganese Total	03/07/12	55	ug/l
Fontburn WTW raw - reservoir	Manganese Total	04/04/12	57	ug/l
Fontburn WTW raw - reservoir	Manganese Total	05/02/12	110	ug/l
Fontburn WTW raw - reservoir	Manganese Total	06/06/12	43	ug/l
Fontburn WTW raw - reservoir	Manganese Total	07/04/12	85	ug/l
Fontburn WTW raw - reservoir	Manganese Total	08/01/12	100	ug/l
Fontburn WTW raw - reservoir	Manganese Total	09/05/12	230	ug/l
Fontburn WTW raw - reservoir	Manganese Total	10/03/12	260	ug/l
Fontburn WTW raw - reservoir	Manganese Total	11/08/12	180	ug/l

Fontburn WTW raw - reservoir	Manganese Total	12/05/12	200	ug/l
Fontburn WTW raw - reservoir	Iron Total	01/13/11	1200	ug/l
Fontburn WTW raw - reservoir	Iron Total	02/17/11	900	ug/l
Fontburn WTW raw - reservoir	Iron Total	03/17/11	840	ug/l
Fontburn WTW raw - reservoir	Iron Total	04/14/11	790	ug/l
Fontburn WTW raw - reservoir	Iron Total	05/19/11	720	ug/l
Fontburn WTW raw - reservoir	Iron Total	06/16/11	750	ug/l
Fontburn WTW raw - reservoir	Iron Total	07/14/11	790	ug/l
Fontburn WTW raw - reservoir	Iron Total	08/18/11	1300	ug/l
Fontburn WTW raw - reservoir	Iron Total	09/15/11	1100	ug/l
Fontburn WTW raw - reservoir	Iron Total	10/13/11	1100	ug/l
Fontburn WTW raw - reservoir	Iron Total	11/17/11	1200	ug/l
Fontburn WTW raw - reservoir	Iron Total	12/15/11	1500	ug/l
Fontburn WTW raw - reservoir	Iron Total	01/04/12	1300	ug/l
Fontburn WTW raw - reservoir	Iron Total	02/01/12	1200	ug/l
Fontburn WTW raw - reservoir	Iron Total	03/07/12	1100	ug/l
Fontburn WTW raw - reservoir	Iron Total	04/04/12	1100	ug/l
Fontburn WTW raw - reservoir	Iron Total	05/02/12	1100	ug/l
Fontburn WTW raw - reservoir	Iron Total	06/06/12	830	ug/l
Fontburn WTW raw - reservoir	Iron Total	07/04/12	1300	ug/l
Fontburn WTW raw - reservoir	Iron Total	08/01/12	1600	ug/l
Fontburn WTW raw - reservoir	Iron Total	09/05/12	2100	ug/l
Fontburn WTW raw - reservoir	Iron Total	10/03/12	1600	ug/l
Fontburn WTW raw - reservoir	Iron Total	11/08/12	1400	ug/l
Fontburn WTW raw - reservoir	Iron Total	12/05/12	1400	ug/l
Fontburn WTW raw - reservoir	Nickel Total	01/13/11	1.9	ug/l
Fontburn WTW raw - reservoir	Nickel Total	02/17/11	1.8	ug/l
Fontburn WTW raw - reservoir	Nickel Total	03/17/11	1.7	ug/l
Fontburn WTW raw - reservoir	Nickel Total	04/14/11	1.6	ug/l
Fontburn WTW raw - reservoir	Nickel Total	05/19/11	1.8	ug/l
Fontburn WTW raw - reservoir	Nickel Total	06/16/11	1.4	ug/l
Fontburn WTW raw - reservoir	Nickel Total	07/14/11	1.7	ug/l
Fontburn WTW raw - reservoir	Nickel Total	08/18/11	2.4	ug/l
Fontburn WTW raw - reservoir	Nickel Total	09/15/11	2	ug/l
Fontburn WTW raw - reservoir	Nickel Total	10/13/11	2.1	ug/l
Fontburn WTW raw - reservoir	Nickel Total	11/17/11	2.1	ug/l
Fontburn WTW raw - reservoir	Nickel Total	12/15/11	2	ug/l
Fontburn WTW raw - reservoir	Nickel Total	01/04/12	2	ug/l
Fontburn WTW raw - reservoir	Nickel Total	02/01/12	1.7	ug/l
Fontburn WTW raw - reservoir	Nickel Total	03/07/12	1.6	ug/l
Fontburn WTW raw - reservoir	Nickel Total	04/04/12	1.5	ug/l
Fontburn WTW raw - reservoir	Nickel Total	05/02/12	1.8	ug/l
Fontburn WTW raw - reservoir	Nickel Total	06/06/12	1.9	ug/l
Fontburn WTW raw - reservoir	Nickel Total	07/04/12	2.2	ug/l
Fontburn WTW raw - reservoir	Nickel Total	08/01/12	2.5	ug/l
Fontburn WTW raw - reservoir	Nickel Total	09/05/12	2.7	ug/l
Fontburn WTW raw - reservoir	Nickel Total	10/03/12	2.3	ug/l
Fontburn WTW raw - reservoir	Nickel Total	11/08/12	2.1	ug/l
Fontburn WTW raw - reservoir	Nickel Total	12/05/12	4.7	ug/l

Lartington WTW raw

Spt Desc	Detdesc	Datetaken	Value	Unitused
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	04/19/11	6.9	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	05/18/11	7	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	06/20/11	7	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	07/13/11	7	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	08/16/11	6.9	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	09/13/11	6.9	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	10/20/11	7.2	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	11/29/11	7.2	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	12/20/11	6.9	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	01/10/12	6.8	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	02/29/12	6.9	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	03/06/12	6.8	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	05/02/12	6.9	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	07/11/12	7	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	07/23/12	7.5	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	08/20/12	7.1	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	09/28/12	7.5	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	10/09/12	7.2	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	11/07/12	7.1	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	11/14/12	7.4	pH Value
Lartington WTW raw - Balderhead Reservoir	Hydrogen ion	12/10/12	7.3	pH Value
Lartington WTW raw - Balderhead Reservoir	Turbidity	04/19/11	2.4	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	05/18/11	2.1	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	06/20/11	3.2	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	07/13/11	1	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	08/16/11	1.2	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	09/13/11	2.4	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	10/20/11	1.6	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	11/29/11	15	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	12/20/11	3.4	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	01/10/12	3.6	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	02/29/12	2.8	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	03/06/12	2.2	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	05/02/12	2	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	07/11/12	2.4	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	07/23/12	1.9	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	08/20/12	1.6	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	09/28/12	2.9	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	10/09/12	1.3	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	11/07/12	1.3	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	11/14/12	2.1	NTU
Lartington WTW raw - Balderhead Reservoir	Turbidity	12/10/12	1.4	NTU
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	04/19/11	130	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	05/18/11	120	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	06/20/11	120	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	07/13/11	110	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	08/16/11	130	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	09/13/11	130	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	10/20/11	140	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	11/29/11	150	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	12/20/11	130	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	01/10/12	140	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	02/29/12	130	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	03/06/12	130	mg/l Pt/Co scal

Lartington WTW raw - Balderhead Reservoir	Colour Filtered	05/02/12	120	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	07/11/12	140	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	07/23/12	150	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	08/20/12	150	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	09/28/12	160	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	10/09/12	150	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	11/07/12	170	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	11/14/12	160	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Colour Filtered	12/10/12	150	mg/l Pt/Co scal
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	04/19/11	21	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	05/18/11	17	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	06/20/11	17	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	07/13/11	17	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	08/16/11	17	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	09/13/11	17	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	10/20/11	21	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	11/29/11	17	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	12/20/11	17	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	01/10/12	18	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	02/29/12	17	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	03/06/12	18	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	05/02/12	17	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	07/11/12	17	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	07/23/12	17	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	08/20/12	17	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	09/28/12	13	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	10/09/12	14	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	11/07/12	15	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	11/14/12	13	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Alkalinity to pH 4.5 (Total)	12/10/12	6.9	mg/l as HCO3
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	04/19/11	210	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	05/18/11	190	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	06/20/11	210	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	07/13/11	160	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	08/16/11	160	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	09/13/11	200	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	10/20/11	190	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	11/29/11	540	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	12/20/11	200	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	01/10/12	210	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	02/29/12	250	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	03/06/12	200	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	05/02/12	220	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	07/11/12	220	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	07/23/12	220	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	08/20/12	190	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	09/28/12	220	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	10/09/12	170	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	11/07/12	150	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	11/14/12	190	ug/l
Lartington WTW raw - Balderhead Reservoir	Aluminium Total	12/10/12	160	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	04/19/11	14	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	05/18/11	17	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	06/20/11	20	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	07/13/11	13	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	08/16/11	17	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	09/13/11	32	ug/l

Lartington WTW raw - Balderhead Reservoir	Manganese Total	10/20/11	20	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	11/29/11	47	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	12/20/11	20	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	01/10/12	23	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	02/29/12	17	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	03/06/12	14	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	05/02/12	16	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	07/11/12	17	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	07/23/12	18	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	08/20/12	19	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	09/28/12	22	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	10/09/12	17	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	11/07/12	23	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	11/14/12	20	ug/l
Lartington WTW raw - Balderhead Reservoir	Manganese Total	12/10/12	19	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	04/19/11	650	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	05/18/11	600	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	06/20/11	600	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	07/13/11	520	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	08/16/11	540	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	09/13/11	680	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	10/20/11	690	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	11/29/11	1100	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	12/20/11	700	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	01/10/12	730	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	02/29/12	660	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	03/06/12	610	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	05/02/12	580	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	07/11/12	610	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	07/23/12	610	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	08/20/12	570	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	09/28/12	710	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	10/09/12	630	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	11/07/12	690	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	11/14/12	700	ug/l
Lartington WTW raw - Balderhead Reservoir	Iron Total	12/10/12	690	ug/l
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	01/19/11	7	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	02/23/11	6.9	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	03/16/11	6.9	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	04/11/11	7.1	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	05/18/11	7.2	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	06/20/11	7.1	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	07/13/11	7	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	08/16/11	6.8	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	09/13/11	7	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	10/20/11	6.8	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	11/29/11	7	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	12/20/11	7	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	01/10/12	6.9	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	02/29/12	7.1	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	03/06/12	7	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	05/02/12	7.4	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	07/11/12	6.8	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	07/23/12	7.6	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	08/20/12	7.3	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	09/28/12	7.6	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	10/09/12	8.2	pH Value

Lartington WTW raw - Blackton Reservoir	Hydrogen ion	11/07/12	7.1	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	11/14/12	7.5	pH Value
Lartington WTW raw - Blackton Reservoir	Hydrogen ion	12/10/12	7.5	pH Value
Lartington WTW raw - Blackton Reservoir	Turbidity	01/19/11	8.6	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	02/23/11	11	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	03/16/11	4.2	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	04/11/11	2.9	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	05/18/11	2.6	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	06/20/11	1.5	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	07/13/11	1.6	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	08/16/11	2.4	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	09/13/11	3.3	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	10/20/11	3.1	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	11/29/11	3.2	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	12/20/11	7.7	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	01/10/12	5.6	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	02/29/12	3.9	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	03/06/12	2.8	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	05/02/12	5.1	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	07/11/12	4.2	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	07/23/12	3	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	08/20/12	2.9	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	09/28/12	11	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	10/09/12	3.7	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	11/07/12	2.3	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	11/14/12	2	NTU
Lartington WTW raw - Blackton Reservoir	Turbidity	12/10/12	5.2	NTU
Lartington WTW raw - Blackton Reservoir	Colour Filtered	01/19/11	130	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	02/23/11	130	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	03/16/11	130	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	04/11/11	130	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	05/18/11	120	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	06/20/11	120	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	07/13/11	130	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	08/16/11	180	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	09/13/11	180	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	10/20/11	170	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	11/29/11	180	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	12/20/11	130	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	01/10/12	120	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	02/29/12	130	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	03/06/12	120	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	05/02/12	130	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	07/11/12	170	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	07/23/12	190	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	08/20/12	200	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	09/28/12	160	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	10/09/12	160	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	11/07/12	170	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	11/14/12	160	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Colour Filtered	12/10/12	150	mg/l Pt/Co scal
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	01/19/11	17	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	02/23/11	17	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	03/16/11	19	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	04/11/11	17	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	05/18/11	17	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	06/20/11	18	mg/l as HCO3

Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	07/13/11	20	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	08/16/11	17	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	09/13/11	21	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	10/20/11	21	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	11/29/11	17	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	12/20/11	21	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	01/10/12	17	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	02/29/12	17	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	03/06/12	17	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	05/02/12	17	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	07/11/12	17	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	07/23/12	17	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	08/20/12	17	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	09/28/12	15	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	10/09/12	16	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	11/07/12	18	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	11/14/12	16	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Alkalinity to pH 4.5 (Total)	12/10/12	9.7	mg/l as HCO3
Lartington WTW raw - Blackton Reservoir	Aluminium Total	01/19/11	400	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	02/23/11	350	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	03/16/11	290	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	04/11/11	170	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	05/18/11	170	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	06/20/11	140	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	07/13/11	160	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	08/16/11	220	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	09/13/11	200	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	10/20/11	220	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	11/29/11	220	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	12/20/11	270	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	01/10/12	260	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	02/29/12	270	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	03/06/12	200	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	05/02/12	340	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	07/11/12	270	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	07/23/12	290	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	08/20/12	210	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	09/28/12	480	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	10/09/12	270	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	11/07/12	150	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	11/14/12	160	ug/l
Lartington WTW raw - Blackton Reservoir	Aluminium Total	12/10/12	280	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	01/19/11	30	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	02/23/11	44	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	03/16/11	28	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	04/11/11	19	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	05/18/11	36	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	06/20/11	29	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	07/13/11	27	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	08/16/11	100	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	09/13/11	69	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	10/20/11	38	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	11/29/11	38	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	12/20/11	33	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	01/10/12	35	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	02/29/12	21	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	03/06/12	19	ug/l

Lartington WTW raw - Blackton Reservoir	Manganese Total	05/02/12	27	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	07/11/12	27	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	07/23/12	56	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	08/20/12	70	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	09/28/12	35	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	10/09/12	26	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	11/07/12	24	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	11/14/12	19	ug/l
Lartington WTW raw - Blackton Reservoir	Manganese Total	12/10/12	30	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	01/19/11	940	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	02/23/11	940	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	03/16/11	790	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	04/11/11	690	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	05/18/11	740	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	06/20/11	650	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	07/13/11	710	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	08/16/11	950	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	09/13/11	1100	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	10/20/11	1000	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	11/29/11	1100	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	12/20/11	820	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	01/10/12	800	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	02/29/12	690	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	03/06/12	630	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	05/02/12	740	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	07/11/12	840	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	07/23/12	940	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	08/20/12	1000	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	09/28/12	1000	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	10/09/12	820	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	11/07/12	810	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	11/14/12	780	ug/l
Lartington WTW raw - Blackton Reservoir	Iron Total	12/10/12	860	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	01/21/11	7.3	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	02/18/11	7.2	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	03/25/11	7.3	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	04/20/11	7.3	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	05/20/11	7.5	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	06/24/11	7.4	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	07/22/11	7.2	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	08/19/11	7.2	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	09/23/11	7.4	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	10/21/11	7.6	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	11/07/11	7.3	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	11/10/11	7.4	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	11/14/11	7.3	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	11/17/11	7.4	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	11/21/11	7.3	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	11/24/11	7.4	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	11/25/11	7.5	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	11/28/11	7.5	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	12/01/11	7.5	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	12/23/11	7.3	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	01/03/12	7.3	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	02/07/12	7.3	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	03/06/12	7.4	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	04/03/12	7.4	pH Value

Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	05/01/12	7.4	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	06/07/12	7.3	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	07/03/12	7.3	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	08/07/12	7.4	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	09/04/12	7.5	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	10/02/12	7.7	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	11/06/12	7.5	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Hydrogen ion	12/04/12	7.6	pH Value
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	01/21/11	82	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	02/18/11	68	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	03/25/11	75	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	04/20/11	75	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	05/20/11	75	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	06/24/11	80	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	07/22/11	75	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	08/19/11	81	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	09/23/11	76	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	10/21/11	72	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	11/25/11	77	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	12/23/11	76	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	01/03/12	79	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	02/07/12	75	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	03/06/12	81	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	04/03/12	87	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	05/01/12	81	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	06/07/12	75	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	07/03/12	71	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	08/07/12	76	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	09/04/12	70	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	10/02/12	69	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	11/06/12	68	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Conductivity 20 Deg. C	12/04/12	67	uS/cm
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	01/21/11	9.3	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	02/18/11	7.5	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	03/25/11	4	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	04/20/11	2.2	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	05/20/11	1.8	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	06/24/11	2.1	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	07/22/11	3.4	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	08/19/11	2	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	09/23/11	2.4	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	10/21/11	2.1	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	11/07/11	1.7	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	11/10/11	1.7	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	11/14/11	1.7	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	11/17/11	1.8	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	11/21/11	1.6	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	11/24/11	2.1	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	11/25/11	1.7	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	11/28/11	3.1	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	12/01/11	3	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	12/23/11	7.7	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	01/03/12	7.2	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	02/07/12	5.7	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	03/06/12	5	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	04/03/12	3.7	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	05/01/12	4.3	NTU

Lartington WTW raw - Hury & Grassholme mixed	Turbidity	06/07/12	2.7	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	07/03/12	11	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	08/07/12	3.8	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	09/04/12	3.4	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	10/02/12	5.6	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	11/06/12	2.4	NTU
Lartington WTW raw - Hury & Grassholme mixed	Turbidity	12/04/12	3.4	NTU
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	01/21/11	100	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	02/18/11	94	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	03/25/11	89	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	04/20/11	89	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	05/20/11	90	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	06/24/11	91	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	07/22/11	120	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	08/19/11	130	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	09/23/11	150	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	10/21/11	160	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	11/10/11	150	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	11/14/11	150	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	11/17/11	140	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	11/21/11	150	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	11/24/11	130	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	11/25/11	170	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	11/28/11	150	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	12/01/11	160	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	12/23/11	130	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	01/03/12	110	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	02/07/12	90	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	03/06/12	82	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	04/03/12	74	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	05/01/12	84	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	06/07/12	80	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	07/03/12	120	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	08/07/12	150	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	09/04/12	160	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	10/02/12	160	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	11/06/12	140	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Colour Filtered	12/04/12	140	mg/l Pt/Co scal
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	01/21/11	3.3	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	02/18/11	3.3	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	03/25/11	8.5	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	03/26/11	7.6	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	04/20/11	11.2	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	05/20/11	10.1	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	06/24/11	14.4	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	07/22/11	12.7	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	08/19/11	14.5	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	09/23/11	11.5	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	10/21/11	11.3	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	11/25/11	9.2	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	12/23/11	3.4	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	01/03/12	6.6	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	02/07/12	4	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	03/06/12	8.2	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	04/03/12	7.7	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	05/01/12	10.1	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	06/07/12	12	Deg. C

Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	07/03/12	14	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	08/07/12	16.1	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	09/04/12	16.7	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	10/02/12	13.2	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	11/06/12	8.6	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Temperature Deg. C	12/04/12	6.3	Deg. C
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	01/07/11	12	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	01/14/11	12	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	01/21/11	12	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	01/28/11	12	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	02/04/11	11	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	02/11/11	10	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	02/18/11	10	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	02/25/11	10	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	03/04/11	10	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	03/11/11	9.8	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	03/18/11	10	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	03/25/11	9.2	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	04/01/11	9.1	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	04/08/11	9.6	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	04/15/11	9.6	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	04/20/11	9.5	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	04/27/11	9.4	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	05/06/11	9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	05/13/11	8.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	05/20/11	9.4	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	05/27/11	9.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	06/03/11	10	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	06/10/11	9.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	06/17/11	10	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	06/24/11	11	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	07/01/11	10	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	07/08/11	10	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	07/15/11	12	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	07/22/11	13	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	07/29/11	13	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	08/05/11	13	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	08/12/11	14	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	08/19/11	15	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	08/26/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	09/02/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	09/09/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	09/16/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	09/23/11	17	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	09/30/11	17	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	10/07/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	10/14/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	10/21/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	10/28/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/04/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/07/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/10/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/11/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/14/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/17/11	15	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/18/11	15	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/21/11	15	mg/l

Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/24/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/25/11	15	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/28/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	12/01/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	12/02/11	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	12/09/11	15	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	12/16/11	14	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	12/23/11	13	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	12/30/11	12	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	01/03/12	12	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	01/10/12	11	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	01/17/12	10	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	01/24/12	9.8	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	01/31/12	9.4	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	02/07/12	9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	02/14/12	8.8	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	02/21/12	8.8	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	02/28/12	9.1	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	03/06/12	8.8	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	03/13/12	8.4	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	03/20/12	8.6	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	03/27/12	8.5	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	04/03/12	8	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	04/10/12	8.3	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	04/17/12	8.8	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	04/24/12	9.6	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	05/01/12	9.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	05/08/12	9.7	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	05/15/12	10	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	05/22/12	11	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	05/29/12	2.1	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	06/07/12	9.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	06/12/12	10	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	06/19/12	12	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	06/26/12	13	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	07/03/12	12	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	07/10/12	13	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	07/17/12	14	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	07/24/12	15	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	07/31/12	14	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	08/07/12	14	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	08/14/12	15	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	08/21/12	15	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	08/28/12	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	09/04/12	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	09/11/12	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	09/18/12	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	09/25/12	17	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	10/02/12	16	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	10/09/12	15	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	10/16/12	15	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	10/23/12	15	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	10/30/12	14	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/06/12	14	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/13/12	15	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/20/12	15	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	11/27/12	13	mg/l

Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	12/04/12	13	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	12/11/12	14	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	12/18/12	12	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Total Organic Carbon	12/27/12	12	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	01/21/11	0.015	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	02/18/11	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	03/25/11	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	04/20/11	0.017	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	05/20/11	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	06/24/11	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	07/22/11	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	08/19/11	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	09/23/11	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	10/21/11	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	11/25/11	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	12/23/11	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	01/03/12	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	02/07/12	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	03/06/12	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	04/03/12	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	05/01/12	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	06/07/12	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	07/03/12	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	08/07/12	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	09/04/12	0.012	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	10/02/12	0.007	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	11/06/12	0.007	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrogen Ammoniacal	12/04/12	0.017	mg/l as NH4
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	01/21/11	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	02/18/11	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	03/25/11	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	04/20/11	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	05/20/11	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	06/24/11	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	07/22/11	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	08/19/11	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	09/23/11	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	10/21/11	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	11/25/11	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	12/23/11	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	01/03/12	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	02/07/12	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	03/06/12	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	04/03/12	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	05/01/12	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	06/07/12	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	07/03/12	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	08/07/12	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	09/04/12	2.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	10/02/12	0.26	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	11/06/12	1.7	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrate	12/04/12	0.88	mg/l as NO3
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	01/21/11	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	02/18/11	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	03/25/11	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	04/20/11	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	05/20/11	0.0014	mg/l as NO2

Lartington WTW raw - Hury & Grassholme mixed	Nitrite	06/24/11	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	07/22/11	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	08/19/11	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	09/23/11	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	10/21/11	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	11/25/11	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	12/23/11	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	01/03/12	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	02/07/12	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	03/06/12	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	04/03/12	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	05/01/12	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	06/07/12	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	07/03/12	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	08/07/12	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	09/04/12	0.0014	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	10/02/12	0.0011	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	11/06/12	0.0011	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Nitrite	12/04/12	0.0011	mg/l as NO2
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	01/21/11	15	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	02/18/11	13	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	03/25/11	14	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	04/20/11	14	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	05/20/11	14	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	06/24/11	16	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	07/22/11	13	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	08/19/11	16	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	09/23/11	17	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	10/21/11	15	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	11/25/11	17	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	12/23/11	14	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	01/03/12	14	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	02/07/12	14	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	03/06/12	14	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	04/03/12	17	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	05/01/12	16	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	06/07/12	15	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	07/03/12	14	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	08/07/12	16	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	09/04/12	16	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	10/02/12	14	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	11/06/12	15	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Hardness Total	12/04/12	14	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	01/21/11	22	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	02/18/11	33	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	03/25/11	27	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	04/20/11	45	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	05/20/11	33	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	06/24/11	30	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	07/22/11	42	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	08/19/11	43	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	09/23/11	34	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	10/21/11	34	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	11/25/11	48	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	12/23/11	45	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	01/03/12	26	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	02/07/12	32	mg/l as HCO3

Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	03/06/12	34	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	04/03/12	36	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	05/01/12	30	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	06/07/12	37	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	07/03/12	30	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	08/07/12	39	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	09/04/12	44	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	10/02/12	42	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	11/06/12	36	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Alkalinity to pH 4.5 (Total)	12/04/12	34	mg/l as HCO3
Lartington WTW raw - Hury & Grassholme mixed	Chloride	01/21/11	7.2	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	02/18/11	6.3	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	03/25/11	6	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	04/20/11	7.4	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	05/20/11	5.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	06/24/11	6	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	07/22/11	5.4	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	08/19/11	4.8	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	09/23/11	5.3	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	10/21/11	5.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	11/25/11	5.3	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	12/23/11	6.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	01/03/12	7	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	02/07/12	7.8	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	03/06/12	8.6	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	04/03/12	7.6	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	05/01/12	7	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	06/07/12	5.2	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	07/03/12	3.7	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	08/07/12	3.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	09/04/12	5.7	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	10/02/12	4.1	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	11/06/12	3.7	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Chloride	12/04/12	4.4	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	01/21/11	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	02/18/11	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	03/25/11	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	04/20/11	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	05/20/11	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	06/24/11	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	07/22/11	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	08/19/11	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	09/23/11	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	10/21/11	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	11/25/11	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	12/23/11	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	01/03/12	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	02/07/12	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	03/06/12	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	04/03/12	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	05/01/12	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	06/07/12	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	07/03/12	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	08/07/12	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	09/04/12	0.49	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	10/02/12	0.29	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	11/06/12	0.29	mg/l

Lartington WTW raw - Hury & Grassholme mixed	Sulphate Dissolved	12/04/12	0.29	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	01/21/11	4.4	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	02/18/11	4.5	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	03/25/11	4.6	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	04/20/11	4.6	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	05/20/11	4.5	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	06/24/11	4.5	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	07/22/11	4.3	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	08/19/11	4.3	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	09/23/11	4.2	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	10/21/11	4.3	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	11/25/11	4.1	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	12/23/11	4.7	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	01/03/12	5.2	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	02/07/12	5.4	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	03/06/12	5.2	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	04/03/12	3.7	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	05/01/12	5.2	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	06/07/12	4.5	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	07/03/12	4.1	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	08/07/12	3.5	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	09/04/12	3.5	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	10/02/12	2.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	11/06/12	3.2	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Sodium Total	12/04/12	3.1	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	01/21/11	1.8	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	02/18/11	1.8	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	03/25/11	1.8	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	04/20/11	1.6	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	05/20/11	2.2	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	06/24/11	2.5	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	07/22/11	0.78	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	08/19/11	1.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	09/23/11	2	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	10/21/11	1.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	11/25/11	2.1	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	12/23/11	1.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	01/03/12	2.4	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	02/07/12	1.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	03/06/12	1.8	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	04/03/12	2.2	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	05/01/12	2.1	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	06/07/12	1.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	07/03/12	1.7	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	08/07/12	2.2	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	09/04/12	2.3	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	10/02/12	1.4	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	11/06/12	2.1	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Magnesium Total	12/04/12	1.5	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	01/21/11	12	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	02/18/11	9.9	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	03/25/11	11	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	04/20/11	11	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	05/20/11	10	mg/l
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	06/24/11	12	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	07/22/11	13	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	08/19/11	13	mg/l as Ca

Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	09/23/11	13	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	10/21/11	12	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	11/25/11	14	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	12/23/11	11	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	01/03/12	10	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	02/07/12	11	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	03/06/12	11	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	04/03/12	14	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	05/01/12	12	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	06/07/12	12	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	07/03/12	11	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	08/07/12	13	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	09/04/12	12	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	10/02/12	12	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	11/06/12	12	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Calcium Total	12/04/12	12	mg/l as Ca
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	01/21/11	0.022	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	02/18/11	0.0081	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	03/25/11	0.025	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	04/20/11	0.0089	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	05/20/11	0.013	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	06/24/11	0.0092	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	07/22/11	0.018	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	08/19/11	0.029	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	09/23/11	0.023	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	10/21/11	0.024	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	11/25/11	0.025	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	12/23/11	0.0081	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	01/03/12	0.0081	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	02/07/12	0.016	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	03/06/12	0.023	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	04/03/12	0.012	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	05/01/12	0.015	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	06/07/12	0.014	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	07/03/12	0.031	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	08/07/12	0.0081	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	09/04/12	0.014	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	10/02/12	0.02	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	11/06/12	0.012	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Cadmium Total	12/04/12	0.01	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	01/21/11	240	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	02/18/11	200	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	03/25/11	160	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	04/20/11	130	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	05/20/11	91	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	06/24/11	98	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	07/22/11	170	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	08/19/11	130	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	09/23/11	120	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	10/21/11	7.3	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	11/07/11	120	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	11/10/11	100	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	11/14/11	120	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	11/17/11	100	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	11/21/11	110	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	11/24/11	120	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	11/25/11	110	ug/l

Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	11/28/11	140	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	12/01/11	120	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	12/23/11	260	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	01/03/12	290	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	02/07/12	230	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	03/06/12	220	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	04/03/12	31	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	05/01/12	220	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	06/07/12	130	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	07/03/12	530	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	08/07/12	170	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	09/04/12	200	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	10/02/12	210	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	11/06/12	140	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Aluminium Total	12/04/12	150	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Dissolved	03/26/11	0.4	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	01/21/11	1.5	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	02/18/11	1.4	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	03/25/11	1.1	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	03/26/11	1.2	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	04/20/11	0.71	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	05/20/11	0.45	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	06/24/11	0.69	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	07/22/11	1.3	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	08/19/11	1.1	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	09/23/11	1.2	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	10/21/11	1.1	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	11/25/11	1	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	12/23/11	2	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	01/03/12	2.1	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	02/07/12	1.1	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	03/06/12	0.98	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	04/03/12	1	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	05/01/12	0.93	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	06/07/12	0.89	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	07/03/12	3.4	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	08/07/12	1.6	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	09/04/12	1.4	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	10/02/12	1.8	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	11/06/12	1.1	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Lead Total	12/04/12	1.2	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Phosphorus Total (As P)	01/21/11	54	ug/l as P
Lartington WTW raw - Hury & Grassholme mixed	Phosphorus Total (As P)	04/20/11	13	ug/l as P
Lartington WTW raw - Hury & Grassholme mixed	Phosphorus Total (As P)	07/22/11	15	ug/l as P
Lartington WTW raw - Hury & Grassholme mixed	Phosphorus Total (As P)	10/21/11	4	ug/l as P
Lartington WTW raw - Hury & Grassholme mixed	Phosphorus Total (As P)	01/03/12	19	ug/l as P
Lartington WTW raw - Hury & Grassholme mixed	Phosphorus Total (As P)	04/03/12	650	ug/l as P
Lartington WTW raw - Hury & Grassholme mixed	Phosphorus Total (As P)	07/03/12	27	ug/l as P
Lartington WTW raw - Hury & Grassholme mixed	Phosphorus Total (As P)	10/02/12	24	ug/l as P
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	01/21/11	20	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	02/18/11	17	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	03/25/11	23	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	04/20/11	23	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	05/20/11	22	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	06/24/11	26	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	07/22/11	32	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	08/19/11	40	ug/l

Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	09/23/11	39	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	10/21/11	0.078	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	11/07/11	24	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	11/10/11	23	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	11/14/11	23	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	11/17/11	23	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	11/21/11	22	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	11/24/11	32	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	11/25/11	28	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	11/28/11	41	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	12/01/11	35	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	12/23/11	26	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	01/03/12	27	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	02/07/12	18	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	03/06/12	19	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	04/03/12	1.4	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	05/01/12	26	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	06/07/12	34	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	07/03/12	36	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	08/07/12	28	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	09/04/12	41	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	10/02/12	33	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	11/06/12	17	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Manganese Total	12/04/12	16	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	01/21/11	520	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	02/18/11	460	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	03/25/11	380	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	04/20/11	330	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	05/20/11	330	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	06/24/11	380	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	07/22/11	460	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	08/19/11	490	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	09/23/11	550	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	10/21/11	2.6	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	11/07/11	540	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	11/10/11	530	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	11/14/11	530	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	11/17/11	510	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	11/21/11	530	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	11/24/11	560	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	11/25/11	540	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	11/28/11	630	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	12/01/11	620	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	12/23/11	640	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	01/03/12	590	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	02/07/12	430	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	03/06/12	420	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	04/03/12	7.7	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	05/01/12	430	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	06/07/12	330	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	07/03/12	620	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	08/07/12	470	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	09/04/12	600	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	10/02/12	660	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	11/06/12	500	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Iron Total	12/04/12	550	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	01/21/11	1.5	ug/l

Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	02/18/11	1.2	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	03/25/11	1	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	04/20/11	0.92	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	05/20/11	1	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	06/24/11	0.91	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	07/22/11	1.2	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	08/19/11	1.3	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	09/23/11	1.3	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	10/21/11	1.3	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	11/25/11	1.2	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	12/23/11	1.1	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	01/03/12	1.2	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	02/07/12	0.94	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	03/06/12	0.9	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	04/03/12	0.79	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	05/01/12	0.95	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	06/07/12	0.92	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	07/03/12	1.6	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	08/07/12	1.3	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	09/04/12	1.3	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	10/02/12	1.5	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	11/06/12	1.2	ug/l
Lartington WTW raw - Hury & Grassholme mixed	Nickel Total	12/04/12	1.1	ug/l
Lartington WTW raw - Selset Reservoir	Hydrogen ion	01/19/11	7.8	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	02/23/11	7.4	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	03/16/11	7.5	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	04/11/11	7.6	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	05/18/11	7.6	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	06/20/11	7.8	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	07/13/11	7.6	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	08/16/11	7.6	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	09/13/11	7.5	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	10/20/11	7.5	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	11/29/11	7.6	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	12/20/11	8.3	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	01/10/12	7.4	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	02/29/12	7.6	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	03/06/12	7.6	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	05/02/12	7.6	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	07/11/12	7.8	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	07/23/12	8	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	08/20/12	7.9	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	09/28/12	7.9	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	10/09/12	7.5	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	11/07/12	7.6	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	11/14/12	8	pH Value
Lartington WTW raw - Selset Reservoir	Hydrogen ion	12/10/12	8	pH Value
Lartington WTW raw - Selset Reservoir	Turbidity	01/19/11	18	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	02/23/11	6.2	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	03/16/11	5	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	04/11/11	5	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	05/18/11	160	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	06/20/11	4.2	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	07/13/11	1.7	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	08/16/11	2.5	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	09/13/11	6.4	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	10/20/11	3.3	NTU

Lartington WTW raw - Selset Reservoir	Turbidity	11/29/11	17	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	12/20/11	15	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	01/10/12	16	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	02/29/12	11	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	03/06/12	20	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	05/02/12	7.8	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	07/11/12	10	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	07/23/12	6.4	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	08/20/12	4.4	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	09/28/12	13	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	10/09/12	5.7	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	11/07/12	5	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	11/14/12	3.7	NTU
Lartington WTW raw - Selset Reservoir	Turbidity	12/10/12	8.9	NTU
Lartington WTW raw - Selset Reservoir	Colour Filtered	01/19/11	89	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	02/23/11	81	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	03/16/11	90	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	04/11/11	93	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	05/18/11	83	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	06/20/11	98	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	07/13/11	120	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	08/16/11	150	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	09/13/11	180	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	10/20/11	170	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	11/29/11	150	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	12/20/11	110	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	01/10/12	81	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	02/29/12	80	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	03/06/12	78	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	05/02/12	97	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	07/11/12	150	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	07/23/12	170	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	08/20/12	170	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	09/28/12	170	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	10/09/12	150	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	11/07/12	150	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	11/14/12	130	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Colour Filtered	12/10/12	130	mg/l Pt/Co scal
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	01/19/11	30	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	02/23/11	26	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	03/16/11	35	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	04/11/11	37	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	05/18/11	59	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	06/20/11	51	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	07/13/11	53	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	08/16/11	66	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	09/13/11	3	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	10/20/11	49	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	11/29/11	45	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	12/20/11	45	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	01/10/12	29	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	02/29/12	39	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	03/06/12	33	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	05/02/12	46	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	07/11/12	50	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	07/23/12	44	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	08/20/12	44	mg/l as HCO3

Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	09/28/12	41	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	10/09/12	40	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	11/07/12	41	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	11/14/12	41	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Alkalinity to pH 4.5 (Total)	12/10/12	34	mg/l as HCO3
Lartington WTW raw - Selset Reservoir	Aluminium Total	01/19/11	540	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	02/23/11	260	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	03/16/11	250	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	04/11/11	150	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	05/18/11	1300	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	06/20/11	190	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	07/13/11	120	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	08/16/11	140	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	09/13/11	160	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	10/20/11	210	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	11/29/11	380	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	12/20/11	380	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	01/10/12	340	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	02/29/12	350	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	03/06/12	480	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	05/02/12	400	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	07/11/12	260	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	07/23/12	240	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	08/20/12	220	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	09/28/12	530	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	10/09/12	320	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	11/07/12	150	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	11/14/12	150	ug/l
Lartington WTW raw - Selset Reservoir	Aluminium Total	12/10/12	290	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	01/19/11	28	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	02/23/11	14	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	03/16/11	15	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	04/11/11	16	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	05/18/11	140	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	06/20/11	14	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	07/13/11	13	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	08/16/11	19	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	09/13/11	41	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	10/20/11	19	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	11/29/11	41	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	12/20/11	24	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	01/10/12	32	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	02/29/12	22	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	03/06/12	37	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	05/02/12	21	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	07/11/12	17	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	07/23/12	28	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	08/20/12	20	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	09/28/12	39	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	10/09/12	15	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	11/07/12	19	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	11/14/12	14	ug/l
Lartington WTW raw - Selset Reservoir	Manganese Total	12/10/12	22	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	01/19/11	640	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	02/23/11	360	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	03/16/11	370	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	04/11/11	320	ug/l

Lartington WTW raw - Selset Reservoir	Iron Total	05/18/11	1800	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	06/20/11	320	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	07/13/11	320	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	08/16/11	400	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	09/13/11	600	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	10/20/11	560	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	11/29/11	840	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	12/20/11	600	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	01/10/12	570	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	02/29/12	460	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	03/06/12	670	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	05/02/12	490	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	07/11/12	540	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	07/23/12	560	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	08/20/12	500	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	09/28/12	810	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	10/09/12	560	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	11/07/12	490	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	11/14/12	470	ug/l
Lartington WTW raw - Selset Reservoir	Iron Total	12/10/12	560	ug/l

Gunnerton WTW raw

Spt Desc	Detdesc	Datetaken	Value	Unitused
Gunnerton WTW raw	Hydrogen ion	01/05/11	7.3	pH Value
Gunnerton WTW raw	Hydrogen ion	02/09/11	7.2	pH Value
Gunnerton WTW raw	Hydrogen ion	03/09/11	7.3	pH Value
Gunnerton WTW raw	Hydrogen ion	04/06/11	7.4	pH Value
Gunnerton WTW raw	Hydrogen ion	05/11/11	7.3	pH Value
Gunnerton WTW raw	Hydrogen ion	06/08/11	7.5	pH Value
Gunnerton WTW raw	Hydrogen ion	07/06/11	7.5	pH Value
Gunnerton WTW raw	Hydrogen ion	08/10/11	7	pH Value
Gunnerton WTW raw	Hydrogen ion	09/07/11	7.4	pH Value
Gunnerton WTW raw	Hydrogen ion	10/05/11	7.4	pH Value
Gunnerton WTW raw	Hydrogen ion	11/09/11	7.4	pH Value
Gunnerton WTW raw	Hydrogen ion	12/07/11	7.6	pH Value
Gunnerton WTW raw	Hydrogen ion	01/20/12	7.4	pH Value
Gunnerton WTW raw	Hydrogen ion	02/17/12	7.4	pH Value
Gunnerton WTW raw	Hydrogen ion	03/16/12	7.4	pH Value
Gunnerton WTW raw	Hydrogen ion	04/13/12	7.5	pH Value
Gunnerton WTW raw	Hydrogen ion	05/18/12	7.6	pH Value
Gunnerton WTW raw	Hydrogen ion	06/15/12	7.3	pH Value
Gunnerton WTW raw	Hydrogen ion	07/20/12	7.1	pH Value
Gunnerton WTW raw	Hydrogen ion	08/17/12	7.1	pH Value
Gunnerton WTW raw	Hydrogen ion	09/14/12	7.6	pH Value
Gunnerton WTW raw	Hydrogen ion	10/19/12	7.6	pH Value
Gunnerton WTW raw	Hydrogen ion	11/16/12	7.5	pH Value
Gunnerton WTW raw	Hydrogen ion	12/14/12	8	pH Value
Gunnerton WTW raw	Conductivity 20 Deg. C	01/05/11	110	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	02/09/11	70	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	03/09/11	72	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	04/06/11	80	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	05/11/11	87	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	06/08/11	95	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	07/06/11	100	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	08/10/11	85	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	09/07/11	87	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	10/05/11	84	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	11/09/11	85	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	12/07/11	85	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	01/20/12	88	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	02/17/12	95	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	03/16/12	99	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	04/13/12	94	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	05/18/12	99	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	06/15/12	99	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	07/20/12	80	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	08/17/12	73	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	09/14/12	80	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	10/19/12	64	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	11/16/12	73	uS/cm
Gunnerton WTW raw	Conductivity 20 Deg. C	12/14/12	84	uS/cm
Gunnerton WTW raw	Turbidity	01/05/11	1.4	NTU
Gunnerton WTW raw	Turbidity	02/09/11	6.6	NTU
Gunnerton WTW raw	Turbidity	03/09/11	1.8	NTU
Gunnerton WTW raw	Turbidity	04/06/11	2.4	NTU
Gunnerton WTW raw	Turbidity	05/11/11	2.8	NTU
Gunnerton WTW raw	Turbidity	06/08/11	1.2	NTU

Gunnerton WTW raw	Turbidity	07/06/11	2	NTU
Gunnerton WTW raw	Turbidity	08/10/11	2.2	NTU
Gunnerton WTW raw	Turbidity	09/07/11	1.2	NTU
Gunnerton WTW raw	Turbidity	10/05/11	0.78	NTU
Gunnerton WTW raw	Turbidity	11/09/11	1.2	NTU
Gunnerton WTW raw	Turbidity	12/07/11	1.5	NTU
Gunnerton WTW raw	Turbidity	01/20/12	1.3	NTU
Gunnerton WTW raw	Turbidity	02/17/12	1	NTU
Gunnerton WTW raw	Turbidity	03/16/12	2.3	NTU
Gunnerton WTW raw	Turbidity	04/13/12	3.1	NTU
Gunnerton WTW raw	Turbidity	05/18/12	2.1	NTU
Gunnerton WTW raw	Turbidity	06/15/12	2.2	NTU
Gunnerton WTW raw	Turbidity	07/20/12	1.7	NTU
Gunnerton WTW raw	Turbidity	08/17/12	3.1	NTU
Gunnerton WTW raw	Turbidity	09/14/12	1.6	NTU
Gunnerton WTW raw	Turbidity	10/19/12	2.1	NTU
Gunnerton WTW raw	Turbidity	11/16/12	1.1	NTU
Gunnerton WTW raw	Turbidity	12/14/12	1.4	NTU
Gunnerton WTW raw	Colour Filtered	01/05/11	74	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	02/09/11	71	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	03/09/11	66	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	04/06/11	70	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	05/11/11	64	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	06/08/11	61	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	07/06/11	67	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	08/10/11	100	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	09/07/11	110	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	10/05/11	99	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	11/09/11	100	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	12/07/11	100	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	01/20/12	73	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	02/17/12	65	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	03/16/12	66	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	04/13/12	78	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	05/18/12	68	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	06/15/12	59	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	07/20/12	96	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	08/17/12	120	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	09/14/12	120	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	10/19/12	120	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	11/16/12	110	mg/l Pt/Co scal
Gunnerton WTW raw	Colour Filtered	12/14/12	98	mg/l Pt/Co scal
Gunnerton WTW raw	Temperature Deg. C	01/05/11	3.2	Deg. C
Gunnerton WTW raw	Temperature Deg. C	02/09/11	4.4	Deg. C
Gunnerton WTW raw	Temperature Deg. C	03/09/11	4.5	Deg. C
Gunnerton WTW raw	Temperature Deg. C	04/06/11	8.7	Deg. C
Gunnerton WTW raw	Temperature Deg. C	05/11/11	10.4	Deg. C
Gunnerton WTW raw	Temperature Deg. C	06/08/11	12.4	Deg. C
Gunnerton WTW raw	Temperature Deg. C	07/06/11	13.2	Deg. C
Gunnerton WTW raw	Temperature Deg. C	08/10/11	14.2	Deg. C
Gunnerton WTW raw	Temperature Deg. C	09/07/11	13.6	Deg. C
Gunnerton WTW raw	Temperature Deg. C	10/05/11	13	Deg. C
Gunnerton WTW raw	Temperature Deg. C	11/09/11	9.6	Deg. C
Gunnerton WTW raw	Temperature Deg. C	12/07/11	6.6	Deg. C
Gunnerton WTW raw	Temperature Deg. C	01/20/12	5	Deg. C
Gunnerton WTW raw	Temperature Deg. C	02/17/12	4.4	Deg. C
Gunnerton WTW raw	Temperature Deg. C	03/16/12	6.9	Deg. C

Gunnerton WTW raw	Temperature Deg. C	04/13/12	8.4	Deg. C
Gunnerton WTW raw	Temperature Deg. C	05/18/12	9.4	Deg. C
Gunnerton WTW raw	Temperature Deg. C	06/15/12	16.3	Deg. C
Gunnerton WTW raw	Temperature Deg. C	07/20/12	12.8	Deg. C
Gunnerton WTW raw	Temperature Deg. C	08/17/12	14.8	Deg. C
Gunnerton WTW raw	Temperature Deg. C	09/14/12	4.3	Deg. C
Gunnerton WTW raw	Temperature Deg. C	10/19/12	10.4	Deg. C
Gunnerton WTW raw	Temperature Deg. C	11/16/12	8.9	Deg. C
Gunnerton WTW raw	Temperature Deg. C	12/14/12	6.3	Deg. C
Gunnerton WTW raw	Total Organic Carbon	01/05/11	8.1	mg/l
Gunnerton WTW raw	Total Organic Carbon	02/09/11	7.9	mg/l
Gunnerton WTW raw	Total Organic Carbon	03/09/11	7.6	mg/l
Gunnerton WTW raw	Total Organic Carbon	04/06/11	8	mg/l
Gunnerton WTW raw	Total Organic Carbon	05/11/11	7.1	mg/l
Gunnerton WTW raw	Total Organic Carbon	06/08/11	7.3	mg/l
Gunnerton WTW raw	Total Organic Carbon	07/06/11	7.8	mg/l
Gunnerton WTW raw	Total Organic Carbon	08/10/11	12	mg/l
Gunnerton WTW raw	Total Organic Carbon	09/07/11	12	mg/l
Gunnerton WTW raw	Total Organic Carbon	10/05/11	12	mg/l
Gunnerton WTW raw	Total Organic Carbon	11/09/11	11	mg/l
Gunnerton WTW raw	Total Organic Carbon	12/07/11	11	mg/l
Gunnerton WTW raw	Total Organic Carbon	01/20/12	8.3	mg/l
Gunnerton WTW raw	Total Organic Carbon	02/17/12	7.6	mg/l
Gunnerton WTW raw	Total Organic Carbon	03/16/12	7.6	mg/l
Gunnerton WTW raw	Total Organic Carbon	04/13/12	8.8	mg/l
Gunnerton WTW raw	Total Organic Carbon	05/18/12	7.7	mg/l
Gunnerton WTW raw	Total Organic Carbon	06/15/12	7.1	mg/l
Gunnerton WTW raw	Total Organic Carbon	07/20/12	11	mg/l
Gunnerton WTW raw	Total Organic Carbon	08/17/12	14	mg/l
Gunnerton WTW raw	Total Organic Carbon	09/14/12	13	mg/l
Gunnerton WTW raw	Total Organic Carbon	10/19/12	14	mg/l
Gunnerton WTW raw	Total Organic Carbon	11/16/12	12	mg/l
Gunnerton WTW raw	Total Organic Carbon	12/14/12	10	mg/l
Gunnerton WTW raw	Nitrogen Ammoniacal	01/05/11	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	02/09/11	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	03/09/11	0.03	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	04/06/11	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	05/11/11	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	06/08/11	0.013	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	07/06/11	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	08/10/11	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	09/07/11	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	10/05/11	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	11/09/11	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	12/07/11	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	01/20/12	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	02/17/12	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	03/16/12	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	04/13/12	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	05/18/12	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	06/15/12	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	07/20/12	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	08/17/12	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	09/14/12	0.012	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	10/19/12	0.0095	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	11/16/12	0.007	mg/l as NH4
Gunnerton WTW raw	Nitrogen Ammoniacal	12/14/12	0.007	mg/l as NH4

Gunnerton WTW raw	Nitrate	01/05/11	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	02/09/11	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	03/09/11	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	04/06/11	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	05/11/11	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	06/08/11	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	07/06/11	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	08/10/11	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	09/07/11	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	10/05/11	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	11/09/11	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	12/07/11	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	01/20/12	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	02/17/12	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	03/16/12	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	04/13/12	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	05/18/12	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	06/15/12	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	07/20/12	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	08/17/12	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	09/14/12	2.7	mg/l as NO3
Gunnerton WTW raw	Nitrate	10/19/12	0.52	mg/l as NO3
Gunnerton WTW raw	Nitrate	11/16/12	0.14	mg/l as NO3
Gunnerton WTW raw	Nitrate	12/14/12	1.2	mg/l as NO3
Gunnerton WTW raw	Nitrite	01/05/11	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	02/09/11	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	03/09/11	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	04/06/11	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	05/11/11	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	06/08/11	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	07/06/11	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	08/10/11	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	09/07/11	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	10/05/11	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	11/09/11	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	12/07/11	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	01/20/12	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	02/17/12	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	03/16/12	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	04/13/12	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	05/18/12	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	06/15/12	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	07/20/12	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	08/17/12	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	09/14/12	0.0014	mg/l as NO2
Gunnerton WTW raw	Nitrite	10/19/12	0.0011	mg/l as NO2
Gunnerton WTW raw	Nitrite	11/16/12	0.0011	mg/l as NO2
Gunnerton WTW raw	Nitrite	12/14/12	0.0011	mg/l as NO2
Gunnerton WTW raw	Hardness Total	01/05/11	21	mg/l
Gunnerton WTW raw	Hardness Total	02/09/11	13	mg/l
Gunnerton WTW raw	Hardness Total	03/09/11	14	mg/l
Gunnerton WTW raw	Hardness Total	04/06/11	15	mg/l
Gunnerton WTW raw	Hardness Total	05/11/11	17	mg/l
Gunnerton WTW raw	Hardness Total	06/08/11	19	mg/l as Ca
Gunnerton WTW raw	Hardness Total	07/06/11	20	mg/l as Ca
Gunnerton WTW raw	Hardness Total	08/10/11	17	mg/l as Ca
Gunnerton WTW raw	Hardness Total	09/07/11	17	mg/l as Ca

Gunnerton WTW raw	Hardness Total	10/05/11	19	mg/l as Ca
Gunnerton WTW raw	Hardness Total	11/09/11	20	mg/l as Ca
Gunnerton WTW raw	Hardness Total	12/07/11	19	mg/l as Ca
Gunnerton WTW raw	Hardness Total	01/20/12	16	mg/l as Ca
Gunnerton WTW raw	Hardness Total	02/17/12	18	mg/l as Ca
Gunnerton WTW raw	Hardness Total	03/16/12	18	mg/l as Ca
Gunnerton WTW raw	Hardness Total	04/13/12	19	mg/l as Ca
Gunnerton WTW raw	Hardness Total	05/18/12	19	mg/l as Ca
Gunnerton WTW raw	Hardness Total	06/15/12	19	mg/l as Ca
Gunnerton WTW raw	Hardness Total	07/20/12	15	mg/l as Ca
Gunnerton WTW raw	Hardness Total	08/17/12	14	mg/l as Ca
Gunnerton WTW raw	Hardness Total	09/14/12	17	mg/l as Ca
Gunnerton WTW raw	Hardness Total	10/19/12	13	mg/l as Ca
Gunnerton WTW raw	Hardness Total	11/16/12	16	mg/l as Ca
Gunnerton WTW raw	Hardness Total	12/14/12	15	mg/l as Ca
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	01/05/11	43	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	02/09/11	24	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	03/09/11	29	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	04/06/11	27	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	05/11/11	43	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	06/08/11	50	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	07/06/11	65	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	08/10/11	38	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	09/07/11	36	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	10/05/11	51	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	11/09/11	40	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	12/07/11	41	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	01/20/12	33	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	02/17/12	38	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	03/16/12	38	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	04/13/12	44	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	05/18/12	56	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	06/15/12	51	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	07/20/12	45	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	08/17/12	39	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	09/14/12	43	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	10/19/12	32	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	11/16/12	38	mg/l as HCO3
Gunnerton WTW raw	Alkalinity to pH 4.5 (Total)	12/14/12	37	mg/l as HCO3
Gunnerton WTW raw	Chloride	01/05/11	10	mg/l
Gunnerton WTW raw	Chloride	02/09/11	6.2	mg/l
Gunnerton WTW raw	Chloride	03/09/11	7.1	mg/l
Gunnerton WTW raw	Chloride	04/06/11	7.8	mg/l
Gunnerton WTW raw	Chloride	05/11/11	7.8	mg/l
Gunnerton WTW raw	Chloride	06/08/11	5.8	mg/l
Gunnerton WTW raw	Chloride	07/06/11	5.5	mg/l
Gunnerton WTW raw	Chloride	08/10/11	5.2	mg/l
Gunnerton WTW raw	Chloride	09/07/11	5	mg/l
Gunnerton WTW raw	Chloride	10/05/11	6.2	mg/l
Gunnerton WTW raw	Chloride	11/09/11	5.2	mg/l
Gunnerton WTW raw	Chloride	12/07/11	4.9	mg/l
Gunnerton WTW raw	Chloride	01/20/12	7.5	mg/l
Gunnerton WTW raw	Chloride	02/17/12	8.4	mg/l
Gunnerton WTW raw	Chloride	03/16/12	8.4	mg/l
Gunnerton WTW raw	Chloride	04/13/12	7.8	mg/l
Gunnerton WTW raw	Chloride	05/18/12	6.9	mg/l
Gunnerton WTW raw	Chloride	06/15/12	7.5	mg/l

Gunnerton WTW raw	Chloride	07/20/12	5.9	mg/l
Gunnerton WTW raw	Chloride	08/17/12	4.9	mg/l
Gunnerton WTW raw	Chloride	09/14/12	4.3	mg/l
Gunnerton WTW raw	Chloride	10/19/12	4.4	mg/l
Gunnerton WTW raw	Chloride	11/16/12	4.8	mg/l
Gunnerton WTW raw	Chloride	12/14/12	5.6	mg/l
Gunnerton WTW raw	Sulphate Dissolved	01/05/11	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	02/09/11	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	03/09/11	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	04/06/11	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	05/11/11	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	06/08/11	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	07/06/11	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	08/10/11	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	09/07/11	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	10/05/11	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	11/09/11	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	12/07/11	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	01/20/12	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	02/17/12	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	03/16/12	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	04/13/12	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	05/18/12	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	06/15/12	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	07/20/12	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	08/17/12	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	09/14/12	0.49	mg/l
Gunnerton WTW raw	Sulphate Dissolved	10/19/12	0.29	mg/l
Gunnerton WTW raw	Sulphate Dissolved	11/16/12	0.29	mg/l
Gunnerton WTW raw	Sulphate Dissolved	12/14/12	0.29	mg/l
Gunnerton WTW raw	Sodium Total	01/05/11	6.9	mg/l
Gunnerton WTW raw	Sodium Total	02/09/11	5.2	mg/l
Gunnerton WTW raw	Sodium Total	03/09/11	5.2	mg/l
Gunnerton WTW raw	Sodium Total	04/06/11	5.3	mg/l
Gunnerton WTW raw	Sodium Total	05/11/11	5.3	mg/l
Gunnerton WTW raw	Sodium Total	06/08/11	5.3	mg/l
Gunnerton WTW raw	Sodium Total	07/06/11	5.2	mg/l
Gunnerton WTW raw	Sodium Total	08/10/11	4.4	mg/l
Gunnerton WTW raw	Sodium Total	09/07/11	4.4	mg/l
Gunnerton WTW raw	Sodium Total	10/05/11	4.4	mg/l
Gunnerton WTW raw	Sodium Total	11/09/11	4.4	mg/l
Gunnerton WTW raw	Sodium Total	12/07/11	4.5	mg/l
Gunnerton WTW raw	Sodium Total	01/20/12	5.8	mg/l
Gunnerton WTW raw	Sodium Total	02/17/12	5.6	mg/l
Gunnerton WTW raw	Sodium Total	03/16/12	5.8	mg/l
Gunnerton WTW raw	Sodium Total	04/13/12	5.8	mg/l
Gunnerton WTW raw	Sodium Total	05/18/12	5.3	mg/l
Gunnerton WTW raw	Sodium Total	06/15/12	5.6	mg/l
Gunnerton WTW raw	Sodium Total	07/20/12	4.6	mg/l
Gunnerton WTW raw	Sodium Total	08/17/12	3.8	mg/l
Gunnerton WTW raw	Sodium Total	09/14/12	3.9	mg/l
Gunnerton WTW raw	Sodium Total	10/19/12	3.6	mg/l
Gunnerton WTW raw	Sodium Total	11/16/12	3.8	mg/l
Gunnerton WTW raw	Sodium Total	12/14/12	4.3	mg/l
Gunnerton WTW raw	Magnesium Total	01/05/11	5.2	mg/l
Gunnerton WTW raw	Magnesium Total	02/09/11	3.2	mg/l
Gunnerton WTW raw	Magnesium Total	03/09/11	3.2	mg/l

Gunnerton WTW raw	Magnesium Total	04/06/11	4	mg/l
Gunnerton WTW raw	Magnesium Total	05/11/11	3.6	mg/l
Gunnerton WTW raw	Magnesium Total	06/08/11	4.6	mg/l
Gunnerton WTW raw	Magnesium Total	07/06/11	5.3	mg/l
Gunnerton WTW raw	Magnesium Total	08/10/11	4.1	mg/l
Gunnerton WTW raw	Magnesium Total	09/07/11	4.4	mg/l
Gunnerton WTW raw	Magnesium Total	10/05/11	4.5	mg/l
Gunnerton WTW raw	Magnesium Total	11/09/11	5	mg/l
Gunnerton WTW raw	Magnesium Total	12/07/11	4.7	mg/l
Gunnerton WTW raw	Magnesium Total	01/20/12	4	mg/l
Gunnerton WTW raw	Magnesium Total	02/17/12	4.5	mg/l
Gunnerton WTW raw	Magnesium Total	03/16/12	4.6	mg/l
Gunnerton WTW raw	Magnesium Total	04/13/12	4.6	mg/l
Gunnerton WTW raw	Magnesium Total	05/18/12	4.5	mg/l
Gunnerton WTW raw	Magnesium Total	06/15/12	4.7	mg/l
Gunnerton WTW raw	Magnesium Total	07/20/12	3.6	mg/l
Gunnerton WTW raw	Magnesium Total	08/17/12	3.5	mg/l
Gunnerton WTW raw	Magnesium Total	09/14/12	4.4	mg/l
Gunnerton WTW raw	Magnesium Total	10/19/12	3.3	mg/l
Gunnerton WTW raw	Magnesium Total	11/16/12	3.9	mg/l
Gunnerton WTW raw	Magnesium Total	12/14/12	3.8	mg/l
Gunnerton WTW raw	Calcium Total	01/05/11	13	mg/l
Gunnerton WTW raw	Calcium Total	02/09/11	7.8	mg/l
Gunnerton WTW raw	Calcium Total	03/09/11	8.8	mg/l
Gunnerton WTW raw	Calcium Total	04/06/11	8.4	mg/l
Gunnerton WTW raw	Calcium Total	05/11/11	11	mg/l
Gunnerton WTW raw	Calcium Total	06/08/11	11	mg/l as Ca
Gunnerton WTW raw	Calcium Total	07/06/11	11	mg/l as Ca
Gunnerton WTW raw	Calcium Total	08/10/11	10	mg/l as Ca
Gunnerton WTW raw	Calcium Total	09/07/11	10	mg/l as Ca
Gunnerton WTW raw	Calcium Total	10/05/11	11	mg/l as Ca
Gunnerton WTW raw	Calcium Total	11/09/11	11	mg/l as Ca
Gunnerton WTW raw	Calcium Total	12/07/11	11	mg/l as Ca
Gunnerton WTW raw	Calcium Total	01/20/12	9.9	mg/l as Ca
Gunnerton WTW raw	Calcium Total	02/17/12	11	mg/l as Ca
Gunnerton WTW raw	Calcium Total	03/16/12	10	mg/l as Ca
Gunnerton WTW raw	Calcium Total	04/13/12	11	mg/l as Ca
Gunnerton WTW raw	Calcium Total	05/18/12	12	mg/l as Ca
Gunnerton WTW raw	Calcium Total	06/15/12	11	mg/l as Ca
Gunnerton WTW raw	Calcium Total	07/20/12	9.6	mg/l as Ca
Gunnerton WTW raw	Calcium Total	08/17/12	8	mg/l as Ca
Gunnerton WTW raw	Calcium Total	09/14/12	10	mg/l as Ca
Gunnerton WTW raw	Calcium Total	10/19/12	7.6	mg/l as Ca
Gunnerton WTW raw	Calcium Total	11/16/12	9.2	mg/l as Ca
Gunnerton WTW raw	Calcium Total	12/14/12	8.9	mg/l as Ca
Gunnerton WTW raw	Cadmium Total	01/05/11	0.0099	ug/l
Gunnerton WTW raw	Cadmium Total	02/09/11	0.038	ug/l
Gunnerton WTW raw	Cadmium Total	03/09/11	0.013	ug/l
Gunnerton WTW raw	Cadmium Total	04/06/11	0.014	ug/l
Gunnerton WTW raw	Cadmium Total	05/11/11	0.0082	ug/l
Gunnerton WTW raw	Cadmium Total	06/08/11	0.0081	ug/l
Gunnerton WTW raw	Cadmium Total	07/06/11	0.0081	ug/l
Gunnerton WTW raw	Cadmium Total	08/10/11	0.021	ug/l
Gunnerton WTW raw	Cadmium Total	09/07/11	0.014	ug/l
Gunnerton WTW raw	Cadmium Total	10/05/11	0.0081	ug/l
Gunnerton WTW raw	Cadmium Total	11/09/11	0.011	ug/l
Gunnerton WTW raw	Cadmium Total	12/07/11	0.011	ug/l

Gunnerton WTW raw	Cadmium Total	01/20/12	0.012	ug/l
Gunnerton WTW raw	Cadmium Total	02/17/12	0.0081	ug/l
Gunnerton WTW raw	Cadmium Total	03/16/12	0.021	ug/l
Gunnerton WTW raw	Cadmium Total	04/13/12	0.02	ug/l
Gunnerton WTW raw	Cadmium Total	05/18/12	0.0098	ug/l
Gunnerton WTW raw	Cadmium Total	06/15/12	0.0081	ug/l
Gunnerton WTW raw	Cadmium Total	07/20/12	0.0081	ug/l
Gunnerton WTW raw	Cadmium Total	08/17/12	0.0081	ug/l
Gunnerton WTW raw	Cadmium Total	09/14/12	0.0081	ug/l
Gunnerton WTW raw	Cadmium Total	10/19/12	0.0081	ug/l
Gunnerton WTW raw	Cadmium Total	11/16/12	0.0081	ug/l
Gunnerton WTW raw	Cadmium Total	12/14/12	0.0072	ug/l
Gunnerton WTW raw	Aluminium Total	01/05/11	110	ug/l
Gunnerton WTW raw	Aluminium Total	02/09/11	320	ug/l
Gunnerton WTW raw	Aluminium Total	03/09/11	150	ug/l
Gunnerton WTW raw	Aluminium Total	04/06/11	160	ug/l
Gunnerton WTW raw	Aluminium Total	05/11/11	120	ug/l
Gunnerton WTW raw	Aluminium Total	06/08/11	76	ug/l
Gunnerton WTW raw	Aluminium Total	07/06/11	94	ug/l
Gunnerton WTW raw	Aluminium Total	08/10/11	140	ug/l
Gunnerton WTW raw	Aluminium Total	09/07/11	130	ug/l
Gunnerton WTW raw	Aluminium Total	10/05/11	100	ug/l
Gunnerton WTW raw	Aluminium Total	11/09/11	110	ug/l
Gunnerton WTW raw	Aluminium Total	12/07/11	100	ug/l
Gunnerton WTW raw	Aluminium Total	01/20/12	100	ug/l
Gunnerton WTW raw	Aluminium Total	02/17/12	85	ug/l
Gunnerton WTW raw	Aluminium Total	03/16/12	93	ug/l
Gunnerton WTW raw	Aluminium Total	04/13/12	120	ug/l
Gunnerton WTW raw	Aluminium Total	05/18/12	93	ug/l
Gunnerton WTW raw	Aluminium Total	06/15/12	78	ug/l
Gunnerton WTW raw	Aluminium Total	07/20/12	150	ug/l
Gunnerton WTW raw	Aluminium Total	08/17/12	180	ug/l
Gunnerton WTW raw	Aluminium Total	09/14/12	140	ug/l
Gunnerton WTW raw	Aluminium Total	10/19/12	170	ug/l
Gunnerton WTW raw	Aluminium Total	11/16/12	110	ug/l
Gunnerton WTW raw	Aluminium Total	12/14/12	150	ug/l
Gunnerton WTW raw	Lead Total	01/05/11	0.46	ug/l
Gunnerton WTW raw	Lead Total	02/09/11	0.86	ug/l
Gunnerton WTW raw	Lead Total	03/09/11	0.62	ug/l
Gunnerton WTW raw	Lead Total	04/06/11	0.57	ug/l
Gunnerton WTW raw	Lead Total	05/11/11	1.2	ug/l
Gunnerton WTW raw	Lead Total	06/08/11	0.37	ug/l
Gunnerton WTW raw	Lead Total	07/06/11	0.54	ug/l
Gunnerton WTW raw	Lead Total	08/10/11	0.71	ug/l
Gunnerton WTW raw	Lead Total	09/07/11	0.47	ug/l
Gunnerton WTW raw	Lead Total	10/05/11	0.59	ug/l
Gunnerton WTW raw	Lead Total	11/09/11	0.47	ug/l
Gunnerton WTW raw	Lead Total	12/07/11	0.45	ug/l
Gunnerton WTW raw	Lead Total	01/20/12	0.35	ug/l
Gunnerton WTW raw	Lead Total	02/17/12	0.45	ug/l
Gunnerton WTW raw	Lead Total	03/16/12	0.46	ug/l
Gunnerton WTW raw	Lead Total	04/13/12	0.89	ug/l
Gunnerton WTW raw	Lead Total	05/18/12	1.3	ug/l
Gunnerton WTW raw	Lead Total	06/15/12	1.2	ug/l
Gunnerton WTW raw	Lead Total	07/20/12	0.8	ug/l
Gunnerton WTW raw	Lead Total	08/17/12	0.7	ug/l
Gunnerton WTW raw	Lead Total	09/14/12	0.54	ug/l

Gunnerton WTW raw	Lead Total	10/19/12	0.73	ug/l
Gunnerton WTW raw	Lead Total	11/16/12	0.33	ug/l
Gunnerton WTW raw	Lead Total	12/14/12	0.58	ug/l
Gunnerton WTW raw	Phosphorus Total (As P)	01/05/11	51	ug/l as P
Gunnerton WTW raw	Phosphorus Total (As P)	04/06/11	7.6	ug/l as P
Gunnerton WTW raw	Phosphorus Total (As P)	07/06/11	8	ug/l as P
Gunnerton WTW raw	Phosphorus Total (As P)	10/05/11	11	ug/l as P
Gunnerton WTW raw	Phosphorus Total (As P)	01/20/12	7.1	ug/l as P
Gunnerton WTW raw	Phosphorus Total (As P)	04/13/12	10	ug/l as P
Gunnerton WTW raw	Phosphorus Total (As P)	07/20/12	10	ug/l as P
Gunnerton WTW raw	Phosphorus Total (As P)	10/19/12	13	ug/l as P
Gunnerton WTW raw	Manganese Total	01/05/11	21	ug/l
Gunnerton WTW raw	Manganese Total	02/09/11	29	ug/l
Gunnerton WTW raw	Manganese Total	03/09/11	21	ug/l
Gunnerton WTW raw	Manganese Total	04/06/11	31	ug/l
Gunnerton WTW raw	Manganese Total	05/11/11	57	ug/l
Gunnerton WTW raw	Manganese Total	06/08/11	24	ug/l
Gunnerton WTW raw	Manganese Total	07/06/11	58	ug/l
Gunnerton WTW raw	Manganese Total	08/10/11	69	ug/l
Gunnerton WTW raw	Manganese Total	09/07/11	34	ug/l
Gunnerton WTW raw	Manganese Total	10/05/11	26	ug/l
Gunnerton WTW raw	Manganese Total	11/09/11	62	ug/l
Gunnerton WTW raw	Manganese Total	12/07/11	14	ug/l
Gunnerton WTW raw	Manganese Total	01/20/12	15	ug/l
Gunnerton WTW raw	Manganese Total	02/17/12	15	ug/l
Gunnerton WTW raw	Manganese Total	03/16/12	33	ug/l
Gunnerton WTW raw	Manganese Total	04/13/12	64	ug/l
Gunnerton WTW raw	Manganese Total	05/18/12	22	ug/l
Gunnerton WTW raw	Manganese Total	06/15/12	47	ug/l
Gunnerton WTW raw	Manganese Total	07/20/12	27	ug/l
Gunnerton WTW raw	Manganese Total	08/17/12	50	ug/l
Gunnerton WTW raw	Manganese Total	09/14/12	53	ug/l
Gunnerton WTW raw	Manganese Total	10/19/12	17	ug/l
Gunnerton WTW raw	Manganese Total	11/16/12	10	ug/l
Gunnerton WTW raw	Manganese Total	12/14/12	22	ug/l
Gunnerton WTW raw	Iron Total	01/05/11	320	ug/l
Gunnerton WTW raw	Iron Total	02/09/11	470	ug/l
Gunnerton WTW raw	Iron Total	03/09/11	280	ug/l
Gunnerton WTW raw	Iron Total	04/06/11	350	ug/l
Gunnerton WTW raw	Iron Total	05/11/11	400	ug/l
Gunnerton WTW raw	Iron Total	06/08/11	260	ug/l
Gunnerton WTW raw	Iron Total	07/06/11	390	ug/l
Gunnerton WTW raw	Iron Total	08/10/11	440	ug/l
Gunnerton WTW raw	Iron Total	09/07/11	400	ug/l
Gunnerton WTW raw	Iron Total	10/05/11	380	ug/l
Gunnerton WTW raw	Iron Total	11/09/11	490	ug/l
Gunnerton WTW raw	Iron Total	12/07/11	430	ug/l
Gunnerton WTW raw	Iron Total	01/20/12	340	ug/l
Gunnerton WTW raw	Iron Total	02/17/12	310	ug/l
Gunnerton WTW raw	Iron Total	03/16/12	370	ug/l
Gunnerton WTW raw	Iron Total	04/13/12	490	ug/l
Gunnerton WTW raw	Iron Total	05/18/12	410	ug/l
Gunnerton WTW raw	Iron Total	06/15/12	350	ug/l
Gunnerton WTW raw	Iron Total	07/20/12	390	ug/l
Gunnerton WTW raw	Iron Total	08/17/12	520	ug/l
Gunnerton WTW raw	Iron Total	09/14/12	530	ug/l
Gunnerton WTW raw	Iron Total	10/19/12	520	ug/l

Gunnerton WTW raw	Iron Total	11/16/12	450	ug/l
Gunnerton WTW raw	Iron Total	12/14/12	450	ug/l
Gunnerton WTW raw	Nickel Total	01/05/11	0.99	ug/l
Gunnerton WTW raw	Nickel Total	02/09/11	1.1	ug/l
Gunnerton WTW raw	Nickel Total	03/09/11	0.88	ug/l
Gunnerton WTW raw	Nickel Total	04/06/11	0.87	ug/l
Gunnerton WTW raw	Nickel Total	05/11/11	0.89	ug/l
Gunnerton WTW raw	Nickel Total	06/08/11	0.93	ug/l
Gunnerton WTW raw	Nickel Total	07/06/11	0.7	ug/l
Gunnerton WTW raw	Nickel Total	08/10/11	0.99	ug/l
Gunnerton WTW raw	Nickel Total	09/07/11	0.9	ug/l
Gunnerton WTW raw	Nickel Total	10/05/11	0.85	ug/l
Gunnerton WTW raw	Nickel Total	11/09/11	1.1	ug/l
Gunnerton WTW raw	Nickel Total	12/07/11	0.92	ug/l
Gunnerton WTW raw	Nickel Total	01/20/12	0.85	ug/l
Gunnerton WTW raw	Nickel Total	02/17/12	0.88	ug/l
Gunnerton WTW raw	Nickel Total	03/16/12	0.7	ug/l
Gunnerton WTW raw	Nickel Total	04/13/12	0.96	ug/l
Gunnerton WTW raw	Nickel Total	05/18/12	0.97	ug/l
Gunnerton WTW raw	Nickel Total	06/15/12	0.92	ug/l
Gunnerton WTW raw	Nickel Total	07/20/12	1.5	ug/l
Gunnerton WTW raw	Nickel Total	08/17/12	1	ug/l
Gunnerton WTW raw	Nickel Total	09/14/12	1.1	ug/l
Gunnerton WTW raw	Nickel Total	10/19/12	1	ug/l
Gunnerton WTW raw	Nickel Total	11/16/12	0.81	ug/l
Gunnerton WTW raw	Nickel Total	12/14/12	0.9	ug/l

Honeyhill WTW raw

Spt Desc	Detdesc	Datetaken	Value	Unitused
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	01/18/11	5.7	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	02/15/11	6.2	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	03/15/11	6.4	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	04/12/11	6.9	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	05/17/11	7.2	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	06/14/11	7.1	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	07/12/11	7.8	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	08/16/11	7.3	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	09/13/11	7.6	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	10/11/11	7.3	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	11/15/11	8.2	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	12/13/11	5.7	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	01/12/12	7.1	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	02/09/12	5.9	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	03/08/12	7.8	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	04/12/12	6.4	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	05/10/12	5.3	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	06/07/12	6.2	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	07/12/12	5	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	08/09/12	5.6	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	09/06/12	7.2	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	10/11/12	7	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	11/08/12	5.8	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Hydrogen ion	12/06/12	5.9	pH Value
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	01/18/11	1.3	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	02/15/11	4.4	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	03/15/11	6.6	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	04/12/11	38	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	05/17/11	34	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	06/14/11	12	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	07/12/11	1.3	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	08/16/11	8.1	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	09/13/11	6.1	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	10/11/11	4.9	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	11/15/11	2.8	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	12/13/11	2.6	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	01/12/12	15	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	02/09/12	1.3	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	03/08/12	6	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	04/12/12	0.99	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	05/10/12	1.4	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	06/07/12	19	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	07/12/12	1.8	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	08/09/12	2.5	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	09/06/12	1.4	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	10/11/12	2.6	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	11/08/12	1.9	NTU
Honey Hill WTW raw - Hysehope Reservoir	Turbidity	12/06/12	2.3	NTU
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	01/18/11	49	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	02/15/11	110	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	03/15/11	95	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	04/12/11	65	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	05/17/11	61	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	06/14/11	47	mg/l Pt/Co scal

Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	07/12/11	59	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	08/16/11	99	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	09/13/11	110	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	10/11/11	67	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	11/15/11	86	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	12/13/11	57	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	01/12/12	89	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	02/09/12	46	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	03/08/12	78	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	04/12/12	36	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	05/10/12	65	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	06/07/12	2.4	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	07/12/12	140	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	08/09/12	140	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	09/06/12	120	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	10/11/12	130	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	11/08/12	130	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Colour Filtered	12/06/12	130	mg/l Pt/Co scal
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	01/18/11	17	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	02/15/11	17	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	03/15/11	17	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	04/12/11	17	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	05/17/11	37	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	06/14/11	21	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	07/12/11	57	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	08/16/11	51	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	09/13/11	48	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	10/11/11	31	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	11/15/11	27	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	12/13/11	17	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	01/12/12	17	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	02/09/12	17	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	03/08/12	24	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	04/12/12	17	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	05/10/12	17	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	06/07/12	17	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	07/12/12	17	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	08/09/12	17	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	09/06/12	17	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	10/11/12	8.4	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	11/08/12	9	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Alkalinity to pH 4.5 (Total)	12/06/12	6.1	mg/l as HCO3
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	01/18/11	300	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	02/15/11	430	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	03/15/11	410	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	04/12/11	1300	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	05/17/11	1100	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	06/14/11	420	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	07/12/11	68	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	08/16/11	300	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	09/13/11	200	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	10/11/11	210	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	11/15/11	180	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	12/13/11	330	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	01/12/12	440	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	02/09/12	280	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	03/08/12	300	ug/l

Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	04/12/12	230	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	05/10/12	320	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	06/07/12	230	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	07/12/12	460	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	08/09/12	510	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	09/06/12	260	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	10/11/12	390	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	11/08/12	360	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Aluminium Total	12/06/12	340	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	01/18/11	140	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	02/15/11	100	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	03/15/11	110	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	04/12/11	970	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	05/17/11	310	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	06/14/11	250	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	07/12/11	39	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	08/16/11	540	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	09/13/11	290	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	10/11/11	77	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	11/15/11	92	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	12/13/11	110	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	01/12/12	130	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	02/09/12	100	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	03/08/12	75	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	04/12/12	79	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	05/10/12	110	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	06/07/12	140	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	07/12/12	130	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	08/09/12	150	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	09/06/12	23	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	10/11/12	120	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	11/08/12	120	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Manganese Total	12/06/12	100	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	01/18/11	580	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	02/15/11	960	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	03/15/11	1200	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	04/12/11	4200	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	05/17/11	3500	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	06/14/11	1000	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	07/12/11	370	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	08/16/11	1200	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	09/13/11	1100	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	10/11/11	670	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	11/15/11	710	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	12/13/11	930	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	01/12/12	1100	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	02/09/12	570	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	03/08/12	880	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	04/12/12	440	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	05/10/12	560	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	06/07/12	15000	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	07/12/12	1300	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	08/09/12	1700	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	09/06/12	790	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	10/11/12	1200	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	11/08/12	1300	ug/l
Honey Hill WTW raw - Hysehope Reservoir	Iron Total	12/06/12	1000	ug/l

Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	01/11/11	6.8	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	02/15/11	6.7	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	03/15/11	6.7	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	04/12/11	6.9	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	05/17/11	6.9	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	06/14/11	7.2	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	07/12/11	7.1	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	08/16/11	7.2	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	09/13/11	7.7	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	10/11/11	7.3	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	11/15/11	7.4	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	12/13/11	7.2	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	01/12/12	7.1	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	02/09/12	7.7	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	03/08/12	7.1	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	04/12/12	7.1	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	05/10/12	6.9	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	06/07/12	6.8	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	07/12/12	6.5	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	08/09/12	6.7	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	09/06/12	7	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	10/11/12	6.8	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	11/08/12	8	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hydrogen ion	12/06/12	6.8	pH Value
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	01/11/11	84	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	02/15/11	78	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	03/15/11	69	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	04/12/11	70	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	05/17/11	69	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	06/14/11	76	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	07/12/11	84	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	08/16/11	91	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	09/13/11	95	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	10/11/11	91	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	11/15/11	79	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	12/13/11	75	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	01/12/12	71	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	02/09/12	68	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	03/08/12	67	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	04/12/12	71	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	05/10/12	64	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	06/07/12	62	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	07/12/12	66	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	08/09/12	66	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	09/06/12	59	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	10/11/12	53	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	11/08/12	50	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Conductivity 20 Deg. C	12/06/12	40	uS/cm
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	01/11/11	1.3	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	02/15/11	1.3	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	03/15/11	1.9	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	04/12/11	4.3	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	05/17/11	5.2	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	06/14/11	11	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	07/12/11	5.7	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	08/16/11	5.3	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	09/13/11	11	NTU

Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	10/11/11	6.5	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	11/15/11	2.4	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	12/13/11	2.9	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	01/12/12	11	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	02/09/12	2.5	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	03/08/12	9	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	04/12/12	2	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	05/10/12	1.6	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	06/07/12	1.6	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	07/12/12	1.3	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	08/09/12	1.2	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	09/06/12	1.3	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	10/11/12	1.5	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	11/08/12	1.7	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Turbidity	12/06/12	4.6	NTU
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	01/11/11	76	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	02/15/11	73	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	03/15/11	69	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	04/12/11	58	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	05/17/11	56	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	06/14/11	48	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	07/12/11	43	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	08/16/11	50	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	09/13/11	53	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	10/11/11	62	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	11/15/11	85	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	12/13/11	86	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	01/12/12	140	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	02/09/12	88	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	03/08/12	78	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	04/12/12	66	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	05/10/12	73	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	06/07/12	67	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	07/12/12	98	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	08/09/12	100	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	09/06/12	120	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	10/11/12	120	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	11/08/12	140	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Colour Filtered	12/06/12	160	mg/l Pt/Co scal
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	01/11/11	3.1	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	02/15/11	3.4	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	03/15/11	3.9	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	04/12/11	7.5	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	05/17/11	4.4	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	06/14/11	10.9	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	07/12/11	14.7	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	08/16/11	13.7	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	09/13/11	12.3	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	10/11/11	12.9	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	11/15/11	9.8	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	12/13/11	8.3	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	01/12/12	5.3	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	02/09/12	4.4	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	03/08/12	4.4	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	04/12/12	10.2	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	05/10/12	10.6	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	06/07/12	9.1	Deg. C

Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	07/12/12	15.2	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	08/09/12	16.9	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	09/06/12	14.9	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	10/11/12	10	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	11/08/12	7.2	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Temperature Deg. C	12/06/12	2.2	Deg. C
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	01/11/11	9.5	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	02/15/11	9	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	03/15/11	8.9	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	04/12/11	7.7	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	05/17/11	7.2	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	06/14/11	7.4	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	07/12/11	6.8	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	08/16/11	8	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	09/13/11	8.5	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	10/11/11	8.9	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	11/15/11	11	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	12/13/11	12	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	01/12/12	12	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	02/09/12	10	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	03/08/12	10	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	04/12/12	8.6	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	05/10/12	9.1	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	06/07/12	9.4	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	07/12/12	12	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	08/09/12	13	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	09/06/12	13	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	10/11/12	15	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	11/08/12	14	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Total Organic Carbon	12/06/12	14	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	01/11/11	0.022	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	02/15/11	0.012	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	03/15/11	0.014	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	04/12/11	0.012	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	05/17/11	0.014	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	06/14/11	0.012	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	07/12/11	0.022	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	08/16/11	0.012	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	09/13/11	0.012	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	10/11/11	0.013	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	11/15/11	0.012	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	12/13/11	0.012	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	01/12/12	0.028	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	02/09/12	0.012	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	03/08/12	0.012	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	04/12/12	0.012	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	05/10/12	0.015	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	06/07/12	0.025	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	07/12/12	0.029	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	08/09/12	0.012	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	09/06/12	0.012	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	10/11/12	0.012	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	11/08/12	0.01	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrogen Ammoniacal	12/06/12	0.014	mg/l as NH4
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	01/11/11	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	02/15/11	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	03/15/11	2.7	mg/l as NO3

Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	04/12/11	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	05/17/11	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	06/14/11	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	07/12/11	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	08/16/11	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	09/13/11	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	10/11/11	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	11/15/11	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	12/13/11	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	01/12/12	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	02/09/12	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	03/08/12	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	04/12/12	3.4	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	05/10/12	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	06/07/12	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	07/12/12	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	08/09/12	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	09/06/12	2.7	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	10/11/12	3.6	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	11/08/12	0.98	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrate	12/06/12	0.49	mg/l as NO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	01/11/11	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	02/15/11	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	03/15/11	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	04/12/11	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	05/17/11	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	06/14/11	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	07/12/11	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	08/16/11	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	09/13/11	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	10/11/11	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	11/15/11	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	12/13/11	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	01/12/12	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	02/09/12	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	03/08/12	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	04/12/12	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	05/10/12	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	06/07/12	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	07/12/12	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	08/09/12	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	09/06/12	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	10/11/12	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	11/08/12	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nitrite	12/06/12	0.001	mg/l as NO2
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	01/11/11	10	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	02/15/11	7.3	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	03/15/11	8.6	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	04/12/11	8.6	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	05/17/11	8.7	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	06/14/11	11	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	07/12/11	8.6	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	08/16/11	14	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	09/13/11	15	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	10/11/11	16	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	11/15/11	14	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	12/13/11	12	mg/l as Ca

Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	01/12/12	11	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	02/09/12	10	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	03/08/12	9.7	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	04/12/12	10	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	05/10/12	9.1	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	06/07/12	8.4	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	07/12/12	6.8	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	08/09/12	8.3	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	09/06/12	7.9	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	10/11/12	6.9	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	11/08/12	7	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Hardness Total	12/06/12	6.5	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	01/11/11	17	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	02/15/11	17	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	03/15/11	28	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	04/12/11	17	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	05/17/11	17	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	06/14/11	17	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	07/12/11	23	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	08/16/11	17	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	09/13/11	20	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	10/11/11	22	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	11/15/11	24	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	12/13/11	25	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	01/12/12	17	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	02/09/12	17	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	03/08/12	18	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	04/12/12	17	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	05/10/12	17	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	06/07/12	17	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	07/12/12	17	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	08/09/12	18	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	09/06/12	17	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	10/11/12	13	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	11/08/12	13	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Alkalinity to pH 4.5 (Total)	12/06/12	14	mg/l as HCO3
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	01/11/11	15	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	02/15/11	12	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	03/15/11	13	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	04/12/11	12	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	05/17/11	12	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	06/14/11	11	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	07/12/11	10	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	08/16/11	12	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	09/13/11	11	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	10/11/11	12	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	11/15/11	9.1	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	12/13/11	9.2	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	01/12/12	10	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	02/09/12	9.9	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	03/08/12	10	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	04/12/12	11	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	05/10/12	11	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	06/07/12	10	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	07/12/12	12	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	08/09/12	11	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	09/06/12	11	mg/l

Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	10/11/12	9.5	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	11/08/12	8.5	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Chloride	12/06/12	5.7	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	01/11/11	11	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	02/15/11	7.1	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	03/15/11	4.9	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	04/12/11	6	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	05/17/11	5.6	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	06/14/11	7.2	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	07/12/11	9.2	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	08/16/11	9.6	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	09/13/11	9.8	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	10/11/11	7.2	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	11/15/11	0.49	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	12/13/11	0.49	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	01/12/12	0.49	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	02/09/12	0.49	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	03/08/12	0.49	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	04/12/12	0.49	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	05/10/12	0.49	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	06/07/12	0.49	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	07/12/12	0.49	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	08/09/12	0.49	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	09/06/12	0.49	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	10/11/12	0.29	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	11/08/12	0.29	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sulphate Dissolved	12/06/12	0.29	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	01/11/11	8.5	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	02/15/11	8.2	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	03/15/11	8	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	04/12/11	8.1	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	05/17/11	7.5	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	06/14/11	7.7	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	07/12/11	7.4	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	08/16/11	7.8	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	09/13/11	8.4	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	10/11/11	7.5	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	11/15/11	6.6	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	12/13/11	6.9	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	01/12/12	7.1	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	02/09/12	6.7	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	03/08/12	6.6	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	04/12/12	6.9	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	05/10/12	6.9	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	06/07/12	7	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	07/12/12	7.3	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	08/09/12	7.3	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	09/06/12	7.1	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	10/11/12	5.8	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	11/08/12	6.1	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Sodium Total	12/06/12	3.1	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	01/11/11	2.6	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	02/15/11	1.6	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	03/15/11	2.4	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	04/12/11	2.4	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	05/17/11	2.4	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	06/14/11	2.8	mg/l

Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	07/12/11	0.78	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	08/16/11	3.2	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	09/13/11	3.1	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	10/11/11	3.3	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	11/15/11	2.5	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	12/13/11	2.5	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	01/12/12	2.5	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	02/09/12	2	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	03/08/12	2.1	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	04/12/12	1.9	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	05/10/12	2	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	06/07/12	2	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	07/12/12	1.5	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	08/09/12	2	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	09/06/12	1.9	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	10/11/12	1.5	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	11/08/12	1.6	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Magnesium Total	12/06/12	1.2	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	01/11/11	6	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	02/15/11	4.7	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	03/15/11	4.7	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	04/12/11	4.7	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	05/17/11	4.8	mg/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	06/14/11	6.1	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	07/12/11	8.6	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	08/16/11	9.2	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	09/13/11	9.5	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	10/11/11	11	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	11/15/11	9.5	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	12/13/11	8.3	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	01/12/12	6.8	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	02/09/12	6.8	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	03/08/12	6.3	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	04/12/12	6.9	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	05/10/12	5.8	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	06/07/12	5.1	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	07/12/12	4.4	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	08/09/12	5.1	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	09/06/12	4.7	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	10/11/12	4.5	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	11/08/12	4.4	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Calcium Total	12/06/12	4.6	mg/l as Ca
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	01/11/11	0.051	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	02/15/11	0.045	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	03/15/11	0.046	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	04/12/11	0.035	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	05/17/11	0.026	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	06/14/11	0.084	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	07/12/11	0.085	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	08/16/11	0.088	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	09/13/11	0.052	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	10/11/11	0.04	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	11/15/11	0.056	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	12/13/11	0.031	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	01/12/12	0.008	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	02/09/12	0.03	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	03/08/12	0.045	ug/l

Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	04/12/12	0.03	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	05/10/12	0.039	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	06/07/12	0.039	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	07/12/12	0.024	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	08/09/12	0.009	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	09/06/12	0.034	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	10/11/12	0.028	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	11/08/12	0.026	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Cadmium Total	12/06/12	0.027	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	01/11/11	230	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	02/15/11	240	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	03/15/11	270	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	04/12/11	200	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	05/17/11	290	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	06/14/11	410	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	07/12/11	390	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	08/16/11	290	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	09/13/11	280	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	10/11/11	190	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	11/15/11	170	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	12/13/11	230	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	01/12/12	370	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	02/09/12	250	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	03/08/12	580	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	04/12/12	170	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	05/10/12	210	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	06/07/12	210	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	07/12/12	270	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	08/09/12	260	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	09/06/12	260	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	10/11/12	260	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	11/08/12	270	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Aluminium Total	12/06/12	410	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	01/11/11	1.7	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	02/15/11	1.7	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	03/15/11	1.4	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	04/12/11	1.4	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	05/17/11	1.7	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	06/14/11	3.4	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	07/12/11	2.5	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	08/16/11	2.3	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	09/13/11	2.8	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	10/11/11	2.1	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	11/15/11	2.3	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	12/13/11	2.3	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	01/12/12	4.2	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	02/09/12	1.8	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	03/08/12	3.7	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	04/12/12	1.2	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	05/10/12	1.4	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	06/07/12	1.1	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	07/12/12	2.1	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	08/09/12	1.5	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	09/06/12	1.5	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	10/11/12	1.6	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	11/08/12	1.7	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Lead Total	12/06/12	6.8	ug/l

Honey Hill WTW raw - Smiddy Shaw Reservoir	Phosphorus Total (As P)	01/11/11	20	ug/l as P
Honey Hill WTW raw - Smiddy Shaw Reservoir	Phosphorus Total (As P)	04/12/11	5.7	ug/l as P
Honey Hill WTW raw - Smiddy Shaw Reservoir	Phosphorus Total (As P)	07/12/11	24	ug/l as P
Honey Hill WTW raw - Smiddy Shaw Reservoir	Phosphorus Total (As P)	10/11/11	11	ug/l as P
Honey Hill WTW raw - Smiddy Shaw Reservoir	Phosphorus Total (As P)	01/12/12	9.9	ug/l as P
Honey Hill WTW raw - Smiddy Shaw Reservoir	Phosphorus Total (As P)	04/12/12	6.4	ug/l as P
Honey Hill WTW raw - Smiddy Shaw Reservoir	Phosphorus Total (As P)	07/12/12	9.3	ug/l as P
Honey Hill WTW raw - Smiddy Shaw Reservoir	Phosphorus Total (As P)	10/11/12	9	ug/l as P
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	01/11/11	37	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	02/15/11	31	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	03/15/11	32	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	04/12/11	22	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	05/17/11	57	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	06/14/11	210	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	07/12/11	320	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	08/16/11	240	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	09/13/11	210	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	10/11/11	47	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	11/15/11	61	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	12/13/11	40	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	01/12/12	92	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	02/09/12	24	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	03/08/12	160	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	04/12/12	22	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	05/10/12	28	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	06/07/12	32	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	07/12/12	29	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	08/09/12	26	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	09/06/12	23	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	10/11/12	22	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	11/08/12	23	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Manganese Total	12/06/12	61	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	01/11/11	490	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	02/15/11	450	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	03/15/11	480	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	04/12/11	390	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	05/17/11	560	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	06/14/11	920	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	07/12/11	890	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	08/16/11	760	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	09/13/11	980	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	10/11/11	610	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	11/15/11	680	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	12/13/11	720	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	01/12/12	990	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	02/09/12	570	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	03/08/12	1000	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	04/12/12	450	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	05/10/12	400	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	06/07/12	400	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	07/12/12	590	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	08/09/12	680	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	09/06/12	800	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	10/11/12	690	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	11/08/12	750	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Iron Total	12/06/12	1100	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	01/11/11	3.4	ug/l

Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	02/15/11	2.9	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	03/15/11	3	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	04/12/11	7.7	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	05/17/11	2.6	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	06/14/11	3.1	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	07/12/11	2.4	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	08/16/11	3.1	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	09/13/11	3	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	10/11/11	2.5	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	11/15/11	3	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	12/13/11	2.6	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	01/12/12	3.2	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	02/09/12	2.6	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	03/08/12	2.7	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	04/12/12	2.4	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	05/10/12	2.6	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	06/07/12	2.7	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	07/12/12	3.2	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	08/09/12	3.5	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	09/06/12	3.4	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	10/11/12	3.2	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	11/08/12	3.1	ug/l
Honey Hill WTW raw - Smiddy Shaw Reservoir	Nickel Total	12/06/12	2.9	ug/l

Horsley WTW raw

Spt Desc	Detdesc	Datetaken	Value	Unitused
Horsley WTW raw	Hydrogen ion	01/24/11	7.6	pH Value
Horsley WTW raw	Hydrogen ion	02/21/11	7.7	pH Value
Horsley WTW raw	Hydrogen ion	03/21/11	7.8	pH Value
Horsley WTW raw	Hydrogen ion	04/18/11	7.9	pH Value
Horsley WTW raw	Hydrogen ion	05/23/11	7.9	pH Value
Horsley WTW raw	Hydrogen ion	06/20/11	7.7	pH Value
Horsley WTW raw	Hydrogen ion	07/25/11	7.6	pH Value
Horsley WTW raw	Hydrogen ion	08/22/11	7.5	pH Value
Horsley WTW raw	Hydrogen ion	09/19/11	7.8	pH Value
Horsley WTW raw	Hydrogen ion	10/24/11	7.7	pH Value
Horsley WTW raw	Hydrogen ion	11/21/11	7.7	pH Value
Horsley WTW raw	Hydrogen ion	12/19/11	7.9	pH Value
Horsley WTW raw	Hydrogen ion	01/04/12	7.7	pH Value
Horsley WTW raw	Hydrogen ion	02/01/12	7.7	pH Value
Horsley WTW raw	Hydrogen ion	03/07/12	7.8	pH Value
Horsley WTW raw	Hydrogen ion	04/04/12	8.1	pH Value
Horsley WTW raw	Hydrogen ion	05/02/12	7.9	pH Value
Horsley WTW raw	Hydrogen ion	06/13/12	7.5	pH Value
Horsley WTW raw	Hydrogen ion	07/04/12	7.5	pH Value
Horsley WTW raw	Hydrogen ion	08/01/12	7.6	pH Value
Horsley WTW raw	Hydrogen ion	09/05/12	7.7	pH Value
Horsley WTW raw	Hydrogen ion	10/03/12	7.6	pH Value
Horsley WTW raw	Hydrogen ion	11/07/12	7.6	pH Value
Horsley WTW raw	Hydrogen ion	12/05/12	8.2	pH Value
Horsley WTW raw	Conductivity 20 Deg. C	01/24/11	190	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	02/21/11	260	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	03/21/11	280	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	04/18/11	270	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	05/23/11	190	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	06/20/11	240	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	07/25/11	190	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	08/22/11	230	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	09/19/11	180	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	10/24/11	160	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	11/21/11	250	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	12/19/11	190	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	01/04/12	190	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	02/01/12	190	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	03/07/12	210	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	04/04/12	330	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	05/02/12	230	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	06/13/12	190	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	07/04/12	240	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	08/01/12	220	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	09/05/12	190	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	10/03/12	200	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	11/07/12	200	uS/cm
Horsley WTW raw	Conductivity 20 Deg. C	12/05/12	230	uS/cm
Horsley WTW raw	Turbidity	01/24/11	3	NTU
Horsley WTW raw	Turbidity	02/21/11	21	NTU
Horsley WTW raw	Turbidity	03/21/11	6.2	NTU
Horsley WTW raw	Turbidity	04/18/11	1.5	NTU
Horsley WTW raw	Turbidity	05/23/11	5.5	NTU
Horsley WTW raw	Turbidity	06/20/11	1.9	NTU

Horsley WTW raw	Turbidity	07/25/11	3.6	NTU
Horsley WTW raw	Turbidity	08/22/11	5	NTU
Horsley WTW raw	Turbidity	09/19/11	2.9	NTU
Horsley WTW raw	Turbidity	10/24/11	2.7	NTU
Horsley WTW raw	Turbidity	11/21/11	50	NTU
Horsley WTW raw	Turbidity	12/19/11	2.3	NTU
Horsley WTW raw	Turbidity	01/04/12	6.1	NTU
Horsley WTW raw	Turbidity	02/01/12	2.2	NTU
Horsley WTW raw	Turbidity	03/07/12	3.1	NTU
Horsley WTW raw	Turbidity	04/04/12	2	NTU
Horsley WTW raw	Turbidity	05/02/12	2.8	NTU
Horsley WTW raw	Turbidity	06/13/12	3.3	NTU
Horsley WTW raw	Turbidity	07/04/12	3.3	NTU
Horsley WTW raw	Turbidity	08/01/12	19	NTU
Horsley WTW raw	Turbidity	09/05/12	2.7	NTU
Horsley WTW raw	Turbidity	10/03/12	29	NTU
Horsley WTW raw	Turbidity	11/07/12	15	NTU
Horsley WTW raw	Turbidity	12/05/12	5.6	NTU
Horsley WTW raw	Colour Filtered	01/24/11	62	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	02/21/11	48	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	03/21/11	43	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	04/18/11	39	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	05/23/11	72	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	06/20/11	51	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	07/25/11	64	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	08/22/11	70	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	09/19/11	98	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	10/24/11	89	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	11/21/11	65	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	12/19/11	68	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	01/04/12	74	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	02/01/12	67	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	03/07/12	63	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	04/04/12	37	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	05/02/12	61	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	06/13/12	100	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	07/04/12	66	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	08/01/12	83	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	09/05/12	120	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	10/03/12	55	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	11/07/12	77	mg/l Pt/Co scal
Horsley WTW raw	Colour Filtered	12/05/12	63	mg/l Pt/Co scal
Horsley WTW raw	Temperature Deg. C	01/24/11	4.4	Deg. C
Horsley WTW raw	Temperature Deg. C	02/21/11	11.2	Deg. C
Horsley WTW raw	Temperature Deg. C	03/21/11	10.4	Deg. C
Horsley WTW raw	Temperature Deg. C	04/18/11	14.1	Deg. C
Horsley WTW raw	Temperature Deg. C	05/23/11	15.9	Deg. C
Horsley WTW raw	Temperature Deg. C	06/20/11	18	Deg. C
Horsley WTW raw	Temperature Deg. C	07/25/11	17.8	Deg. C
Horsley WTW raw	Temperature Deg. C	08/22/11	17.6	Deg. C
Horsley WTW raw	Temperature Deg. C	09/19/11	13.1	Deg. C
Horsley WTW raw	Temperature Deg. C	10/24/11	14.3	Deg. C
Horsley WTW raw	Temperature Deg. C	11/21/11	11.3	Deg. C
Horsley WTW raw	Temperature Deg. C	12/19/11	6.2	Deg. C
Horsley WTW raw	Temperature Deg. C	01/04/12	8.2	Deg. C
Horsley WTW raw	Temperature Deg. C	02/01/12	8.6	Deg. C
Horsley WTW raw	Temperature Deg. C	03/07/12	11.3	Deg. C

Horsley WTW raw	Temperature Deg. C	04/04/12	12.2	Deg. C
Horsley WTW raw	Temperature Deg. C	05/02/12	13.9	Deg. C
Horsley WTW raw	Temperature Deg. C	06/13/12	14.9	Deg. C
Horsley WTW raw	Temperature Deg. C	07/04/12	18.5	Deg. C
Horsley WTW raw	Temperature Deg. C	08/01/12	19.1	Deg. C
Horsley WTW raw	Temperature Deg. C	09/05/12	17.4	Deg. C
Horsley WTW raw	Temperature Deg. C	10/03/12	13.1	Deg. C
Horsley WTW raw	Temperature Deg. C	11/07/12	11.8	Deg. C
Horsley WTW raw	Temperature Deg. C	12/05/12	9.4	Deg. C
Horsley WTW raw	Total Organic Carbon	01/05/11	7.7	mg/l
Horsley WTW raw	Total Organic Carbon	01/10/11	7.4	mg/l
Horsley WTW raw	Total Organic Carbon	01/17/11	7.9	mg/l
Horsley WTW raw	Total Organic Carbon	01/24/11	8.4	mg/l
Horsley WTW raw	Total Organic Carbon	01/31/11	9	mg/l
Horsley WTW raw	Total Organic Carbon	02/07/11	7.8	mg/l
Horsley WTW raw	Total Organic Carbon	02/21/11	8	mg/l
Horsley WTW raw	Total Organic Carbon	02/28/11	11	mg/l
Horsley WTW raw	Total Organic Carbon	03/07/11	6.1	mg/l
Horsley WTW raw	Total Organic Carbon	03/14/11	11	mg/l
Horsley WTW raw	Total Organic Carbon	03/21/11	7.1	mg/l
Horsley WTW raw	Total Organic Carbon	03/28/11	6.3	mg/l
Horsley WTW raw	Total Organic Carbon	04/05/11	11	mg/l
Horsley WTW raw	Total Organic Carbon	04/11/11	8.6	mg/l
Horsley WTW raw	Total Organic Carbon	04/18/11	6.5	mg/l
Horsley WTW raw	Total Organic Carbon	04/27/11	8.7	mg/l
Horsley WTW raw	Total Organic Carbon	05/04/11	6	mg/l
Horsley WTW raw	Total Organic Carbon	05/09/11	6.1	mg/l
Horsley WTW raw	Total Organic Carbon	05/16/11	9.2	mg/l
Horsley WTW raw	Total Organic Carbon	05/23/11	11	mg/l
Horsley WTW raw	Total Organic Carbon	06/01/11	12	mg/l
Horsley WTW raw	Total Organic Carbon	06/06/11	8.5	mg/l
Horsley WTW raw	Total Organic Carbon	06/13/11	6.7	mg/l
Horsley WTW raw	Total Organic Carbon	06/20/11	7.6	mg/l
Horsley WTW raw	Total Organic Carbon	06/27/11	14	mg/l
Horsley WTW raw	Total Organic Carbon	07/04/11	8.9	mg/l
Horsley WTW raw	Total Organic Carbon	07/11/11	7.5	mg/l
Horsley WTW raw	Total Organic Carbon	07/18/11	17	mg/l
Horsley WTW raw	Total Organic Carbon	07/25/11	11	mg/l
Horsley WTW raw	Total Organic Carbon	08/01/11	8.9	mg/l
Horsley WTW raw	Total Organic Carbon	08/08/11	16	mg/l
Horsley WTW raw	Total Organic Carbon	08/15/11	13	mg/l
Horsley WTW raw	Total Organic Carbon	08/22/11	11	mg/l
Horsley WTW raw	Total Organic Carbon	08/31/11	13	mg/l
Horsley WTW raw	Total Organic Carbon	09/05/11	11	mg/l
Horsley WTW raw	Total Organic Carbon	09/12/11	12	mg/l
Horsley WTW raw	Total Organic Carbon	09/19/11	14	mg/l
Horsley WTW raw	Total Organic Carbon	09/26/11	12	mg/l
Horsley WTW raw	Total Organic Carbon	10/03/11	11	mg/l
Horsley WTW raw	Total Organic Carbon	10/10/11	14	mg/l
Horsley WTW raw	Total Organic Carbon	10/17/11	13	mg/l
Horsley WTW raw	Total Organic Carbon	10/24/11	13	mg/l
Horsley WTW raw	Total Organic Carbon	10/31/11	12	mg/l
Horsley WTW raw	Total Organic Carbon	11/07/11	12	mg/l
Horsley WTW raw	Total Organic Carbon	11/14/11	13	mg/l
Horsley WTW raw	Total Organic Carbon	11/21/11	9.4	mg/l
Horsley WTW raw	Total Organic Carbon	11/28/11	12	mg/l
Horsley WTW raw	Total Organic Carbon	12/05/11	11	mg/l

Horsley WTW raw	Total Organic Carbon	12/12/11	10	mg/l
Horsley WTW raw	Total Organic Carbon	12/19/11	9.5	mg/l
Horsley WTW raw	Total Organic Carbon	12/28/11	9	mg/l
Horsley WTW raw	Total Organic Carbon	01/04/12	10	mg/l
Horsley WTW raw	Total Organic Carbon	01/11/12	7.9	mg/l
Horsley WTW raw	Total Organic Carbon	01/18/12	9.2	mg/l
Horsley WTW raw	Total Organic Carbon	01/25/12	9.2	mg/l
Horsley WTW raw	Total Organic Carbon	02/01/12	8.7	mg/l
Horsley WTW raw	Total Organic Carbon	02/08/12	8.1	mg/l
Horsley WTW raw	Total Organic Carbon	02/15/12	7.5	mg/l
Horsley WTW raw	Total Organic Carbon	02/22/12	9.3	mg/l
Horsley WTW raw	Total Organic Carbon	02/29/12	8.2	mg/l
Horsley WTW raw	Total Organic Carbon	03/07/12	9	mg/l
Horsley WTW raw	Total Organic Carbon	03/14/12	9.9	mg/l
Horsley WTW raw	Total Organic Carbon	03/21/12	10	mg/l
Horsley WTW raw	Total Organic Carbon	03/28/12	5.9	mg/l
Horsley WTW raw	Total Organic Carbon	04/04/12	5.7	mg/l
Horsley WTW raw	Total Organic Carbon	04/11/12	11	mg/l
Horsley WTW raw	Total Organic Carbon	04/18/12	7.8	mg/l
Horsley WTW raw	Total Organic Carbon	04/25/12	11	mg/l
Horsley WTW raw	Total Organic Carbon	05/02/12	8.2	mg/l
Horsley WTW raw	Total Organic Carbon	05/09/12	5.3	mg/l
Horsley WTW raw	Total Organic Carbon	05/16/12	9	mg/l
Horsley WTW raw	Total Organic Carbon	05/23/12	9.4	mg/l
Horsley WTW raw	Total Organic Carbon	05/30/12	7.9	mg/l
Horsley WTW raw	Total Organic Carbon	06/06/12	7.3	mg/l
Horsley WTW raw	Total Organic Carbon	06/13/12	14	mg/l
Horsley WTW raw	Total Organic Carbon	06/20/12	13	mg/l
Horsley WTW raw	Total Organic Carbon	06/27/12	9.9	mg/l
Horsley WTW raw	Total Organic Carbon	07/04/12	10	mg/l
Horsley WTW raw	Total Organic Carbon	07/11/12	13	mg/l
Horsley WTW raw	Total Organic Carbon	07/18/12	10	mg/l
Horsley WTW raw	Total Organic Carbon	07/25/12	13	mg/l
Horsley WTW raw	Total Organic Carbon	08/01/12	12	mg/l
Horsley WTW raw	Total Organic Carbon	08/08/12	13	mg/l
Horsley WTW raw	Total Organic Carbon	08/15/12	11	mg/l
Horsley WTW raw	Total Organic Carbon	08/22/12	17	mg/l
Horsley WTW raw	Total Organic Carbon	08/29/12	19	mg/l
Horsley WTW raw	Total Organic Carbon	09/05/12	14	mg/l
Horsley WTW raw	Total Organic Carbon	09/12/12	14	mg/l
Horsley WTW raw	Total Organic Carbon	09/19/12	13	mg/l
Horsley WTW raw	Total Organic Carbon	09/26/12	12	mg/l
Horsley WTW raw	Total Organic Carbon	10/03/12	11	mg/l
Horsley WTW raw	Total Organic Carbon	10/10/12	10	mg/l
Horsley WTW raw	Total Organic Carbon	10/17/12	12	mg/l
Horsley WTW raw	Total Organic Carbon	10/24/12	9.5	mg/l
Horsley WTW raw	Total Organic Carbon	10/31/12	11	mg/l
Horsley WTW raw	Total Organic Carbon	11/07/12	10	mg/l
Horsley WTW raw	Total Organic Carbon	11/14/12	11	mg/l
Horsley WTW raw	Total Organic Carbon	11/21/12	14	mg/l
Horsley WTW raw	Total Organic Carbon	11/28/12	10	mg/l
Horsley WTW raw	Total Organic Carbon	12/05/12	2.2	mg/l
Horsley WTW raw	Total Organic Carbon	12/12/12	7.9	mg/l
Horsley WTW raw	Total Organic Carbon	12/19/12	9	mg/l
Horsley WTW raw	Total Organic Carbon	12/28/12	8.6	mg/l
Horsley WTW raw	Nitrogen Ammoniacal	01/24/11	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	02/21/11	0.012	mg/l as NH4

Horsley WTW raw	Nitrogen Ammoniacal	03/21/11	0.016	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	04/18/11	0.021	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	05/23/11	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	06/20/11	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	07/25/11	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	08/22/11	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	09/19/11	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	10/24/11	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	11/21/11	0.027	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	12/19/11	0.016	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	01/04/12	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	02/01/12	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	03/07/12	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	04/04/12	0.034	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	05/02/12	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	06/13/12	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	07/04/12	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	08/01/12	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	09/05/12	0.012	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	10/03/12	0.023	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	11/07/12	0.0075	mg/l as NH4
Horsley WTW raw	Nitrogen Ammoniacal	12/05/12	0.016	mg/l as NH4
Horsley WTW raw	Nitrate	01/24/11	5.1	mg/l as NO3
Horsley WTW raw	Nitrate	02/21/11	7	mg/l as NO3
Horsley WTW raw	Nitrate	03/21/11	6.9	mg/l as NO3
Horsley WTW raw	Nitrate	04/18/11	3.7	mg/l as NO3
Horsley WTW raw	Nitrate	05/23/11	3	mg/l as NO3
Horsley WTW raw	Nitrate	06/20/11	2.7	mg/l as NO3
Horsley WTW raw	Nitrate	07/25/11	2.7	mg/l as NO3
Horsley WTW raw	Nitrate	08/22/11	2.7	mg/l as NO3
Horsley WTW raw	Nitrate	09/19/11	2.7	mg/l as NO3
Horsley WTW raw	Nitrate	10/24/11	2.8	mg/l as NO3
Horsley WTW raw	Nitrate	11/21/11	3.7	mg/l as NO3
Horsley WTW raw	Nitrate	12/19/11	3.5	mg/l as NO3
Horsley WTW raw	Nitrate	01/04/12	3.1	mg/l as NO3
Horsley WTW raw	Nitrate	02/01/12	3.8	mg/l as NO3
Horsley WTW raw	Nitrate	03/07/12	3.6	mg/l as NO3
Horsley WTW raw	Nitrate	04/04/12	3.7	mg/l as NO3
Horsley WTW raw	Nitrate	05/02/12	4.9	mg/l as NO3
Horsley WTW raw	Nitrate	06/13/12	3.6	mg/l as NO3
Horsley WTW raw	Nitrate	07/04/12	4	mg/l as NO3
Horsley WTW raw	Nitrate	08/01/12	3.4	mg/l as NO3
Horsley WTW raw	Nitrate	09/05/12	3.3	mg/l as NO3
Horsley WTW raw	Nitrate	10/03/12	2.7	mg/l as NO3
Horsley WTW raw	Nitrate	11/07/12	2.9	mg/l as NO3
Horsley WTW raw	Nitrate	12/05/12	4.7	mg/l as NO3
Horsley WTW raw	Nitrite	01/24/11	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	02/21/11	0.0057	mg/l as NO2
Horsley WTW raw	Nitrite	03/21/11	0.0072	mg/l as NO2
Horsley WTW raw	Nitrite	04/18/11	0.0076	mg/l as NO2
Horsley WTW raw	Nitrite	05/23/11	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	06/20/11	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	07/25/11	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	08/22/11	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	09/19/11	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	10/24/11	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	11/21/11	0.012	mg/l as NO2

Horsley WTW raw	Nitrite	12/19/11	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	01/04/12	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	02/01/12	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	03/07/12	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	04/04/12	0.016	mg/l as NO2
Horsley WTW raw	Nitrite	05/02/12	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	06/13/12	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	07/04/12	0.011	mg/l as NO2
Horsley WTW raw	Nitrite	08/01/12	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	09/05/12	0.0014	mg/l as NO2
Horsley WTW raw	Nitrite	10/03/12	0.0042	mg/l as NO2
Horsley WTW raw	Nitrite	11/07/12	0.0011	mg/l as NO2
Horsley WTW raw	Nitrite	12/05/12	0.0011	mg/l as NO2
Horsley WTW raw	Hardness Total	01/24/11	36	mg/l
Horsley WTW raw	Hardness Total	02/21/11	46	mg/l
Horsley WTW raw	Hardness Total	03/21/11	50	mg/l
Horsley WTW raw	Hardness Total	04/18/11	53	mg/l
Horsley WTW raw	Hardness Total	05/23/11	38	mg/l
Horsley WTW raw	Hardness Total	06/20/11	48	mg/l as Ca
Horsley WTW raw	Hardness Total	07/25/11	34	mg/l as Ca
Horsley WTW raw	Hardness Total	08/22/11	45	mg/l as Ca
Horsley WTW raw	Hardness Total	09/19/11	36	mg/l as Ca
Horsley WTW raw	Hardness Total	10/24/11	31	mg/l as Ca
Horsley WTW raw	Hardness Total	11/21/11	51	mg/l as Ca
Horsley WTW raw	Hardness Total	12/19/11	35	mg/l as Ca
Horsley WTW raw	Hardness Total	01/04/12	33	mg/l as Ca
Horsley WTW raw	Hardness Total	02/01/12	38	mg/l as Ca
Horsley WTW raw	Hardness Total	03/07/12	41	mg/l as Ca
Horsley WTW raw	Hardness Total	04/04/12	57	mg/l as Ca
Horsley WTW raw	Hardness Total	05/02/12	43	mg/l as Ca
Horsley WTW raw	Hardness Total	06/13/12	38	mg/l as Ca
Horsley WTW raw	Hardness Total	07/04/12	45	mg/l as Ca
Horsley WTW raw	Hardness Total	08/01/12	47	mg/l as Ca
Horsley WTW raw	Hardness Total	09/05/12	35	mg/l as Ca
Horsley WTW raw	Hardness Total	10/03/12	42	mg/l as Ca
Horsley WTW raw	Hardness Total	11/07/12	41	mg/l as Ca
Horsley WTW raw	Hardness Total	12/05/12	43	mg/l as Ca
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	01/24/11	78	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	02/21/11	93	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	03/21/11	120	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	04/18/11	120	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	05/23/11	81	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	06/20/11	92	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	07/25/11	88	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	08/22/11	110	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	09/19/11	77	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	10/24/11	78	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	11/21/11	120	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	12/19/11	74	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	01/04/12	70	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	02/01/12	78	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	03/07/12	87	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	04/04/12	110	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	05/02/12	88	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	06/13/12	75	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	07/04/12	68	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	08/01/12	71	mg/l as HCO3

Horsley WTW raw	Alkalinity to pH 4.5 (Total)	09/05/12	88	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	10/03/12	90	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	11/07/12	87	mg/l as HCO3
Horsley WTW raw	Alkalinity to pH 4.5 (Total)	12/05/12	86	mg/l as HCO3
Horsley WTW raw	Chloride	01/24/11	14	mg/l
Horsley WTW raw	Chloride	02/21/11	17	mg/l
Horsley WTW raw	Chloride	03/21/11	18	mg/l
Horsley WTW raw	Chloride	04/18/11	18	mg/l
Horsley WTW raw	Chloride	05/23/11	12	mg/l
Horsley WTW raw	Chloride	06/20/11	12	mg/l
Horsley WTW raw	Chloride	07/25/11	11	mg/l
Horsley WTW raw	Chloride	08/22/11	12	mg/l
Horsley WTW raw	Chloride	09/19/11	11	mg/l
Horsley WTW raw	Chloride	10/24/11	10	mg/l
Horsley WTW raw	Chloride	11/21/11	14	mg/l
Horsley WTW raw	Chloride	12/19/11	16	mg/l
Horsley WTW raw	Chloride	01/04/12	14	mg/l
Horsley WTW raw	Chloride	02/01/12	17	mg/l
Horsley WTW raw	Chloride	03/07/12	16	mg/l
Horsley WTW raw	Chloride	04/04/12	28	mg/l
Horsley WTW raw	Chloride	05/02/12	17	mg/l
Horsley WTW raw	Chloride	06/13/12	12	mg/l
Horsley WTW raw	Chloride	07/04/12	14	mg/l
Horsley WTW raw	Chloride	08/01/12	12	mg/l
Horsley WTW raw	Chloride	09/05/12	12	mg/l
Horsley WTW raw	Chloride	10/03/12	12	mg/l
Horsley WTW raw	Chloride	11/07/12	12	mg/l
Horsley WTW raw	Chloride	12/05/12	15	mg/l
Horsley WTW raw	Sulphate Dissolved	01/24/11	22	mg/l
Horsley WTW raw	Sulphate Dissolved	02/21/11	23	mg/l
Horsley WTW raw	Sulphate Dissolved	03/21/11	25	mg/l
Horsley WTW raw	Sulphate Dissolved	04/18/11	28	mg/l
Horsley WTW raw	Sulphate Dissolved	05/23/11	19	mg/l
Horsley WTW raw	Sulphate Dissolved	06/20/11	33	mg/l
Horsley WTW raw	Sulphate Dissolved	07/25/11	23	mg/l
Horsley WTW raw	Sulphate Dissolved	08/22/11	28	mg/l
Horsley WTW raw	Sulphate Dissolved	09/19/11	17	mg/l
Horsley WTW raw	Sulphate Dissolved	10/24/11	18	mg/l
Horsley WTW raw	Sulphate Dissolved	11/21/11	31	mg/l
Horsley WTW raw	Sulphate Dissolved	12/19/11	19	mg/l
Horsley WTW raw	Sulphate Dissolved	01/04/12	16	mg/l
Horsley WTW raw	Sulphate Dissolved	02/01/12	19	mg/l
Horsley WTW raw	Sulphate Dissolved	03/07/12	25	mg/l
Horsley WTW raw	Sulphate Dissolved	04/04/12	40	mg/l
Horsley WTW raw	Sulphate Dissolved	05/02/12	23	mg/l
Horsley WTW raw	Sulphate Dissolved	06/13/12	21	mg/l
Horsley WTW raw	Sulphate Dissolved	07/04/12	26	mg/l
Horsley WTW raw	Sulphate Dissolved	08/01/12	29	mg/l
Horsley WTW raw	Sulphate Dissolved	09/05/12	18	mg/l
Horsley WTW raw	Sulphate Dissolved	10/03/12	21	mg/l
Horsley WTW raw	Sulphate Dissolved	11/07/12	20	mg/l
Horsley WTW raw	Sulphate Dissolved	12/05/12	22	mg/l
Horsley WTW raw	Sodium Total	01/24/11	8.8	mg/l
Horsley WTW raw	Sodium Total	02/21/11	11	mg/l
Horsley WTW raw	Sodium Total	03/21/11	12	mg/l
Horsley WTW raw	Sodium Total	04/18/11	12	mg/l
Horsley WTW raw	Sodium Total	05/23/11	8.2	mg/l

Horsley WTW raw	Sodium Total	06/20/11	10	mg/l
Horsley WTW raw	Sodium Total	07/25/11	8.7	mg/l
Horsley WTW raw	Sodium Total	08/22/11	9.4	mg/l
Horsley WTW raw	Sodium Total	09/19/11	7.6	mg/l
Horsley WTW raw	Sodium Total	10/24/11	7.8	mg/l
Horsley WTW raw	Sodium Total	11/21/11	11	mg/l
Horsley WTW raw	Sodium Total	12/19/11	10	mg/l
Horsley WTW raw	Sodium Total	01/04/12	9	mg/l
Horsley WTW raw	Sodium Total	02/01/12	11	mg/l
Horsley WTW raw	Sodium Total	03/07/12	10	mg/l
Horsley WTW raw	Sodium Total	04/04/12	20	mg/l
Horsley WTW raw	Sodium Total	05/02/12	11	mg/l
Horsley WTW raw	Sodium Total	06/13/12	9.2	mg/l
Horsley WTW raw	Sodium Total	07/04/12	9.6	mg/l
Horsley WTW raw	Sodium Total	08/01/12	8.4	mg/l
Horsley WTW raw	Sodium Total	09/05/12	8.3	mg/l
Horsley WTW raw	Sodium Total	10/03/12	7.3	mg/l
Horsley WTW raw	Sodium Total	11/07/12	8.9	mg/l
Horsley WTW raw	Sodium Total	12/05/12	9.9	mg/l
Horsley WTW raw	Magnesium Total	01/24/11	4.6	mg/l
Horsley WTW raw	Magnesium Total	02/21/11	5.8	mg/l
Horsley WTW raw	Magnesium Total	03/21/11	6.2	mg/l
Horsley WTW raw	Magnesium Total	04/18/11	7.4	mg/l
Horsley WTW raw	Magnesium Total	05/23/11	4.8	mg/l
Horsley WTW raw	Magnesium Total	06/20/11	7.4	mg/l
Horsley WTW raw	Magnesium Total	07/25/11	3.6	mg/l
Horsley WTW raw	Magnesium Total	08/22/11	5.8	mg/l
Horsley WTW raw	Magnesium Total	09/19/11	4.6	mg/l
Horsley WTW raw	Magnesium Total	10/24/11	4.1	mg/l
Horsley WTW raw	Magnesium Total	11/21/11	6.9	mg/l
Horsley WTW raw	Magnesium Total	12/19/11	4.8	mg/l
Horsley WTW raw	Magnesium Total	01/04/12	4.1	mg/l
Horsley WTW raw	Magnesium Total	02/01/12	5.8	mg/l
Horsley WTW raw	Magnesium Total	03/07/12	5.5	mg/l
Horsley WTW raw	Magnesium Total	04/04/12	8.4	mg/l
Horsley WTW raw	Magnesium Total	05/02/12	5.3	mg/l
Horsley WTW raw	Magnesium Total	06/13/12	5.5	mg/l
Horsley WTW raw	Magnesium Total	07/04/12	5.9	mg/l
Horsley WTW raw	Magnesium Total	08/01/12	6.2	mg/l
Horsley WTW raw	Magnesium Total	09/05/12	5.2	mg/l
Horsley WTW raw	Magnesium Total	10/03/12	4.7	mg/l
Horsley WTW raw	Magnesium Total	11/07/12	5.4	mg/l
Horsley WTW raw	Magnesium Total	12/05/12	5.2	mg/l
Horsley WTW raw	Calcium Total	01/24/11	29	mg/l
Horsley WTW raw	Calcium Total	02/21/11	36	mg/l
Horsley WTW raw	Calcium Total	03/21/11	40	mg/l
Horsley WTW raw	Calcium Total	04/18/11	41	mg/l
Horsley WTW raw	Calcium Total	05/23/11	30	mg/l
Horsley WTW raw	Calcium Total	06/20/11	36	mg/l as Ca
Horsley WTW raw	Calcium Total	07/25/11	29	mg/l as Ca
Horsley WTW raw	Calcium Total	08/22/11	36	mg/l as Ca
Horsley WTW raw	Calcium Total	09/19/11	29	mg/l as Ca
Horsley WTW raw	Calcium Total	10/24/11	25	mg/l as Ca
Horsley WTW raw	Calcium Total	11/21/11	39	mg/l as Ca
Horsley WTW raw	Calcium Total	12/19/11	27	mg/l as Ca
Horsley WTW raw	Calcium Total	01/04/12	26	mg/l as Ca
Horsley WTW raw	Calcium Total	02/01/12	29	mg/l as Ca

Horsley WTW raw	Calcium Total	03/07/12	32	mg/l as Ca
Horsley WTW raw	Calcium Total	04/04/12	44	mg/l as Ca
Horsley WTW raw	Calcium Total	05/02/12	35	mg/l as Ca
Horsley WTW raw	Calcium Total	06/13/12	29	mg/l as Ca
Horsley WTW raw	Calcium Total	07/04/12	36	mg/l as Ca
Horsley WTW raw	Calcium Total	08/01/12	37	mg/l as Ca
Horsley WTW raw	Calcium Total	09/05/12	27	mg/l as Ca
Horsley WTW raw	Calcium Total	10/03/12	34	mg/l as Ca
Horsley WTW raw	Calcium Total	11/07/12	32	mg/l as Ca
Horsley WTW raw	Calcium Total	12/05/12	34	mg/l as Ca
Horsley WTW raw	Cadmium Total	01/24/11	0.069	ug/l
Horsley WTW raw	Cadmium Total	02/21/11	0.07	ug/l
Horsley WTW raw	Cadmium Total	03/21/11	0.076	ug/l
Horsley WTW raw	Cadmium Total	04/18/11	0.096	ug/l
Horsley WTW raw	Cadmium Total	05/23/11	0.11	ug/l
Horsley WTW raw	Cadmium Total	06/20/11	0.091	ug/l
Horsley WTW raw	Cadmium Total	07/25/11	0.075	ug/l
Horsley WTW raw	Cadmium Total	08/22/11	0.087	ug/l
Horsley WTW raw	Cadmium Total	09/19/11	0.075	ug/l
Horsley WTW raw	Cadmium Total	10/24/11	0.084	ug/l
Horsley WTW raw	Cadmium Total	11/21/11	0.13	ug/l
Horsley WTW raw	Cadmium Total	12/19/11	0.047	ug/l
Horsley WTW raw	Cadmium Total	01/04/12	0.036	ug/l
Horsley WTW raw	Cadmium Total	02/01/12	0.073	ug/l
Horsley WTW raw	Cadmium Total	03/07/12	0.076	ug/l
Horsley WTW raw	Cadmium Total	04/04/12	0.1	ug/l
Horsley WTW raw	Cadmium Total	05/02/12	0.12	ug/l
Horsley WTW raw	Cadmium Total	06/13/12	0.099	ug/l
Horsley WTW raw	Cadmium Total	07/04/12	0.07	ug/l
Horsley WTW raw	Cadmium Total	08/01/12	0.32	ug/l
Horsley WTW raw	Cadmium Total	09/05/12	0.069	ug/l
Horsley WTW raw	Cadmium Total	10/03/12	0.12	ug/l
Horsley WTW raw	Cadmium Total	11/07/12	0.15	ug/l
Horsley WTW raw	Cadmium Total	12/05/12	0.13	ug/l
Horsley WTW raw	Aluminium Total	01/24/11	210	ug/l
Horsley WTW raw	Aluminium Total	02/21/11	810	ug/l
Horsley WTW raw	Aluminium Total	03/21/11	280	ug/l
Horsley WTW raw	Aluminium Total	04/18/11	100	ug/l
Horsley WTW raw	Aluminium Total	05/23/11	230	ug/l
Horsley WTW raw	Aluminium Total	06/20/11	84	ug/l
Horsley WTW raw	Aluminium Total	07/25/11	440	ug/l
Horsley WTW raw	Aluminium Total	08/22/11	150	ug/l
Horsley WTW raw	Aluminium Total	09/19/11	150	ug/l
Horsley WTW raw	Aluminium Total	10/24/11	150	ug/l
Horsley WTW raw	Aluminium Total	11/21/11	570	ug/l
Horsley WTW raw	Aluminium Total	12/19/11	160	ug/l
Horsley WTW raw	Aluminium Total	01/04/12	410	ug/l
Horsley WTW raw	Aluminium Total	02/01/12	120	ug/l
Horsley WTW raw	Aluminium Total	03/07/12	250	ug/l
Horsley WTW raw	Aluminium Total	04/04/12	85	ug/l
Horsley WTW raw	Aluminium Total	05/02/12	170	ug/l
Horsley WTW raw	Aluminium Total	06/13/12	230	ug/l
Horsley WTW raw	Aluminium Total	07/04/12	260	ug/l
Horsley WTW raw	Aluminium Total	08/01/12	1200	ug/l
Horsley WTW raw	Aluminium Total	09/05/12	150	ug/l
Horsley WTW raw	Aluminium Total	10/03/12	1300	ug/l
Horsley WTW raw	Aluminium Total	11/07/12	550	ug/l

Horsley WTW raw	Aluminium Total	12/05/12	580	ug/l
Horsley WTW raw	Lead Total	01/24/11	2.5	ug/l
Horsley WTW raw	Lead Total	02/21/11	3.3	ug/l
Horsley WTW raw	Lead Total	03/21/11	2.8	ug/l
Horsley WTW raw	Lead Total	04/18/11	1.1	ug/l
Horsley WTW raw	Lead Total	05/23/11	5	ug/l
Horsley WTW raw	Lead Total	06/20/11	2.3	ug/l
Horsley WTW raw	Lead Total	07/25/11	2.5	ug/l
Horsley WTW raw	Lead Total	08/22/11	2.8	ug/l
Horsley WTW raw	Lead Total	09/19/11	3.6	ug/l
Horsley WTW raw	Lead Total	10/24/11	2.9	ug/l
Horsley WTW raw	Lead Total	11/21/11	2.3	ug/l
Horsley WTW raw	Lead Total	12/19/11	1.8	ug/l
Horsley WTW raw	Lead Total	01/04/12	2.1	ug/l
Horsley WTW raw	Lead Total	02/01/12	1.8	ug/l
Horsley WTW raw	Lead Total	03/07/12	1.6	ug/l
Horsley WTW raw	Lead Total	04/04/12	1.5	ug/l
Horsley WTW raw	Lead Total	05/02/12	3.2	ug/l
Horsley WTW raw	Lead Total	06/13/12	3.9	ug/l
Horsley WTW raw	Lead Total	07/04/12	3.3	ug/l
Horsley WTW raw	Lead Total	08/01/12	33	ug/l
Horsley WTW raw	Lead Total	09/05/12	3.7	ug/l
Horsley WTW raw	Lead Total	10/03/12	11	ug/l
Horsley WTW raw	Lead Total	11/07/12	8.1	ug/l
Horsley WTW raw	Lead Total	12/05/12	3.4	ug/l
Horsley WTW raw	Phosphorus Total (As P)	01/24/11	86	ug/l as P
Horsley WTW raw	Phosphorus Total (As P)	04/18/11	25	ug/l as P
Horsley WTW raw	Phosphorus Total (As P)	07/25/11	24	ug/l as P
Horsley WTW raw	Phosphorus Total (As P)	10/24/11	13	ug/l as P
Horsley WTW raw	Phosphorus Total (As P)	01/04/12	23	ug/l as P
Horsley WTW raw	Phosphorus Total (As P)	04/04/12	46	ug/l as P
Horsley WTW raw	Phosphorus Total (As P)	07/04/12	11	ug/l as P
Horsley WTW raw	Phosphorus Total (As P)	10/03/12	91	ug/l as P
Horsley WTW raw	Manganese Dissolved	09/19/12	28	ug/l
Horsley WTW raw	Manganese Dissolved	09/26/12	56	ug/l
Horsley WTW raw	Manganese Dissolved	10/03/12	7.2	ug/l
Horsley WTW raw	Manganese Dissolved	10/10/12	21	ug/l
Horsley WTW raw	Manganese Dissolved	10/17/12	7.7	ug/l
Horsley WTW raw	Manganese Dissolved	10/24/12	25	ug/l
Horsley WTW raw	Manganese Dissolved	10/31/12	17	ug/l
Horsley WTW raw	Manganese Dissolved	11/07/12	74	ug/l
Horsley WTW raw	Manganese Dissolved	11/14/12	7.3	ug/l
Horsley WTW raw	Manganese Dissolved	11/21/12	6	ug/l
Horsley WTW raw	Manganese Dissolved	11/28/12	16	ug/l
Horsley WTW raw	Manganese Dissolved	12/05/12	12	ug/l
Horsley WTW raw	Manganese Dissolved	12/12/12	8	ug/l
Horsley WTW raw	Manganese Dissolved	12/19/12	8.1	ug/l
Horsley WTW raw	Manganese Dissolved	12/28/12	12	ug/l
Horsley WTW raw	Manganese Total	01/24/11	15	ug/l
Horsley WTW raw	Manganese Total	02/21/11	62	ug/l
Horsley WTW raw	Manganese Total	03/21/11	30	ug/l
Horsley WTW raw	Manganese Total	04/18/11	20	ug/l
Horsley WTW raw	Manganese Total	05/23/11	37	ug/l
Horsley WTW raw	Manganese Total	06/20/11	25	ug/l
Horsley WTW raw	Manganese Total	07/25/11	73	ug/l
Horsley WTW raw	Manganese Total	08/22/11	48	ug/l
Horsley WTW raw	Manganese Total	09/19/11	35	ug/l

Horsley WTW raw	Manganese Total	10/24/11	18	ug/l
Horsley WTW raw	Manganese Total	11/21/11	360	ug/l
Horsley WTW raw	Manganese Total	12/19/11	17	ug/l
Horsley WTW raw	Manganese Total	01/04/12	25	ug/l
Horsley WTW raw	Manganese Total	02/01/12	15	ug/l
Horsley WTW raw	Manganese Total	03/07/12	31	ug/l
Horsley WTW raw	Manganese Total	04/04/12	17	ug/l
Horsley WTW raw	Manganese Total	05/02/12	14	ug/l
Horsley WTW raw	Manganese Total	06/13/12	21	ug/l
Horsley WTW raw	Manganese Total	07/04/12	55	ug/l
Horsley WTW raw	Manganese Total	08/01/12	170	ug/l
Horsley WTW raw	Manganese Total	09/05/12	22	ug/l
Horsley WTW raw	Manganese Total	09/19/12	28	ug/l
Horsley WTW raw	Manganese Total	09/26/12	56	ug/l
Horsley WTW raw	Manganese Total	10/03/12	290	ug/l
Horsley WTW raw	Manganese Total	10/10/12	21	ug/l
Horsley WTW raw	Manganese Total	10/17/12	41	ug/l
Horsley WTW raw	Manganese Total	10/24/12	25	ug/l
Horsley WTW raw	Manganese Total	10/31/12	18	ug/l
Horsley WTW raw	Manganese Total	11/07/12	220	ug/l
Horsley WTW raw	Manganese Total	11/14/12	12	ug/l
Horsley WTW raw	Manganese Total	11/21/12	300	ug/l
Horsley WTW raw	Manganese Total	11/28/12	16	ug/l
Horsley WTW raw	Manganese Total	12/05/12	210	ug/l
Horsley WTW raw	Manganese Total	12/12/12	14	ug/l
Horsley WTW raw	Manganese Total	12/19/12	12	ug/l
Horsley WTW raw	Manganese Total	12/28/12	15	ug/l
Horsley WTW raw	Iron Total	01/24/11	480	ug/l
Horsley WTW raw	Iron Total	02/21/11	810	ug/l
Horsley WTW raw	Iron Total	03/21/11	460	ug/l
Horsley WTW raw	Iron Total	04/18/11	320	ug/l
Horsley WTW raw	Iron Total	05/23/11	380	ug/l
Horsley WTW raw	Iron Total	06/20/11	240	ug/l
Horsley WTW raw	Iron Total	07/25/11	630	ug/l
Horsley WTW raw	Iron Total	08/22/11	530	ug/l
Horsley WTW raw	Iron Total	09/19/11	540	ug/l
Horsley WTW raw	Iron Total	10/24/11	720	ug/l
Horsley WTW raw	Iron Total	11/21/11	1800	ug/l
Horsley WTW raw	Iron Total	12/19/11	480	ug/l
Horsley WTW raw	Iron Total	01/04/12	560	ug/l
Horsley WTW raw	Iron Total	02/01/12	490	ug/l
Horsley WTW raw	Iron Total	03/07/12	650	ug/l
Horsley WTW raw	Iron Total	04/04/12	310	ug/l
Horsley WTW raw	Iron Total	05/02/12	390	ug/l
Horsley WTW raw	Iron Total	06/13/12	620	ug/l
Horsley WTW raw	Iron Total	07/04/12	450	ug/l
Horsley WTW raw	Iron Total	08/01/12	420	ug/l
Horsley WTW raw	Iron Total	09/05/12	850	ug/l
Horsley WTW raw	Iron Total	10/03/12	1600	ug/l
Horsley WTW raw	Iron Total	11/07/12	1300	ug/l
Horsley WTW raw	Iron Total	12/05/12	1300	ug/l
Horsley WTW raw	Nickel Total	01/24/11	2	ug/l
Horsley WTW raw	Nickel Total	02/21/11	2	ug/l
Horsley WTW raw	Nickel Total	03/21/11	1.6	ug/l
Horsley WTW raw	Nickel Total	04/18/11	1.2	ug/l
Horsley WTW raw	Nickel Total	05/23/11	1.7	ug/l
Horsley WTW raw	Nickel Total	06/20/11	1.7	ug/l

Horsley WTW raw	Nickel Total	07/25/11	2	ug/l
Horsley WTW raw	Nickel Total	08/22/11	2	ug/l
Horsley WTW raw	Nickel Total	09/19/11	1.9	ug/l
Horsley WTW raw	Nickel Total	10/24/11	2	ug/l
Horsley WTW raw	Nickel Total	11/21/11	1.8	ug/l
Horsley WTW raw	Nickel Total	12/19/11	1.6	ug/l
Horsley WTW raw	Nickel Total	01/04/12	1.8	ug/l
Horsley WTW raw	Nickel Total	02/01/12	1.2	ug/l
Horsley WTW raw	Nickel Total	03/07/12	1.4	ug/l
Horsley WTW raw	Nickel Total	04/04/12	1	ug/l
Horsley WTW raw	Nickel Total	05/02/12	1.5	ug/l
Horsley WTW raw	Nickel Total	06/13/12	2	ug/l
Horsley WTW raw	Nickel Total	07/04/12	2	ug/l
Horsley WTW raw	Nickel Total	08/01/12	4.4	ug/l
Horsley WTW raw	Nickel Total	09/05/12	1.7	ug/l
Horsley WTW raw	Nickel Total	10/03/12	2.7	ug/l
Horsley WTW raw	Nickel Total	11/07/12	2.1	ug/l
Horsley WTW raw	Nickel Total	12/05/12	1.7	ug/l

Mosswood WTW raw

Spt Desc	Detdesc	Datetaken	Value	Unitused
Mosswood WTW raw	Hydrogen ion	01/27/11	8.5	pH Value
Mosswood WTW raw	Hydrogen ion	02/24/11	7.1	pH Value
Mosswood WTW raw	Hydrogen ion	03/24/11	7.6	pH Value
Mosswood WTW raw	Hydrogen ion	04/28/11	7.2	pH Value
Mosswood WTW raw	Hydrogen ion	05/26/11	7.4	pH Value
Mosswood WTW raw	Hydrogen ion	06/23/11	7.7	pH Value
Mosswood WTW raw	Hydrogen ion	07/28/11	7.8	pH Value
Mosswood WTW raw	Hydrogen ion	08/25/11	7.5	pH Value
Mosswood WTW raw	Hydrogen ion	09/22/11	7.9	pH Value
Mosswood WTW raw	Hydrogen ion	10/27/11	7.3	pH Value
Mosswood WTW raw	Hydrogen ion	11/24/11	7.8	pH Value
Mosswood WTW raw	Hydrogen ion	12/29/11	7.5	pH Value
Mosswood WTW raw	Hydrogen ion	01/27/12	7.1	pH Value
Mosswood WTW raw	Hydrogen ion	02/24/12	7.2	pH Value
Mosswood WTW raw	Hydrogen ion	03/23/12	8.1	pH Value
Mosswood WTW raw	Hydrogen ion	04/27/12	7.6	pH Value
Mosswood WTW raw	Hydrogen ion	05/25/12	7.1	pH Value
Mosswood WTW raw	Hydrogen ion	06/22/12	7.1	pH Value
Mosswood WTW raw	Hydrogen ion	07/27/12	7.3	pH Value
Mosswood WTW raw	Hydrogen ion	08/24/12	7.1	pH Value
Mosswood WTW raw	Hydrogen ion	09/28/12	7.2	pH Value
Mosswood WTW raw	Hydrogen ion	10/26/12	7.1	pH Value
Mosswood WTW raw	Hydrogen ion	11/23/12	7.3	pH Value
Mosswood WTW raw	Hydrogen ion	12/28/12	7.4	pH Value
Mosswood WTW raw	Conductivity 20 Deg. C	01/27/11	120	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	02/24/11	81	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	03/24/11	82	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	04/28/11	86	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	05/26/11	84	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	06/23/11	89	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	07/28/11	89	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	08/25/11	85	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	09/22/11	87	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	10/27/11	87	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	11/24/11	94	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	12/29/11	83	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	01/27/12	89	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	02/24/12	87	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	03/23/12	94	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	04/27/12	86	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	05/25/12	85	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	06/22/12	82	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	07/27/12	80	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	08/24/12	76	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	09/28/12	75	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	10/26/12	74	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	11/23/12	72	uS/cm
Mosswood WTW raw	Conductivity 20 Deg. C	12/28/12	74	uS/cm
Mosswood WTW raw	Turbidity	01/27/11	4.1	NTU
Mosswood WTW raw	Turbidity	02/24/11	2.9	NTU
Mosswood WTW raw	Turbidity	03/24/11	3.1	NTU
Mosswood WTW raw	Turbidity	04/28/11	1.8	NTU
Mosswood WTW raw	Turbidity	05/26/11	4.6	NTU

Mosswood WTW raw	Turbidity	06/23/11	3.8	NTU
Mosswood WTW raw	Turbidity	07/28/11	1.4	NTU
Mosswood WTW raw	Turbidity	08/25/11	1.4	NTU
Mosswood WTW raw	Turbidity	09/22/11	2.7	NTU
Mosswood WTW raw	Turbidity	10/27/11	3.4	NTU
Mosswood WTW raw	Turbidity	11/24/11	3	NTU
Mosswood WTW raw	Turbidity	12/29/11	96	NTU
Mosswood WTW raw	Turbidity	01/27/12	120	NTU
Mosswood WTW raw	Turbidity	02/24/12	17	NTU
Mosswood WTW raw	Turbidity	03/23/12	14	NTU
Mosswood WTW raw	Turbidity	04/27/12	4.7	NTU
Mosswood WTW raw	Turbidity	05/25/12	1.9	NTU
Mosswood WTW raw	Turbidity	06/22/12	1.8	NTU
Mosswood WTW raw	Turbidity	07/27/12	3.8	NTU
Mosswood WTW raw	Turbidity	08/24/12	1.2	NTU
Mosswood WTW raw	Turbidity	09/28/12	4.6	NTU
Mosswood WTW raw	Turbidity	10/26/12	2	NTU
Mosswood WTW raw	Turbidity	11/23/12	1.5	NTU
Mosswood WTW raw	Turbidity	12/28/12	2	NTU
Mosswood WTW raw	Colour Filtered	01/27/11	58	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	02/24/11	57	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	03/24/11	56	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	04/28/11	52	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	05/26/11	45	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	06/23/11	42	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	07/28/11	41	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	08/25/11	51	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	09/22/11	53	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	10/27/11	60	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	11/24/11	58	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	12/29/11	60	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	01/27/12	56	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	02/24/12	55	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	03/23/12	54	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	04/27/12	60	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	05/25/12	59	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	06/22/12	61	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	07/27/12	79	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	08/24/12	80	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	09/28/12	84	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	10/26/12	82	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	11/23/12	81	mg/l Pt/Co scal
Mosswood WTW raw	Colour Filtered	12/28/12	81	mg/l Pt/Co scal
Mosswood WTW raw	Temperature Deg. C	01/27/11	4.3	Deg. C
Mosswood WTW raw	Temperature Deg. C	02/24/11	5.8	Deg. C
Mosswood WTW raw	Temperature Deg. C	03/24/11	4.9	Deg. C
Mosswood WTW raw	Temperature Deg. C	04/28/11	9.9	Deg. C
Mosswood WTW raw	Temperature Deg. C	05/26/11	9.7	Deg. C
Mosswood WTW raw	Temperature Deg. C	06/23/11	11.4	Deg. C
Mosswood WTW raw	Temperature Deg. C	07/28/11	17.5	Deg. C
Mosswood WTW raw	Temperature Deg. C	08/25/11	14.3	Deg. C
Mosswood WTW raw	Temperature Deg. C	09/22/11	11.5	Deg. C
Mosswood WTW raw	Temperature Deg. C	10/27/11	11.5	Deg. C
Mosswood WTW raw	Temperature Deg. C	11/24/11	9.1	Deg. C
Mosswood WTW raw	Temperature Deg. C	12/29/11	4.2	Deg. C
Mosswood WTW raw	Temperature Deg. C	01/27/12	3.9	Deg. C
Mosswood WTW raw	Temperature Deg. C	02/24/12	3.9	Deg. C

Mosswood WTW raw	Temperature Deg. C	03/23/12	5.6	Deg. C
Mosswood WTW raw	Temperature Deg. C	04/27/12	8	Deg. C
Mosswood WTW raw	Temperature Deg. C	05/25/12	9.7	Deg. C
Mosswood WTW raw	Temperature Deg. C	06/22/12	11.6	Deg. C
Mosswood WTW raw	Temperature Deg. C	07/27/12	16.3	Deg. C
Mosswood WTW raw	Temperature Deg. C	08/24/12	15.4	Deg. C
Mosswood WTW raw	Temperature Deg. C	09/28/12	13.1	Deg. C
Mosswood WTW raw	Temperature Deg. C	10/26/12	10	Deg. C
Mosswood WTW raw	Temperature Deg. C	11/23/12	7.9	Deg. C
Mosswood WTW raw	Temperature Deg. C	12/28/12	4.2	Deg. C
Mosswood WTW raw	Total Organic Carbon	01/27/11	7.7	mg/l
Mosswood WTW raw	Total Organic Carbon	02/24/11	7.3	mg/l
Mosswood WTW raw	Total Organic Carbon	03/24/11	7.1	mg/l
Mosswood WTW raw	Total Organic Carbon	04/28/11	7.2	mg/l
Mosswood WTW raw	Total Organic Carbon	05/26/11	6.4	mg/l
Mosswood WTW raw	Total Organic Carbon	06/23/11	6.6	mg/l
Mosswood WTW raw	Total Organic Carbon	07/28/11	6.2	mg/l
Mosswood WTW raw	Total Organic Carbon	08/25/11	7.1	mg/l
Mosswood WTW raw	Total Organic Carbon	09/22/11	7.4	mg/l
Mosswood WTW raw	Total Organic Carbon	10/27/11	7.9	mg/l
Mosswood WTW raw	Total Organic Carbon	11/24/11	8	mg/l
Mosswood WTW raw	Total Organic Carbon	12/29/11	9.3	mg/l
Mosswood WTW raw	Total Organic Carbon	01/27/12	7.7	mg/l
Mosswood WTW raw	Total Organic Carbon	02/24/12	7.4	mg/l
Mosswood WTW raw	Total Organic Carbon	03/23/12	1.4	mg/l
Mosswood WTW raw	Total Organic Carbon	04/27/12	7.4	mg/l
Mosswood WTW raw	Total Organic Carbon	05/25/12	8.2	mg/l
Mosswood WTW raw	Total Organic Carbon	06/22/12	8.2	mg/l
Mosswood WTW raw	Total Organic Carbon	07/27/12	9.6	mg/l
Mosswood WTW raw	Total Organic Carbon	08/24/12	9.5	mg/l
Mosswood WTW raw	Total Organic Carbon	09/28/12	10	mg/l
Mosswood WTW raw	Total Organic Carbon	10/26/12	10	mg/l
Mosswood WTW raw	Total Organic Carbon	11/23/12	11	mg/l
Mosswood WTW raw	Total Organic Carbon	12/28/12	9.9	mg/l
Mosswood WTW raw	Nitrogen Ammoniacal	01/27/11	0.019	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	02/24/11	0.021	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	03/24/11	0.013	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	04/28/11	0.012	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	05/26/11	0.012	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	06/23/11	0.039	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	07/28/11	0.016	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	08/25/11	0.035	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	09/22/11	0.012	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	10/27/11	0.012	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	11/24/11	0.012	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	12/29/11	0.012	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	01/27/12	0.019	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	02/24/12	0.012	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	03/23/12	0.012	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	04/27/12	0.018	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	05/25/12	0.029	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	06/22/12	0.056	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	07/27/12	0.013	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	08/24/12	0.012	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	09/28/12	0.007	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	10/26/12	0.007	mg/l as NH4
Mosswood WTW raw	Nitrogen Ammoniacal	11/23/12	0.007	mg/l as NH4

Mosswood WTW raw	Nitrogen Ammoniacal	12/28/12	0.014	mg/l as NH4
Mosswood WTW raw	Nitrate	01/27/11	5.4	mg/l as NO3
Mosswood WTW raw	Nitrate	02/24/11	4	mg/l as NO3
Mosswood WTW raw	Nitrate	03/24/11	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	04/28/11	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	05/26/11	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	06/23/11	2.8	mg/l as NO3
Mosswood WTW raw	Nitrate	07/28/11	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	08/25/11	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	09/22/11	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	10/27/11	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	11/24/11	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	12/29/11	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	01/27/12	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	02/24/12	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	03/23/12	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	04/27/12	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	05/25/12	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	06/22/12	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	07/27/12	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	08/24/12	2.7	mg/l as NO3
Mosswood WTW raw	Nitrate	09/28/12	1.2	mg/l as NO3
Mosswood WTW raw	Nitrate	10/26/12	2.2	mg/l as NO3
Mosswood WTW raw	Nitrate	11/23/12	2.2	mg/l as NO3
Mosswood WTW raw	Nitrate	12/28/12	2.3	mg/l as NO3
Mosswood WTW raw	Nitrite	01/27/11	0.0014	mg/l as NO2
Mosswood WTW raw	Nitrite	02/24/11	0.0084	mg/l as NO2
Mosswood WTW raw	Nitrite	03/24/11	0.0014	mg/l as NO2
Mosswood WTW raw	Nitrite	04/28/11	0.0014	mg/l as NO2
Mosswood WTW raw	Nitrite	05/26/11	0.0014	mg/l as NO2
Mosswood WTW raw	Nitrite	06/23/11	0.0018	mg/l as NO2
Mosswood WTW raw	Nitrite	07/28/11	0.0026	mg/l as NO2
Mosswood WTW raw	Nitrite	08/25/11	0.013	mg/l as NO2
Mosswood WTW raw	Nitrite	09/22/11	0.0014	mg/l as NO2
Mosswood WTW raw	Nitrite	10/27/11	0.031	mg/l as NO2
Mosswood WTW raw	Nitrite	11/24/11	0.0014	mg/l as NO2
Mosswood WTW raw	Nitrite	12/29/11	0.0049	mg/l as NO2
Mosswood WTW raw	Nitrite	01/27/12	0.0014	mg/l as NO2
Mosswood WTW raw	Nitrite	02/24/12	0.0014	mg/l as NO2
Mosswood WTW raw	Nitrite	03/23/12	0.0014	mg/l as NO2
Mosswood WTW raw	Nitrite	04/27/12	0.0014	mg/l as NO2
Mosswood WTW raw	Nitrite	05/25/12	0.0014	mg/l as NO2
Mosswood WTW raw	Nitrite	06/22/12	0.0023	mg/l as NO2
Mosswood WTW raw	Nitrite	07/27/12	0.0014	mg/l as NO2
Mosswood WTW raw	Nitrite	08/24/12	0.0014	mg/l as NO2
Mosswood WTW raw	Nitrite	09/28/12	0.0011	mg/l as NO2
Mosswood WTW raw	Nitrite	10/26/12	0.0011	mg/l as NO2
Mosswood WTW raw	Nitrite	11/23/12	0.0011	mg/l as NO2
Mosswood WTW raw	Nitrite	12/28/12	0.0011	mg/l as NO2
Mosswood WTW raw	Hardness Total	01/27/11	11	mg/l
Mosswood WTW raw	Hardness Total	02/24/11	11	mg/l
Mosswood WTW raw	Hardness Total	03/24/11	13	mg/l
Mosswood WTW raw	Hardness Total	04/28/11	12	mg/l
Mosswood WTW raw	Hardness Total	05/26/11	13	mg/l as Ca
Mosswood WTW raw	Hardness Total	06/23/11	14	mg/l as Ca
Mosswood WTW raw	Hardness Total	07/28/11	13	mg/l as Ca
Mosswood WTW raw	Hardness Total	08/25/11	13	mg/l as Ca

Mosswood WTW raw	Hardness Total	09/22/11	13	mg/l as Ca
Mosswood WTW raw	Hardness Total	10/27/11	14	mg/l as Ca
Mosswood WTW raw	Hardness Total	11/24/11	15	mg/l as Ca
Mosswood WTW raw	Hardness Total	12/29/11	12	mg/l as Ca
Mosswood WTW raw	Hardness Total	01/27/12	12	mg/l as Ca
Mosswood WTW raw	Hardness Total	02/24/12	12	mg/l as Ca
Mosswood WTW raw	Hardness Total	03/23/12	14	mg/l as Ca
Mosswood WTW raw	Hardness Total	04/27/12	12	mg/l as Ca
Mosswood WTW raw	Hardness Total	05/25/12	12	mg/l as Ca
Mosswood WTW raw	Hardness Total	06/22/12	11	mg/l as Ca
Mosswood WTW raw	Hardness Total	07/27/12	11	mg/l as Ca
Mosswood WTW raw	Hardness Total	08/24/12	12	mg/l as Ca
Mosswood WTW raw	Hardness Total	09/28/12	11	mg/l as Ca
Mosswood WTW raw	Hardness Total	10/26/12	17	mg/l as Ca
Mosswood WTW raw	Hardness Total	11/23/12	11	mg/l as Ca
Mosswood WTW raw	Hardness Total	12/28/12	10	mg/l as Ca
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	01/27/11	20	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	02/24/11	23	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	03/24/11	33	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	04/28/11	22	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	05/26/11	17	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	06/23/11	17	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	07/28/11	24	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	08/25/11	28	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	09/22/11	17	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	10/27/11	24	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	11/24/11	43	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	12/29/11	23	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	01/27/12	22	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	02/24/12	18	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	03/23/12	25	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	04/27/12	26	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	05/25/12	20	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	06/22/12	17	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	07/27/12	17	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	08/24/12	19	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	09/28/12	22	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	10/26/12	21	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	11/23/12	22	mg/l as HCO3
Mosswood WTW raw	Alkalinity to pH 4.5 (Total)	12/28/12	18	mg/l as HCO3
Mosswood WTW raw	Chloride	01/27/11	11	mg/l
Mosswood WTW raw	Chloride	02/24/11	11	mg/l
Mosswood WTW raw	Chloride	03/24/11	10	mg/l
Mosswood WTW raw	Chloride	04/28/11	10	mg/l
Mosswood WTW raw	Chloride	05/26/11	11	mg/l
Mosswood WTW raw	Chloride	06/23/11	11	mg/l
Mosswood WTW raw	Chloride	07/28/11	9.6	mg/l
Mosswood WTW raw	Chloride	08/25/11	11	mg/l
Mosswood WTW raw	Chloride	09/22/11	10	mg/l
Mosswood WTW raw	Chloride	10/27/11	10	mg/l
Mosswood WTW raw	Chloride	11/24/11	9.4	mg/l
Mosswood WTW raw	Chloride	12/29/11	11	mg/l
Mosswood WTW raw	Chloride	01/27/12	11	mg/l
Mosswood WTW raw	Chloride	02/24/12	12	mg/l
Mosswood WTW raw	Chloride	03/23/12	11	mg/l
Mosswood WTW raw	Chloride	04/27/12	11	mg/l
Mosswood WTW raw	Chloride	05/25/12	10	mg/l

Mosswood WTW raw	Chloride	06/22/12	9.5	mg/l
Mosswood WTW raw	Chloride	07/27/12	10	mg/l
Mosswood WTW raw	Chloride	08/24/12	8.8	mg/l
Mosswood WTW raw	Chloride	09/28/12	8.9	mg/l
Mosswood WTW raw	Chloride	10/26/12	8	mg/l
Mosswood WTW raw	Chloride	11/23/12	8.8	mg/l
Mosswood WTW raw	Chloride	12/28/12	8.7	mg/l
Mosswood WTW raw	Sulphate Dissolved	01/27/11	7.8	mg/l
Mosswood WTW raw	Sulphate Dissolved	02/24/11	5.3	mg/l
Mosswood WTW raw	Sulphate Dissolved	03/24/11	6.5	mg/l
Mosswood WTW raw	Sulphate Dissolved	04/28/11	6.8	mg/l
Mosswood WTW raw	Sulphate Dissolved	05/26/11	8.5	mg/l
Mosswood WTW raw	Sulphate Dissolved	06/23/11	8.1	mg/l
Mosswood WTW raw	Sulphate Dissolved	07/28/11	6.4	mg/l
Mosswood WTW raw	Sulphate Dissolved	08/25/11	7.9	mg/l
Mosswood WTW raw	Sulphate Dissolved	09/22/11	6.1	mg/l
Mosswood WTW raw	Sulphate Dissolved	10/27/11	2.8	mg/l
Mosswood WTW raw	Sulphate Dissolved	11/24/11	6	mg/l
Mosswood WTW raw	Sulphate Dissolved	12/29/11	3.2	mg/l
Mosswood WTW raw	Sulphate Dissolved	01/27/12	5.5	mg/l
Mosswood WTW raw	Sulphate Dissolved	02/24/12	6.8	mg/l
Mosswood WTW raw	Sulphate Dissolved	03/23/12	7.7	mg/l
Mosswood WTW raw	Sulphate Dissolved	04/27/12	6.1	mg/l
Mosswood WTW raw	Sulphate Dissolved	05/25/12	0.49	mg/l
Mosswood WTW raw	Sulphate Dissolved	06/22/12	0.49	mg/l
Mosswood WTW raw	Sulphate Dissolved	07/27/12	0.49	mg/l
Mosswood WTW raw	Sulphate Dissolved	08/24/12	0.49	mg/l
Mosswood WTW raw	Sulphate Dissolved	09/28/12	0.29	mg/l
Mosswood WTW raw	Sulphate Dissolved	10/26/12	0.29	mg/l
Mosswood WTW raw	Sulphate Dissolved	11/23/12	0.29	mg/l
Mosswood WTW raw	Sulphate Dissolved	12/28/12	0.29	mg/l
Mosswood WTW raw	Sodium Total	01/27/11	7.2	mg/l
Mosswood WTW raw	Sodium Total	02/24/11	7.2	mg/l
Mosswood WTW raw	Sodium Total	03/24/11	7.5	mg/l
Mosswood WTW raw	Sodium Total	04/28/11	7.5	mg/l
Mosswood WTW raw	Sodium Total	05/26/11	7.3	mg/l
Mosswood WTW raw	Sodium Total	06/23/11	7.4	mg/l
Mosswood WTW raw	Sodium Total	07/28/11	7.5	mg/l
Mosswood WTW raw	Sodium Total	08/25/11	7.6	mg/l
Mosswood WTW raw	Sodium Total	09/22/11	7.5	mg/l
Mosswood WTW raw	Sodium Total	10/27/11	7.4	mg/l
Mosswood WTW raw	Sodium Total	11/24/11	7.4	mg/l
Mosswood WTW raw	Sodium Total	12/29/11	7.7	mg/l
Mosswood WTW raw	Sodium Total	01/27/12	7.9	mg/l
Mosswood WTW raw	Sodium Total	02/24/12	7.9	mg/l
Mosswood WTW raw	Sodium Total	03/23/12	7.9	mg/l
Mosswood WTW raw	Sodium Total	04/27/12	7.9	mg/l
Mosswood WTW raw	Sodium Total	05/25/12	7.3	mg/l
Mosswood WTW raw	Sodium Total	06/22/12	6.7	mg/l
Mosswood WTW raw	Sodium Total	07/27/12	6.9	mg/l
Mosswood WTW raw	Sodium Total	08/24/12	6.9	mg/l
Mosswood WTW raw	Sodium Total	09/28/12	6.4	mg/l
Mosswood WTW raw	Sodium Total	10/26/12	6.5	mg/l
Mosswood WTW raw	Sodium Total	11/23/12	6.5	mg/l
Mosswood WTW raw	Sodium Total	12/28/12	5.8	mg/l
Mosswood WTW raw	Magnesium Total	01/27/11	2.2	mg/l
Mosswood WTW raw	Magnesium Total	02/24/11	2.2	mg/l

Mosswood WTW raw	Magnesium Total	03/24/11	3.3	mg/l
Mosswood WTW raw	Magnesium Total	04/28/11	2.3	mg/l
Mosswood WTW raw	Magnesium Total	05/26/11	3	mg/l
Mosswood WTW raw	Magnesium Total	06/23/11	3.1	mg/l
Mosswood WTW raw	Magnesium Total	07/28/11	3	mg/l
Mosswood WTW raw	Magnesium Total	08/25/11	2.6	mg/l
Mosswood WTW raw	Magnesium Total	09/22/11	2.8	mg/l
Mosswood WTW raw	Magnesium Total	10/27/11	3.1	mg/l
Mosswood WTW raw	Magnesium Total	11/24/11	2.7	mg/l
Mosswood WTW raw	Magnesium Total	12/29/11	2.9	mg/l
Mosswood WTW raw	Magnesium Total	01/27/12	2.6	mg/l
Mosswood WTW raw	Magnesium Total	02/24/12	2.8	mg/l
Mosswood WTW raw	Magnesium Total	03/23/12	2.7	mg/l
Mosswood WTW raw	Magnesium Total	04/27/12	2.5	mg/l
Mosswood WTW raw	Magnesium Total	05/25/12	2.6	mg/l
Mosswood WTW raw	Magnesium Total	06/22/12	2.5	mg/l
Mosswood WTW raw	Magnesium Total	07/27/12	2.3	mg/l
Mosswood WTW raw	Magnesium Total	08/24/12	2.4	mg/l
Mosswood WTW raw	Magnesium Total	09/28/12	2.2	mg/l
Mosswood WTW raw	Magnesium Total	10/26/12	2.2	mg/l
Mosswood WTW raw	Magnesium Total	11/23/12	2	mg/l
Mosswood WTW raw	Magnesium Total	12/28/12	2	mg/l
Mosswood WTW raw	Calcium Total	01/27/11	7.6	mg/l
Mosswood WTW raw	Calcium Total	02/24/11	7.1	mg/l
Mosswood WTW raw	Calcium Total	03/24/11	7.7	mg/l
Mosswood WTW raw	Calcium Total	04/28/11	7.8	mg/l
Mosswood WTW raw	Calcium Total	05/26/11	7.8	mg/l as Ca
Mosswood WTW raw	Calcium Total	06/23/11	8.9	mg/l as Ca
Mosswood WTW raw	Calcium Total	07/28/11	8.2	mg/l as Ca
Mosswood WTW raw	Calcium Total	08/25/11	8.5	mg/l as Ca
Mosswood WTW raw	Calcium Total	09/22/11	8.6	mg/l as Ca
Mosswood WTW raw	Calcium Total	10/27/11	9.1	mg/l as Ca
Mosswood WTW raw	Calcium Total	11/24/11	11	mg/l as Ca
Mosswood WTW raw	Calcium Total	12/29/11	7.6	mg/l as Ca
Mosswood WTW raw	Calcium Total	01/27/12	7.6	mg/l as Ca
Mosswood WTW raw	Calcium Total	02/24/12	7.9	mg/l as Ca
Mosswood WTW raw	Calcium Total	03/23/12	9.1	mg/l as Ca
Mosswood WTW raw	Calcium Total	04/27/12	8.2	mg/l as Ca
Mosswood WTW raw	Calcium Total	05/25/12	7.5	mg/l as Ca
Mosswood WTW raw	Calcium Total	06/22/12	7.2	mg/l as Ca
Mosswood WTW raw	Calcium Total	07/27/12	7.2	mg/l as Ca
Mosswood WTW raw	Calcium Total	08/24/12	7.8	mg/l as Ca
Mosswood WTW raw	Calcium Total	09/28/12	7.3	mg/l as Ca
Mosswood WTW raw	Calcium Total	10/26/12	14	mg/l as Ca
Mosswood WTW raw	Calcium Total	11/23/12	7.5	mg/l as Ca
Mosswood WTW raw	Calcium Total	12/28/12	6.7	mg/l as Ca
Mosswood WTW raw	Zinc Total	04/27/12	80	ug/l
Mosswood WTW raw	Cadmium Total	01/27/11	0.082	ug/l
Mosswood WTW raw	Cadmium Total	02/24/11	0.08	ug/l
Mosswood WTW raw	Cadmium Total	03/24/11	0.087	ug/l
Mosswood WTW raw	Cadmium Total	04/28/11	0.085	ug/l
Mosswood WTW raw	Cadmium Total	05/26/11	0.068	ug/l
Mosswood WTW raw	Cadmium Total	06/23/11	0.056	ug/l
Mosswood WTW raw	Cadmium Total	07/28/11	0.025	ug/l
Mosswood WTW raw	Cadmium Total	08/25/11	0.038	ug/l
Mosswood WTW raw	Cadmium Total	09/22/11	0.024	ug/l
Mosswood WTW raw	Cadmium Total	10/27/11	0.035	ug/l

Mosswood WTW raw	Cadmium Total	11/24/11	0.023	ug/l
Mosswood WTW raw	Cadmium Total	12/29/11	0.14	ug/l
Mosswood WTW raw	Cadmium Total	01/27/12	0.057	ug/l
Mosswood WTW raw	Cadmium Total	02/24/12	0.5	ug/l
Mosswood WTW raw	Cadmium Total	03/23/12	0.093	ug/l
Mosswood WTW raw	Cadmium Total	04/27/12	0.17	ug/l
Mosswood WTW raw	Cadmium Total	05/25/12	0.082	ug/l
Mosswood WTW raw	Cadmium Total	06/22/12	0.077	ug/l
Mosswood WTW raw	Cadmium Total	07/27/12	0.059	ug/l
Mosswood WTW raw	Cadmium Total	08/24/12	0.069	ug/l
Mosswood WTW raw	Cadmium Total	09/28/12	0.098	ug/l
Mosswood WTW raw	Cadmium Total	10/26/12	0.054	ug/l
Mosswood WTW raw	Cadmium Total	11/23/12	0.036	ug/l
Mosswood WTW raw	Cadmium Total	12/28/12	0.072	ug/l
Mosswood WTW raw	Aluminium Total	01/27/11	280	ug/l
Mosswood WTW raw	Aluminium Total	02/24/11	210	ug/l
Mosswood WTW raw	Aluminium Total	03/24/11	200	ug/l
Mosswood WTW raw	Aluminium Total	04/28/11	130	ug/l
Mosswood WTW raw	Aluminium Total	05/26/11	200	ug/l
Mosswood WTW raw	Aluminium Total	06/23/11	130	ug/l
Mosswood WTW raw	Aluminium Total	07/28/11	97	ug/l
Mosswood WTW raw	Aluminium Total	08/25/11	83	ug/l
Mosswood WTW raw	Aluminium Total	09/22/11	78	ug/l
Mosswood WTW raw	Aluminium Total	10/27/11	92	ug/l
Mosswood WTW raw	Aluminium Total	11/24/11	110	ug/l
Mosswood WTW raw	Aluminium Total	12/29/11	870	ug/l
Mosswood WTW raw	Aluminium Total	01/27/12	250	ug/l
Mosswood WTW raw	Aluminium Total	02/24/12	1700	ug/l
Mosswood WTW raw	Aluminium Total	03/23/12	440	ug/l
Mosswood WTW raw	Aluminium Total	04/27/12	150	ug/l
Mosswood WTW raw	Aluminium Total	05/25/12	110	ug/l
Mosswood WTW raw	Aluminium Total	06/22/12	140	ug/l
Mosswood WTW raw	Aluminium Total	07/27/12	200	ug/l
Mosswood WTW raw	Aluminium Total	08/24/12	130	ug/l
Mosswood WTW raw	Aluminium Total	09/28/12	200	ug/l
Mosswood WTW raw	Aluminium Total	10/26/12	150	ug/l
Mosswood WTW raw	Aluminium Total	11/23/12	120	ug/l
Mosswood WTW raw	Aluminium Total	12/28/12	190	ug/l
Mosswood WTW raw	Lead Total	01/27/11	5.5	ug/l
Mosswood WTW raw	Lead Total	02/24/11	5.3	ug/l
Mosswood WTW raw	Lead Total	03/24/11	73	ug/l
Mosswood WTW raw	Lead Total	04/28/11	2.4	ug/l
Mosswood WTW raw	Lead Total	05/26/11	3.3	ug/l
Mosswood WTW raw	Lead Total	06/23/11	3.1	ug/l
Mosswood WTW raw	Lead Total	07/28/11	1.5	ug/l
Mosswood WTW raw	Lead Total	08/25/11	2	ug/l
Mosswood WTW raw	Lead Total	09/22/11	3	ug/l
Mosswood WTW raw	Lead Total	10/27/11	4.9	ug/l
Mosswood WTW raw	Lead Total	11/24/11	6.7	ug/l
Mosswood WTW raw	Lead Total	12/29/11	120	ug/l
Mosswood WTW raw	Lead Total	01/27/12	110	ug/l
Mosswood WTW raw	Lead Total	02/24/12	87	ug/l
Mosswood WTW raw	Lead Total	03/23/12	9.3	ug/l
Mosswood WTW raw	Lead Total	04/27/12	20	ug/l
Mosswood WTW raw	Lead Total	05/25/12	5.8	ug/l
Mosswood WTW raw	Lead Total	06/22/12	4.9	ug/l
Mosswood WTW raw	Lead Total	07/27/12	7.2	ug/l

Mosswood WTW raw	Lead Total	08/24/12	4	ug/l
Mosswood WTW raw	Lead Total	09/28/12	13	ug/l
Mosswood WTW raw	Lead Total	10/26/12	5.3	ug/l
Mosswood WTW raw	Lead Total	11/23/12	3.5	ug/l
Mosswood WTW raw	Lead Total	12/28/12	5.3	ug/l
Mosswood WTW raw	Phosphorus Total (As P)	01/27/11	27	ug/l as P
Mosswood WTW raw	Phosphorus Total (As P)	04/28/11	14	ug/l as P
Mosswood WTW raw	Phosphorus Total (As P)	07/28/11	8.5	ug/l as P
Mosswood WTW raw	Phosphorus Total (As P)	10/27/11	17	ug/l as P
Mosswood WTW raw	Phosphorus Total (As P)	01/27/12	14	ug/l as P
Mosswood WTW raw	Phosphorus Total (As P)	04/27/12	15	ug/l as P
Mosswood WTW raw	Phosphorus Total (As P)	07/27/12	13	ug/l as P
Mosswood WTW raw	Phosphorus Total (As P)	10/26/12	17	ug/l as P
Mosswood WTW raw	Manganese Total	01/27/11	24	ug/l
Mosswood WTW raw	Manganese Total	02/24/11	25	ug/l
Mosswood WTW raw	Manganese Total	03/24/11	25	ug/l
Mosswood WTW raw	Manganese Total	04/28/11	43	ug/l
Mosswood WTW raw	Manganese Total	05/26/11	56	ug/l
Mosswood WTW raw	Manganese Total	06/23/11	54	ug/l
Mosswood WTW raw	Manganese Total	07/28/11	22	ug/l
Mosswood WTW raw	Manganese Total	08/25/11	42	ug/l
Mosswood WTW raw	Manganese Total	09/22/11	34	ug/l
Mosswood WTW raw	Manganese Total	10/27/11	60	ug/l
Mosswood WTW raw	Manganese Total	11/24/11	97	ug/l
Mosswood WTW raw	Manganese Total	12/29/11	320	ug/l
Mosswood WTW raw	Manganese Total	01/27/12	40	ug/l
Mosswood WTW raw	Manganese Total	02/24/12	250	ug/l
Mosswood WTW raw	Manganese Total	03/23/12	100	ug/l
Mosswood WTW raw	Manganese Total	04/27/12	34	ug/l
Mosswood WTW raw	Manganese Total	05/25/12	15	ug/l
Mosswood WTW raw	Manganese Total	06/22/12	24	ug/l
Mosswood WTW raw	Manganese Total	07/27/12	40	ug/l
Mosswood WTW raw	Manganese Total	08/24/12	26	ug/l
Mosswood WTW raw	Manganese Total	09/28/12	62	ug/l
Mosswood WTW raw	Manganese Total	10/26/12	36	ug/l
Mosswood WTW raw	Manganese Total	11/23/12	24	ug/l
Mosswood WTW raw	Manganese Total	12/28/12	22	ug/l
Mosswood WTW raw	Iron Total	01/27/11	390	ug/l
Mosswood WTW raw	Iron Total	02/24/11	330	ug/l
Mosswood WTW raw	Iron Total	03/24/11	320	ug/l
Mosswood WTW raw	Iron Total	04/28/11	260	ug/l
Mosswood WTW raw	Iron Total	05/26/11	310	ug/l
Mosswood WTW raw	Iron Total	06/23/11	240	ug/l
Mosswood WTW raw	Iron Total	07/28/11	170	ug/l
Mosswood WTW raw	Iron Total	08/25/11	200	ug/l
Mosswood WTW raw	Iron Total	09/22/11	240	ug/l
Mosswood WTW raw	Iron Total	10/27/11	330	ug/l
Mosswood WTW raw	Iron Total	11/24/11	450	ug/l
Mosswood WTW raw	Iron Total	12/29/11	1700	ug/l
Mosswood WTW raw	Iron Total	01/27/12	520	ug/l
Mosswood WTW raw	Iron Total	02/24/12	2200	ug/l
Mosswood WTW raw	Iron Total	03/23/12	720	ug/l
Mosswood WTW raw	Iron Total	04/27/12	320	ug/l
Mosswood WTW raw	Iron Total	05/25/12	230	ug/l
Mosswood WTW raw	Iron Total	06/22/12	280	ug/l
Mosswood WTW raw	Iron Total	07/27/12	420	ug/l
Mosswood WTW raw	Iron Total	08/24/12	370	ug/l

Mosswood WTW raw	Iron Total	09/28/12	540	ug/l
Mosswood WTW raw	Iron Total	10/26/12	440	ug/l
Mosswood WTW raw	Iron Total	11/23/12	400	ug/l
Mosswood WTW raw	Iron Total	12/28/12	420	ug/l
Mosswood WTW raw	Nickel Total	01/27/11	2.9	ug/l
Mosswood WTW raw	Nickel Total	02/24/11	2.4	ug/l
Mosswood WTW raw	Nickel Total	03/24/11	9.4	ug/l
Mosswood WTW raw	Nickel Total	04/28/11	2.1	ug/l
Mosswood WTW raw	Nickel Total	05/26/11	2.1	ug/l
Mosswood WTW raw	Nickel Total	06/23/11	2.1	ug/l
Mosswood WTW raw	Nickel Total	07/28/11	2	ug/l
Mosswood WTW raw	Nickel Total	08/25/11	1.9	ug/l
Mosswood WTW raw	Nickel Total	09/22/11	2	ug/l
Mosswood WTW raw	Nickel Total	10/27/11	2	ug/l
Mosswood WTW raw	Nickel Total	11/24/11	2.2	ug/l
Mosswood WTW raw	Nickel Total	12/29/11	5.2	ug/l
Mosswood WTW raw	Nickel Total	01/27/12	6.7	ug/l
Mosswood WTW raw	Nickel Total	02/24/12	5.4	ug/l
Mosswood WTW raw	Nickel Total	03/23/12	2.4	ug/l
Mosswood WTW raw	Nickel Total	04/27/12	2.5	ug/l
Mosswood WTW raw	Nickel Total	05/25/12	2.7	ug/l
Mosswood WTW raw	Nickel Total	06/22/12	2.6	ug/l
Mosswood WTW raw	Nickel Total	07/27/12	2.8	ug/l
Mosswood WTW raw	Nickel Total	08/24/12	2.8	ug/l
Mosswood WTW raw	Nickel Total	09/28/12	2.5	ug/l
Mosswood WTW raw	Nickel Total	10/26/12	2.7	ug/l
Mosswood WTW raw	Nickel Total	11/23/12	2.7	ug/l
Mosswood WTW raw	Nickel Total	12/28/12	2.5	ug/l

Warkworth WTW raw

Spt Desc	Detdesc	Datetaken	Value	Unitused
Warkworth WTW raw	Hydrogen ion	01/05/11	8.1	pH Value
Warkworth WTW raw	Hydrogen ion	01/12/11	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	01/19/11	7.6	pH Value
Warkworth WTW raw	Hydrogen ion	01/26/11	8	pH Value
Warkworth WTW raw	Hydrogen ion	02/02/11	8.1	pH Value
Warkworth WTW raw	Hydrogen ion	02/09/11	7.6	pH Value
Warkworth WTW raw	Hydrogen ion	02/16/11	8.1	pH Value
Warkworth WTW raw	Hydrogen ion	02/23/11	7.7	pH Value
Warkworth WTW raw	Hydrogen ion	03/02/11	8	pH Value
Warkworth WTW raw	Hydrogen ion	03/09/11	8.2	pH Value
Warkworth WTW raw	Hydrogen ion	03/16/11	7.9	pH Value
Warkworth WTW raw	Hydrogen ion	03/23/11	7.9	pH Value
Warkworth WTW raw	Hydrogen ion	03/30/11	8.3	pH Value
Warkworth WTW raw	Hydrogen ion	04/06/11	8.2	pH Value
Warkworth WTW raw	Hydrogen ion	04/13/11	8.3	pH Value
Warkworth WTW raw	Hydrogen ion	04/20/11	8.5	pH Value
Warkworth WTW raw	Hydrogen ion	04/27/11	8.3	pH Value
Warkworth WTW raw	Hydrogen ion	05/04/11	8.1	pH Value
Warkworth WTW raw	Hydrogen ion	05/11/11	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	05/18/11	8	pH Value
Warkworth WTW raw	Hydrogen ion	05/25/11	8.2	pH Value
Warkworth WTW raw	Hydrogen ion	06/01/11	8.2	pH Value
Warkworth WTW raw	Hydrogen ion	06/08/11	8.2	pH Value
Warkworth WTW raw	Hydrogen ion	06/15/11	8.6	pH Value
Warkworth WTW raw	Hydrogen ion	06/22/11	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	06/29/11	7.9	pH Value
Warkworth WTW raw	Hydrogen ion	07/06/11	8.4	pH Value
Warkworth WTW raw	Hydrogen ion	07/13/11	8.6	pH Value
Warkworth WTW raw	Hydrogen ion	07/20/11	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	07/27/11	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	08/03/11	8.2	pH Value
Warkworth WTW raw	Hydrogen ion	08/10/11	7.6	pH Value
Warkworth WTW raw	Hydrogen ion	08/17/11	7.9	pH Value
Warkworth WTW raw	Hydrogen ion	08/24/11	8	pH Value
Warkworth WTW raw	Hydrogen ion	08/31/11	8.1	pH Value
Warkworth WTW raw	Hydrogen ion	09/07/11	8	pH Value
Warkworth WTW raw	Hydrogen ion	09/14/11	7.9	pH Value
Warkworth WTW raw	Hydrogen ion	09/21/11	7.4	pH Value
Warkworth WTW raw	Hydrogen ion	09/28/11	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	10/05/11	8	pH Value
Warkworth WTW raw	Hydrogen ion	10/12/11	8	pH Value
Warkworth WTW raw	Hydrogen ion	10/19/11	7.6	pH Value
Warkworth WTW raw	Hydrogen ion	10/26/11	7.6	pH Value
Warkworth WTW raw	Hydrogen ion	11/02/11	8	pH Value
Warkworth WTW raw	Hydrogen ion	11/09/11	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	11/16/11	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	11/23/11	7.9	pH Value
Warkworth WTW raw	Hydrogen ion	11/30/11	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	12/07/11	7.7	pH Value
Warkworth WTW raw	Hydrogen ion	12/14/11	7.7	pH Value
Warkworth WTW raw	Hydrogen ion	12/21/11	7.8	pH Value

Warkworth WTW raw	Hydrogen ion	12/28/11	7.9	pH Value
Warkworth WTW raw	Hydrogen ion	01/03/12	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	01/10/12	8	pH Value
Warkworth WTW raw	Hydrogen ion	01/17/12	7.9	pH Value
Warkworth WTW raw	Hydrogen ion	01/24/12	8	pH Value
Warkworth WTW raw	Hydrogen ion	01/31/12	7.9	pH Value
Warkworth WTW raw	Hydrogen ion	02/07/12	8	pH Value
Warkworth WTW raw	Hydrogen ion	02/14/12	8.1	pH Value
Warkworth WTW raw	Hydrogen ion	02/21/12	8.1	pH Value
Warkworth WTW raw	Hydrogen ion	02/28/12	8.2	pH Value
Warkworth WTW raw	Hydrogen ion	03/06/12	8	pH Value
Warkworth WTW raw	Hydrogen ion	03/13/12	8.1	pH Value
Warkworth WTW raw	Hydrogen ion	03/20/12	8.3	pH Value
Warkworth WTW raw	Hydrogen ion	03/27/12	8.1	pH Value
Warkworth WTW raw	Hydrogen ion	04/03/12	8.1	pH Value
Warkworth WTW raw	Hydrogen ion	04/10/12	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	04/17/12	8.1	pH Value
Warkworth WTW raw	Hydrogen ion	04/24/12	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	05/01/12	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	05/08/12	8	pH Value
Warkworth WTW raw	Hydrogen ion	05/15/12	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	05/22/12	8	pH Value
Warkworth WTW raw	Hydrogen ion	05/29/12	8.5	pH Value
Warkworth WTW raw	Hydrogen ion	06/08/12	7.7	pH Value
Warkworth WTW raw	Hydrogen ion	06/12/12	8.2	pH Value
Warkworth WTW raw	Hydrogen ion	06/19/12	7.7	pH Value
Warkworth WTW raw	Hydrogen ion	06/26/12	7.7	pH Value
Warkworth WTW raw	Hydrogen ion	07/03/12	7.7	pH Value
Warkworth WTW raw	Hydrogen ion	07/10/12	7.7	pH Value
Warkworth WTW raw	Hydrogen ion	07/17/12	7.9	pH Value
Warkworth WTW raw	Hydrogen ion	07/24/12	8.2	pH Value
Warkworth WTW raw	Hydrogen ion	07/31/12	8.5	pH Value
Warkworth WTW raw	Hydrogen ion	08/07/12	7.9	pH Value
Warkworth WTW raw	Hydrogen ion	08/14/12	8.4	pH Value
Warkworth WTW raw	Hydrogen ion	08/21/12	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	08/28/12	7.9	pH Value
Warkworth WTW raw	Hydrogen ion	09/04/12	8	pH Value
Warkworth WTW raw	Hydrogen ion	09/11/12	8.2	pH Value
Warkworth WTW raw	Hydrogen ion	09/18/12	8.5	pH Value
Warkworth WTW raw	Hydrogen ion	09/25/12	7.4	pH Value
Warkworth WTW raw	Hydrogen ion	10/02/12	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	10/09/12	8.1	pH Value
Warkworth WTW raw	Hydrogen ion	10/16/12	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	10/23/12	8.2	pH Value
Warkworth WTW raw	Hydrogen ion	10/30/12	8	pH Value
Warkworth WTW raw	Hydrogen ion	11/06/12	8.1	pH Value
Warkworth WTW raw	Hydrogen ion	11/13/12	8.1	pH Value
Warkworth WTW raw	Hydrogen ion	11/20/12	8	pH Value
Warkworth WTW raw	Hydrogen ion	11/27/12	7.4	pH Value
Warkworth WTW raw	Hydrogen ion	12/04/12	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	12/11/12	8	pH Value
Warkworth WTW raw	Hydrogen ion	12/18/12	7.8	pH Value
Warkworth WTW raw	Hydrogen ion	12/28/12	7.6	pH Value
Warkworth WTW raw	Conductivity 20 Deg. C	01/05/11	240	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	01/12/11	140	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	01/19/11	210	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	01/26/11	270	uS/cm

Warkworth WTW raw	Conductivity 20 Deg. C	02/02/11	290	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	02/09/11	190	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	02/16/11	230	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	02/23/11	250	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	03/02/11	270	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	03/09/11	310	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	03/16/11	250	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	03/23/11	300	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	03/30/11	320	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	04/06/11	250	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	04/13/11	290	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	04/20/11	310	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	04/27/11	340	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	05/04/11	350	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	05/11/11	240	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	05/18/11	350	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	05/25/11	330	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	06/01/11	330	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	06/08/11	360	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	06/15/11	300	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	06/22/11	270	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	06/29/11	320	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	07/06/11	330	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	07/13/11	290	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	07/20/11	180	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	07/27/11	250	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	08/03/11	310	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	08/10/11	170	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	08/17/11	220	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	08/24/11	250	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	08/31/11	250	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	09/07/11	280	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	09/14/11	250	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	09/21/11	220	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	09/28/11	260	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	10/05/11	300	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	10/12/11	260	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	10/19/11	250	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	10/26/11	280	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	11/02/11	260	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	11/09/11	260	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	11/16/11	250	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	11/23/11	270	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	11/30/11	200	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	12/07/11	220	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	12/14/11	190	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	12/21/11	190	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	12/28/11	210	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	01/03/12	240	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	01/10/12	250	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	01/17/12	300	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	01/24/12	260	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	01/31/12	360	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	02/07/12	370	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	02/14/12	310	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	02/21/12	320	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	02/28/12	290	uS/cm

Warkworth WTW raw	Conductivity 20 Deg. C	03/06/12	320	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	03/13/12	280	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	03/20/12	300	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	03/27/12	340	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	04/03/12	360	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	04/10/12	230	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	04/17/12	270	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	04/24/12	240	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	05/01/12	250	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	05/08/12	310	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	05/15/12	260	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	05/22/12	250	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	05/29/12	290	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	06/08/12	180	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	06/12/12	160	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	06/19/12	180	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	06/26/12	220	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	07/03/12	230	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	07/10/12	240	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	07/17/12	280	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	07/24/12	300	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	07/31/12	320	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	08/07/12	180	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	08/14/12	320	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	08/21/12	180	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	08/28/12	240	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	09/04/12	280	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	09/11/12	320	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	09/18/12	310	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	09/25/12	110	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	10/02/12	250	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	10/09/12	280	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	10/16/12	270	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	10/23/12	290	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	10/30/12	290	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	11/06/12	270	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	11/13/12	260	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	11/20/12	280	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	11/27/12	110	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	12/04/12	290	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	12/11/12	240	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	12/18/12	240	uS/cm
Warkworth WTW raw	Conductivity 20 Deg. C	12/28/12	160	uS/cm
Warkworth WTW raw	Turbidity	01/19/11	7.3	NTU
Warkworth WTW raw	Turbidity	02/23/11	33	NTU
Warkworth WTW raw	Turbidity	03/23/11	2.2	NTU
Warkworth WTW raw	Turbidity	04/20/11	1.7	NTU
Warkworth WTW raw	Turbidity	05/25/11	1.6	NTU
Warkworth WTW raw	Turbidity	06/22/11	4.6	NTU
Warkworth WTW raw	Turbidity	07/20/11	30	NTU
Warkworth WTW raw	Turbidity	08/24/11	3.9	NTU
Warkworth WTW raw	Turbidity	09/21/11	2.2	NTU
Warkworth WTW raw	Turbidity	10/26/11	2.5	NTU
Warkworth WTW raw	Turbidity	11/23/11	1.4	NTU
Warkworth WTW raw	Turbidity	12/21/11	7.3	NTU
Warkworth WTW raw	Turbidity	01/03/12	7.8	NTU
Warkworth WTW raw	Turbidity	02/07/12	2.8	NTU

Warkworth WTW raw	Turbidity	03/06/12	1.6	NTU
Warkworth WTW raw	Turbidity	04/03/12	1.3	NTU
Warkworth WTW raw	Turbidity	05/01/12	12	NTU
Warkworth WTW raw	Turbidity	06/08/12	59	NTU
Warkworth WTW raw	Turbidity	07/03/12	6.3	NTU
Warkworth WTW raw	Turbidity	08/07/12	17	NTU
Warkworth WTW raw	Turbidity	09/04/12	3.2	NTU
Warkworth WTW raw	Turbidity	10/02/12	5.9	NTU
Warkworth WTW raw	Turbidity	11/06/12	13	NTU
Warkworth WTW raw	Turbidity	12/04/12	5.8	NTU
Warkworth WTW raw	Colour Filtered	01/19/11	28	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	02/23/11	28	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	03/23/11	15	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	04/20/11	13	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	05/25/11	13	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	06/22/11	50	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	07/20/11	100	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	08/24/11	52	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	09/21/11	41	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	10/26/11	24	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	11/23/11	20	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	12/21/11	45	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	01/03/12	44	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	02/07/12	9.7	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	03/06/12	14	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	04/03/12	11	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	05/01/12	42	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	06/08/12	83	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	07/03/12	39	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	08/07/12	100	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	09/04/12	33	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	10/02/12	27	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	11/06/12	31	mg/l Pt/Co scal
Warkworth WTW raw	Colour Filtered	12/04/12	20	mg/l Pt/Co scal
Warkworth WTW raw	Temperature Deg. C	01/19/11	5.9	Deg. C
Warkworth WTW raw	Temperature Deg. C	02/23/11	5.2	Deg. C
Warkworth WTW raw	Temperature Deg. C	03/23/11	6.1	Deg. C
Warkworth WTW raw	Temperature Deg. C	04/20/11	12.4	Deg. C
Warkworth WTW raw	Temperature Deg. C	05/25/11	14.7	Deg. C
Warkworth WTW raw	Temperature Deg. C	06/22/11	16.4	Deg. C
Warkworth WTW raw	Temperature Deg. C	07/20/11	15.1	Deg. C
Warkworth WTW raw	Temperature Deg. C	08/24/11	16.6	Deg. C
Warkworth WTW raw	Temperature Deg. C	09/21/11	13.3	Deg. C
Warkworth WTW raw	Temperature Deg. C	10/26/11	10.4	Deg. C
Warkworth WTW raw	Temperature Deg. C	11/23/11	8.2	Deg. C
Warkworth WTW raw	Temperature Deg. C	12/21/11	5.4	Deg. C
Warkworth WTW raw	Temperature Deg. C	01/03/12	7.4	Deg. C
Warkworth WTW raw	Temperature Deg. C	02/07/12	1.5	Deg. C
Warkworth WTW raw	Temperature Deg. C	03/06/12	6.1	Deg. C
Warkworth WTW raw	Temperature Deg. C	04/03/12	10.6	Deg. C
Warkworth WTW raw	Temperature Deg. C	05/01/12	8.1	Deg. C
Warkworth WTW raw	Temperature Deg. C	06/08/12	10.8	Deg. C
Warkworth WTW raw	Temperature Deg. C	07/03/12	15.4	Deg. C
Warkworth WTW raw	Temperature Deg. C	08/07/12	18.1	Deg. C
Warkworth WTW raw	Temperature Deg. C	09/04/12	15.6	Deg. C
Warkworth WTW raw	Temperature Deg. C	10/02/12	11.1	Deg. C
Warkworth WTW raw	Temperature Deg. C	11/06/12	11.5	Deg. C

Warkworth WTW raw	Temperature Deg. C	12/04/12	3.1	Deg. C
Warkworth WTW raw	Total Organic Carbon	01/19/11	5.2	mg/l
Warkworth WTW raw	Total Organic Carbon	02/23/11	6.1	mg/l
Warkworth WTW raw	Total Organic Carbon	03/23/11	3.4	mg/l
Warkworth WTW raw	Total Organic Carbon	04/20/11	3.2	mg/l
Warkworth WTW raw	Total Organic Carbon	05/25/11	3.3	mg/l
Warkworth WTW raw	Total Organic Carbon	06/22/11	8.6	mg/l
Warkworth WTW raw	Total Organic Carbon	07/20/11	15	mg/l
Warkworth WTW raw	Total Organic Carbon	08/24/11	7.6	mg/l
Warkworth WTW raw	Total Organic Carbon	09/21/11	6.6	mg/l
Warkworth WTW raw	Total Organic Carbon	10/26/11	4.7	mg/l
Warkworth WTW raw	Total Organic Carbon	11/23/11	4.2	mg/l
Warkworth WTW raw	Total Organic Carbon	12/21/11	7.6	mg/l
Warkworth WTW raw	Total Organic Carbon	01/03/12	7.4	mg/l
Warkworth WTW raw	Total Organic Carbon	02/07/12	2.8	mg/l
Warkworth WTW raw	Total Organic Carbon	03/06/12	3	mg/l
Warkworth WTW raw	Total Organic Carbon	04/03/12	2.6	mg/l
Warkworth WTW raw	Total Organic Carbon	05/01/12	7.7	mg/l
Warkworth WTW raw	Total Organic Carbon	06/08/12	14	mg/l
Warkworth WTW raw	Total Organic Carbon	07/03/12	6.7	mg/l
Warkworth WTW raw	Total Organic Carbon	08/07/12	14	mg/l
Warkworth WTW raw	Total Organic Carbon	09/04/12	5.3	mg/l
Warkworth WTW raw	Total Organic Carbon	10/02/12	12	mg/l
Warkworth WTW raw	Total Organic Carbon	11/06/12	6.1	mg/l
Warkworth WTW raw	Total Organic Carbon	12/04/12	4.1	mg/l
Warkworth WTW raw	Nitrogen Ammoniacal	01/19/11	0.022	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	02/23/11	0.067	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	03/23/11	0.016	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	04/20/11	0.046	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	05/25/11	0.054	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	06/22/11	0.056	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	07/20/11	0.052	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	08/24/11	0.03	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	09/21/11	0.022	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	10/26/11	0.017	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	11/23/11	0.017	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	12/21/11	0.025	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	01/03/12	0.018	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	02/07/12	0.021	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	03/06/12	0.017	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	04/03/12	0.03	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	05/01/12	0.029	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	06/08/12	0.067	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	07/03/12	0.037	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	08/07/12	0.019	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	09/04/12	0.023	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	10/02/12	0.027	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	11/06/12	0.01	mg/l as NH4
Warkworth WTW raw	Nitrogen Ammoniacal	12/04/12	0.039	mg/l as NH4
Warkworth WTW raw	Nitrate	01/19/11	4.2	mg/l as NO3
Warkworth WTW raw	Nitrate	02/23/11	4.4	mg/l as NO3
Warkworth WTW raw	Nitrate	03/23/11	3.8	mg/l as NO3
Warkworth WTW raw	Nitrate	04/20/11	2.9	mg/l as NO3
Warkworth WTW raw	Nitrate	05/25/11	3.2	mg/l as NO3
Warkworth WTW raw	Nitrate	06/22/11	2.7	mg/l as NO3
Warkworth WTW raw	Nitrate	07/20/11	2.7	mg/l as NO3
Warkworth WTW raw	Nitrate	08/24/11	2.7	mg/l as NO3

Warkworth WTW raw	Nitrate	09/21/11	2.7	mg/l as NO3
Warkworth WTW raw	Nitrate	10/26/11	3.4	mg/l as NO3
Warkworth WTW raw	Nitrate	11/23/11	3.2	mg/l as NO3
Warkworth WTW raw	Nitrate	12/21/11	4	mg/l as NO3
Warkworth WTW raw	Nitrate	01/03/12	4.8	mg/l as NO3
Warkworth WTW raw	Nitrate	02/07/12	5	mg/l as NO3
Warkworth WTW raw	Nitrate	03/06/12	3	mg/l as NO3
Warkworth WTW raw	Nitrate	04/03/12	2.7	mg/l as NO3
Warkworth WTW raw	Nitrate	05/01/12	6.1	mg/l as NO3
Warkworth WTW raw	Nitrate	06/08/12	3.2	mg/l as NO3
Warkworth WTW raw	Nitrate	07/03/12	3.2	mg/l as NO3
Warkworth WTW raw	Nitrate	08/07/12	2.7	mg/l as NO3
Warkworth WTW raw	Nitrate	09/04/12	4.2	mg/l as NO3
Warkworth WTW raw	Nitrate	10/02/12	4.8	mg/l as NO3
Warkworth WTW raw	Nitrate	11/06/12	4.3	mg/l as NO3
Warkworth WTW raw	Nitrate	12/04/12	5.8	mg/l as NO3
Warkworth WTW raw	Nitrite	01/19/11	0.0064	mg/l as NO2
Warkworth WTW raw	Nitrite	02/23/11	0.012	mg/l as NO2
Warkworth WTW raw	Nitrite	03/23/11	0.012	mg/l as NO2
Warkworth WTW raw	Nitrite	04/20/11	0.021	mg/l as NO2
Warkworth WTW raw	Nitrite	05/25/11	0.03	mg/l as NO2
Warkworth WTW raw	Nitrite	06/22/11	0.022	mg/l as NO2
Warkworth WTW raw	Nitrite	07/20/11	0.0056	mg/l as NO2
Warkworth WTW raw	Nitrite	08/24/11	0.0042	mg/l as NO2
Warkworth WTW raw	Nitrite	09/21/11	0.0014	mg/l as NO2
Warkworth WTW raw	Nitrite	10/26/11	0.0056	mg/l as NO2
Warkworth WTW raw	Nitrite	11/23/11	0.0087	mg/l as NO2
Warkworth WTW raw	Nitrite	12/21/11	0.007	mg/l as NO2
Warkworth WTW raw	Nitrite	01/03/12	0.013	mg/l as NO2
Warkworth WTW raw	Nitrite	02/07/12	0.013	mg/l as NO2
Warkworth WTW raw	Nitrite	03/06/12	0.0092	mg/l as NO2
Warkworth WTW raw	Nitrite	04/03/12	0.018	mg/l as NO2
Warkworth WTW raw	Nitrite	05/01/12	0.013	mg/l as NO2
Warkworth WTW raw	Nitrite	06/08/12	0.014	mg/l as NO2
Warkworth WTW raw	Nitrite	07/03/12	0.0061	mg/l as NO2
Warkworth WTW raw	Nitrite	08/07/12	0.0041	mg/l as NO2
Warkworth WTW raw	Nitrite	09/04/12	0.01	mg/l as NO2
Warkworth WTW raw	Nitrite	10/02/12	0.0074	mg/l as NO2
Warkworth WTW raw	Nitrite	11/06/12	0.0045	mg/l as NO2
Warkworth WTW raw	Nitrite	12/04/12	0.0075	mg/l as NO2
Warkworth WTW raw	Hardness Total	01/19/11	30	mg/l
Warkworth WTW raw	Hardness Total	02/23/11	47	mg/l
Warkworth WTW raw	Hardness Total	03/23/11	57	mg/l
Warkworth WTW raw	Hardness Total	04/20/11	62	mg/l
Warkworth WTW raw	Hardness Total	05/25/11	63	mg/l
Warkworth WTW raw	Hardness Total	06/22/11	48	mg/l as Ca
Warkworth WTW raw	Hardness Total	07/20/11	34	mg/l as Ca
Warkworth WTW raw	Hardness Total	08/24/11	45	mg/l as Ca
Warkworth WTW raw	Hardness Total	09/21/11	38	mg/l as Ca
Warkworth WTW raw	Hardness Total	10/26/11	50	mg/l as Ca
Warkworth WTW raw	Hardness Total	11/23/11	53	mg/l as Ca
Warkworth WTW raw	Hardness Total	12/21/11	35	mg/l as Ca
Warkworth WTW raw	Hardness Total	01/03/12	42	mg/l as Ca
Warkworth WTW raw	Hardness Total	02/07/12	64	mg/l as Ca
Warkworth WTW raw	Hardness Total	03/06/12	61	mg/l as Ca
Warkworth WTW raw	Hardness Total	04/03/12	67	mg/l as Ca
Warkworth WTW raw	Hardness Total	05/01/12	49	mg/l as Ca

Warkworth WTW raw	Hardness Total	06/08/12	37	mg/l as Ca
Warkworth WTW raw	Hardness Total	07/03/12	42	mg/l as Ca
Warkworth WTW raw	Hardness Total	08/07/12	34	mg/l as Ca
Warkworth WTW raw	Hardness Total	09/04/12	56	mg/l as Ca
Warkworth WTW raw	Hardness Total	10/02/12	49	mg/l as Ca
Warkworth WTW raw	Hardness Total	11/06/12	54	mg/l as Ca
Warkworth WTW raw	Hardness Total	12/04/12	56	mg/l as Ca
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	01/19/11	130	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	02/23/11	100	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	03/23/11	97	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	04/20/11	150	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	05/25/11	160	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	06/22/11	110	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	07/20/11	86	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	08/24/11	120	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	09/21/11	57	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	10/26/11	100	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	11/23/11	130	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	12/21/11	63	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	01/03/12	86	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	02/07/12	140	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	03/06/12	140	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	04/03/12	150	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	05/01/12	100	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	06/08/12	88	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	07/03/12	98	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	08/07/12	82	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	09/04/12	140	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	10/02/12	120	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	11/06/12	120	mg/l as HCO3
Warkworth WTW raw	Alkalinity to pH 4.5 (Total)	12/04/12	120	mg/l as HCO3
Warkworth WTW raw	Chloride	01/19/11	12	mg/l
Warkworth WTW raw	Chloride	02/23/11	16	mg/l
Warkworth WTW raw	Chloride	03/23/11	15	mg/l
Warkworth WTW raw	Chloride	04/20/11	16	mg/l
Warkworth WTW raw	Chloride	05/25/11	18	mg/l
Warkworth WTW raw	Chloride	06/22/11	12	mg/l
Warkworth WTW raw	Chloride	07/20/11	10	mg/l
Warkworth WTW raw	Chloride	08/24/11	10	mg/l
Warkworth WTW raw	Chloride	09/21/11	9.4	mg/l
Warkworth WTW raw	Chloride	10/26/11	14	mg/l
Warkworth WTW raw	Chloride	11/23/11	14	mg/l
Warkworth WTW raw	Chloride	12/21/11	14	mg/l
Warkworth WTW raw	Chloride	01/03/12	16	mg/l
Warkworth WTW raw	Chloride	02/07/12	33	mg/l
Warkworth WTW raw	Chloride	03/06/12	23	mg/l
Warkworth WTW raw	Chloride	04/03/12	18	mg/l
Warkworth WTW raw	Chloride	05/01/12	15	mg/l
Warkworth WTW raw	Chloride	06/08/12	11	mg/l
Warkworth WTW raw	Chloride	07/03/12	10	mg/l
Warkworth WTW raw	Chloride	08/07/12	9.5	mg/l
Warkworth WTW raw	Chloride	09/04/12	14	mg/l
Warkworth WTW raw	Chloride	10/02/12	13	mg/l
Warkworth WTW raw	Chloride	11/06/12	13	mg/l
Warkworth WTW raw	Chloride	12/04/12	18	mg/l
Warkworth WTW raw	Sulphate Dissolved	01/19/11	23	mg/l
Warkworth WTW raw	Sulphate Dissolved	02/23/11	24	mg/l

Warkworth WTW raw	Sulphate Dissolved	03/23/11	36	mg/l
Warkworth WTW raw	Sulphate Dissolved	04/20/11	37	mg/l
Warkworth WTW raw	Sulphate Dissolved	05/25/11	41	mg/l
Warkworth WTW raw	Sulphate Dissolved	06/22/11	44	mg/l
Warkworth WTW raw	Sulphate Dissolved	07/20/11	19	mg/l
Warkworth WTW raw	Sulphate Dissolved	08/24/11	28	mg/l
Warkworth WTW raw	Sulphate Dissolved	09/21/11	53	mg/l
Warkworth WTW raw	Sulphate Dissolved	10/26/11	54	mg/l
Warkworth WTW raw	Sulphate Dissolved	11/23/11	28	mg/l
Warkworth WTW raw	Sulphate Dissolved	12/21/11	22	mg/l
Warkworth WTW raw	Sulphate Dissolved	01/03/12	26	mg/l
Warkworth WTW raw	Sulphate Dissolved	02/07/12	36	mg/l
Warkworth WTW raw	Sulphate Dissolved	03/06/12	34	mg/l
Warkworth WTW raw	Sulphate Dissolved	04/03/12	47	mg/l
Warkworth WTW raw	Sulphate Dissolved	05/01/12	29	mg/l
Warkworth WTW raw	Sulphate Dissolved	06/08/12	25	mg/l
Warkworth WTW raw	Sulphate Dissolved	07/03/12	23	mg/l
Warkworth WTW raw	Sulphate Dissolved	08/07/12	14	mg/l
Warkworth WTW raw	Sulphate Dissolved	09/04/12	29	mg/l
Warkworth WTW raw	Sulphate Dissolved	10/02/12	25	mg/l
Warkworth WTW raw	Sulphate Dissolved	11/06/12	31	mg/l
Warkworth WTW raw	Sulphate Dissolved	12/04/12	29	mg/l
Warkworth WTW raw	Sodium Total	01/19/11	10	mg/l
Warkworth WTW raw	Sodium Total	02/23/11	11	mg/l
Warkworth WTW raw	Sodium Total	03/23/11	15	mg/l
Warkworth WTW raw	Sodium Total	04/20/11	17	mg/l
Warkworth WTW raw	Sodium Total	05/25/11	18	mg/l
Warkworth WTW raw	Sodium Total	06/22/11	18	mg/l
Warkworth WTW raw	Sodium Total	07/20/11	10	mg/l
Warkworth WTW raw	Sodium Total	08/24/11	13	mg/l
Warkworth WTW raw	Sodium Total	09/21/11	13	mg/l
Warkworth WTW raw	Sodium Total	10/26/11	18	mg/l
Warkworth WTW raw	Sodium Total	11/23/11	12	mg/l
Warkworth WTW raw	Sodium Total	12/21/11	11	mg/l
Warkworth WTW raw	Sodium Total	01/03/12	12	mg/l
Warkworth WTW raw	Sodium Total	02/07/12	26	mg/l
Warkworth WTW raw	Sodium Total	03/06/12	19	mg/l
Warkworth WTW raw	Sodium Total	04/03/12	18	mg/l
Warkworth WTW raw	Sodium Total	05/01/12	12	mg/l
Warkworth WTW raw	Sodium Total	06/08/12	10	mg/l
Warkworth WTW raw	Sodium Total	07/03/12	10	mg/l
Warkworth WTW raw	Sodium Total	08/07/12	8.3	mg/l
Warkworth WTW raw	Sodium Total	09/04/12	13	mg/l
Warkworth WTW raw	Sodium Total	10/02/12	11	mg/l
Warkworth WTW raw	Sodium Total	11/06/12	12	mg/l
Warkworth WTW raw	Sodium Total	12/04/12	14	mg/l
Warkworth WTW raw	Magnesium Total	01/19/11	5.8	mg/l
Warkworth WTW raw	Magnesium Total	02/23/11	8.3	mg/l
Warkworth WTW raw	Magnesium Total	03/23/11	11	mg/l
Warkworth WTW raw	Magnesium Total	04/20/11	13	mg/l
Warkworth WTW raw	Magnesium Total	05/25/11	13	mg/l
Warkworth WTW raw	Magnesium Total	06/22/11	10	mg/l
Warkworth WTW raw	Magnesium Total	07/20/11	6.8	mg/l
Warkworth WTW raw	Magnesium Total	08/24/11	9	mg/l
Warkworth WTW raw	Magnesium Total	09/21/11	8	mg/l
Warkworth WTW raw	Magnesium Total	10/26/11	10	mg/l
Warkworth WTW raw	Magnesium Total	11/23/11	11	mg/l

Warkworth WTW raw	Magnesium Total	12/21/11	6.6	mg/l
Warkworth WTW raw	Magnesium Total	01/03/12	7.8	mg/l
Warkworth WTW raw	Magnesium Total	02/07/12	13	mg/l
Warkworth WTW raw	Magnesium Total	03/06/12	12	mg/l
Warkworth WTW raw	Magnesium Total	04/03/12	14	mg/l
Warkworth WTW raw	Magnesium Total	05/01/12	8.9	mg/l
Warkworth WTW raw	Magnesium Total	06/08/12	7.5	mg/l
Warkworth WTW raw	Magnesium Total	07/03/12	7.8	mg/l
Warkworth WTW raw	Magnesium Total	08/07/12	6.6	mg/l
Warkworth WTW raw	Magnesium Total	09/04/12	11	mg/l
Warkworth WTW raw	Magnesium Total	10/02/12	9	mg/l
Warkworth WTW raw	Magnesium Total	11/06/12	10	mg/l
Warkworth WTW raw	Magnesium Total	12/04/12	9.9	mg/l
Warkworth WTW raw	Calcium Total	01/19/11	20	mg/l
Warkworth WTW raw	Calcium Total	02/23/11	33	mg/l
Warkworth WTW raw	Calcium Total	03/23/11	39	mg/l
Warkworth WTW raw	Calcium Total	04/20/11	41	mg/l
Warkworth WTW raw	Calcium Total	05/25/11	42	mg/l
Warkworth WTW raw	Calcium Total	06/22/11	31	mg/l as Ca
Warkworth WTW raw	Calcium Total	07/20/11	23	mg/l as Ca
Warkworth WTW raw	Calcium Total	08/24/11	30	mg/l as Ca
Warkworth WTW raw	Calcium Total	09/21/11	25	mg/l as Ca
Warkworth WTW raw	Calcium Total	10/26/11	33	mg/l as Ca
Warkworth WTW raw	Calcium Total	11/23/11	35	mg/l as Ca
Warkworth WTW raw	Calcium Total	12/21/11	24	mg/l as Ca
Warkworth WTW raw	Calcium Total	01/03/12	29	mg/l as Ca
Warkworth WTW raw	Calcium Total	02/07/12	43	mg/l as Ca
Warkworth WTW raw	Calcium Total	03/06/12	41	mg/l as Ca
Warkworth WTW raw	Calcium Total	04/03/12	43	mg/l as Ca
Warkworth WTW raw	Calcium Total	05/01/12	35	mg/l as Ca
Warkworth WTW raw	Calcium Total	06/08/12	25	mg/l as Ca
Warkworth WTW raw	Calcium Total	07/03/12	29	mg/l as Ca
Warkworth WTW raw	Calcium Total	08/07/12	23	mg/l as Ca
Warkworth WTW raw	Calcium Total	09/04/12	38	mg/l as Ca
Warkworth WTW raw	Calcium Total	10/02/12	34	mg/l as Ca
Warkworth WTW raw	Calcium Total	11/06/12	37	mg/l as Ca
Warkworth WTW raw	Calcium Total	12/04/12	39	mg/l as Ca
Warkworth WTW raw	Cadmium Total	01/19/11	0.01	ug/l
Warkworth WTW raw	Cadmium Total	02/23/11	0.017	ug/l
Warkworth WTW raw	Cadmium Total	03/23/11	0.0081	ug/l
Warkworth WTW raw	Cadmium Total	04/20/11	0.0081	ug/l
Warkworth WTW raw	Cadmium Total	05/25/11	0.0081	ug/l
Warkworth WTW raw	Cadmium Total	06/22/11	0.0081	ug/l
Warkworth WTW raw	Cadmium Total	07/20/11	0.032	ug/l
Warkworth WTW raw	Cadmium Total	08/24/11	0.009	ug/l
Warkworth WTW raw	Cadmium Total	09/21/11	0.0081	ug/l
Warkworth WTW raw	Cadmium Total	10/26/11	0.014	ug/l
Warkworth WTW raw	Cadmium Total	11/23/11	0.0081	ug/l
Warkworth WTW raw	Cadmium Total	12/21/11	0.0081	ug/l
Warkworth WTW raw	Cadmium Total	01/03/12	0.0081	ug/l
Warkworth WTW raw	Cadmium Total	02/07/12	0.0081	ug/l
Warkworth WTW raw	Cadmium Total	03/06/12	0.0081	ug/l
Warkworth WTW raw	Cadmium Total	04/03/12	0.0081	ug/l
Warkworth WTW raw	Cadmium Total	05/01/12	0.015	ug/l
Warkworth WTW raw	Cadmium Total	06/08/12	0.053	ug/l
Warkworth WTW raw	Cadmium Total	07/03/12	0.01	ug/l
Warkworth WTW raw	Cadmium Total	08/07/12	0.0081	ug/l

Warkworth WTW raw	Cadmium Total	09/04/12	0.0081	ug/l
Warkworth WTW raw	Cadmium Total	10/02/12	0.043	ug/l
Warkworth WTW raw	Cadmium Total	11/06/12	0.0081	ug/l
Warkworth WTW raw	Cadmium Total	12/04/12	0.0024	ug/l
Warkworth WTW raw	Aluminium Total	01/05/11	560	ug/l
Warkworth WTW raw	Aluminium Total	01/12/11	1000	ug/l
Warkworth WTW raw	Aluminium Total	01/19/11	730	ug/l
Warkworth WTW raw	Aluminium Total	01/26/11	390	ug/l
Warkworth WTW raw	Aluminium Total	02/02/11	230	ug/l
Warkworth WTW raw	Aluminium Total	02/09/11	620	ug/l
Warkworth WTW raw	Aluminium Total	02/16/11	790	ug/l
Warkworth WTW raw	Aluminium Total	02/23/11	1500	ug/l
Warkworth WTW raw	Aluminium Total	03/02/11	290	ug/l
Warkworth WTW raw	Aluminium Total	03/09/11	180	ug/l
Warkworth WTW raw	Aluminium Total	03/16/11	320	ug/l
Warkworth WTW raw	Aluminium Total	03/23/11	270	ug/l
Warkworth WTW raw	Aluminium Total	03/30/11	510	ug/l
Warkworth WTW raw	Aluminium Total	04/06/11	5300	ug/l
Warkworth WTW raw	Aluminium Total	04/13/11	100	ug/l
Warkworth WTW raw	Aluminium Total	04/20/11	90	ug/l
Warkworth WTW raw	Aluminium Total	04/27/11	460	ug/l
Warkworth WTW raw	Aluminium Total	05/04/11	360	ug/l
Warkworth WTW raw	Aluminium Total	05/11/11	100	ug/l
Warkworth WTW raw	Aluminium Total	05/18/11	450	ug/l
Warkworth WTW raw	Aluminium Total	05/25/11	72	ug/l
Warkworth WTW raw	Aluminium Total	06/01/11	260	ug/l
Warkworth WTW raw	Aluminium Total	06/08/11	1700	ug/l
Warkworth WTW raw	Aluminium Total	06/15/11	91	ug/l
Warkworth WTW raw	Aluminium Total	06/22/11	420	ug/l
Warkworth WTW raw	Aluminium Total	06/29/11	900	ug/l
Warkworth WTW raw	Aluminium Total	07/06/11	130	ug/l
Warkworth WTW raw	Aluminium Total	07/13/11	110	ug/l
Warkworth WTW raw	Aluminium Total	07/20/11	860	ug/l
Warkworth WTW raw	Aluminium Total	07/27/11	260	ug/l
Warkworth WTW raw	Aluminium Total	08/03/11	130	ug/l
Warkworth WTW raw	Aluminium Total	08/10/11	1200	ug/l
Warkworth WTW raw	Aluminium Total	08/17/11	210	ug/l
Warkworth WTW raw	Aluminium Total	08/24/11	160	ug/l
Warkworth WTW raw	Aluminium Total	08/31/11	130	ug/l
Warkworth WTW raw	Aluminium Total	09/07/11	330	ug/l
Warkworth WTW raw	Aluminium Total	09/14/11	4700	ug/l
Warkworth WTW raw	Aluminium Total	09/21/11	190	ug/l
Warkworth WTW raw	Aluminium Total	09/28/11	290	ug/l
Warkworth WTW raw	Aluminium Total	10/05/11	250	ug/l
Warkworth WTW raw	Aluminium Total	10/12/11	260	ug/l
Warkworth WTW raw	Aluminium Total	10/19/11	230	ug/l
Warkworth WTW raw	Aluminium Total	10/26/11	260	ug/l
Warkworth WTW raw	Aluminium Total	11/02/11	68	ug/l
Warkworth WTW raw	Aluminium Total	11/09/11	190	ug/l
Warkworth WTW raw	Aluminium Total	11/16/11	310	ug/l
Warkworth WTW raw	Aluminium Total	11/23/11	160	ug/l
Warkworth WTW raw	Aluminium Total	11/30/11	240	ug/l
Warkworth WTW raw	Aluminium Total	12/07/11	560	ug/l
Warkworth WTW raw	Aluminium Total	12/14/11	740	ug/l
Warkworth WTW raw	Aluminium Total	12/21/11	470	ug/l
Warkworth WTW raw	Aluminium Total	12/28/11	270	ug/l
Warkworth WTW raw	Aluminium Total	01/03/12	550	ug/l

Warkworth WTW raw	Aluminium Total	01/10/12	240	ug/l
Warkworth WTW raw	Aluminium Total	01/17/12	380	ug/l
Warkworth WTW raw	Aluminium Total	01/24/12	190	ug/l
Warkworth WTW raw	Aluminium Total	01/31/12	1500	ug/l
Warkworth WTW raw	Aluminium Total	02/07/12	320	ug/l
Warkworth WTW raw	Aluminium Total	02/14/12	390	ug/l
Warkworth WTW raw	Aluminium Total	02/21/12	200	ug/l
Warkworth WTW raw	Aluminium Total	02/28/12	230	ug/l
Warkworth WTW raw	Aluminium Total	03/06/12	140	ug/l
Warkworth WTW raw	Aluminium Total	03/13/12	250	ug/l
Warkworth WTW raw	Aluminium Total	03/20/12	370	ug/l
Warkworth WTW raw	Aluminium Total	03/27/12	210	ug/l
Warkworth WTW raw	Aluminium Total	04/03/12	150	ug/l
Warkworth WTW raw	Aluminium Total	04/10/12	220	ug/l
Warkworth WTW raw	Aluminium Total	04/17/12	1700	ug/l
Warkworth WTW raw	Aluminium Total	04/24/12	810	ug/l
Warkworth WTW raw	Aluminium Total	05/01/12	880	ug/l
Warkworth WTW raw	Aluminium Total	05/08/12	300	ug/l
Warkworth WTW raw	Aluminium Total	05/15/12	310	ug/l
Warkworth WTW raw	Aluminium Total	05/22/12	220	ug/l
Warkworth WTW raw	Aluminium Total	05/29/12	240	ug/l
Warkworth WTW raw	Aluminium Total	06/08/12	4000	ug/l
Warkworth WTW raw	Aluminium Total	06/12/12	420	ug/l
Warkworth WTW raw	Aluminium Total	06/19/12	610	ug/l
Warkworth WTW raw	Aluminium Total	06/26/12	780	ug/l
Warkworth WTW raw	Aluminium Total	07/03/12	520	ug/l
Warkworth WTW raw	Aluminium Total	07/10/12	1300	ug/l
Warkworth WTW raw	Aluminium Total	07/17/12	500	ug/l
Warkworth WTW raw	Aluminium Total	07/24/12	350	ug/l
Warkworth WTW raw	Aluminium Total	07/31/12	250	ug/l
Warkworth WTW raw	Aluminium Total	08/07/12	610	ug/l
Warkworth WTW raw	Aluminium Total	08/14/12	430	ug/l
Warkworth WTW raw	Aluminium Total	08/21/12	580	ug/l
Warkworth WTW raw	Aluminium Total	08/28/12	1400	ug/l
Warkworth WTW raw	Aluminium Total	09/04/12	340	ug/l
Warkworth WTW raw	Aluminium Total	09/11/12	350	ug/l
Warkworth WTW raw	Aluminium Total	09/18/12	96	ug/l
Warkworth WTW raw	Aluminium Total	09/25/12	23000	ug/l
Warkworth WTW raw	Aluminium Total	10/02/12	320	ug/l
Warkworth WTW raw	Aluminium Total	10/09/12	180	ug/l
Warkworth WTW raw	Aluminium Total	10/16/12	4700	ug/l
Warkworth WTW raw	Aluminium Total	10/23/12	300	ug/l
Warkworth WTW raw	Aluminium Total	10/30/12	280	ug/l
Warkworth WTW raw	Aluminium Total	11/06/12	870	ug/l
Warkworth WTW raw	Aluminium Total	11/13/12	130	ug/l
Warkworth WTW raw	Aluminium Total	11/20/12	810	ug/l
Warkworth WTW raw	Aluminium Total	11/27/12	5100	ug/l
Warkworth WTW raw	Aluminium Total	12/04/12	320	ug/l
Warkworth WTW raw	Aluminium Total	12/11/12	1200	ug/l
Warkworth WTW raw	Aluminium Total	12/18/12	1400	ug/l
Warkworth WTW raw	Aluminium Total	12/28/12	3200	ug/l
Warkworth WTW raw	Lead Total	01/19/11	0.42	ug/l
Warkworth WTW raw	Lead Total	02/23/11	1.5	ug/l
Warkworth WTW raw	Lead Total	03/23/11	0.24	ug/l
Warkworth WTW raw	Lead Total	04/20/11	0.1	ug/l
Warkworth WTW raw	Lead Total	05/25/11	0.11	ug/l
Warkworth WTW raw	Lead Total	06/22/11	0.45	ug/l

Warkworth WTW raw	Lead Total	07/20/11	2.2	ug/l
Warkworth WTW raw	Lead Total	08/24/11	0.42	ug/l
Warkworth WTW raw	Lead Total	09/21/11	0.21	ug/l
Warkworth WTW raw	Lead Total	10/26/11	0.21	ug/l
Warkworth WTW raw	Lead Total	11/23/11	0.11	ug/l
Warkworth WTW raw	Lead Total	12/21/11	0.57	ug/l
Warkworth WTW raw	Lead Total	01/03/12	0.62	ug/l
Warkworth WTW raw	Lead Total	02/07/12	0.094	ug/l
Warkworth WTW raw	Lead Total	03/06/12	0.089	ug/l
Warkworth WTW raw	Lead Total	04/03/12	0.092	ug/l
Warkworth WTW raw	Lead Total	05/01/12	0.72	ug/l
Warkworth WTW raw	Lead Total	06/08/12	3.3	ug/l
Warkworth WTW raw	Lead Total	07/03/12	0.59	ug/l
Warkworth WTW raw	Lead Total	08/07/12	1.3	ug/l
Warkworth WTW raw	Lead Total	09/04/12	0.26	ug/l
Warkworth WTW raw	Lead Total	10/02/12	0.43	ug/l
Warkworth WTW raw	Lead Total	11/06/12	0.69	ug/l
Warkworth WTW raw	Lead Total	12/04/12	0.33	ug/l
Warkworth WTW raw	Phosphorus Total (As P)	01/19/11	100	ug/l as P
Warkworth WTW raw	Phosphorus Total (As P)	04/20/11	24	ug/l as P
Warkworth WTW raw	Phosphorus Total (As P)	07/20/11	88	ug/l as P
Warkworth WTW raw	Phosphorus Total (As P)	10/26/11	33	ug/l as P
Warkworth WTW raw	Phosphorus Total (As P)	01/03/12	43	ug/l as P
Warkworth WTW raw	Phosphorus Total (As P)	04/03/12	40	ug/l as P
Warkworth WTW raw	Phosphorus Total (As P)	07/03/12	43	ug/l as P
Warkworth WTW raw	Phosphorus Total (As P)	10/02/12	35	ug/l as P
Warkworth WTW raw	Manganese Total	01/05/11	44	ug/l
Warkworth WTW raw	Manganese Total	01/12/11	56	ug/l
Warkworth WTW raw	Manganese Total	01/19/11	51	ug/l
Warkworth WTW raw	Manganese Total	01/26/11	58	ug/l
Warkworth WTW raw	Manganese Total	02/02/11	40	ug/l
Warkworth WTW raw	Manganese Total	02/09/11	44	ug/l
Warkworth WTW raw	Manganese Total	02/16/11	41	ug/l
Warkworth WTW raw	Manganese Total	02/23/11	77	ug/l
Warkworth WTW raw	Manganese Total	03/02/11	42	ug/l
Warkworth WTW raw	Manganese Total	03/09/11	44	ug/l
Warkworth WTW raw	Manganese Total	03/16/11	32	ug/l
Warkworth WTW raw	Manganese Total	03/23/11	45	ug/l
Warkworth WTW raw	Manganese Total	03/30/11	49	ug/l
Warkworth WTW raw	Manganese Total	04/06/11	45	ug/l
Warkworth WTW raw	Manganese Total	04/13/11	31	ug/l
Warkworth WTW raw	Manganese Total	04/20/11	28	ug/l
Warkworth WTW raw	Manganese Total	04/27/11	43	ug/l
Warkworth WTW raw	Manganese Total	05/04/11	54	ug/l
Warkworth WTW raw	Manganese Total	05/11/11	11	ug/l
Warkworth WTW raw	Manganese Total	05/18/11	61	ug/l
Warkworth WTW raw	Manganese Total	05/25/11	38	ug/l
Warkworth WTW raw	Manganese Total	06/01/11	61	ug/l
Warkworth WTW raw	Manganese Total	06/08/11	170	ug/l
Warkworth WTW raw	Manganese Total	06/15/11	35	ug/l
Warkworth WTW raw	Manganese Total	06/22/11	64	ug/l
Warkworth WTW raw	Manganese Total	06/29/11	120	ug/l
Warkworth WTW raw	Manganese Total	07/06/11	77	ug/l
Warkworth WTW raw	Manganese Total	07/13/11	58	ug/l
Warkworth WTW raw	Manganese Total	07/20/11	110	ug/l
Warkworth WTW raw	Manganese Total	07/27/11	180	ug/l
Warkworth WTW raw	Manganese Total	08/03/11	56	ug/l

Warkworth WTW raw	Manganese Total	08/10/11	630	ug/l
Warkworth WTW raw	Manganese Total	08/17/11	46	ug/l
Warkworth WTW raw	Manganese Total	08/24/11	37	ug/l
Warkworth WTW raw	Manganese Total	08/31/11	38	ug/l
Warkworth WTW raw	Manganese Total	09/07/11	360	ug/l
Warkworth WTW raw	Manganese Total	09/14/11	3500	ug/l
Warkworth WTW raw	Manganese Total	09/21/11	33	ug/l
Warkworth WTW raw	Manganese Total	09/28/11	98	ug/l
Warkworth WTW raw	Manganese Total	10/05/11	450	ug/l
Warkworth WTW raw	Manganese Total	10/12/11	56	ug/l
Warkworth WTW raw	Manganese Total	10/19/11	57	ug/l
Warkworth WTW raw	Manganese Total	10/26/11	120	ug/l
Warkworth WTW raw	Manganese Total	11/02/11	19	ug/l
Warkworth WTW raw	Manganese Total	11/09/11	28	ug/l
Warkworth WTW raw	Manganese Total	11/16/11	47	ug/l
Warkworth WTW raw	Manganese Total	11/23/11	27	ug/l
Warkworth WTW raw	Manganese Total	11/30/11	54	ug/l
Warkworth WTW raw	Manganese Total	12/07/11	41	ug/l
Warkworth WTW raw	Manganese Total	12/14/11	110	ug/l
Warkworth WTW raw	Manganese Total	12/21/11	44	ug/l
Warkworth WTW raw	Manganese Total	12/28/11	38	ug/l
Warkworth WTW raw	Manganese Total	01/03/12	59	ug/l
Warkworth WTW raw	Manganese Total	01/10/12	28	ug/l
Warkworth WTW raw	Manganese Total	01/17/12	44	ug/l
Warkworth WTW raw	Manganese Total	01/24/12	22	ug/l
Warkworth WTW raw	Manganese Total	01/31/12	59	ug/l
Warkworth WTW raw	Manganese Total	02/07/12	29	ug/l
Warkworth WTW raw	Manganese Total	02/14/12	30	ug/l
Warkworth WTW raw	Manganese Total	02/21/12	20	ug/l
Warkworth WTW raw	Manganese Total	02/28/12	29	ug/l
Warkworth WTW raw	Manganese Total	03/06/12	16	ug/l
Warkworth WTW raw	Manganese Total	03/13/12	26	ug/l
Warkworth WTW raw	Manganese Total	03/20/12	27	ug/l
Warkworth WTW raw	Manganese Total	03/27/12	32	ug/l
Warkworth WTW raw	Manganese Total	04/03/12	30	ug/l
Warkworth WTW raw	Manganese Total	04/10/12	33	ug/l
Warkworth WTW raw	Manganese Total	04/17/12	460	ug/l
Warkworth WTW raw	Manganese Total	04/24/12	55	ug/l
Warkworth WTW raw	Manganese Total	05/01/12	36	ug/l
Warkworth WTW raw	Manganese Total	05/08/12	28	ug/l
Warkworth WTW raw	Manganese Total	05/15/12	27	ug/l
Warkworth WTW raw	Manganese Total	05/22/12	27	ug/l
Warkworth WTW raw	Manganese Total	05/29/12	32	ug/l
Warkworth WTW raw	Manganese Total	06/08/12	140	ug/l
Warkworth WTW raw	Manganese Total	06/12/12	35	ug/l
Warkworth WTW raw	Manganese Total	06/19/12	37	ug/l
Warkworth WTW raw	Manganese Total	06/26/12	36	ug/l
Warkworth WTW raw	Manganese Total	07/03/12	36	ug/l
Warkworth WTW raw	Manganese Total	07/10/12	68	ug/l
Warkworth WTW raw	Manganese Total	07/17/12	42	ug/l
Warkworth WTW raw	Manganese Total	07/24/12	31	ug/l
Warkworth WTW raw	Manganese Total	07/31/12	25	ug/l
Warkworth WTW raw	Manganese Total	08/07/12	46	ug/l
Warkworth WTW raw	Manganese Total	08/14/12	55	ug/l
Warkworth WTW raw	Manganese Total	08/21/12	47	ug/l
Warkworth WTW raw	Manganese Total	08/28/12	68	ug/l
Warkworth WTW raw	Manganese Total	09/04/12	39	ug/l

Warkworth WTW raw	Manganese Total	09/11/12	40	ug/l
Warkworth WTW raw	Manganese Total	09/18/12	16	ug/l
Warkworth WTW raw	Manganese Total	09/25/12	480	ug/l
Warkworth WTW raw	Manganese Total	10/02/12	39	ug/l
Warkworth WTW raw	Manganese Total	10/09/12	19	ug/l
Warkworth WTW raw	Manganese Total	10/16/12	190	ug/l
Warkworth WTW raw	Manganese Total	10/23/12	33	ug/l
Warkworth WTW raw	Manganese Total	10/30/12	34	ug/l
Warkworth WTW raw	Manganese Total	11/06/12	100	ug/l
Warkworth WTW raw	Manganese Total	11/13/12	26	ug/l
Warkworth WTW raw	Manganese Total	11/20/12	33	ug/l
Warkworth WTW raw	Manganese Total	11/27/12	300	ug/l
Warkworth WTW raw	Manganese Total	12/04/12	41	ug/l
Warkworth WTW raw	Manganese Total	12/11/12	43	ug/l
Warkworth WTW raw	Manganese Total	12/18/12	43	ug/l
Warkworth WTW raw	Manganese Total	12/28/12	150	ug/l
Warkworth WTW raw	Iron Total	01/05/11	800	ug/l
Warkworth WTW raw	Iron Total	01/12/11	1200	ug/l
Warkworth WTW raw	Iron Total	01/19/11	410	ug/l
Warkworth WTW raw	Iron Total	01/26/11	260	ug/l
Warkworth WTW raw	Iron Total	02/02/11	320	ug/l
Warkworth WTW raw	Iron Total	02/09/11	520	ug/l
Warkworth WTW raw	Iron Total	02/16/11	690	ug/l
Warkworth WTW raw	Iron Total	02/23/11	1300	ug/l
Warkworth WTW raw	Iron Total	03/02/11	390	ug/l
Warkworth WTW raw	Iron Total	03/09/11	270	ug/l
Warkworth WTW raw	Iron Total	03/16/11	440	ug/l
Warkworth WTW raw	Iron Total	03/23/11	210	ug/l
Warkworth WTW raw	Iron Total	03/30/11	170	ug/l
Warkworth WTW raw	Iron Total	04/06/11	520	ug/l
Warkworth WTW raw	Iron Total	04/13/11	200	ug/l
Warkworth WTW raw	Iron Total	04/20/11	160	ug/l
Warkworth WTW raw	Iron Total	04/27/11	120	ug/l
Warkworth WTW raw	Iron Total	05/04/11	110	ug/l
Warkworth WTW raw	Iron Total	05/11/11	51	ug/l
Warkworth WTW raw	Iron Total	05/18/11	140	ug/l
Warkworth WTW raw	Iron Total	05/25/11	140	ug/l
Warkworth WTW raw	Iron Total	06/01/11	140	ug/l
Warkworth WTW raw	Iron Total	06/08/11	210	ug/l
Warkworth WTW raw	Iron Total	06/15/11	130	ug/l
Warkworth WTW raw	Iron Total	06/22/11	350	ug/l
Warkworth WTW raw	Iron Total	06/29/11	300	ug/l
Warkworth WTW raw	Iron Total	07/06/11	200	ug/l
Warkworth WTW raw	Iron Total	07/13/11	200	ug/l
Warkworth WTW raw	Iron Total	07/20/11	1400	ug/l
Warkworth WTW raw	Iron Total	07/27/11	360	ug/l
Warkworth WTW raw	Iron Total	08/03/11	260	ug/l
Warkworth WTW raw	Iron Total	08/10/11	810	ug/l
Warkworth WTW raw	Iron Total	08/17/11	590	ug/l
Warkworth WTW raw	Iron Total	08/24/11	460	ug/l
Warkworth WTW raw	Iron Total	08/31/11	470	ug/l
Warkworth WTW raw	Iron Total	09/07/11	280	ug/l
Warkworth WTW raw	Iron Total	09/14/11	4400	ug/l
Warkworth WTW raw	Iron Total	09/21/11	260	ug/l
Warkworth WTW raw	Iron Total	09/28/11	240	ug/l
Warkworth WTW raw	Iron Total	10/05/11	140	ug/l
Warkworth WTW raw	Iron Total	10/12/11	230	ug/l

Warkworth WTW raw	Iron Total	10/19/11	250	ug/l
Warkworth WTW raw	Iron Total	10/26/11	210	ug/l
Warkworth WTW raw	Iron Total	11/02/11	260	ug/l
Warkworth WTW raw	Iron Total	11/09/11	300	ug/l
Warkworth WTW raw	Iron Total	11/16/11	390	ug/l
Warkworth WTW raw	Iron Total	11/23/11	190	ug/l
Warkworth WTW raw	Iron Total	11/30/11	480	ug/l
Warkworth WTW raw	Iron Total	12/07/11	320	ug/l
Warkworth WTW raw	Iron Total	12/14/11	810	ug/l
Warkworth WTW raw	Iron Total	12/21/11	530	ug/l
Warkworth WTW raw	Iron Total	12/28/11	540	ug/l
Warkworth WTW raw	Iron Total	01/03/12	560	ug/l
Warkworth WTW raw	Iron Total	01/10/12	250	ug/l
Warkworth WTW raw	Iron Total	01/17/12	210	ug/l
Warkworth WTW raw	Iron Total	01/24/12	310	ug/l
Warkworth WTW raw	Iron Total	01/31/12	1300	ug/l
Warkworth WTW raw	Iron Total	02/07/12	200	ug/l
Warkworth WTW raw	Iron Total	02/14/12	410	ug/l
Warkworth WTW raw	Iron Total	02/21/12	200	ug/l
Warkworth WTW raw	Iron Total	02/28/12	250	ug/l
Warkworth WTW raw	Iron Total	03/06/12	110	ug/l
Warkworth WTW raw	Iron Total	03/13/12	220	ug/l
Warkworth WTW raw	Iron Total	03/20/12	170	ug/l
Warkworth WTW raw	Iron Total	03/27/12	160	ug/l
Warkworth WTW raw	Iron Total	04/03/12	130	ug/l
Warkworth WTW raw	Iron Total	04/10/12	270	ug/l
Warkworth WTW raw	Iron Total	04/17/12	2300	ug/l
Warkworth WTW raw	Iron Total	04/24/12	820	ug/l
Warkworth WTW raw	Iron Total	05/01/12	700	ug/l
Warkworth WTW raw	Iron Total	05/08/12	230	ug/l
Warkworth WTW raw	Iron Total	05/15/12	320	ug/l
Warkworth WTW raw	Iron Total	05/22/12	320	ug/l
Warkworth WTW raw	Iron Total	05/29/12	140	ug/l
Warkworth WTW raw	Iron Total	06/08/12	3400	ug/l
Warkworth WTW raw	Iron Total	06/12/12	540	ug/l
Warkworth WTW raw	Iron Total	06/19/12	560	ug/l
Warkworth WTW raw	Iron Total	06/26/12	730	ug/l
Warkworth WTW raw	Iron Total	07/03/12	480	ug/l
Warkworth WTW raw	Iron Total	07/10/12	1400	ug/l
Warkworth WTW raw	Iron Total	07/17/12	450	ug/l
Warkworth WTW raw	Iron Total	07/24/12	330	ug/l
Warkworth WTW raw	Iron Total	07/31/12	160	ug/l
Warkworth WTW raw	Iron Total	08/07/12	940	ug/l
Warkworth WTW raw	Iron Total	08/14/12	230	ug/l
Warkworth WTW raw	Iron Total	08/21/12	920	ug/l
Warkworth WTW raw	Iron Total	08/28/12	1400	ug/l
Warkworth WTW raw	Iron Total	09/04/12	490	ug/l
Warkworth WTW raw	Iron Total	09/11/12	290	ug/l
Warkworth WTW raw	Iron Total	09/18/12	220	ug/l
Warkworth WTW raw	Iron Total	09/25/12	16000	ug/l
Warkworth WTW raw	Iron Total	10/02/12	380	ug/l
Warkworth WTW raw	Iron Total	10/09/12	300	ug/l
Warkworth WTW raw	Iron Total	10/16/12	5100	ug/l
Warkworth WTW raw	Iron Total	10/23/12	380	ug/l
Warkworth WTW raw	Iron Total	10/30/12	410	ug/l
Warkworth WTW raw	Iron Total	11/06/12	670	ug/l
Warkworth WTW raw	Iron Total	11/13/12	300	ug/l

Warkworth WTW raw	Iron Total	11/20/12	830	ug/l
Warkworth WTW raw	Iron Total	11/27/12	8700	ug/l
Warkworth WTW raw	Iron Total	12/04/12	360	ug/l
Warkworth WTW raw	Iron Total	12/11/12	1200	ug/l
Warkworth WTW raw	Iron Total	12/18/12	1100	ug/l
Warkworth WTW raw	Iron Total	12/28/12	3200	ug/l
Warkworth WTW raw	Nickel Total	01/19/11	1.8	ug/l
Warkworth WTW raw	Nickel Total	02/23/11	3.1	ug/l
Warkworth WTW raw	Nickel Total	03/23/11	1.6	ug/l
Warkworth WTW raw	Nickel Total	04/20/11	0.85	ug/l
Warkworth WTW raw	Nickel Total	05/25/11	1	ug/l
Warkworth WTW raw	Nickel Total	06/22/11	1.1	ug/l
Warkworth WTW raw	Nickel Total	07/20/11	2.6	ug/l
Warkworth WTW raw	Nickel Total	08/24/11	1.3	ug/l
Warkworth WTW raw	Nickel Total	09/21/11	0.93	ug/l
Warkworth WTW raw	Nickel Total	10/26/11	1.2	ug/l
Warkworth WTW raw	Nickel Total	11/23/11	0.63	ug/l
Warkworth WTW raw	Nickel Total	12/21/11	1.2	ug/l
Warkworth WTW raw	Nickel Total	01/03/12	1.3	ug/l
Warkworth WTW raw	Nickel Total	02/07/12	0.54	ug/l
Warkworth WTW raw	Nickel Total	03/06/12	0.6	ug/l
Warkworth WTW raw	Nickel Total	04/03/12	0.41	ug/l
Warkworth WTW raw	Nickel Total	05/01/12	1.6	ug/l
Warkworth WTW raw	Nickel Total	06/08/12	4.5	ug/l
Warkworth WTW raw	Nickel Total	07/03/12	1.8	ug/l
Warkworth WTW raw	Nickel Total	08/07/12	2	ug/l
Warkworth WTW raw	Nickel Total	09/04/12	1.1	ug/l
Warkworth WTW raw	Nickel Total	10/02/12	1.2	ug/l
Warkworth WTW raw	Nickel Total	11/06/12	1.9	ug/l
Warkworth WTW raw	Nickel Total	12/04/12	1.5	ug/l

Whittle Dene WTW raw

Spt Desc	Detdesc	Datetaken	Value	Unitused
Whittle Dene raw	Hydrogen ion	01/26/11	7.9	pH Value
Whittle Dene raw	Hydrogen ion	02/23/11	7.9	pH Value
Whittle Dene raw	Hydrogen ion	03/30/11	8.1	pH Value
Whittle Dene raw	Hydrogen ion	04/27/11	7.7	pH Value
Whittle Dene raw	Hydrogen ion	05/25/11	7.7	pH Value
Whittle Dene raw	Hydrogen ion	06/29/11	7.7	pH Value
Whittle Dene raw	Hydrogen ion	07/27/11	7.8	pH Value
Whittle Dene raw	Hydrogen ion	08/31/11	7.8	pH Value
Whittle Dene raw	Hydrogen ion	09/28/11	7.8	pH Value
Whittle Dene raw	Hydrogen ion	10/26/11	7.9	pH Value
Whittle Dene raw	Hydrogen ion	11/30/11	7.9	pH Value
Whittle Dene raw	Hydrogen ion	12/28/11	8	pH Value
Whittle Dene raw	Hydrogen ion	01/25/12	7.9	pH Value
Whittle Dene raw	Hydrogen ion	02/29/12	7.9	pH Value
Whittle Dene raw	Hydrogen ion	03/28/12	7.9	pH Value
Whittle Dene raw	Hydrogen ion	04/25/12	8	pH Value
Whittle Dene raw	Hydrogen ion	05/30/12	7.9	pH Value
Whittle Dene raw	Hydrogen ion	06/27/12	8	pH Value
Whittle Dene raw	Hydrogen ion	07/25/12	8.3	pH Value
Whittle Dene raw	Hydrogen ion	08/29/12	7.9	pH Value
Whittle Dene raw	Hydrogen ion	09/26/12	8	pH Value
Whittle Dene raw	Hydrogen ion	11/02/12	8.2	pH Value
Whittle Dene raw	Hydrogen ion	11/28/12	7.8	pH Value
Whittle Dene raw	Hydrogen ion	12/28/12	7.8	pH Value
Whittle Dene raw	Conductivity 20 Deg. C	01/26/11	280	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	02/23/11	340	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	03/30/11	260	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	04/27/11	210	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	05/25/11	170	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	06/29/11	170	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	07/27/11	220	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	08/31/11	220	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	09/28/11	180	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	10/26/11	190	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	11/30/11	240	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	12/28/11	300	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	01/25/12	250	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	02/29/12	250	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	03/28/12	220	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	04/25/12	310	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	05/30/12	270	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	06/27/12	370	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	07/25/12	320	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	08/29/12	260	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	09/26/12	260	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	11/02/12	290	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	11/28/12	340	uS/cm
Whittle Dene raw	Conductivity 20 Deg. C	12/28/12	350	uS/cm
Whittle Dene raw	Turbidity	01/26/11	1.9	NTU
Whittle Dene raw	Turbidity	02/23/11	2.2	NTU
Whittle Dene raw	Turbidity	03/30/11	1.6	NTU
Whittle Dene raw	Turbidity	04/27/11	2.4	NTU
Whittle Dene raw	Turbidity	05/25/11	4	NTU
Whittle Dene raw	Turbidity	06/29/11	3.7	NTU

Whittle Dene raw	Turbidity	07/27/11	1.8	NTU
Whittle Dene raw	Turbidity	08/31/11	2.3	NTU
Whittle Dene raw	Turbidity	09/28/11	1.7	NTU
Whittle Dene raw	Turbidity	10/26/11	1.5	NTU
Whittle Dene raw	Turbidity	11/30/11	3.1	NTU
Whittle Dene raw	Turbidity	12/28/11	3.3	NTU
Whittle Dene raw	Turbidity	01/25/12	1.9	NTU
Whittle Dene raw	Turbidity	02/29/12	2	NTU
Whittle Dene raw	Turbidity	03/28/12	1.3	NTU
Whittle Dene raw	Turbidity	04/25/12	2.9	NTU
Whittle Dene raw	Turbidity	05/30/12	2.1	NTU
Whittle Dene raw	Turbidity	06/27/12	2.6	NTU
Whittle Dene raw	Turbidity	07/25/12	2.9	NTU
Whittle Dene raw	Turbidity	08/29/12	2.3	NTU
Whittle Dene raw	Turbidity	09/26/12	13	NTU
Whittle Dene raw	Turbidity	11/02/12	3.5	NTU
Whittle Dene raw	Turbidity	11/28/12	21	NTU
Whittle Dene raw	Turbidity	12/28/12	13	NTU
Whittle Dene raw	Colour Filtered	01/26/11	47	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	02/23/11	34	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	03/30/11	41	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	04/27/11	40	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	05/25/11	48	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	06/29/11	54	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	07/27/11	55	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	08/31/11	55	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	09/28/11	63	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	10/26/11	76	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	11/30/11	76	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	12/28/11	56	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	01/25/12	57	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	02/29/12	54	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	03/28/12	49	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	04/25/12	39	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	05/30/12	36	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	06/27/12	35	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	07/25/12	41	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	08/29/12	47	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	09/26/12	61	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	11/02/12	50	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	11/28/12	41	mg/l Pt/Co scal
Whittle Dene raw	Colour Filtered	12/28/12	35	mg/l Pt/Co scal
Whittle Dene raw	Temperature Deg. C	01/26/11	6.5	Deg. C
Whittle Dene raw	Temperature Deg. C	02/23/11	6.4	Deg. C
Whittle Dene raw	Temperature Deg. C	03/30/11	9.8	Deg. C
Whittle Dene raw	Temperature Deg. C	04/27/11	14.3	Deg. C
Whittle Dene raw	Temperature Deg. C	05/25/11	13.6	Deg. C
Whittle Dene raw	Temperature Deg. C	06/29/11	13.2	Deg. C
Whittle Dene raw	Temperature Deg. C	07/27/11	17.2	Deg. C
Whittle Dene raw	Temperature Deg. C	08/31/11	14.9	Deg. C
Whittle Dene raw	Temperature Deg. C	09/28/11	12.7	Deg. C
Whittle Dene raw	Temperature Deg. C	10/26/11	12.7	Deg. C
Whittle Dene raw	Temperature Deg. C	11/30/11	10.5	Deg. C
Whittle Dene raw	Temperature Deg. C	12/28/11	9.9	Deg. C
Whittle Dene raw	Temperature Deg. C	01/25/12	8.3	Deg. C
Whittle Dene raw	Temperature Deg. C	02/29/12	11.7	Deg. C
Whittle Dene raw	Temperature Deg. C	03/28/12	13.3	Deg. C

Whittle Dene raw	Temperature Deg. C	04/25/12	12.1	Deg. C
Whittle Dene raw	Temperature Deg. C	05/30/12	15.2	Deg. C
Whittle Dene raw	Temperature Deg. C	06/27/12	12.2	Deg. C
Whittle Dene raw	Temperature Deg. C	07/25/12	18.1	Deg. C
Whittle Dene raw	Temperature Deg. C	08/29/12	16.5	Deg. C
Whittle Dene raw	Temperature Deg. C	09/26/12	14	Deg. C
Whittle Dene raw	Temperature Deg. C	11/02/12	13.8	Deg. C
Whittle Dene raw	Temperature Deg. C	11/28/12	11.7	Deg. C
Whittle Dene raw	Temperature Deg. C	12/28/12	7.8	Deg. C
Whittle Dene raw	Total Organic Carbon	01/05/11	7.9	mg/l
Whittle Dene raw	Total Organic Carbon	01/12/11	7.3	mg/l
Whittle Dene raw	Total Organic Carbon	01/19/11	7.5	mg/l
Whittle Dene raw	Total Organic Carbon	01/26/11	7.8	mg/l
Whittle Dene raw	Total Organic Carbon	02/02/11	7.8	mg/l
Whittle Dene raw	Total Organic Carbon	02/09/11	7.2	mg/l
Whittle Dene raw	Total Organic Carbon	02/16/11	7	mg/l
Whittle Dene raw	Total Organic Carbon	02/23/11	7	mg/l
Whittle Dene raw	Total Organic Carbon	03/02/11	6.8	mg/l
Whittle Dene raw	Total Organic Carbon	03/09/11	6.9	mg/l
Whittle Dene raw	Total Organic Carbon	03/16/11	7.4	mg/l
Whittle Dene raw	Total Organic Carbon	03/23/11	7	mg/l
Whittle Dene raw	Total Organic Carbon	03/30/11	6.8	mg/l
Whittle Dene raw	Total Organic Carbon	04/06/11	7.3	mg/l
Whittle Dene raw	Total Organic Carbon	04/13/11	6.9	mg/l
Whittle Dene raw	Total Organic Carbon	04/20/11	6.4	mg/l
Whittle Dene raw	Total Organic Carbon	04/27/11	7.1	mg/l
Whittle Dene raw	Total Organic Carbon	05/04/11	7.4	mg/l
Whittle Dene raw	Total Organic Carbon	05/11/11	7.4	mg/l
Whittle Dene raw	Total Organic Carbon	05/18/11	7.7	mg/l
Whittle Dene raw	Total Organic Carbon	05/25/11	7.9	mg/l
Whittle Dene raw	Total Organic Carbon	06/01/11	8	mg/l
Whittle Dene raw	Total Organic Carbon	06/08/11	8.3	mg/l
Whittle Dene raw	Total Organic Carbon	06/15/11	8.1	mg/l
Whittle Dene raw	Total Organic Carbon	06/22/11	8.2	mg/l
Whittle Dene raw	Total Organic Carbon	06/29/11	8.3	mg/l
Whittle Dene raw	Total Organic Carbon	07/06/11	8.7	mg/l
Whittle Dene raw	Total Organic Carbon	07/13/11	8.9	mg/l
Whittle Dene raw	Total Organic Carbon	07/20/11	9.3	mg/l
Whittle Dene raw	Total Organic Carbon	07/27/11	8.8	mg/l
Whittle Dene raw	Total Organic Carbon	08/03/11	9	mg/l
Whittle Dene raw	Total Organic Carbon	08/10/11	8.7	mg/l
Whittle Dene raw	Total Organic Carbon	08/17/11	9.1	mg/l
Whittle Dene raw	Total Organic Carbon	08/24/11	9	mg/l
Whittle Dene raw	Total Organic Carbon	08/31/11	9.5	mg/l
Whittle Dene raw	Total Organic Carbon	09/07/11	9.7	mg/l
Whittle Dene raw	Total Organic Carbon	09/14/11	9.4	mg/l
Whittle Dene raw	Total Organic Carbon	09/21/11	9.5	mg/l
Whittle Dene raw	Total Organic Carbon	09/28/11	9.7	mg/l
Whittle Dene raw	Total Organic Carbon	10/05/11	9.7	mg/l
Whittle Dene raw	Total Organic Carbon	10/12/11	9.9	mg/l
Whittle Dene raw	Total Organic Carbon	10/19/11	10	mg/l
Whittle Dene raw	Total Organic Carbon	10/26/11	11	mg/l
Whittle Dene raw	Total Organic Carbon	11/02/11	11	mg/l
Whittle Dene raw	Total Organic Carbon	11/09/11	10	mg/l
Whittle Dene raw	Total Organic Carbon	11/16/11	11	mg/l
Whittle Dene raw	Total Organic Carbon	11/23/11	12	mg/l
Whittle Dene raw	Total Organic Carbon	11/30/11	11	mg/l

Whittle Dene raw	Total Organic Carbon	12/07/11	11	mg/l
Whittle Dene raw	Total Organic Carbon	12/14/11	11	mg/l
Whittle Dene raw	Total Organic Carbon	12/21/11	9	mg/l
Whittle Dene raw	Total Organic Carbon	12/28/11	8.5	mg/l
Whittle Dene raw	Total Organic Carbon	01/04/12	8.3	mg/l
Whittle Dene raw	Total Organic Carbon	01/11/12	7.7	mg/l
Whittle Dene raw	Total Organic Carbon	01/18/12	7.8	mg/l
Whittle Dene raw	Total Organic Carbon	01/25/12	8.7	mg/l
Whittle Dene raw	Total Organic Carbon	02/01/12	8.5	mg/l
Whittle Dene raw	Total Organic Carbon	02/08/12	8.2	mg/l
Whittle Dene raw	Total Organic Carbon	02/15/12	7.6	mg/l
Whittle Dene raw	Total Organic Carbon	02/22/12	8.2	mg/l
Whittle Dene raw	Total Organic Carbon	02/29/12	7.8	mg/l
Whittle Dene raw	Total Organic Carbon	03/07/12	8.3	mg/l
Whittle Dene raw	Total Organic Carbon	03/14/12	8.1	mg/l
Whittle Dene raw	Total Organic Carbon	03/21/12	7.9	mg/l
Whittle Dene raw	Total Organic Carbon	03/28/12	7.9	mg/l
Whittle Dene raw	Total Organic Carbon	04/04/12	7.8	mg/l
Whittle Dene raw	Total Organic Carbon	04/11/12	8	mg/l
Whittle Dene raw	Total Organic Carbon	04/18/12	8	mg/l
Whittle Dene raw	Total Organic Carbon	04/25/12	7.3	mg/l
Whittle Dene raw	Total Organic Carbon	05/02/12	6.1	mg/l
Whittle Dene raw	Total Organic Carbon	05/09/12	6.8	mg/l
Whittle Dene raw	Total Organic Carbon	05/16/12	6.4	mg/l
Whittle Dene raw	Total Organic Carbon	05/23/12	7.5	mg/l
Whittle Dene raw	Total Organic Carbon	05/30/12	7.1	mg/l
Whittle Dene raw	Total Organic Carbon	06/06/12	7.1	mg/l
Whittle Dene raw	Total Organic Carbon	06/13/12	7.3	mg/l
Whittle Dene raw	Total Organic Carbon	06/20/12	7	mg/l
Whittle Dene raw	Total Organic Carbon	06/27/12	7.4	mg/l
Whittle Dene raw	Total Organic Carbon	07/04/12	6.8	mg/l
Whittle Dene raw	Total Organic Carbon	07/11/12	9.3	mg/l
Whittle Dene raw	Total Organic Carbon	07/18/12	7.6	mg/l
Whittle Dene raw	Total Organic Carbon	07/25/12	8	mg/l
Whittle Dene raw	Total Organic Carbon	08/01/12	7.8	mg/l
Whittle Dene raw	Total Organic Carbon	08/08/12	7.9	mg/l
Whittle Dene raw	Total Organic Carbon	08/15/12	8	mg/l
Whittle Dene raw	Total Organic Carbon	08/22/12	8.6	mg/l
Whittle Dene raw	Total Organic Carbon	08/29/12	8.4	mg/l
Whittle Dene raw	Total Organic Carbon	09/05/12	8.5	mg/l
Whittle Dene raw	Total Organic Carbon	09/12/12	8.7	mg/l
Whittle Dene raw	Total Organic Carbon	09/19/12	8.7	mg/l
Whittle Dene raw	Total Organic Carbon	09/26/12	10	mg/l
Whittle Dene raw	Total Organic Carbon	10/03/12	8.4	mg/l
Whittle Dene raw	Total Organic Carbon	10/10/12	7.7	mg/l
Whittle Dene raw	Total Organic Carbon	10/17/12	8	mg/l
Whittle Dene raw	Total Organic Carbon	10/24/12	7.6	mg/l
Whittle Dene raw	Total Organic Carbon	11/02/12	8.6	mg/l
Whittle Dene raw	Total Organic Carbon	11/07/12	8.9	mg/l
Whittle Dene raw	Total Organic Carbon	11/14/12	8.9	mg/l
Whittle Dene raw	Total Organic Carbon	11/21/12	8.9	mg/l
Whittle Dene raw	Total Organic Carbon	11/28/12	3.2	mg/l
Whittle Dene raw	Total Organic Carbon	12/05/12	8.1	mg/l
Whittle Dene raw	Total Organic Carbon	12/12/12	6.6	mg/l
Whittle Dene raw	Total Organic Carbon	12/19/12	7.1	mg/l
Whittle Dene raw	Total Organic Carbon	12/28/12	6.9	mg/l
Whittle Dene raw	Nitrogen Ammoniacal	01/26/11	0.012	mg/l as NH4

Whittle Dene raw	Nitrogen Ammoniacal	02/23/11	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	03/30/11	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	04/27/11	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	05/25/11	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	06/29/11	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	07/27/11	0.02	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	08/31/11	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	09/28/11	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	10/26/11	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	11/30/11	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	12/28/11	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	01/25/12	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	02/29/12	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	03/28/12	0.019	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	04/25/12	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	05/30/12	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	06/27/12	0.013	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	07/25/12	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	08/29/12	0.012	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	09/26/12	0.009	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	11/02/12	0.0075	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	11/28/12	0.0075	mg/l as NH4
Whittle Dene raw	Nitrogen Ammoniacal	12/28/12	0.007	mg/l as NH4
Whittle Dene raw	Nitrate	01/26/11	5.8	mg/l as NO3
Whittle Dene raw	Nitrate	02/23/11	7	mg/l as NO3
Whittle Dene raw	Nitrate	03/30/11	4.4	mg/l as NO3
Whittle Dene raw	Nitrate	04/27/11	2.7	mg/l as NO3
Whittle Dene raw	Nitrate	05/25/11	2.7	mg/l as NO3
Whittle Dene raw	Nitrate	06/29/11	2.7	mg/l as NO3
Whittle Dene raw	Nitrate	07/27/11	2.7	mg/l as NO3
Whittle Dene raw	Nitrate	08/31/11	2.7	mg/l as NO3
Whittle Dene raw	Nitrate	09/28/11	2.7	mg/l as NO3
Whittle Dene raw	Nitrate	10/26/11	2.7	mg/l as NO3
Whittle Dene raw	Nitrate	11/30/11	3.1	mg/l as NO3
Whittle Dene raw	Nitrate	12/28/11	4.7	mg/l as NO3
Whittle Dene raw	Nitrate	01/25/12	3.2	mg/l as NO3
Whittle Dene raw	Nitrate	02/29/12	3.3	mg/l as NO3
Whittle Dene raw	Nitrate	03/28/12	2.7	mg/l as NO3
Whittle Dene raw	Nitrate	04/25/12	6.3	mg/l as NO3
Whittle Dene raw	Nitrate	05/30/12	3.4	mg/l as NO3
Whittle Dene raw	Nitrate	06/27/12	5.1	mg/l as NO3
Whittle Dene raw	Nitrate	07/25/12	3.2	mg/l as NO3
Whittle Dene raw	Nitrate	08/29/12	2.7	mg/l as NO3
Whittle Dene raw	Nitrate	09/26/12	5.2	mg/l as NO3
Whittle Dene raw	Nitrate	11/02/12	3.2	mg/l as NO3
Whittle Dene raw	Nitrate	11/28/12	6.3	mg/l as NO3
Whittle Dene raw	Nitrate	12/28/12	6.9	mg/l as NO3
Whittle Dene raw	Nitrite	01/26/11	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	02/23/11	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	03/30/11	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	04/27/11	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	05/25/11	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	06/29/11	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	07/27/11	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	08/31/11	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	09/28/11	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	10/26/11	0.0014	mg/l as NO2

Whittle Dene raw	Nitrite	11/30/11	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	12/28/11	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	01/25/12	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	02/29/12	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	03/28/12	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	04/25/12	0.0018	mg/l as NO2
Whittle Dene raw	Nitrite	05/30/12	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	06/27/12	0.0023	mg/l as NO2
Whittle Dene raw	Nitrite	07/25/12	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	08/29/12	0.0014	mg/l as NO2
Whittle Dene raw	Nitrite	09/26/12	0.0091	mg/l as NO2
Whittle Dene raw	Nitrite	11/02/12	0.0056	mg/l as NO2
Whittle Dene raw	Nitrite	11/28/12	0.0011	mg/l as NO2
Whittle Dene raw	Nitrite	12/28/12	0.0037	mg/l as NO2
Whittle Dene raw	Hardness Total	01/26/11	54	mg/l
Whittle Dene raw	Hardness Total	02/23/11	69	mg/l
Whittle Dene raw	Hardness Total	03/30/11	50	mg/l
Whittle Dene raw	Hardness Total	04/27/11	43	mg/l
Whittle Dene raw	Hardness Total	05/25/11	33	mg/l
Whittle Dene raw	Hardness Total	06/29/11	33	mg/l as Ca
Whittle Dene raw	Hardness Total	07/27/11	44	mg/l as Ca
Whittle Dene raw	Hardness Total	08/31/11	47	mg/l as Ca
Whittle Dene raw	Hardness Total	09/28/11	38	mg/l as Ca
Whittle Dene raw	Hardness Total	10/26/11	39	mg/l as Ca
Whittle Dene raw	Hardness Total	11/30/11	50	mg/l as Ca
Whittle Dene raw	Hardness Total	12/28/11	63	mg/l as Ca
Whittle Dene raw	Hardness Total	01/25/12	51	mg/l as Ca
Whittle Dene raw	Hardness Total	02/29/12	53	mg/l as Ca
Whittle Dene raw	Hardness Total	03/28/12	42	mg/l as Ca
Whittle Dene raw	Hardness Total	04/25/12	64	mg/l as Ca
Whittle Dene raw	Hardness Total	05/30/12	58	mg/l as Ca
Whittle Dene raw	Hardness Total	06/27/12	79	mg/l as Ca
Whittle Dene raw	Hardness Total	07/25/12	67	mg/l as Ca
Whittle Dene raw	Hardness Total	08/29/12	57	mg/l as Ca
Whittle Dene raw	Hardness Total	09/26/12	55	mg/l as Ca
Whittle Dene raw	Hardness Total	11/02/12	63	mg/l as Ca
Whittle Dene raw	Hardness Total	11/28/12	74	mg/l as Ca
Whittle Dene raw	Hardness Total	12/28/12	76	mg/l as Ca
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	01/26/11	120	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	02/23/11	170	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	03/30/11	120	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	04/27/11	86	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	05/25/11	74	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	06/29/11	82	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	07/27/11	110	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	08/31/11	130	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	09/28/11	98	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	10/26/11	95	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	11/30/11	130	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	12/28/11	160	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	01/25/12	130	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	02/29/12	130	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	03/28/12	96	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	04/25/12	150	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	05/30/12	130	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	06/27/12	200	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	07/25/12	160	mg/l as HCO3

Whittle Dene raw	Alkalinity to pH 4.5 (Total)	08/29/12	140	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	09/26/12	130	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	11/02/12	160	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	11/28/12	190	mg/l as HCO3
Whittle Dene raw	Alkalinity to pH 4.5 (Total)	12/28/12	190	mg/l as HCO3
Whittle Dene raw	Chloride	01/26/11	14	mg/l
Whittle Dene raw	Chloride	02/23/11	17	mg/l
Whittle Dene raw	Chloride	03/30/11	13	mg/l
Whittle Dene raw	Chloride	04/27/11	13	mg/l
Whittle Dene raw	Chloride	05/25/11	11	mg/l
Whittle Dene raw	Chloride	06/29/11	9	mg/l
Whittle Dene raw	Chloride	07/27/11	11	mg/l
Whittle Dene raw	Chloride	08/31/11	10	mg/l
Whittle Dene raw	Chloride	09/28/11	8.3	mg/l
Whittle Dene raw	Chloride	10/26/11	9.1	mg/l
Whittle Dene raw	Chloride	11/30/11	11	mg/l
Whittle Dene raw	Chloride	12/28/11	13	mg/l
Whittle Dene raw	Chloride	01/25/12	13	mg/l
Whittle Dene raw	Chloride	02/29/12	13	mg/l
Whittle Dene raw	Chloride	03/28/12	12	mg/l
Whittle Dene raw	Chloride	04/25/12	16	mg/l
Whittle Dene raw	Chloride	05/30/12	13	mg/l
Whittle Dene raw	Chloride	06/27/12	13	mg/l
Whittle Dene raw	Chloride	07/25/12	14	mg/l
Whittle Dene raw	Chloride	08/29/12	11	mg/l
Whittle Dene raw	Chloride	09/26/12	13	mg/l
Whittle Dene raw	Chloride	11/02/12	11	mg/l
Whittle Dene raw	Chloride	11/28/12	12	mg/l
Whittle Dene raw	Chloride	12/28/12	13	mg/l
Whittle Dene raw	Sulphate Dissolved	01/26/11	22	mg/l
Whittle Dene raw	Sulphate Dissolved	02/23/11	25	mg/l
Whittle Dene raw	Sulphate Dissolved	03/30/11	18	mg/l
Whittle Dene raw	Sulphate Dissolved	04/27/11	17	mg/l
Whittle Dene raw	Sulphate Dissolved	05/25/11	13	mg/l
Whittle Dene raw	Sulphate Dissolved	06/29/11	14	mg/l
Whittle Dene raw	Sulphate Dissolved	07/27/11	16	mg/l
Whittle Dene raw	Sulphate Dissolved	08/31/11	17	mg/l
Whittle Dene raw	Sulphate Dissolved	09/28/11	14	mg/l
Whittle Dene raw	Sulphate Dissolved	10/26/11	14	mg/l
Whittle Dene raw	Sulphate Dissolved	11/30/11	18	mg/l
Whittle Dene raw	Sulphate Dissolved	12/28/11	20	mg/l
Whittle Dene raw	Sulphate Dissolved	01/25/12	18	mg/l
Whittle Dene raw	Sulphate Dissolved	02/29/12	19	mg/l
Whittle Dene raw	Sulphate Dissolved	03/28/12	18	mg/l
Whittle Dene raw	Sulphate Dissolved	04/25/12	21	mg/l
Whittle Dene raw	Sulphate Dissolved	05/30/12	25	mg/l
Whittle Dene raw	Sulphate Dissolved	06/27/12	22	mg/l
Whittle Dene raw	Sulphate Dissolved	07/25/12	24	mg/l
Whittle Dene raw	Sulphate Dissolved	08/29/12	18	mg/l
Whittle Dene raw	Sulphate Dissolved	09/26/12	17	mg/l
Whittle Dene raw	Sulphate Dissolved	11/02/12	22	mg/l
Whittle Dene raw	Sulphate Dissolved	11/28/12	21	mg/l
Whittle Dene raw	Sulphate Dissolved	12/28/12	22	mg/l
Whittle Dene raw	Sodium Total	01/26/11	8.7	mg/l
Whittle Dene raw	Sodium Total	02/23/11	10	mg/l
Whittle Dene raw	Sodium Total	03/30/11	9.3	mg/l
Whittle Dene raw	Sodium Total	04/27/11	8.7	mg/l

Whittle Dene raw	Sodium Total	05/25/11	7.6	mg/l
Whittle Dene raw	Sodium Total	06/29/11	7.4	mg/l
Whittle Dene raw	Sodium Total	07/27/11	8.1	mg/l
Whittle Dene raw	Sodium Total	08/31/11	7.8	mg/l
Whittle Dene raw	Sodium Total	09/28/11	7.1	mg/l
Whittle Dene raw	Sodium Total	10/26/11	7.2	mg/l
Whittle Dene raw	Sodium Total	11/30/11	8.2	mg/l
Whittle Dene raw	Sodium Total	12/28/11	9.7	mg/l
Whittle Dene raw	Sodium Total	01/25/12	9.4	mg/l
Whittle Dene raw	Sodium Total	02/29/12	8.9	mg/l
Whittle Dene raw	Sodium Total	03/28/12	8.7	mg/l
Whittle Dene raw	Sodium Total	04/25/12	10	mg/l
Whittle Dene raw	Sodium Total	05/30/12	9.8	mg/l
Whittle Dene raw	Sodium Total	06/27/12	9.5	mg/l
Whittle Dene raw	Sodium Total	07/25/12	8.9	mg/l
Whittle Dene raw	Sodium Total	08/29/12	8.4	mg/l
Whittle Dene raw	Sodium Total	09/26/12	7.4	mg/l
Whittle Dene raw	Sodium Total	11/02/12	8.5	mg/l
Whittle Dene raw	Sodium Total	11/28/12	8.6	mg/l
Whittle Dene raw	Sodium Total	12/28/12	8.7	mg/l
Whittle Dene raw	Magnesium Total	01/26/11	6.8	mg/l
Whittle Dene raw	Magnesium Total	02/23/11	7.9	mg/l
Whittle Dene raw	Magnesium Total	03/30/11	6.3	mg/l
Whittle Dene raw	Magnesium Total	04/27/11	5.9	mg/l
Whittle Dene raw	Magnesium Total	05/25/11	5.5	mg/l
Whittle Dene raw	Magnesium Total	06/29/11	5.5	mg/l
Whittle Dene raw	Magnesium Total	07/27/11	6	mg/l
Whittle Dene raw	Magnesium Total	08/31/11	6.8	mg/l
Whittle Dene raw	Magnesium Total	09/28/11	5.7	mg/l
Whittle Dene raw	Magnesium Total	10/26/11	5.1	mg/l
Whittle Dene raw	Magnesium Total	11/30/11	6.7	mg/l
Whittle Dene raw	Magnesium Total	12/28/11	7	mg/l
Whittle Dene raw	Magnesium Total	01/25/12	6.6	mg/l
Whittle Dene raw	Magnesium Total	02/29/12	7.1	mg/l
Whittle Dene raw	Magnesium Total	03/28/12	6.4	mg/l
Whittle Dene raw	Magnesium Total	04/25/12	7.7	mg/l
Whittle Dene raw	Magnesium Total	05/30/12	7.7	mg/l
Whittle Dene raw	Magnesium Total	06/27/12	8.9	mg/l
Whittle Dene raw	Magnesium Total	07/25/12	7.4	mg/l
Whittle Dene raw	Magnesium Total	08/29/12	7.1	mg/l
Whittle Dene raw	Magnesium Total	09/26/12	6.2	mg/l
Whittle Dene raw	Magnesium Total	11/02/12	7.5	mg/l
Whittle Dene raw	Magnesium Total	11/28/12	7.4	mg/l
Whittle Dene raw	Magnesium Total	12/28/12	8	mg/l
Whittle Dene raw	Calcium Total	01/26/11	42	mg/l
Whittle Dene raw	Calcium Total	02/23/11	56	mg/l
Whittle Dene raw	Calcium Total	03/30/11	40	mg/l
Whittle Dene raw	Calcium Total	04/27/11	33	mg/l
Whittle Dene raw	Calcium Total	05/25/11	24	mg/l
Whittle Dene raw	Calcium Total	06/29/11	24	mg/l as Ca
Whittle Dene raw	Calcium Total	07/27/11	34	mg/l as Ca
Whittle Dene raw	Calcium Total	08/31/11	36	mg/l as Ca
Whittle Dene raw	Calcium Total	09/28/11	29	mg/l as Ca
Whittle Dene raw	Calcium Total	10/26/11	31	mg/l as Ca
Whittle Dene raw	Calcium Total	11/30/11	39	mg/l as Ca
Whittle Dene raw	Calcium Total	12/28/11	51	mg/l as Ca
Whittle Dene raw	Calcium Total	01/25/12	41	mg/l as Ca

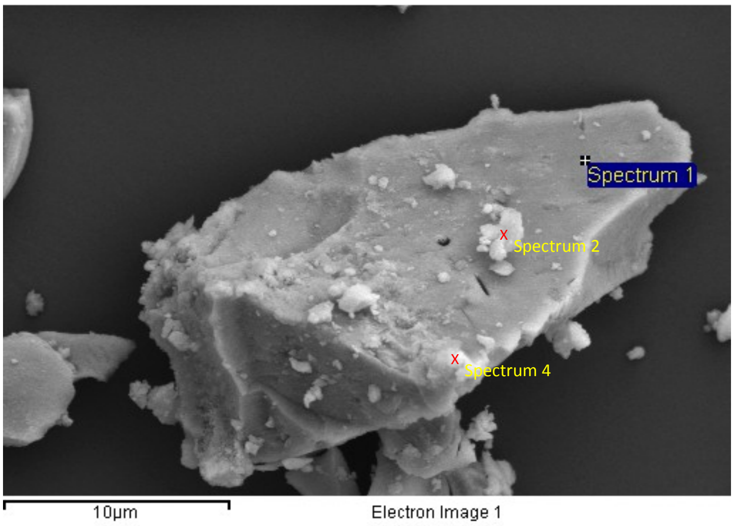
Whittle Dene raw	Calcium Total	02/29/12	41	mg/l as Ca
Whittle Dene raw	Calcium Total	03/28/12	31	mg/l as Ca
Whittle Dene raw	Calcium Total	04/25/12	51	mg/l as Ca
Whittle Dene raw	Calcium Total	05/30/12	46	mg/l as Ca
Whittle Dene raw	Calcium Total	06/27/12	64	mg/l as Ca
Whittle Dene raw	Calcium Total	07/25/12	54	mg/l as Ca
Whittle Dene raw	Calcium Total	08/29/12	46	mg/l as Ca
Whittle Dene raw	Calcium Total	09/26/12	45	mg/l as Ca
Whittle Dene raw	Calcium Total	11/02/12	51	mg/l as Ca
Whittle Dene raw	Calcium Total	11/28/12	62	mg/l as Ca
Whittle Dene raw	Calcium Total	12/28/12	62	mg/l as Ca
Whittle Dene raw	Cadmium Total	01/26/11	0.0099	ug/l
Whittle Dene raw	Cadmium Total	02/23/11	0.0081	ug/l
Whittle Dene raw	Cadmium Total	03/30/11	0.012	ug/l
Whittle Dene raw	Cadmium Total	04/27/11	0.0081	ug/l
Whittle Dene raw	Cadmium Total	05/25/11	0.0081	ug/l
Whittle Dene raw	Cadmium Total	06/29/11	0.0081	ug/l
Whittle Dene raw	Cadmium Total	07/27/11	0.0081	ug/l
Whittle Dene raw	Cadmium Total	08/31/11	0.0081	ug/l
Whittle Dene raw	Cadmium Total	09/28/11	0.0081	ug/l
Whittle Dene raw	Cadmium Total	10/26/11	0.0081	ug/l
Whittle Dene raw	Cadmium Total	11/30/11	0.0081	ug/l
Whittle Dene raw	Cadmium Total	12/28/11	0.0081	ug/l
Whittle Dene raw	Cadmium Total	01/25/12	0.0081	ug/l
Whittle Dene raw	Cadmium Total	02/29/12	0.0081	ug/l
Whittle Dene raw	Cadmium Total	03/28/12	0.0081	ug/l
Whittle Dene raw	Cadmium Total	04/25/12	0.009	ug/l
Whittle Dene raw	Cadmium Total	05/30/12	0.014	ug/l
Whittle Dene raw	Cadmium Total	06/27/12	0.0098	ug/l
Whittle Dene raw	Cadmium Total	07/25/12	0.0081	ug/l
Whittle Dene raw	Cadmium Total	08/29/12	0.0081	ug/l
Whittle Dene raw	Cadmium Total	09/26/12	0.0081	ug/l
Whittle Dene raw	Cadmium Total	11/02/12	0.0081	ug/l
Whittle Dene raw	Cadmium Total	11/28/12	0.0024	ug/l
Whittle Dene raw	Cadmium Total	12/28/12	0.0024	ug/l
Whittle Dene raw	Aluminium Total	01/26/11	88	ug/l
Whittle Dene raw	Aluminium Total	02/23/11	120	ug/l
Whittle Dene raw	Aluminium Total	03/30/11	54	ug/l
Whittle Dene raw	Aluminium Total	04/27/11	69	ug/l
Whittle Dene raw	Aluminium Total	05/25/11	120	ug/l
Whittle Dene raw	Aluminium Total	06/29/11	120	ug/l
Whittle Dene raw	Aluminium Total	07/27/11	60	ug/l
Whittle Dene raw	Aluminium Total	08/31/11	54	ug/l
Whittle Dene raw	Aluminium Total	09/28/11	45	ug/l
Whittle Dene raw	Aluminium Total	10/26/11	65	ug/l
Whittle Dene raw	Aluminium Total	11/30/11	120	ug/l
Whittle Dene raw	Aluminium Total	12/28/11	120	ug/l
Whittle Dene raw	Aluminium Total	01/25/12	110	ug/l
Whittle Dene raw	Aluminium Total	02/29/12	77	ug/l
Whittle Dene raw	Aluminium Total	03/28/12	40	ug/l
Whittle Dene raw	Aluminium Total	04/25/12	100	ug/l
Whittle Dene raw	Aluminium Total	05/30/12	72	ug/l
Whittle Dene raw	Aluminium Total	06/27/12	140	ug/l
Whittle Dene raw	Aluminium Total	07/25/12	65	ug/l
Whittle Dene raw	Aluminium Total	08/29/12	41	ug/l
Whittle Dene raw	Aluminium Total	09/26/12	450	ug/l
Whittle Dene raw	Aluminium Total	11/02/12	91	ug/l

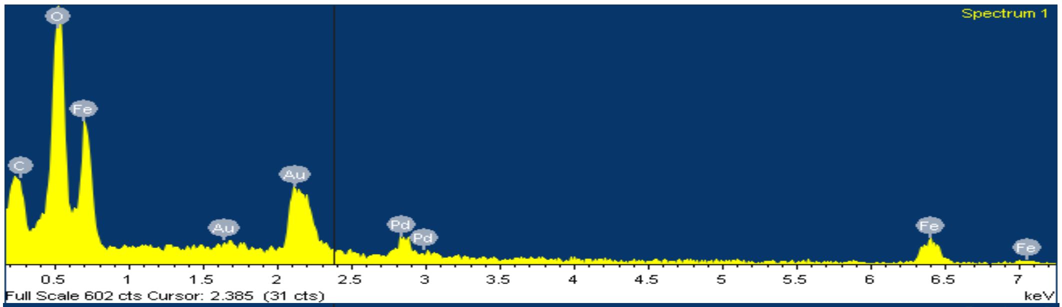
Whittle Dene raw	Aluminium Total	11/28/12	720	ug/l
Whittle Dene raw	Aluminium Total	12/28/12	870	ug/l
Whittle Dene raw	Lead Total	01/26/11	0.23	ug/l
Whittle Dene raw	Lead Total	02/23/11	0.23	ug/l
Whittle Dene raw	Lead Total	03/30/11	0.17	ug/l
Whittle Dene raw	Lead Total	04/27/11	0.23	ug/l
Whittle Dene raw	Lead Total	05/25/11	0.54	ug/l
Whittle Dene raw	Lead Total	06/29/11	0.64	ug/l
Whittle Dene raw	Lead Total	07/27/11	0.23	ug/l
Whittle Dene raw	Lead Total	08/31/11	0.25	ug/l
Whittle Dene raw	Lead Total	09/28/11	0.25	ug/l
Whittle Dene raw	Lead Total	10/26/11	0.23	ug/l
Whittle Dene raw	Lead Total	11/30/11	0.43	ug/l
Whittle Dene raw	Lead Total	12/28/11	0.34	ug/l
Whittle Dene raw	Lead Total	01/25/12	0.26	ug/l
Whittle Dene raw	Lead Total	02/29/12	0.27	ug/l
Whittle Dene raw	Lead Total	03/28/12	0.17	ug/l
Whittle Dene raw	Lead Total	04/25/12	0.23	ug/l
Whittle Dene raw	Lead Total	05/30/12	0.62	ug/l
Whittle Dene raw	Lead Total	06/27/12	0.31	ug/l
Whittle Dene raw	Lead Total	07/25/12	0.34	ug/l
Whittle Dene raw	Lead Total	08/29/12	0.15	ug/l
Whittle Dene raw	Lead Total	09/26/12	0.87	ug/l
Whittle Dene raw	Lead Total	11/02/12	0.39	ug/l
Whittle Dene raw	Lead Total	11/28/12	1.3	ug/l
Whittle Dene raw	Lead Total	12/28/12	0.98	ug/l
Whittle Dene raw	Phosphorus Total (As P)	01/12/11	140	ug/l as P
Whittle Dene raw	Phosphorus Total (As P)	03/30/11	20	ug/l as P
Whittle Dene raw	Phosphorus Total (As P)	06/29/11	22	ug/l as P
Whittle Dene raw	Phosphorus Total (As P)	09/28/11	19	ug/l as P
Whittle Dene raw	Phosphorus Total (As P)	01/25/12	27	ug/l as P
Whittle Dene raw	Phosphorus Total (As P)	04/25/12	24	ug/l as P
Whittle Dene raw	Phosphorus Total (As P)	07/25/12	21	ug/l as P
Whittle Dene raw	Phosphorus Total (As P)	11/02/12	40	ug/l as P
Whittle Dene raw	Manganese Total	01/26/11	15	ug/l
Whittle Dene raw	Manganese Total	02/23/11	14	ug/l
Whittle Dene raw	Manganese Total	03/30/11	17	ug/l
Whittle Dene raw	Manganese Total	04/27/11	39	ug/l
Whittle Dene raw	Manganese Total	05/25/11	55	ug/l
Whittle Dene raw	Manganese Total	06/29/11	120	ug/l
Whittle Dene raw	Manganese Total	07/27/11	29	ug/l
Whittle Dene raw	Manganese Total	08/31/11	39	ug/l
Whittle Dene raw	Manganese Total	09/28/11	21	ug/l
Whittle Dene raw	Manganese Total	10/26/11	18	ug/l
Whittle Dene raw	Manganese Total	11/30/11	17	ug/l
Whittle Dene raw	Manganese Total	12/28/11	17	ug/l
Whittle Dene raw	Manganese Total	01/25/12	9.5	ug/l
Whittle Dene raw	Manganese Total	02/29/12	13	ug/l
Whittle Dene raw	Manganese Total	03/28/12	11	ug/l
Whittle Dene raw	Manganese Total	04/25/12	15	ug/l
Whittle Dene raw	Manganese Total	05/30/12	47	ug/l
Whittle Dene raw	Manganese Total	06/27/12	27	ug/l
Whittle Dene raw	Manganese Total	07/25/12	45	ug/l
Whittle Dene raw	Manganese Total	08/29/12	33	ug/l
Whittle Dene raw	Manganese Total	09/26/12	29	ug/l
Whittle Dene raw	Manganese Total	11/02/12	43	ug/l
Whittle Dene raw	Manganese Total	11/28/12	29	ug/l

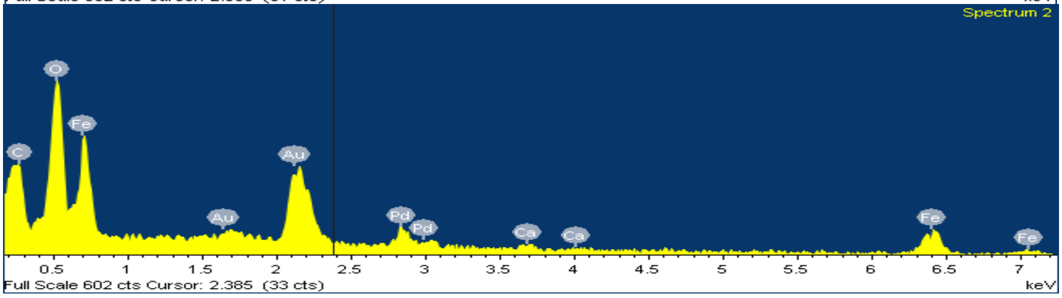
Whittle Dene raw	Manganese Total	12/28/12	23	ug/l
Whittle Dene raw	Iron Total	01/26/11	270	ug/l
Whittle Dene raw	Iron Total	02/23/11	230	ug/l
Whittle Dene raw	Iron Total	03/30/11	180	ug/l
Whittle Dene raw	Iron Total	04/27/11	230	ug/l
Whittle Dene raw	Iron Total	05/25/11	360	ug/l
Whittle Dene raw	Iron Total	06/29/11	440	ug/l
Whittle Dene raw	Iron Total	07/27/11	230	ug/l
Whittle Dene raw	Iron Total	08/31/11	250	ug/l
Whittle Dene raw	Iron Total	09/28/11	240	ug/l
Whittle Dene raw	Iron Total	10/26/11	330	ug/l
Whittle Dene raw	Iron Total	11/30/11	430	ug/l
Whittle Dene raw	Iron Total	12/28/11	340	ug/l
Whittle Dene raw	Iron Total	01/25/12	320	ug/l
Whittle Dene raw	Iron Total	02/29/12	290	ug/l
Whittle Dene raw	Iron Total	03/28/12	230	ug/l
Whittle Dene raw	Iron Total	04/25/12	240	ug/l
Whittle Dene raw	Iron Total	05/30/12	300	ug/l
Whittle Dene raw	Iron Total	06/27/12	260	ug/l
Whittle Dene raw	Iron Total	07/25/12	240	ug/l
Whittle Dene raw	Iron Total	08/29/12	190	ug/l
Whittle Dene raw	Iron Total	09/26/12	510	ug/l
Whittle Dene raw	Iron Total	11/02/12	320	ug/l
Whittle Dene raw	Iron Total	11/28/12	720	ug/l
Whittle Dene raw	Iron Total	12/28/12	700	ug/l
Whittle Dene raw	Nickel Total	01/26/11	2.2	ug/l
Whittle Dene raw	Nickel Total	02/23/11	1.3	ug/l
Whittle Dene raw	Nickel Total	03/30/11	1.2	ug/l
Whittle Dene raw	Nickel Total	04/27/11	1.3	ug/l
Whittle Dene raw	Nickel Total	05/25/11	1.4	ug/l
Whittle Dene raw	Nickel Total	06/29/11	1.3	ug/l
Whittle Dene raw	Nickel Total	07/27/11	1.8	ug/l
Whittle Dene raw	Nickel Total	08/31/11	1.3	ug/l
Whittle Dene raw	Nickel Total	09/28/11	1.2	ug/l
Whittle Dene raw	Nickel Total	10/26/11	1.4	ug/l
Whittle Dene raw	Nickel Total	11/30/11	1.7	ug/l
Whittle Dene raw	Nickel Total	12/28/11	1.5	ug/l
Whittle Dene raw	Nickel Total	01/25/12	1.6	ug/l
Whittle Dene raw	Nickel Total	02/29/12	0.89	ug/l
Whittle Dene raw	Nickel Total	03/28/12	1	ug/l
Whittle Dene raw	Nickel Total	04/25/12	1.2	ug/l
Whittle Dene raw	Nickel Total	05/30/12	1.6	ug/l
Whittle Dene raw	Nickel Total	06/27/12	1.3	ug/l
Whittle Dene raw	Nickel Total	07/25/12	1.1	ug/l
Whittle Dene raw	Nickel Total	08/29/12	1	ug/l
Whittle Dene raw	Nickel Total	09/26/12	1.2	ug/l
Whittle Dene raw	Nickel Total	11/02/12	1.5	ug/l
Whittle Dene raw	Nickel Total	11/28/12	1.9	ug/l
Whittle Dene raw	Nickel Total	12/28/12	1.7	ug/l

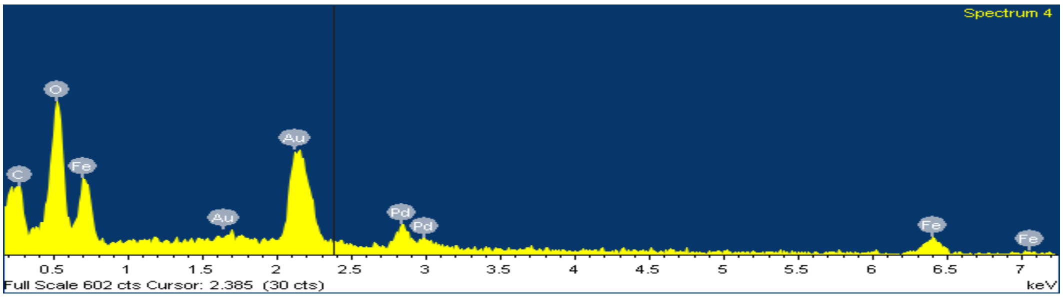
Appendix 3 - SEM and EDX scans of WTR particles untreated and Pb-treated

SEM image of Broken Scar WTR particle (Au-Pd coated, powdered (<63um) sample) with EDX points and corresponding EDX spectrum 1,2 and 4.





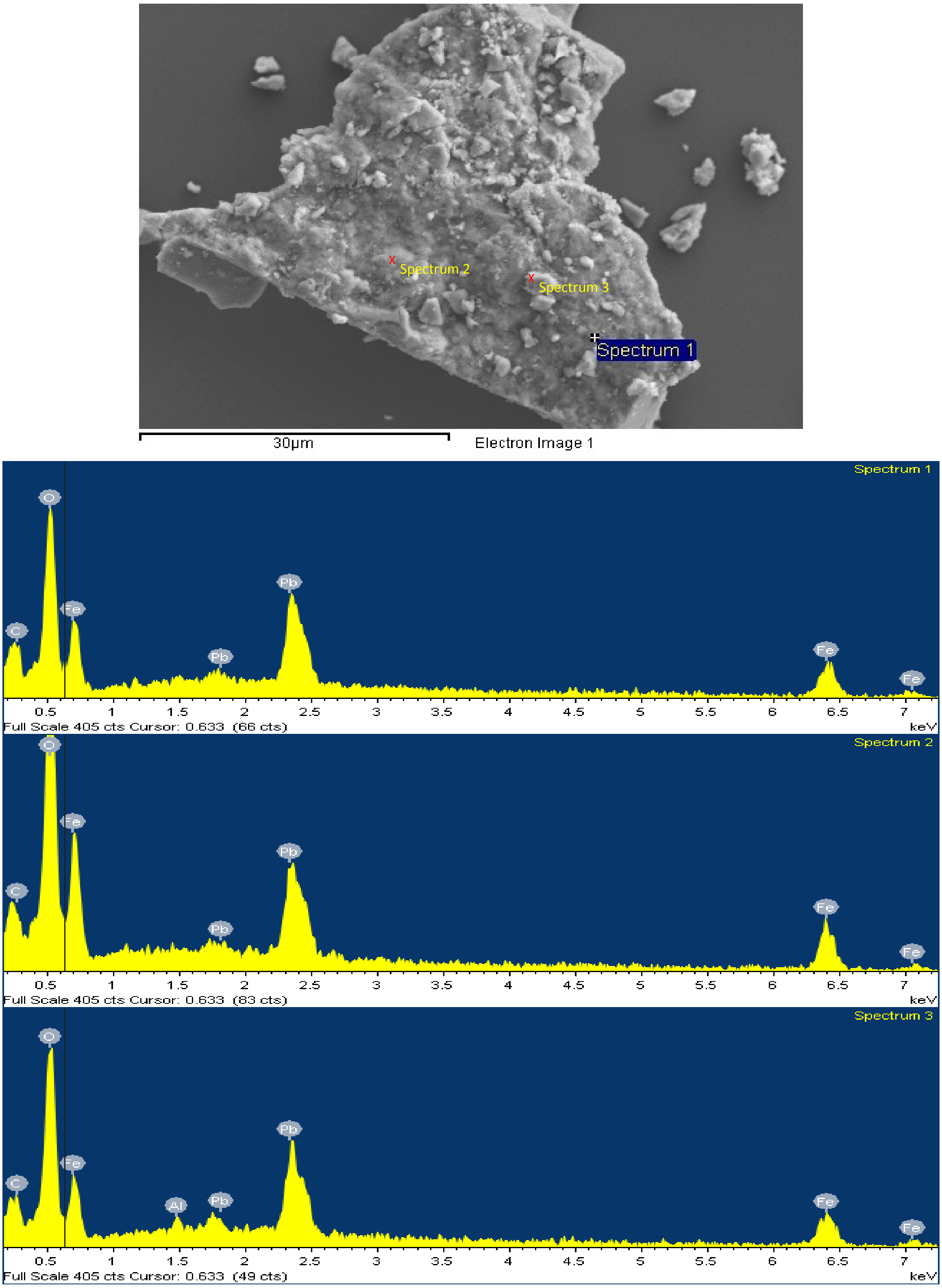




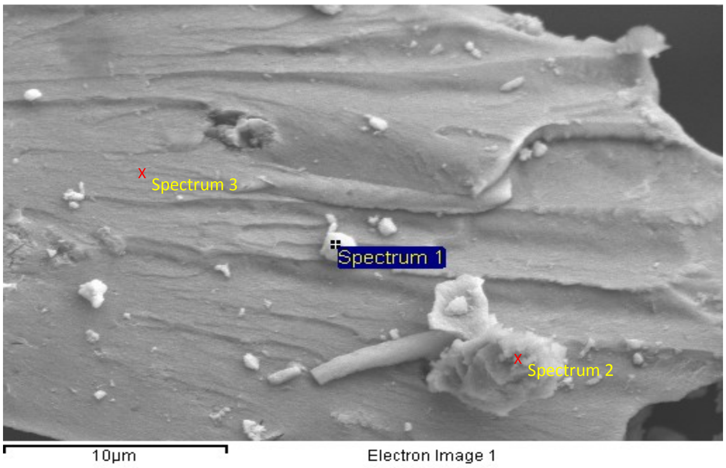
EDX analysis was gathered on several Au-Pd coated WTR particles to gather qualitative data on its surface composition. The location of four EDX points of analysis are indicated on the WTR particle presented above, along with the corresponding EDX spectrums. These results are representative of the range of WTR surfaces that were examined.

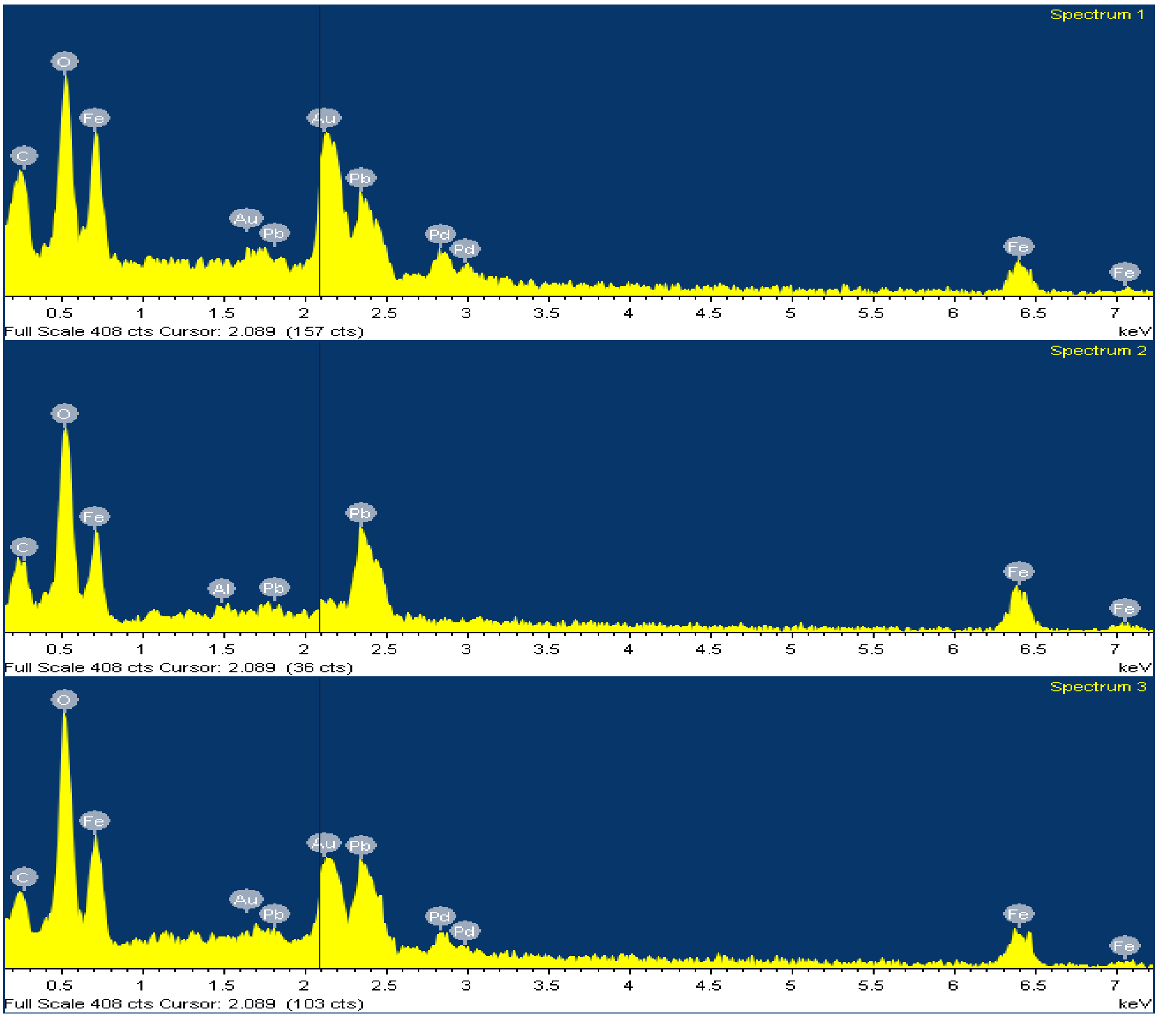
The SEM image shows a ~25 µm WTR particle with small clasts spread over the surface. EDX analysis was focussed on the flat WTR surface and on the rough clast-like particles on the surface to establish if these fractions had different compositions. The two EDX spectrums show qualitatively consistent results; with carbon, oxygen and iron predominating as expected. In addition, Ca was detected in spectrum 2, suggesting that the small clumps could contain a higher concentration of carbonates or clay particles.

SEM image of Pb-treated (3d) Broken Scar WTR particle (Au-Pd coated, powdered (<63um) sample) with EDX points and corresponding EDX spectrum 1,2 and 3.

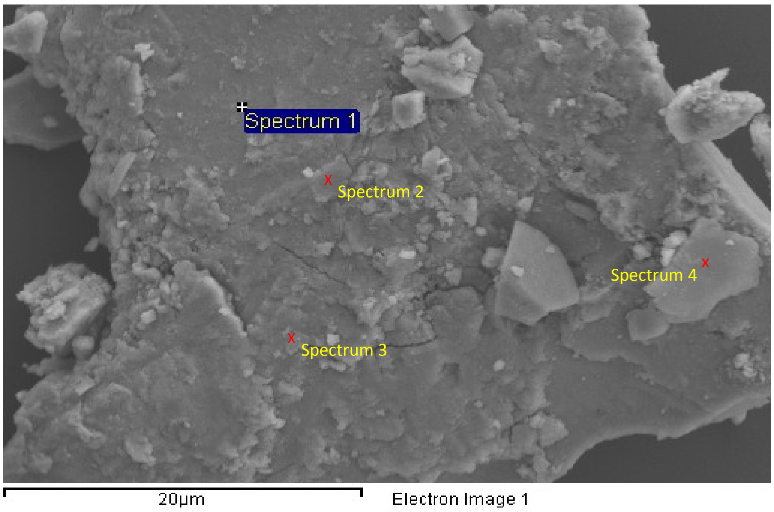


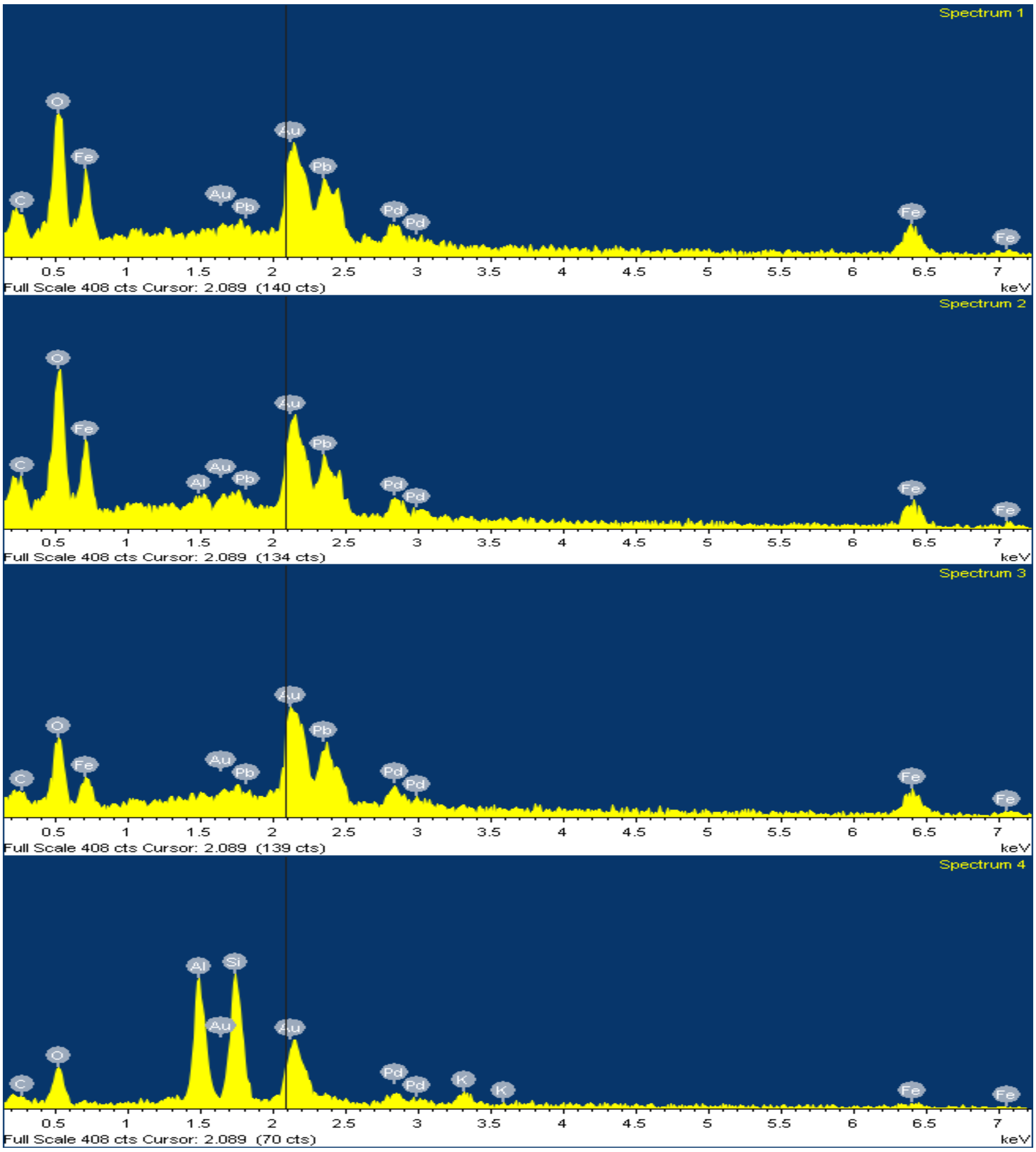
SEM image of Pb-treated (3d) Broken Scar WTR particle (Au-Pd coated, powdered (<63um) sample) with EDX points and corresponding EDX spectrum 1,2 and 3.





SEM image of Pb-treated (14d) Broken Scar WTR particle (Au-Pd coated, powdered (<63um) sample) with EDX points and corresponding EDX spectrum 1,2, 3 and 4.





Appendix 4 - PHREEQC data

Pb solid	**Eqn for ppt formation**	**log_k**
Massicot	Pb+2 + H2O = PbO + 2H+	-12.894
Litharge	Pb+2 + H2O = PbO + 2H+	-12.694
PbO:0.33H2O	Pb+2 + 1.33H2O = PbO:0.33H2O + 2H+	-12.98
Pb(OH)2	Pb+2 + 2H2O = Pb(OH)2 + 2H+	-8.15
Pb2O(OH)2	2Pb+2 + 3H2O = Pb2O(OH)2 + 4H+	-26.188
Cerrusite	Pb+2 + CO3-2 = PbCO3	13.13
Pb2OCO3	2Pb+2 + H2O + CO3-2 = Pb2OCO3 + 2H+	0.5578
Pb3O2CO3	3Pb+2 + CO3-2 +2H2O = Pb3O2CO3 + 4H+	-11.02
Hydrocerrusite	3Pb+2 + 2H2O + 2CO3-2 = Pb3(OH)2(CO3)2 + 2H+	18.7705
Pb10(OH)6O(CO3)6	10Pb+2 + 6CO3-2 + 7H2O = Pb10(OH)6OCO36 + 8H+	8.76

```
------------------
Reading data base.
------------------
        SOLUTION_MASTER_SPECIES
        SOLUTION_SPECIES
        SOLUTION_SPECIES
        PHASES
        PHASES
        SURFACE_MASTER_SPECIES
        SURFACE_SPECIES
        END
------------------------------------
Reading input data for simulation 1.
------------------------------------

        TITLE Speciating Pb in 0.1M NaNO3 in atm.
        SOLUTION_SPECIES
        Pb+2 + H2O = PbOH+ + H+
                log_k    -7.597
        Pb+2 + 2H2O = Pb(OH)2 + 2H+
                log_k    -17.094
        Pb+2 + 3H2O = Pb(OH)3- + 3H+
                log_k    -28.091
        2Pb+2 + H2O = Pb2OH+3 + H+
                log_k    -6.397
        3Pb+2 + 4H2O = Pb3(OH)4+2 + 4H+
                log_k    -23.888
        Pb+2 + 4H2O = Pb(OH)4-2 + 4H+
```

```
                log_k       -39.699
        4Pb+2 + 4H2O = Pb4(OH)4+4 + 4H+
                log_k       -19.988
        Pb+2 + NO3- = PbNO3+
                log_k       1.17
        Pb+2 + 2NO3- = Pb(NO3)2
                log_k       1.4
        Pb+2 + 2CO3-2 = Pb(CO3)2-2
                log_k       9.938
        Pb+2 + CO3-2 = PbCO3
                log_k       6.478
        Pb+2 + CO3-2 + H+ = PbHCO3+
                log_k       13.2
        PHASES
        Pb(OH)2(s)
                Pb(OH)2 + 2H+ = Pb+2 + 2H2O
                log_k       8.15
        Fix_pH
           H+ = H+
           log_k 0
        SOLUTION 1 A: Speciation in pure water
           pH    7
           units mol/kgw
           Pb    4.826e-05
        END
```

```
-----
TITLE
-----

 Speciating Pb in 0.1M NaNO3 in atm.

-------------------------------------------
Beginning of initial solution calculations.
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Initial solution 1.     A: Speciation in pure water

-----------------------------Solution composition------------------------------

        Elements          Molality       Moles

        Pb              4.826e-05   4.826e-05

----------------------------Description of solution----------------------------

                                 pH  =   7.000
                                 pe  =   4.000
                      Activity of water  =   1.000
                         Ionic strength  =   8.233e-05
                       Mass of water (kg)  =   1.000e+00
                 Total alkalinity (eq/kg)  =   9.561e-06
                    Total carbon (mol/kg)  =   0.000e+00
                       Total CO2 (mol/kg)  =   0.000e+00
                      Temperature (deg C)  =  25.000
                  Electrical balance (eq)  =   8.696e-05
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  99.77
                               Iterations  =   4
                                  Total H  = 1.110137e+02
```

```
                    Total O  = 5.550684e+01

----------------------------Distribution of species----------------------------

                                        Log       Log        Log
            Species           Molality    Activity  Molality  Activity     Gamma

            OH-            1.018e-07   1.007e-07    -6.992    -6.997    -0.005
            H+             1.011e-07   1.000e-07    -6.995    -7.000    -0.005
            H2O            5.551e+01   1.000e+00     1.744    -0.000     0.000
H(0)         1.416e-25
            H2             7.079e-26   7.079e-26   -25.150   -25.150     0.000
O(0)         0.000e+00
            O2             0.000e+00   0.000e+00   -41.995   -41.995     0.000
Pb           4.826e-05
            Pb+2           3.872e-05   3.713e-05    -4.412    -4.430    -0.018
            PbOH+          9.490e-06   9.391e-06    -5.023    -5.027    -0.005
            Pb(OH)2        2.990e-08   2.990e-08    -7.524    -7.524     0.000
            Pb2OH+3        6.075e-09   5.526e-09    -8.216    -8.258    -0.041
            Pb3(OH)4+2     6.909e-10   6.625e-10    -9.161    -9.179    -0.018
            Pb4(OH)4+4     2.312e-10   1.954e-10    -9.636    -9.709    -0.073
            Pb(OH)3-       3.043e-12   3.011e-12   -11.517   -11.521    -0.005
            Pb(OH)4-2      7.744e-17   7.425e-17   -16.111   -16.129    -0.018

------------------------------Saturation indices------------------------------

            Phase            SI log IAP  log KT

            Fix_pH          -7.00   -7.00    0.00  H+
            Litharge        -3.12    9.57   12.69  PbO
            Massicot        -3.32    9.57   12.89  PbO
            Minium         -22.81   50.71   73.52  Pb3O4
            O2(g)          -39.09   44.00   83.09  O2
            Pb(OH)2          1.42    9.57    8.15  Pb(OH)2
            Pb(OH)2(s)       1.42    9.57    8.15  Pb(OH)2
            Pb2O(OH)2       -7.05   19.14   26.19  Pb2O(OH)2
            Pb2O3          -19.90   41.14   61.04  Pb2O3
            Pbmetal        -16.68  -12.43    4.25  Pb
            PbO:0.3H2O      -3.41    9.57   12.98  PbO:0.33H2O
            Plattnerite    -18.03   31.57   49.60  PbO2

------------------
End of simulation.
------------------

------------------------------------
Reading input data for simulation 2.
------------------------------------

            SOLUTION 2 B: Speciation in NaNO3 solution
                pH    7
                units mol/kgw
                Pb    4.826e-05
                Na    0.1
                N(5)  0.1           charge
            END
```

PHREEQC OUTPUT SUMMARY

IN THE 1WT% (4.82E-05 M) // 20WT% EXPERIMENTS (9.6e-04 M Pb) pptn begins at:

Massicot does not form between pH 1 and 10 // pH 9.1

Litharge does not form between pH 1 and 10 // pH 8.9

PbO:0.33H2O does not form between pH 1 and 10 // pH 9.2

Pb(OH)2 pH 6.6 // 5.5

Pb2O(OH)2 does not form between pH 1 and 10 // pH 9.4

Cerrusite pH 6.6 // 5.7

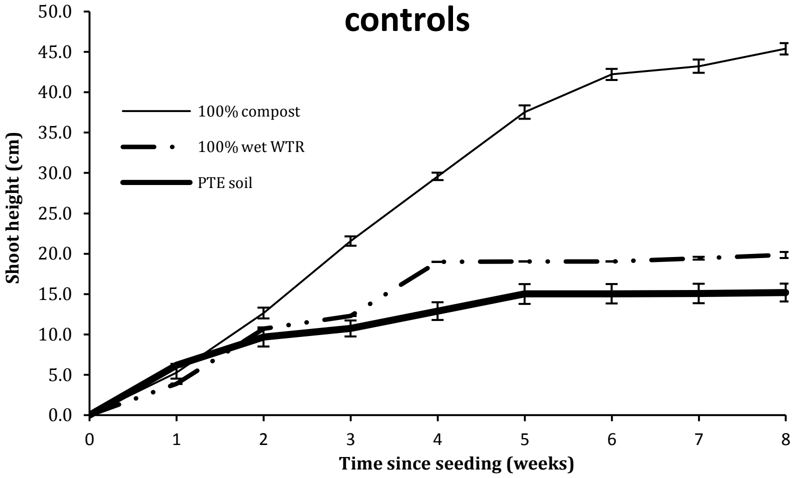
Pb2OCO3 pH 8.4 // 6.7

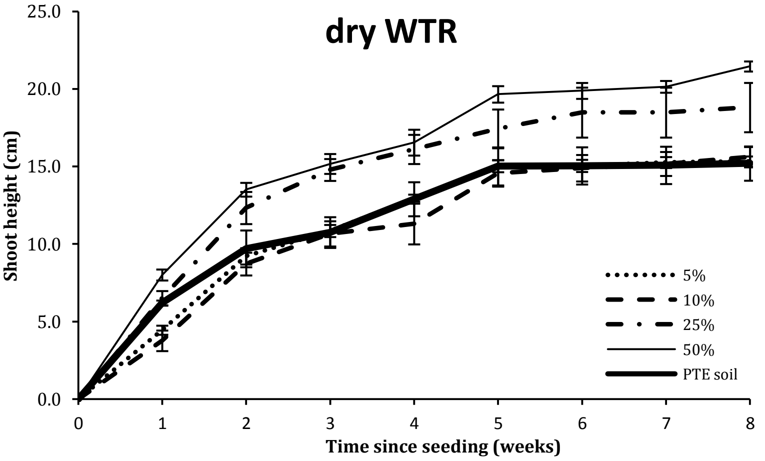
Pb3O2CO3 pH 8.5 // 7.0

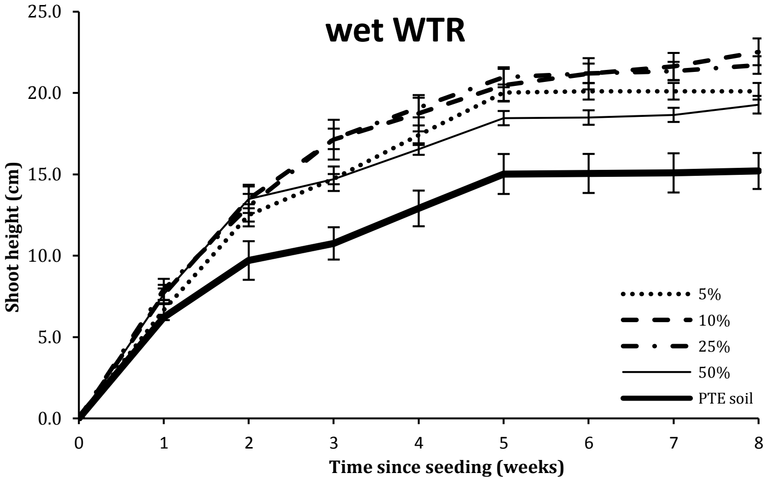
Hydrocerrusite pH 6.5 // 5.1

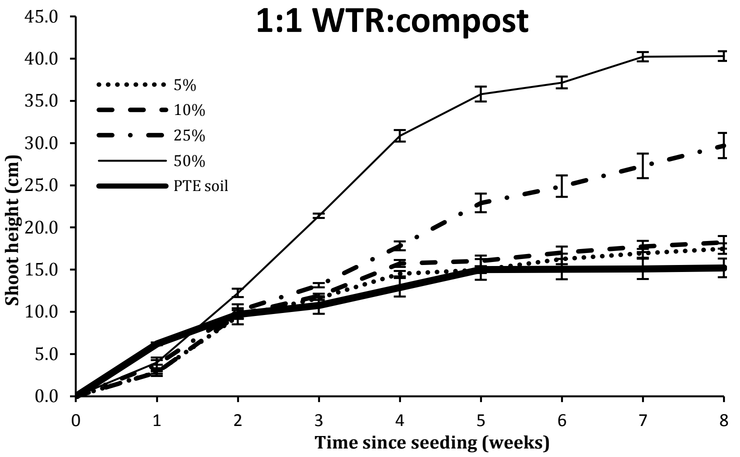
Pb10(OH)6O(CO3)6 does not form between pH 1 and 10 // does not form between pH 1 and 10

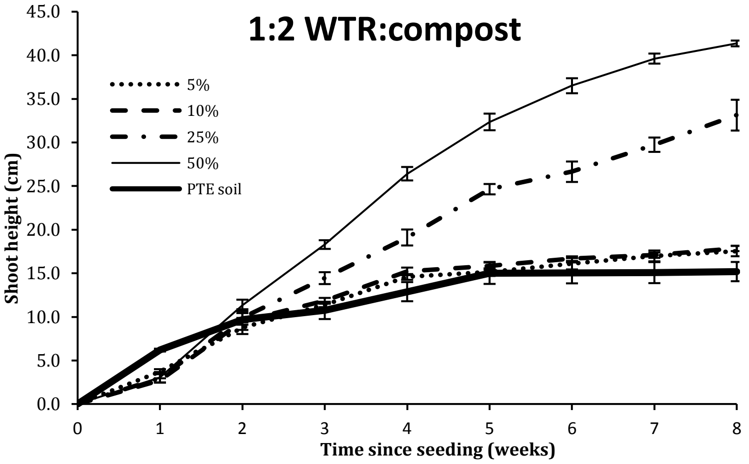
Appendix 5 - Weekly plant growth graphs

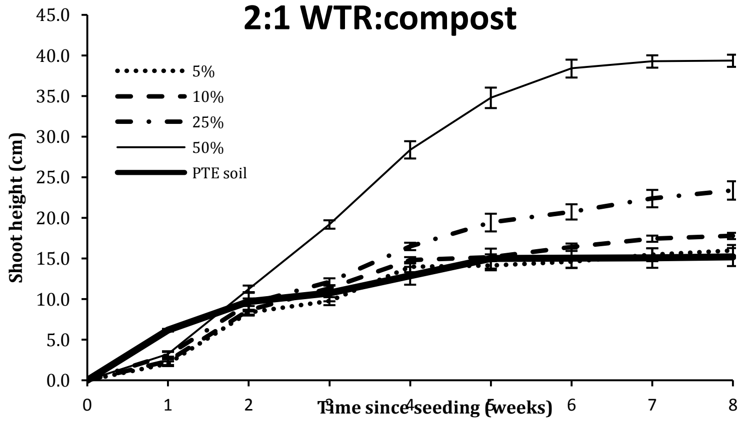


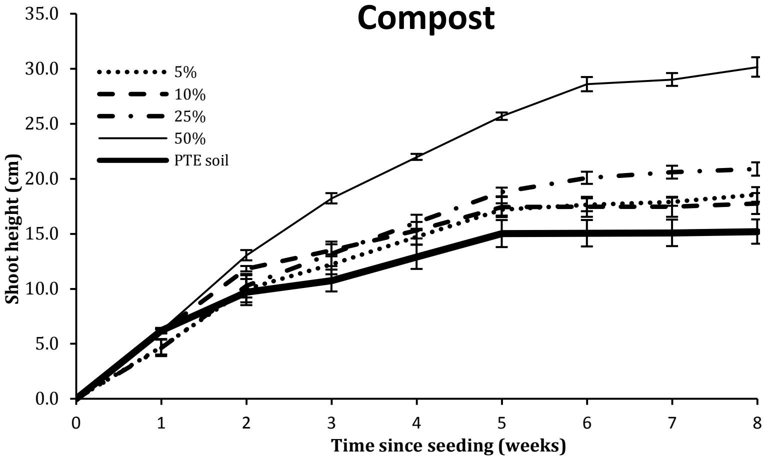





1:1 WTR:compost
Shoot height (cm)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
5%
10%
25%
50%
PTE soil
0
1
2
3
4
5
6
7
8
Time since seeding (weeks)


1:2 WTR:compost
Shoot height (cm)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
5%
10%
25%
50%
PTE soil
0
1
2
3
4
5
6
7
8
Time since seeding (weeks)

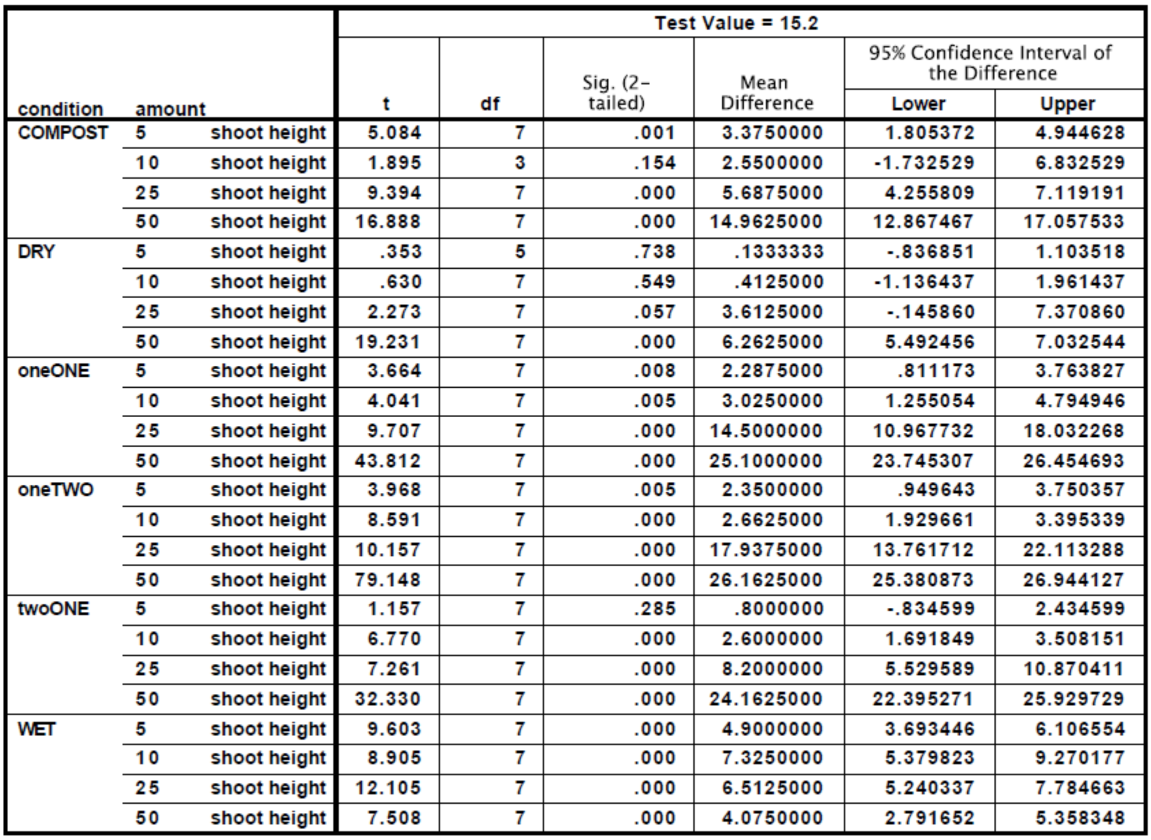

2:1 WTR:compost
Shoot height (cm)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
5%
10%
25%
50%
PTE soil
0
1
2
3
4
5
6
7
8
Time since seeding (weeks)


Compost
5%
10%
25%
50%
PTE soil
Shoot height (cm)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
1
2
3
4
5
6
7
8
Time since seeding (weeks)

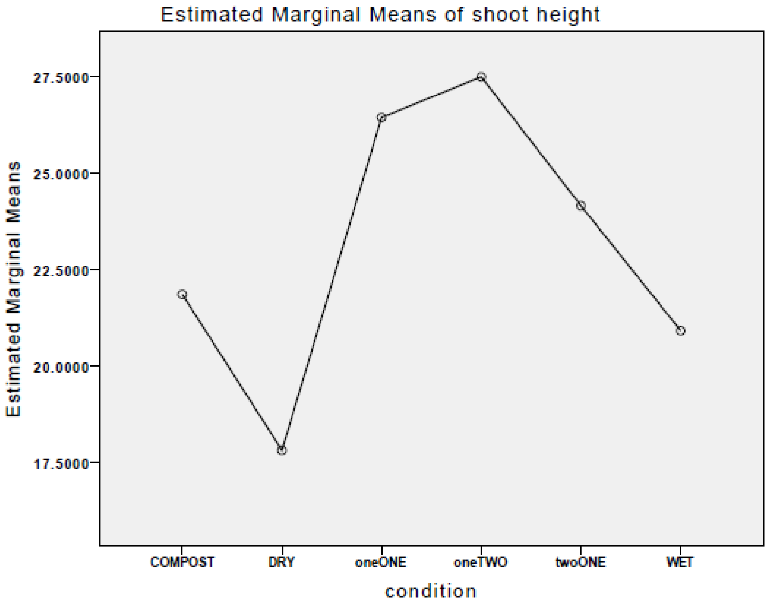
Appendix 6 - SPSS Statistical Outputs

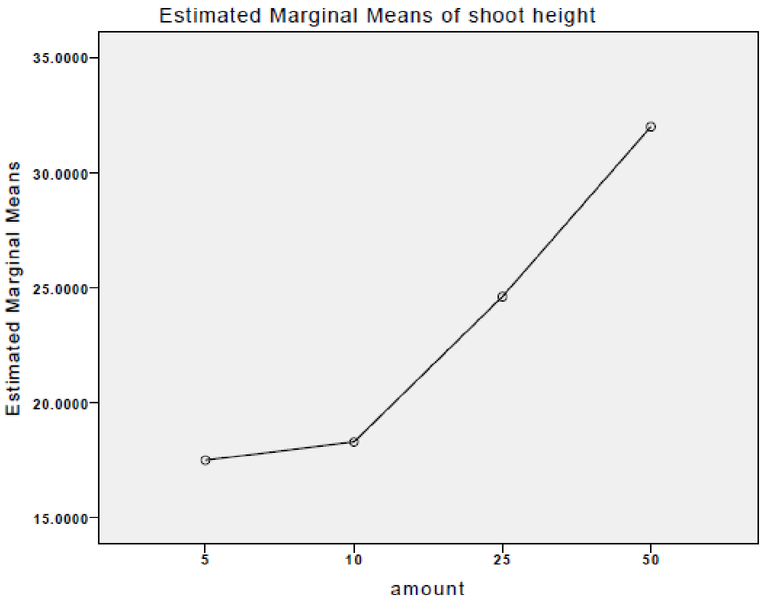
SHOOT HEIGHT:

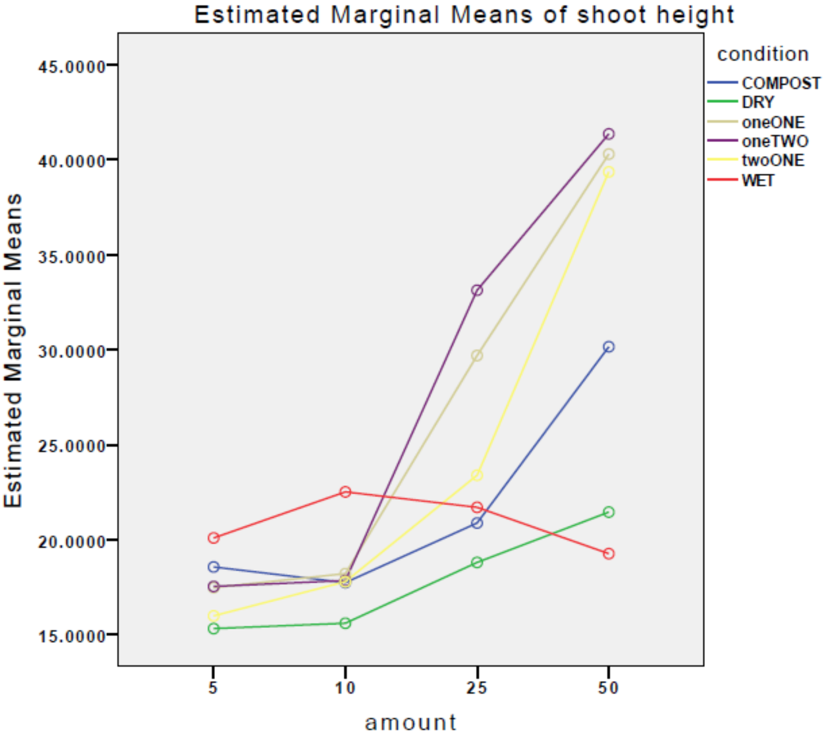
One-Sample Test



			Test Value = 15.2					
							95% Confidence Interval of the Difference	
condition	amount		t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
COMPOST	5	shoot height	5.084	7	.001	3.3750000	1.805372	4.944628
	10	shoot height	1.895	3	.154	2.5500000	-1.732529	6.832529
	25	shoot height	9.394	7	.000	5.6875000	4.255809	7.119191
	50	shoot height	16.888	7	.000	14.9625000	12.867467	17.057533
DRY	5	shoot height	.353	5	.738	.1333333	-.836851	1.103518
	10	shoot height	.630	7	.549	.4125000	-1.136437	1.961437
	25	shoot height	2.273	7	.057	3.6125000	-.145860	7.370860
	50	shoot height	19.231	7	.000	6.2625000	5.492456	7.032544
oneONE	5	shoot height	3.664	7	.008	2.2875000	.811173	3.763827
	10	shoot height	4.041	7	.005	3.0250000	1.255054	4.794946
	25	shoot height	9.707	7	.000	14.5000000	10.967732	18.032268
	50	shoot height	43.812	7	.000	25.1000000	23.745307	26.454693
oneTWO	5	shoot height	3.968	7	.005	2.3500000	.949643	3.750357
	10	shoot height	8.591	7	.000	2.6625000	1.929661	3.395339
	25	shoot height	10.157	7	.000	17.9375000	13.761712	22.113288
	50	shoot height	79.148	7	.000	26.1625000	25.380873	26.944127
twoONE	5	shoot height	1.157	7	.285	.8000000	-.834599	2.434599
	10	shoot height	6.770	7	.000	2.6000000	1.691849	3.508151
	25	shoot height	7.261	7	.000	8.2000000	5.529589	10.870411
	50	shoot height	32.330	7	.000	24.1625000	22.395271	25.929729
WET	5	shoot height	9.603	7	.000	4.9000000	3.693446	6.106554
	10	shoot height	8.905	7	.000	7.3250000	5.379823	9.270177
	25	shoot height	12.105	7	.000	6.5125000	5.240337	7.784663
	50	shoot height	7.508	7	.000	4.0750000	2.791652	5.358348




Estimated Marginal Means of shoot height
Estimated Marginal Means
35.0000
30.0000
25.0000
20.0000
15.0000
5
10
25
50
amount

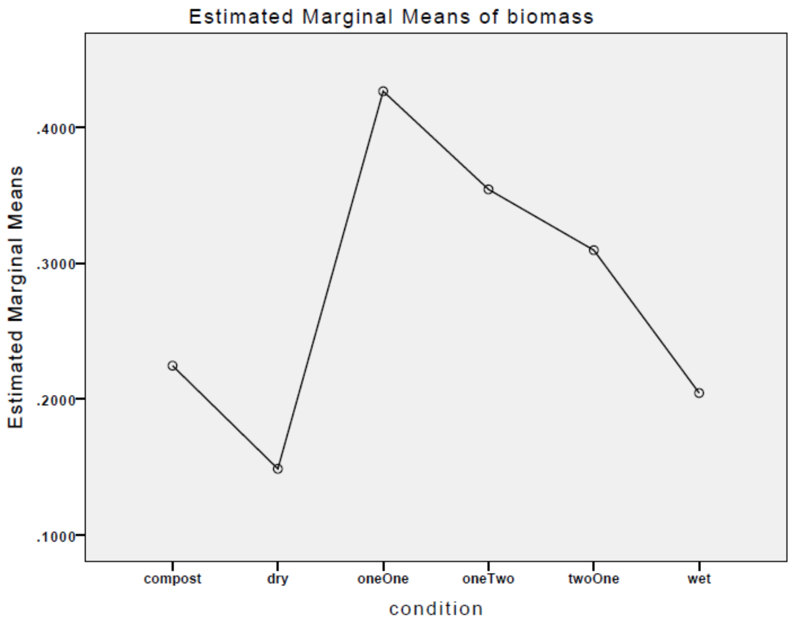

Estimated Marginal Means of shoot height
Estimated Marginal Means
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
5
10
25
50
amount
condition
COMPOST
DRY
oneONE
oneTWO
twoONE
WET

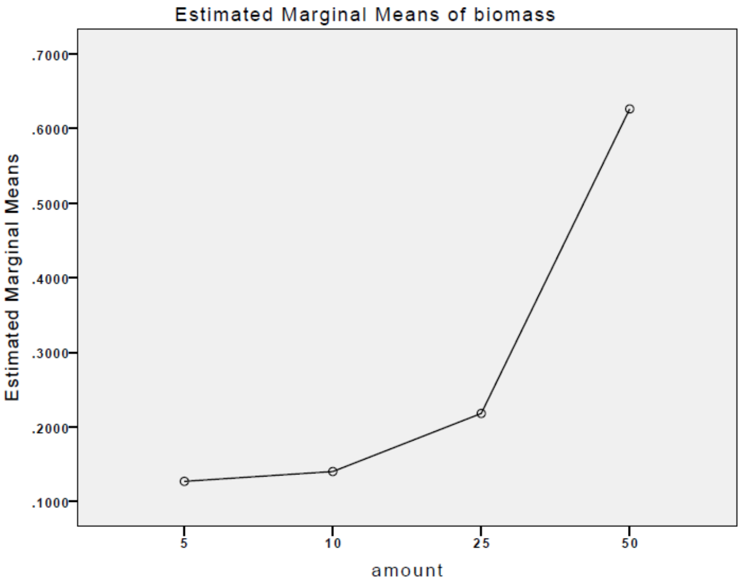
PLANT BIOMASS:

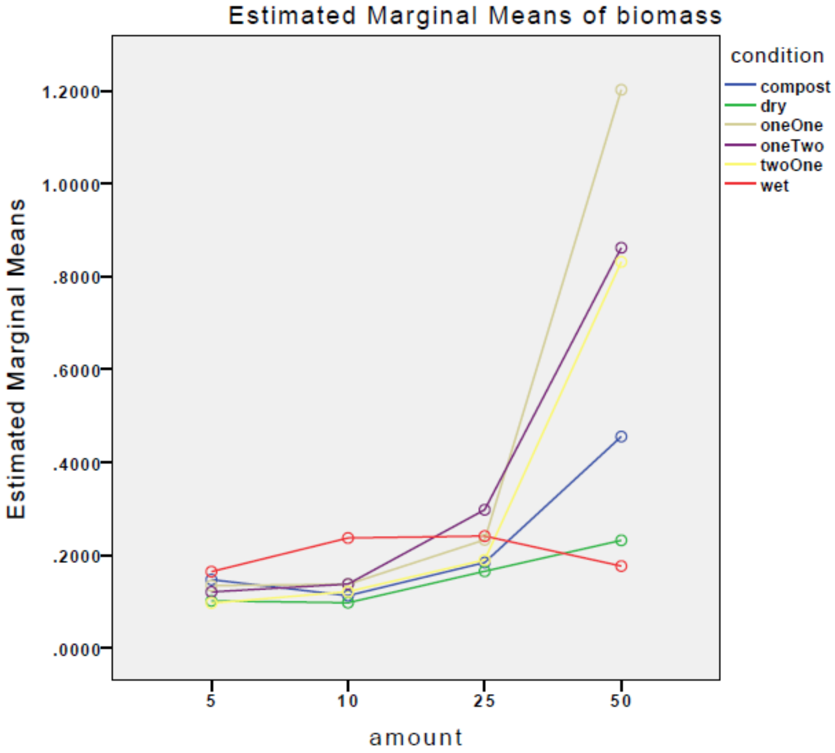
One-Sample Test

			Test Value = 0.091666667					
							95% Confidence Interval of the Difference	
condition	amount		t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
compost	5	biomass	5.722	7	.001	.0553333	.032469	.078198
	10	biomass	3.042	3	.056	.0208333	-.000965	.042632
	25	biomass	11.857	7	.000	.0922083	.073819	.110598
	50	biomass	10.027	7	.000	.3634583	.277745	.449172
dry	5	biomass	1.259	5	.263	.0095000	-.009889	.028889
	10	biomass	.480	7	.646	.0055833	-.021897	.033064
	25	biomass	2.735	5	.041	.0733333	.004399	.142268
	50	biomass	14.463	7	.000	.1399583	.117076	.162840
oneOne	5	biomass	3.974	7	.005	.0424583	.017197	.067719
	10	biomass	3.321	7	.013	.0454583	.013087	.077829
	25	biomass	5.274	7	.001	.1410833	.077825	.204342
	50	biomass	12.398	7	.000	1.1103333	.898565	1.322102
oneTwo	5	biomass	5.283	7	.001	.0288333	.015928	.041739
	10	biomass	6.272	7	.000	.0458333	.028555	.063112
	25	biomass	6.412	7	.000	.2058333	.129927	.281740
	50	biomass	11.467	6	.000	.7700476	.605727	.934368
twoOne	5	biomass	.534	7	.610	.0047083	-.016132	.025549
	10	biomass	3.735	7	.007	.0294583	.010810	.048107
	25	biomass	4.461	7	.003	.0978333	.045975	.149692
	50	biomass	9.798	7	.000	.7397083	.561196	.918221
wet	5	biomass	6.574	7	.000	.0725833	.046474	.098693
	10	biomass	7.797	7	.000	.1450833	.101081	.189085
	25	biomass	11.781	7	.000	.1492083	.119260	.179157
	50	biomass	6.806	7	.000	.0845833	.055196	.113971

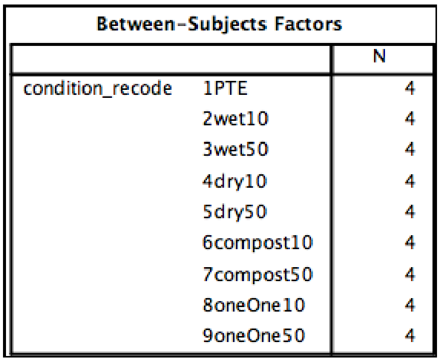
Profile Plots




Estimated Marginal Means of biomass
Estimated Marginal Means
.7000
.6000
.5000
.4000
.3000
.2000
.1000
5
10
25
50
amount

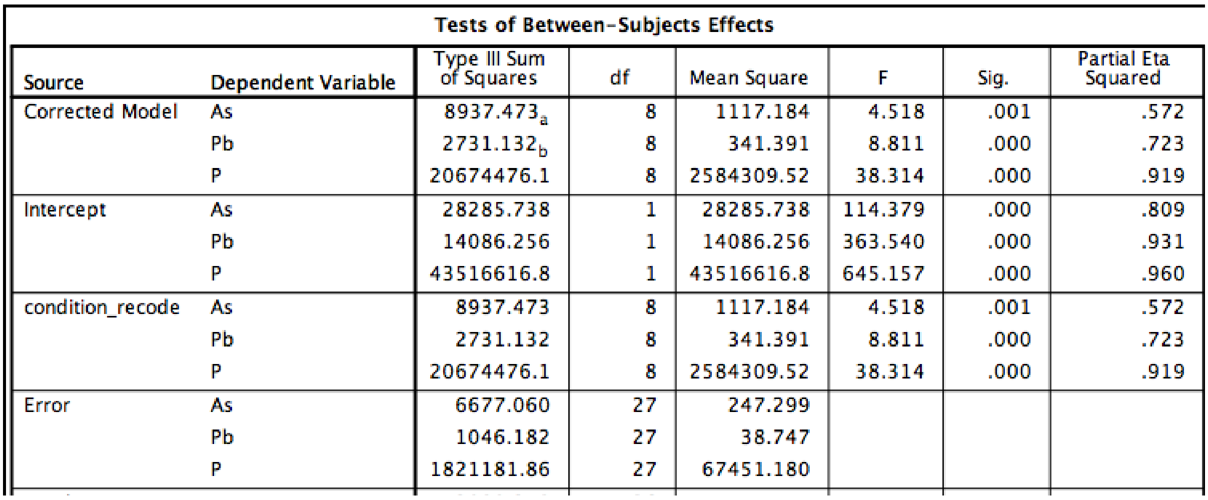

Estimated Marginal Means of biomass
condition
compost
dry
oneOne
oneTwo
twoOne
wet
Estimated Marginal Means
1.2000
1.0000
.8000
.6000
.4000
.2000
.0000
5
10
25
50
amount

ELEMENT DATA



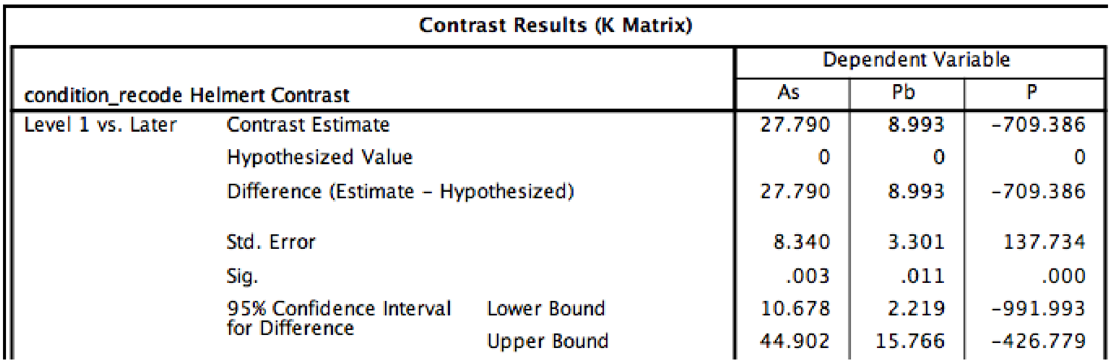
Between-Subjects Factors

		N
condition_recode	1PTE	4
	2wet10	4
	3wet50	4
	4dry10	4
	5dry50	4
	6compost10	4
	7compost50	4
	8oneOne10	4
	9oneOne50	4



Tests of Between-Subjects Effects

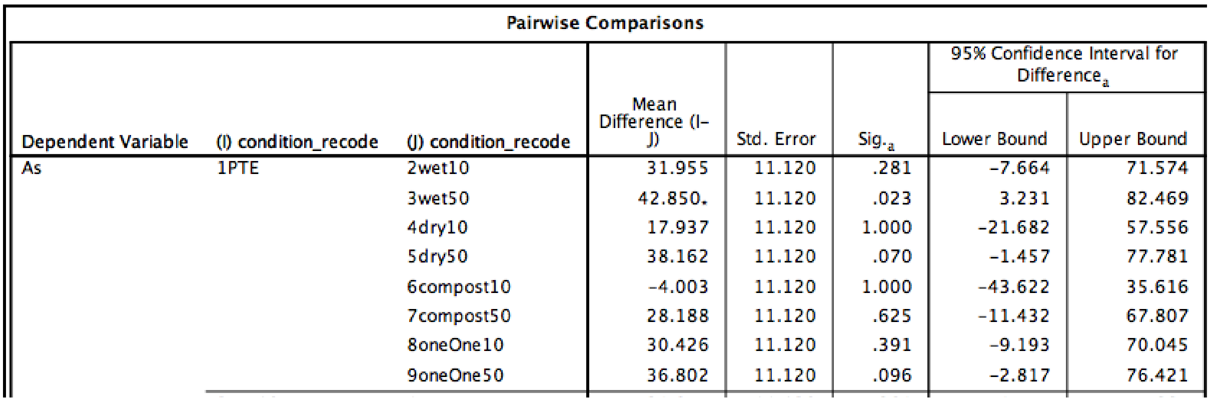
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	As	8937.473_a	8	1117.184	4.518	.001	.572
	Pb	2731.132_b	8	341.391	8.811	.000	.723
	P	20674476.1	8	2584309.52	38.314	.000	.919
Intercept	As	28285.738	1	28285.738	114.379	.000	.809
	Pb	14086.256	1	14086.256	363.540	.000	.931
	P	43516616.8	1	43516616.8	645.157	.000	.960
condition_recode	As	8937.473	8	1117.184	4.518	.001	.572
	Pb	2731.132	8	341.391	8.811	.000	.723
	P	20674476.1	8	2584309.52	38.314	.000	.919
Error	As	6677.060	27	247.299			
	Pb	1046.182	27	38.747			
	P	1821181.86	27	67451.180			



Contrast Results (K Matrix)

condition_recode Helmert Contrast			Dependent Variable		
			As	Pb	P
Level 1 vs. Later	Contrast Estimate		27.790	8.993	-709.386
	Hypothesized Value		0	0	0
	Difference (Estimate - Hypothesized)		27.790	8.993	-709.386
	Std. Error		8.340	3.301	137.734
	Sig.		.003	.011	.000
	95% Confidence Interval for Difference	Lower Bound	10.678	2.219	-991.993
		Upper Bound	44.902	15.766	-426.779

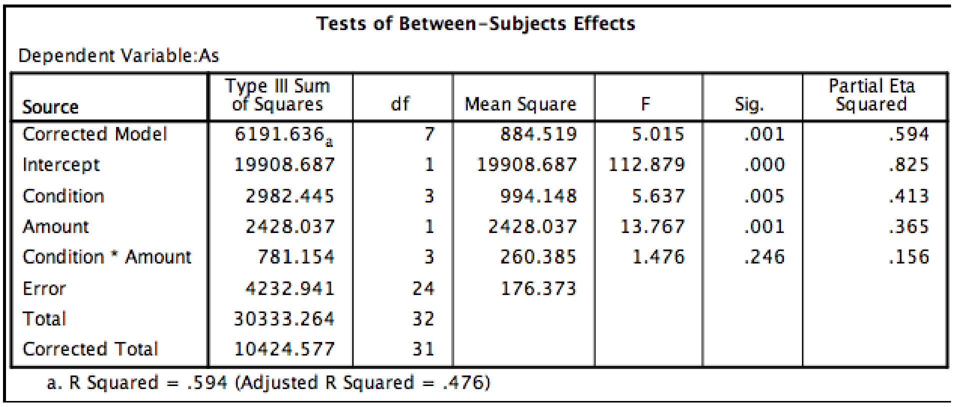
Arsenic



Pairwise Comparisons

Dependent Variable	(I) condition_recode	(J) condition_recode	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
						Lower Bound	Upper Bound
As	1PTE	2wet10	31.955	11.120	.281	-7.664	71.574
		3wet50	42.850*	11.120	.023	3.231	82.469
		4dry10	17.937	11.120	1.000	-21.682	57.556
		5dry50	38.162	11.120	.070	-1.457	77.781
		6compost10	-4.003	11.120	1.000	-43.622	35.616
		7compost50	28.188	11.120	.625	-11.432	67.807
		8oneOne10	30.426	11.120	.391	-9.193	70.045
		9oneOne50	36.802	11.120	.096	-2.817	76.421

Difference between 10% and 50% treatments:



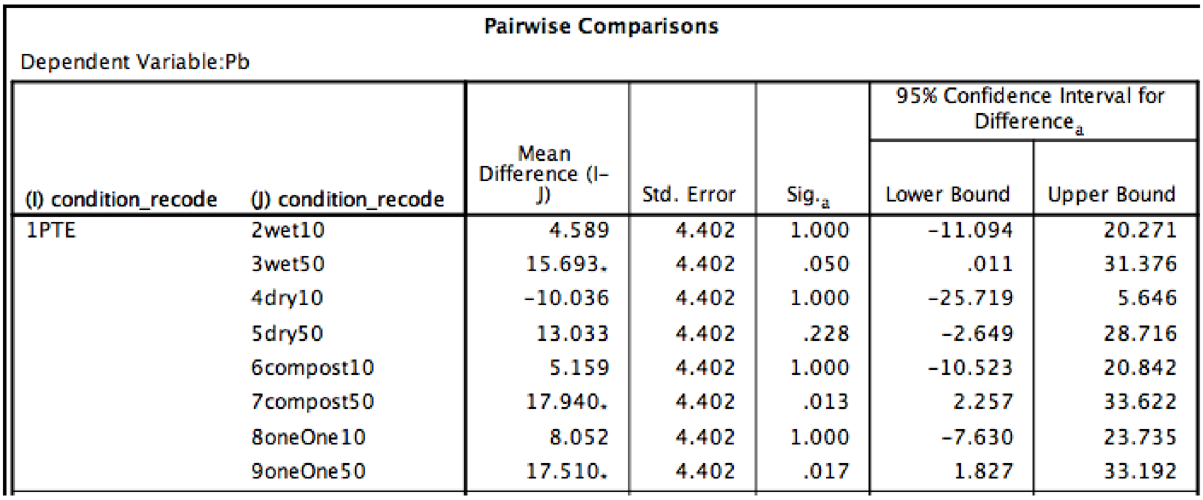
Tests of Between-Subjects Effects

Dependent Variable:As

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	6191.636[a]	7	884.519	5.015	.001	.594
Intercept	19908.687	1	19908.687	112.879	.000	.825
Condition	2982.445	3	994.148	5.637	.005	.413
Amount	2428.037	1	2428.037	13.767	.001	.365
Condition * Amount	781.154	3	260.385	1.476	.246	.156
Error	4232.941	24	176.373			
Total	30333.264	32				
Corrected Total	10424.577	31				

a. R Squared = .594 (Adjusted R Squared = .476)

Lead

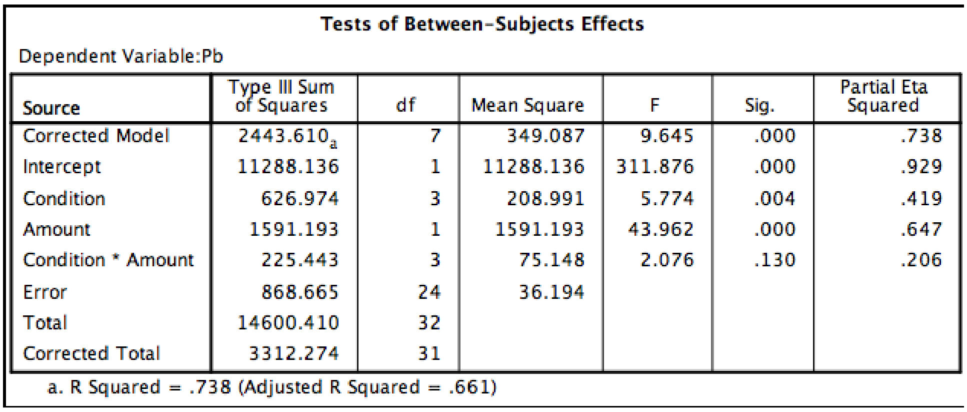


Pairwise Comparisons

Dependent Variable:Pb

(I) condition_recode	(J) condition_recode	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1PTE	2wet10	4.589	4.402	1.000	-11.094	20.271
	3wet50	15.693*	4.402	.050	.011	31.376
	4dry10	-10.036	4.402	1.000	-25.719	5.646
	5dry50	13.033	4.402	.228	-2.649	28.716
	6compost10	5.159	4.402	1.000	-10.523	20.842
	7compost50	17.940*	4.402	.013	2.257	33.622
	8oneOne10	8.052	4.402	1.000	-7.630	23.735
	9oneOne50	17.510*	4.402	.017	1.827	33.192

Difference between 10% and 50% treatments:



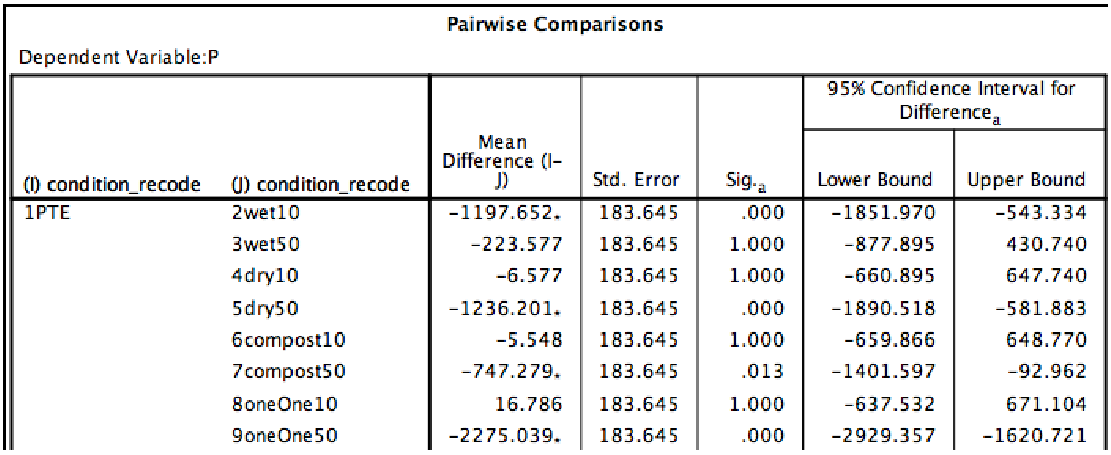
Tests of Between-Subjects Effects

Dependent Variable:Pb

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2443.610$_{a}$	7	349.087	9.645	.000	.738
Intercept	11288.136	1	11288.136	311.876	.000	.929
Condition	626.974	3	208.991	5.774	.004	.419
Amount	1591.193	1	1591.193	43.962	.000	.647
Condition * Amount	225.443	3	75.148	2.076	.130	.206
Error	868.665	24	36.194			
Total	14600.410	32				
Corrected Total	3312.274	31				

a. R Squared = .738 (Adjusted R Squared = .661)

Phosphorus

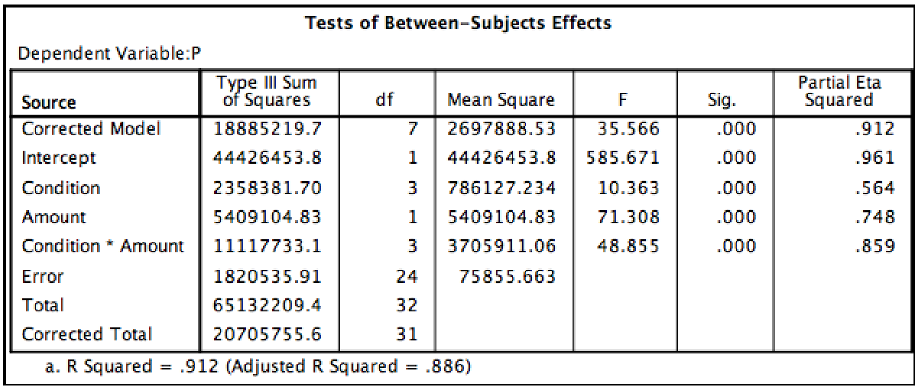


Pairwise Comparisons

Dependent Variable:P

(I) condition_recode	(J) condition_recode	Mean Difference (I-J)	Std. Error	Sig.$_{a}$	95% Confidence Interval for Difference$_{a}$	
					Lower Bound	Upper Bound
1PTE	2wet10	-1197.652.	183.645	.000	-1851.970	-543.334
	3wet50	-223.577	183.645	1.000	-877.895	430.740
	4dry10	-6.577	183.645	1.000	-660.895	647.740
	5dry50	-1236.201.	183.645	.000	-1890.518	-581.883
	6compost10	-5.548	183.645	1.000	-659.866	648.770
	7compost50	-747.279.	183.645	.013	-1401.597	-92.962
	8oneOne10	16.786	183.645	1.000	-637.532	671.104
	9oneOne50	-2275.039.	183.645	.000	-2929.357	-1620.721

Difference between 10% and 50% treatments:

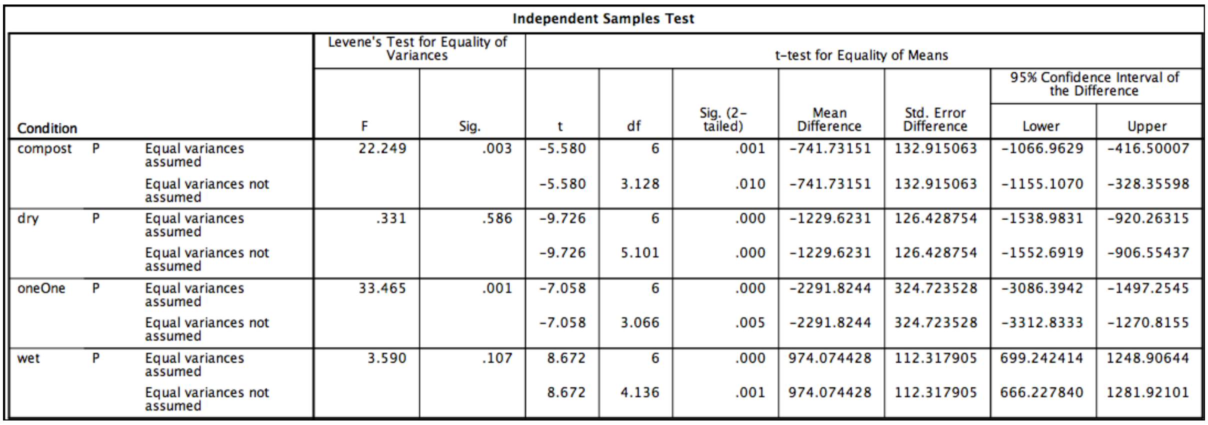


Tests of Between-Subjects Effects

Dependent Variable:P

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	18885219.7	7	2697888.53	35.566	.000	.912
Intercept	44426453.8	1	44426453.8	585.671	.000	.961
Condition	2358381.70	3	786127.234	10.363	.000	.564
Amount	5409104.83	1	5409104.83	71.308	.000	.748
Condition * Amount	11117733.1	3	3705911.06	48.855	.000	.859
Error	1820535.91	24	75855.663			
Total	65132209.4	32				
Corrected Total	20705755.6	31				

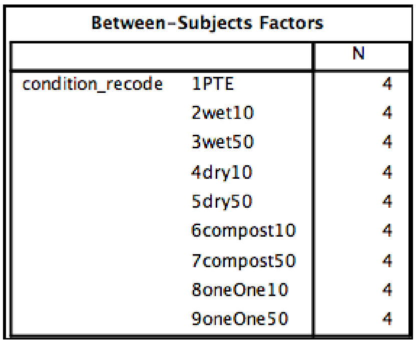
a. R Squared = .912 (Adjusted R Squared = .886)



Independent Samples Test

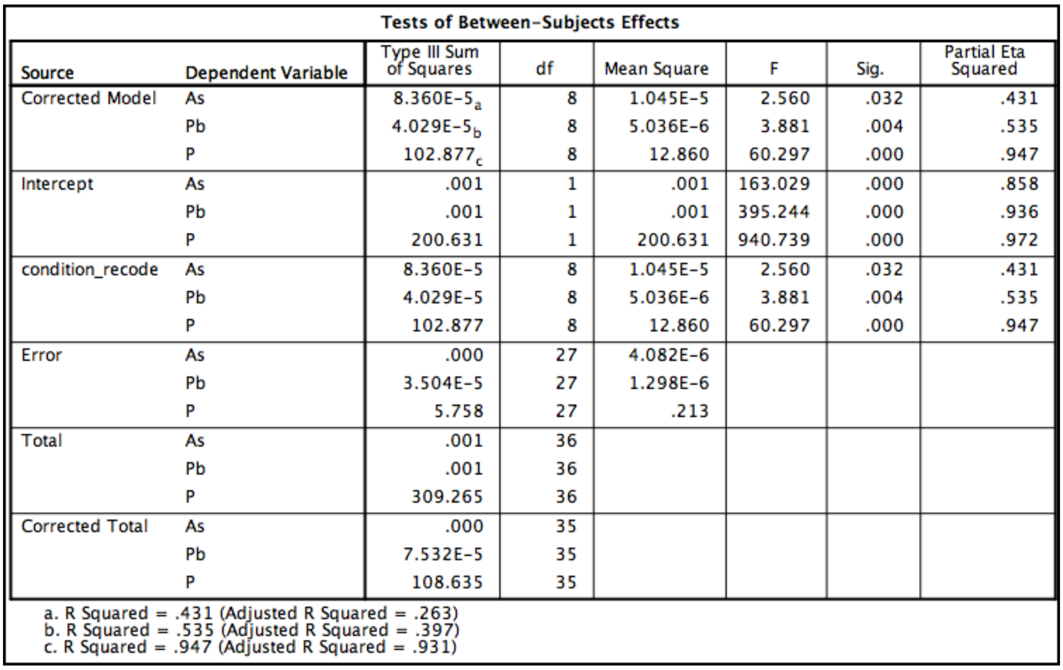
Condition			Levene's Test for Equality of Variances		t-test for Equality of Means						
			F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
compost	P	Equal variances assumed	22.249	.003	-5.580	6	.001	-741.73151	132.915063	-1066.9629	-416.50007
		Equal variances not assumed			-5.580	3.128	.010	-741.73151	132.915063	-1155.1070	-328.35598
dry	P	Equal variances assumed	.331	.586	-9.726	6	.000	-1229.6231	126.428754	-1538.9831	-920.26315
		Equal variances not assumed			-9.726	5.101	.000	-1229.6231	126.428754	-1552.6919	-906.55437
oneOne	P	Equal variances assumed	33.465	.001	-7.058	6	.000	-2291.8244	324.723528	-3086.3942	-1497.2545
		Equal variances not assumed			-7.058	3.066	.005	-2291.8244	324.723528	-3312.8333	-1270.8155
wet	P	Equal variances assumed	3.590	.107	8.672	6	.000	974.074428	112.317905	699.242414	1248.90644
		Equal variances not assumed			8.672	4.136	.001	974.074428	112.317905	666.227840	1281.92101

TRANSFER COEFFICIENT DATA



Between-Subjects Factors

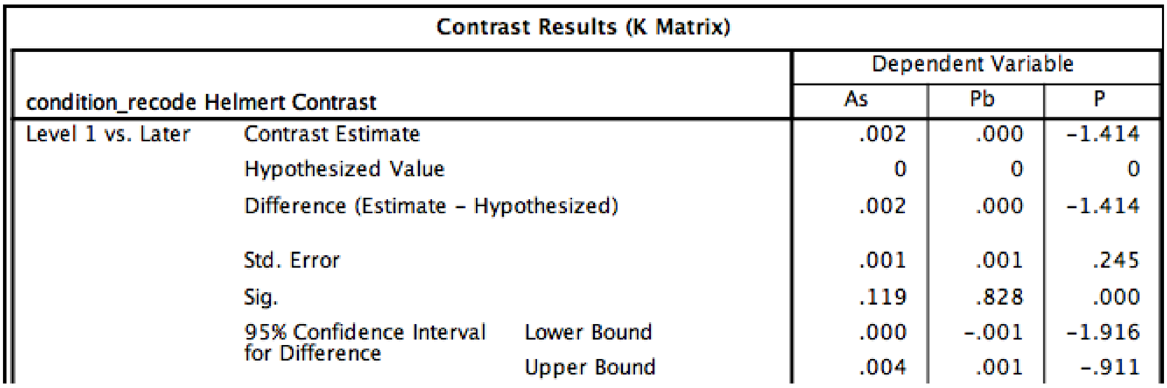
		N
condition_recode	1PTE	4
	2wet10	4
	3wet50	4
	4dry10	4
	5dry50	4
	6compost10	4
	7compost50	4
	8oneOne10	4
	9oneOne50	4



Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	As	8.360E-5^a	8	1.045E-5	2.560	.032	.431
	Pb	4.029E-5^b	8	5.036E-6	3.881	.004	.535
	P	102.877^c	8	12.860	60.297	.000	.947
Intercept	As	.001	1	.001	163.029	.000	.858
	Pb	.001	1	.001	395.244	.000	.936
	P	200.631	1	200.631	940.739	.000	.972
condition_recode	As	8.360E-5	8	1.045E-5	2.560	.032	.431
	Pb	4.029E-5	8	5.036E-6	3.881	.004	.535
	P	102.877	8	12.860	60.297	.000	.947
Error	As	.000	27	4.082E-6			
	Pb	3.504E-5	27	1.298E-6			
	P	5.758	27	.213			
Total	As	.001	36				
	Pb	.001	36				
	P	309.265	36				
Corrected Total	As	.000	35				
	Pb	7.532E-5	35				
	P	108.635	35				

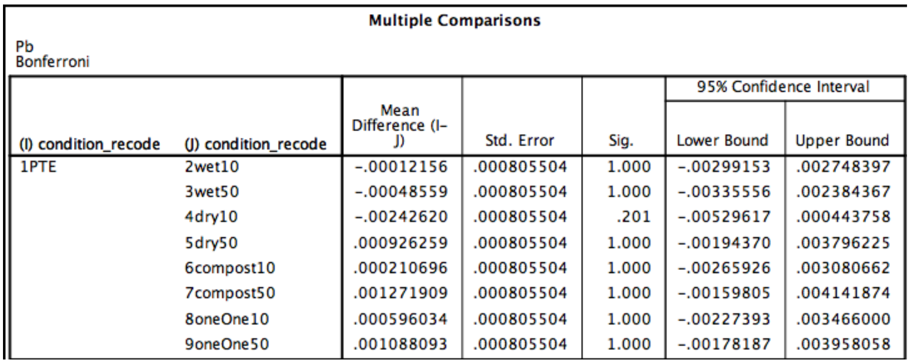
a. R Squared = .431 (Adjusted R Squared = .263)
b. R Squared = .535 (Adjusted R Squared = .397)
c. R Squared = .947 (Adjusted R Squared = .931)



Contrast Results (K Matrix)

condition_recode Helmert Contrast			Dependent Variable As	 Pb	 P
Level 1 vs. Later	Contrast Estimate		.002	.000	-1.414
	Hypothesized Value		0	0	0
	Difference (Estimate - Hypothesized)		.002	.000	-1.414
	Std. Error		.001	.001	.245
	Sig.		.119	.828	.000
	95% Confidence Interval for Difference	Lower Bound	.000	-.001	-1.916
		Upper Bound	.004	.001	-.911

Lead

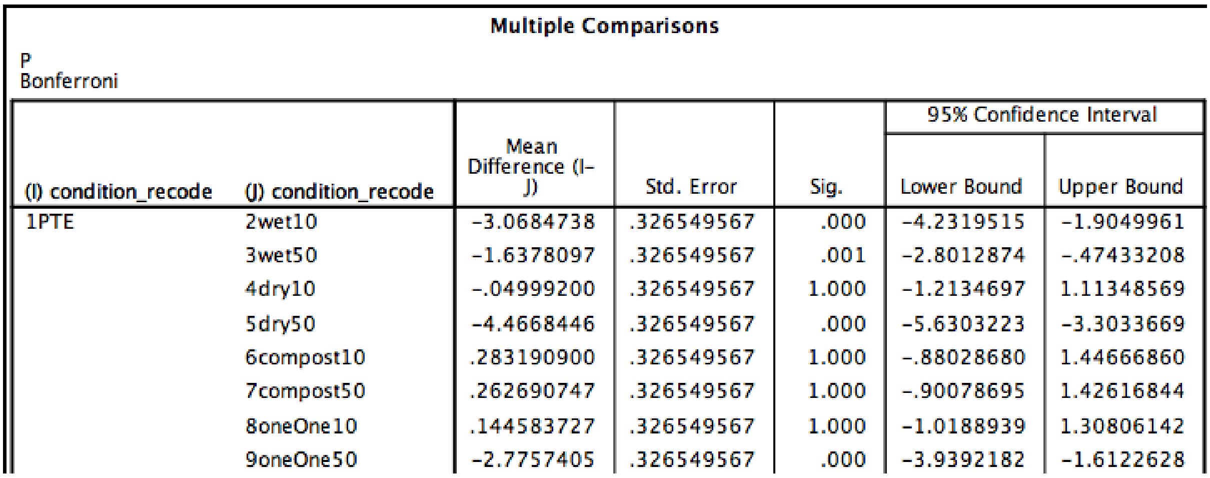


Multiple Comparisons

Pb
Bonferroni

(I) condition_recode	(J) condition_recode	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	 Upper Bound
1PTE	2wet10	-.00012156	.000805504	1.000	-.00299153	.002748397
	3wet50	-.00048559	.000805504	1.000	-.00335556	.002384367
	4dry10	-.00242620	.000805504	.201	-.00529617	.000443758
	5dry50	.000926259	.000805504	1.000	-.00194370	.003796225
	6compost10	.000210696	.000805504	1.000	-.00265926	.003080662
	7compost50	.001271909	.000805504	1.000	-.00159805	.004141874
	8oneOne10	.000596034	.000805504	1.000	-.00227393	.003466000
	9oneOne50	.001088093	.000805504	1.000	-.00178187	.003958058

Phosphorus



Multiple Comparisons

P
Bonferroni

(I) condition_recode	(J) condition_recode	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	 Upper Bound
1PTE	2wet10	-3.0684738	.326549567	.000	-4.2319515	-1.9049961
	3wet50	-1.6378097	.326549567	.001	-2.8012874	-.47433208
	4dry10	-.04999200	.326549567	1.000	-1.2134697	1.11348569
	5dry50	-4.4668446	.326549567	.000	-5.6303223	-3.3033669
	6compost10	.283190900	.326549567	1.000	-.88028680	1.44666860
	7compost50	.262690747	.326549567	1.000	-.90078695	1.42616844
	8oneOne10	.144583727	.326549567	1.000	-1.0188939	1.30806142
	9oneOne50	-2.7757405	.326549567	.000	-3.9392182	-1.6122628

Appendix 7 - Relevant Publications

1. Johnson K., Purvis G., Lopez-capel E., Peacock C., Gray N., Wagner T., Marz C., Bowen L., Ojeda J., Finlay N., Robertson S., Worrall F., Greenwel H. (2015). Towards a mechanistic understanding of carbon stabilisation in manganese oxides. Nature Communications, 6.

2. McCann, C.M, Gray, N.D., Tourney, J., Davenport, R.J., Wade, M., Finlay, N.C., Hudson-Edwards, K.A., and Johnson, K.L. (2015). Remediation of a historically Pb contaminated soil using a model natural Mn oxide waste. Chemosphere, 138, 211-217.

3. Bambra C, Robertson S, Kasim A, Smith J, Cairns-Nagi J M, Copeland A, Finlay N, Johnson K, (2014) "Healthy land? An examination of the area-level association between brownfield land and morbidity and mortality in England" Environment and Planning A 46(2) 433 – 454.