INVESTIGATION OF SOIL AND GROUNDWATER ACIDITY, STIRLING

REPORT TO THE MINISTER FOR THE ENVIRONMENT AND HERITAGE

April 2002

Water & Rivers Commission
Department of Environmental Protection

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Identification of Problem and Immediate Response

Concern about acidic groundwater in Stirling was raised in mid-December 2001 by a concerned resident whose garden was dying. The resident contacted the City of Stirling, and preliminary testing by the City of Stirling indicated that the groundwater was extremely acidic and contained high metal concentrations. The City of Stirling contacted the Swan Regional Office of the Water and Rivers Commission on 20 December 2001, and the Commission provided technical advice to Stirling on 21 December 2001 that the problem was likely to be due to the disturbance of acid sulfate soils.

The City of Stirling invited officers from the Commission to a meeting and site inspection about the issue on 7 January 2002 and this indicated the scale of the problem. On 10 January 2002 the Department of Health (DOH) released a press release about acidity and the City of Stirling delivered letters warning of the issue to householders in an area that could be affected by groundwater acidity. The letter also indicated that the Water and Rivers Commission would undertake groundwater testing to determine the extent of the acidity problem.

Further testing was carried out on the initial affected bore for arsenic on 14 January 2002 as this contaminant was not originally sampled and commonly occurs in groundwater in areas affected by acid sulfate soils. The results of chemical analysis indicating a high arsenic concentration were received by the Commission on 29 January 2002. This was immediately referred to DOH. This agency put out a media release about the detection of arsenic on 1 February 2002.

Investigations

Since January 2002 a major program of investigation and testing has been undertaken. Preliminary groundwater sampling indicated that arsenic and heavy metal concentrations of possible health concern were only found where groundwater was acidic (less than pH 5.5), and therefore measurement of pH was used a screening tool to select bores that required chemical analysis for arsenic and heavy metals.

A total of 802 domestic bores were screened for pH, and 49 bores were sampled for arsenic and heavy metals. Of these bores, 22 were found to have arsenic concentrations that exceeded the Australian drinking water guideline value (7µg/L).

Between 14 and 22 February, the Commission installed 13 investigation bores to determine possible sources of acidity and arsenic contamination. The drilling indicated that the major sources of contamination were new residential developments on the Roselea and Hamilton Lake estates and excavated wetlands in public open space on Spoonbill Reserve. Drilling and groundwater sampling downgradient of peat stockpiles and excavated lakes indicated that groundwater was acidic to 3-5 metres below the watertable but that pH values returned to background values of 6 to 7 at greater depths.

Vegetable, fruit and soil samples were collected from 11 premises to determine whether crops were accumulating heavy metals and arsenic from soil. None of the plant samples exceeded the Australian food standard for arsenic, but 14 samples exceeded the standard for lead. Lead in food is unlikely to be associated with groundwater acidification but the Department of Health is continuing to investigate this issue.

Of a total of 20 peat samples taken from peat stockpiles on development sites, nine indicated that the material had a moderate to high acid generation potential, suggesting that the peat is the major source of acidity in the area.

Causes of the Acidity and Arsenic in the Groundwater

There are several factors that have contributed to groundwater acidity in the area. These include:

- *Dewatering* – the water table in the development areas was lowered by as much as 6 metres to allow the excavation and removal of peat which was unsuitable for housing foundations. Additional dewatering was carried out in the area to construct sewerage infrastructure.
- *Peat stockpiles* – peat excavated from the development areas was stockpiled before removal. Some of this material had a high acid generation potential, and visual inspection of the stockpiles indicated the presence of large amounts of jarosite and other sulfate salts.
- *Peat fire* – a fire burning within peat in the development area for about three weeks is also likely to have contributed to oxidation of sulfide minerals.
- *Excavated wetlands* – lakes in public parks had been created by excavating soils to the water table and stockpiling the spoil in the centre of the lakes to create islands. Many shallow bores downgradient in the direction of groundwater flow from these lakes had low pH values and high arsenic concentrations.
- *Climatic factors* – Perth has had a long succession of dry winters, and the winter of 2001 was exceptionally dry. The water table during the summer months of 2001/2002 was lower than average, and many shallow bores ran dry due to the combined effects of the dry weather and dewatering.

Extent of Acidity at Stirling

Investigations to date show that groundwater acidity issue is restricted to 49 domestic bores immediately downgradient in the direction of groundwater flow from the Roselea and Stirling Lakes residential estates, and the Spoonbill Reserve.

Public Health and Environmental Implications - Test results discussion

Arsenic and heavy metal concentrations in groundwater in the area are unlikely to have a significant effect on public health as groundwater in the area is mostly used for irrigation and not for drinking. The Department of Health recommends that water from domestic bores in the metropolitan area is not used for drinking, mainly because of the risk of bacterial contamination.

Although some Water Corporation water supply bores occur in the area, these pump water from deep in the aquifer, and ongoing monitoring indicates that these are unaffected by contamination.

Immediate Corrective Action

The stockpiling of peat on the Stirling Lakes estate is in breach of the dewatering conditions for the site, and the proponent has been directed to remove the material. Under Section 73 of the Environmental Protection Act, proponents on the Roselea estate have been served with notices to remove the stockpiled peat from the area. It is proposed that proponents on the Stirling Lakes estate be served with a Section 73 notice shortly.

History of Regulatory actions

Roselea development was subject to Water and Rivers Commission groundwater abstraction permit and licence to cover the company's dewatering operations that included the submission of a Sampling and Analysis Plan for approval. Monitoring results between December 1999 to April 2001 did not indicate adverse changes in the groundwater condition during the active dewatering periods. Although some metals such as aluminium, zinc and cadmium were occasionally detected in the groundwater, it did not however, impact on the receiving surface waters. Since that time no further monitoring results have been received. Dewatering operations ceased in August 2001. Roselea's groundwater permit expired on 17 December 2001. An application has been received for renewal and is currently being reviewed.

In May 2001 several complaints were received by the Department of Environmental Protection about the peat stockpile fire at the Roselea Estate. Investigation revealed that the peat was smouldering for about three weeks impacting on the local residents with offensive odour and smoke.

Stirling Lakes was granted a groundwater permit on 26 May 2000 with commitment from the developer (MM Development) to maintain water quality standards (ANZECC, 1992) including the removal of peat as soon as practicable following extraction. Monitoring results indicated little variation in pH values between June 2000 and May 2001.

Departmental fax on 11 September 2000 to Welltech (Dewatering Operator) indicated that the monitoring results showed marginal decline in the groundwater pH and slight elevation of zinc and lead contamination. Regular lime dosing was undertaken to overcome the problem.

Statutory Approvals for Developments

The assessment of new urban developments is the joint responsibility of the Department of Environmental Protection (DEP), the Environmental Protection Authority (EPA), the Western Australian Planning Commission (WAPC), and local government. The bulk of land development proposals are informally assessed by the EPA (DEP under delegation) on the basis of competent and responsible developers ensuring developments are environmentally acceptable. The system recognises the degree of management that should be done by the government agencies while not subsidising from the public purse the development industry which reaps the benefits of projects. Currently there are about 965 informal assessments per year out of 1000 proposals referred to the EPA (ie EPA formally assesses 35 proposals a year). The EPA/DEP receives about 160 subdivision referrals per year and 350 rezoning proposals. Currently urban development approvals are not referred to WRC, although this system will change as part of the formation of the Department of Environment, Water and Catchment Protection.

Future Management of Acid Sulfate Soil Exposures

The significance of acid sulfate soils is widely understood in the literature and is relevant on the eastern seaboard. Historically, however, this issue has not been seen as critical in urban Perth. As noted above, responsibility for environmental management of urban development rests across state and local governments and developers. The Stirling groundwater acidity and arsenic contamination issue highlights the need for state planning and environmental approvals processes and the management actions of developers to better identify and respond to the potential for acid sulfate soils exposure.

Unlike many other states, Western Australia does not have a State Planning Policy that specifically addresses acid sulfate soils, and consequently there is an ongoing risk that sites with acid sulfate soils will be developed inappropriately in WA. The soil characteristics in the Stirling area are not typical of acid sulfate soils found in other states. Further research is required to properly identify the characteristics for acid forming soils in WA. Issues such as the groundwater acidity problem in Stirling could be effectively managed if WA were to develop and adopt an acid sulfate SPP modelled on Queensland and New South Wales policies. This would ensure that acid sulfate soils are considered at a very early stage in a development program before soils are disturbed and acidity problems are created.
It is also recommended that Western Australia adopts and implements measures set out in the National Strategy for the Management of Coastal Acid Sulfate Soils (available at web site http://www.affa.gov.au/docs/operating_environment/armcanz/pubsinfo/ass/ass.html).

The principal objectives of the National Strategy are:

1. to identify and define the extent of acid sulfate soils in coastal areas of Australia
2. to avoid disturbance of coastal acid sulfate soils wherever possible
3. to mitigate impacts when disturbance of these soils is unavoidable
4. to rehabilitate environmental impacts caused by the disturbance of acid sulfate soils.

In Western Australia, the first objective is particularly important as there is currently only a very general understanding of the distribution of acid sulfate soils within the State. Queensland and New South Wales have produced detailed acid-sulfate risk maps for coastal areas, and a similar mapping exercise in Western Australia could identify areas where inappropriate development may cause acidity problems.

In February 2002, the Water and Rivers Commission conducted a desktop study of areas with potential for acid sulfate soils (PASS) in the Perth metropolitan area. This indicative study is a first pass only to guide future detailed mapping of PASS and ASS. DEWCP will now write to each metropolitan local government authority advising them of the potential for sulfate soils presence in their areas asking that the issue be taken into consideration for any future residential developments. DEWCP will also write to the WA Planning Commission, Urban Development Institute of Australia (WA) and Association of Consulting Engineers (WA) ensuring they are aware of the issue and that it is considered as part of their deliberations.

Conclusion and Recommendations

The acidification of groundwater in Stirling presents a considerable management challenge for the State. It is manageable, provided State and local governments and developers act on recommendations contained in this report. Until recently, acid sulfate soils have not been a significant issue in Western Australia but the episode in Stirling provides a serious wake-up call to lift the profile of the issue and our capacity to respond to it.

The following measures are recommended to ameliorate the groundwater acidity and arsenic contamination issue in Stirling:

1. ***Development of Acid Sulfate Soil Management Plans*** - It is recommended that no further dewatering or peat excavation takes place on the Roselea or Stirling Lakes estates until the proponents have developed an acid sulfate management plan and have demonstrated to the satisfaction of regulatory authorities that the distribution of Potential Acid Sulfate Soil (PASS) has been identified and that management measures are in place to prevent further groundwater quality impacts.

2. ***Backfilling of acid surface water bodies*** – It is recommended that options for remedying the conditions of the acidic water bodies on Spoonbill Reserve and the excavated surface water bodies on the Roselea estate be investigated immediately. A practical option is to backfill the affected lakes and water bodies with alkaline material (such as crushed limestone).

3. ***Removal of peat stockpiles*** – Peat stockpiles should be removed from the site to prevent further acid generation on the Roselea and Stirling Lakes estates. The material should be treated to prevent formation of acid conditions and safely disposed of.

4. ***Water table management*** – Groundwater pumping in the area should be managed to minimise water table declines to prevent ongoing acidification. It is recommended that the Water and Rivers Commission instigate the development of a groundwater management strategy for the area in consultation with the City of Stirling, adjoining developers and local residents to prevent further groundwater acidification occurring. Any further development would need to be consistent with the groundwater management strategy.

5. ***Rehabilitation and monitoring of affected Domestic Bores*** – A combination of climatic variation and peat disturbance has contributed to the acidification of groundwater. Domestic bores in the immediate area that are affected by acidity should be remediated such as by bore deepening. It is recommended that the adjoining developers and the City of Stirling consult with the affected bore owners in this regard. It is also recommended that the City of Stirling facilitate ongoing monitoring of pH to ensure that new bores are not affected by groundwater acidity. Bores with pH values less than 5.5 should be sampled by the City of Stirling for arsenic and heavy metal content with advice from the Water and Rivers Commission.

6. ***Assessment of the Effects of Acidity on urban infrastructure*** - The presence of acid sulfate soils in the vicinity of the Roselea and Stirling Lakes estates may present a long term threat to sub-surface infrastructure. It is recommended that the owners of sub-surface infrastructure carry out an assessment of any current and potential impacts of acidity on infrastructure in the area.

7. ***Assessment of drainage impacts on Herdsman Lake*** - It is recommended that the Water and Rivers Commission, in consultation with the City of Stirling and the Water Corporation, undertake a risk assessment of the effects of drainage from the vicinity of the Roselea and Hamilton Lake estates on Herdsman Lake and implement appropriate management measures to protect this wetland.

Further general recommendations for future management

8. The State should develop and implement a Statement of Planning Policy on Acid Sulfate Soils modelled on those developed in other states.

9. It is recommended that Western Australia adopts and implements measures set out in the National Strategy for the Management of Coastal Acid Sulfate Soils.

10. The State should support the National Coastal Mapping project for ASS proposed by the National Coastal Acid Sulfate Soil Committee (NatCASS).

11. It is recommended that the EPA should review its informal review process to ensure issues such as acid sulfate soils are highlighted as part of management requirements for developers.

NOTE: Recommendations 8 through 10 are unfunded and cannot be implemented with current departmental resources.

1.0 INTRODUCTION

Future urban development in the Perth metropolitan area is likely to encroach into a number of existing and historical wetlands where sediments commonly contain iron sulfide minerals, principally pyrite. These minerals form under waterlogged conditions when there is no oxygen available to allow the sulfides to decompose. The sulfide-rich material is commonly known as potential acid sulfate soil (PASS) because it has the potential to oxidise to sulfuric acid on exposure to air. Exposing of the pyrite to air by excavation, drainage, stockpiling of peaty materials or lowering of groundwater table can cause the sulfide to form sulfuric acid, often releasing toxic metals from the soils including arsenic into groundwater. Until recently the presence of PASS in wetlands has not been fully investigated. Inappropriate management of these areas can produce immediate and a longer term impacts with substantial health, environmental and economic consequences such as:

- polluting water supplies with aluminium, iron, arsenic and other metals, possibly causing significant health problems if untreated water is used for drinking;
- corroding concrete and metal structures by acid water; and
- causing death of aquatic organisms and riparian vegetation.

Under natural conditions, PASS may produce some acidity after drought periods as a result of oxidation of the exposed sulfides. In a natural system the main driving forces for water fluctuations are evapotranspiration and rainfall[1]. Recent increases in groundwater abstraction for irrigation and excessive dewatering by urban developers has contributed to declining water table in the Stirling area. The situation is further compounded by the stockpiling of thousands of tonnes of pyritic materials that have allowed the rapid oxidation of the sulfides to form sulfuric acid. Surface water bodies in a development site were found to be acidic with pH values between 2 and 3. The council lakes within a recreational park located north west of the development site recorded a pH level of less than 3.2.

Several domestic bores next to the development site were impacted by acidic groundwater ranging from pH 2.6 and 4 at a depth of 12-15 metres below ground level.

The groundwater acidity screening conducted between January and February 2002 on more than 800 domestic bores, revealed more than 40 bores are affected by acidity between pH 2.6 and 5.5 down to a depth of 10 – 12 metres. More than 20 domestic bores were contaminated with arsenic and other metals. The arsenic concentrations exceeded the National Health and Medical Research Council recommended threshold of 7ug/L for drinking water.

[1] Cook, F.J et al – Irrigation and drainage: Effects on acidity export from acid sulfate soils

2.0 BACKGROUND

2.1 Geological setting

The city of Perth lies on the Swan Coastal Plain, an alluvial and aeolian plain largely formed of Quaternary sand and sand/limestone dunes that are as much as 100 metres thick. The plain lacks surface drainage due the high permeability of the sediments (that is, surface water soaks in quickly), and the only fresh surface water in the region is in wetlands in interdunal depressions which are surface expressions of the water table of an extensive unconfined aquifer. Groundwater is extremely important for water supply, and provides about 70% of all water used in the region. There are more than 130 000 domestic bores in the metropolitan area that are used for garden watering. On average, 25-30% of houses in Perth have domestic bores, and in some suburbs, such as Stirling, where the water table is very shallow, almost all houses have bores.

The coastline in Perth does not have mangroves or salt marshes typically associated with acid sulfate soils on the eastern seaboard, and most of the sandy soils in the region have little or no acid generation potential except near existing or historical wetlands where pyritic peat deposits up to 6 metres thick may occur. The dewatering and excavation of these soils for urban development near wetlands can cause environmental impacts on wetlands, and there are potential health effects on domestic bore users from elevated arsenic concentrations (up to 800 μg/L) and low pH values (as low as pH 2.4) in these areas. The most significant occurrence of acid sulfate soil impacts in Perth was recorded this year in the suburb of Stirling associated with new urban developments in the area.

2.2 Discovery of the Stirling groundwater acidity issue

Concern about acidic groundwater in Stirling was initially raised in mid-December 2001 by a resident in Jones Street who found that his vegetable crop had progressively been affected by water from his bore. The resident contacted the City of Stirling, and testing carried out by Environmental Health Officers indicated that the groundwater was extremely acidic (pH less than 3) and contained very high metal concentrations (particularly aluminium and iron) and high levels of sulfate. The City of Stirling contacted the Swan regional office of the Water and Rivers Commission (WRC) about the issue on 20 December 2001, and the WRC Land and Water Quality Branch were contacted on 21 December 2001 for technical advice on the cause of the problem. The Land and Water Quality Branch indicated that the likely cause of the problem was the disturbance of acid sulfate soils by new residential developments near the affected bore, and that there was a risk that acidic, metal-rich drainage from the area could affect Herdsman Lake.

2.3 Contributing factors to the acidity issue

Field inspections and preliminary sampling in the area have indicated that there are likely to be several sources of the groundwater acidity caused by the disturbance of acid sulfate soils. These included:

- *Dewatering* – The water table in the development areas was lowered by as much as 6 metres to allow the excavation and removal of peat which was unsuitable for housing foundations. Additional dewatering was carried out in the area to construct sewage infrastructure.
- *Peat stockpiles* – Peat excavated from the development areas was stockpiled before removal. Some of this material had a high acid generation potential, and visual inspection of the stockpiles indicated the presence of large amounts of jarosite and other sulfate salts.

- *Peat fire* – Peat in the area had been slowly burning for approximately three weeks. This is also likely to have caused the rapid oxidation of pyritic material.
- *Artificial Lakes* – Lakes in public parks have been created by excavating soils to the water table and stockpiling the spoil in the centre of the lakes to create islands.
- *Climatic factors* – Perth has had a long succession of dry winters, and the winter of 2001 was exceptionally dry. The water table during the summer months of 2001/2002 was lower than average, and many shallow bores ran dry due to the combined effects of the dry weather and dewatering. The reduced water table would expose the pyrites to oxygen and produce sulfate.

2.4 Statutory approvals process for new residential developments

The majority of urban developments are informally assessed by the Environmental Protection Authority. It is expected that consultants, acting on behalf of developers, understand the technical issues associated with developing these sites, and raise issues with regulatory authorities as appropriate.

There are two residential developments in Stirling that may have contributed to the groundwater acidity issue. These are the Roselea and the Hamilton Lake developments (Figure 1). The approvals process for these developments is described below.

2.4.1 Roselea

On 7 May 1999, the City of Stirling referred District Planning Scheme No. 2 Amendment No. 358 to rezone the land generally bounded by Jones Street, Grindleford Drive and Karrinyup Road, Stirling from "Low Density Residential R20", "Rural" and "Private Institutions" to "Residential – Jones Street Precinct" for assessment.

Accompanying the Scheme Amendment report was the Roselea Structure Plan (April 99) Technical Appendix, which included an Environmental Assessment and Management Plan (April 1999) prepared by Alan Tingay & Associates acting for the developer WR Carpenter Properties Pty Ltd. The Management Plan referred to the removal of peat from the site and additional clean fill being imported for future development. However, it appears that the Management Plan did not identify the PASS occurring on site. The main issue that was of concern was in relation to potential site contamination due to previous landuse as market gardens.

Consequently, the Department of Environmental Protection (DEP) requested further information, in a letter of 3 June 1999, on the inclusion of scheme provisions relating to the implementation of a Contaminated Soil Management Plan.

The City of Stirling responded to the DEP's request for information in a letter of 14 June 1999 and stated that it would undertake to modify the amending documents to include a section relating to the Contaminated Soil Management Plan, which stated:

> *The development of the precinct shall be undertaken in a manner which ensures that any contaminated soil is remediated to the requirement of the City of Stirling and the DEP in accordance with a Contaminated Soil Management Plan to be prepared and implemented to the satisfaction of both of these authorities.*
>
> *In this respect, an adequate soil sampling program is to be finalised to the satisfaction of the DEP prior to any subdivision occurring.*

As a result of the above, the Environmental Protection Authority (EPA) set a level of assessment at “Scheme Not Assessed – Advice Given” on 2 July 1999. Under delegation from the EPA, the DEP provided the following advice:

- **Soil contamination –** the DEP identified that the subject land had been previously used for market garden activities and that there was the potential for soil and groundwater pollution and that the above provision be included during finalisation of the amendment.
- **Surface water quality** – recommended that the proposed management measures for the reconstruction of the Albert Street Link drain into a “living stream” and the development of a water quality monitoring program be referred to the Water and Rivers Commission (WRC) prior to implementation.

The DEP also provided advice relating to noise and dust impacts.

A copy of this letter was forwarded to WRC for their information. As highlighted above, the potential for acid sulfate soils was not identified as an issue on site during the EPA’s assessment process.

However, the potential for acid sulfate soils occurring on site was raised by the WRC in a letter to Alan Tingay & Associates, dated 5 November 1999. The DEP’s Contaminated Sites Branch and Evaluation Division received an electronic copy of this letter, which commented on a draft Sampling and Analysis Plan, Dewatering Program Jones Street, Stirling (October 1999). The letter referred to being involved in several aspects of this proposal since receiving the DEP’s letter of 2 July 1999 to the City of Stirling regarding Amendment 358 and highlighted that dewatering of the site may lead to the generation of a significant volume of acid-sulfate soil.

Subject to conditions, the Western Australian Planning Commission (WAPC) approved subdivision of the Roselea development (WAPC Ref: 112189) in a letter dated 2 March 2000. The WAPC identified the DEP as a nominated authority when advising the WAPC on the clearance of subdivision condition numbers 19, 20 and 21 (WAPC Ref: 112189), which required a Noise Management Plan, Air Quality Management Plan and Contaminated Soil Management Plan respectively.

Since then, the DEP has received the above Environmental Management Plans for Stage 1 of the Roselea development from ATA Environmental. Stage 1 covers the southern section of the land previously rezoned under the City of Stirling’s Scheme Amendment 358. The DEP stated in letters dated 8 December 2000 and 21 December 2000 (see Attachment 3) that the Environmental Management Plans for Stage 1 appeared to be adequate. However, the DEP advised ATA Environmental that they should liaise with WRC with regard to groundwater and surface water contamination at the site.

The balance of the land to the north still requires clearance of subdivision conditions before development can proceed and to date the DEP has not received the above Environmental Management Plans for this stage of development.

In a letter dated 2 January 2002, the WAPC referred a proposed residential subdivision (WAPC Ref: 118165) for Lots 42, 201 & 1009 Karrinyup Road, Stirling for comment. The proposed subdivision appears to amend the subdivision for the northern part of the Stage 1 (which has received subdivision approval, WAPC Ref: 112189) and the southern part of Stage 2 (which has not received subdivision approval). In a letter dated 4 February 2002, the DEP received an amended plan of the proposed subdivision (WAPC Ref: 118165) from the WAPC.

In light of the recent events which have taken place regarding the acidic groundwater issue within the Stirling area, the EPA requested the following information before it could finalise its consideration of the proposed subdivision (WAPC Ref: 118165):

- acid potential of soils and groundwater on site;
- groundwater pH and heavy metal concentrations;
- the requirement for a Acid Sulfate Soil Management Plan; and
- information on the quality of peat material being removed from the site and location for off-site disposal/use of the material.

Since then, the DEP has been advised by the WAPC in a letter dated 5 March 2002 that the subdivision application for Lots 42, 201 & 1009 Karrinyup Road (WAPC Ref: 118165) has been cancelled at the applicant's request.

2.4.2 Hamilton/Stirling Lakes

On 10 March 2000, the City of Stirling requested the DEP's comments on a residential design layout for Stirling Lakes, formerly known as the Stirling Lakes Precinct Area, which is bounded by Karrinyup road, Hamilton Street, Hutton Street, Mitchell Freeway and Telford Crescent, from the City of Stirling. Accompanying the design layout was an Environmental Overview Report (January 2000) prepared by Bowman Bishaw Gorham for Menzies Court Holdings Ltd. The report referred to peat being currently mined from a large proportion of the site, however, the potential for acid sulfate soils occurring on site was not identified.

The DEP provided the City of Stirling with preliminary comments, in a letter dated 12 April 2000, on the environmental issues concerning the Stirling Lakes area. The comments provided were with regard to the creation of the proposed lakes, wetlands, surface water quality, groundwater quality, site contamination, mosquitoes and midges, and surrounding land uses.

In a letter of 17 April 2000, the WAPC referred a proposed residential subdivision (WAPC Ref: 113695) of Lot 53 & Pt Lot 19 Karrinyup Road, Stirling to the DEP for comment. The proposed subdivision covered the northern half of the design layout for Stirling Lakes. The DEP informed the WAPC, in a letter dated 1 May 2000, that preliminary comments had been provided on the residential design layout for the subject area and that further information was still required before the EPA could set a level of assessment.

The DEP provided further comment on 1 June 2000, which was in relation to surface water quality, site remediation and management of mosquitoes and midges. Bowman Bishaw Gorham provided the DEP with the further information requested by the DEP in its previous letters.

As a result, the EPA set a level of assessment for the proposed subdivision of Lot 53 and Pt Lot 19 Karrinyup Road, Stirling (WAPC Ref: 113695) at "Informal Review with Public Advice" on 7 August 2000.

No appeals were received against the level of assessment set for the proposed subdivision and the DEP under delegation from the EPA provided the WAPC with advice, in a letter dated 31 August 2000, on the following issues:

- **Nutrient Export & Budget –** recommended the preparation of a Nutrient and Irrigation Management Plan that this be imposed as a subdivision condition.
- **Site Contamination** – recommended that a site investigation to determine the extent and severity of contamination be imposed as a subdivision condition, with a Site Remediation and Validation Report to be prepared if the site is found to be contaminated.
- **Management of Mosquitoes and Midges –** recommended that a mosquito management program be imposed as a subdivision condition.

The DEP also provided comments relating to industrial noise, traffic noise and rail vibration.

Subject to conditions, the Western Australian Planning Commission (WAPC) approved the subdivision of Lot 53 & Pt Lot 19 Karrinyup Road, Stirling (WAPC Ref: 113695). The DEP was identified as a nominated authority when advising the WAPC on the clearance of subdivision condition numbers 5, 23 and 24, which requires the provision of a Contaminated Soil Management Plan, Nutrient and Irrigation Management Plan and a Mosquito Management Plan respectively.

To date the DEP has received none of the above Management Plans for comment. As highlighted above, the potential for acid sulfate soils was not identified as an issue on site during the EPA's assessment process.

Note:

The DEP receives approximately 160 subdivision referrals per year and 350 rezoning proposals per year. The WRC does not receive any subdivision referrals in the City of Stirling due to an arrangement with the WAPC where subdivisions within the metropolitan area are not referred to the WRC.

2.5 History of Regulatory actions - Roselea and Stirling Lakes

The permit and licensing systems for the Roselea and Stirling Lakes developments are managed by the Water and Rivers Commission Swan Region Office.

Roselea development was subject to Water and Rivers Commission groundwater abstraction permit and licence to cover the company's dewatering operations that included the submission of a Sampling and Analysis Plan for approval. The dewatering operation involved 9 abstraction spears which pumped the groundwater into the Water Corporation's main drains along Albert Street and Jones Street. Monitoring results between December 1999 to April 2001 did not show adverse change in the groundwater conditions during the active dewatering periods. Although some metals such as aluminium, zinc and cadmium were occasionally detected in the groundwater, it did not however, impact on the receiving surface waters. Since that time no further monitoring results have been received. Dewatering operations ceased in August 2001. Roselea's groundwater permit expired on 17 December 2001. An application has been received for renewal and is currently being reviewed.

In May 2001 several complaints were received by the Department of Environmental Protection about the peat stockpile fire at the Roselea Estate. Investigation revealed that the peat was smouldering for about three weeks impacting on the local residents with offensive odour and smoke.

Stirling Lakes was granted a groundwater permit on 26 May 2000 with commitment from the developer (MM Development) to maintain water quality standards (ANZECC, 1992) including the removal of peat as soon as practicable following extraction. Monitoring results indicate little variation in pH values between June 2000 and May 2001.

Departmental fax on 11 September 2000 to Welltech (Dewatering Operator) indicated that their monitoring results showed marginal decline in the groundwater pH and slight elevation of zinc and lead contamination. Regular lime dosing was undertaken to overcome the problem.

Following a letter to MM Development about the breach of permit conditions on 16 January 2002, Mr Pollock responded via letter on 30 January 2002 that the peat stockpile was reduced by 50% since September 2001. This could not be substantiated because there was no estimation of the quantity of earlier stockpile on the site.

The stockpiling of peat on the Stirling Lakes estate is in breach of the dewatering conditions for the site, and the proponent has been directed to remove the material. Under Section 73 of the Environmental Protection Act, proponents on the Roselea estate have been served with notices to remove the stockpiled peat from the area. It is proposed that proponents on the Stirling Lakes estate be served with a Section 73 notice shortly.

2.6 Significance of acid sulfate soils

With the media attention on salinity, it is often easy to forget that another significant environmental problem which besets Australia's wetlands and waterways is acid sulfate runoff. The disturbance of acid sulfate soils (ASS) is a significant environmental issue in coastal regions of Australia, particularly in Queensland and New South Wales, and is a major health issue in South and South East Asia.

Acid sulfate soils are soils that naturally contain large amounts of pyrite and other iron sulfide minerals. They have formed naturally over the last 10,000 years in waterlogged areas, and are usually associated with estuaries, mangroves, coastal salt marshes or with wetlands. If these soils are exposed to air by drainage or by excavation, the sulfide minerals react with oxygen in the atmosphere to form sulfuric acid, and leachate from the soil may contain very high concentration of metals. The release of acidic, metal-rich leachate into waterways or the ocean can have severe impact on aquatic life, and large fish kills have occurred in rivers on the eastern seaboard as a result of the drainage of ASS. Without adequate management, the acidity of drainage and groundwater can also corrode concrete and steel infrastructure in urban developments on this soil type.

There are more than two million hectares of acid sulfate soils in Australia, and these mostly occur along the northern and eastern coastlines of the continent. These soils contain a total of about one billion tonnes of pyrite. One tonne of pyrite can generate about 1.5 tonnes of sulfuric acid when oxidised.

The ASS in south-western coastal areas in Western Australia have a very limited distribution, and are mostly restricted to the immediate vicinity of existing and historical wetlands.

Further information on the distribution and impacts of ASS in Australia can be found in a publication produced by Environment Australia, which is available as a PDF file at the following web site:

http://www.ea.gov.au/coasts/programs/cassp/booklet.html

Pyrite in acid sulfate soils commonly contains large amounts of arsenic that is released if the pyrite is oxidised. The arsenic may leach into groundwater, and can be a significant health issue if the groundwater is used as a source of drinking water.

3.0 RESPONSE TO WATER QUALITY PROBLEMS IN STIRLING

3.1 Initial assessment

The City of Stirling invited Dr Steve Appleyard from the Land and Water Quality Branch to a meeting and site visit on 7 January 2002 to further discuss the issue. During the site visit, it became apparent that the acidity problem was likely to be widespread in the area, as in addition to the affected bore, there were open excavations in the area containing acidic water. An excavated soil profile in the area showed the typical yellow mottles of the mineral jarosite that indicated acid sulfate soils, and peat stockpiles on new residential development areas also showed evidence of acid generation. The lakes in Spoonbill Reserve with playground facilities were also found to be acidic. City of Stirling officers have since indicated that they had been monitoring the acidity of water in these lakes, and had been aware of low pH problems, since at least 1995.

The Water and Rivers Commission contacted the Department of Health (DOH) immediately after the site inspection in Stirling, and an emergency meeting was convened on the 9 January 2002 with City of Stirling officers, the Mayor, proponents of the Roselea residential development, DOH, DEP and the WRC officers. The purpose of the meeting was to address the potential health threats caused by the acidic water. Prior to the meeting, officers from the WRC and the City of Stirling undertook a rapid pH assessment of surface water bodies and council reticulation bores to determine the extent of the area affected by the acidity. This assessment indicated that surface water acidity occurred on Roselea Estate and in the council lakes at Spoonbill Reserve.

The major outcomes of the meeting were:

- The developers and City of Stirling would erect signs on all surface water bodies containing acidic water to warn against contact with the water;
- The Department of Health would put out a media release about health risks of coming into contact with acidic water in lakes or spray from bores affected by acidity (see Attachment 2, dated 10 January 2002).
- The City of Stirling would letter-drop each household in an area bounded by Albert Street and Hamilton Street on the east, Amelia Street on the north, Cedric Street and Mitchell Freeway on the south west boundary, warning of the health risks of coming into contact with acidic water and offering pH testing (see Attachment 3, dated 11 January 2002).
- The WRC and the City of Stirling would undertake investigations to determine the extent and severity of the acidity problem.
- The WRC expressed concern that arsenic had not been analysed in the initial metal analysis by the City of Stirling and would undertake further sampling for this toxic metal.

Following the 7 January 2002 meeting more domestic bores in various pH ranges were tested for arsenic and heavy metals to determine whether these contaminants were present at significant concentrations, and to determine whether there was a relationship between arsenic concentrations and water pH.

Sampling indicated that arsenic was present in all the sampled bores, but not at concentrations of health significance above a pH of 5.5. A small proportion of groundwater samples with a pH of less than 5.5 contained arsenic at concentrations of health concern. Consequently, measurement pH was used as screening tool to select bores that would require chemical analysis for arsenic and heavy metals.

High concentrations of arsenic (800 µg/L) about 114 times above the NHMRC, 1996 guidelines for drinking water, was detected in a bore located immediately adjacent to Roselea Garden on the 29 January 2002. The DOH was immediately notified, and DOH put out a media release on 1 February 2002 indicating the presence of arsenic in some bores. The issue received extensive coverage on television, on radio, and in the press (see Attachment 4).

3.2 Assessment of private bores

Initially, more than 60 domestic and Council bores were tested for pH, but this was increased to about 802 bores following media interest in the discovery of high concentrations of arsenic found in six domestic bores. Testing of pH was carried out both by the WRC and the Stirling City Council. Due to the large demand for pH assessment, residents were referred to the City of Stirling for an initial pH test. Where pH was greater than 5.5, no further sampling was required, but bores with a pH at or less than 5.5 were sampled for metal analysis. Of the 802 domestic bores assessed for pH, 49 were sampled for chemical analysis.

3.3 Assessment of water supply production bores

Stirling is situated within the Gwelup Underground Water Pollution Control Area (UWPCA), and the Water Corporation pumps water from several production bores for public water supply in the area. Immediately after the detection of acidic conditions in domestic bores, the Water Corporation were warned about the risk of water supplies being contaminated. These bores are routinely monitored for a wide range of chemicals, and the water treatment plant at Gwelup would remove any arsenic present in groundwater. However, the Water Corporation conducted additional testing for arsenic on each of the bores on 9 January. The results of these investigations indicated that two production bores were affected by slightly elevated of arsenic contamination and pH was in the neutral range. The DOH is currently investigating this issue.

3.4 Public Information Session

The Water and Rivers Commission and the Health Department held a public information session between 3:00pm and 9:00pm at the Tuscani Club, 100 Jones Street, Sterling, on 28 February 2002. All local residents who had contacted the relevant authorities and had had their groundwater bores tested were invited to attend via letter.

The information display included maps of areas of impacted bores, descriptions of acid sulfate soil issues and health information. Copies of a ‘Frequently Asked Questions’ Information Sheet were also available (see Attachment 5). Representatives from WRC and DOH were available to answer questions. The session was well attended with a steady flow of residents throughout the afternoon and evening.

The main issues arising from the session were as follows;

- Residents with impacted bores were concerned with who would reinstate bores to tap into the deep aquifer;
- Some residents are planning to form a local action group to seek ‘compensation’ from responsible parties;
- Concerns were raised about the future groundwater quality in the area that may impact on groundwater bores not currently affected; and
- Concerns were raised about the safety of consuming vegetables grown in the area.

3.5 Preliminary mapping of Potential Acid Sulfate Soils

In February 2002, the Water and Rivers Commission conducted a desktop study of areas with potential for acid sulfate soils (PASS) in the Perth metropolitan area. This indicative study is a first pass only to guide future detailed mapping of PASS in the State. Its present form cannot be used as a prescriptive guide for management decisions without considering other factors such as groundwater fluctuations and soils.

However DEWCP will now write to each metropolitan local government authority advising them of the potential for sulfate soils presence in their areas asking that the issue be taken into consideration for any future residential developments. DEWCP will also write to the WA Planning Commission, Urban Development Institute of Australia (WA) and Association of Consulting Engineers (WA) ensuring they are aware of the ASS issue and that it is considered as part of their deliberations.

The State should support the National Coastal Mapping project for ASS proposed by the National Coastal Acid Sulfate Soil Committee (NatCASS).

3.6 Other actions

In addition to the above, the following actions were undertaken:

- sampling and analysis of vegetables (especially from commercial growers) in the area by DOH and City of Stirling;
- sampling and analysis of samples from peat stockpiles on the Stirling Lakes and Stirling Gardens development sites by WRC;
- sampling and analysis of sediment and water from the Spoonbill Lakes by WRC; and
- sampling and analysis of soil from commercial vegetable growers and private premises by DOH and City of Stirling.

These actions are detailed in subsequent sections of this report.

4.0 SAMPLING METHODOLOGY

4.1 Private Groundwater Bores

Preliminary pH screening was conducted extensively to locate the hotspots within the declared affected areas. Initially, residents registered their addresses with the City of Stirling, the WRC, or the Health Department to have their bores sampled. Officers from the WRC and/or City of Stirling individually visited each property and had the resident run their bore for two minutes. The bore water was then used to rinse the sampling bucket, prior to collecting a sample. The water pH was measured immediately using a calibrated portable pH probe.

Bores recording a low pH (less than 5.5) were sampled for toxic metals. These samples were collected in polyethylene bottles provided by the laboratory and delivered to the Chemistry Centre of WA in accordance with the Chain of Custody procedures.

The laboratory analysed the groundwater samples using the methods outlined in Table 1.

Analyte	**Method of analysis**
Arsenic, As	Vapour generation atomic absorption
Lead, Pb; Cadmium, Cd	ICPMS
Aluminium,Al; Barium, Ba; Boron, B; Calcium, Ca; Chromium, Cr; Cobalt, Co; Copper,Cu; Iron, Fe; Potassium,K; Magnesium, Mg; Manganese,Mn; Molybdenum, Mo; Sodium, Na; Nickel,Ni; Sulfur expressed as sulfate; Vanadium, V; Zinc, Zn	ICPAES
PH	Meter
Conductivity	Meter
Chloride	Segmented flow auto analyser

Table 1 : Analytical methods used by the laboratory (water)

As the demand for bore water testing increased, residents were requested to collect their own samples in clean bottles and take them to the City of Stirling for pH screening. The City of Stirling undertook the vast majority of pH measurements within 24 hours of receiving the samples, using a calibrated portable pH probe. Residents unable to take samples to the City of Stirling were visited individually as outlined above.

In total, over 800 local bores were screened for pH during February 2002, and 49 were sampled for chemical analysis.

4.2 Groundwater monitoring – drilling program

Between 14 – 22 February, WRC officers installed thirteen investigation bores to depths between 13 – 15 metres below the ground level replicating the normal domestic bore depths in the affected areas. Figure 1 shows the location of the monitoring bores marked as SLA#1 to SLA#13. Each bore was constructed with a length of 0.4 mm slotted PVC 50mm casing, flushed at ground level, capped and distinctly marked. A centrifugal pump was used to recover the groundwater water samples for analysis. Discrete water samples were retrieved at 3 metre intervals down the soil profile. The retrieved water samples were field tested for pH and salinity using a calibrated WTW meter. Acid washed polyethylene bottles were used to collect the samples for chemical analysis, stored in an esky for up to six hours, and delivered to the Chemistry Centre of WA (CCWA) in accordance with the Change of Custody procedures.

The laboratory analysed the groundwater samples using the methods outlined in Table 1.

4.3 Soil from Peat Stockpiles

Thirteen samples were retrieved from the peat stockpile on the Stirling Lakes development and seven peat stockpile samples were collected from the Roselea Gardens development on 21 February. The locations of the peat stockpiles are shown in Figure 1. The samples were collected by officers from the WRC and DEP. The samples were randomly selected, collected in glass jars, and delivered to the CCWA to determine the Net Acid Generation (NAG).

At the laboratory the samples were dried to 38 – 40^{o}C and crushed to a normal 75 μm average particle size. Homogenised sub-samples of the powdered samples were subjected to chemical tests. The pH was determined by a pH electrodes on a slurry (1 part of solid to 2 parts water, w/w) that had been allowed to maturate for 24 hours.

4.3.1 Net Acid Generation (NAG) test description

The sample was allowed to react with hydrogen peroxide (H_2O_2) at pH 4.5, the excess H_2O_2 was decomposed and the solution was allowed to cool prior to make up and determine of pH and acidity. Hydrogen peroxide has the advantage of being a neutral oxidation reagent. In its pure state H_2O_2 does not contribute to the alkalinity or acidity of the sample (a vital consideration for acidity titration methods).

4.3.2 Gross Acid Production Potential (GAPP)

This is calculated from the total sulfur value and expressed as sulfuric acid. The test may over estimate the acid producing potential of a soil as it assumes all sulfur is present as sulfide. A corrected GAPP makes allowance for sulfur present in the less deleterious form.

To determine sulfate sulfur the samples were heated with dilute hydrochloric acid to drive off any sulfur present as sulfide. The residual sulfur present in solution is assumed to be due to sulfates. The sulfur concentration was measured using inductively coupled plasma atomic emission spectroscopy (ICPAES)

4.4 Sediment and water samples from the Spoonbill Lakes

One sediment and two water samples were collected from the Spoonbill Lakes by WRC officers on 15 February 2001. The locations of these samples are shown in Figure 1.

The water samples were collected in laboratory acid-washed polyethylene bottles using a sampling pole to reach beyond the shoreline. The sediment sample was collected in a glass jar from the yellow stained layer of the southern lake shoreline. The samples were stored in an esky for approximately two hours, and delivered to the CCWA in accordance with the Chain of Custody procedures.

The water samples were analysed at the laboratory using the methods described in Table 1. The sediment sample was analysed using the methods outlined in Table 2.

Analyte	Method of analysis
Arsenic, As	Aqua Regia digest and vapour generation atomic absorption spectroscopy
Aluminium,Al; Barium, Ba; Boron, B; Cadmium, Cd Chromium, Cr; Cobalt, Co; Copper,Cu; Iron, Fe; Mg; Manganese,Mn; Molybdenum, Mo; Lead, Pb; Nickel,Ni; Sulfur expressed as sulfate; Vanadium, V; Zinc, Zn	Aqua Regia digest and ICPAES

Table 2 : Analytical methods used by the laboratory (sediment)

4.5 Soil samples from Stirling properties

In February and March 2002, the City of Stirling collected six soil samples from commercial vegetable grower's properties, and four soil samples from residential properties found to have bore water with a low pH. The samples were composite samples, approximately 1 kilogram in weight, taken to a depth of 10 centimetres. They were collected in food grade plastic bags and submitted to CCWA within 5 hours of collection.

The samples were analysed at the laboratory using the methods outlined in Table 3.

Analyte	Method of analysis
Arsenic, As	Acid digest and vapour generation atomic absorption
Lead, Pb	Aqua regia and FAAS
Aluminium,Al; Barium, Ba; Boron, B; Cadmium, Cd; Chromium, Cr; Cobalt, Co; Copper,Cu; Iron, Fe; Manganese,Mn; Molybdenum, Mo; Nickel,Ni; Sulfur expressed as sulfate; Vanadium, V; Zinc, Zn	Aqua regia and ICPAES

Table 3: Analytical methods used by the laboratory (soil)

4.6 Plant samples

In February 2002, the City of Stirling collected various fruit and vegetable samples from 11 premises, mostly commercial growers. Samples included pumpkins, tomatoes, potatoes, strawberries, sweet potatoes, eggplant, grapes, radish, onions, cabbage, zucchini, oranges, plums, lettuces, celeriac, parsley, mint and leek.

The plants were initially sampled as whole plants, including roots, and were analysed by the laboratory in both washed and unwashed forms.

Fruit and vegetables were later collected without roots; approximately 2 kilograms if a large fruit, or five samples of the same fruit if small.

Samples were collected in food grade plastic bags or bags/boxes provided by the growers, and submitted to CCWA within 5 hours of collection.

The samples were analysed at the laboratory using the methods outlined in Table 4.

Analyte	Method of analysis
Arsenic, As	Acid digest and vapour generation atomic absorption
Lead, Pb; Cadmium, Cd	Nitric acid / peroxide digest and ICPMS
Aluminium,Al; Barium, Ba; Boron, B; Chromium, Cr; Cobalt, Co; Copper,Cu; Iron, Fe; Manganese,Mn; Molybdenum, Mo; Nickel,Ni; Sulfur expressed as sulfate; Vanadium, V; Zinc, Zn	Nitric acid / peroxide digest and ICPAES

Table 4: Analytical methods used by the laboratory (plants)

4.7 Criteria to assess public health and environmental impact

Public health and environmental risk factors are the two key components used in assessing the impact of various contaminants in the environment. The risk assessment process is a determination of the level of risk for human, fauna or flora. The level of risk is associated with specific doses of the pollutants which could result from either or both direct and indirect exposure.

Health risk assessment is a process of predicting whether an adult or child is likely to suffer adverse health effects from exposure to levels of contaminants over certain periods. The precise risks cannot be quantified but the aim of the guidelines is to have a conservative approach where information may be limited, allowing for a margin of safety.

4.7.1 Water

All water analysis results were compared with the *National Health and Medical Research Council Drinking Water Guidelines (1996).* These guidelines apply to human health and are based on a number of factors such as a life-time's consumption of water at those levels. The application of these standards reflects the chronic contamination levels that are not likely to impact on human health, and generally provides a conservative assessment. Domestic bore owners have been advised against using their bore water for drinking purposes.

The Australian and New Zealand Environment and Conservation Council Guidelines for Protection of Aquatic Ecosystems (Fresh Water) (1992) were also used to assess the water results due to the potential for the water to enter surface water bodies. The use of these guidelines is to ensure no acute and long-term impact on aquatic fauna.

In addition, the soluble chloride : soluble sulfate ($Cl:SO_4$) ratio was used as an indicator to determine whether sulfidic material was being, or had been, oxidised. Where the analysis indicates that there is an elevated level of sulfate ions relative to the chloride ions, these results may indicate the presence of acid sulfate soils. A $Cl:SO_4$ ratio by mass of less than 4, and certainly a ratio less than 2, is a strong indication of an extra source of sulfate from previous sulfide oxidation.[2]

[2] Queensland Government Department of Natural Resources, 2000 – State Planning Policy 1/00 Planning and Management of Coastal Development involving Acid Sulfate Soils.

4.7.2 Soil

Soil analysis results were compared against the Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites (ANZECC/NHMRC) (1992) Ecological Investigation Levels. These guidelines are based on threshold levels for phytotoxicity and uptake of contaminants which may result in impairment of plant growth or reproduction or unacceptable residue levels. The use of these levels was adopted due to the potential for impact on sensitive receiving waterbodies, including the conservation category Herdsman Lake, and the Gwelup Underground Water Pollution Control Area.

4.7.3 Plants

Plant analysis results were compared with the *Australian and New Zealand Food Authority Food Standard Code (1998).* These guidelines apply to human health and are based on a number of factors such as a life-time's consumption of food at those levels. The application of these standards ensures the food is safe to eat and people are unlikely to become ill.

5.0 RESULTS AND DISCUSSION

5.1 Water

Analytes	pH	As	Al	Cu	Pb	Zn	Cd	Ni	SO4	Cr	Fe
ANZECC (1992)	6.5– 9	0.05	0.005 pH<6.5 0.1 pH>6.5	0.005	0.005	0.05	0.002	0.15		0.005	1
NHMRC (1996)	6.5-8.5	0.007	0.2*	2	0.01	3*	0.002	0.02	500	0.05	0.3*
01E0839/001	*2.6*	**0.23**	*180*	<0.002	**0.02**	*0.16*	**0.013**	-	**2720**	-	*810*
01E0839/002	*3.4*	**0.80**	*24*	*0.009*	0.009	*0.11*	<0.005	-	**722**	-	*190*
01E0839/003	*2.7*	**0.021**	*290*	*0.073*	-	*0.69*	<0.005	-	**4430**	-	*1300*
01E0839/004	*3.8*	**0.061**	*48*	*0.012*	**0.054**	*0.085*	<0.005	-	**922**	-	*180*
01E0912/004	*2.4*	**0.018**	*0.44*	<0.02	<0.0005	<0.05	<0.005	0.01	**602**	<0.02	*120*
01E0984/001	*3.8*	**0.031**	*3.3*	<0.02	0.0041	*0.08*	<0.005	0.01	287	<0.02	*8.2*
01E0965/001	*2.9*	**0.007**	*48*	<0.02	**0.015**	*0.21*	0.0009	**0.04**	**1110**	**0.1**	*310*
01E0839/005	*3.8*	**0.011**	*11*	<0.002	0.0021	0.045	<0.005	**0.04**	497	-	*41*
01E0839/006	*3.6*	**0.022**	*22*	<0.002	0.0038	0.033	<0.005	-	**541**	-	*87*
01E0911/004	*3*	**0.011**	*1.8*	<0.02	<0.0005	<0.02	<0.005	0.01	156	<0.02	*11*
01E0965/004	*3*	**0.17**	*83*	<0.02	0.002	*0.22*	<0.0005	0.02	**1840**	<0.02	*440*
01E0965/005	*3.4*	**0.064**	*62*	*0.13*	0.002	*0.13*	<0.005	0.02	**1150**	0.03	*190*
01E0958/007	*4.5*	**0.038**	*4.2*	<0.02	<0.0005	0.03	<0.0005	0.01	306	<0.02	*66*
01E0957/001	*2.5*	0.005	*39*	*0.06*	**0.025**	*1.2*	<0.0005	**0.07**	**775**	0.02	*140*
01E1044/001	*5*	0.001	*58*	*1.3*	**0.22**	*5*	0.0014	**0.39**	**805**	0.05	*17*
01E0957/002	*2.6*	**0.014**	*26*	<0.02	0.002	*0.15*	<0.0005	**0.14**	467	0.04	*99*
01E0957/005	*2.6*	**0.016**	*22*	*0.04*	**0.024**	*0.1*	<0.0005	0.02	**833**	<0.02	*150*
01E0957/006	*2.9*	**0.022**	*6.3*	<0.02	0.008	0.02	<0.0005	0.01	317	<0.02	*51*
01E0958/001	*3.8*	**0.009**	*2.6*	<0.02	0.007	*0.12*	<0.0005	0.01	394	<0.02	*79*
01E0958/002	*4.3*	**0.064**	*11*	<0.02	0.0008	0.03	<0.0005	0.01	**520**	<0.02	*87*
01E0958/003	*4.3*	**0.023**	*9.2*	<0.02	0.001	*0.11*	<0.0005	0.01	**776**	<0.02	*150*
01E0958/005	*4.5*	**0.1**	*3.3*	<0.02	<0.0005	0.02	<0.0005	0.02	**867**	<0.02	*170*
01E0976/001	*6.4*	**0.03**	*0.12*	<0.02	<0.0005	<0.02	<0.0005	0.01	367	<0.02	*33*
01E0958/006	*4.1*	**0.029**	*3.1*	<0.0005	0.003	0.03	<0.0005	0.01	397	<0.02	*33*
01E0911/001	*3.5*	**0.013**	*16*	<0.02	0.008	0.03	<0.0005	0.01	475	<0.02	*73*
01E0957/007	*2.6*	0.001	*40*	0.02	0.003	0.11	<0.0005	**0.13**	**1110**	**0.34**	*51*

- Taste threshold rather than health values. *Italics* refers to ANZECC 1992 criteria and **bold** refers to NHMRC 1996 criteria

Table 5 – Results of the Sampled Domestic Bores with recorded pH below 5.5

Site location	Depth (metres below ground level)	pH	Ec MS/m	As mg/L	Al mg/L	Cd mg/L	Cr mg/L	Pb mg/L	Ni mg/L	Fe mg/L	Cl:SO_4 ratio
SLA # 1 Upgradient & north-east of Spoonbill Lakes	3.7	4	94.3	0.15	3.8	0.001	<0.02	0.014	0.02	31	0.23
	6.7	6.1	112	0.076	0.033	<0.0005	<0.02	<0.0005	<0.01	1.9	0.24
	9.7	5.9	106	0.078	0.048	<0.0005	<0.02	0.0006	<0.01	7.1	0.24
	12.7	6.2	58	0.004	0.13	<0.0005	<0.02	<0.0005	<0.01	11	0.82
SLA # 2 Downgradient and west of southern Spoonbill Lake	4.7	3.1	152	0.34	44	0.0018	0.07	0.18	0.04	54	0.14
	7.7	3.8	154	0.73	26	0.0036	0.03	0.027	0.07	63	0.13
SLA # 3 Downgradient and at south-western extremity of Spoonbill Lakes	3.6	3.2	181	0.056	48	<0.0005	0.21	0.014	0.08	48	0.29
	6.6	5.7	156	0.016	0.56	<0.0005	<0.02	0.0027	0.01	98	0.14
	9.6	6.5	110	0.003	0.48	0.0034	<0.02	0.001	0.02	12	0.42
	12.6	5.9	117	<0.001	0.036	<0.0005	<0.02	<0.0005	<0.01	18	0.28
SLA # 4 Downgradient and at south-western extremity of northern Spoonbill Lake	5.2	3.1	136	0.12	31	<0.0005	0.04	0.0097	0.02	56	0.12
	8.2	3.9	102	0.006	38	<0.0005	0.03	0.0057	0.01	25	0.14
	11.2	4.1	156	0.003	0.72	<0.0005	<0.02	0.002	<0.01	140	0.09
	14.2	4.4	132	0.004	0.069	<0.0005	<0.02	<0.0005	0.01	98	0.16
SLA # 5 Jones St – downgradient of Roselea development	3.6	2.6	504	7.3	230	0.0072	0.31	0.017	0.15	1200	0.02
	6.6	3.4	381	0.28	160	<0.0005	0.14	0.0025	0.13	1000	0.03
	9.6	3.8	429	0.017	200	<0.0005	0.1	0.0048	0.29	1200	0.02
	12.6	5.6	142	0.024	0.21	<0.0005	<0.02	<0.0005	<0.01	110	0.14
	15.6	4.4	147	0.025	2.8	<0.0005	<0.02	0.0071	0.05	180	0.12
SLA # 6 Telford Cres – downgradient of Stirling Lakes development	4.6	3	127	0.004	60	<0.0005	0.03	0.022	0.02	39	0.2
	7.6	4	69	0.017	1.3	<0.0005	<0.02	0.001	0.01	26	0.67
	10.6	5.4	121	0.009	0.043	<0.0005	<0.02	<0.0005	<0.01	17	1.21
	13.6	6.8	55	0.001	0.024	<0.0005	<0.02	<0.0005	<0.01	0.58	2.6
SLA # 7 Graham Burkett Reserve – upgradent of Roselea Gardens development	5.7	6.8	66	0.007	0.16	0.0005	<0.02	<0.0005	<0.01	0.21	1.85
	8.7	6.6	58	0.004	0.2	<0.0005	<0.02	<0.0005	<0.01	0.05	2.5
	11.7	6.5	53	0.003	0.54	<0.0005	<0.02	<0.0005	<0.01	0.1	2.1
SLA # 8 Downgradient of ornamental lake in Sandpiper Reserve	4.7	6	207	0.004	0.044	<0.0005	<0.02	<0.0005	0.01	56	0.38
	7.7	4.6	171	0.046	0.29	<0.0005	<0.02	<0.0005	0.01	51	0.16
	10.7	5.6	182	0.003	0.062	0.0012	<0.02	<0.0005	0.01	28	0.09
	13.7	6.2	153	0.001	0.94	<0.0005	<0.02	<0.0005	<0.01	4.5	0.17
SLA # 9 Downgradient of Stirling Lakes Development	3.2	3.4	115	0.74	0.94	0.0012	<0.02	0.0049	0.02	76	0.2
	6.2	5.9	136	0.016	0.066	<0.0005	<0.02	<0.0005	<0.01	100	0.1
	9.2	6.3	92.6	0.002	0.024	<0.0005	<0.02	<0.0005	<0.01	38	0.5

Site location	Depth (metres below ground level)	pH	Ec mS/m	As mg/L	Al mg/L	Cd mg/L	Cr mg/L	Pb mg/L	Ni mg/L	Fe mg/L	$Cl:SO_4$ ratio
SLA # 11 Base of north-western toe of Stirling Lakes peat stockpile	3.2	5.9	294	0.14	0.03	<0.0005	<0.02	<0.0005	0.01	350	0.07
SLA # 12 Upgradient of Stirling Lakes development – corner Phillip Way / Hamilton St	4.7	6.6	39	0.006	0.14	0.62	<0.02	0.087	<0.01	0.07	1.2
	7.7	6.9	62.2	<0.001	0.046	0.012	<0.02	<0.0005	<0.01	0.14	2.7
	10.7	6.3	76.8	<0.001	0.038	0.0031	<0.02	<0.0005	<0.01	0.25	1.3
	13.7	6.2	62.8	<0.001	0.039	0.0023	<0.02	<0.0005	<0.01	0.09	1.3
SLA # 13 South-western corner of Stirling Lakes peat stockpile	2.5	5.6	89.4	0.14	0.16	0.0027	<0.02	<0.0005	<0.01	74	0.2
	5.5	6.2	72.1	0.051	0.89	<0.0005	<0.02	<0.0005	0.013	22	0.6

Note: As, Cd, Cr, Pb and Ni are shaded if they exceed the NHMRC 1996 Drinking Water Guidelines.

Al and Fe are shaded if they exceed the ANZECC 1992 Aquatic Freshwater Ecosystem Protection Guidelines.

pH is shaded if it is <5.5.

Table 6: Analytical Results from Groundwater Drilling Program 14-22 February 2002.

5.1.1 pH

pH is commonly used as an indicator of acidity or alkalinity in water or soil. Most natural fresh waters have a pH close to 7.0 (neutral), and marine waters close to 8.2. In groundwater the pH is usually controlled by the presence of carbonate-bicarbonate buffer system. It is generally accepted that a pH range of 5-9 is not considered acutely lethal to most aquatic life, however pH less than 4.5 can be extremely toxic to plants and gilled organisms including harmful effects on eggs and fry of sensitive fish[3]. Although pH is generally used as an indicative measurement of soluble acidity in water for ASS, it does not account for the total soluble acidity in ASS because of the presence of soluble iron and aluminium species. However, the reaction between acid and soil constituents, mainly peat clay soils, releases aluminium, iron, manganese and other metals such as arsenic and copper[4].

The pH screening test was conducted to determine the potential risk of acidic groundwater contamination in Stirling. More than 800 domestic bores and 13 shallow monitoring piezometer were installed at strategic locations to determine the extent of groundwater acidity. Figure 2 shows the extent of acidity which affected 49 domestic bores with pH less than 5.5. The impacted areas are primarily close to the development sites on Jones Street, Landrail Road, Sittela Street and the northern intersection of Telford Crescent and Karrinyup Road. An isolated groundwater acidic condition was detected close to Spoonbill lake system including the lake. Generally the pH varied between 2.6 and 4.5.

Table 6 shows the results of the shallow monitoring bores and metals analysis. Down gradient monitoring bores SLA#2 and SLA#3 show that the acidic groundwater conditions extend to 6.6m below ground level (BGL) with the exception of SLA#4 located on the south-western extremity of Spoonbill lake (north) showing the acidity extends deeper than 14m below the

[3] Fromm, P.O., 1980 – A review of some physiological and toxicological responses of freshwater fish to acid stress.
[4] Fitzpatrick et al, 1996 – Acid sulfate soil assessment coastal , inland and minesite conditions

ground level. The upgradient bore located north-east of Spoonbill lake shows a similar pattern of acidity but limited to less than 4m below the ground level. The results indicate that the local groundwater in the immediate vicinity of the two lakes has been impacted by acidity.

Monitoring bore SLA#5 located adjacent to Roselea development recorded acidic condition down to 16m BLG. The local acidic groundwater has impacted a number of domestic bores along Jones Street within the immediate vicinity. The upgradient bore from the Roselea development on Graham Burkett Reserve recorded close to neutral pH values, indicating that the area east of the development site is not affected by groundwater acidity.

Monitoring bore SLA#6 located adjacent to the Stirling Lakes development indicated that acidic groundwater extended to 10m below the ground level, and this again is confirmed by a number of impacted domestic bore along Telford Crescent downgradient of SLA#6.

An assessment of the groundwater quality adjacent to the peat stockpile at the Stirling Lakes development found bore SLA#9 has acidic groundwater at 3m BGL. This indicates that the shallow acidic groundwater may be moving offsite in a south westerly direction. The upgradient bore SLA#12 recorded close to neutral pH values indicating that the area east of the development along Hamilton Street is not impacted by the acidic groundwater.

5.1.2 Arsenic

Arsenic is released into the environment naturally by weathering of arsenic containing rocks and from human activities. Several forms of arsenic occur in natural waters and the arsenic solubility is extensively influenced by redox and pH within the soil environment. In well aerated peat soils, the inorganic forms of arsenic are expected to predominate.

The World Health Organisation set the guideline concentration of arsenic at 0.01 mg/L (WHO, 1994). In Australia, the National Health and Medical Research Council has recommended a threshold of 0.007 mg/L (NHMRC, 1996).

Of the 49 domestic bores tested for arsenic, 22 exceeded the Australian Drinking Water Guidelines for arsenic as shown in Table 5. The highest arsenic concentration was about 114 times above the health guideline value. The arsenic hotspots, as shown in Figure 3, are generally located in those areas having low pH with the exception of one at pH 6.4.

The presence of oxidation of ASS generates significant amounts of acidity and mineral activity from the concentration of metals undergoing hydrolysis and dissociation in water. This is demonstrated in Charts 1 and 2 showing that higher concentration of arsenic is related to low pH value.

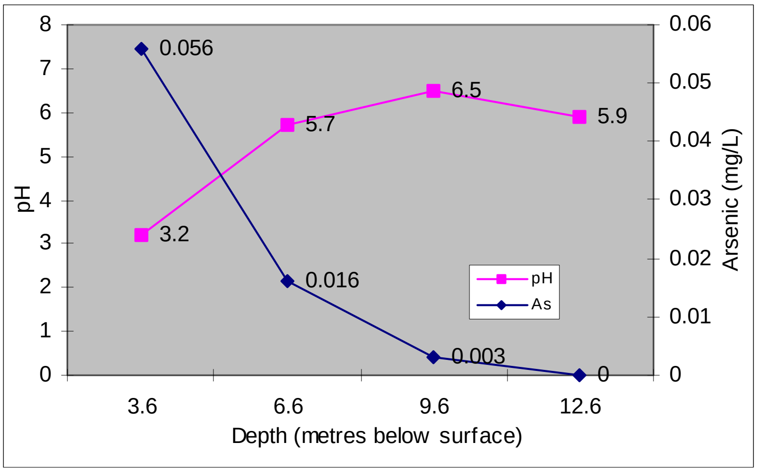

Chart 1: SLA#3 - Downgradient and at south-western extremity of southern Spoonbill Lake.

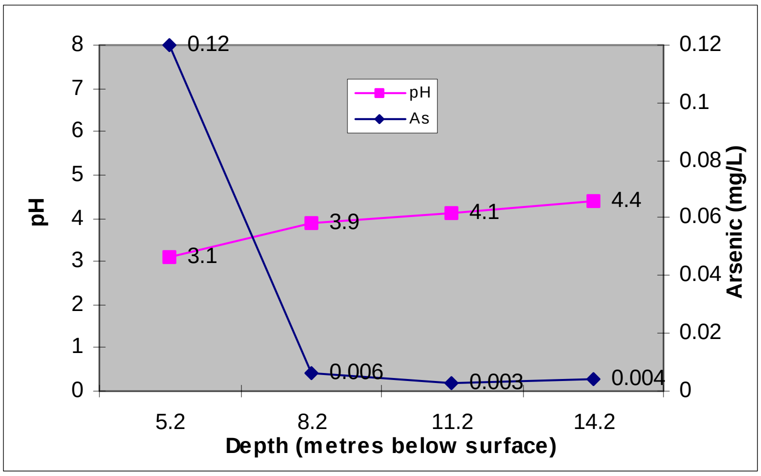

Chart 2: SLA#4 – Downgradient and at south-western extremity of northern Spoonbill Lake.

Arsenic contamination above the health criteria was detected in the monitoring bores downgradient of Spoonbill lakes and the development sites. Although SLA#1 located upgradient of Spoonbill north lake has shown high arsenic concentrations it could be attributed by the radial groundwater influence from the lake system. The highest arsenic detection was at SLA#5 on Jones Street that exceeded the health guidelines by more than 1000 times. The arsenic concentration ranges between 7.3 – 0.009 mg/L.

5.1.3 Lead

Lead contamination in the environment is likely from precipitation, fall out from dust in urban areas, street runoff, agricultural and industrial applications. The use of lead-rich herbicides and insecticides was a significant source of lead in the past, with some orchard soils receiving up to 10kg Pb/Ha/yr. This has caused lead concentrations in some of soils to exceed 5000 mg/kg[5]. Lead is generally present in very low concentration in the natural waters. In fresh waters, the main species of lead are those in the lead organic complexes, with very small amount of free lead ions. The acute toxicity of lead to several species of freshwater animals was greater in soft water than hard water.[6] Both NHMRC and ANZECC guidelines are used to assess the lead contamination because the aquatic ecosystem is less tolerant to higher lead concentrations.

Figure 4 shows the spread of lead contamination in the sampled bores that exceeded the health guidelines ranging between 0.18 and 0.02 mg/L. In all 6 domestic bores and 6 groundwater monitoring bores exceeded the health guidelines and 4 groundwater samples exceeded the environmental guidelines for aquatic ecosystem protection.

5.1.4 Aluminium

The bioavailability and toxicity of aluminium is generally greatest in acid solutions[7]. Aluminium is generally more toxic over the pH range 4.4-5.4, with a maximum toxicity occurring around pH 5.0–5.2.[8]. Under very acidic conditions, the inorganic monomeric aluminium concentrations of only 0.1 mg/L can be toxic to some fish species[9]

Although there is no health limit for aluminium toxicity, the high aluminium concentrations can impact both flora and fauna and therefore the ANZECC 1992 guidelines for aquatic ecosystems

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[5] Merry et al 1983 – Accumulation of copper, lead arsenic in Australian orchard soils.
[6] Hart, B.T. 1982 – Water quality management: monitoring and diffuse runoff.
[7] Campbell & Stokes, 1985 – Acidification and toxicity of metals to aquatic biota
[8] Schofield & Trojnar, 1980 – Aluminium toxicity to brook trout in acidified waters.
[9] Driscoll et al, 1980 – Effect of aluminium speciation on fish in dilute acidified waters.

protection were used to assess environmental risk. Figure 5 shows the extent of aluminium contamination in all the sampled bores that exceeded the ANZECC 1992 guidelines by orders of magnitude. The highest concentration is 58,000 times above the ANZECC guidelines for acidic waters.

5.1.5 Chloride Sulfate Ratio

The oxidation of sulfides to sulfate in ASS generates sulfate that will narrow the chloride (Cl) to sulfate (SO_4) ratio. The Cl:SO_4 ratio in seawater and in rainfall is 7. A Cl:SO_4 ratio less than 2 is a strong indication of an extra source of sulfate from previous sulfide oxidation. Table 5 shows that most Cl:SO_4 ratio in the monitored bores are less than 2 suggesting that they are affected by ASS, and that there is high potential of continuing acidification unless active management measures are taken.

5.1.6 Other metals

The groundwater sampling detected the presence of other toxic metals including copper, zinc, cadmium and nickel, but contamination by these metals is not considered wide spread within the impacted area.

Copper was detected in six domestic bores at concentrations that exceeded the ANZECC 1992 guidelines but were within the health limits. The exceedance is not considered high when compared to other urban catchments.

Zinc contamination was detected in 13 domestic bores at concentrations that exceeded the ANZECC 1992 guidelines. The zinc contamination is not considered excessive when compared to other urban catchments.

Cadmium was detected in five monitored bores and in one domestic bore above the health limit. Compared to lead, cadmium is readily taken up by plants, but unlike the other metals, cadmium is not phytotoxic at low concentrations that pose concern from the human health viewpoint[10]. The highest cadmium concentration in groundwater is in Jones Street. It is interesting to note that the upgradient bore off Hamilton Street also recorded high cadmium concentration. It is likely caused by previous market garden practices in fertiliser and pesticide application on soils.

Total chromium was detected in three monitored bores and in one domestic bore above the ANZECC 1992 and the health guidelines. The concentration ranges from 0.07 – 0.31 mg/L.

Minor nickel contamination was found in six sampled bores with concentration ranging between 0.29 – 0.04 mg/L exceeding the health guidelines.

High iron and sulfate concentrations were found in most domestic bores. This is expected in areas affected by ASS where the oxidation of the pyritic sulfur produces dissolved ferrous iron sulfate, and further oxidation to ferric iron is mediated by iron oxidising bacteria, particularly *Thiobacillus ferooxidans*[11]. At low pH the ferric iron remains in solution and diffuses to the pyrite surface where it is reduced to ferrous generating acidity. The soluble iron may migrate several kilometres offsite in acid solution before precipitating as ochre in a more oxidising environment. The residents in the affected area have reported increased iron contamination in their bores causing considerable staining and crop damage

[10] McLaughlin et al, 1998 – Metlas and micronutrients – food safety issues
[11] Wakao et al 1984 - Bacterial pyrite oxidation III, Adsorption of Thiobacillus ferooxidants on solid surfaces and its effect on iron release from pyrite.

5.2 Soil samples

5.2.1 Commercial growers

None of the soil samples tested exceeded the draft Contaminated Site Assessment Criteria guidelines 2000 value for arsenic of 20 mg/kg. Two samples exceeded the environmental investigation level for copper and one for sulfate

5.2.2 Peat Stockpile

Soil samples from the peat stockpiles were subject to net acid generation and gross acid production potential. Of the 20 samples of the stockpile materials 6 samples have high potential acid generation and one sample has moderate acid generation potential from Stirling Lakes development. Two samples from Roselea development show high acid generation capacity.

The results in Table 7 show the net acid generation and the gross acid production potential for the 9 stockpile samples. The highest gross acid production potential for the peat stockpile is estimated at 81kg H_2SO_4/tonne of soil material.

Stockpile Reference	Slurry	NAG	NAG H_2SO_4	Total Sulfur	Sulfur present as sulfate	GAPP H_2SO_4
	pH	pH	Kg/tonne	% S	% S	Kg/tonne
003	5.2	3.0	42	1.12	0.34	24
004	5.1	4.7	15	0.94	0.2	23
006	6.0	3.9	23	0.24	0.12	3.6
007	4.3	3.1	60	0.76	0.27	14
008	5.1	3.0	50	1.57	0.45	34
010	3.1	2.2	159	3.51	0.85	81
011	3.7	3.3	47	0.65	0.36	8.8
012	4.3	3.7	20	0.55	0.32	7.0
013	4.0	4.6	22	0.5	0.28	6.7

Table 7: The results of static acid based accounting test.

5.3 Plant samples

The most important elements to consider for food chain contamination are arsenic, cadmium, mercury, lead and selenium. When soils are enriched with these materials they are likely to be caused by human activities such through agricultural, industrial or urban development [12].

None of the plant samples tested exceeded the ANZFA Food Standards Code, 1998 value for arsenic of 1 mg/kg. Fourteen samples exceeded the ANZFA Food Standards Code, value for lead of 0.1 mg/kg. No samples exceeded the cadmium value of 0.1 mg./kg.

[12] McLaughlin, et al, 1998 – Metals and micronutrients – food safety issues

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Stirling acidity issue

Preliminary investigations indicate that groundwater acidity and arsenic contamination in Stirling has been caused by the combined effects of dewatering for residential development, excavation and stockpiling of sulphide-rich peat and abnormally dry weather. These factors have exposed the normally waterlogged soil to the air, causing the rapid oxidation of sulphides and generating acidic, arsenic-rich leachate that has contaminated shallow groundwater. The acidity of groundwater in 44 of the 800 bores tested is sufficiently high to kill or impair the growth of garden plants, and arsenic concentrations in 22 bores exceed the national drinking water guideline value of 7 µg/L by a factor of up to more than 1000 (maximum measured concentration of 7300 µg/L), noting that the Health Department strongly recommends against drinking untreated bore water.

The contamination is most extensive down-gradient in the direction of groundwater flow (south-west) from the Roselea development and south-west of excavated lakes on Spoonbill Reserve. Contamination caused by activities on the proposed Stirling Lakes residential estate is much more localised.

Without adequate management, acidic groundwater and drainage from the site has the potential to continue to affect groundwater usage from shallow bores, affect the environmental values of the conservation-category Herdsman Lake, and pose a threat to the long-term integrity of sub-surface urban infrastructure in the area (concrete and steel footings, pipelines etc.). The inappropriate use of bores contaminated by arsenic (use for drinking, children playing under sprinklers) could also continue to pose a risk to public health. The following measures are recommended to ameliorate these potential impacts:

6.1.1 Development of Acid Sulfate Soil Management Plans.

It is recommended that no further dewatering or peat excavation takes place on the Roselea or Stirling Lakes estates until the proponents have developed an acid sulfate management plan and have demonstrated to the satisfaction of planning and environmental regulatory authorities that the distribution of Potential Acid Sulfate Soil (PASS) has been identified and that management measures are in place to prevent further groundwater quality impacts. Western Australia does not currently have guidelines for the assessment and management of acid sulfate soils, so it is recommended that guidelines developed by the Queensland Department of Natural Resources are used as these incorporate best management practices and, together with similar New South Wales guidelines, are *de facto* national standards. The Queensland assessment and management guidelines form part of a State Planning Policy (SPP) for acid sulfate management for that State, and are available as PDF files at the following web site:

http://www.nrm.qld.gov.au/resourcenet/land/landplan/lp-ass/ass-spp.html

6.1.2 Remediation of acidic surface water bodies

Without ongoing treatment with lime or other management measures, the acidity and metal contamination within the Spoonbill lakes and excavations to the water table on the Roselea estate will continue to present a public health risk, particularly to young children. They will also continue to act as a source of groundwater acidity and arsenic contamination. These water bodies currently have limited environmental values, and it is recommended that options for remedying acidic water bodies on Spoonbill Reserve be investigated immediately and include measures to retard any further pyrite oxidation. A practical option is to backfill the affected lakes and impacted water bodies with alkaline materials (such as crushed limestone). Soil around the lakes in the Spoonbill Reserve may be contaminated with high concentrations of heavy metals, and the islands in the centre of the lakes may have been formed from excavated soil that could contain pyrite. It is recommended that the extent and severity of metal contamination in this material is assessed using contaminated soil guidelines developed by the Department of Environmental Protection, and that contaminated soil is excavated and disposed of at a suitable landfill site or in an acceptable manner approved by the regulatory agency.

6.1.3 Removal of peat stockpiles

The peat stockpiles on the Stirling Lakes and Roselea Estates contain material with a moderate to high acid generation capacity and pose an ongoing risk to groundwater quality downgradient (south-west) of the stockpiles. It is recommended that this material is removed from the area as soon as is practicable to mitigate this risk. This action has been initiated by the Department of Environmental Protection.

Without adequate lime dosing (at least 1.5 times the acid generation capacity) the peat will be unsuitable for use in agriculture due to the risk of generating excessive soil acidity. Much of material will also be unsuitable for use in gardens due to its high heavy metal content and so disposal at a suitable landfill site may be the only disposal option. The New South Wales EPA recommends the following measures are adopted when disposing of acid sulfate soils in landfill sites:

- The status of the waste ASS (potential or actual ASS) should be determined using the assessment techniques outlined in acid sulfate soil assessment guidelines before disposal is considered.
- Potential and actual ASS must be treated by the generator before acceptance by a landfill occupier for disposal. Treatment should be undertaken in accordance with the neutralising techniques outlined in acid sulfate soil assessment guidelines.

Landfill operators should consider the following points when accepting ASS for disposal in a landfill:

- Significant amounts of waste ASS should be managed within a discrete cell (that is, a lined monocell) of a landfill. This will ensure that any potential acidic leachate generated by waste ASS that may not be fully neutralised by the above treatment can be controlled to reduce the likelihood of such leachate coming into contact with other types of waste.
- Special care should be taken to ensure that contaminated, hazardous or industrial wastes are not in the vicinity of the ASS.
- ASS must not be used as a cover material, as it may oxidise and produce highly acidic leachate.

6.1.4 Water table management

Groundwater acidity problems may continue to occur in residential areas adjacent to the Roselea and Stirling Lakes estates unless management measures are implemented to control the extent to which the watertable is lowered by groundwater pumping and seasonal factors in the area. Management measures that could be implemented include:

- Determine the vertical distribution of potential acid sulfate soils in the area to allow maximum extent that the water table can be drawn down by pumping before additional acidity may be caused by the exposure of sulfide minerals to air. This work is proposed as part of a proposed project to be undertaken by a masters student in the area.

- Install monitoring and aquifer testing bores to determine how the water table in the area responds to different rates of groundwater pumping and to variations in winter rainfall. Ongoing monitoring of water levels in monitoring bores would indicate when the water table has declined to the point that further acid generation is possible.
- Develop a flexible and adaptive water allocation policy for domestic and council bores in the area.
- Ensure that any drains in the area are not excavated into potential acid sulfate soils below the water table. Broad, shallow drains are preferable to deep, narrow drains.

It is recommended that the Water and Rivers Commission instigate the development of a groundwater management strategy for the area in consultation with the City of Stirling, adjoining developers and local residents to prevent further groundwater acidification occurring. Any further development would need to be consistent with the groundwater management strategy.

6.1.5 Rehabilitation and monitoring of affected domestic bores

A combination of climatic variation and peat disturbance has contributed to the acidification of groundwater. Domestic bores in the immediate area that are affected by acidity should be remediated such as by bore deepening. It is recommended that the adjoining developers and the City of Stirling consult with the affected bore owners in this regard. It is also recommended that the City of Stirling facilitate ongoing monitoring of pH to ensure that new bores are not affected by groundwater acidity. Bores with pH values less than 5.5 should be sampled by the City of Stirling for arsenic and heavy metal content with advice from the Water and Rivers Commission.

6.1.6 Assessment of the effects of acidity on urban infrastructure

The presence of acid sulfate soils in the vicinity of the Roselea and Stirling Lakes estates may present a long term threat to sub-surface infrastructure. It is recommended that the owners of sub-surface infrastructure carry out an assessment of any current and potential impacts of acidity on infrastructure in the area.

6.1.7 Protecting Herdsman Lake from acidic drainage

Drainage from the vicinity of the Roselea and Stirling Lakes is carried in drains that discharge into Herdsman Lake and has the potential to affect this conservation-category wetland. The acidity of drainage downstream of the Roselea and Hamilton Lake estates is currently being moderated by the use of limestone in drains, but this is likely to only be a short-term strategy. Additionally, the neutralisation of the acid drainage is generating highly turbid water containing flocs of aluminium and iron hydroxides that may also cause environmental effects in Herdsman Lake.

It is recommended that the Water and Rivers Commission, in consultation with the City of Stirling and the Water Corporation, undertake a risk assessment of the effects of drainage from the vicinity of the Roselea and Hamilton Lake estates on Herdsman Lake and implement appropriate management measures to protect this wetland.

6.2 State planning and environmental approvals issues

The groundwater acidity and arsenic contamination issue in Stirling has resulted from the inadequate consideration of acid sulfate soil issues in current State planning and environmental approval processes. This does not absolve developers from ensuring that developments are environmentally acceptable or suggest that informal reviews are not the appropriate mechanism for dealing with land developments. However, unlike many other states, Western Australia does not have a State Planning Policy that specifically addresses acid sulfate soils, and consequently there is an ongoing risk that sites with acid sulfate soils will be developed inappropriately within WA. Issues like the groundwater acidity problem in Stirling could be largely eliminated if WA were to develop and adopt an acid sulfate SPP modelled on Queensland and New South Wales policies. This would ensure that acid sulfate soils are considered at a very early stage in a development program before soils are disturbed and acidity problems are created.

It is also recommended that Western Australia adopts and implements measures set out in the National Strategy for the Management of Coastal Acid Sulfate Soils (available at web site http://www.affa.gov.au/docs/operating_environment/armcanz/pubsinfo/ass/ass.html).

The principal objectives of the National Strategy are:

1 to identify and define the extent of acid sulfate soils in coastal areas of Australia

2 to avoid disturbance of coastal acid sulfate soils wherever possible

3 to mitigate impacts when disturbance of these soils is unavoidable

4 to rehabilitate environmental impacts caused by the disturbance of acid sulfate soils.

In Western Australia, the first objective is particularly important as there is currently only a very general understanding of the distribution of acid sulfate soils within the State. Queensland and New South Wales have produced detailed acid-sulfate risk maps for coastal areas, and a similar mapping exercise in Western Australia could identify areas where inappropriate development may cause acidity problems.

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Stirling Acid Water Investigation
Government of Western Australia
15
14
13
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SLA #1
SLA #2
SLA #3
SLA #4
SLA #5
SLA #6
SLA #7
SLA #8
SLA #9
SLA #11
SLA #12
SLA #13
WATER SAMPLE
SOIL SAMPLE
PEAT STOCKPILE
PEAT STOCKPILE
Soil and Groundwater Samples
Groundwater Flow Direction
Groundwater Sampling Bore
Surface Drain Network
Study Area
Groundwater Contours - 1m interval (Estimated Maximum water table contours in metres above AHD)
Peat Stockpiles
N
2001 SkyView Aerial Imagery Courtesy - DOLA
Surface Drain Network Data - Watercorp
Groundwater Contours - Water and Rivers Commission
100 0 100 200 m

FIGURE 1.

Stirling Acid Water Investigation - pH

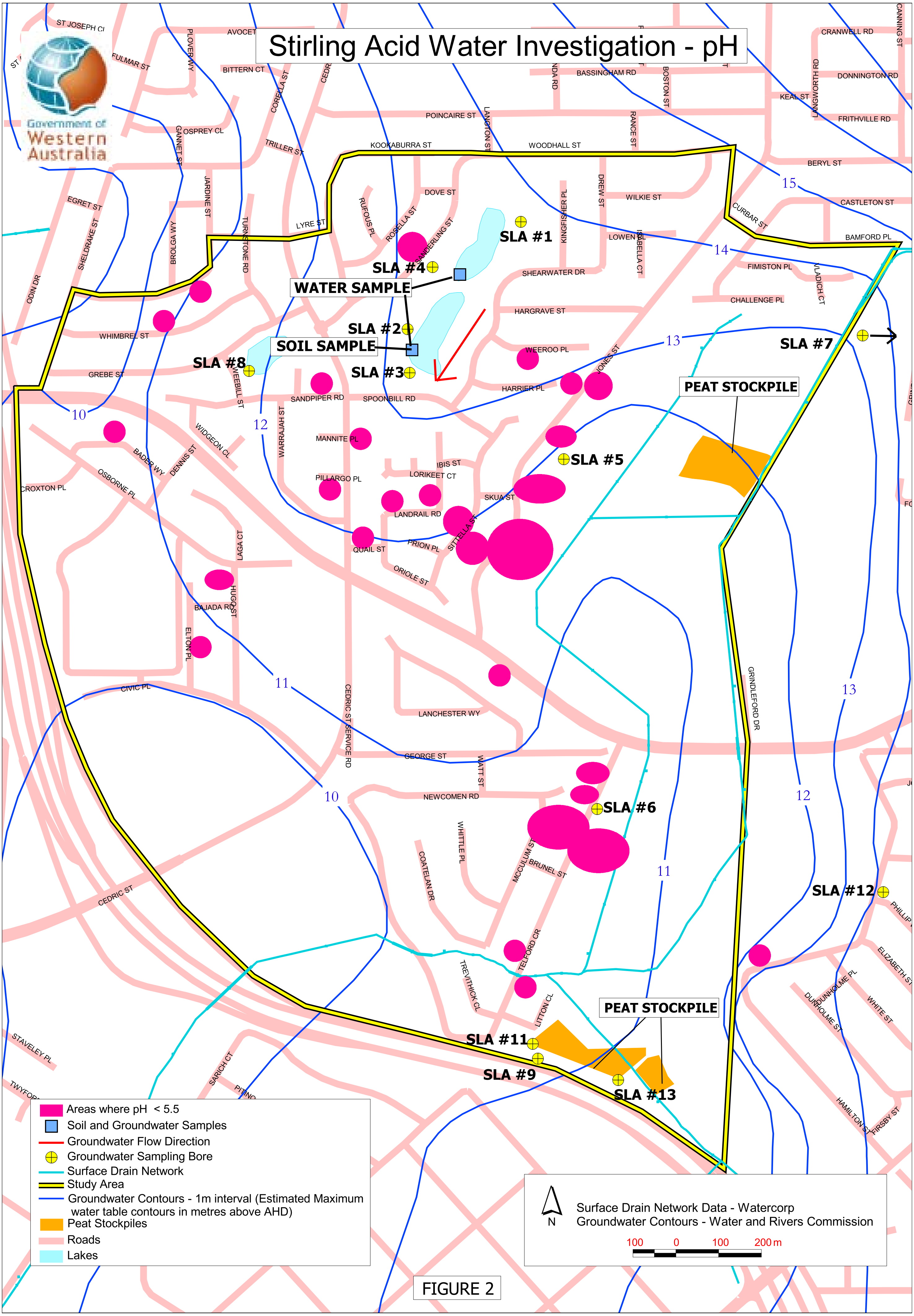
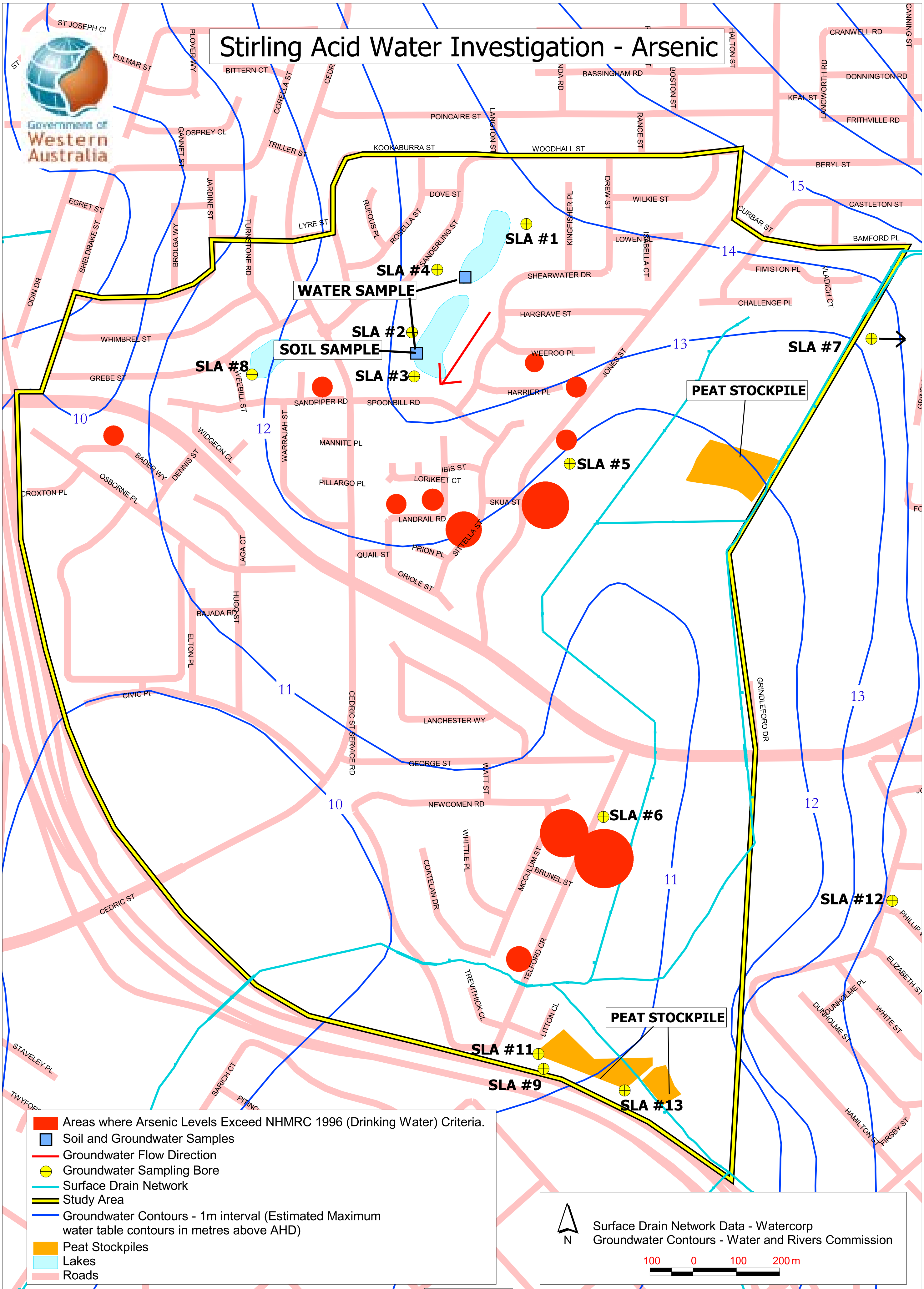


FIGURE 2



Stirling Acid Water Investigation - Arsenic
Government of Western Australia
WATER SAMPLE
SOIL SAMPLE
SLA #1
SLA #2
SLA #3
SLA #4
SLA #5
SLA #6
SLA #7
SLA #8
SLA #9
SLA #11
SLA #12
SLA #13
PEAT STOCKPILE
PEAT STOCKPILE
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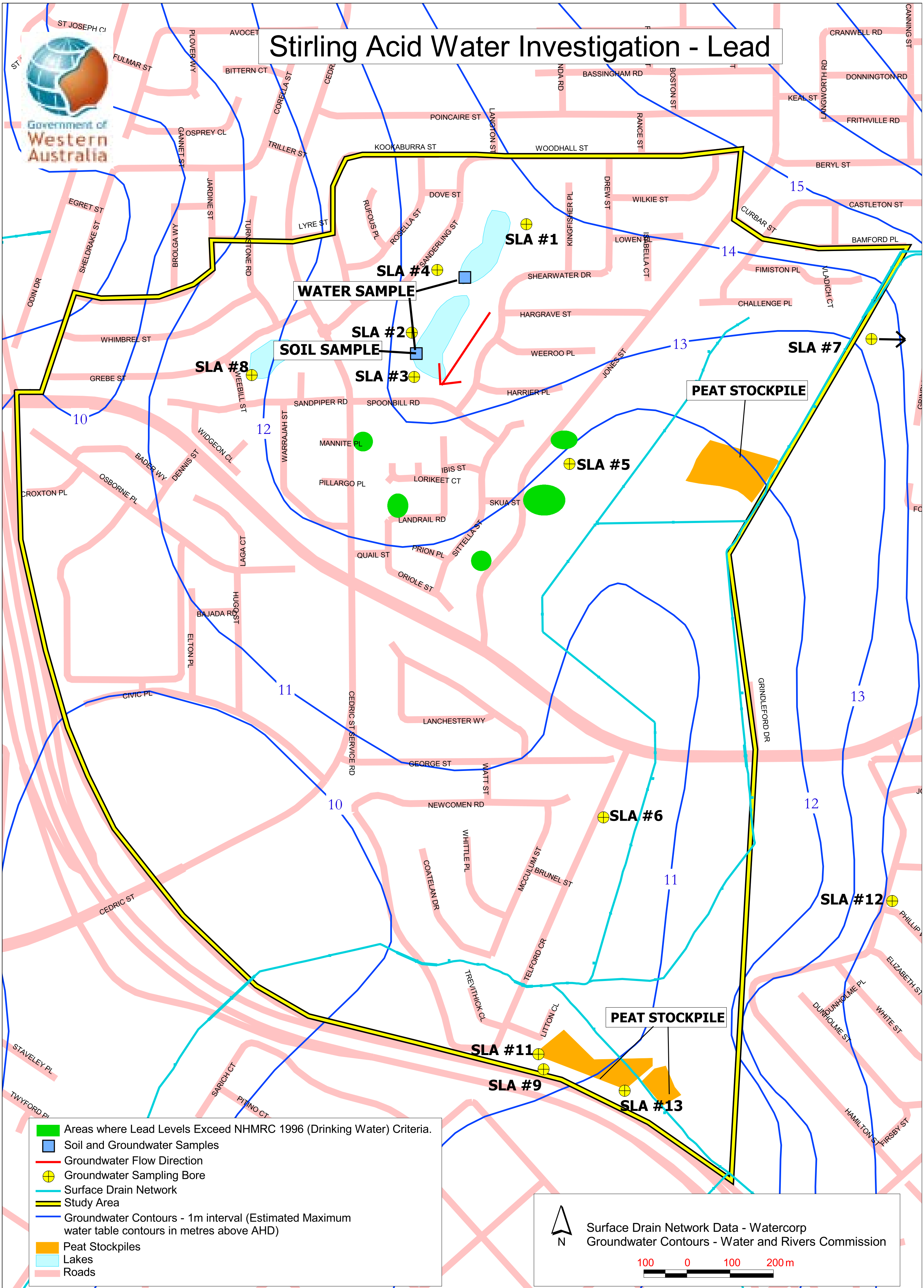
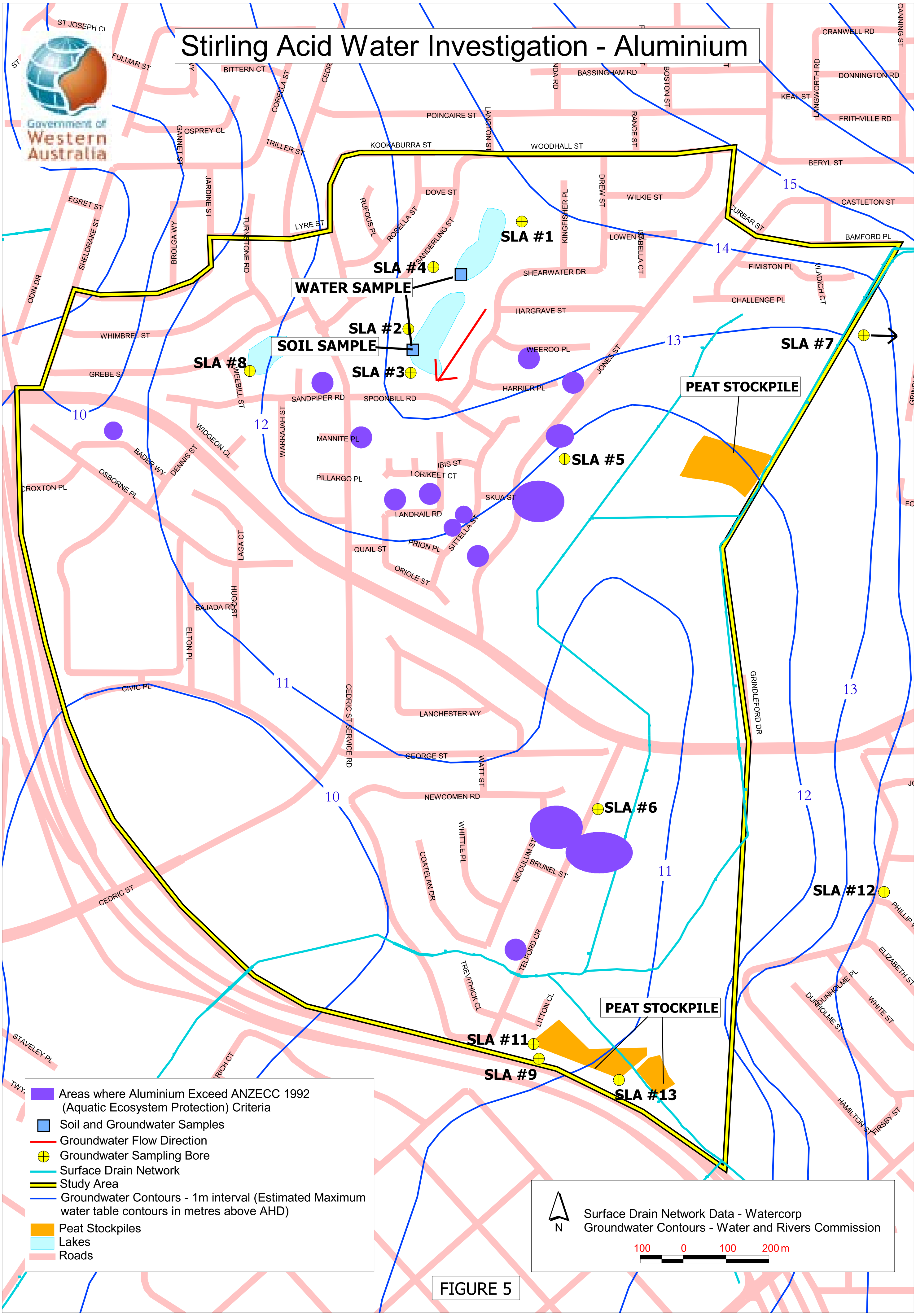
ST JOSEPH CL
FULMAR ST
PLOVER WY
BITTERN CT
COREILLA ST
BASSINGHAM RD
BOSTON ST
HALTON ST
CRANWELL RD
DONNINGTON RD
KEAL ST
FRITHVILLE RD
POINCAIRE ST
LANGTON ST
OSPREY CL
GANNET ST
TRILLER ST
KOOKABURRA ST
WOODHALL ST
BERYL ST
DOVE ST
DREW ST
WILKIE ST
CASTLETON ST
CURBAR ST
BAMFORD PL
EGRET ST
JARDINE ST
BROLGA WY
TURNSTONE RD
LYRE ST
RUFOUS PL
ROSELLA ST
SANDERLING ST
KINGFISHER PL
LOWEN PL
ISABELLA CT
SHEARWATER DR
FIMISTON PL
CHALLENGE PL
SHELDRAKE ST
ODIN DR
WHIMBREL ST
HARGRAVE ST
GREBE ST
WEEROO PL
JONES ST
HARRIER PL
WEEBILL ST
SANDPIPER RD
SPOONBILL RD
WIDGEON CL
WARRAJAH ST
MANNITE PL
BADER WY
DENNIS ST
OSBORNE PL
IBIS ST
LORIKEET CT
PILLARGO PL
CROXTON PL
SKUA ST
LANDRAIL RD
SITTELLA ST
PRION PL
QUAIL ST
ORIOLE ST
LAGA CT
BAJADA RD
HUGO ST
ELTON PL
CIVIC PL
LANCHESTER WY
CEDRIC ST SERVICE RD
GEORGE ST
WATT ST
NEWCOMEN RD
WHITTLE PL
COATELAN DR
MCCULUM ST
BRUNEL ST
GRINDLEFORD DR
CEDRIC ST
TELFORD CR
TREVITHICK CL
LITTON CL
SARICH CT
STAVELEY PL
PHILLIP
ELIZABETH ST
DUNHOLME PL
DUNHOLME ST
WHITE ST
HAMILTON ST
FIRSBY ST
Areas where Arsenic Levels Exceed NHMRC 1996 (Drinking Water) Criteria.
Soil and Groundwater Samples
Groundwater Flow Direction
Groundwater Sampling Bore
Surface Drain Network
Study Area
Groundwater Contours - 1m interval (Estimated Maximum water table contours in metres above AHD)
Peat Stockpiles
Lakes
Roads
N
Surface Drain Network Data - Watercorp
Groundwater Contours - Water and Rivers Commission
100 0 100 200 m

FIGURE 3


Stirling Acid Water Investigation - Lead
Government of Western Australia
SLA #1
SLA #2
SLA #3
SLA #4
SLA #5
SLA #6
SLA #7
SLA #8
SLA #9
SLA #11
SLA #12
SLA #13
WATER SAMPLE
SOIL SAMPLE
PEAT STOCKPILE
PEAT STOCKPILE
Areas where Lead Levels Exceed NHMRC 1996 (Drinking Water) Criteria.
Soil and Groundwater Samples
Groundwater Flow Direction
Groundwater Sampling Bore
Surface Drain Network
Study Area
Groundwater Contours - 1m interval (Estimated Maximum water table contours in metres above AHD)
Peat Stockpiles
Lakes
Roads
N
Surface Drain Network Data - Watercorp
Groundwater Contours - Water and Rivers Commission
100 0 100 200 m
FIGURE 4


Stirling Acid Water Investigation - Aluminium
Government of Western Australia
SLA #1
SLA #2
SLA #3
SLA #4
SLA #5
SLA #6
SLA #7
SLA #8
SLA #9
SLA #11
SLA #12
SLA #13
WATER SAMPLE
SOIL SAMPLE
PEAT STOCKPILE
PEAT STOCKPILE
10
11
12
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14
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ST JOSEPH CI
FULMAR ST
BITTERN CT
COREELLA ST
CEDR
BASSINGHAM RD
BOSTON ST
CRANWELL RD
DONNINGTON RD
KEAL ST
LANGWORTH RD
FRITHVILLE RD
CANNING ST
POINCAIRE ST
LANGTON ST
RANCE ST
OSPREY CL
GANNET ST
TRILLER ST
KOOKABURRA ST
WOODHALL ST
BERYL ST
CASTLETON ST
EGRET ST
JARDINE ST
DOVE ST
DREW ST
WILKIE ST
CURBAR ST
SHELDRAKE ST
BROLGA WY
TURNSTONE RD
LYRE ST
RUFOUS PL
ROSELLA ST
SANDERLING ST
KINGFISHER PL
LOWEN PL
ISABELLA CT
BAMFORD PL
ODIN DR
SHEARWATER DR
FIMISTON PL
VLADICH CT
CHALLENGE PL
HARGRAVE ST
WHIMBREL ST
WEEROO PL
JONES ST
GREBE ST
WEEBILL ST
HARRIER PL
SANDPIPER RD
SPOONBILL RD
WARRAJAH ST
MANNITE PL
WIDGEON CL
BADER WY
DENNIS ST
OSBORNE PL
CROXTON PL
IBIS ST
LORIKEET CT
PILLARGO PL
SKUA ST
LANDRAIL RD
SITTELLA ST
PRION PL
QUAIL ST
ORIOLE ST
LAGA CT
HUGO ST
BAJADA RD
ELTON PL
GRINDLEFORD DR
CIVIC PL
LANCHESTER WY
CEDRIC ST SERVICE RD
GEORGE ST
WATT ST
NEWCOMEN RD
WHITTLE PL
COATELAN DR
MCCULUM ST
BRUNEL ST
CEDRIC ST
TELFORD CR
TREVITHICK CL
LITTON CL
PHILLIP
ELIZABETH ST
DUNHOLME PL
DUNHOLME ST
WHITE ST
HAMILTON ST
FIRSBY ST
STAVELEY PL
Areas where Aluminium Exceed ANZECC 1992 (Aquatic Ecosystem Protection) Criteria
Soil and Groundwater Samples
Groundwater Flow Direction
Groundwater Sampling Bore
Surface Drain Network
Study Area
Groundwater Contours - 1m interval (Estimated Maximum water table contours in metres above AHD)
Peat Stockpiles
Lakes
Roads
N
Surface Drain Network Data - Watercorp
Groundwater Contours - Water and Rivers Commission
100 0 100 200 m

FIGURE 5

ATTACHMENT 1

Department of **Health**
Government of **Western Australia**

Public Affairs

Media Statement

10 January 2002

Parts of Stirling affected by acidic groundwater: Department of Health

The Department of Health has warned against contact with groundwater, following the detection of isolated pockets of highly acidic waters in Perth's northern suburbs.

The acidic water is caused when naturally occurring sulphide minerals in peat sediments are exposed to air.

Acting Director of Environmental Health Brian Devine said the problem may be the result of successive dry summers leading to a low water table, combined with local excavation works.

He said that while the problem seemed to occur in small pockets rather than over a widespread area, it was important for the community to be aware of the situation.

"At this stage we are aware of only one residential and one council groundwater bore being affected," Mr Devine said.

"The Spoonbill wetland in the suburb of Stirling has also been identified as being affected by high acidity.

"Investigations and health warnings are focused on properties west of Main Street, south of Beryl Street and east of the Spoonbill wetland in the suburbs of Stirling and Balcatta.

Mr Devine said people in the affected area should avoid skin or eye contact with ground water. The Department of Health has always advised against drinking untreated groundwater from any area.

"Contact with acidic water may cause skin and mucous membrane irritation," he said.

"If exposed to acidic water, external affected areas should be thoroughly washed with scheme tap water and a doctor should be consulted if irritation persists."

Mr Devine said the City of Stirling and land developers in the area were erecting signs around affected surface water.

The Water and Rivers Commission was investigating other surface water that could be affected.

In addition, further testing of groundwater bores was being undertaken and a door-to-door survey in the area would be carried out to locate and test residential groundwater bores.

City of Stirling Chief Executive Officer Lindsay Delahaunty said the problem was first noticed when a local resident found water from her garden bore was affecting her lawn and vegetable garden.

“We are concerned that water from some bores could cause skin irritation or damage gardens,” Mr Delahaunty said.

“Therefore, we are contacting residents in the affected area to advise them to avoid contact with water from their garden bores until a sample of the water has been tested by authorities.

“The City has set up a direct contact line to advise residents in the affected area and I would encourage people in the area to heed the health warnings on signs around affected surface water and avoid contact with water from their garden bores.

“The City will continue to work with the authorities and land developers to rectify the problem.”

Residents with queries about the effect of exposure to acidic water should contact the Department of Health on 9388 4997.

Queries about acid sulphate soils or the sampling being program should be directed to the Water and Rivers Commission on 9278 0517.

Bore owners in the affected area should call the City’s of Stirling’s Senior Environmental Health Officer on 9345 8793.

Media contacts:
Department of Health, Jean Perkins, 9222 4333
Water and Rivers Commission, Paul McLeod 92787 0718
City of Stirling, Peter Beard 9345 8657

ATTACHMENT 2

Letter to residents in affected area.

11 January 2002

Dear Resident

Recent tests of bore water in your area by the Water and Rivers Commission have revealed high acidity levels in a small number of bores.

High acidity levels of this type occur naturally and area caused by below-ground peat being exposed to air through lowering of the water table. The Water and Rivers Commission have advised this could be attributable to Perth's recent run of dry winters and removal of peat for sub-divisional development in the area.

Contact with acidic bore water may cause skin or eye irritation and could damage your garden. The City of Stirling recommends that if you own a bore you should avoid contact with the water until a sample has been analysed by the Water and Rivers Commission. Analysis is a simple process and collection of a sample can be arranged by calling Steve Appleyard at the Water and Rivers Commission on 9278 0517.

The City of Stirling is working with the developers, Department of Health and the Water and Rivers Commission to rectify the situation.

If you require any further information please call the city of Stirling's Senior Environmental Health Officer Mr Neil Duffin on 9345 8793.

Yours Sincerely,

Lindsay Delahaunty
Chief Executive Officer

ATTACHMENT 3

Arsenic water fears

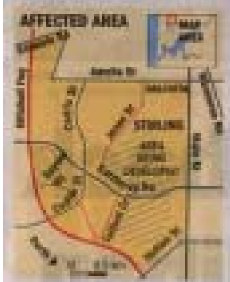
Urban spread, dry winter blamed for contamination

By Sarah Heinzman

THE Health Department has warned residents against drinking groundwater or eating fruit and vegetables irrigated with groundwater after an arsenic scare yesterday.

Experts say it could be decades before the contamination in Perth's northern suburbs is cleared.

Six bores have tested positive to high levels of arsenic, with one bore recording levels 100 times the acceptable limit.



The bores also contained high levels of lead, iron and sulfate.

All bores which tested positive to the heavy metals were shallow. Four of them were on Jones Street which runs through Balcatta and Stirling and the other two were in Butler Way and Telford Crescent, Stirling.

The draining of marshy land for housing development and last year's dry winter have been blamed for the problem.

Water and Rivers Commission groundwater contamination manager Steve Appleyard said the groundwater levels in the area had been lowered by excessive pumping of water.

This was a major contributor to the arsenic problem.

He said arsenic occurred naturally in layers of peat in marshy land.

It was concentrated when the ground dried and released when it was wet again.

The West Australian understands property developers are issued licences by the commission to drain water from land to prepare it for development.

The commission said developers had not breached any conditions of their licences.

It is not clear how many developers or how many subdivisions are in the affected area.

A developer in the area contacted by *The West Australian* said it had not been approached by the commission about the problem.

Mr Appleyard said arsenic contamination could become more widespread in the area as the heavy metal leached to lower groundwater supplies.

He said it would be decades before the problem would correct itself. In the meantime, the only solution available to residents was to dig a deeper bore or switch entirely to scheme water.

Jones Street resident Alinio Petrozzi, whose bore is contaminated, said he noticed discoloration of his water and that his plants were suffering 18 months ago. "I'm surprised and disappointed," Mr Petrozzi said. "I always believed this water was good enough for the garden."

He said he used to be able to grow big tomatoes good enough to put in competitions but now he found it hard to grow any at all.

Health Department principal toxicologist Peter Di Marco said if water containing arsenic was drunk over a long period, it could lead to a range of health problems, including cancer.

He said physical contact with the water should also be avoided as its acidity could cause skin and mucous membrane irritation.

While the risk of illness from eating contaminated fruit and vegetables was low, further testing was needed to find the levels of heavy metals.

Environment Minister Judy Edwards said last night the State Government had ordered a full investigation into the matter.

Dangerous drop: Alinio Petrozzi helps Water and Rivers Commission worker Stephen Wong take a bore water sample from his Stirling home. Safety fears have been raised after high levels of heavy metals, including arsenic, were found in several bores. PICTURE: ROD TAYLOR

Acidic bore water found

■ By Andrew Gregory

THE Health Department has warned Stirling and Balcatta residents to be cautious after acidic groundwater was found in bores.

Bore water contaminated with sulphuric acid was discovered about two weeks ago with a pH reading of 2.5, indicating an acidity similar to lemon juice or vinegar. Normal drinking water has a pH balance of about seven.

The department warned residents west of Main Street, south of Beryl Street and east of Jones Street not to drink bore water from the area and to wash thoroughly any area of the body which came into contact with it.

One private and one council and the Spoonbill wetland were affected.

ATTACHMENT 4

Department of **Health**
Government of **Western Australia**

STIRLING GROUNDWATER CONTAMINATION
FREQUENTLY ASKED QUESTIONS

What is the extent of the affected area and how many bores have been affected?

The area of concern and under investigation was bordered by Poincaire Street in the North, Grindleford Drive in the East, just below Karrinyup Road in the South and the Mitchell Freeway in the West. The area has now been restricted to the Jones Street and Telford Crescent areas and West Southwest of Spoonbill Wetlands.

The sampling program has tested over 800 individual bores for acidity with more than 40 of these being analysed for metals. The majority of bores were not contaminated. The findings from sampling in the Stirling area can be summarised:

- Bores affected by acidic water less than pH4.5 appears to be restricted to approximately 40 bores.
- Slightly elevated levels of some metals, particularly arsenic, were found in some bores with a pH of less than 4.5.
- With the exception of one bore, bores tested with a pH greater than 5.5 have not been found to be affected by elevated heavy metals of concern.

What does pH mean?

pH is a measure of the acidity or alkalinity of H_2O solutions. pH 7 is neutral, above 7 is alkaline and below is acidic. The Australian Drinking Water Guidelines sets a guideline for this characteristic of water between 6.5-8.5.

How do I know if my bore has been affected?

Affected bores have almost exclusively been found to have a low pH. The results indicate that if your bore water has a pH greater than 5.5 the level of metals should be within the levels recommended by the Australian Drinking Water Guidelines and the bore water is safe to be used for irrigation purposes.

What has caused the groundwater contamination?

Acid sulfate soils, which are soils that contain iron sulphides, are found naturally in the Stirling/Balcatta area. When exposed to air, iron sulphides oxidise and produce sulfuric acid. The soil itself can neutralise some of the sulfuric acid but the remaining acid moves through the soil, acidifying the soil, groundwater and eventually surface water. Areas where iron sulphide layers occur are waterlogged. Drainage and excavation of these areas expose the iron sulphide layers to air, which accentuates the rate of oxidation, and this concentrated acid can overwhelm the natural ability for the environment to neutralise it. This is what appears to have happened in the Stirling/Balcatta area. Lowering of the water table and sulphide soil disturbance has resulted in an increase in sulphuric acid in the groundwater.

How long as the groundwater been contaminated?

It is possible that there has been an acidic water issue in the area for at least the last 12 months.

Water and Rivers Commission is investigating the extent of groundwater impact and once the information has been collated a better estimate of how long the problem has been present can be made.

How long until the contamination is fixed?

It is difficult to say exactly how long this problem will exist. Experience from the Eastern States would indicate that high acidity in groundwater might persist for decades. Acidic groundwater will continue to leach metals, if present, until the water pH returns to more neutral conditions.

What types of contaminants are in the groundwater?

There is a high sulphuric acid content in the soil and groundwater that has resulted in the leaching of some elements from the surrounding soil. Elements that can be leached from the soil include metals. The metals sampled for were Aluminium, Barium, Boron, Calcium, Chromium, Cobalt, Copper; Iron, Potassium, Magnesium, Manganese, Molybdenum, Sodium, Nickel, Sulphur (expressed as sulphate), Vanadium, Zinc, Lead, Cadmium and Arsenic. The majority of bores sampled were free of contamination. Groundwater is not recommended for drinking water purposes but if the levels are compared to the Australian Drinking Water Guidelines there were a few bores with slightly elevated levels of Arsenic, Lead, Iron, Nickel, Aluminium and Copper that exceed these guidelines

Where are these contaminants coming from?

As the sulphuric acid moves through the soil it strips metals from the soil and into the water. These metals have affected the groundwater quality in some areas.

The sources of the metals in the soil are most likely from natural sources as well as past horticultural, industrial or urban activities.

How is it possible for the contamination to get into my vegetables?

Many, but not all, of the contaminants of concern are actually essential for plant growth and human nutrition but these same elements may be toxic to plants and animals at high concentrations, whilst others have inadvertently entered the food chain. The ability of plants to accumulate and translocate these toxic elements to edible and harvested parts depends on the soil, climate factors, plant type and agricultural practices. In addition the availability of the contaminant to humans also depends on the contaminant in the food, dietary composition and nutritional status of the individual.

Tests conducted on vegetables from residential and commercial properties using groundwater for irrigation in the Stirling area have shown slightly elevated levels of lead, but not other metals. Elevated levels of lead were not found in water or soil samples collected from some of the same properties. Therefore, there does not appear to be a correlation between the levels of lead in bore water or soil samples with levels found in the vegetables. The Department of Health is working with other agencies to investigate the likely source.

While the results indicate that the level of lead in some produce is above the maximum limit allowed under the Food Standards Code, consumers are unlikely to have been exposed to a sufficient amount of lead from the affected vegetables to present a health risk.

What has been done in response to the contamination?

The Department of Health has been working in collaboration with the City of Stirling, Water and Rivers Commission and the Department of Environmental Protection to determine those people affected by acidic water and the bores which are at risk from metal contamination.

Residents have been encouraged to bring water from their bore and have it tested for pH levels at the City of Stirling offices. If the pH of the groundwater was below 5.5 further testing was initiated.

What are the likely health effects from these contaminants?

The levels of metals detected, while elevated in some of the affected bores, is not considered sufficient to pose a risk to bore owners. Notwithstanding, the highly acidic nature of the affected bores could result in skin, eye and mucous membrane irritation if exposed. If your bore water has been tested and shown to be acidic you should consider using alternative water sources for irrigation.

I'm pregnant; will my baby be affected?

The level of metals in water used for irrigation is not sufficient to cause harm to you or your baby. While the levels of some metals were found to be slightly elevated in some fruit and vegetables, they are below a level that would cause a health effect if the produce has been consumed.

I am still worried about what these chemicals might do to my health. What should I do?

If you have any concerns about your health we recommend that you talk to your doctor, who is in the best position to assess your health. The Toxicology Section of the Environmental Health Branch is able to provide advice on the effects of exposure to chemicals. If you doctor requires more information on a particular chemical, he/she can call 1800 020 080, or you can leave your details at that number to have an officer from the Toxicology Section return your call.

What is being done about fixing the problem?

The Water and Rivers Commission and the Department of Environmental Protection are still investigating the problem and will be exploring different management options that can be taken.

If you are one of the bore owners with acidic water it is recommended that you explore using alternative water sources for irrigation. The Department of Health takes this opportunity to remind bore owners that untreated bore water is not recommended for use as a drinking water source.