REPORT

Auckland Council - Environmental Services Unit

Stokes Point Reserve, Northcote Soil Contamination, Human Health Risk Assessment

Report prepared for:

Auckland Council - Environmental Services Unit

Report prepared by:

Tonkin & Taylor Ltd

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1 Introduction

Tonkin & Taylor Ltd (T&T) has been requested by Auckland Council to prepare this updated version of the human health risk assessment for soil contamination at the Stokes Point Reserve, Northcote (refer Figure 1) to address peer-review comments received from the Auckland Regional Public Health Service (ARPHS). This updated human health risk assessment has been prepared in accordance with our proposal of 08 February 2011.

1.1 Background

We understand that as part of the Auckland Harbour Bridge Maintenance Consent Renewal a ground contamination assessment of the reserve was undertaken. Near surface samples (i.e. upper 0.1 m) were collected by OPUS International Consultants Ltd (OPUS) on a general grid pattern across the reserve on 05 August 2010. Twenty (20) samples were tested for metals and seven (7) of those samples were selected for total petroleum hydrocarbon (TPH), polycyclic aromatic hydrocarbon (PAH) and BTEX (benzene, toluene, ethylbenzene and xylene) analysis (refer Figure 2 for sample locations). For the purpose of the human health risk assessment, we have assumed that the site contamination investigation provided to us was conducted in accordance with Ministry for the Environment Guidelines[1].

An excerpt from the report provided to Tonkin & Taylor Ltd (T&T) summarises the test results and indicates copper, lead, zinc and benzo(a)pyrene equivalent (B(a)P eq.) concentrations exceed the permitted activity acceptance criteria set out in the Proposed Auckland Regional Plan: Air, Land and Water (Proposed ARP:ALW). T&T also undertook an independent evaluation of the results against the former Auckland City Council investigation/remediation criteria for soils – human health in a parkland/recreation setting (herein referred to as Council investigation criteria), which indicated some marginal exceedances of lead and B(a)P eq. The tabulated results presented in the report are attached in Appendix A.

In February 2011, additional site investigation work was undertaken by T&T to provide further characterisation of ground contamination at the site. The results of the additional soil testing indicated many B(a)P eq. concentrations and one lead concentration in the soil exceed the Council investigation criteria for parkland/recreation use (refer Figure 2 for the distribution of contaminants). Given the low usage rate of the reserve being significantly different to the usage rate of a typical reserve, Council requested this risk assessment to provide a more realistic understanding of the actual risk and the need for remediation works (if any).

1.2 Scope of work

The Tier 2 human health risk assessment presented here includes the following:

- Hazard Identification: Evaluation against screening criteria, review of toxicity information and identification of contaminants of concern.
- Exposure Assessment: Review of the source characteristics and exposure pathway assessment including exposure pathways, populations and exposure factors.
- Toxicity Assessment: Review of the toxicity data available for the contaminants of concern.
- Risk Characterisation: Presents the carcinogenic and non- carcinogenic risk estimate and derived soil guideline values.

[1] MfE, 2004, Site Investigation and Analysis of Soils, Contaminated Land Management Guidelines No. 5

The risk assessment has been undertaken to estimate the risk to child and adult users of the site and to derive acceptable soil guideline values using a quantitative risk assessment model. Further discussion about the model is provided in the following sections. Dr. Tim Sprott (Occupational Medicine Specialist) has provided advice regarding appropriate exposure factors to be used in the quantitative modelling.

2 Hazard Identification

2.1 Site investigation and Tier 1 screening level assessment

As discussed in Section 1.1, site investigation works have been undertaken across the site by OPUS to support the Auckland Harbour Bridge Maintenance Consent Renewal. The findings of the site investigation works were reported in November 2010.

OPUS only evaluated the soil test results against the Proposed ARP:ALW Permitted Activity soil acceptance criteria for discharges. T&T has undertaken an independent evaluation of the results against the Council investigation criteria and also the recently revised proposed NES soil contaminant values[2]. Although the revised proposed NES soil contaminant values were not available at the time of the investigation works or during preparation of this report, they have been given consideration in this updated report. This Tier 1 screening evaluation indicated the following exceedances:

- Lead with two concentrations of 620 mg/kg and 890 mg/kg above the Council investigation criterion of 600 mg/kg. One sample very marginally exceeded the revised NES soil contaminant value for lead at 880 mg/kg.
- B(a)P eq. (representing carcinogenic PAHs) with three concentrations between 2.01 mg/kg and 8.6 mg/kg, above the investigation criterion of 2 mg/kg. All B(a)P eq. concentrations are below the revised proposed NES soil contaminant value of 40 mg/kg.

To collect further information relating to the original August 2010 soil contaminant levels, T&T undertook additional ground contamination assessment across the reserve on 23 February 2011. The findings of the investigations have been reported separately[3] and the tabulated results presented in the report are attached in Appendix A. Evaluation of the results against the Council investigation criteria and revised proposed NES soil contaminant values indicates the following exceedances:

- 26 of 49 samples with B(a)P eq. concentrations between 2 mg/kg and 83 mg/kg, which exceed the Council investigation criterion of 2 mg/kg. The calculated 95% UCL of 15.8 mg/kg also exceeds the Council investigation criterion.
- 2 of 49 samples with B(a)P eq. concentrations of 46 mg/kg and 83 mg/kg above the revised proposed NES soil contaminant value of 40 mg/kg.
- 1 sample with a lead concentration of 840 mg/kg that exceeds the Council investigation criterion of 600 mg/kg. The calculated 95% UCL of 220 mg/kg is below the criterion.
- All lead test results are below the revised proposed NES soil contaminant value of 880 mg/kg.

2.2 Contaminants of concern

Based on evaluation of the soil test results against the Council investigation criteria we have identified lead and carcinogenic PAHs as the contaminants of concern on Stokes Point Reserve. In line with current New Zealand (and international) practice, the potential adverse effects of PAHs have been considered by calculating the B(a)P equivalent concentration. Thus the B(a)P eq. is used to represent individual carcinogenic PAH compounds of concern for this risk assessment.

[2] MfE June 2011. *Methodology for Deriving Standards for Contaminants in Soil to Protect Human Health.*
[3] T&T March 2011. *Stokes Point Reserve, Northcote – Ground Contamination Assessment. 26922.006.*

Lead and B(a)P eq. are of concern because of their known toxicity to human health. The toxicity characteristics and important exposure pathways for lead and B(a)P eq. are presented in Appendix B.

3 Exposure Assessment

This assessment evaluates pathways relating to exposure from contaminants in the soil only. The potential exposure pathways and potential receptor populations are discussed below.

3.1 Source characteristics

The source zone for the contaminants is considered to be the near surface soils across the reserve (i.e. surface to 0.5 m depth). The main source of contaminants is understood to be:

- Fill material imported to the site.
- Possible leaching from a former coal tar sealed footpath beneath the existing concrete footpath.

To a lesser extent:

- Historic coatings of the Auckland Harbour Bridge removed during uncontrolled surface preparation for painting and subsequent deposition onto park soils.
- Exhaust deposition from vehicular traffic using the bridge.

Statistics for the contaminants of concern in the near surface soils (including OPUS 2010 results) were determined using ProUCL software and are provided in Table 2 below. ProUCL worksheets are attached in Appendix C.

Table 2: Summary data for contaminants of concern

Contaminant	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	95% UCL[1] (mg/kg)
Lead	5.4	890	206	260
B(a)P eq.	0.04	83	7	10

Notes:
<LD indicates concentrations below laboratory limit of detection
1 – The calculated 95% UCL includes all soil test results available for the site (OPUS 2010 and T&T 2011).

3.2 Exposure pathway assessment

The exposure pathway assessment identifies the potential routes for exposure to contaminants in the near surface soil across the reserve.

3.2.1 Human exposure pathways

Contamination poses a risk to human health if there is a complete pathway between the source of contamination and the human receptor. The main direct exposure pathways at the reserve that could lead to impacts on human health are ingestion of soil and dermal exposure. The reserve appears to have a good cover of grass, however, some bare patches of exposed soil have been observed near the residential property on the western side of the reserve.

The inhalation pathway is not considered valid for lead due to its inability to partition into vapour and due to the low vapour pressure of benzo (a) pyrene, it does not readily volatilise to the atmosphere and is therefore, not modelled via the inhalation pathway.

In summary the following pathways have been assessed:

- Direct ingestion of soil.
- Dermal (skin) exposure (B(a)P eq. only – (dermal uptake of lead is considered negligible).

3.2.2 Exposed populations

A number of potential receptors were identified, who have the potential to become exposed to the contaminants of concern on the reserve. These are as follows:

- Children visiting the reserve.
- Adults visiting the reserve.
- Adult ground maintenance staff.

The Stokes Point Reserve occupies a relatively small area of land that does not have a children's playground and is not used for active sports and recreation. Passive uses include partial views across to the docks and CBD from the eastern side of the bridge, walking under the bridge structure or around the bridge footing to view the remains of a Maori pa fortification ditch and a memorial plaque. The car park area also serves to provide access down to the ferry via a footpath along the western side of the reserve. Although a site specific user survey was outside the scope of this risk assessment, T&T and Council representatives have made numerous visits to the reserve, during which time the limited usage and more transitory nature of the reserve was observed. Our observations substantiate New Zealand Transport Agency's description of the usage.

The recently revised proposed NES guidance documents states that 'the parks/recreation scenario covers public and private green areas and reserves that are used for active sports and recreation. The scenario is intended to cover playing fields and suburban reserves where children play frequently'. We discussed the usage of the reserve with Dr Tim Sprott and agreed that Stokes Point Reserve does not fit the typical description of the parks/recreation scenario, however, taking a conservative approach, and where appropriate, we adopted the parks/recreation exposure factors from the draft MfE guidance document[4] available at the time of preparing this report.

Ground maintenance staff have been considered as potential receptors, however, their future exposure to residual surface soil contaminants can be controlled through an appropriate site management plan.

3.2.3 Exposure factors

The exposure factors used in this risk assessment are largely based on parkland/recreational values provided by MfE in their draft guidance document. Table 5 below lists the exposure factors adopted to derive the soil guideline values. Site specific exposure parameters adopted for this Tier 2 risk assessment are discussed below.

3.2.4 Children visiting the reserve

The MfE Sheep Dip Guidelines[5] indicates a child soil ingestion rate for a parkland/recreational setting is 50 mg/day. As mentioned above, because children are unlikely to actively play on the reserve and due to the very limited use of the reserve, we discussed adopting a more appropriate soil ingestion rate with Dr. Sprott. Dr. Sprott suggested a more representative soil ingestion rate

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[4] MfE, February 2010, *Draft Methodology for Deriving Soil Guideline Values Protective of Human Health.*
[5] MfE, November 2006, *Identifying, Investigating and Managing Risks Associated with Former Sheep-dip Sites.*

for children visiting the reserve would be 15 mg/day, which was the value adopted by MfE in their draft guidance document for parks/recreation.

We note that in the recently published proposed NES guidance documents the child soil ingestion rate has been increased to 25 mg/kg, however, because the reserve does not conform to MfE's parks/recreation scenario (i.e. 'public and private green areas and reserves that are used for active sports and recreation… intended to cover playing fields and suburban reserves where children play frequently'), the child soil ingestion rate in this risk assessment has remained as 15 mg/day.

3.2.5 Adults visiting the reserve

MfE's draft guidance document utilises an adult soil ingestion rate of 75 mg/day, which is representative of adults playing sports and is not considered appropriate for use in this setting. Given the usage of the reserve and following advice from Dr. Sprott, we have adopted the adult soil ingestion rate from the MfE Sheep Dip Guidelines of 10 mg/day.

Table 3 lists the relevant exposure factors applicable to this health risk assessment.

Table 3: Exposure factors

Exposure Factor	Stokes Point Reserve	Reference
Exposure Frequency (days/yr)	200 (child)/150 (adult)	MfE 2010[1]
Exposure Duration – child (yr)	6	MfE 2010[1]
Exposure Duration – adult (yr)	14	MfE 2010[1]
Averaging time – non threshold (yr)	75	MfE 2010[1]
Body weight – child (kg)	15	MfE 2010[1]
Body weight – adult (kg)	70	MfE 2010[1]
Soil ingestion rate – child (mg/day)	15	MfE 2010[1]
Soil ingestion rate – adult (mg/day)	10	MfE 2006[2]
Age-adjusted ingestion factor (-)	6 (child)/2 (adult)	Site specific calculation for adult users
Exposed skin surface area – child (cm^2)	1,900	MfE 2010[1]
Exposed skin surface area – adult (cm^2)	3,670	MfE 2010[1]
Soil adherence factor – child (mg/cm^2)	0.04	MfE 2010[1]
Soil adherence factor – adult (mg/cm^2)	0.06	MfE 2010[1]
Age-adjusted dermal exposure factor (-)	30.4 (child)/44 (adult)	MfE 2010[1]

Notes:

1 - MfE, February 2010. *Draft Methodology for Deriving Soil Guideline Values Protective of Human Health.*

2 - MfE November 2006. *Identifying, Investigating and Managing Risks Associated with Former Sheep-dip Sites.*

4 Toxicity Assessment

4.1 Dose response relationship and weight of evidence for toxicity/carcinogenicity

4.1.1 Lead

Although the USEPA classifies lead as both a carcinogen (B2 weight of evidence, a possible human carcinogen) and a non-carcinogen, lead is generally assessed as a non-carcinogen only (i.e. threshold contaminant. MfE has provided a reference health standard (RHS) for lead in the draft guidance document with a value of 0.00357 mg/kg/day. The technical basis for selecting the RHS for lead is provided by MfE[6].

4.1.2 Carcinogenic PAHs (Benzo (a) pyrene equivalent)

B(a)P is classified as a probable non-threshold indirect human carcinogen by IARC -Group B2[7] and US EPA[8]. Long term B(a)P exposure has been positively associated with lung, bladder, stomach and skin cancers[9 10 11 12].

The carcinogenic, non-threshold toxicity factors for B(a)P equivalent have been obtained from the Ministry for the Environment[13]. Although toxicity factors have been published by MfE in the draft guidance documents and in the recently revised guidance documents to the proposed NES, we consider it remains appropriate to adopt the ingestion slope factor of 7.3 $(mg/kg/d)^{-1}$ to derive carcinogenic acceptance criteria for the ingestion and dermal exposure pathways because it ensures a **more conservative** risk assessment. In the absence of a dermal slope factor for B(a)P, the ingestion slope factor was used to derive the acceptance criterion for dermal exposure, consistent with MfE[14].

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6 MfE, 2010, *Draft Toxicological Intake Values for Priority Contaminants in Soil.*

7 IARC 1987 IARC summaries and evaluations: Benzo(a)pyrene. Lyon, France, International Agency for Research on Cancer. Supplement 7.

8 US EPA 1994a Integrated Risk Information System IRIS). Benzo(a)pyrene.

9 WHO 1991. Benzo(a)pyrene WHO Food Additive Series 28. Geneva, World Health Organisation

10 WHO 2000. Polycyclic aromatic hydrocarbons. WHO Regional Office for Europe, Copenhagen, Denmark; Chapter 5.

11 ATSDR (Agency for Toxic Substances and Disease Registry) 1995. Toxicological profile for Polycyclic aromatic hydrocarbons. Atlanta, Georgia, USA, US Department of Health and Human Studies.

12 California Environmental Protection Agency 1997 Public Health Goal for Benzo(a)pyrene in Drinking Water.

13 MfE, August 1999. Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand.

14 MfE, August 1997. Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand.

5 Risk Characterisation

5.1 Introduction

The exposure and toxicity factors discussed in the previous sections were used to estimate (characterise) the risk presented by the contaminants of concern at the site. Detailed results of the modelling, including the input data, calculations, risk estimates/hazard quotients and soil guideline values are presented in Appendix D on the MathCAD worksheets. For New Zealand, to establish an acceptable level of risk, a hazard quotient (non-carcinogenic risk) of less than one (<1) or a lifetime cancer risk estimate (carcinogenic risk) of less than 1 in 100,000 (or $1x10^{-5}$) are used.

Table 4 presents the 95% UCL concentrations for lead and B(a)P eq. along with the carcinogenic and non-carcinogenic risk estimates for exposure to soils across the entire site.

Table 4: 95% UCL concentrations and risk estimate/hazard quotient

Contaminant of Concern	Exposure Pathway	95%UCL Concentration	Hazard Quotient	Risk Estimate[1]
Lead	Soil Ingestion	260 mg/kg	0.04 (Child) 0.005 (Adult)	-
B(a)P eq.	Soil Ingestion/ Dermal Contact	10 mg/kg	-	0.5 in 100,000 (Child) 0.3 in 100,000 (Adult)
Notes: 1 – The risk estimate is the sum of the risk via soil ingestion and dermal exposure.				

5.2 Risk estimates for B(a)P eq. concentrations (carcinogenic risk)

The excess lifetime cancer risk estimates for children and adults have been calculated using the 95% UCL concentration for B(a)P eq. The risk estimates shown on the table represent the sum of the individual risk estimate for the soil ingestion and dermal exposure pathways.

Based on the 95% UCL concentration for B(a)P eq., which represents the conditions for the entire site, the calculated excess lifetime cancer risk estimates for children and adults are less than 1 in 100,000. On this basis, there is an acceptable level of risk associated with the B(a)P eq. concentrations in the soils across the site.

However, MfE guidelines[15] indicate that as a rule of thumb, a site will be considered acceptable from a risk standpoint if the 95% UCL is at or below the guideline, provided no result is more than twice the guideline value. Based on the 1 in 100,000 acceptable level of carcinogenic risk a site specific soil guideline value (combined soil ingestion and dermal contact) for B(a)P eq. is **21 mg/kg.** Two samples alongside the concrete footpath on the western part of the site (HA7 and HA8) indicate B(a)P eq. concentrations of 46 mg/kg and 83 mg/kg, more than twice the site specific soil guideline value.

The concrete footpath is situated on a raised part of the site on the western boundary, away from the main grassed areas of the site. The public use the footpath for access to and from the Ferry terminal and so pass through the area relatively quickly. Exposure to these contaminated soils

[15] MfE 2004. *Contaminated Land Management Guidelines No.5. Site Investigation and Analysis of Soils.*

adjacent to the footpath is, on balance, likely to be less than other areas of the site. Additionally, the identified B(a)P eq. hotspots are all situated on the periphery of the path, which falls away steeply into the bush. Slope stability risk has not yet been assessed but this factor will be evaluated in reference to any proposed remedial and/or management works.

While the assessment indicates that contaminant levels in surface soils do not pose an unacceptable risk to park users, conservative application of MfE's rule of thumb would mean that soils adjacent to the footpath (at HA7 and HA8) should be considered for remediation and/or management. However, we consider the application of remediation and/or management around HA7 would be unnecessary given the 0.5 m depth of the B(a)P eq. reading.

We note that evaluation of the soil test results against the recently revised proposed NES soil contaminant value for B(a)P eq. of 40 mg/kg (not available at the time of preparing version 1 of this report) results in similar remediation/management requirements to those using the 21 mg/kg site specific guideline value.

5.3 Hazard quotients for lead concentrations (non-carcinogenic risk)

The hazard quotient, representing the non-carcinogenic risk, has been calculated for child and adult receptors with exposure to lead via soil ingestion only (refer Section 3.2.1 for not including exposure via dermal contact). The hazard quotients calculated for the 95% UCL lead concentration are presented separately for a child and adult in Table 4 above.

The hazard quotients for the child and adult receptors are all less than one, which indicates there is an acceptable level of risk associated with the lead concentrations recorded across the site. We have also checked the maximum concentrations of lead against the site specific soil guideline value of **4,745 mg/kg** to confirm the rule of thumb for applying the 95% UCL concentration. All lead concentrations are well below the site specific soil guideline value, therefore, on this basis no further action is required regarding lead concentrations in soil at the site.

Evaluation of the soil test results against the recently revised proposed NES soil contaminant value for lead of 880 mg/kg (not available at the time of preparing version 1 of this report), indicates only a single slight exceedance of 890 mg/kg was recorded during the OPUS investigations. On this basis, the outcome of the risk assessment does not change.

6 Regulatory Requirements

A detailed assessment of the regulatory requirements regarding the site's contamination has been provided in the T&T ground contamination assessment report. The findings are summarised below.

6.1 North Shore City District Plan

The presence of lead and B(a)P eq. above the Council investigation criterion for parkland/recreation use (and interim Tier 2 acceptance criterion) indicates there is a potential risk to human health from exposure to B(a)P eq. in soils. Auckland Council is unlikely to allow the ongoing use of the site without remediation and/or management works alongside the concrete footpath. In accordance with Rule 10.8.3.1 of the North Shore City District Plan, remediation of the B(a)P eq. impacted soils is likely to require resource consent as a Controlled Activity.

6.2 Auckland Regional Plan

Metals and B(a)P eq. concentrations have been recorded above the Proposed ARP:ALW PA acceptance criteria for discharges. Although concentrations in the soil exist above the Proposed ARP:ALW PA acceptance criteria any remediation works undertaken will likely be a permitted activity under Rule 5.5.42A of the Proposed ARP:ALW Plan (subject to a number of conditions). This rule allows land owned by a territorial authority to be remediated so long as the remediation is to enable existing land use to meet public health or environmental protection criteria consistent with their current use.

If contaminated fill material above the Proposed ARP:ALW PA acceptance criteria remains on site following remediation then Auckland Council would likely require an application be made for the ongoing discharge of contaminants to land or water under Rule 5.5.43 of the Proposed ARP:ALW Plan.

7 Remediation/Management

Based on the findings of the risk assessment, remediation/management options were required to reduce the risk of exposure to the high levels of B(a)P eq. recorded alongside the footpath on the western part of the reserve.

Because of concerns associated with the ongoing stability of the steep wooded slope west of the footpath, it was not practical to remove the B(a)P eq. impacted soil. As an alternative option to soil excavation, the ongoing risk to users of the reserve is being managed by isolating the contaminated soils beneath a barrier system installed along both sides of the footpath. The barrier system has been appropriately designed to take into account the usage level of the site and to prevent users accessing the underlying soils. These details have been discussed with the landowner (Auckland Council Local and Sports Parks), and will be included in their next iteration of the Stokes Point Reserve Management Plan.

Playworks Construction Ltd installed the barrier system in June 2011 and July 2011. The barrier system comprises, from top to bottom:

- 100 mm of mulch.
- Combined geotextile/geogrid layer – secured with steel pins.

Long term monitoring and maintenance procedures for the barrier system are set out in the Site Management Plan prepared by Auckland Council.

8 Summary of Human Health Risk Assessment

This human health risk assessment has been undertaken to evaluate the potential of adverse impacts to human health from residual lead and B(a)P eq. concentrations recorded in the surface soils of Stokes Point Reserve and has been updated to reflect comments received from ARPHS.

Given the location of the reserve (i.e. beneath the Auckland Harbour Bridge) and the absence of any playground equipment, use of the reserve is limited and transitory. Observations made by T&T and Auckland Council representatives during site investigation works and numerous other visits substantiate the low usage pattern of the reserve described by the New Zealand Transport Agency. Exposure values used in this assessment reflect these conditions.

The risk posed by the lead and B(a)P eq. concentrations in soil has been estimated by calculating the hazard quotient for non-carcinogenic risk and the excess lifetime cancer risk for carcinogenic risk. Evaluation of the risk estimates against those applicable in New Zealand indicates that as a whole, contaminant levels do not pose an unacceptable risk to human health. However, applying the MfE's rule of thumb would require management and/or remediation of a limited area of B(a)P eq. contamination at sample locations HA7 and HA8. However, we consider the application of remediation and/or management around HA7 would be unnecessary given the 0.5 m depth of the B(a)P eq. reading.

A barrier system was installed in June 2011 and July 2011 along both sides of the footpath to isolate the B(a)P eq. impacted soils and prevent future exposure to the users of the reserve. Long term monitoring and maintenance procedures for the barrier system are set out in the Site Management Plan prepared by Auckland Council.

Should there be any change in land use, especially for higher-sensitivity use (e.g. children's playground; community garden) then potential risks to users should be re-evaluated.

9 Applicability

This report has been prepared for the benefit of Auckland Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

This opinion is not intended to be advice that is covered by the Financial Advisers Act 2010.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
....	....
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Figures

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Street map sourced from Land Information New Zealand data (Crown Copyright Reserved).

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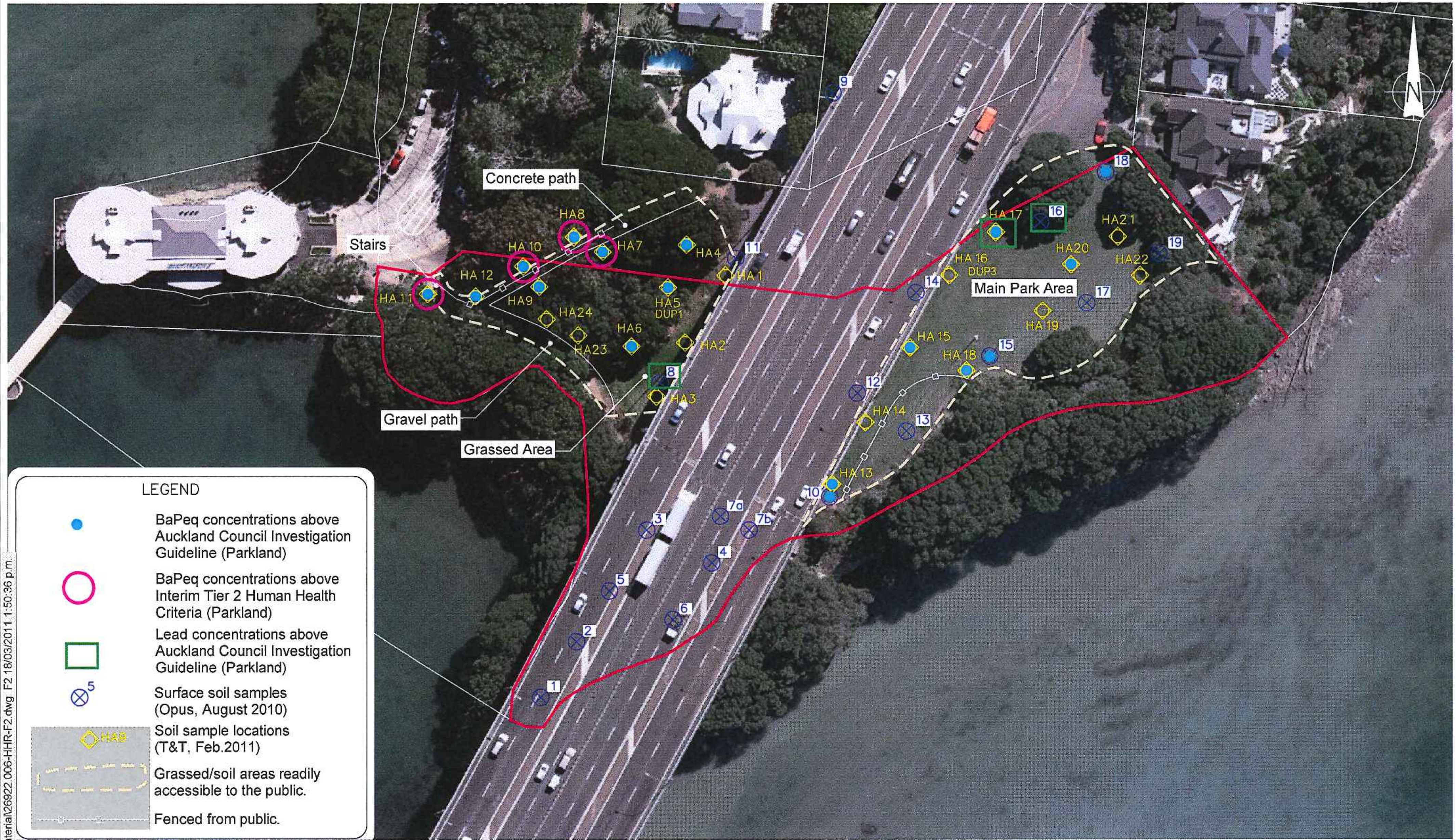

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AUCKLAND COUNCIL
TIER 2 HUMAN HEALTH RISK ASSESSMENT STOKES POINT RESERVE, NORTHCOTE
Sample and Contamination Distribution Plan

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Appendix A: Tabulated Results

Table 1: Stokes Point Reserve Soil Test Results (T&T February 2011)

	Sample Name:	Auckland Council Investigation Criteria (Parkland/Recreation)	P:ALW Permitted Activity Soil Acceptance Criteria	Stokes Point Interim Tier 2 Human Health Criteria (Parkland)	HA1-0.0m	HA2-0.0M	HA2-0.25M	HA3-0.0M	HA4-0M	HA4-0.25M-0.35M	HA5-0.0M	DUP1 (HA5-0.0M)	QA/QC	HA5-0.25M	HA5-0.5M	HA6-0.0M	HA6-0.25M	HA7-0.0M	HA7-0.25M	HA7-0.5M	HA8-0.0M	HA8-0.25M	HA8-0.5M	HA9-0.0M	HA9-0.25M
	Date:				23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	Relative Percentage Difference	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn																									
Total Recoverable Arsenic	mg/kg dry wt	100	100	-	4	5	<2	2	5	-	3	3	0	5	-	4	-	4	3	-	4	-	-	4	-
Total Recoverable Cadmium	mg/kg dry wt	40	7.5	-	0.38	1.26	< 0.10	0.74	1.11	-	0.21	0.31	38	0.5	-	0.46	-	0.6	< 0.10	-	0.32	-	-	0.32	-
Total Recoverable Chromium	mg/kg dry wt	24,000	400	-	48	69	10	220	72	-	24	34	34	27	-	45	-	35	9	-	30	-	-	27	-
Total Recoverable Copper	mg/kg dry wt	2,000	325	-	24	64	6	69	63	-	17	26	42	36	-	40	-	55	6	-	34	-	-	32	-
Total Recoverable Lead	mg/kg dry wt	600	250	4,745	60	**280**	13.3	**390**	**350**	94	42	88	71	**460**	31	**260**	36	**310**	15.8	12.4	123	9.4	9.8	139	15.6
Total Recoverable Nickel	mg/kg dry wt	600	105	-	25	38	6	**122**	54	-	16	28	55	25	-	30	-	37	22	-	79	-	-	22	-
Total Recoverable Zinc	mg/kg dry wt	14,000	400	-	160	**760**	34	**2,000**	**640**	155	120	191	46	360	35	**450**	59	**510**	15	9	210	4	7	**400**	25
Polycyclic Aromatic Hydrocarbons Screening in Soil																									
Acenaphthene	mg/kg dry wt	9,400	-	-	0.04	0.49	< 0.03	< 0.03	0.06	0.04	< 0.03	0.05	50	0.11	0.04	< 0.04	< 0.03	0.21	2.5	2.2	6.1	< 0.04	< 0.03	0.19	0.1
Acenaphthylene	mg/kg dry wt	4,700	-	-	0.04	0.06	< 0.03	< 0.03	0.25	0.13	0.07	0.45	146	0.95	< 0.04	0.19	0.03	0.52	0.24	1.56	1.88	< 0.04	< 0.03	0.53	0.28
Anthracene	mg/kg dry wt	47,000	-	-	0.15	0.3	< 0.03	0.03	0.43	0.27	0.1	0.73	152	1.62	0.13	0.28	0.08	0.97	5.5	6	17.2	< 0.04	0.03	0.86	0.57
Benzo[a]anthracene	mg/kg dry wt	-	-	-	0.4	0.68	< 0.03	0.11	2.1	1.42	0.5	5.2	165	7.3	0.31	1.6	0.52	4.7	8.7	19	40	0.15	0.17	5.1	3.3
Benzo[a]pyrene (BAP)	mg/kg dry wt	-	-	-	0.4	0.73	< 0.03	0.12	2.8	2.1	0.77	7.1	161	9.1	0.42	2.1	0.69	5.9	9.4	32	56	0.21	0.19	6.5	4.8
Benzo[b]fluoranthene + Benzo[j]fluoranth	mg/kg dry wt	-	-	-	0.6	1.06	< 0.03	0.18	3.5	2.4	0.96	8.6	160	9.5	0.52	2.6	0.81	7.3	10.4	44	71	0.33	0.25	8.5	5.5
Benzo[g,h,i]perylene	mg/kg dry wt	-	-	-	0.35	0.61	< 0.03	0.14	2.2	1.47	0.62	5.6	160	6.7	0.34	1.61	0.49	4.5	6.9	18	33	0.18	0.16	5.3	3.4
Benzo[k]fluoranthene	mg/kg dry wt	-	-	-	0.24	0.41	< 0.03	0.07	1.38	0.96	0.37	3.5	162	4.1	0.2	1	0.31	2.9	4.5	13.5	30	0.12	0.09	3.4	2.2
Chrysene	mg/kg dry wt	-	-	-	0.45	0.69	< 0.03	0.11	1.99	1.44	0.59	4.7	155	6	0.36	1.57	0.57	4.1	7	20	37	0.15	0.17	4.1	3.1
Dibenzo[a,h]anthracene	mg/kg dry wt	-	-	-	0.06	0.11	< 0.03	< 0.03	0.39	0.27	0.11	1.09	163	1.54	0.05	0.3	0.08	0.93	1.52	4.5	8.9	< 0.04	< 0.03	1.31	0.67
Fluoranthene	mg/kg dry wt	6,300	-	-	0.99	2.2	< 0.03	0.24	4.4	2.9	1.01	9.8	163	16.6	0.69	3.2	0.91	9.5	27	43	111	0.29	0.38	8.7	5.9
Fluorene	mg/kg dry wt	6,300	-	-	0.04	0.41	< 0.03	< 0.03	0.08	0.06	< 0.03	0.16	137	0.32	0.03	0.04	< 0.03	0.2	1.86	1.61	5.5	< 0.04	< 0.03	0.17	0.12
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	-	-	-	0.24	0.48	< 0.03	0.09	1.76	1.15	0.48	4.3	160	6	0.24	1.31	0.38	4	6.2	15.9	36	0.13	0.13	5.2	2.8
Naphthalene	mg/kg dry wt	120	69	-	< 0.16	0.26	< 0.15	< 0.13	< 0.2	< 0.13	< 0.15	0.18	143	0.3	< 0.16	< 0.17	< 0.14	< 0.3	0.55	0.76	1.43	< 0.16	< 0.15	0.17	0.15
Phenanthrene	mg/kg dry wt	4,700	-	-	0.5	3	< 0.03	0.2	1.41	1.34	0.35	3.6	165	7.7	0.41	0.98	0.3	3.3	28	28	86	0.14	0.21	2.9	2.2
Pyrene	mg/kg dry wt	4,700	1,600	-	1.04	2.1	0.03	0.26	5.2	3.2	1.27	10.5	157	16.3	0.83	3.8	1.05	10.2	23	42	95	0.33	0.43	9.2	6.2
Benzo(a)pyrene equivalent	mg/kg dry wt	2	2.15	21	0.61	1.11	0.04	0.18	**4.08**	**2.98**	1.12	**10.40**	161	**13.39**	0.60	**3.07**	0.98	**8.76**	**13.97**	**45.94**	**82.97**	0.30	0.27	**10.07**	**6.88**

Table 1 Continued: Stokes Point Reserve Soil Test Results (T&T February 2011)

	Sample Name:	Auckland Council Investigation Guidelines (Parkland/Recreation)	P:ALW Permitted Activity Soil Acceptance Criteria	Stokes Point Interim Tier 2 Human Health Criteria (Parkland)	HA10-0.0M	HA10-0.25M	HA11-0.0M	HA11-0.25M	HA11-0.5M	HA12-0.0M	HA12-0.25M	HA12-0.5M	HA13-0.0M	HA13-0.5M	HA14-0.0M	HA15-0.0M	HA15-0.25M	HA16-0.0M	DUP3	QA/QC	HA17-0.0M	HA17-0.25M	HA17-0.5M	HA18-0M	HA18-0.25M
	Date:				23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	Relative Percentage Difference	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn																									
Total Recoverable Arsenic	mg/kg dry wt	100	100	-	4	-	6	-	-	5	2	-	7	2	4	3	3	3	3	0	3	2	-	4	-
Total Recoverable Cadmium	mg/kg dry wt	40	7.5	-	0.14	-	0.21	-	-	0.42	< 0.10	-	1.18	0.14	1	1.52	0.27	0.68	0.89	27	1.09	0.16	-	0.55	-
Total Recoverable Chromium	mg/kg dry wt	24,000	400	-	18	-	19	-	-	30	11	-	104	19	78	64	64	53	50	6	73	21	-	66	-
Total Recoverable Copper	mg/kg dry wt	2,000	325	-	15	-	25	-	-	45	9	-	72	18	55	44	27	40	43	7	70	17	-	55	-
Total Recoverable Lead	mg/kg dry wt	600	250	4,745	41	10.2	103	32	12.8	152	11	8.7	**360**	65	**480**	**420**	79	**520**	**520**	0	**840**	109	5.4	**380**	93
Total Recoverable Nickel	mg/kg dry wt	600	105	-	19	-	30	-	-	45	6	-	58	15	41	27	45	27	28	4	47	45	-	36	-
Total Recoverable Zinc	mg/kg dry wt	14,000	400	-	139	11	126	30	14	270	15	20	**3,300**	103	**910**	**770**	320	**600**	**600**	0	**880**	102	4	**430**	260
Polycyclic Aromatic Hydrocarbons Screening in Soil																									
Acenaphthene	mg/kg dry wt	9,400	-	-	0.34	0.09	0.5	0.13	< 0.03	0.11	0.05	< 0.03	0.19	< 0.03	0.03	0.04	0.13	< 0.03	< 0.03	0	0.03	0.21	< 0.03	< 0.03	0.03
Acenaphthylene	mg/kg dry wt	4,700	-	-	1.43	0.42	1.21	0.66	0.15	0.33	0.58	< 0.03	< 0.03	< 0.03	0.1	0.15	0.05	0.06	0.05	18	0.12	0.45	< 0.03	0.08	0.16
Anthracene	mg/kg dry wt	47,000	-	-	3.7	0.87	2.6	0.83	0.15	0.55	0.69	< 0.03	1.08	< 0.03	0.2	0.35	0.31	0.11	0.09	20	0.21	0.89	< 0.03	0.14	0.22
Benzo[a]anthracene	mg/kg dry wt	-	-	-	13.6	4.8	13.9	6.6	1.22	3.2	4.6	0.11	1.97	0.04	1.03	1.8	1.26	0.86	0.76	12	1.76	6.1	< 0.03	1.06	1.34
Benzo[a]pyrene (BAP)	mg/kg dry wt	-	-	-	16.4	6.5	20	9.7	1.98	4.4	6.4	0.17	1.22	0.05	1.2	2.3	1.24	1.14	0.93	20	2.3	7.3	< 0.03	1.41	1.75
Benzo[b]fluoranthene + Benzo[j]fluoranth	mg/kg dry wt	-	-	-	22	7.3	27	10.9	2.6	5.6	7.8	0.25	2.1	0.07	1.76	3	1.92	1.58	1.41	11	3.1	9	< 0.03	1.93	2.2
Benzo[g,h,i]perylene	mg/kg dry wt	-	-	-	11.5	4.8	12.6	8.1	1.6	3.5	5.5	0.17	0.71	0.05	1.13	1.87	1	0.99	0.88	12	1.88	6.1	< 0.03	1.21	1.31
Benzo[k]fluoranthene	mg/kg dry wt	-	-	-	7.4	3	8.6	4.7	0.98	2.3	3.2	0.09	0.83	0.03	0.7	1.17	0.77	0.64	0.57	12	1.22	3.8	< 0.03	0.78	0.89
Chrysene	mg/kg dry wt	-	-	-	10.4	4.2	12.4	6.4	1.32	2.7	4	0.12	1.62	0.04	1.05	1.75	1.11	0.9	0.81	11	1.71	5.4	< 0.03	1.05	1.33
Dibenzo[a,h]anthracene	mg/kg dry wt	-	-	-	2.9	0.94	3.9	1.49	0.25	0.89	1.18	< 0.03	0.2	< 0.03	0.21	0.38	0.21	0.21	0.18	15	0.39	1.27	< 0.03	0.25	0.25
Fluoranthene	mg/kg dry wt	6,300	-	-	28	8.7	32	13.5	2.5	5.5	6.8	0.16	5.1	0.09	2.2	3.8	3.1	1.81	1.56	15	3.6	12.1	< 0.03	2.1	2.3
Fluorene	mg/kg dry wt	6,300	-	-	0.88	0.15	0.57	0.2	0.04	0.1	0.11	< 0.03	0.24	< 0.03	0.05	0.09	0.09	0.03	< 0.03	0	0.04	0.2	< 0.03	0.03	0.04
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	-	-	-	10.7	3.9	15	6.2	1.24	3.5	5.1	0.13	0.69	0.03	0.78	1.42	0.69	0.73	0.61	18	1.4	4.4	< 0.03	0.9	1.03
Naphthalene	mg/kg dry wt	120	69	-	0.48	0.17	0.6	0.35	< 0.15	< 0.15	0.17	< 0.15	< 0.14	< 0.14	< 0.13	< 0.13	< 0.13	< 0.14	< 0.15	7	< 0.14	0.25	< 0.14	< 0.13	< 0.15
Phenanthrene	mg/kg dry wt	4,700	-	-	16.1	3.9	12.7	5.4	0.87	1.98	2.6	0.07	3.8	0.04	1.05	1.56	1.68	0.63	0.47	29	0.99	4.4	< 0.03	0.73	0.86
Pyrene	mg/kg dry wt	4,700	1,600	-	25	8.8	29	13.6	2.6	5.9	7.4	0.21	3.8	0.09	2.3	4	2.7	1.88	1.68	11	3.7	12.7	< 0.03	2.2	2.8
Benzo(a)pyrene equivalent	mg/kg dry wt	2	2.15	21	**24.77**	**9.38**	**30.47**	**14.09**	**2.85**	**6.78**	**9.69**	0.24	2.00	0.08	1.85	**3.44**	1.93	1.74	1.45	18	**3.46**	**10.95**	0.04	2.14	**2.56**

Table 1 Continued: Stokes Point Reserve Soil Test Results (T&T February 2011)

	Sample Name:	Auckland Council Investigation Guidelines (Parkland/Recreation)	P:ALW Permitted Activity Soil Acceptance Criteria	Stokes Point Interim Tier 2 Human Health Criteria (Parkland)	HA19-0.0M	HA19-0.25M	HA20-0.0M	HA20-0.25M	HA21-0.0M	HA22-0.0M	HA22-0.5M	HA23-0.0M	HA24-0.0M
	Date:				23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11	23-Feb-11
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn													
Total Recoverable Arsenic	mg/kg dry wt	100	100	-	< 2	< 2	2	-	< 2	2	< 2	3	3
Total Recoverable Cadmium	mg/kg dry wt	40	7.5	-	0.22	< 0.10	0.27	-	0.24	0.24	< 0.10	0.27	< 0.10
Total Recoverable Chromium	mg/kg dry wt	24,000	400	-	22	11	26	-	22	21	14	37	14
Total Recoverable Copper	mg/kg dry wt	2,000	325	-	26	3	31	-	27	27	3	32	9
Total Recoverable Lead	mg/kg dry wt	600	250	4,745	183	11.2	220	68	189	171	7.5	109	19.1
Total Recoverable Nickel	mg/kg dry wt	600	105	-	10	6	36	-	14	10	6	51	4
Total Recoverable Zinc	mg/kg dry wt	14,000	400	-	250	10	220	70	200	210	14	**420**	75
Polycyclic Aromatic Hydrocarbons Screening in Soil													
Acenaphthene	mg/kg dry wt	9,400	-	-	< 0.04	< 0.03	0.03	0.05	< 0.04	< 0.03	< 0.03	0.09	< 0.03
Acenaphthylene	mg/kg dry wt	4,700	-	-	< 0.04	< 0.03	0.08	0.11	0.06	< 0.03	< 0.03	0.05	< 0.03
Anthracene	mg/kg dry wt	47,000	-	-	< 0.04	< 0.03	0.14	0.2	0.11	0.03	< 0.03	0.16	0.04
Benzo[a]anthracene	mg/kg dry wt	-	-	-	0.13	< 0.03	1.04	1.29	0.85	0.27	< 0.03	0.74	0.22
Benzo[a]pyrene (BAP)	mg/kg dry wt	-	-	-	0.18	< 0.03	1.37	1.87	1.11	0.39	< 0.03	1.01	0.29
Benzo[b]fluoranthene + Benzo[j]fluoranth	mg/kg dry wt	-	-	-	0.26	< 0.03	1.86	2.3	1.57	0.57	< 0.03	1.46	0.41
Benzo[g,h,i]perylene	mg/kg dry wt	-	-	-	0.18	< 0.03	1.15	1.36	0.97	0.38	< 0.03	0.9	0.27
Benzo[k]fluoranthene	mg/kg dry wt	-	-	-	0.11	< 0.03	0.74	0.9	0.62	0.21	< 0.03	0.57	0.17
Chrysene	mg/kg dry wt	-	-	-	0.15	< 0.03	1.18	1.3	0.92	0.3	< 0.03	0.89	0.26
Dibenzo[a,h]anthracene	mg/kg dry wt	-	-	-	0.05	< 0.03	0.23	0.25	0.21	0.07	< 0.03	0.2	0.05
Fluoranthene	mg/kg dry wt	6,300	-	-	0.26	< 0.03	2.4	2.5	1.86	0.55	< 0.03	2.2	0.53
Fluorene	mg/kg dry wt	6,300	-	-	< 0.04	< 0.03	0.04	0.05	< 0.04	< 0.03	< 0.03	0.06	< 0.03
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	-	-	-	0.13	< 0.03	0.87	1.08	0.75	0.26	< 0.03	0.69	0.19
Naphthalene	mg/kg dry wt	120	69	-	< 0.17	< 0.14	< 0.15	< 0.15	< 0.16	< 0.14	< 0.14	< 0.17	< 0.15
Phenanthrene	mg/kg dry wt	4,700	-	-	0.08	< 0.03	0.95	1.06	0.54	0.15	< 0.03	1.11	0.25
Pyrene	mg/kg dry wt	4,700	1,600	-	0.29	< 0.03	2.5	2.8	1.99	0.61	< 0.03	2.2	0.53
Benzo(a)pyrene equivalent	mg/kg dry wt	2	2.15	21	0.29	0.04	2.06	**2.69**	1.71	0.59	0.04	1.56	0.44

Table Notes:
Bold values indicate concentrations above the Proposed Auckland Regional Plan: Air, Land, Water (P:ALW) Permitted Activity Soil Acceptance Criteria
Blue shaded values indicate concentrations above the Auckland Council Investigation Criteria- Human Health - Parkland/Recreation use
Red shaded values indicate concentrations above the Interim Tier 2 Human Health Criteria - Parkland use
Thick box border results highlight the supplementay testing results

Table 2: Stokes Point Reserve Soil Test Results (Opus August 2010)

	Sample Name:	Auckland Council Investigation Guidelines	P:ALW Permitted Activity Soil Acceptance Criteria	Stokes Point Interim Tier 2 Human Health Criteria	AHB1	AHB2	AHB3	AHB4	AHB5	AHB6	AHB7a	AHB7b	AHB8	AHB9	AHB10	AHB11	AHB12	AHB13	AHB14	AHB15	AHB16	AHB17	AHB18	AHB19
	Date:				5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10	5-Aug-10
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn																								
Chromium	mg/kg dry wt	24,000	400	-	44	76	116	105	115	76	168	141	210	44	136	38	36	87	48	38	49	23	26	31
Chromium VI	mg/kg dry wt	-	-	-	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Copper	mg/kg dry wt	2,000	325	-	101	27	52	47	36	26	**510**	57	220	161	67	18	23	60	31	36	53	33	23	40
Lead	mg/kg dry wt	600	250	4,745	150	210	**350**	220	193	176	**390**	**420**	**890**	**410**	**570**	36	160	**490**	230	230	**620**	230	119	220
Zinc	mg/kg dry wt	14,000	400	-	**820**	**6,100**	**1,500**	**1,730**	**1,610**	**1,370**	**1,610**	**1,730**	**5,500**	**540**	**3,600**	79	**420**	**740**	**520**	290	**580**	260	104	310
Polycyclic Aromatic Hydrocarbons Screening in Soil																								
Benzo(a)pyrene equi	mg/kg dry wt	2	2.15	21	0.07	-	0.06	-	-	0.08	-	-	-	-	**8.60**	-	-	-	-	2.01	-	-	**5.95**	-

Table Notes:

Bold values indicate concentrations above the Proposed Auckland Regional Plan: Air, Land, Water (P:ALW) Permitted Activity Soil Acceptance Criteria

Blue shaded values indicate concentrations above the Auckland Council Investigation Criteria- Human Health - Parkland/Rec

Red shaded values indicate concentrations above the Interim Tier 2 Human Health Criteria - Parkland use

Thick box border results highlight the supplementay testing results

Appendix B: Toxicity Characteristics of Contaminants of Concern

Carcinogenic PAHs – B(a)P equivalent

B(a)P is the most studied PAH compound. The B(a)P eq. value represents an estimate of the cumulative effects of seven common carcinogenic PAH species listed by the US EPA (refer Table 1), and is determined by the use of toxic equivalence factors (TEFs). The TEF for a specific compound may be defined as the ratio of the carcinogenic potency of the compound to that of benzo (a) pyrene (i.e. TEF <1 indicates a compound is a less potent carcinogen than benzo (a) pyrene)[16].

Table 1: Carcinogenic PAHs and toxic equivalence factors

Carcinogenic PAH compound	Toxic equivalence factor
Benzo (a) pyrene	1
Benzo (a) anthracene	0.1
Benzo (b) fluoranthene	0.1
Benzo (k) fluoranthene	0.1
Chrysene	0.01
Dibenzo (a,h) anthracene	1
Indeno (1,2,3-cd) pyrene	0.1

The individual PAH compound B(a)P, has a very low vapour pressure and low water solubility. These properties reduce the ability of B(a)P to migrate through both the air and water mediums under normal soil conditions. With a low vapour pressure B(a)P does not readily vaporise, which results in minimal exposure via the vapour inhalation pathway. B(a)P has a very high organic carbon partition coefficient (Koc), which infers that it is readily adsorbed to soil and sediment and this limits its ability to dissolve into water. This property is reflected in the low water solubility of B(a)P.

B(a)P can be absorbed through the gastrointestinal tract, the lungs and the skin. Following oral intake, B(a)P has been shown to be distributed to the kidneys and testes, and following inhalation, after 1 hour was found to be present in the stomach and small intestine, and on decline the large intestine and caecum[17]. B(a)P is reportedly metabolised mainly but not exclusively in the liver, and the metabolites are excreted in urine and faeces.

Long term B(a)P exposure has been positively associated with lung, bladder, stomach and skin cancers[18 19 20 21].

It is considered appropriate to use B(a)P eq. as a marker for PAHs for the Tier 2 assessment as it is considered to be the most strongly carcinogenic of the almost 500 PAHs[2 & 5].

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[16] MfE, August 1999. Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand.

[17] Mitchell CE (1982) Distribution and retention of benzo[a]pyrene in rats after inhalation. *Toxicology Letters* 11, 35, 42 (cited in WHO, 1998a).

[18] WHO 1991. Benzo(a)pyrene WHO Food Additive Series 28. Geneva, World Health Organisation

[19] WHO 2000. Polycyclic aromatic hydrocarbons. WHO Regional Office for Europe, Copenhagen, Denmark; Chapter 5.

[20] ATSDR (Agency for Toxic Substances and Disease Registry) 1995. Toxicological profile for Polycyclic aromatic hydrocarbons. Atlanta, Georgia, USA, US Department of Health and Human Studies.

[21] California Environmental Protection Agency 1997 Public Health Goal for Benzo(a)pyrene in Drinking Water.

Lead

Lead is a heavy metal with well documented chronic and acute toxicity. Children are particularly at risk to the toxicity of lead, the chronic effects of which include anaemia, colic, acute encephalopathy, adverse reproductive outcomes and possibly carcinogenesis[22]. Acute toxicity (above 15 µg/dL) in children prone to pica (soil eating behaviour) is common and can cause anorexia, vomiting, and convulsions. It can also cause permanent brain damage and reversible renal injury. Lower blood lead levels may cause impaired neurocognitive development in children[23] [24] at levels near or below 10 µg/dL.

It is considered that inorganic lead is present in the soils at the site. Inorganic lead binds strongly to organic matter and is relatively immobile in soils, however transport via erosion or geochemical weathering can still occur. Lead in soil tends to slowly convert to more insoluble species such as sulphate, sulphide, oxide and phosphate salts. Plant uptake of inorganic lead or lead salts is not considered significant and there is little biomagnification of lead through the food chain.

Once deposited in water, lead partitions rapidly between sediment and the dissolved phase depending upon the pH, salinity, and the presence of organic matter. The main species of lead in fresh waters are lead carbonate and lead-organic complexes. When released to the air, lead will generally be associated with particulate matter and is subject to settlement from where it will convert to lead salts (in soil) or lead carbonate (in water).

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[22] Carl Zenz, O Dickerson, EP Howarth, 1994. Occupational Medicine, 3rd ed.

[23] WHO 2000. Safety evaluation of certain food additive and contaminants. Lead. WHO Food Additive Series 44. Geneva, World Health Organisation.

[24] US EPA 1994 Technical support document: parameters and equations used in the integrated exposure uptake biokinetic model for lead in children (v0.99d). US EPA Washington DC.

Appendix C: ProUCL Worksheets

General UCL Statistics for Full Data Sets

B(a)P - full data set.

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

B(a)P

General Statistics

Number of Valid Observations	55	Number of Distinct Observations	51
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.04	Minimum of Log Data	-3.219
Maximum	82.97	Maximum of Log Data	4.418
Mean	6.615	Mean of log Data	0.49
Median	2.01	SD of log Data	1.948
SD	13.34		
Coefficient of Variation	2.017		
Skewness	4.211		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.311	Lilliefors Test Statistic	0.112
Lilliefors Critical Value	0.119	Lilliefors Critical Value	0.119
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	9.626	95% H-UCL	28.39
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	26.58
95% Adjusted-CLT UCL	10.67	97.5% Chebyshev (MVUE) UCL	33.79
95% Modified-t UCL	9.796	99% Chebyshev (MVUE) UCL	47.94
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.447	Data Follow Appr. Gamma Distribution at 5% Significance Level	
Theta Star	14.8		
MLE of Mean	6.615		
MLE of Standard Deviation	9.896		
nu star	49.15		
Approximate Chi Square Value (.05)	34.06	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0456	95% CLT UCL	9.574
Adjusted Chi Square Value	33.72	95% Jackknife UCL	9.626
		95% Standard Bootstrap UCL	9.552
Anderson-Darling Test Statistic	0.817	95% Bootstrap-t UCL	12.45
Anderson-Darling 5% Critical Value	0.825	95% Hall's Bootstrap UCL	22.26
Kolmogorov-Smirnov Test Statistic	0.128	95% Percentile Bootstrap UCL	9.563
Kolmogorov-Smirnov 5% Critical Value	0.128	95% BCA Bootstrap UCL	11.06
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	14.46
		97.5% Chebyshev(Mean, Sd) UCL	17.85
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	24.52
95% Approximate Gamma UCL	9.547		
95% Adjusted Gamma UCL	9.643		
Potential UCL to Use		Use 95% Adjusted Gamma UCL	9.643

General UCL Statistics for Full Data Sets

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

lead

General Statistics			
Number of Valid Observations	69	Number of Distinct Observations	59
Raw Statistics		**Log-transformed Statistics**	
Minimum	5.4	Minimum of Log Data	1.686
Maximum	890	Maximum of Log Data	6.791
Mean	206.9	Mean of log Data	4.651
Median	152	SD of log Data	1.389
SD	202.4		
Coefficient of Variation	0.979		
Skewness	1.303		
Relevant UCL Statistics			
Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.16	Lilliefors Test Statistic	0.124
Lilliefors Critical Value	0.107	Lilliefors Critical Value	0.107
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	247.5	95% H-UCL	396.4
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	525.1
95% Adjusted-CLT UCL	251	97.5% Chebyshev (MVUE) UCL	636.5
95% Modified-t UCL	248.1	99% Chebyshev (MVUE) UCL	855.4
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.835	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	247.8		
MLE of Mean	206.9		
MLE of Standard Deviation	226.4		
nu star	115.2		
Approximate Chi Square Value (.05)	91.42	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0465	95% CLT UCL	246.9
Adjusted Chi Square Value	90.97	95% Jackknife UCL	247.5
		95% Standard Bootstrap UCL	245.7
Anderson-Darling Test Statistic	0.74	95% Bootstrap-t UCL	250.9
Anderson-Darling 5% Critical Value	0.787	95% Hall's Bootstrap UCL	251.8
Kolmogorov-Smirnov Test Statistic	0.0906	95% Percentile Bootstrap UCL	247.9
Kolmogorov-Smirnov 5% Critical Value	0.111	95% BCA Bootstrap UCL	251.5
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	313.1
		97.5% Chebyshev(Mean, Sd) UCL	359
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	449.3
95% Approximate Gamma UCL	260.7		
95% Adjusted Gamma UCL	262		
Potential UCL to Use		Use 95% Approximate Gamma UCL	260.7

Appendix D: MathCAD Worksheets

HAZARD QUOTIENT FOR THRESHOLD CONTAMINANTS FOR STOKES POINT RESERVE

This worksheet calculates Hazard Quotients based on the soil ingestion pathway. The exposure parameters are based mainly on MfE 2010 with some adjustments specific to Stokes Point Reserve.

References

MfE 2010, Draft Methodology for Deriving Soil Guideline Values Protective of Human Health

Units

$$\mu g := \frac{mg}{1000}$$

Exposure Parameters

The National Environmental Standarda (NES) inputs and calculations proposed by MfE (2010) for Parkland/Recreational use are as follows.

Body weight for an adult	$BW_a := 70kg$
Body weight for a child	$BW_c := 15kg$
Exposure duration for adult	$ED_a := 14yr$
Exposure duration for child	$ED_c := 6yr$
Exposure frequency for adult	$EF_a := 150day \cdot yr^{-1}$
Exposure frequency for child	$EF_c := 200day \cdot yr^{-1}$
Soil ingestion rate for an adult	$IngR_a := 75mg \cdot day^{-1}$
Soil ingestion rate for a child	$IngR_c := 15mg \cdot day^{-1}$
Averaging time for threshold compounds for adult	$AT_a := 5110day$
Averaging time for threshold compounds for child	$AT_c := 2190day$
Bioavailability	$BIO := 1$
Background Intake	$BI := mg \cdot kg^{-1} day^{-1}$
Lead SGV concentration - child	$Csoil_{sgvc} := 4745mg \cdot kg^{-1}$
Lead SGV concentration - adult	$Csoil_{sgva} := 7177mg \cdot kg^{-1}$

Toxicity Values - Ingestion

Reference Health Standard - Lead	$RHSing_{Lead} := 0.00357mg \cdot kg^{-1} day^{-1}$

Background Intake for a child - Lead $BI_{Leadc} := 0.00097 mg \cdot kg^{-1} day^{-1}$

Background Intake for an adult - Lead $BI_{Leada} := 0.00041 mg \cdot kg^{-1} day^{-1}$

Toxicity Values - Dermal

Note. The dermal absorption factors (AF) for Lead is zero, hence the dermal exposure pathway has not been included.

Equations

SGV for threshold contaminants by soil ingestion

$$SGV_{soiling}(RHS, BI, BW, IngR, EF, AT, ED) := \frac{(RHS - BI) \cdot BW \cdot AT}{IngR \cdot EF \cdot ED}$$

Intake Rate for soil ingestion

$$IR_{soiling}(Csoil, IngR, EF, ED, BW, AT) := \frac{Csoil \cdot IngR \cdot EF \cdot ED}{BW \cdot AT}$$

Hazard Quotient

$$HQ_{soiling}(IR, RHSing, BI) := \frac{IR}{(RHSing - BI)}$$

Results - Soil Ingestion SGV

$$SGV_{soiling}\left(RHSing_{Lead}, BI_{Leadc}, BW_c, IngR_c, EF_c, AT_c, ED_c\right) = 4745 \cdot mg \cdot kg^{-1}$$

$$SGV_{soiling}\left(RHSing_{Lead}, BI_{Leada}, BW_a, IngR_a, EF_a, AT_a, ED_a\right) = 7177 \cdot mg \cdot kg^{-1}$$

Results - Soil Ingestion Intake Rate

$$IR_{soiling}\left(Csoil_{sgvc}, IngR_c, EF_c, ED_c, BW_c, AT_c\right) = 0.0026 \cdot mg \cdot kg^{-1} \cdot day^{-1}$$

$$IR_{soiling}\left(Csoil_{sgva}, IngR_a, EF_a, ED_a, BW_a, AT_a\right) = 0.0032 \cdot mg \cdot kg^{-1} \cdot day^{-1}$$

Results - Soil Ingestion Hazard Quotient (HQ=1)

$$HQ_{soiling}\left(IR_{soiling}\left(Csoil_{sgvc}, IngR_c, EF_c, ED_c, BW_c, AT_c\right), RHSing_{Lead}, BI_{Leadc}\right) = 1.0$$

$$HQ_{soiling}\left(IR_{soiling}\left(Csoil_{sgva}, IngR_a, EF_a, ED_a, BW_a, AT_a\right), RHSing_{Lead}, BI_{Leada}\right) = 1.0$$

The SGV and hazard quotient dervied matches those documented in MfE 2010

Stokes Point Reserve - Site Specific Hazard Quotient

Hazard quotient based on adjusted soil ingestion rates for a child and adult given the infrequent usage of the reserve

Exposure factors

Soil ingestion rate for a child $IngR_{csp} := 15mg \cdot day^{-1}$

Soil ingestion rate for an adult $IngR_{asp} := 10mg \cdot day^{-1}$

Measured soil contaminant concentrations

Maximum available soil concentration $Csoil_{max} := 890mg \cdot kg^{-1}$

95% UCL of available soil concentrations $Csoil_{95\%} := 260mg \cdot kg^{-1}$

Results - Soil Ingestion Intake Rate

Soil ingestion intake rate - child

$$IR_{soiling}(Csoil_{max}, IngR_{csp}, EF_c, ED_c, BW_c, AT_c) = 0.0005 \cdot mg \cdot kg^{-1} \cdot day^{-1}$$

Soil ingestion intake rate - adult

$$IR_{soiling}(Csoil_{max}, IngR_{asp}, EF_a, ED_a, BW_a, AT_a) = 5.23 \times 10^{-5} \cdot mg \cdot kg^{-1} \cdot day^{-1}$$

Results - Soil Ingestion Hazard quotient

Hazard quotient with maximum concentrations - Child

$$HQ_{soiling}(IR_{soiling}(Csoil_{max}, IngR_{csp}, EF_c, ED_c, BW_c, AT_c), RHSing_{Lead}, BI_{Leadc}) = 0.2$$

Hazard quotient with maximum concentrations - Adult

$$HQ_{soiling}(IR_{soiling}(Csoil_{max}, IngR_{asp}, EF_a, ED_a, BW_a, AT_a), RHSing_{Lead}, BI_{Leada}) = 0.02$$

Hazard quotient with 95 % UCL concentrations - Child

$$HQ_{soiling}\left(IR_{soiling}\left(Csoil_{95\%}, IngR_{asp}, EF_c, ED_c, BW_c, AT_c\right), RHSing_{Lead}, BI_{Leadc}\right) = 0.04$$

Hazard quotient with 95 % UCL concentrations - Adult

$$HQ_{soiling}\left(IR_{soiling}\left(Csoil_{95\%}, IngR_{asp}, EF_a, ED_a, BW_a, AT_a\right), RHSing_{Lead}, BI_{Leada}\right) = 0.005$$

LIFETIME CANCER RISK B(a)P eq. (NON-THRESHOLD) BASED ON SOIL INGESTION AND DERMAL EXPOSURE FOR STOKES POINT RESERVE

This worksheet calculates the lifetime cancer risk based on the soil ingestion and dermal pathways. The method to calucate the risk is from the draft MfE (2010) guidelines, which includes an age adjustment. Other documents are referenced below.

References

MfE 1999, Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand

MfE 2010, Draft Methodology for Deriving Soil Guideline Values Protective of Human Health

Units

$$\mu g := \frac{mg}{1000}$$

Exposure Parameters

Body weight for an adult $BW_a := 70kg$

Body weight for a child $BW_c := 15kg$

Proposed BaP SGV Ingestion - child $Csoil_{BaPingc} := 980mg \cdot kg^{-1}$

Proposed BaP SGV Ingestion - adult $Csoil_{BaPinga} := 523mg \cdot kg^{-1}$

Proposed BaP SGV Dermal - child $Csoil_{BaPdermc} := 3223mg \cdot kg^{-1}$

Proposed BaP SGV Dermal - adult $Csoil_{BaPderma} := 2970mg \cdot kg^{-1}$

Exposure duration for an adult $ED_a := 14yr$

Exposure duration for a child $ED_c := 6yr$

Exposure frequency for an adult $EF_a := 150day \cdot yr^{-1}$

Exposure frequency for a child $EF_c := 200day \cdot yr^{-1}$

Averaging time for nonthreshold compounds $AT := 27375day$

Soil ingestion rate for an adult $IngR_a := 75mg \cdot day^{-1}$

Soil ingestion rate for a child $IngR_c := 15mg \cdot day^{-1}$

Age adjusted soil ingestion rate for an adult $IngR_{adja} := IngR_a \cdot \frac{ED_a}{BW_a}$

$IngR_{adja} = 15 \cdot mg \cdot yr \cdot (kg \cdot day)^{-1}$

Age adjusted soil ingestion rate for a child $IngR_{adjc} := IngR_c \cdot \frac{ED_c}{BW_c}$

$IngR_{adjc} = 6 \cdot mg \cdot yr \cdot (kg \cdot day)^{-1}$

Bioavailability $BIO := 1$

Soil to skin adherence factor child $AH_c := 0.04 \frac{mg}{day \cdot cm^2}$

Soil to skin adherence factor adult $AH_a := 0.06 \frac{mg}{day \cdot cm^2}$

Skin area for an adult $SA_a := 3670cm^2$

Skin area for a child $SA_c := 1900cm^2$

Age adjusted dermal exposure factor for an adult $AD_{adja} := AH_a \cdot SA_a \cdot \frac{ED_a}{BW_a}$

$AD_{adja} = 44.0 \cdot mg \cdot \frac{yr}{kg \cdot day}$

Age adjusted dermal exposure factor $AD_{adjc} := AH_c \cdot SA_c \cdot \frac{ED_c}{BW_c}$

$AD_{adjc} = 30.4 \cdot mg \cdot \frac{yr}{kg \cdot day}$

Toxicity Values - Ingestion

Risk Specific Dose (MfE, 2010) - ingestion - BaP eq. $RSDing_{BaP} := 0.233 \left(mg \cdot kg^{-1} day^{-1}\right)^{-1}$

Toxicity Values - Dermal

Dermal soil absorption factor - BaP Equ $AF_{BaP} := 0.06$

Risk Specific Dose (MfE, 2010) - ingestion - BaP eq. $RSDderm_{BaP} := 0.233 \left(mg \cdot kg^{-1} day^{-1}\right)^{-1}$

Equations

Target risk for B(a)P eq by soil ingestion

$$\text{Risksoiling}(RSD, Csoil, IngR, EF, AT) := \frac{RSD \cdot Csoil \cdot IngR \cdot EF}{AT}$$

Target risk for B(a)P eq bydermal contact

$$\text{Riskdermal}(RSD, Csoil, AD, EF, AF, AT) := \frac{RSD \cdot Csoil \cdot AD \cdot EF \cdot AF}{AT}$$

Results - Ingestion

BaP Lifetime Cancer Risk

Child $\text{Risksoiling}\left(RSDing_{BaP}, Csoil_{BaPingc}, IngR_{adjc}, EF_c, AT\right) = 1.0 \times 10^{-5}$

Adult $\text{Risksoiling}\left(RSDing_{BaP}, Csoil_{BaPinga}, IngR_{adja}, EF_a, AT\right) = 1.0 \times 10^{-5}$

Results - Dermal

BaP Lifetime Cancer Risk

Child $\text{Riskdermal}\left(RSDderm_{BaP}, Csoil_{BaPdermc}, AD_{adjc}, EF_c, AF_{BaP}, AT\right) = 1.0 \times 10^{-5}$

Adult $\text{Riskdermal}\left(RSDderm_{BaP}, Csoil_{BaPderma}, AD_{adja}, EF_a, AF_{BaP}, AT\right) = 1.0 \times 10^{-5}$

The lifetime excess cancer risk calculated above using confirms the proposed NES SGV have a risk estimate of 1 in 100,000

Stokes Point Reserve Site Specific Exposure Factors

Lifetime cancer risk estimate based on adjusted soil ingestion rates for a child and adult based with infrequent park use, risk specific dose and dermal absorption factor for B(a)P eq. based on Petroleum Guidelines

Soil ingestion rate for a child $IngRSP_c := 15mg \cdot day^{-1}$

Soil ingestion rate for an adult $IngRSP_a := 10mg \cdot day^{-1}$

Age adjusted soil ingestion rate for a child $IngRSP_{adjc} := IngRSP_c \cdot \frac{ED_c}{BW_c}$

$IngRSP_{adjc} = 6 \cdot mg \cdot yr \cdot (kg \cdot day)^{-1}$

Age adjusted soil ingestion rate for an adult

$$IngRSP_{adja} := IngRSP_a \cdot \frac{ED_a}{BW_a}$$

$$IngRSP_{adja} = 2 \cdot mg \cdot yr \cdot (kg \cdot day)^{-1}$$

Slope factor for B(a)P eq. (MfE 1999) - ingestion
Expressed as Risk Specific Dose

$$RSDingSP_{BaP} := 7.3 \left(mg \cdot kg^{-1} day^{-1}\right)^{-1}$$

Slope factor for B(a)P eq. (MfE 1999) - dermal
Expressed as Risk Specific Dose

$$RSDdermSP_{BaP} := 7.3 \left(mg \cdot kg^{-1} day^{-1}\right)^{-1}$$

Dermal soil absorption factor (MfE, 1999) - B(a)P eq.

$$AFSP_{BaP} := 0.1$$

Stokes Point Reserve Site - SGV

The Stokes Point SGVs are presented below. The basis for calculating the SGVs below are provided on a separate worksheet

SGV for soil ingestion - child $Csoil_{BaPingSPc} := 32 \cdot mg \cdot kg^{-1}$

SGV for soil ingestion - adult $Csoil_{BaPingSPa} := 128 \cdot mg \cdot kg^{-1}$

SGV for dermal contact - child $Csoil_{BaPdermSPc} := 63 \cdot mg \cdot kg^{-1}$

SGV for dermal contact - adult $Csoil_{BaPdermSPa} := 58 \cdot mg \cdot kg^{-1}$

Lifetime Cancer Risk Results - Ingestion

Stokes Point cancer risk for the soil ingestion SGV - child - 32 mg/kg

$$Risksoiling\left(RSDingSP_{BaP}, Csoil_{BaPingSPc}, IngRSP_{adjc}, EF_c, AT\right) = 1.0 \times 10^{-5}$$

Stokes Point cancer risk for the soil ingestion SGV - adult - 128 mg/kg

$$Risksoiling\left(RSDingSP_{BaP}, Csoil_{BaPingSPa}, IngRSP_{adja}, EF_a, AT\right) = 1.0 \times 10^{-5}$$

Stokes Point cancer risk for the maximum B(a)P eq. concentration
for soil ingestion - child

$$Risksoiling\left(RSDingSP_{BaP}, 46mg \cdot kg^{-1}, IngRSP_{adjc}, EF_c, AT\right) = 1.5 \times 10^{-5}$$

$$\mathrm{Risksoiling}\left(\mathrm{RSDingSP_{BaP}}, 83\mathrm{mg}\cdot\mathrm{kg}^{-1}, \mathrm{IngRSP_{adjc}}, \mathrm{EF_c}, \mathrm{AT}\right) = 2.7\times 10^{-5}$$

Stokes Point cancer risk for the maximum B(a)P eq. concentration
for soil ingestion - adult

$$\mathrm{Risksoiling}\left(\mathrm{RSDingSP_{BaP}}, 46\mathrm{mg}\cdot\mathrm{kg}^{-1}, \mathrm{IngRSP_{adja}}, \mathrm{EF_a}, \mathrm{AT}\right) = 3.7\times 10^{-6}$$

$$\mathrm{Risksoiling}\left(\mathrm{RSDingSP_{BaP}}, 83\mathrm{mg}\cdot\mathrm{kg}^{-1}, \mathrm{IngRSP_{adja}}, \mathrm{EF_a}, \mathrm{AT}\right) = 6.6\times 10^{-6}$$

Stokes Point cancer risk for the 95% UCL B(a)P eq. concentration
for soil ingestion - child

$$\mathrm{Risksoiling}\left(\mathrm{RSDingSP_{BaP}}, 10\mathrm{mg}\cdot\mathrm{kg}^{-1}, \mathrm{IngRSP_{adjc}}, \mathrm{EF_c}, \mathrm{AT}\right) = 3.2\times 10^{-6}$$

Stokes Point cancer risk for the 95% UCL B(a)P eq. concentration
for soil ingestion - adult

$$\mathrm{Risksoiling}\left(\mathrm{RSDingSP_{BaP}}, 10\mathrm{mg}\cdot\mathrm{kg}^{-1}, \mathrm{IngRSP_{adja}}, \mathrm{EF_a}, \mathrm{AT}\right) = 8.0\times 10^{-7}$$

Lifetime Cancer Risk Results - Dermal

Stokes Point cancer risk for dermal contact SGV - child

$$\mathrm{Riskdermal}\left(\mathrm{RSDdermSP_{BaP}}, \mathrm{Csoil_{BaPdermSPc}}, \mathrm{AD_{adjc}}, \mathrm{EF_c}, \mathrm{AFSP_{BaP}}, \mathrm{AT}\right) = 1.0\times 10^{-5}$$

Stokes Point cancer risk for dermal contact SGV - adult

$$\mathrm{Riskdermal}\left(\mathrm{RSDdermSP_{BaP}}, \mathrm{Csoil_{BaPdermSPa}}, \mathrm{AD_{adja}}, \mathrm{EF_a}, \mathrm{AFSP_{BaP}}, \mathrm{AT}\right) = 1.0\times 10^{-5}$$

Stokes Point cancer risk for the maximum B(a)P eq. concentration
for dermal contact - child

$$\mathrm{Riskdermal}\left(\mathrm{RSDdermSP_{BaP}}, 46\mathrm{mg}\cdot\mathrm{kg}^{-1}, \mathrm{AD_{adjc}}, \mathrm{EF_c}, \mathrm{AFSP_{BaP}}, \mathrm{AT}\right) = 7.5\times 10^{-6}$$

$$\mathrm{Riskdermal}\left(\mathrm{RSDdermSP_{BaP}}, 83\mathrm{mg}\cdot\mathrm{kg}^{-1}, \mathrm{AD_{adjc}}, \mathrm{EF_c}, \mathrm{AFSP_{BaP}}, \mathrm{AT}\right) = 1.3\times 10^{-5}$$

Stokes Point cancer risk for the maximum B(a)P eq. concentration
for dermal contact - adult

$$\text{Riskdermal}\left(\text{RSDdermSP}_{\text{BaP}}, 46\text{mg}\cdot\text{kg}^{-1}, \text{AD}_{\text{adja}}, \text{EF}_{\text{a}}, \text{AFSP}_{\text{BaP}}, \text{AT}\right) = 8.1\times 10^{-6}$$

$$\text{Riskdermal}\left(\text{RSDdermSP}_{\text{BaP}}, 83\text{mg}\cdot\text{kg}^{-1}, \text{AD}_{\text{adja}}, \text{EF}_{\text{a}}, \text{AFSP}_{\text{BaP}}, \text{AT}\right) = 1.5\times 10^{-5}$$

Stokes Point cancer risk for the 95% UCL B(a)P eq. concentration
for dermal contact - child

$$\text{Riskdermal}\left(\text{RSDdermSP}_{\text{BaP}}, 10\text{mg}\cdot\text{kg}^{-1}, \text{AD}_{\text{adjc}}, \text{EF}_{\text{c}}, \text{AFSP}_{\text{BaP}}, \text{AT}\right) = 1.6\times 10^{-6}$$

Stokes Point cancer risk for the 95% UCL B(a)P eq. concentration
for dermal contact - adult

$$\text{Riskdermal}\left(\text{RSDdermSP}_{\text{BaP}}, 10\text{mg}\cdot\text{kg}^{-1}, \text{AD}_{\text{adja}}, \text{EF}_{\text{a}}, \text{AFSP}_{\text{BaP}}, \text{AT}\right) = 1.8\times 10^{-6}$$

SOIL ACCEPTANCE CRITERIA FOR B(a)P eq. (NON-THRESHOLD) BASED ON INGESTION AND DERMAL EXPOSURE FOR STOKES POINT RESERVE

This worksheet calculates soil guideline values (SGV) based on the soil ingestion and dermal pathways and calculates a combined SGV. The method is from the draft MfE (2010) guidelines, which includes an age adjustment. Other documents used are referenced below.

References

MfE 1999, Guidelines for Assessing and Managing Contaminated Gasworks Site in New Zealand

T&T 2008, Human Health Risk Assessment Report, Victoria Park, Auckland

MfE 2010, Draft Methodology for Deriving Soil Guideline Values Protective of Human Health

Units

$$\mu g := \frac{mg}{1000}$$

Exposure Parameters

The National Environmental Standards (NES) inputs and calculations proposed by MfE (2010a) for Parkland/Recreational use are as follows.

Body weight for a child $BW_c := 15kg$

Body weight for an adult $BW_a := 70kg$

Target risk $Risk := 10^{-5}$

Exposure duration for a child $ED_c := 6yr$

Exposure duration for an adult $ED_a := 14yr$

Exposure frequency for a child $EF_c := 200day \cdot yr^{-1}$

Exposure frequency for an adult $EF_a := 150day \cdot yr^{-1}$

Averaging time for nonthreshold compounds $AT := 27375day$

Soil ingestion rate for a child $IngR_c := 15mg \cdot day^{-1}$

Soil ingestion rate for an adult $IngR_a := 75mg \cdot day^{-1}$

Age adjusted soil ingestion rate for a child $IngR_{adjc} := IngR_c \cdot \frac{ED_c}{BW_c}$

$$IngR_{adjc} = 6 \cdot mg \cdot yr \cdot (kg \cdot day)^{-1}$$

Age adjusted soil ingestion rate for an adult $IngR_{adja} := IngR_a \cdot \frac{ED_a}{BW_a}$

$IngR_{adja} = 15 \cdot mg \cdot yr \cdot (kg \cdot day)^{-1}$

Bioavailability $BIO := 1$

Soil to skin adherence factor for a child $AH_c := 0.04 \frac{mg}{day \cdot cm^2}$

Soil to skin adherence factor and adult $AH_a := 0.06 \frac{mg}{day \cdot cm^2}$

Skin area for a child $SA_c := 1900cm^2$

Skin area for an adult $SA_a := 3670cm^2$

Age adjusted dermal exposure factor for a child $AD_{adjc} := AH_c \cdot SA_c \cdot \frac{ED_c}{BW_c}$

$AD_{adjc} = 30.4 \cdot mg \cdot \frac{yr}{kg \cdot day}$

Age adjusted dermal exposure factor for an adult $AD_{adja} := AH_a \cdot SA_a \cdot \frac{ED_a}{BW_a}$

$AD_{adja} = 44.0 \cdot mg \cdot \frac{yr}{kg \cdot day}$

Toxicity Values - Ingestion

Risk Specific Dose (MfE, 2010) - ingestion - B(a)P eq. $RSDing_{BaP} := 0.000043mg \cdot kg^{-1} day^{-1}$

Toxicity Values - Dermal

Dermal soil absorption factor (MfE, 2010) - B(a)P eq. $AF_{BaP} := 0.06$

Risk Specific Dose (MfE, 2010) - dermal - B(a)P eq. $RSDderm_{BaP} := 0.000043mg \cdot kg^{-1} day^{-1}$

Equations (MfE, 1010)

SGV for non-threshold contaminants by soil ingestion $SGV_{soiling}(RSD, AT, IR, EF) := \frac{RSD \cdot AT}{IR \cdot EF}$

SGV for non-threshold contaminants for dermal exposure $SGV_{soilderm}(RSD, AT, AD, EF, AF) := \frac{RSD \cdot AT}{AD \cdot EF \cdot AF}$

Soil ingestion and dermal exposure combined

$$SGV_{soilcomb}(RSDing, RSDderm, AT, IR, EF, AD, AF) := \frac{1}{\left[\frac{1}{\left(\frac{RSDing \cdot AT}{IR \cdot EF}\right)} + \frac{1}{\left(\frac{RSDderm \cdot AT}{AD \cdot EF \cdot AF}\right)}\right]}$$

Based on the above, the SGVs in the proposed NES are:

Results - Ingestion

Child $SGV_{soiling}\left(RSDing_{BaP}, AT, IngR_{adjc}, EF_c\right) = 981 \cdot mg \cdot kg^{-1}$

Adult $SGV_{soiling}\left(RSDing_{BaP}, AT, IngR_{adja}, EF_a\right) = 523 \cdot mg \cdot kg^{-1}$

Results - Dermal

Child $SGV_{soilderm}\left(RSDderm_{BaP}, AT, AD_{adjc}, EF_c, AF_{BaP}\right) = 3227 \cdot mg \cdot kg^{-1}$

Adult $SGV_{soilderm}\left(RSDderm_{BaP}, AT, AD_{adja}, EF_a, AF_{BaP}\right) = 2970 \cdot mg \cdot kg^{-1}$

Results - Combined

Child $SGV_{soilcomb}\left(RSDing_{BaP}, RSDderm_{BaP}, AT, IngR_{adjc}, EF_c, AD_{adjc}, AF_{BaP}\right) = 752 \cdot mg \cdot kg^{-1}$

Adult $SGV_{soilcomb}\left(RSDing_{BaP}, RSDderm_{BaP}, AT, IngR_{adja}, EF_a, AD_{adja}, AF_{BaP}\right) = 445 \cdot mg \cdot kg^{-1}$

These match the documented adult SGVs in MfE 2010, as they are more stringent than the child.

Stokes Point Reserve - Site Specific SGV

SGV based on adjusted soil ingestion rates for a child and adult based with infrequent park use, slope factor and dermal absorption factor for B(a)P eq. based on Petroleum Guidelines

Soil ingestion rate for a child $IngRSP_c := 15mg \cdot day^{-1}$

Soil ingestion rate for an adult $IngRSP_a := 10mg \cdot day^{-1}$

Age adjusted soil ingestion rate for a child $IngRSP_{adjc} := IngRSP_c \cdot \frac{ED_c}{BW_c}$

$$IngRSP_{adjc} = 6 \cdot mg \cdot yr \cdot (kg \cdot day)^{-1}$$

Age adjusted soil ingestion rate for an adult

$$IngRSP_{adja} := IngRSP_a \cdot \frac{ED_a}{BW_a}$$

$$IngRSP_{adja} = 2 \cdot mg \cdot yr \cdot (kg \cdot day)^{-1}$$

Slope factor for B(a)P eq. (MfE 1999) - ingestion
Expressed as Risk Specific Dose

$$RSDingSP_{BaP} := 0.0014 \mu g \cdot kg^{-1} day^{-1}$$

Slope factor for B(a)P eq. (MfE 1999) - dermal
Expressed as Risk Specific Dose

$$RSDdermSP_{BaP} := 0.0014 \mu g \cdot kg^{-1} day^{-1}$$

Dermal soil absorption factor (MfE, 1999) - B(a)P eq.

$$AFSP_{BaP} := 0.1$$

Results Stokes Point Reserve - Ingestion SGV

Child visiting $SGV_{soiling}(RSDingSP_{BaP}, AT, IngRSP_{adjc}, EF_c) = 31.9 \cdot mg \cdot kg^{-1}$

Adult visiting $SGV_{soiling}(RSDingSP_{BaP}, AT, IngRSP_{adja}, EF_a) = 128 \cdot mg \cdot kg^{-1}$

Results Stokes Point Reserve - Dermal SGV

Child visiting $SGV_{soilderm}(RSDdermSP_{BaP}, AT, AD_{adjc}, EF_c, AFSP_{BaP}) = 63 \cdot mg \cdot kg^{-1}$

Adult visiting $SGV_{soilderm}(RSDdermSP_{BaP}, AT, AD_{adja}, EF_a, AFSP_{BaP}) = 58 \cdot mg \cdot kg^{-1}$

Results Stokes Point Reserve- Combined SGV

Child visiting Stokes Point

$$SGV_{soilcomb}(RSDingSP_{BaP}, RSDdermSP_{BaP}, AT, IngRSP_{adjc}, EF_c, AD_{adjc}, AFSP_{BaP}) = 21 \cdot mg \cdot kg^{-1}$$

Adult visiting Stokes Point

$$SGV_{soilcomb}(RSDingSP_{BaP}, RSDdermSP_{BaP}, AT, IngRSP_{adja}, EF_a, AD_{adja}, AFSP_{BaP}) = 40 \cdot mg \cdot kg^{-1}$$

SOIL ACCEPTANCE CRITERIA FOR LEAD (THRESHOLD) BASED ON INGESTION AND DERMAL EXPOSURE FOR STOKES POINT RESERVE

This worksheet calculates soil guideline values (SGV) based on the soil ingestion pathway. The method is from the draft MfE (2010) guidelines. Other documents used are referenced below.

References

T&T 2008, Human Health Risk Assessment Report, Victoria Park, Auckland

MfE 2010, Draft Methodology for Deriving Soil Guideline Values Protective of Human Health

Units

$$\mu g := \frac{mg}{1000}$$

Exposure Parameters

The National Environmental Standards (NES) inputs and calculations proposed by MfE (2010a) for Parkland/Recreational use are as follows.

Body weight for a child $BW_c := 15kg$

Body weight for an adult $BW_a := 70kg$

Target risk $Risk := 10^{-5}$

Exposure duration for a child $ED_c := 6yr$

Exposure duration for an adult $ED_a := 14yr$

Exposure frequency for a child $EF_c := 200day \cdot yr^{-1}$

Exposure frequency for an adult $EF_a := 150day \cdot yr^{-1}$

Averaging time for threshold compounds - child (6yr x365 dy) $AT_c := 2190day$

Averaging time for threshold compounds - adult (6yr x365 dy) $AT_a := 5110day$

Soil ingestion rate for a child $IngR_c := 15mg \cdot day^{-1}$

Soil ingestion rate for an adult $IngR_a := 75mg \cdot day^{-1}$

Bioavailability $BIO := 1$

Toxicity Values - Ingestion

Risk Specific Dose (MfE, 2010) - ingestion - Lead	$RSDingSP_{Pb} := 0.00357 mg \cdot kg^{-1} day^{-1}$

Background intake (MfE, 2010) - Lead - child	$BI_{Pbc} := 0.00097\ mg \cdot kg^{-1} day^{-1}$

Background intake (MfE, 2010) - Lead - adult	$BI_{Pba} := 0.00041\ mg \cdot kg^{-1} day^{-1}$

Equations (MfE, 1010)

SGV for threshold contaminants by soil ingestion

$$SGV_{soiling}(RSD, BI, BW, AT, IR, EF, ED) := \frac{(RSD - BI) \cdot BW \cdot AT}{IR \cdot EF \cdot ED}$$

Based on the above, the SGVs in the proposed NES are:

Results - Ingestion

Child	$SGV_{soiling}(RSDingSP_{Pb}, BI_{Pbc}, BW_c, AT_c, IngR_c, EF_c, ED_c) = 4745 \cdot mg \cdot kg^{-1}$

Adult	$SGV_{soiling}(RSDingSP_{Pb}, BI_{Pba}, BW_a, AT_a, IngR_a, EF_a, ED_a) = 7177 \cdot mg \cdot kg^{-1}$

The child guideline values derived matches the documented SGV in MfE 2010 (adopted because it is more stringent than the adult).

Stokes Point Reserve - Site Specific SGV

SGV based on adjusted soil ingestion rates for a child and adult with infrequent park use.

Soil ingestion rate for a child	$IngRSP_c := 15 mg \cdot day^{-1}$

Soil ingestion rate for an adult	$IngRSP_a := 10 mg \cdot day^{-1}$

Results Stokes Point Reserve - Ingestion SGV

Child visiting	$SGV_{soiling}(RSDingSP_{Pb}, BI_{Pbc}, BW_c, AT_c, IngRSP_c, EF_c, ED_c) = 4745 \cdot mg \cdot kg^{-1}$

Adult visiting	$SGV_{soiling}(RSDingSP_{Pb}, BI_{Pba}, BW_a, AT_a, IngRSP_a, EF_a, ED_a) = 53825 \cdot mg \cdot kg^{-1}$