8.14. Tidal Pool Swimming Enclosure Proposal Hayes St Beach - Water and Sediment Testing Results

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ATTACHMENTS:
1. Framework for Human Health Risk Assessment Risks Report [**8.14.1** - 40 pages]

PURPOSE:

This report details the outcomes of a human health screening assessment on Hayes Street Beach's water and sediments to ascertain the potential public health impacts of the installation and use of a tidal swimming pool enclosure at this location.

EXECUTIVE SUMMARY:

The outcomes of the sediment and surface water sampling of the Hayes Street Beach tidal pool enclosure proposal has revealed that there are no risk issues of concern in relation to the presence of a range of common contaminants in sediments and surface waters in this location. The next step in this process would be to allocate a budget to allow for the lodgement of a Development Application for the installation of the tidal pool enclosure.

FINANCIAL IMPLICATIONS:

The Capital Works Program in the Draft Delivery Program 2022-2026 has no budget allocation for this project. If the project is to proceed to the Development Proposal stage it will need to be added to future iterations of the Program. The Capital Works Budget would need to be reassessed and revised.

RECOMMENDATION:
1. THAT the report be received.

LINK TO COMMUNITY STRATEGIC PLAN

The relationship with the Community Strategic Plan is as follows:

1. Our Living Environment
1.1 Protected and enhanced natural environment and biodiversity
1.3 Quality urban greenspaces

BACKGROUND

At Council's meeting on 21 May 2021, Council resolved:

> *"THAT Council employ the services of a suitably qualified consultant to undertake a human health screening level assessment on Hayes Street Beach water and sediment in order to ascertain the appropriateness of the location for a tidal swimming pool enclosure:*
> *THAT Council staff prepare a further report to Council on the results of the initial human health screening level assessment conducted at Hayes Street Beach."*

This follows on from a previous Council report that explored a list of possible locations for the tidal pool enclosure together with preliminary costings for the lodgement of a Development Application and associated necessary studies as well as an estimate of the costs of the actual construction and maintenance of the enclosure.

CONSULTATION REQUIREMENTS

Community engagement is not required.

DETAIL

Following on from discussions with Transport for NSW (Maritime) regarding an acceptable site for a tidal pool enclosure, Hayes Street Beach was prioritised as a preferred site. Discussions were held with Transport for NSW (Maritime) as they are the landowners for any installation of a tidal pool.

To determine whether that site demonstrated any human health risk to the community, consultants were engaged to undertake water and sediment sampling in the vicinity of the proposed swimming enclosure's location.

The methodology for the assessment of the human health risks was in conformity with the *Framework for Human Health Risk Assessment: recreational areas as prepared by enRisks for Sydney Water, dated 22 May 2020.*

The methodology is consistent with how a number of other potential swimming sites along the Parramatta River have been assessed for public health risks. The methodology has been accepted by NSW Health, Department of Planning Infrastructure and Environment and Sydney Water for the purposes of assessing Human Health Risk Assessment (HHRA) for recreational swimming sites.

It must be noted, that unlike the assessment of land contamination for potential land use guidelines (National Environment Protection [Assessment of Site Contamination] Measure), there are no such, ready-made and applied, standards that can be applied to recreational swimming sites.

For the purposes of assessing sediment data, soil guidelines normally applied to public open space are most relevant. These guidelines are calculated by assuming the public are exposed to that soil every day of the year and that 50mg of soil is ingested and that soil will get onto the skin of the hands, feet, forearms and lower legs. The standards are based on an occupational exposure; therefore the above exposure occurs over a 35-40 year length of time.

In applying these same chemical limits to a residential swimming site, the above public open space soil guidelines are considered conservative for screening the sediment results due to:

- Young children are unlikely to visit this area every day of the year
- Sediments in this area are unlikely to adhere to the skin for very long given their sandy nature
- The sediments will get washed off the skin as the child plays in the water
- The wetness of the sediment means that the sediment is less mobile and less likely to be incidentally ingested.

The potential for exposure to chemical contaminants for swimmers using that area include chemical sources from historical manufacturing and industrial activities, discharge of urban stormwater and sewer overflows. Key contaminants may include heavy metals, organochloride pesticides, dioxins and furans, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), brominated flame retardants and polyfluoroalkyl substances (PFAS).

There is also a microbiological exposure with the potential use of site given that sewer overflows occur regularly in this area, usually triggered by moderate to heavy rainfall. Dissipation of the microbiological risk to swimmers occurs usually with the onset of 48 hours of dry weather.

Sediment sampling occurred over six sites, both onshore and intertidal at differing depths. Water sampling also occurred during both dry and wet weather events.

Results of Sampling

Table 2 on page 16 of the attached report details the results of the **sediment sampling** together with the human health screening guideline that is applied in this instance. The results indicate that all the chemical parameters are below the screening guidelines. The maximum concentration for PAHs in one of the intertidal sandy muds was slightly above the conservative national screening guideline for soil. The other five locations were below the standard. It should be noted that although there was one exceedance of the screening guideline does not mean that there is an unacceptable risk to health. As previously mentioned, the screening guideline is based on a soil exposure as previously detailed and given the exposure to swimmers will not mirror the assumptions made in the exposures to soil, then exposure to slightly higher concentrations of chemicals will not affect the health of the swimmers of the facility.

It is the consultant's view that of the chemicals detected and their concentrations were not of sufficient concern to warrant a more detailed assessment of human health risks.

Table 3 on page 18 of the attached report detail the results of the **surface water sampling** conducted. It is the view of the consultant that given that "no analytes detected in surface water, during any of the sampling events and weather conditions, that report concentrations exceeding the adopted screening level guidelines", that there is no requirement to undertake any more detailed assessment of human health risks relevant to surface water quality.

It is the consultants considered view that "based on the available data and the details of this assessment, it has been concluded that there are no risk issues of concern in relation to the presence of a range of common contaminants in sediments and surface waters at Hayes Street Beach."

Next Steps

For Council to pursue the installation of the tidal pool enclosure at Hayes Street Beach, it would be necessary to lodge a Development Application for assessment as per the following advice from Council's Planning section:

> *Any swimming pool program would require development consent from council and landowners' consent from RMS as it would be considered integrated development.*
>
> *In the first instance it would be advisable to sound out RMS if they would be amenable to giving consent to such a project as without this it would not be able to proceed.*
>
> *Typically, such a DA would need to be accompanied by ecological, environmental reports and surveys including assessment to whether there would be any impact on waterway navigation and boat traffic. leading to the requirement for the approval from Transport for NSW (Sydney Ferries) NSW Fisheries, and Department of Environment. In addition to this a plan of management for the construction including all environmental protection measures would also need to be provided. All reports would need to be lodged as part of the DA and would need to be completed at the cost of the developer.*

I note from the proposed locations in the report that the locations are adjacent to Council's parks that are identified as Heritage Conservation Areas, so any application would need a Heritage Impact Statement.

In terms of plans, a full suite of architectural drawings would be required and would need to show long sections of the proposed enclosures from the land into the water and a site plan detailing the location of the enclosures. It would be advisable to engage a consultant familiar with land water interfaces as it is quite specialised.

It is estimated that to prepare and lodge the Development Application, preparation of technical reports including approval from State Government Agencies that a budget of $400,000 would be required and the approval process could take twelve months.

It is further estimated that the installation of the structure including steel piling, HDPE sleeve and polyethylene netting (based on a 40m x 40-meter dimension) would be $600,00 - $800,000. Maintenance costs of the structure is estimated at $20,000 per annum.

Human Health Risk Assessment: Hayes Street Beach

Prepared for: North Sydney Council

7 April 2022

EnRiskS

Document History and Status

Report Reference	SW/22/HSB001
Revision	B – Final
Date	7 April 2022
Previous Revisions	A – Draft (30 March 2022)

Limitations

Environmental Risk Sciences Pty Ltd has prepared this report for the use of North Sydney Council, Sydney Water, Department of Planning Infrastructure and Environment and NSW Health in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report.

It is prepared in accordance with the scope of work and for the purpose outlined in the **Section 1** of this report.

The methodology adopted and sources of information used are outlined in this report. Environmental Risk Sciences has made no independent verification of this information beyond the agreed scope of works and assumes no responsibility for any inaccuracies or omissions. No indications were found that information provided for use in this assessment was false.

This report was prepared in March/April 2022 and is based on the information provided and reviewed at that time. Environmental Risk Sciences disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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Glossary of Terms

ANZECC	Australia and New Zealand Environment and Conservation Council
AT	Averaging time
BW	Body weight
CF	Unit conversion factor
CoPC	Contaminant of potential concern
CSM	Conceptual site model
ED	Exposure duration
EF	Exposure frequency
EPA	Environment Protection Authority
ET	Exposure time
HHERA	Human health and Environmental Risk Assessment
HI	Hazard index
HIL	Health investigation level
HQ	Hazard quotient
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NSW DECC	New South Wales Department of Environment and Climate Change
TRV	Toxicity reference value
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound
WHO	World Health Organization

Section 1. Introduction

1.1 Background

Environmental Risk Sciences Pty Ltd (enRiskS) has been commissioned by North Sydney Council to conduct a Human Health Risk Assessment (HHRA) in relation to the recreational swimming site – Hayes Street Beach – which is adjacent to the Neutral Bay ferry wharf in Neutral Bay, NSW (the "site") (refer to **Figure 1**).

This location has been used for swimming for many decades. The area comprises a sandy beach some of which is exposed at all tides. Recreational activities include beach play, wading, swimming and boating.

1.2 Objectives

The objective of this assessment is to evaluate risks to human health in relation to potential exposures to contaminants that may be present in surface water and sediments (where relevant) in the swimming area at Hayes Street Beach.

The HHRA has not addressed the presence of any physical hazards (such as sharps or debris), microbiological hazards or safety issues (relating to public access to waterways). In addition, this assessment does not address any ecological risk issues relating to contamination.

Figure 1: Location of Hayes Street Beach

Swimming area

Section 2. Methodology

The HHRA has been prepared in accordance with the following framework:

- Framework for Human Health Risk Assessment: recreational Areas. Report prepared by enRiskS for Sydney Water, dated 22 May 2020.

Following this framework, the assessment of risks to human health has been undertaken in accordance with guidance available from enHealth, the National Environmental Protection Council (NEPC) and the National health and Medical Research Committee (NHMRC) as detailed in the following:

- enHealth 2012, Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards (enHealth 2012a)
- enHealth 2012, Australian Exposure Factors Guide (enHealth 2012b)
- NEPC, National Environmental Protection Measure (NEPM) – Assessment of Site Contamination referred to as NEPM (2013), including:
  - Schedule B1 Investigation Levels for Soil and Groundwater (NEPC 1999 amended 2013a)
  - Schedule B4 Guideline on Health Risk Assessment Methodology (NEPC 1999 amended 2013b)
  - Schedule B7 Guideline on Health-Based Investigation Levels (NEPC 1999 amended 2013c)
- NHMRC 2008, Guidelines for Managing Risks in Recreational Water (NHMRC 2008)
- NHMRC 2011 updated 2021, Australian Drinking Water Guidelines (NHMRC 2011 updated 2021).

In addition, protocols and guidelines developed by international agencies such as the United States Environmental Protection Authority (USEPA) and the World Health Organisation (WHO) have been used (and referenced) to provide supplementary guidance where required.

The overall approach to the assessment of human health risks is outlined in **Figure 2** (modified from enHealth (enHealth 2012a)).

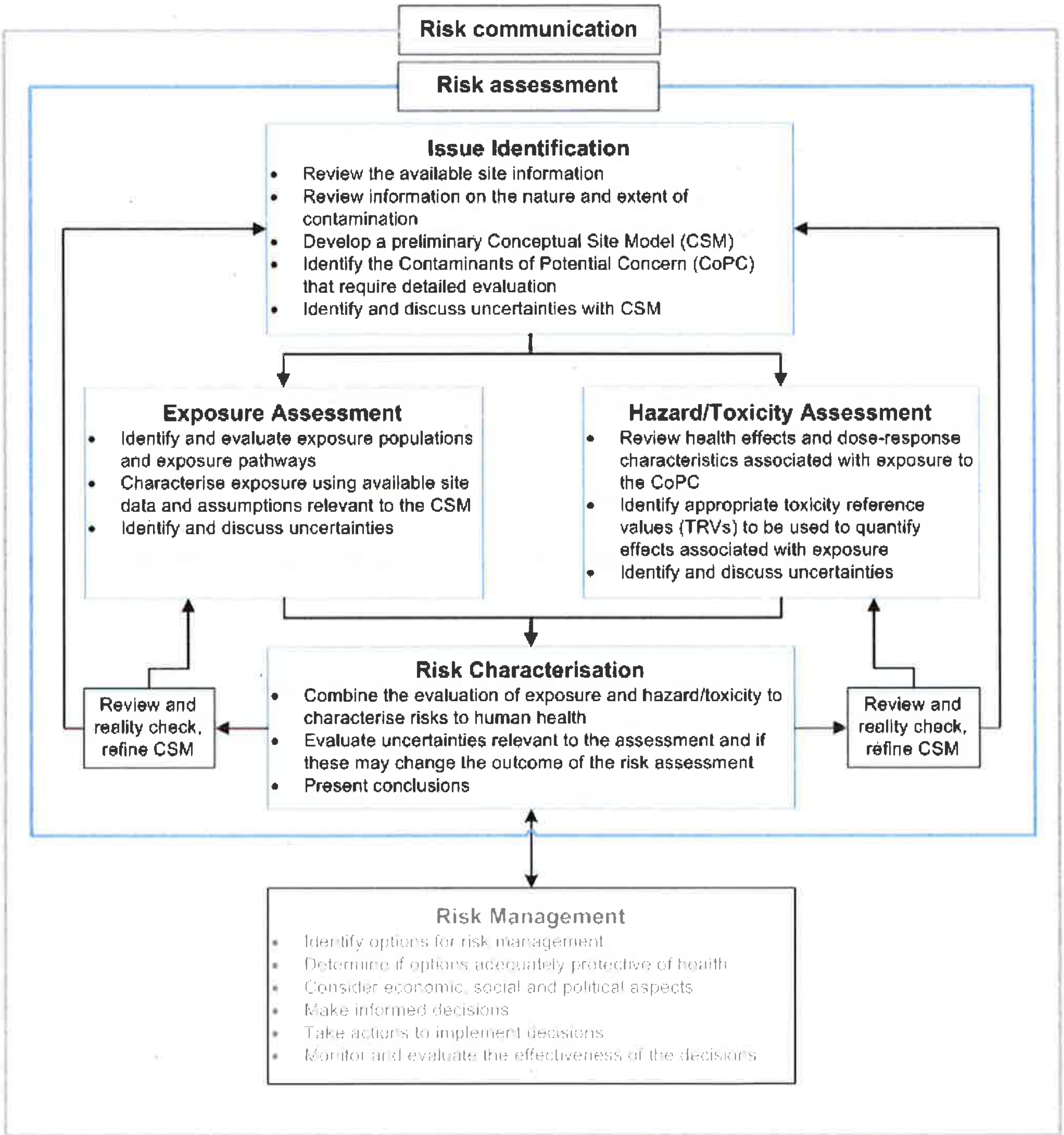

Figure 2: Overall approach to HHRA

Section 3. Issue identification

3.1 General

This section provides understanding the potential for contamination that may be present in the proposed recreation area and the potential for exposure to be of importance for the recreational use of this area.

3.2 Potential for contamination

The area is located within Neutral Bay.

The use of ferries to transport people and goods between Circular Quay and Mosman's Bay began in 1873. The actual Hayes Street ferry wharf location was put in place in 1909. A tram service also operated in the area between 1890 and 1956 with trams terminated in a building adjacent to the wharf. Hayes Street was named after Patrick Hayes who owned a brick works and formed the Neutral Bay Ferry Company in 1885. He also established a soap factory at Kurraba Point (the eastern side of Neutral Bay). The buildings close to the wharf were all residential until the 1940s when one was taken over for the Sydney Volunteer Coastal and Harbour Patrol. The Commonwealth took over that building (and an adjacent one) for defence purposes and eventually demolished it in the 1960s. Other houses were used for boarding (North Sydney Council undated[1]).

Assessments by universities in Sydney have commonly focused on ecological issues related to the presence of contamination, significantly elevated concentrations of contaminants such as heavy metals, organochlorine pesticides, dioxins and furans, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), brominated flame retardants and per and polyfluoroalkyl substances (PFAS) have been identified in numerous locations within the Harbour particularly in Parramatta River, linked to areas of former manufacturing and industrial activities.

The discharge of urban stormwater also has the potential to affect water quality throughout Sydney Harbour. Neutral Bay has a large catchment area that drains into the bay via stormwater drains. Key pollutants identified in urban runoff that discharge to the bay include nutrients, heavy metals, organochlorine and organophosphorus pesticides, PAHs, phenols and sewage from overflows. Other contaminants may include PFAS.

Lotsearch reporting

A search of history and surrounding land uses, including information relevant to the potential presence of contamination, has been completed for Hayes Street Beach and is included in **Attachment A**.

This search identified the following:

- The historical aerial photographs of the site indicate the following:
  - 1930 – 2021 – a residential area
- There are no records of contaminating activities or businesses on the site.

[1] https://www.northsydney.nsw.gov.au/files/f1a7bf15-d2d0-4078-bd41-a15d00cd8a60/Gem_of_the_Harbour.pdf

- Listed contaminated sites in the area include the defence base – Sub Base Platypus which is on the western side of Neutral Bay. The base and the sediments in front of it were impacted by gasworks waste historically. The area has been remediated.
- Infrastructure construction – Warringah Freeway, train construction and Sydney Harbour Tunnel – are all activities licenced by the EPA in the vicinity of Hayes Street Beach.
- The Royal Sydney Yacht Squadron is also a licenced activity in this vicinity (i.e. slipway/marina).

Summary

While there have been a range of contaminating historical activities that have affected Sydney Harbour generally, there do not appear to be any additional activities that have occurred in the area of Hayes Street Beach that change or add to the general pattern of contamination in the area. It is noted that low levels of gasworks waste may have moved from the Sub Base Platypus area around Neutral Bay prior to remediation being completed.

3.3 Potential for exposure to contaminants from recreational activities

The beach is located in an urbanised area adjacent to houses and the ferry wharf. The area is a sandy beach some of which remains exposed at all times (refer to **Figure 3**).

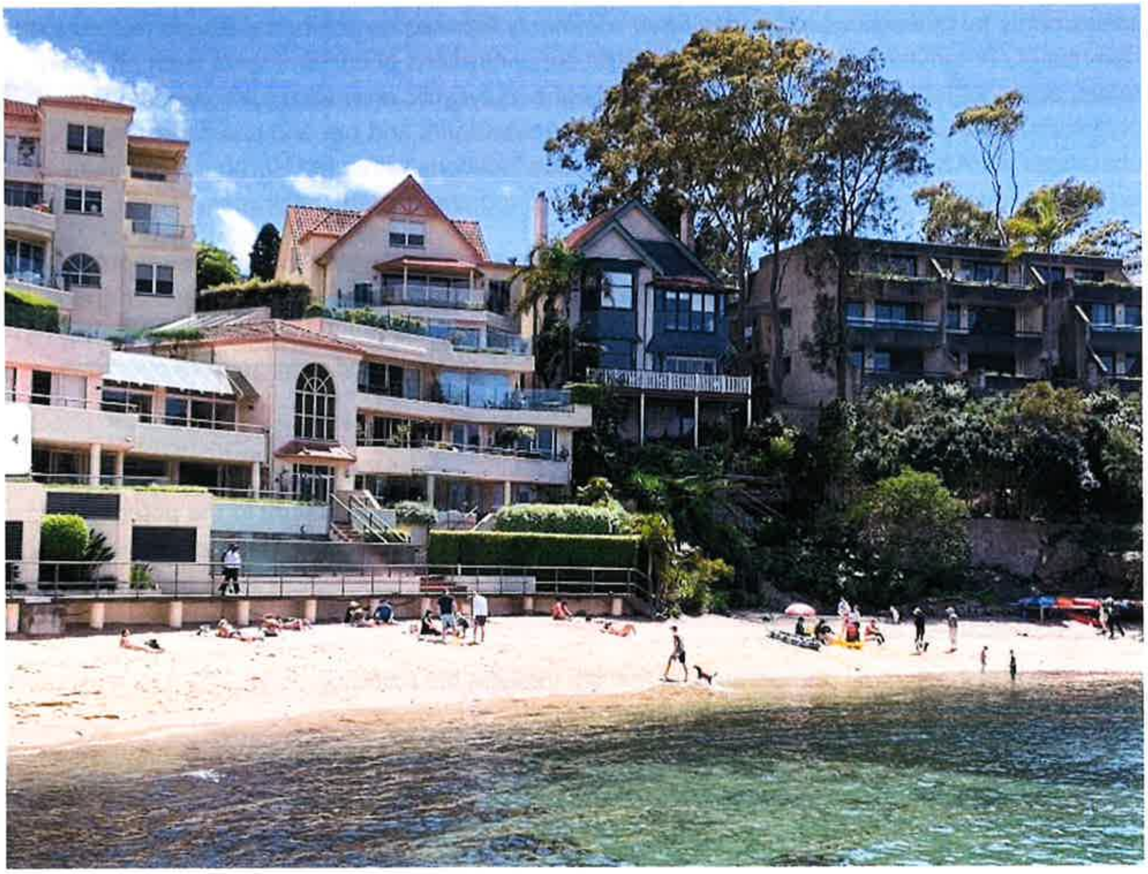

Figure 3: Hayes Street Beach

The swimming area includes potential for direct access to existing sediments along the shoreline (high-tide and low tide) and direct contact with surface water in the area during swimming or boating activities.

For this location and these activities, the exposures that are of key importance are:

- ingestion and dermal contact with sediments that can be accessed at low and high tide (above the water line)
- ingestion and dermal contact with contaminants in surface water.

Any sediments that are present at depth (underwater at all times) would not be able to stick to and stay on the skin as they will always be washed off prior to a person leaving the water. The sediment may become suspended in the water while swimming and so incidental ingestion and dermal contact can occur while such material is present within the water column.

The sediment sampling targeted the area close to the water but above the high tide mark to represent areas where children may play regularly and sediments in that area are more likely to stay on the skin as the child moves away but these areas are likely to be more sandy (chemicals of interest in this investigation are less likely to stick to sandy particles). So, in addition, sampling targeted the area that may be covered by water at high tide but uncovered at low tide (i.e. intertidal area) to represent areas where the sediments may be more muddy (and so more likely to contain these chemicals) and where children may play and where sediments may stick to the skin but not get washed off as the child leaves the area.

To evaluate potential risks to health relevant to these types of exposures, data have been collected to characterise sediment quality and surface water quality. In relation to the sampling of surface water, this targeted different conditions, including those that would result in suspended sediments being present. These data appropriately allow the assessment of all exposures in water – to contaminants dissolved in water and those present in suspended sediments in the water which may be ingested or be in contact with the skin.

It is expected that most of the contamination that may be present in surface water is not volatile (i.e. chemicals that evaporate into the air from the water surface – these are chemicals like those present in petrol or solvents). If such chemicals are present in water, then the public may also be exposed via inhalation of vapours close to the water surface.

Figure 4 presents a diagrammatic conceptual site model (CSM) that shows the recreational exposure scenario evaluated in this assessment and the key pathways of exposure that need to be considered when evaluating risks to human health.

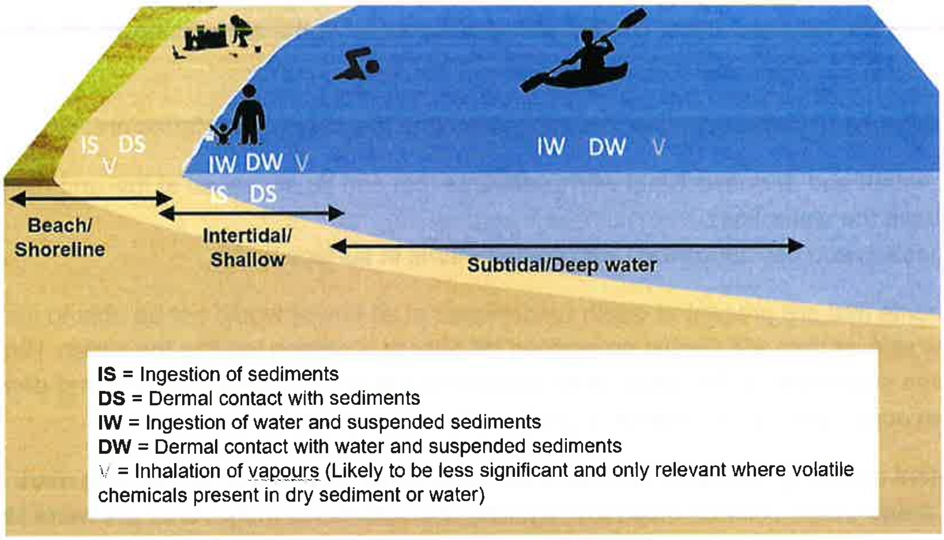

Figure 4: CSM for Hayes Street Beach

3.4 Sampling of sediments

Sediment quality in the proposed swim area was evaluated in the following report:

- Royal Haskoning Australia DHV 2022, Water and Sediment Quality Sampling: Recreational water use Hayes Street Beach – Neutral Beach. Prepared for North Sydney Council, dated March 2022. This report is included as **Appendix B** to this report.

In relation to this location, the work undertaken involved the following:

- Sediment sampling was completed on 20 December 2021.
- Sediment samples were collected from 6 locations from the shoreline of the proposed swimming area. The sampling locations are shown on **Figure 5**. The sediments sampled included:
  - Hayes Street Beach onshore where 3 samples were collected from surface to 0.3 m
  - Hayes Street Beach intertidal zone where 3 samples were collected from surface to 0.1 m

Figure 6 includes photographs showing the nature of the materials sampled. It is noted that the sediments in deeper water were similar in appearance to those close to the beach. Exposure to sandy materials along the shoreline would occur more often during access and use of the recreation area. It is noted that these photos show the materials look quite sandy in both areas.

Figure 5: Location of sediment samples (HS01-S-HS06-S) and surface water samples (HS01-W-HS03-W)

HS01-S

HS02-S

HS03-S

HS04-S

HS05-S

HS06-S

Figure 6: Nature of sediment samples from Hayes Street Beach swim area

Sufficient samples (6 samples) have been collected to enable an assessment of potential exposure to be undertaken.

- All samples were analysed for the following contaminants of potential concern (which are relevant based on the history of Hayes Street Beach):
    - trace metals and metalloids (Sb, As, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Se, Ag, V and Zn)
    - polycyclic aromatic hydrocarbons (PAHs) (including the most important subset – those related to benzo[a]pyrene – these are referred to throughout this assessment as benzo[a]pyrene equivalents)
    - benzene, toluene, ethylbenzene and total xylenes (BTEX) and total petroleum hydrocarbons (TPHs)
    - polychlorinated dibenzo-*p*-dioxin and polychlorinated dibenzofurans (PCDD/Fs)
    - polychlorinated biphenyls (PCBs)
    - organochlorine pesticides (OCs) (includes hexachlorobenzene)
    - organophosphorus pesticides (OPs).

Tributyltin (TBT) is a chemical that can be present in waterways from its use in antifouling paints on boats (a use that is now banned). It is not a chemical that is particularly hazardous for people and there is no reason to expect significantly elevated levels at Hayes Street Beach. Previous investigations in the vicinity of Homebush Bay reported concentrations ranging from <0.0005 to 0.043 mg Sn/kg dry weight. There are no Australian guidelines for human health protection for TBT in soil or sediment. The USEPA value is 19 mg/kg – i.e. approximately 1,000 times higher than the concentrations reported in Parramatta River (USEPA 2021). Consequently, it was not included as a key contaminant for this assessment.

Polychlorinated biphenyls (PCBs) have been analysed using the standard screening analytical method based on arochlors (i.e. different types of PCB oils as were available when these materials were available for purchase). It is acknowledged that a sub group of PCBs can contribute to the overall equivalent dioxin-like compounds concentrations. Previous investigations undertaken for swimming areas in Parramatta River and for the large investigations in Homebush Bay have considered the potential for dioxin-like PCBs to contribute to the overall dioxin equivalent concentrations in Sydney Harbour. Given the source of these compounds in the Harbour (contamination in Homebush Bay which was predominantly chemicals in the dioxins group rather than furans or dioxin-like PCBs), it is not expected that this sub group would contribute significantly. This was confirmed by results at other swim sites which reported that dioxin-like PCBs contribute between 0.8 and 5% to the overall equivalent dioxin-like compounds concentrations. Consequently, more detailed assessment of dioxin-like PCBs was not included in this assessment.

Sediment grain size was also analysed. While not directly used in this assessment, it is noted that the beach sands and the intertidal material were similar – primarily fine to coarse sands with a minor gravel component in the intertidal zone samples (HS04-HS06) (i.e. 87-99% sand (less than 600 μm; mostly less than 150 μm).

Quality assurance and quality control samples were collected, and an evaluation of data quality was undertaken and presented in the Royal Haskoning report. This review indicated that data were suitable for interpretative purposes.

3.5 Sampling of surface water

Surface water quality at Hayes Street Beach has been evaluated in the following report:

- Royal Haskoning Australia DHV 2022, Water and Sediment Quality Sampling: Recreational water use Hayes Street Beach – Neutral Beach. Prepared for North Sydney Council, dated March 2022. This report is included as **Appendix B** to this report.

The sampling of surface water was undertaken over 2 sampling events as follows:

- 20 December 2021 – sampling was undertaken on a mostly sunny day with no rainfall in the preceding 72 hours. The conditions during sampling were noted to be an outgoing tide with windy conditions (31 km/hr to ENE). The water was slightly turbid, greeny blue with minor amounts of surface debris including leaf litter and household waste (i.e. plastics, bottles).

- 1 February 2022 – sampling was undertaken on a sunny day with some rainfall in the preceding 72 hours (7 mm). The conditions during sampling were noted to be an outgoing tide with windy conditions (30 km/hr to N). The water was clear and blue with minor amounts of surface debris including leaf litter and household waste (mostly soft plastics).

Three water samples were collected from the proposed swimming area during each sampling event (as shown in **Figure 5**). It is noted that, while 2 rounds of water sampling were undertaken rather than 4 rounds as specified in the Framework (enRiskS 2020), the conditions during these sampling rounds did include sampling after rainfall and sampling while the water was turbid.

All samples collected were analysed for the following contaminants of potential concern (as total concentrations):

- total suspended solids (TSS)
- trace metals and metalloid (As, Ag, Be, B, Cd, Cr, Co, Cu, Hg, Mn, Mo, Ni, Pb, Se, Sb, Sn and Zn)
- organochlorine pesticides (OCs)
- organophosphorus pesticides (OPs)
- dioxins/furans
- polycyclic aromatic hydrocarbons (PAHs) (including the most important subset – those related to benzo[a]pyrene – these are referred to throughout this assessment as benzo[a]pyrene equivalents).

In addition, temperature, conductivity, turbidity, pH and dissolved oxygen were measured.

Review of data quality by Royal Haskoning DHV (2022) concluded that the data were suitable for interpretative purposes.

Section 4. Screening level assessment

4.1 General

A screening level assessment has been undertaken for this assessment. This involves comparison of the available data (usually the maximum concentration found anywhere at a site) with screening level guidelines to determine if the concentrations present are high enough to warrant a more detailed assessment of risk. The screening level guidelines adopted are intended to be conservative and protective of exposures that may occur during recreational use of the area by all members of the community (including young children). If the maximum concentration in a single sample is above the relevant screening guideline, that triggers a more site specific assessment. It does not mean health effects are likely due to the conservative assumptions built into the guidelines. This is discussed further below.

For Hayes Street Beach, this review has considered exposure to sediments and surface water.

4.2 Review of sediment data

There are no screening guidelines that are specific to the presence of contamination in sediments that are based on protecting human health. However, guidelines are available for contamination in soil and these guidelines can be adopted as conservative screening guidelines for sediment for the purpose of the proposed risk assessments. These guidelines are from the National Environment Protection (Assessment of Site Contamination) Measure (i.e. ASC NEPM) which is used for the assessment of contaminated land throughout Australia (NEPC 1999 amended 2013a).

For the purpose of screening sediment data, soil guidelines relevant to public open space are applicable. These guidelines are calculating by assuming the public (including young children, who are the most sensitive group) are exposed to soil every day of the year (365 days). It is assumed that for every day a young child may be exposed they will ingest 50 mg of soil and the soil will get onto the skin of their hands, feet, forearms and lower legs every time. The calculations also assume the fine layer of soil will remain on the skin for the rest of the day (i.e. they won't shower until the evening or next morning).

These guidelines (public open space) are normally applied to areas which may be used as children's playgrounds and parks as well as high schools etc.

These soil guidelines are considered conservative for screening the sediment results for this investigation because:

- young children are unlikely to visit this area every day of the year
- sediments in this area are unlikely to stick to the skin for very long given their sandy nature (i.e. larger particles that fall off or get brushed off when leaving the beach)
- the sediments will get washed off the skin as a child plays in the water
- the wetness of the sediment means they don't kick up into the air as people walk across so potentially less particles will be incidentally ingested.

Even though some sediments (more likely muddier sediments which were not found to any great extent here) may stick to the skin better than soil, the assumptions adopted in the soil guidelines are considered to adequately conservative for screening.

Guidelines adopted for the purposed of screening sediment concentrations are as follows:

- NEPM Health Investigation Levels (HILs) (NEPC 1999 amended 2013a) for public open space, HIL-C.
- NEPM Health Screening Levels (HSLs) (NEPC 1999 amended 2013a) for volatile petroleum hydrocarbons, relevant to exposures in public open space areas, HSL-C. It is noted that these guidelines only relate to potential inhalation exposures where volatile petroleum hydrocarbons are present in dry sediments (i.e. the beach sand). These do not apply to wet sediment.
- CRC CARE HSLs (CRC CARE 2011) for direct contact exposures with petroleum hydrocarbons, relevant to exposures in public open space areas (HSL-C). These guidelines are derived using an approach consistent with the NEPM HILs and relate to the protection of potential ingestion and dermal contact with petroleum hydrocarbon contamination.
- USEPA Regional Screening Levels (RSLs) for residential soil adopting an individual target HI of 1 and carcinogenic risk of $1x10^{-5}$ (USEPA 2021). (The USEPA guidelines only include values for residential soil and industrial soil so the residential ones have been used here).

For the assessment of dioxin-like compounds, the are no soil or sediment guidelines available in Australia. Internationally, there are a number of sediment guidelines available, many of which relate to ecological protection which is not relevant to this assessment. Some guidelines are based on the protection of human health, while the basis of protection is not clear for a number of other guidelines.

Due to this lack of clarity about the basis for some sediment quality guidelines for dioxin-like compounds, soil guidelines for these chemicals designed for human health protection have also been considered, as summarised in **Table 1**.

In reviewing these guidelines and others known to apply to ecological systems, it is noted that the values for ecological and human health protection are quite similar for these chemicals. The national plan for the management of dioxin-like compounds in Australia documents a range of soil quality guidelines from international sources as at 2005 (EPHC 2005). Most of these guidelines remain unchanged. Only the USEPA value has been updated since 2005 and the updated value is included in **Table 1**.

Table 1: Soil quality guidelines from international sources – dioxin-like compounds

Source	Soil Quality Guidelines (pg TEQ/g dry weight)
Canada (CCME 2017)	4
Finland (EPHC 2005)	2
Japan (EPHC 2005)	1
Germany (EPHC 2005)	1,000
The Netherlands (EPHC 2005)	1,000
Italy (EPHC 2005)	5,000
USEPA (EPHC 2005)	1,000
USEPA RSL (USEPA 2021) – residential exposures	50
USEPA RSL (USEPA 2021) – industrial worker exposures	220
Sweden (EPHC 2005)	250

For this assessment, the most recent USEPA values have been considered for screening data to evaluate the potential for human health effects.

Table 2 presents a summary of the analytes detected and concentrations reported in sediments for Hayes Street Beach, with comparison against the screening level guidelines adopted.

Table 2: Screening level assessment – Hayes Street Beach sediments

Chemical detected	Maximum sediment concentration (mg/kg dry weight)		Screening guideline – Human health (mg/kg dry weight)
	Sandy materials closer to shoreline (HS01-S-HS03-S)	Intertidal sandy muds (HS04-S-HS06-S)	
Arsenic	**1.65**	**2.59**	300 N
Chromium (Cr VI assumed)	**2.3**	**2.4**	300 N
Cobalt	**1.4**	**2.2**	300 N
Copper	**17.8**	**31.4**	17,000 N
Lead	**24.6**	**41.7**	600 N
Manganese	**77**	**124**	19,000 N
Mercury (inorganic)	**0.02**	**0.08**	80 N
Nickel	**1.6**	**1.9**	1,200 N
Vanadium	**8.7**	**10.9**	390 U
Zinc	**56.2**	**97.6**	30,000 N
Benzo[a]pyrene equivalents (subset of PAHs)	**1.3**	**4.4**	3 N
Total PAHs	**7.28**	**28.4**	300 N
Sum of DDTs pesticides (i.e. DDD+DDE+DDT)	<0.0005	**0.004**	400 N
	(pg TEQ/g)	**(pg TEQ/g)**	**(pg TEQ/g)**
Dioxin-like compounds – PCDD/F*	**5.79**	**5.77**	50 U

Notes:

N = NEPM HIL-C (recreational soil)

U = USEPA RSL for residential soil (USEPA 2021)

* = WHO_{05}-TEQ upper bound (i.e. adopting the LOR where not detected) (Van den Berg et al. 2006)

Bolded values are those where the chemical was detected at levels above the limit of reporting

Review of **Table 2** indicates that the concentrations reported in all the sediments sampled are well below the adopted screening criteria for most of the chemicals. This means that even if a child was exposed 365 days per year in the same way as assumed in the guideline calculations their exposure would be below the level health authorities consider to be acceptable.

The maximum concentration for the subset of PAHs (i.e. benzo[a]pyrene and related chemicals) was slightly above the conservative national screening guideline for soil. The other 5 locations where sediment samples were collected reported concentrations lower than the screening guideline (ranged from 0.9 to 2.5 mg/kg). The average sediment concentration across the whole area is 2.1 mg/kg.

Exceedance of a screening guideline (for the maximum concentration) does not mean that there is an unacceptable risk to health. These guidelines are based on assuming a person will be exposed in a particular fashion, If a person is exposed less often (i.e. not every day of the year) or to lower amounts of the sediment (i.e. less than 50 mg/day or less than covering hands, arms, feet and legs) then a person can be exposed to sediments with slightly higher concentrations and still be in compliance with health guidance. Instead, such exceedances trigger more detailed assessment of risks to human health. This will be further assessed in **Section 5**.

For most compounds detected in sediments there is a significant margin of safety between the detected concentration and the adopted guideline sufficient to address any spatial variability in sediments within the swim area. The concentrations reported in sediments are generally fairly consistent indicating that typical use of the area where exposure to a range of sediments may occur would be represented by the data collected.

Based on the screening level assessment undertaken, there is no requirement to undertake any more detailed assessment of human health risks relevant to sediment quality for most of the common contaminants. Further assessment of potential human health risks is provided in **Section 5** for the subset of PAHs – i.e. benzo[a]pyrene and related chemicals.

4.3 Review of surface water data

Water at Hayes Street Beach is saline. Hence the water at the beach is not suitable for drinking at any time. As a result, it is overly conservative to adopt drinking water guidelines in a screening level assessment for recreational exposures. Drinking water guidelines assume that an individual consumes 2 litres of water every day for a lifetime, and that intakes via ingestion contribute between 10% and 20% of the total intake of that chemical every day.

NHMRC (NHMRC 2008, 2019) provides guidance on the assessment of chemical contamination in recreational water. These guidelines cover a wide range of recreational exposures in water such as swimming, diving, boating, sailboarding and the guidelines are designed to be protective of exposures for all members of the public, including children, as well as other such as tourists and sporting groups. In relation to the assessment of chemical contaminants, the guidelines are intended to address all recreational exposures that include direct contact with water (with absorption via the skin, eyes and mucous membranes), ingestion (particularly important for young children) and inhalation (of water spray).

The NHMRC recreational water guidelines generally recommend the use of a screening level guideline that is 10 times higher than the Australian Drinking Water Guideline (NHMRC 2011 updated 2021). This approach is consistent with that adopted by the WHO (WHO 2006a) for recreational exposures.

Based on the above, screening level guidelines relevant to recreational exposures have been adopted from the following sources:

- Recreational water guidelines for other chemicals, determined to be 10 x drinking water guideline, where the drinking water guideline has been obtained from the following:
  - Australian Drinking Water Guidelines (NHMRC 2011 updated 2021)
  - Australian Guidelines for Water Recycling (NRMMC 2008), which includes guidelines derived for pharmaceuticals and a range of other chemicals not included in the drinking water guidelines, but likely to be in recycled water
  - WHO Guidelines for Drinking Water Quality (WHO 2017)
  - USEPA Residential Tap Water guidelines (USEPA 2021) (where there are no guidelines from NHMRC or WHO, and the approach adopted by the USEPA is consistent with Australian guidance from enHealth (enHealth 2012a))

It is noted that only health based guidelines have been adopted from the above sources. Some chemicals also include guidelines that are protective of aesthetics in drinking water (taste, odour, protection of equipment from corrosion etc). These have not been adopted for the purpose of screening surface water for recreational use.

Table 3 presents a summary of the concentrations of chemicals that have been detected in each surface water sample. The results presented relate to unfiltered samples. The unfiltered samples include suspended sediments within the water as this represents what people are exposed too when they are swimming. These concentrations have been compared against the recreational water guidelines, adopted for the purpose of screening.

It is noted that none of the chemicals detected are considered to be volatile, and most of the chemicals analysed have not been detected in any of the water samples collected. There are no samples where the analytical limit of reporting is elevated (or higher than the LOR relevant to the analytical method used). Note that the units for concentrations in water vary within the table (mg/L for metals and pg/L for dioxin-like compounds).

Table 3: Screening level assessment – Hayes Street Beach surface waters

Analyte detected	Concentration reported in each sample (mg/L)						Adopted screening level guideline (mg/L)
	Round 1 (20/12/21)			Round 2 (1/2/22)			
	HS01-W	HS02-W	HS03-W	HS01-W	HS02-W	HS03-W	
Arsenic	**0.0019**	**0.0017**	**0.0017**	**0.0018**	**0.0019**	**0.0019**	0.1 A
Cadmium	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.02 A
Chromium	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.5 A
Copper	**0.009**	**0.003**	**0.003**	**0.003**	**0.003**	**0.004**	20 A
Lead	**0.001**	**0.0007**	**0.001**	**0.0009**	**0.0013**	**0.0017**	0.1 A
Mercury	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	0.01 A
Nickel	**0.0008**	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.2 A
Zinc	**0.034**	**0.01**	**0.016**	**0.005**	**0.008**	**0.006**	60 U
Benzo[a]pyrene equlvalents (subset of PAHs)	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	0.00001 A
Total PAHs	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	NG
Sum of DDTs pesticides (i.e. DDD+DDE+DDT)	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.009 A
Dioxins and furans	pg/L						pg/L
WHO-TEQ (LOR)*	<54.33	<54.33	<54.33	<54.33	<54.33	<54.33	160 R

Notes:

A = Recreational guideline which is 10 x Australian Drinking Water Guideline (health based guidelines) (NHMRC 2011 updated 2021)

U = USEPA RSL for recreational water (10 X USEPA RSL for residential tap water) (USEPA 2021)

* = WHO_{05}-TEQ upper bound (i.e. adopting the LOR where not detected) (Van den Berg et al. 2006)

Bolded values are those where the chemical was detected at levels above the limit of reporting

Review of the data presented in **Table 3** indicates that there are no analytes detected in surface water, during any of the sampling events and weather conditions, that report concentrations exceeding the adopted screening level guidelines. The guidelines adopted are protective of all exposures relevant to the proposed use of the area for swimming activities.

No dioxin like compounds were detected in the surface water samples. The listed concentration is the limit of reporting for the equivalent concentration (i.e. based on assuming all the individual dioxin like compounds are present at the individual limits of reporting).

No PAHs were detected in the surface water samples. The listed concentration is the limit of reporting.

For those chemicals detected in surface water, there is a significant margin of safety between the detected concentration and the adopted guideline (3 fold to 5,000 fold) and this addresses sufficiently any variability in surface water concentrations that may occur over time.

Based on the screening level assessment undertaken, there is no requirement to undertake any more detailed assessment of human health risks relevant to surface water quality.

4.4 Uncertainties

The key uncertainties related to the assessment undertaken for Hayes Street Beach relate to the data relied on for the screening level assessment undertaken.

Sediment quality data was collected during one sampling event in December 2021. Sediment quality is not expected to vary to any great extent over time hence these data are considered to be representative of concentrations that may be present in sediments that the public may be exposed to when using the swim site in the future.

The surface water data was collected in December 2021 and February 2022 and covered a range of conditions that included after rainfall and while water was somewhat turbid. These data provide an assessment of variability over those conditions. It is noted that, for all of the compounds detected in surface water, the variability was low between the 3 locations across Hayes Street Beach and between sampling events and hence the potential for significant variability under different conditions is expected to be limited.

In addition, evaluation of the data for surface water for all the swimming areas (proposed and in place) to date (across Parramatta River as well as Hayes Street Beach) provides the following ranges for the chemicals commonly detected in water. The concentrations reported at Hayes Street Beach are within these ranges. It is also noted the concentration ranges for each chemical are all within a factor of 10 (i.e. of similar order of magnitude) indicating that variability is quite small.

Analyte	Number of samples	Minimum concentration (mg/L)	Maximum concentration (mg/L)
Arsenic	42	<0.0005	0.0028
Cadmium	42	<0.0001	0.00011
Chromium	42	<0.0005	0.0047
Copper	42	0.003	0.01
Lead	42	0.0007	0.0074
Nickel	42	<0.0005	0.002
Zinc	42	0.0099	0.07
Dioxins and furans		**(pg/L)**	**(pg/L)**
WHO-TEQ (LOR)*	26	4.7	76

There is sufficient margin of safety in the data collected and relied on in this assessment to address any additional variability in concentrations that may occur during other conditions.

Section 5. Detailed assessment

5.1 Introduction

This section provides a more detailed assessment of risks to human health associated with direct contact exposures to the important subset of PAHs (i.e. benzo[a]pyrene and related chemicals) identified in sediments at Hayes Street Beach.

The assessment of risks to human health relevant to benzo[a]pyrene and related chemicals requires an understanding of the toxicity of these chemicals and how adults and children may be exposed to sediments at the beach.

5.2 Conceptual site model

The source of benzo[a]pyrene and related chemicals (and all the PAHs) in the sediments is likely to be historical activities at a gasworks that was present in the vicinity of Sub Base Platypus prior to its use as a defence facility.

The gasworks operated from 1876 to 1932.

The site was taken by the government for use as a torpedo factory in 1942 and, after the war, activity at the site was expanded to house the submarine fleet. All defence activities ceased at the site in 1999. Remediation of the site (both from remaining contamination due to the gasworks and the defence facility) was commenced in 2005. The remediation of the land has been completed and the site was opened as a public park in 2018[2]. The sediments immediately in front of Sub Base Platypus were not identified as needing remediation but they are likely to contain PAHs from the gasworks.

The maximum concentration of this group of chemicals in the intertidal sediments at Hayes Street Beach were slightly above the screening criteria triggering this further assessment. As already noted, the concentrations in the other 5 samples and the overall average concentration were below the screening guideline (i.e. in compliance).

Where recreational users of Hayes Street Beach come into direct contact with sediments while swimming, the key pathways of exposure relate to:

- incidental ingestion of sediments (particularly for young children)
- dermal contact (i.e. absorption through the skin).

It is highly unlikely that exposure via dust inhalation could occur given that these sediments (those in the intertidal zone) are wet or under water. Dust inhalation is normally an exposure pathway that contributes minimally to the development of a guideline for soil, and in this situation, it will contribute even less. This pathway has not been considered in this assessment.

It has been assumed in this assessment that any chemicals in the sediments that people might be exposed to are 100% bioavailable (i.e. can easily be taken in during dermal contact or easily desorb from sediment in the stomach and be taken up into the body when the sediment are ingested). It is unlikely that this is true, given the age of contamination likely in these sediments. This

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[2] https://www.harbourtrust.gov.au/en/our-story/harbour-history/history-of-sub-base-platypus/

contamination is around 100 years old and these chemicals get bound more and more into the sediment particles as they age. It is much more likely that only negligible amounts of these chemicals attached to these sediments are likely to come off the sediment particles and enter the body when people may be exposed. Assuming 100% bioavailability is a conservative assumption which builds more confidence into this assessment as it means the assessment is likely to overestimate how much a person may be exposed.

5.3 Background information – benzo[a]pyrene and related chemicals

PAHs are a large group of organic compounds. These chemicals have two or more fused aromatic rings made up of carbon and hydrogen atoms. There are several hundred PAHs, including derivatives of PAHs.

The best known (and studied) is benzo[a]pyrene (BaP) which is the focus of this assessment along with the related sub-group of PAHs that act in the same fashion as BaP.

While there are hundreds of PAHs, typically only 16 individual PAHs are analysed in site contamination investigations. These individual PAHs address a broad range of the equivalent carbon spectrum and are therefore more commonly reported and assessed (WHO 1998).

PAHs are formed whenever organic materials are burned – i.e. from incomplete combustion of organic materials such as processing of coal, crude oil, combustion of natural gas, refuse, vehicle emissions, heating, cooking and tobacco smoking as well as natural processes including carbonisation. These chemicals are also formed naturally in plants.

Because there are so many sources (many of which are naturally occurring), PAHs are present almost everywhere. Food is considered to be the major source of human exposure to PAHs due to the formation of PAHs during cooking or from atmospheric deposition of PAHs on grains, fruits and vegetables (WHO 1998).

The major sources of these chemicals to soil at any given location invariably mean that there will always be a mixture present not just an individual compound. Various PAH source types can be distinguished based on the characteristic mix of PAHs present and information about the history of a site, but the contaminated soil matrix is nonetheless challenging (regardless of source) from an environmental risk assessment perspective, since in soil contaminated by PAHs there is likely to be a diverse compositional range of PAHs which have different effects at differing doses (WHO 1998).

5.4 Toxicity of benzo[a]pyrene and related chemicals

5.4.1 General

Several comprehensive reviews of polycyclic aromatic hydrocarbons (PAHs) and benzo(a)pyrene (BaP) in the environment and toxicity to humans are available (ATSDR 1995; CCME 2008; USEPA 2017; WHO 1998).

The major approach advocated by regulatory agencies such as the NEPC (Fitzgerald, D.J. 1991, 1998; Fitzgerald, D. James et al. 2004; NEPC 1999 amended 2013c), California EPA (CEPA 1999), Netherlands (Baars et al. 2001), the UK Environment Agency (UK DEFRA and EA 2002), Canada (CCME 2008, 2010) and USEPA (USEPA 2014) for assessing the human health risks of PAH-containing mixtures involves the use of “toxicity equivalence factors” (TEFs). This approach relates the toxicity of other (potentially carcinogenic) individual PAHs to that of BaP, the most widely studied chemical from the critical subset.

There are more than a dozen sets of equivalency numbers that have been proposed over the last two decades. The most recent (published final) review of TEFs and their basis, presented by CCME suggests the use of TEFs recommended by the World Health Organization, with minor modifications (CCME 2008, 2010; WHO 1998). This is a scheme based on order of magnitude cancer potency.

Any finer-scale assertions about relative potency for more generic application are hard to justify, given the current state of knowledge and confounding influences such as the route of exposure, or non-additive effects in complex PAH mixtures. It is not currently possible to develop different relative potency schemes across different exposure routes (oral, dermal, inhalation), owing to a lack of data. Hence, the TEFs adopted have been applied for all routes of exposure for these chemicals. Application of the TEFs are relevant to the assessment of PAHs that are considered to be carcinogenic. Other PAHs that are not carcinogenic are assessed separately on an individual basis using a threshold approach (*this step was carried out in the screening level assessment shown in **Table 2** in **Section 4.2** which showed total PAHs were less than the relevant screening criteria*).

The following table presents a summary of the TEFs adopted for the assessment of benzo[a]pyrene and related chemicals:

Table 4: TEFs for PAHs (CCME 2010)

PAH	IARC Classification	US EPA Classification	TEF
Benzo(a)anthracene	2B	B2	0.1
Benzo(a)pyrene	1	B2	1
Benzo(b+j)fluoranthene	2B	B2	0.1
Benzo(k)fluoranthene	2B	B2	0.1
Benzo(g,h,i)perylene*	3	D	0.01
Chrysene	2B	B2	0.01
Dibenz(a,h)anthracene	2A	B2	1
Indeno(1,2,3-cd)pyrene	2B	B2	0.1

Notes: 1/A= Human Carcinogen, 2A/B2= Probable Human Carcinogen, 2B/C=Possible Human Carcinogen, 3/D= Not classifiable.
* Benzo(g,h,i)perylene included due to positive findings in genotoxicity studies (WHO 1998). Note there are insufficient data available to determine carcinogenicity.

It has been assumed that the toxic effects of different PAH compounds in a mixture are additive. Experimental evidence suggests that this is a fair assumption (CCME 2008, 2010; Fitzgerald, D.J. 1991, 1998).

The following relates to the approach used to assess BaP (which can be used for the assessment of BaP alone or for the subset of related chemicals using the TEFs listed in **Table 4**).

5.4.2 Dermal Exposures

This subset of PAHs can act by direct contact on the skin surface as well as being absorbed through the skin into the body. This additional aspect of exposure that is relevant for dermal exposure to soil or sediment containing these chemicals was assessed in detail in the toxicological profile developed for the ASC NEPM (Appendix A2, Schedule B7 (NEPC 1999 amended 2013c)). This assessment has considered the information provided in that profile to ensure adequate evaluation of this aspect.

5.4.3 Background

Older assessments have determined that intakes of BaP from sources other than soil were in the range 0.2 to 1.6 µg/day with intakes derived from food identified as the most significant (Fitzgerald, D.J. 1991).

In 2006, the WHO Joint Expert Committee on Food Additives (JECFA) reviewed potential intakes and health effects of PAHs in food. They found that intake of benzo[a]pyrene was on average 0.28 µg/day with a high level intake of 0.7 µg/day (WHO 2006b).

5.4.4 Classification

The International Agency for Research on Cancer has classified BaP as 1: human carcinogen (IARC 2010). The USEPA has classified BaP as B2: probable human carcinogen (USEPA 2014).

5.4.5 Toxicity Reference Values

The most recent USEPA toxicological review notes that exposure to BaP is associated with developmental (including developmental neurotoxicity), reproductive, and immunological effects in animal studies. Epidemiology studies (i.e. studies in people) have shown exposure to BaP is associated with adverse birth outcomes (including reduced birth weight, postnatal body weight, and head circumference), neurobehavioral effects, and decreased fertility (USEPA 2017).

In regard to cancer, studies have shown that benzo[a]pyrene is carcinogenic at multiple tumour sites (alimentary tract, liver, kidney, respiratory tract, pharynx, and skin) by all routes of exposure in animals. In addition, occupational studies where people are exposed to PAH mixtures such as aluminium production, chimney sweeping, coal gasification, coal-tar distillation, coke production, iron and steel founding, and paving and roofing with coal tar pitch there is strong evidence of carcinogenicity, particularly lung cancer (USEPA 2017).

BaP has been shown to be carcinogenic via all routes of exposure. BaP is an indirect carcinogen, that is, its carcinogenicity results from its metabolites, primarily various epoxides, as opposed to BaP itself. These metabolites can attach to DNA forming adducts which cause disruption when DNA replicates. Several different types of tumours have been observed as a result of exposure to BaP, although tumour development is closely related to route of administration, i.e., dermal application induces skin tumours and oral administration induces gastric tumours. BaP is considered to be a genotoxic carcinogen (USEPA 2017; WHO 1998).

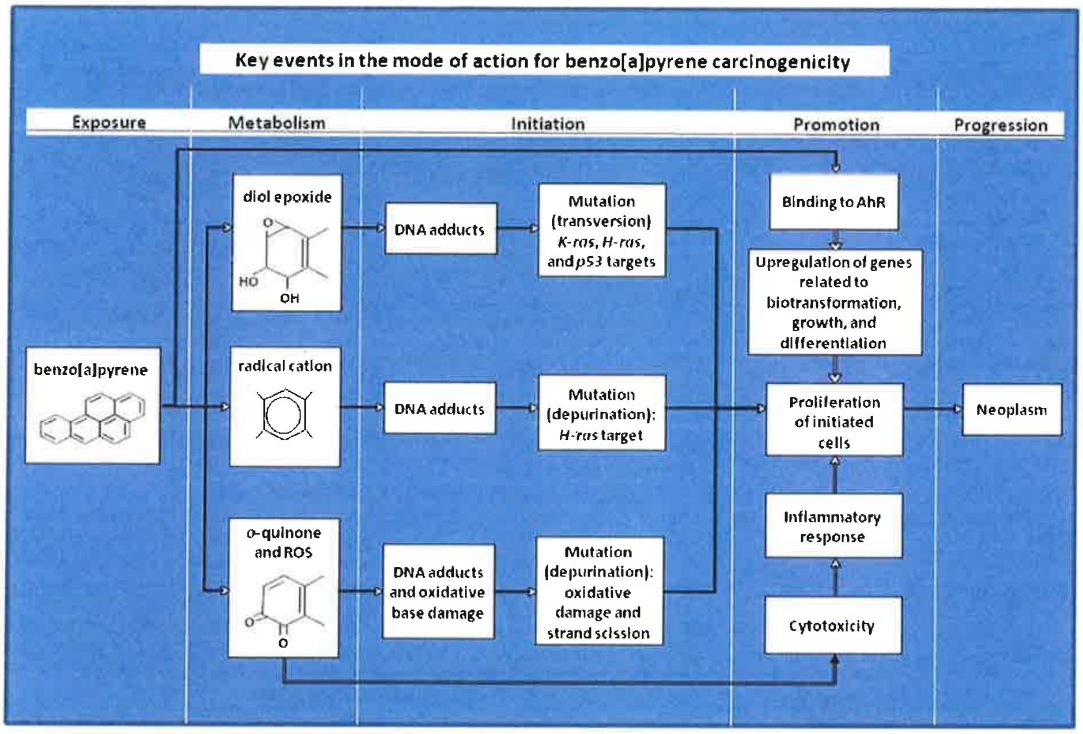

Figure 7: Proposed metabolic activation pathways and key events in the carcinogenic mode of action for benzo[a]pyrene (USEPA 2017)

In addition, BaP has been demonstrated to be a skin irritant and dermal sensitiser (WHO 1998).

The USEPA has concluded that BaP (and the related PAHs assessed on the basis of TEFs) acts via a mutagenic mode of action and recommends that susceptibility associated with early lifetime exposures be addressed. No non-threshold values available for BaP have been derived to specifically address early lifetime susceptibility and hence this issue needs to be addressed when characterising exposure to BaP at a particular site depending on the age of people who may be users of the site (USEPA 2005, 2017).

On this basis, a peer-reviewed non-threshold reference value is recommended for BaP. The following non-threshold values are available from Level 1 Australian and International sources:

Table 5: Adopted Toxicity Reference Values for PAHs/Benzo[a]pyrene

Source	Value	Basis/Comments
Australian		
ADWG (NHMRC 2011 updated 2021)	Not available	Current guideline of 0.00001 mg/L is based on the consideration of health effects in relation to the limit of determination for analysis. The assessment provided by the WHO is noted.
OCS	No evaluation available	
International		
WHO (WHO 2011) (WHO 2000) (WHO 2010)	SF = 0.5 $(mg/kg/day)^{-1}$ **UR =8.7x10^{-5} (ng/m^3)$^{-1}$**	A drinking water guideline of 0.0007 mg/L was derived on the basis of an excess lifetime cancer risk of10^{-5} from an oral carcinogenicity study and a two-stage birth-death mutation model. Slope factor has been calculated on the basis of a 70 kg adult and consumption of 2 L water per day. Inhalation unit risk derived based on observations in coke oven workers to mixtures of PAHs. It is noted that the composition of PAHs to which coke oven workers are exposed may differ from that present in ambient air or derived from

Source	Value	Basis/Comments
		soil contamination. It is noted that an inhalation UR is in the same order of magnitude as that derived using a linear multistage model associated with lung tumours in a rat inhalation study of coal tar/pitch condensation aerosols.
MfE (MfE 2011)	**SF = 0.233 (mg/kg/day)$^{-1}$**	Review of the carcinogenic reference values available for oral intakes by MfE considered the range of values available and differences in approaches adopted for low dose extrapolation. The application of cross-species scaling appeared to be the most significant factor affecting the cancer potency estimates. While not applying cross-species scaling is consistent with the approach outlined in NHMRC, the MfE review recommended that it is appropriate for BaP (NHMRC 1999). Review of available studies (14 risk estimates using 4 databases) resulted in the calculation of a slope factor based on the geometric mean and scaled allometrically.
UK (UK DEFRA and EA 2002)	Derived index doses from WHO evaluations	Oral index dose derived on the basis of WHO approach and a lifetime cancer risk of 10^{-5}. Inhalation index dose based on WHO approach and adopting an air guideline of 0.25 ng/m^3. The air guideline is equivalent to a lifetime cancer risk of $4x10^{-5}$.
RIVM (Baars et al. 2001)	SF = 0.2 (mg/kg/day)$^{-1}$	Oral SF derived by RIVM based on a chronic oral carcinogenic rat study and linear multistage model. The study considered was more recent than that considered by the WHO. No inhalation assessment is provided by RIVM.
CCME (CCME 2010)	SF = 2.3 (mg/kg/day)$^{-1}$	Oral SF derived from a less than lifetime diet study on inbred CFW-Swiss mice associated with incidence of papillomas and squamous cell carcinomas and linear extrapolation. This is the same study as used by the USEPA in the derivation of their oral slope factor. The CCME review also noted that dermal exposures and primary oral exposures result in different kinds of cancers. Health Canada is currently reviewing data with respect to the derivation of a dermal cancer slope factor, which may require consideration when peer-reviewed and published. The oral slope factor has been used to derive a soil guideline associated with exposures via oral, dermal and inhalation exposures.
Health Canada (Health Canada 2016)	SF = 1.3 (mg/kg/day)$^{-1}$	SF based on the lowest $BMDL_{10}$ for forestomach tumours (i.e. papillomas etc) in female mice. Two studies were assessed, both of which were chronic, used multiple doses and sufficient animals in each exposure group.
OEHHA (CEPA 1999)	SF = 11.5 (mg/kg/day)$^{-1}$ UR =0.0011 to 0.0033 (µg/m^3)$^{-1}$ (i.e.1.1-3.3 (ng/m^3)$^{-1}$)	Oral SF derived using the same model and study as reported by the USEPA (IRIS 2010) and CCME (2008), with the upper end of the range of values adopted by OEHHA. Inhalation UR derived on the basis of respiratory tract tumours in an inhalation study in hamsters and a linearised multistage model.
USEPA (USEPA 2014)	SF = 7.3 (mg/kg/day)$^{-1}$	Oral SF (last reviewed in 1994) derived on the basis of the same study considered by CCME (above) where a range of slope factors were derived (4.5 to 11.7 (mg/kg/day)$^{-1}$). The geometric mean was adopted as the recommended slope factor for derivation of a drinking water guideline. No assessment of inhalation toxicity is available.
USEPA (USEPA 2017)	SF = 1 (mg/kg/day)$^{-1}$ IUR = $6x10^{-4}$ (µg/m^3)$^{-1}$ (i.e.0.6 (ng/m^3)$^{-1}$)	Oral SF was derived using two studies from 1998 and 2001. The study from 2001 was conducted on male and female Wistar rats which showed forestomach, liver, oral cavity, jejunum, kidney, auditory canal (Zymbal gland) tumours, and skin or mammary gland tumours. The 1998 study reported forestomach, oesophageal, tongue, and larynx tumours in female $B6C3F_1$ mice. Slope factors were calculated using body weight scaling to determine a human equivalent dose. The slope factors for the study in rats ranged from 0.04 to 0.3 (mg/kg/day)$^{-1}$. For the mice study the slope factor was 1.4 (mg/kg/day)$^{-1}$. There are no data to support any one result as most relevant for extrapolating to humans. If it is assumed all slope factors are equally relevant for extrapolating to humans, then statistical evaluation of the data gives slope factors of 0.5, 0.6 and 0.7 per mg/kg-day depending on the statistic. The mice study found tumours in forestomach, an organ not found in people and which may increase how long the stomach lining is exposed to BaP. The rat study used exposure via gavage rather than in food. So, while the studies were robust there are some aspects that create uncertainty. For the inhalation unit risk (IUR), the single lifetime inhalation study available for BaP was used. This study was undertaken in 1981 and used hamsters. Other studies since have used instillation to dose animals and these supported the findings but are not able to be used to develop the IUR.

The review conducted by MfE provided a discussion of the impact of differences in methodology used by various agencies for low dose extrapolation (MfE 2011).

There is a wide range of non-threshold reference values available for oral intakes of BaP (and the other related PAHs).

The MfE (MfE 2011) discussion notes that the following:

- WHO slope factor based on a study from 1990 that used unrealistic exposure conditions (rejected by USEPA)
- WHO determined a slope factor of 0.5 per mg/kg/day using this study and their approach for genotoxic carcinogens but USEPA determined a slope factor of 5.9 per mg/kg/day using the same study and their approach for genotoxic carcinogens which included allometric scaling
- Other organisations (California, UK, Canada) used a much older study (from 1967) which did not cover exposure over a whole lifetime
- The major difference between all the various slope factors for BaP was the different approaches to extrapolate from the point of departure dose (usually 5 or 10% effect) to the slope factor, including allometric scaling rather than the actual toxicological information from the studies
- The US agencies use allometric scaling while some European agencies and the NHMRC in Australia recommend against use of such scaling when calculating slope factors
- A number of assessments covered in this review have used the same more recent studies as used by the USEPA in their most recent assessment from 2017
- The most recent studies used by the USEPA (and other reviews) are ones where the animals were exposed to coal tar.

As a result, the geometric mean value for the slope factors without scaling was chosen for use in contaminated land investigations in Australia.

As noted in Appendix A2 of Schedule B7 of the ASC NEPM, a number of variations were considered in the HIL calculations.

The calculations of the HILs considered the use of a range of different values for some of the assumptions required for these calculations. The different values were presented to the Australian regulators overseeing the ASC NEPM process for their consideration.

The variations included:

- using the standard USEPA approach to assess exposure via dermal contact
- using the Knafla et al. approach
- using the slope factor derived for the WHO drinking water guidelines (0.5 per mg/kg bw/d)
- using the slope factor from the NZ Ministry for the Environment guidance (0.233 per mg/kg bw/d)
- using an age dependent adjustment factor for cancer or not (NEPC 1999 amended 2013c).

A choice was made by Australian regulators as to which set of these variables were to be included in the calculations for the HILs. HILs for low density residential land uses were calculated using 5 different sets of values for the relevant assumptions:

- use of oral TRV from NZ MfE (for both ingestion and dermal contact) and no age dependent adjustment factor
- use of oral TRV from WHO (for both ingestion and dermal contact) and no age dependent adjustment factor

- use of oral TRV from NZ MfE (for both ingestion and dermal contact) with age dependent adjustment factors
- use of oral TRV from WHO (for both ingestion and dermal contact) with age dependent adjustment factors
- use of oral TRV from NZ MfE for ingestion and Knalfa approach for dermal contact) and no age dependent adjustment factor

The resultant guidance values (HIL-A) ranged from 0.3 to 20 mg/kg. The Australian regulators chose 3 mg/kg for use as the conservative, widely applicable guideline. This was on the basis that, while some sites requiring evaluation are former gasworks or other sites with highly bioavailable PAHs, many sites have PAHs present from less bioavailable sources including asphalt and ash.

The ASC NEPM review recommends the use of the MfE slope factor for site-specific risk assessments especially where the source of PAHs is one of these less bioavailable forms (MfE 2011; NEPC 1999 amended 2013c). It also recommends that consideration of whether to adjust for early life stage exposure and dermal exposure be undertaken on a site-specific basis depending on the source of PAHs at the site and the proposed use of the site.

The NZ MfE slope factor has been adopted for this assessment in line with the ASC NEPM recommendations. The use of an age dependent adjustment factor has also been included.

5.5 Exposure assessment

The quantification of potential exposure to sediments during recreational use at Hayes Street Beach has been undertaken on the basis of the equations and exposure assumptions presented in **Table 6**. These are the equations and exposure assumptions recommended for use in such an assessment within the Framework document adopted for such assessments in Sydney Harbour (enRiskS 2020).

These assumptions are considered to be highly conservative for assessing exposure to the intertidal sediments at this site, as these would only be exposed during low tides. It is only during low tide that these sediments can remain on the skin for an extended period or have the potential to be ingested during eating or when a hand touches the mouth. The likelihood and frequency of exposure when these sediments are exposed (i.e. low tide) is expected to much lower than presented in **Table 6**.

The calculations using these equations and assumed parameter values are shown in **Appendix C**.

Table 6: Equations and parameters for recreational exposures – Ingestion and dermal contact with sediments

Ingestion of sediment: $\text{Daily Chemical Intake}_{is} = C_s \bullet \frac{IRs \bullet B \bullet CF \bullet EF \bullet ED}{BW \bullet AT}$

Dermal contact with sediment: $\text{Daily Chemical Intake}_{ds} = C_s \bullet \frac{SAs \bullet AF \bullet ABSd \bullet CF \bullet EF \bullet ED}{BW \bullet AT}$

	Description	Suggested default value		Reference
		Child*	Adult	
Cs	Concentration of chemical in sediments (mg/kg)	Maximum value measured = 4.4 mg/kg (as total BaP TEQ)		
IRs	Ingestion rate of sediment (mg/day)	50	25	Assumed the same as soil ingestion rate adopted for open space/park areas in the NEPM (NEPC 1999 amended 2013c). The

				value adopted is generally similar to the estimated sediment intake for 1 hour continuous contact with sediments (Wilson et al. 2015). A higher value may be used where sediment contact may occur for longer periods of time every day.
B	Bioavailability of chemical via ingestion (unitless)	1	1	100% assumed for all chemicals unless site-specific bioaccessibility analysis is undertaken
SAs	Skin surface area covered with sediment (cm^2)	2100	4750	Value for children based on 95% value for hands, feet and 50% of arms and legs being dirty (enHealth 2012b). Value for adults based on 95% value for hands, feet and forearms (enHealth 2012b)
AF	Adherence factor or amount of sediment that adheres to the skin per unit area which depends on soil/sediment properties and area of body (mg/cm^2)	1	1	Maximum value relevant to the adherence of sediment to skin (MDEP 2002)
ABSd	Dermal absorption fraction	0.06	0.06	Value relevant to BaP (Appendix A2 of Schedule B7) (NEPC 1999 amended 2013c)
CF	Conversion factor (kg/mg)	$1x10^{-6}$		Convert mg to kg
EF	Exposure frequency (days/year)	150	150	Upper estimate for recreational exposures from enHealth (enHealth 2012b), as adopted by NHMRC (NHMRC 2019)
ED	Exposure duration (years)	6	30	Duration of time as a young child from ages 0 to 5 years and assumes exposure as an adult occurs for 30 years consistent with NEPM (NEPC 1999 amended 2013c)
BW	Body weight (kg)	15	70	Consistent with the body weights adopted in NEPM for these age groups (NEPC 1999 amended 2013c)
AT	Averaging time (days)	Threshold = ED (Years) x 365 (days/year) Non-threshold = 70 (years) x 365 (days/year)		As per enHealth and NEPM

* Exposures by a child aged 2-3 years considered most conservative due to the amount of sediment and water likely to be ingested, per unit body weight

5.6 Risk characterisation

Risk characterisation is the final step in a quantitative risk assessment. It involves the incorporation of the exposure and toxicity assessment to provide a quantitative evaluation of risk. Risk is characterised separately for threshold and non-threshold carcinogenic effects as outlined below. The non-threshold approach is relevant for this assessment of benzo[a]pyrene and related chemicals.

5.6.1 Assessment of Threshold Effects

The quantification of potential exposure and risks to human health associated with the presence of chemicals where a threshold dose-response approach is appropriate is to be undertaken by comparing the estimated intake (or exposure concentration) with the threshold values adopted that represent a tolerable intake (or concentration), with consideration for background intakes[3]. The calculated ratio is termed a Hazard Index (HI), which is the sum of all ratios (termed Hazard Quotients (HQ)) over all relevant pathways of exposure, as detailed in the NEPM (NEPC 1999 amended 2013b). These are calculated using the following equations:

$$\text{Hazard Quotient (HQ) (oral or dermal)} = \frac{\text{Daily Chemical Intake}}{\text{(TRV-Background)}}$$

$$\text{Hazard Quotient (HQ) (inhalation)} = \frac{\text{Exposure Concentration}}{\text{(TRV-Background)}}$$

$$\text{Hazard Index (HI)} = \sum_{\text{Allpathways}} \text{HQ}$$

The interpretation of an acceptable HI/RI needs to recognise an inherent degree of conservatism that is built into the establishment of appropriate TRVs adopted (using many uncertainty factors) and the exposure assessment. Hence, in reviewing and interpreting the calculated HI the following is noted:

- A HI less than or equal to a value of 1 (where intake or exposure is less than or equal to the threshold) represents no cause for concern as outlined in NEPM guidance (NEPC 1999 amended 2013b)
- A HI greater than 1 would be considered to warrant some form of action, which may involve further evaluation of the risks to reduce uncertainties and determine whether action or management is required to reduce the risks.

5.6.2 Assessment of Non-Threshold Carcinogenic Effects

Non-threshold carcinogenic risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential non-threshold carcinogen. As the risk is an incremental lifetime risk, it is an increased risk over and above background. Hence, background intakes are not considered in the calculation of a non-threshold risk. The numerical estimate of increased lifetime cancer risk (ILCR) is calculated as follows for oral/dermal and inhalation exposures:

$$\text{ILCR (oral, dermal)} = \text{Daily chemical intake x TRV (cancer slope factor)}$$

$$\text{ILCR (inhalation)} = \text{Exposure concentration in air x TRV (inhalation slope factor)}$$

$$\text{Total ILCR} = \sum_{\substack{\text{All ages} \\ \text{All pathways}}} \text{ILCR}$$

[3] Background intakes are intakes of a chemical that are derived from sources other than the contamination being assessed. This may include dietary intakes and intakes from drinking water or urban air.

The total non-threshold ILCR is the sum of the risk for each chemical for each pathway. The total ILCR associated with lifetime exposure to all the key contaminants identified has been calculated by summing risk associated for the different age group exposure periods. This assumes exposure occurs at the recreational location for an individual while as a child and then as and older child/adult.

For the assessment of contaminated land the following outlines the level of non-threshold carcinogenic risk that is considered to be acceptable as presented in the NEPM (NEPC 1999 amended 2013c):

- Calculated ILCR $\leq 1 \times 10^{-5}$ are considered to be acceptable; and
- Calculated ILCR greater than 1×10^{-5} would be considered to warrant some form of action, which may involve further evaluation of the risks to reduce uncertainties and determine whether action or management is required to reduce the risks.

5.6.3 Calculated risks

Appendix C presents the risk calculations undertaken to evaluate potential exposures by adults and children using Hayes Street Beach, where exposure to benzo[a]pyrene and related chemicals in sediments is the key exposure of concern.

Based on the calculations presented, the calculated non-threshold risk assuming a person (child or adult) attends Hayes Street Beach on 150 days per year (every year) and is exposed to the intertidal sediments at low tide such that the sediments could stay on the skin for an extended period, is:

- Young children = 4×10^{-7} without the USEPA recommended age adjustment
- Young child = 2×10^{-6} with the USEPA recommended age adjustment
- Adults = 8×10^{-7}
- Acceptable Risk $\leq 1 \times 10^{-5}$

Based on the calculations undertaken and the relevant uncertainties, all calculated risks are less than 1×10^{-5} and hence there are no unacceptable risks identified.

5.7 Uncertainties

The quantification of potential exposure to benzo[a]pyrene and related chemicals in sediments requires estimation of parameters that relate to how often people access the recreational area and the physical and behavioural characteristics of these groups of people. The parameters adopted for this assessment are considered to be conservative and are expected to overestimate actual exposure and risk.

The assessment has considered the current information in relation to the toxicity of benzo[a]pyrene and related chemicals using a TEQ approach. The approach adopted is considered to be adequately protective of health and consistent with international evaluations.

The quantification of risk has considered the maximum concentration of benzo[a]pyrene and related chemicals in the sediments sampled. The maximum concentration relates to sediments in the intertidal zone that are less likely to be accessed (when not covered with water) on a regular basis.

Much lower concentrations of these chemicals were reported in the sandy materials at the beach which are more readily accessible under all tidal conditions.

Section 6. Conclusions

This assessment at Hayes Street Beach, Neutral Bay has evaluated potential risks to the health of recreational users of the beach from exposure to chemical contaminants. The area includes an existing beach area where sand and sediments may be accessible during beach play and wading activities. The area is used for swimming and boating activities. In addition, the Neutral Bay ferry also uses the area.

The focus of this risk assessment has been chemicals detected in sediments and in surface water (dissolved in the water and/or attached to suspended sediments).

Based on the available data and the details of this assessment, it has been concluded that there are no risk issues of concern in relation to the presence of a range of common contaminants in sediments and surface waters at Hayes Street Beach.

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