NORTHERN RIVERS CONTAMINATED LAND PROGRAM

Radiation from Heavy Mineral Sands Residues (HMSRs)

NORTHERN RIVERS
Contaminated Land Program

Sand mining activities have occurred extensively along coastal areas of Australia, including the NSW north coast. These activities may have concentrated deposits of naturally occurring radioactive materials (NORMs). Such land requires investigation and potentially remediation before the land can be subdivided or developed under the NSW contaminated land and planning framework.

Assessment of heavy mineral sand residues (HMSRs) impacted sites is a specialised practice. This factsheet has been developed to support council staff when considering sites affected by HMSRs. It identifies the key issues with reference to relevant legislation, technical guidelines and associated reference material, to ensure that assessments are conducted to a suitable standard.

Heavy Mineral Sands and Radiation

Heavy mineral sands are natural quartz sand deposits that contain significant concentrations of industrially useful heavy minerals such as zircon, rutile, ilmenite, and monazite. Zircon, rutile and ilmenite are typically used for pigments, refractory materials, abrasives, insulation, manufacturing, and the like, while monazite is a source of rare earth metals used in smart phones, computers and other electronic devices.

They are called heavy mineral sands, as the average specific gravity for each typical mineral (4.23 – 5.7) is nearly double the specific gravity of quartz (2.65). Most heavy mineral sands have a distinguishing colour, generally black to gunmetal grey with a glassy – metallic lustre, although zircon and monazite can be hard to discern from quartz sands.

All of these heavy minerals contain some NORMs, with the radionuclides of concern being those in the thorium 232 (Th-232) series and the uranium 238 (U-238) series, including their radioactive decay products such as radon gas. During radioactive decay of NORMs, alpha, beta and gamma radiation can be emitted during the various decay stages. The concentration of radioactivity for these minerals can trigger the definition of a “radioactive substance” under the Radiation Control (RC) Act 1990.

Where are Mineral Sands Found?

Figure 1 shows the occurrences of heavy mineral sand deposits and previous sand mining locations on the NSW north coast.

Sites associated with heavy mineral sands include former sand mining sites and processing plants, or land where heavy mineral sand residues have been stockpiled, used as fill or bedding sands, pumped as tailings slurries, or used in service trenching or top-dressing. While more often associated with low lying land in close proximity to former dry processing plants and transport routes, HMSRs are not exclusively restricted to these areas.

Councils may have information on areas potentially affected by historic sand mining in their local government area (typically only for large scale projects), including former processing sites or where HMSRs have been stockpiled or used as fill or top dressing.

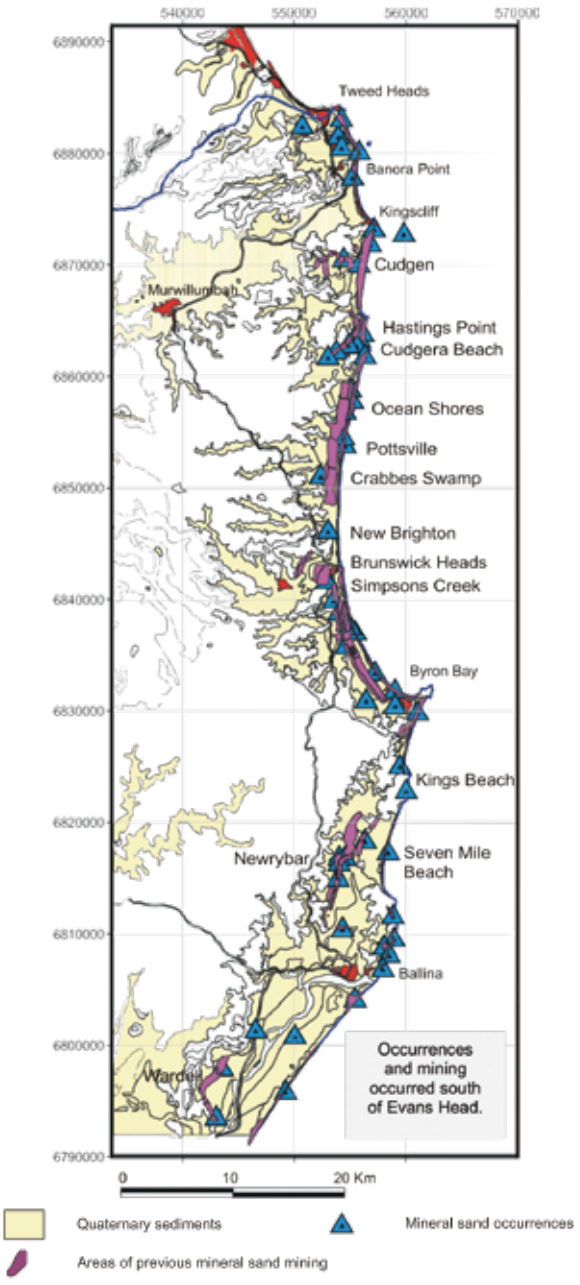


Figure 1: Mineral sand occurrences in Northern NSW (Brown et. al., 2001)

Sand mining on Main Beach Byron Bay (1967)
Photo from the Richmond Tweed Regional Library and Byron Bay Historical Society.

Triggers to Require a Radiation Assessment

A radiation assessment may be required when Council needs to consider either a change of use or new development (usually via a Development Application) for sites located within known or likely areas affected by heavy mineral sands.

Site Assessment of Heavy Mineral Sands Residues

Council may require an assessment of sites potentially affected by heavy mineral sands to demonstrate suitability for the proposed development or land use.

Queensland Health (2020) and ARPANSA guidance (2008, 2017 and 2020) provide specific details for the assessment of HMSR sites. The reporting of site assessments must be in accordance with NSW EPA statutory guidelines (e.g. EPA 2020, EPA 1995, and ASC NEPM 2013; or subsequent updates).

Is the Consultant Suitably Qualified?

Suitably qualified and experienced practitioners should assess and manage land for radioactive substances, including site investigations at both surface and depth.

Practitioners must demonstrate that they and/or their specialist technical support have suitable experience and expertise in the radiological aspects of HMSRs. This should include membership in the Australasian Radiation Protection Society (ARPS), or similar. As a minimum, the consultant must be covered by appropriate professional indemnity insurance.

For more complex sites, NSW EPA recommends the engagement of accredited site auditors.

Preliminary Conceptual Site Model

Assessment of HMSRs typically targets the exposure to gamma radiation from the concentrates in soils and fill materials.

In following the general assessment principles of the ASC NEPM (2013) and to demonstrate that a site investigation is appropriate, a site-specific conceptual site model (CSM) should be developed to confirm the potential pathways (e.g. soil, surface waters, groundwaters and air).

Detailed site histories and robust CSMs are required to justify the appropriateness of any proposed site investigation. The generalised CSM for HMSRs is shown in Figure 2, however this must be confirmed on a site specific basis.

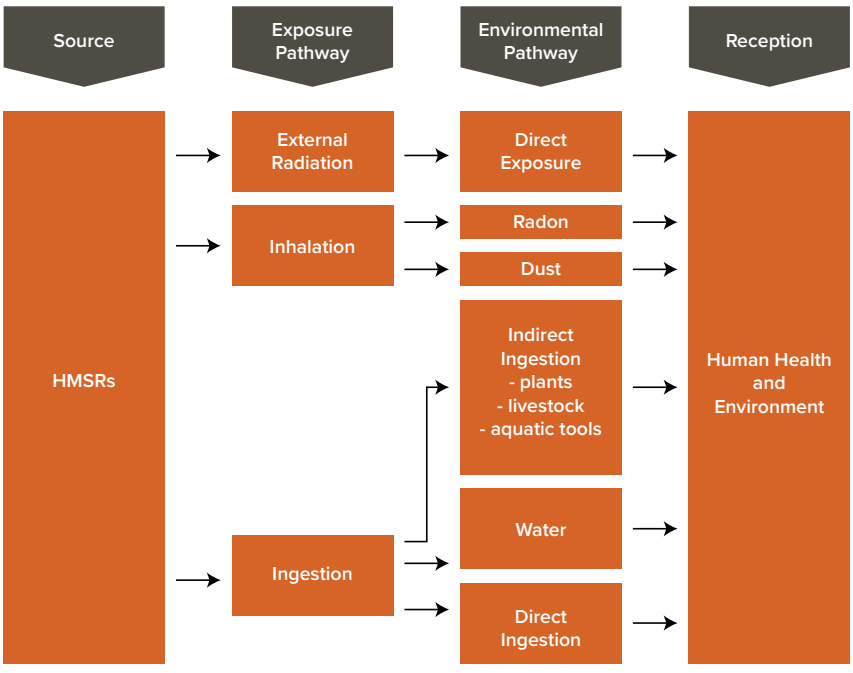


Figure 2: Preliminary CSM for HMSRs (modified from RNS 2019)
Specific pathways to be confirmed on a site-by-site basis.

Surface and Subsurface Investigations

Walk-over surface gamma surveys may indicate acceptably low levels even where HMSRs are buried at depth, as overlying materials (soil, fill, hardstand, concrete, etc.) can shield gamma radiation. Therefore, subsurface investigations are generally required in areas historically associated with mineral sand activities.

Queensland Health (2020) describes that walkover surface gamma surveys "should be conducted using a 2 m grid pattern for residential properties or other properties at which the occupancy of particular individuals is or could be high, and a 5 m grid for all other properties".

Measurements should be conducted with an appropriate dose rate meter approximately one metre above the ground surface. Using this measurement geometry and with typical soil densities and moisture content, approximately 90% of the measured exposure rate originates from the top 0.2 m of material over an 8 m radii.

Queensland Health (2020) recommends, "holes may be drilled on a regular grid of 10m or closer as informed by the site history or surface dose rate". The target depth should consider the site history, the CSM, results of radiation measurements, and field observations. While HMSRs are more commonly found in surficial soils (i.e. < 1 m), placement can also be found at depth (e.g. 1 m – 3 m), and investigations at depth should be conducted consistent with the requirements of the ASC NEPM and EPA guidance.

Test pits/trenches are preferred for subsurface investigations as they allow for visual assessment of soil features and soil heterogeneity. This is the case for HMSRs, as due to the range of colours, HMSRs are often difficult to distinguish from natural sands in small diameter boreholes.

Radiation meters cannot provide quantitative data from depth in pits, trenches or excavations, due to geometry effects. Subsurface samples should be collected and analysed at appropriately accredited laboratories. Derived dose rates can then be calculated from the activity concentrations of the isotopes.

Exposed mineral sands at development site
Photo supplied by Marc Salmon, Easterly Point Environmental Pty Ltd

Radiation Monitoring Equipment

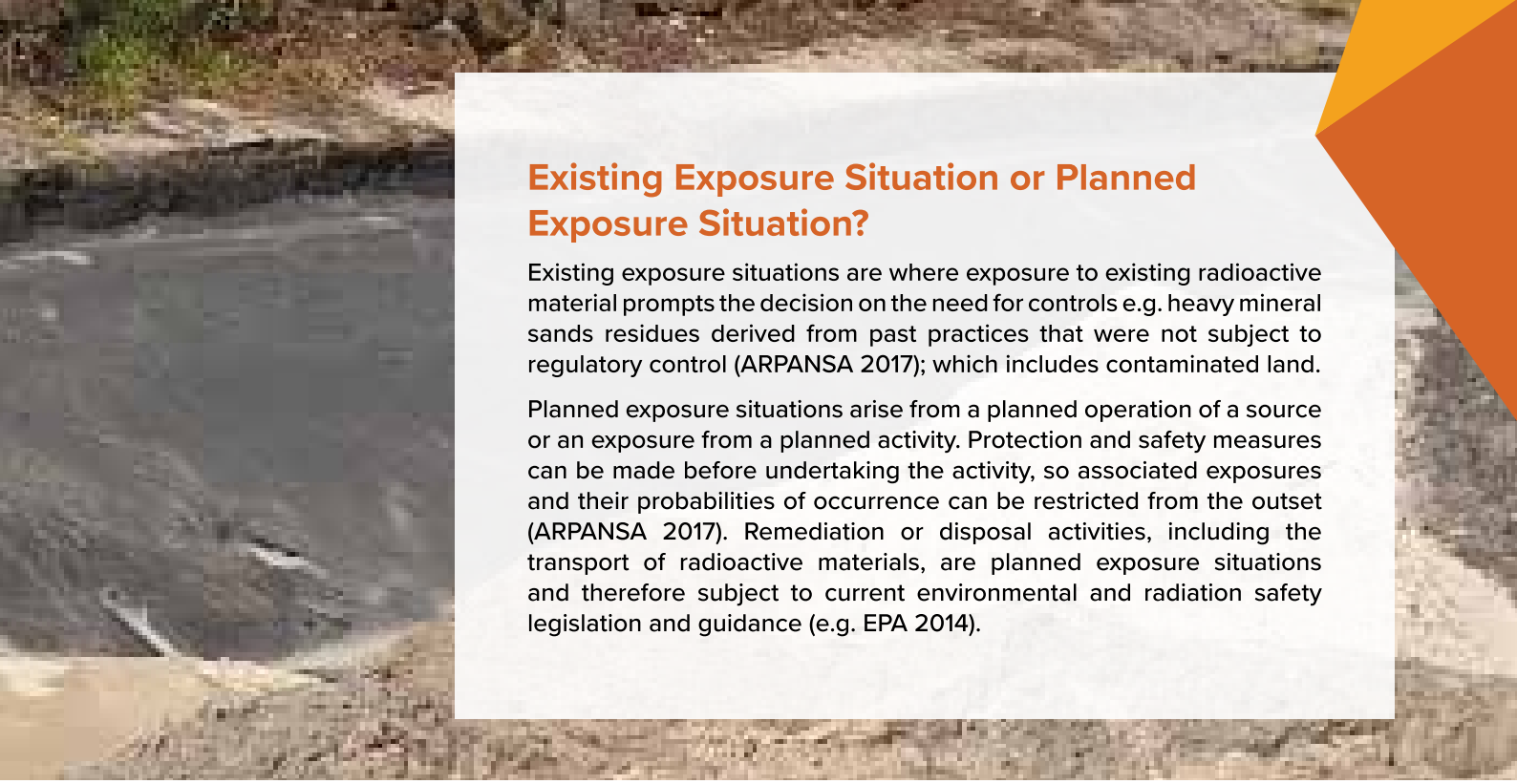
Queensland Health (2020) states that radiation monitoring equipment used for radiation surveys should:

- have a suitable energy response to detect the suspected contaminants;
- have a minimum detectable level lower than that of natural background radiation; and
- be able to distinguish the presence of the radioactive contaminant from the naturally occurring background radioactive material.

If the contaminant is a mineral sand or other NORM, monitoring instruments are suitable if:

- it measures the air kerma rate, air absorbed dose rate or ambient dose equivalent rate of photon energies over a range of at least 30 keV to 3 MeV;
- the effective range of dose rate should be from 0.01 µGy/h to at least 30 µGy/h or 0.01 µSv/h to at least 30 µSv/h;
- the linearity of the detector to dose rate should not exceed the range from -15% to +25% over the effective measurement range;
- the response to photon energy between 80 keV and 1.5 MeV should be within ± 30%; and
- the variation of the dose rate due to random fluctuations should be less than 20% for the most sensitive scale.

Radiation monitoring instruments should be calibrated annually against a recognised national or international standard, as well as being subjected to regular consistency checks.



Existing Exposure Situation or Planned Exposure Situation?

Existing exposure situations are where exposure to existing radioactive material prompts the decision on the need for controls e.g. heavy mineral sands residues derived from past practices that were not subject to regulatory control (ARPANSA 2017); which includes contaminated land.

Planned exposure situations arise from a planned operation of a source or an exposure from a planned activity. Protection and safety measures can be made before undertaking the activity, so associated exposures and their probabilities of occurrence can be restricted from the outset (ARPANSA 2017). Remediation or disposal activities, including the transport of radioactive materials, are planned exposure situations and therefore subject to current environmental and radiation safety legislation and guidance (e.g. EPA 2014).

Dose Criteria

The dose criteria relate only to existing exposure situations that are addressed under the contaminated land framework.

Dose criteria for a range of land uses are shown in Table 1, along with the remediation target level of 0.3 mSv/y. This remediation target level is consistent with both the use of dose constraints for planned exposures situations, and the as low as reasonably achievable (ALARA) principle, taking onto account economic and societal factors (ARPANSA 2017).

Based on Schedule 5 of the Radiation Control (RC) Regulation 2013, the regulatory dose limit for members of the public is 1 mSv/year (milli-sievert/year), which excludes any dose attributable to naturally occurring background levels of radiation.

Using the most conservative exposure duration of 8,766 hours per year, the mid-point conversion coefficient of 0.8 Sv Gy^{-1} (grays) and including background radiation (cosmic and terrestrial), the residential land use criterion proposed is 0.3 µGy/h. This can be thought of as the residential health investigation level (HIL-A) value in the context of the ASC NEPM (2013, B1).

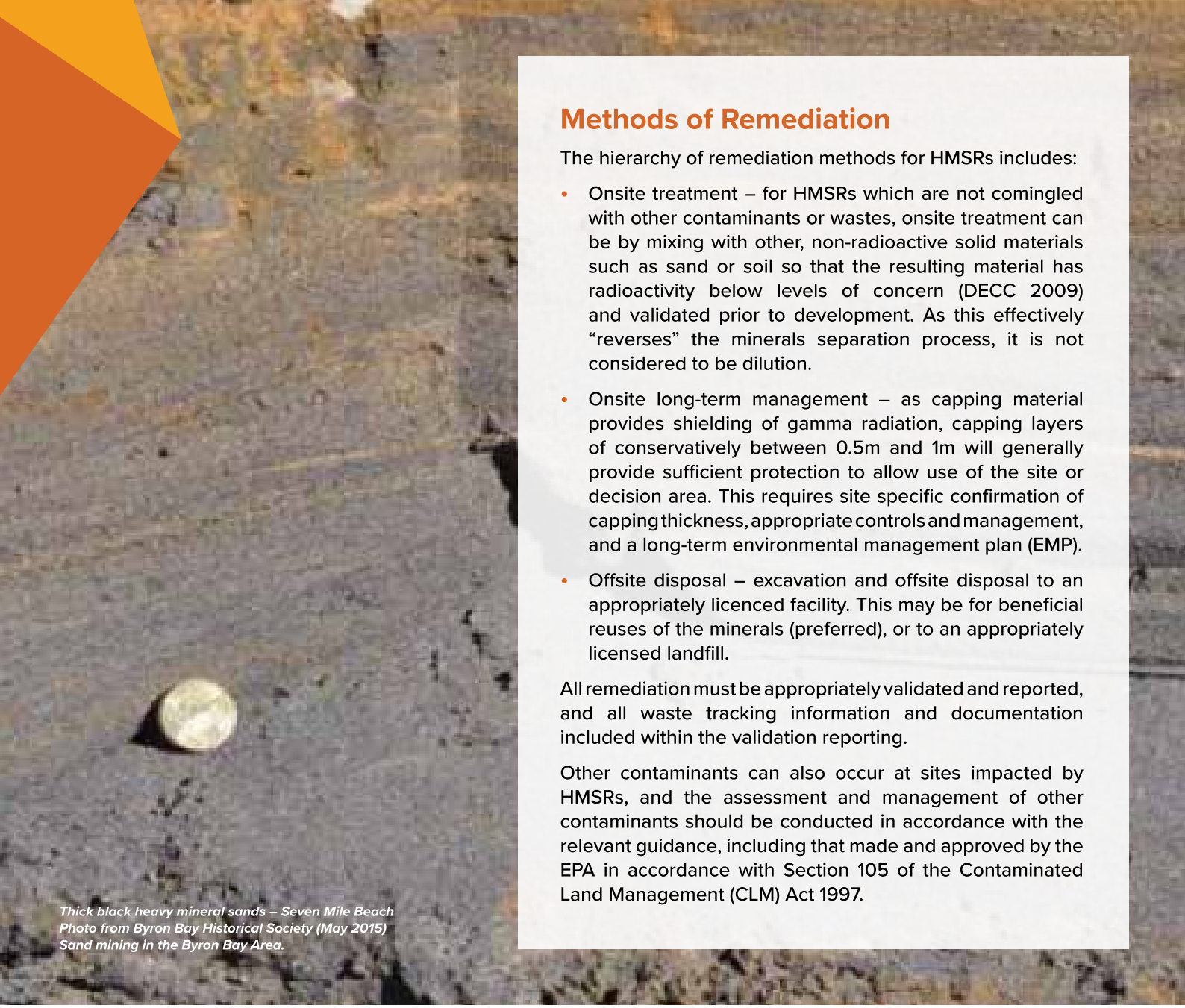
This dose criterion should be compared to the 95% upper confidence limit of the arithmetic mean ($UCL_{\bar{x}}$) of the collected sample data for the site or decision area, noting that radiologically impacted material should not be included in data sets with non-impacted material for data assessment.

Also, using the ASC NEPM data assessment framework of the maximum value not exceeding the action level by more than 250%, the maximum value for residential land use should not exceed 0.5 µGy/h (2.5 mSv/y), and the standard deviation of the data set should be ≤ 0.2 µGy/h (0.5 mSv/y).

Table 1: "HIL" Dose Criteria for Heavy Mineral Sands Residues by Land Use (µGy/h)[1, 2]

	95% UCL $\bar{x}$ [3]	Maximum	Standard Deviation
Dose constraint[4] – 0.3 mSv/y	0.2	0.25	0.15
Residential (HIL-A and HIL-B)[4] – 1 mSv/y	0.3	0.5	0.2
Recreational/ Open space (HIL-C)[5] – 1 mSv/y	2.0	4.5	1.0
Commercial/industrial (HIL-D)[6] – 1 mSv/y	0.7	1.6	0.4

Table Notes:
1. Coefficient of 0.8 Sv Gy^{-1} used to convert absorbed dose in air to effective dose; 2. Includes background of 0.095 µGy/h terrestrial and 0.038 µGy/h cosmic. Site specific, normal naturally occurring background levels may be determined following the methodology in ASC NEPM (2013, B5b); 3. 95% upper confidence limit (UCL) of the arithmetic mean ($\bar{x}$); 4. Exposure duration of 8,766 hours per year; 5. Exposure duration of not more than 730 hours per year (ASC NEPM 2013, B7); and 6. Exposure duration of not more than 2,160 hours per year (ASC NEPM 2013, B7). 7. Table adapted from Salmon (2021).



Thick black heavy mineral sands – Seven Mile Beach
Photo from Byron Bay Historical Society (May 2015)
Sand mining in the Byron Bay Area.

Methods of Remediation

The hierarchy of remediation methods for HMSRs includes:

- Onsite treatment – for HMSRs which are not comingled with other contaminants or wastes, onsite treatment can be by mixing with other, non-radioactive solid materials such as sand or soil so that the resulting material has radioactivity below levels of concern (DECC 2009) and validated prior to development. As this effectively "reverses" the minerals separation process, it is not considered to be dilution.
- Onsite long-term management – as capping material provides shielding of gamma radiation, capping layers of conservatively between 0.5m and 1m will generally provide sufficient protection to allow use of the site or decision area. This requires site specific confirmation of capping thickness, appropriate controls and management, and a long-term environmental management plan (EMP).
- Offsite disposal – excavation and offsite disposal to an appropriately licenced facility. This may be for beneficial reuses of the minerals (preferred), or to an appropriately licensed landfill.

All remediation must be appropriately validated and reported, and all waste tracking information and documentation included within the validation reporting.

Other contaminants can also occur at sites impacted by HMSRs, and the assessment and management of other contaminants should be conducted in accordance with the relevant guidance, including that made and approved by the EPA in accordance with Section 105 of the Contaminated Land Management (CLM) Act 1997.

References

- Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) (2008) *Management of Naturally Occurring Radioactive Material (NORM); Radiation Protection Series No. 15.*
- ARPANSA (2017) *Guide for Radiation Protection in Existing Exposure Situations; Radiation Protection Series G-2.*
- ARPANSA (2020) *Code for Radiation Protection in Planned Exposure Situations; Radiation Protection Series C-1 (Rev. 1).*
- Brown R.E., Henley H.F. and Stroud W.J. (December 2001) *Warwick – Tweed Heads 1:250,000 Sheet Area (New South Wales Portion), Volume 1, Geology, Mineral Occurrences, Exploration and Geochemistry,* (Ref. GS2001/087), Geological Survey of New South Wales, Department of Mineral Resources, Sydney NSW.
- Department of Environment and Climate Change NSW (DECC) (2009) *Guidance for Licensing of Mineral-sand Mining that Generates Radioactive Residues.*
- Environment Protection Authority (EPA) (1995) *Contaminated Sites: Sampling Design Guidelines.*
- EPA (2014) *Waste classification guidelines Part 3: Waste containing radioactive material.*
- EPA (2020) *Contaminated land guidelines: Consultants reporting on contaminated land.*
- National Environment Protection Council (NEPC) (2013) *National Environment Protection (Assessment of Site Contamination) Measure 1999.*
- Queensland Health (2020) *Land contaminated by radioactive material – A guide to assessment, management and remediation.*
- Radiation and Nuclear Science (RNS) (2019) *Radiological Baseline Reconstruction, Minjerribah (Nth Stradbroke Island), (Ref. RSS19-005).*
- New South Wales Government: Radiation Control Regulation (2013).
- Salmon M.C (June 2021) *Radiological dose criteria for heavy mineral sands residues in Queensland,* Version 3 (revised with updated guidance and dose criteria), Easterly Point Environmental, Byron Bay, NSW.

This publication was produced by the Northern Rivers Contaminated Land Program (NRCLP). The NRCLP was developed under the NSW EPA Council Regional Capacity Building program to support and assist the following councils to build capacity in the assessment and management of contaminated land.

NORTHERN RIVERS
Contaminated Land Program

Richmond Valley Council | Kyogle Council | ballina shire council | TWEED SHIRE COUNCIL | lismore city council | Byron Shire Council

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Address for Correspondence:
Northern Rivers Contaminated Land Program
C/- Public and Environmental Health Department
Ballina Shire Council
PO Box 40,
BALLINA NSW 2478
Phone: (02) 6686 1214
Email: christine.pitman@ballina.nsw.gov.au

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Cover photo: Exposed mineral sands at development site - Marc Salmon, Easterly Point Environmental Pty Ltd

Northern Rivers Contaminated Land Program - Radiation Assessment Report Summary Table

NORTHERN RIVERS
Contaminated Land Program

PROPERTY DESCRIPTION AND SITE HISTORY REVIEW	PAGE NO.
Address, Lot and DP, map of entire site as well as the investigation area(s)	
Site history has considered the potential for HMSRs at surface and depth	
CONCEPTUAL SITE MODEL	
Source, pathway, receptors, including whether HMSRs exist at surface and depth, and figures including plans and cross-sections	
SAMPLING AND ANALYSIS QUALITY PLAN (SAQP)	
Justification for the sampling design (how will the data be representative and relevant)	
Frequency and pattern of sampling	
Data quality objectives	
SAMPLING METHODOLOGY	
Description of sample methodology	
Use of appropriate radiation monitoring equipment i.e. radiation dose meters are suitable for environmental radiation surveys (including measurement range from 0.01 µGy/h - 30 µGy/h or 0.01 µSv/h to 30 µSv/h)	
NOTABLE CONTAMINANT CONCENTRATIONS E.G. MAXIMUM CONCENTRATIONS AND VALIDATION RESULTS	
Samples compared against appropriate land use dose criteria	
Discussion on data usability (field and laboratory QA/QC)	
Statistical analysis of separate material types	
NATURE AND EXTENT OF REMAINING EXISTING EXPOSURE SITUATION	
Areas that exceed dose criteria identified in investigation, areas unable to be remediated within the scope of the work, or areas not assessed	
WASTE REMOVED	
During remediation (details of classification and disposal, including waste documentation)	
REMEDIATION SUMMARY	
What was removed or treated? Was it successful, is residual contamination remaining?	
Is there a need for an ongoing Environmental Management Plan (EMP)?	
APPROPRIATELY EXPERIENCED AND QUALIFIED PRACTITIONERS	
Practitioner has appropriate experience and qualifications including certification and membership	
The practitioner's professional indemnity (PI) insurance does not exclude naturally occurring radioactive materials (NORMs)	
REPORT DETAILS	
Report title:	
Produced by:	**ABN:**
Provided to Byron Shire Council on:	
I of state that I have undertaken this assessment in accordance with the guidelines made and approved by the NSW Environment Protection Authority.	
Name:	**Signature:**
Contact details:	