Technical Assessment Report for the Existing Coastal Waters Discharge via the 'Cooling Water Outlet Basin', at Koeberg Nuclear Power Station

Coastal Waters Discharge Permit Application

September 2017

Revision 2

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DEA Reference Number: 2012/011/WC/Koeberg Power Station

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Synopsis

An application in terms of Section 69 of the National Environmental Management: Integrated Coastal Management Act (NEM: ICMA), Act 24 of 2008, for a Coastal Waters Discharge Permit (CWDP) has been made by Eskom for the discharge emanating from Koeberg Nuclear Power Station (KNPS).

The discharge activity is associated with the operation of the power station, which utilises large volumes of seawater for cooling purposes. In addition to the cooling water discharge, industrial and domestic effluent is produced and is discharged along with the cooling water via the Koeberg cooling water outlet basin (KCWOB), which is situated south of the Koeberg cooling water intake basin (KCWIB).

KNPS has an existing statutory approval for the discharge activity. Through the promulgation of the NEM: ICMA in 2008, this Act has since repealed those provisions in terms of marine discharges, and therefore KNPS is required to apply for a CWDP in terms of the NEM:ICMA. This technical assessment report has been drafted and supporting specialist studies have been conducted in support of this application.

Advisian, a WorleyParsons (Pty) Ltd. Group Company, has been appointed by Eskom to undertake the associated Public Participation Process.

Disclaimer

Project No: C00278-DEA Ref. No.:2012/011/WC/Koeberg Power Station – Technical Assessment Report for the Existing Coastal Waters Discharge via the 'Cooling Water Outlet Basin', at Koeberg Nuclear Power Station: Coastal Waters Discharge Permit Application

Rev	Description	Author	Review	Advisian Approval	Date
1	For submission to the regulatory authority	KC Pontac	DB Jeannes / R Moffat	Ryan Jonas	05 Sept 2016
2	CWDP Amendment	KC Pontac	DB Jeannes	Ryan Jonas	06 Sept 2017
		K Pontac	Eskom		

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1 INTERPRETATION AND TERMINOLOGY

1.1 Abbreviations

The following abbreviations are used in this Scope:

Abbreviations	Description
AADQ	Annual Authorised Discharge Quantity
AE	Alcohol Ethoxylates
AES	Alcohol Ethoxysulfates
APG	Steam Generator Blow-down System
ATE	Condensate Polishing Plant System
BAT	Best Available Technology/Technique
BCLME	Benguela Current Large Marine Ecosystem
BOD	Biochemical Oxygen Demand
BWRO	Brackish Water Reverse Osmosis Plant (also referred to as the Ground Water Reverse Osmosis Plant [SRO])
CD	Chart Datum
COD	Chemical Oxygen Demand
CRF	Circulating Water System
CTE	Chlorination Plant System
CWDP	Coastal Waters Discharge Permit
DEA	Department of Environmental Affairs (National)
DEL	Electrical Building Ventilation System
DoE	Department of Energy
DWAF	Department of Water Affairs and Forestry (now known as the Department of Water Affairs and Sanitation)
EEZ	Exclusive Economic Zone
EDTA	Ethylenediaminetetraacetic Acid
ERICA	Environmental Risks from Ionising Contaminants: Assessment and Management
ETA	Ethanolamine
GAC	Generic Assessment Criteria
GNR	Government Notice Regulations
HAT	Highest Astronomical Tide
IAEA	International Atomic Energy Agency

Abbreviations	Description
ICRP	International Commission of Radiation Protection
KER	Radiological Effluent Monitoring and Discharge System
KNPS	Koeberg Nuclear Power Station
KCWIB	Koeberg Cooling Water Intake Basin
KCWOB	Koeberg Cooling Water Outfall Basin
LAS	Linear Alkylbenzene Sulfonate
LAT	Lowest Astronomical Tide
LD	Licensing Document
m^3	Meters cubed
m^3/a	Meters cubed per annum
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
ML	Mean Level
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MPA	Marine Protected Areas
MSL	Mean Sea Level
mSv	Millisievert
MWe	Megawatt Electrical
NEM:ICMA	National Environmental Management: Integrated Coastal Management Act, Act No. 24 of 2008
NIL	Nuclear Installation Licence
NNR	National Nuclear Regulator
NNRA	National Nuclear Regulatory Act, Act No. 47 of 1999
NOEC	No Observed Effect Concentration
NWA	National Water Act, Act No. 36 of 1998
PRDW	PRDW Africa (Pty) Ltd (Consulting Port and Coastal Engineers)
PSIF	Public Safety Information Forum
PSU	Practical Salinity Unit. 1 psu is equivalent to 1 g/l or 1 ppth
PWR	Pressurised Water Reactor
REIA	Radiological Environmental Impact Assessment
SDA	Demineralised Water Production Plant

Abbreviations	Description
SDX	Chemical Effluents System / (also knowns as the Demineraliser Plant Sumps System)
SEC	Essential Service Water System
SED	Demineralised Water Distribution System (Nuclear Island)
SEK	Secondary Releases System (also known as the Conventional Island Liquid Waste Monitoring and Discharge System)
SEO	Storm Water System
SER	Demineralised Water Distribution System (Conventional Island)
SEU	Domestic Waste Water Treatment System
SRO	Ground Water Reverse Osmosis Plant (also referred to as the Brackish Water Reverse Osmosis Plant [BWRO])
SSRP	Safety Standards and Regulatory Practices
SWRO	Sea Water Reverse Osmosis Plant
TRO	Total Residual Oxidants
TSS	Total Suspended Sediment
WA	Water Act, Act No. 54 of 1956
WANO	World Association of Nuclear Operators
WWTW	Waste Water Treatment Works
XCA	Auxiliary Boiler Plant

1.2 Terminology

Term	Description
Advection	The transfer of a property such as heat by the movement of water.
Aspect	Element of an organisation's activities, products or services that can interact with the environment.
Bathymetry	Underwater depth of the ocean bed.
Biocide	A substance, such as a chlorine or Dibromo Nitrilopropionamide (DBNPA), that is capable of destroying living organisms if applied in sufficient doses.
Biofouling	The fouling of underwater pipes and other surfaces by marine organisms such as barnacles, mussels and algae.
Breakwater	A barrier built out into the sea to protect a coast, harbour or coastal structure from the force of waves.
Coastal Zone	The area comprising coastal public property, the coastal protection zone, coastal access land and coastal protected areas, the seashore, coastal waters and the Exclusive Economic Zone and includes any aspect of the environment on, in, under and above such area.

Term	Description
Current	Flow of water in a specific direction.
Current direction	The direction towards which the current is flowing, measured clockwise from true north.
D_{50}	Median grain size.
Direct (once-through) water cooling	A process of heat removal from industrial equipment using water as the heat conductor, where the water is discharged back into the original body of water after use (sea or fresh water can be used).
Dispersion	Mixing of one substance into another.
Dose	The amount of radiation received, where the use of a more specific term, such as "effective dose" or "equivalent dose" is not necessary for defining the quantity of interest.
Dose limit	The value of the effective dose or equivalent dose to individuals from actions authorised by a nuclear installation licence, which must not be exceeded.
Ecological	The scientific analysis and study of interactions among organisms and their environment.
Effluent	A complex waste material (e.g. liquid industrial discharge or sewage) that may be discharged into the environment.
Endemicity	Present within a localized area or specific region
Environment	Refers to the surroundings within which humans exist and that are made up of – (i) the land, water and atmosphere of the earth; (ii) micro-organisms, plant and animal life; (iii) any part or combination of (i) and (ii) and the interrelationships among and between them; and (iv) (iv) the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and wellbeing
Environmental Authorisation	An authorisation granted in respect of coastal activities by a competent authority in terms of Chapter 5 of the National Environmental Management Act, Act No. 107 of 1998 (NEMA), as amended;
Environmental monitoring	The measurement of external dose rates, due to sources in the environment, and of radioactive nuclide concentrations in environmental media.
Environmental Management Plan	An environmental management tool used to ensure that undue or reasonably avoidable adverse impacts of the construction, operation and decommissioning of a project are prevented; and that the positive benefits of the projects are enhanced[2].
Hydrodynamics	The movement of fluid.
Impact	A description of the potential effect or consequence of an aspect of the development on a specified component of the biophysical, social or economic environment within a defined time and space.

Term	Description
Mixing zone	An administrative construct which defines a limited area or volume of the receiving water where the initial dilution of a discharge is allowed to occur, until the water quality standards are met. In practice, it may occur within the near-field or far-field of a hydrodynamic mixing process and therefore depends on source, ambient and regulatory constraints.
Near field	The zone close to the discharge point where the mixing is dominated by the momentum and buoyancy of the discharge.
Others	Are people or organisations who are not the Employer, the Consultant, the Adjudicator or any employee, Sub-Consultant or supplier to the Consultant.
Radwaste	Radiological Waste
Radioactive nuclide	Any unstable atomic nucleus, which decays spontaneously with the accompanying emission of ionising radiation.
Radioactive waste	Any material, whatever its physical form, remaining from an action requiring a nuclear installation licence, and for which no further use is foreseen, and that contains or is contaminated with radioactive material and does not comply with the requirements for clearance. The quantitative or qualitative criteria specified by the operator and approved by the regulator, for radioactive waste to be accepted by the operator of a repository for disposal, or by the operator of a storage facility for storage.
Salinity	The measure of the salts dissolved in water.
Sea	Means all marine waters, including— (a) the high seas; (b) all marine waters under the jurisdiction of any state; and (c) the bed, subsoil and substrata beneath those waters, but does not include estuaries;
Stakeholders	A subgroup of the public whose interests may be positive or negatively affected by a proposal or activity and its consequences. The term includes the proponent, authorities and all interested and affected parties.
Stratification	Formation of water layers based on salinity and temperature.
Surf Zone	The zone of wave action extending from the water line (which varies with wave conditions, tide, surge, set-up etc.) out to the most seaward point of the breaker zone (breaking waves).
Thermal discharge	The discharge of heated cooling water used in power generation into a colder body of water such as the ocean.
Thermal plume	Hot water discharged into a receiving body of water which moves as a single mass until it cools and gradually mixes with the cooler water.
Wave direction	The direction from which the wave is coming, measure clockwise from true north.
Wave transformation	Waves that propagate towards the shore interact with coastal structures and the sea bed which results in a change of wave shape and incoming direction.
Wind direction	The direction from which the wind is coming, measure clockwise from true

Term	Description
	north.
Wind setup	The vertical rise in the still water level on the leeward side of a body of water caused by wind stresses on the surface of the water.
95th percentile	The value below which 95% of the observations are found.

2 INTRODUCTION

2.1 Purpose of the Report

This assessment report supports the application for a Coastal Waters Discharge Permit (CWDP) in terms of Section 69 of the National Environmental Management: Integrated Coastal Management Act (NEM: ICMA), Act 24 of 2008, made by Koeberg Nuclear Power Station (KNPS). The discharge activity is associated with the operation of the power station, which utilises seawater for cooling purposes and the dilution of industrial effluent produced by the plant.

KNPS has an existing statutory approval for the discharge activity, Permit 853N and Exemption 1133B (Appendix A:) in terms of the Water Act (WA), Act 54 of 1956. This authorisation was issued on 17 July 1985 by the Department of Water Affairs (DWA), who at the time was the competent authority responsible for the governance of coastal water discharge under the relevant WA. In terms of the transitional provisions of the National Water Act (NWA), Act 36 of 1998, the discharge activity (permit 853N and associated 1133B exemption) is an existing lawful use and therefore valid in terms of this Act (Act 36 of 1998).

In 2008, the NEM: ICMA was promulgated in order to improve the conservation and sustainable management of the South African coastal environment. Thus, the administrative duties pertinent to marine discharges were transferred from the DWA to the Department of Environmental Affairs: Oceans and Coasts (DEA). In light of the relevant statute change, KNPS is required to apply for a CWDP in terms of the NEM: ICMA, Section 69.

It is understood that the intention of the CWDP is to replace the marine discharge requirements that exist under the NWA; however, the discharge operations at KNPS have been in compliance with the existing water permit and exemption recognised by the NWA, and cognisance of this should be taken into consideration by the DEA.

As part of the application submission, a suite of specialist studies concluded and reports have been compiled (refer to Appendix B:) as a response to the DEA's minimum information request as indicated in the guideline document *"Generic Assessment Criteria for Coastal Waters Discharge Permits" (DEA 2014)*. Furthermore, the above-mentioned documentation has been circulated in a public participation process, to lobby for stakeholder engagement on this activity as per the guideline document *"Public Participation Requirements for a Coastal Waters Discharge Permit Application"* (DEA 2014). The comments and concerns received to date have been collated and responded to. Refer to Appendix G: for the public participation process report, which includes the comments and responses table and proof of the public engagement conducted.

2.2 Scope of the Application

The focus of this application is mainly on the non-radiological effluent discharge to the Atlantic Ocean during the operation of KNPS. Though, it should be noted that KNPS discharges minimal residual treated radiological effluent along with the non-radiological effluent, as this is considered best practice to minimise the radioactive dose to members of public, workers, plants and animals. The concentration of radiological effluent released to the environment depends on the level of radioactivity of the effluent (further discussed below) and the dilution capacity of the cooling water discharged.

The discharge of radiological effluent is governed by the National Nuclear Regulatory Act, 1999 (NNRA) (Act No. 47 of 1999) and administered by the Department of Energy (DoE). The nuclear regulations (GNR 388) regulated by the National Nuclear Regulator (NNR), set the criteria for the discharge of radioactive liquid releases to the environment and specify the monitoring and measurement of released activity. The NNR prescribes annual effective dose limits (i.e. Annual Authorised Discharge Quantity (AADQ)) for members of the public; these are set in accordance with the conditions of licence and the Regulations on Safety Standards and Regulatory Practices (SSRP). Public doses resulting from effluent discharges from KNPS must comply with the dose constraint of 0.25 mSv/a and the system of AADQs applicable to the site.

2.3 Regulatory Requirements

2.3.1 National Environmental Management: Integrated Coastal Management Act (NEM: ICMA)

Anyone wishing to discharge effluent from a land-based source into coastal waters must apply to the DEA for a CWDP in terms of the NEM: ICMA. Section 69(3) of the Act states:

> *"Any person who wishes to discharge effluent into coastal waters in circumstances that are not authorised under a general authorisation referred to in subsection (2) must apply to the Department for a coastal water discharge permit."*

The definition of effluent (as per the Act): (a) any liquid discharged into the coastal environment as waste, and includes any substance dissolved or suspended in the liquid; or (b) liquid which is of a different temperature from the receiving body of water. In this instance KNPS triggers the threshold both in terms of discharge and characterisation of the effluent.

2.3.2 Seashore Act

Eskom currently has two leases[1] with the Western Cape Nature Conservation Board, under the Seashore Act, Act No. 21 of 1935 (refer to Appendix C: for a copy of the Seashore leases). These leases allow Eskom to use the sea-shore area for the maintenance of the intake and outlet water system, as well as for the pumping of seawater to and from Koeberg. The first lease (1/04-020-90216) provides that the leased site shall be used "exclusively for the use and maintenance of an intake and outlet water system" (i.e. KCWIB and KCWOB, refer to Figure 1), "*for the pumping of seawater*" to and from Koeberg and for no other purpose without the prior permission of the lessor.

2.3.3 National Nuclear Regulatory Act (NNRA)

In terms of the NNRA, nuclear installation licenses contain conditions deemed necessary to ensure the protection of persons, property and the environment against nuclear damage. The current KNPS installation license, NIL-01 variation 18, contains 19 conditions (Table 1). In

[1] Lease 1/04-020-90216, and Lease 1/04-020-90335.

accordance with the conditions of license, Koeberg is required to ensure that arrangements acceptable to the NNR are established and implemented with the respect to the following aspects:

Table 1: Nuclear License Conditions applicable to KNPS

Plant Description and Configuration	Safety Assessment
Scope of Activities that may be undertaken	Controls and Limitations on Operation
Maintenance and in-Service Inspection	Operational Radiation Protection
Effluent Management	Waste Management
Environmental Monitoring	Emergency Planning and Preparedness
Transport	Physical Security
Quality Management	Acceptance and Approval
Decommissioning	Organisational Change
Records Management and Reporting	Plant Modifications
Medical Surveillance	Radioactive Waste Management
Public Safety Information Forums	Financial Liability for Nuclear Damage
Holder Inspection Programme to ensure Compliance with Conditions of Authorisation	___

In terms of Section 26(2) of the NNR Act, Eskom, as the nuclear licence holder, implements an inspection programme to ensure compliance with the conditions of the Nuclear Installation Licence, NIL-01. The NNR implements an independent system of compliance inspections to provide assurance of compliance with the conditions of the nuclear licence in terms of Section 5(d) of the NNR Act.

Further to effluent discharge dose constraint mentioned in section 2.2, the regulatory annual effective dose limit prescribed by the NNR for members of the public from authorised actions is 1 mSv. No action may be authorised which would give rise to any member of the public receiving a radiation dose from all authorised actions exceeding 1 mSv in a year.

As per the NNR Annual Report (2015), there were no safety concerns regarding the safety of the public living around KNPS. In accordance with the conditions of licence and the Regulations on SSRP[2], the public doses resulting from effluent discharges from KNPS must comply with the dose constraint of 0.25 mSv/a and the system of AADQs applicable to the site. KNPS complied with the AADQs and the projected public doses resulting from the effluent releases (both liquid and gaseous), were well within the dose constraint for the 2014 calendar year (refer to Table 2). Proof of this compliance has been published in the NNR Annual Report, and historic compliance data in terms of NNR dose requirements is provided in Appendix D:.

[2] Published as GNR 388 dated 28 April 2006.

Table 2: The projected public dose from effluent discharge for key radionuclides for 2014 (Source: NNR Annual Report 2015)

Quarter	Liquid pathway dose in mSv/a	Gaseous pathway dose in mSv/a	Total projected dose in mSv/a
1	0.000 373	0.000 045	0.000 418
2	0.00 046 177	0.00 009 361	0.00 055 538
3	0.00 004 176	0.00 008 292	0.00 012 468
4	0. 000 158 592	0.000 015 243	0.000 173 835
Total for the calendar year January – December 2014	0.001 035 122	0.000 236 773	0.001 271 895

2.3.4 Applicable Guidance

This CWDP application has been prepared using the following guidance documents:

- National Guideline for the Discharge of Effluent from Land-based Sources into the Coastal Environment (DEA, 2014);
- Assessment Framework for the Management of Effluent from Land Based Sources Discharged to the Marine Environment (DEA, 2015);
- Generic Assessment Criteria for Coastal Waters Discharge Permits (DEA, 2014); and
- Guideline on Public Participation Requirements for a Coastal Waters Discharge Permit Application (DEA, 2014).

2.4 Contents of the Report and Supporting Documentation

Table 3 outlines the structure of this supporting document. This structure is based on the 2014 DEA guidance document *"Generic Assessment Criteria for Coastal Waters Discharge Permits"*. Though, the structure has been amended to best suit this application as it is for an existing discharge activity and the complex nature of the discharge. The information requirements as set out in the Generic Assessment Criteria (GAC) document have been addressed as far as it is relevant to this application, the table below highlights the section details and where it may be found.

Table 3: CWDP Application Technical Report Structure

Section Reference	Title	Brief Description
1	Document interpretation and terminology.	Provides the description of abbreviations and terminology used throughout this document.
2	Introduction	Presents the need for the CWDP application and its associated Environmental Regulations.

Section Reference	Title	Brief Description
3	Baseline Information	Provides a brief description of the discharge activity and the receiving environment. GAC requirements: scope of the study area and its features; i.e. biochemical processes; marine ecology; microbiological factors; etc.
4	Discharge Characterisation	Presents a more detailed description of the effluent discharged; its source as per the various industrial systems; and the hydraulic design of the discharge infrastructure. GAC requirements: hydraulic design and achievable dilution.
5	Pollution Abatement Measures and Application of BAT	Presents the techniques adopted at KNPS to minimise emissions and their associated impacts, and demonstrates the use of Best Available Technology/Technique (BAT).
6	Environmental Impact and Risk Assessment	Summarises the various specialist studies conducted on the receiving environment. GAC requirements: achievable dilution and compliance with environmental quality objectives.
7	Monitoring Programme	Provides an outline of how discharges are monitored. In addition, it outlines the marine environmental monitoring conducted at KNPS and presents the proposed monitoring as recommended by the latest studies. GAC requirements: monitoring programme.
8	Compliance with Environmental Quality Objectives and Contingency Planning	Illustrates how the effluent discharge activity is managed and the implementation of management systems/plans. Furthermore, it outlines the contingency planning implemented. GAC requirements: reporting and contingency planning.
9	Conclusion	Summary of the report and the way forward.
Appendix A	Water Use Permit and Exemption.	Copy of the existing Water Use Permit and applicable exemption, in terms of the National Water Act.
Appendix B	Specialist Studies.	B1 – Marine Study Report; and B2 – Dispersion Modelling Study Report.
Appendix C	Sea-shore Leases	Copy of the existing KNPS Sea-shore Leases
Appendix D	NNR Dose Requirements Historic Compliance Data	Copy of the monitoring and compliance data for KNPS.
Appendix E	Summary of historic marine studies conducted at KNPS.	Summary of the monitoring and compliance studies conducted at KNPS site.

Section Reference	Title	Brief Description
Appendix F	Compliance monitoring data for the past 5 years.	Copy of the monitoring and compliance data for KNPS for the past 7 years (2010 – 2016).

3 BASELINE INFORMATION

This section presents the scope of the study area and its relevant environmental features.

3.1 General Description

KNPS is situated in an area near the southern limit of the relatively uniform Namaqua marine biogeographic region. This area is dominated by the cold Benguela current system, in which the upwelling of cool nutrient rich waters results in high biological productivity.[3] However, this coast is characterised by low species richness and low endemicity. There are no identified areas of special conservation for marine mammals, invertebrates or fish within the immediate vicinity of KNPS.[3] However, the Koeberg Private Nature Reserve around the KNPS has been recognised as an area of conservation importance for seabirds and shorebirds.[4] Penguins and seabird colonies are situated on Robben Island about 15 km to the south of KNPS. There are no other notably rare or endangered species that are known to occur in the immediate area.[5]

3.1.1 Location

KNPS (Cape Farm Duynefontyn No. 1552) is located approximately 30 km north of Cape Town, near Melkbosstrand on the West Coast of South Africa. The operation of the plant, a Pressurised Water Reactor (PWR), requires large volumes of cooling water, to condense steam used in the turbines that generate electricity for export to the National Grid.

The two 900 MWe (megawatts electrical) nuclear reactors applies the direct or once-through cooling water system. Cooling water is drawn from the Atlantic Ocean, passed through the various industrial processes on site and returned to the sea with a temperature ~11 °C above that abstracted. In addition to the cooling water discharge, industrial and domestic effluent is produced and is discharged via the KCWOB, which is situated south of the Koeberg Cooling Water Intake Basin (KCWIB) (see Figure 1).

[3] Griffiths, C.L., and Robinson, T.B., 2005.
[4] Parsons, N.J., 2006.
[5] Robinson, T.B., 2012a.

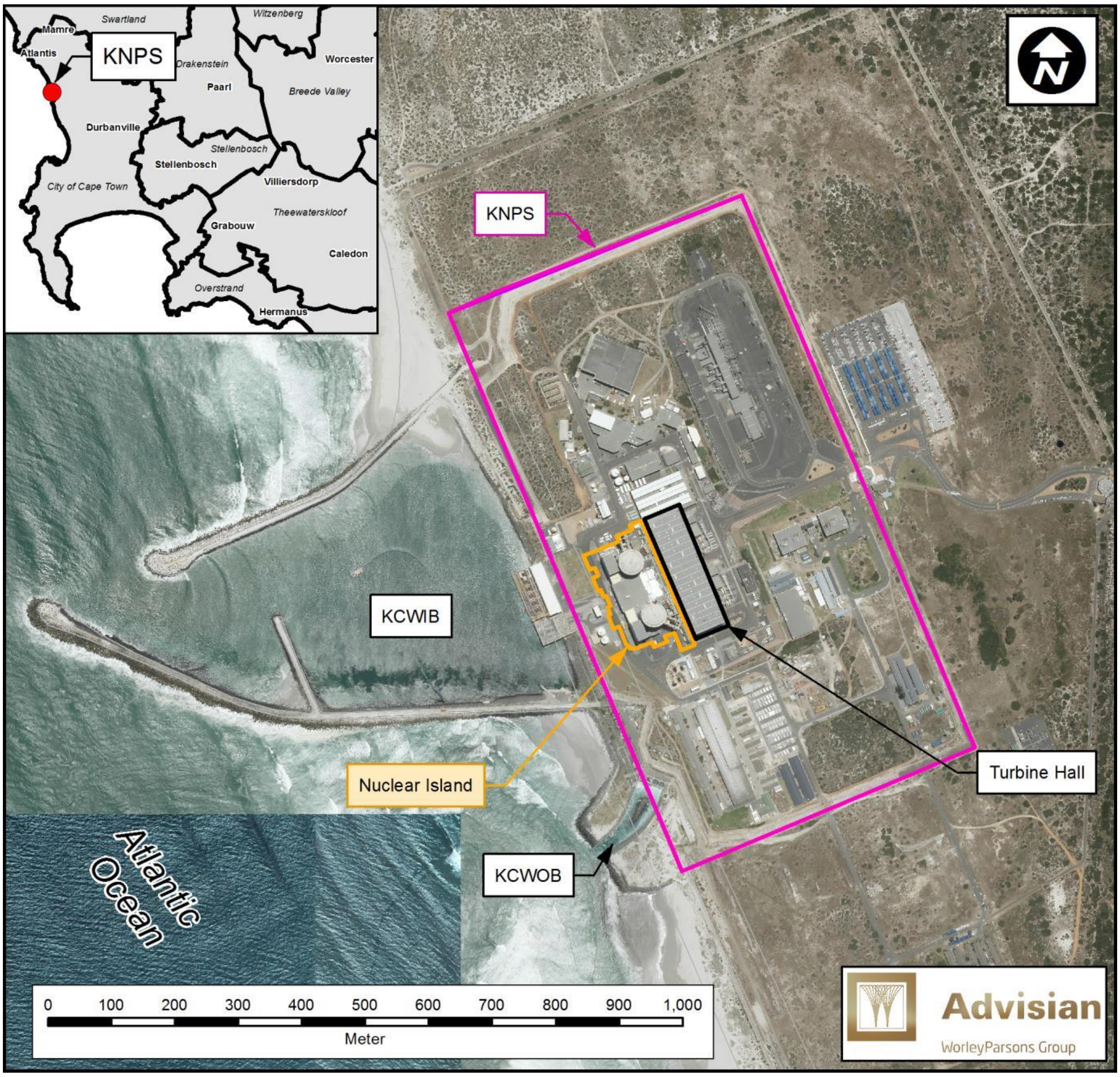

Figure 1: Aerial Image of Koeberg Nuclear Power Station

The KCWOB consists of a concrete channel approximately 150 m long initiating on land and discharging into the sea at a depth of approximately -2 m CD (see Figure 2).[6] The design of the channel and the magnitude of the effluent discharged (~86 m^3/s) inhibit the flow of ambient seawater back into the KCWOB, and therefore the discharge location is considered to be at the end of the channel.[6] The coordinates of the discharge location are 33°40′50.18″S and 18°25′50.45″E (GCP).

[6] PRDW, 2017.

Figure 2: Aerial Image of the Koeberg Cooling Water Outfall Basin (source: PRDW, 2017)

In addition to the discharge point at the KCWOB, there are a few industrial systems which discharge via the Stormwater - Northern side (SEO-N) system, into the KCWIB. This discharge point is mainly used for the draining of stormwater collected from the northern half of KNPS. The discharge volume from this point is not considered significant, due to the large volume of water abstracted within the basin which ensures that the effluent is ultimately "re-used" in the plant by passing back through the cooling water system (CRF) and effectively discharging within the KCWOB.[7]

3.2 Weather

Weather data measured at KNPS meteorological station (October 1997 – June 2010) indicates the strongest winds occur during the summer months. These winds are characterised as strong, persistent south-easterly winds. Winter months are generally calmer, with the strongest winds from north-west to north-north-easterly direction.

Temperatures during summer months vary between 15 °C and 35 °C, while during winter temperatures are reduced to 5 °C to 25 °C.

[7] Refer to section 5.5 of PRDW, 2017 (Appendix B:2) for further validation of this assumption.

3.3 Geology/Sediment

PRDW[6] states KNPS site is characterized by a shallow sloping sandy beach, with slops decreasing from north to south. The report further states that between +3 m CD and +13 m CD, the average beach slope ranges from 1:12 in the north to 1:60 in the south.

Watermeyer, et al.,[8] indicated that rocks of the Malmesbury Series of Precambrian age occur at the site within -5 m CD to -12 m CD. Previous studies also indicated that Malmesbury Shales are variably weathered to depths of about -54 m CD to -65 m CD.

Sediment samples collected nearshore (between -9 and -29 m CD) and from the beach at high and low tide, indicate KNPS has a D_{50} of approximately 0.2 mm and a grading of approximately 1.2. The samples collected north of KNPS reflect a steeper beach slope and larger waves. Samples collected offshore reflect the deposition of finer sediments in deeper water.

3.4 Biodiversity and Biological Communities

The southern Benguela Current Ecoregion is biologically productive due to coastal upwelling which provides the inorganic nutrients that drive high plankton productivity at the base of a food chain that supports pelagic and demersal fisheries and associated predator populations.[9]

3.4.1 Intertidal Zone

Sandy shores dominate the intertidal zone in the vicinity of the KCWOB. To the north of KNPS, is a 10 km long wave exposed sandy beach, consisting of relatively coarse-grained quartz sand and weathered shell. To the south of KNPS is a 6 km long sandy beach, consisting of finer sediments and a wider intertidal zone. Invertebrate species found on these beaches are typical of the west coast. Macro-faunal communities are dominated by polychaete worms low on the sea shore while they become dominated by crustaceans in the high shore.[3] The commercially important White Sand Mussel, *Donax serra,* also occurs in the low shore.[5]

Very little natural rocky shore exists in the area under consideration and the KCWIB breakwaters represent the major hard substratum available in the intertidal zone. On the sea side, the breakwaters are protected by concrete dolosse and on the inside; they are built up with rocks of assorted sizes which form a gentle sloping intertidal zone.[5]

Robinson[10] found that on the sea side of the breakwaters the intertidal zone was very exposed and biological communities consisted mainly of the alien mussels, *Mytilus galloprovincialis,* and various barnacle species. In addition, it was found that the communities within the shelter of the basin were far more diverse and included mussels, limpets and numerous algae. All species recorded are common on the west coast.[5]

Numerous marine birds have been recorded breeding in the intertidal zone around KNPS. These include the Swift Tern, *Sterna bergii; the* Hartlaub's Gull, *Larus hartlaubii*, the 'Endangered' Bank

[8] Watermeyer, et al., 1972.
[9] Lwandle, 2017.
[10] Robinson, T.B., 2012a.

Cormorant, *Phalacrocorax neglectus*, the 'Near-threatened' African Black Oystercatcher, *Haematopus moquini*; Crowned Cormorant, *P. coronatus,* and the Cape Cormorant, *P. capensis*. The Hartlaub's Gull, Bank Cormorant and the African Black Oystercatcher are endemic to the region.[5]

The private nature reserve that surrounds KNPS has been identified as an area of conservation importance because it meets the criteria for the Ramsar Convention and is considered to be an Important Bird Area (BirdLife Africa).[11] In particular, the protection offered by the Koeberg Private Nature Reserve has enabled an increase in density of breeding pairs of the Near-threatened African Black Oystercatcher.[5]

3.4.2 The Benthic Environment

Both rocky and sandy bottoms occur in the nearshore environment in the immediate area of KNPS.[12] Communities inhabiting rocky substrata are dominated by the Mussel *Choromytilus meridionalis;* by the Sea Urchin, *Parechinus angulosa* and by gastropods of the genus *Burnupena* - This community structure is typical of the South African west coast. Both West Coast Rock Lobster, *Jasus lalandii,* and Abalone, *Haliotis midae,* occur on nearby shallow reefs. Sandy bottom communities support no species of note and are characterised by large numbers of polychaete worms, burrowing anemones and small crustaceans.[5]

3.4.3 The Open Water Environment

The most common fish occurring in the KCWIB of KNPS are the Southern Harder, *Liza richardsoni,* and the Catshark, *Poromerma africanum*.[12] While a number of marine mammals are known to frequent the west coast, only the South African Fur Seal, *Arctocephalus pusillus pusillus,* has been recorded spending long periods in the immediate area of KNPS.[5]

The high densities of phytoplankton and zooplankton substantially contribute to the well-known productivity of the west coast. Algae blooms are however temporary and localised, depending to a large degree on prevailing weather conditions. Although a large number of species have been identified in the vicinity of KNPS, taxonomy of these groups is difficult and a number of species remain undescribed.[5]

3.4.4 Marine Protected Areas (MPAs)

The nearest MPAs to the facility are 16 mile beach to the north, Robben Island to the south-west and the Benguela Mud MPA to the north-west further offshore.[9]

3.5 Oceanography

KNPS is situated within the southern Benguela ecosystem, which is known for its dynamic coastal upwelling and swell events, than by consistent current flows. This feature is driven by equatorward winds that are predominantly seasonal with the highest frequency occurring in the austral spring and summer.[9]

[11] PRDW, 2012.
[12] Cook, 1984.

3.5.1 Water Levels

The Port of Cape Town data (Table 4) is assumed relevant for KNPS in terms of water levels.

Table 4: Tidal characteristics for the Port of Cape Town (SANHO, 2016; PRDW, 2017)

Description	Level [m CD]
Highest Astronomical Tide (HAT)	2.02
Mean High Water Springs (MHWS)	1.74
Mean High Water Neaps (MHWN)	1.26
Mean Level (ML)	0.98
Mean Low Water Neaps (MLWN)	0.70
Mean Low Water Springs (MLWS)	0.25
Lowest Astronomical Tide (LAT)	0.00

3.5.2 Waves

Nearshore wave data indicate an exposed wave climate with median and 99^{th} percentile significant wave heights ranging from 1.5 m to 4.5 m.[6]

3.5.3 Currents

Nearshore current data at KNPS indicate that nearshore (10 m water depth) surface current velocities were mostly <53 cm/s while velocities at the base of the water column were predominantly <28 cm/s.[9] At 30 m water depth surface currents were mostly <35 cm/s and near the seafloor (<14 cm/s).[9] Flow directions at both sites were shore parallel at the seabed oscillating directionally between north and south. Flow direction at the sea surface at the shallow water site oscillated between north north-west and south south-east but had greater offshore (north-west) and onshore (south east) flows at the deeper site.[9] These currents are consistent with those measured for the region.

3.5.4 Water Temperature

Seawater temperature datasets indicates a well-mixed water column during the winter months (May to mid-September), with relatively little variability in temperatures. While in the summer months (mid-September to April), a higher variability in temperatures is experienced, as well as differences between shallower and deeper waters which indicates the presence of water column stratification.

The coastline opposite KNPS experiences the effects via invasion of the area by cool water (9-13°C), however when upwelling weakens and stops due to a decline of wind force the cool dense water retreats offshore and is replaced by warmer (>20°C) previously-mixed water.[9]

3.5.5 Salinity

Samples indicates an average of 35 psu with little variation (<1.0 psu).[6]

4 DISCHARGE CHARACTERISATION

This section describes the loops (see Figure 3) and its associated systems which generate effluent at KNPS that are relevant to the coastal waters discharge activity, and include the following subsections:

- Simplified overview of the two pressurised water reactors at KNPS;
- About the effluent - details and type;
- Simplified description of the source of the discharges;
- Summary of plant items and structures from which the discharges will arise; and
- Summary of plant and infrastructure for handling the cooling water and effluent.

4.1 Simplified Overview of KNPS

KNPS operates on three separate water systems i.e. primary, secondary and tertiary loops, which work as the coolant, with seawater as the ultimate heat sink. It is important to note the three loops are separate and operate independently, which means the water in the reactor (which is radioactive but in an enclosed system) does not come into contact with the other two loops and therefore does not contaminate the water in these associated systems.

Figure 3 shows the conceptual diagram of KNPS, and is discussed further below.

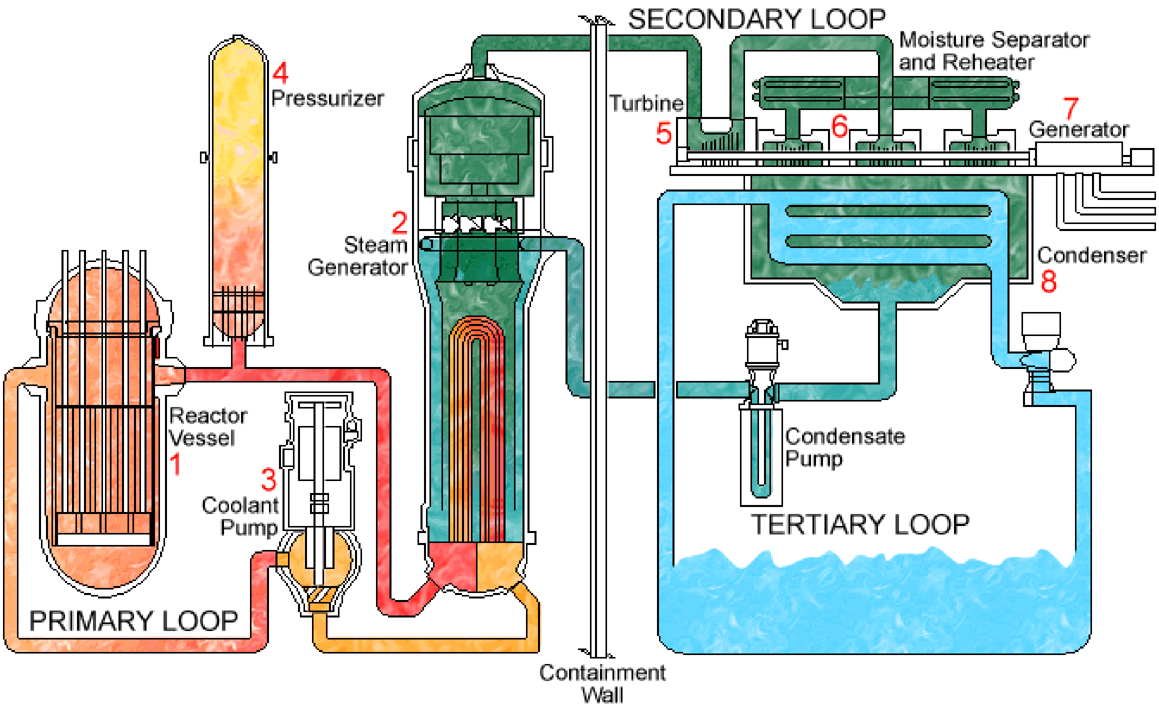

Figure 3: Conceptual diagram of KNPS

There are various contributing factors which influences the volume and characteristics of the effluent generated at KNPS. One of these factors is the operational state of each of KNPS units (KNPS has two units). The operational states are described as:

1. Reactors operating at full power - this state infers the units operate at full capacity and routine effluent discharges are made during this period;

2. Reactor power changes and shutdown - where the power output of one or both units is increased or decreased which may require a non-routine or exceptional effluent discharge; and

3. Outages and/or plant maintenance, where one unit is shut down at a time for refuelling and/or routine maintenance. During this state cooling water continues to be pumped through the unit, and again may require a non-routine/exceptional effluent discharge. An additional impact of this state is that the compliment of workers present on site increases substantially. The duration of this operational state is 1- 3 months. Each reactor unit is refuelled once every 18 months in a staggered approach such that one reactor unit is being refuelled every 9 months.

4.1.1 The Primary Loop

The water contained in this loop is pressurised and enclosed within the reactor building / nuclear island. The loop entails the reactor core and cooling loops, each containing a reactor coolant pump and a steam generator. The pressurised water extracts the heat generated within the reactor vessel, and is then passed through the steam generators' cooling loops, after which the heat is transferred to the water of the secondary loop.

4.1.2 The Secondary Loop

The water contained in this loop is separate of the primary loop. This system is mainly located within the turbine hall / conventional island, where it supplies steam to the turbo generator. The evaporated water generated in the steam generator drives a turbine coupled to the generator which in turn produces electricity. Once the steam leaves the turbine, it is cooled and returned to its liquid state in the condenser and finally returned to the steam generator.

4.1.3 The Tertiary Loop

Again, this loop is separate from the above-mentioned loops. This loop circulates seawater for the purposes of cooling the condenser and unlike the other loops is an open system (i.e. circulates abstracted water once-through and is directly discharged to the sea).

4.2 About the Effluent

There are various systems located within the three (aforementioned) loops which produce effluent that is discharged off-site. For the purposes of this application, the focus of this report and supporting specialist studies remain on systems which generate non-radiological, liquid effluent.

However, because few of these systems (i.e. SEK and KER) also discharge radionuclides, and to ensure a comprehensive study, the heavy metals contained in the discharge has been included in the specialist studies conducted. The regulations pertaining radiological effluent discharge is discussed in section 2.3.3, the characterisation discussed in section 4.3.15, and the assessment thereof in section 6.2.

Please refer to section 2.2 for the bases of the exclusion of radiological effluent from this application.

The following discharge systems have been identified and are discussed below.

- Sources of effluent related to the Tertiary System:
  - The Main Circulating Water System (CRF);
  - The Essential Service Water System (SEC).
- Sources of effluent related to the Secondary System:
  - The Secondary Releases System (SEK) (note this system is common to both the secondary and primary loops);
  - The Electrical Building Ventilation System (DEL);
  - The Auxiliary Boiler Plant System (XCA);
  - The Demineraliser Plant Sumps System (SDX);
  - The Demineralised Water Production Plant (SDA);
  - Reverse Osmosis Plant (SRO/BWRO);
  - The Chlorination Plant System (CTE); and
- Sources of effluent related to the Primary System:
  - The Radiological Effluent Discharge System (KER).

In addition to the above, there are systems which operate separately from the systems associated with energy production, these are listed as follows:

- The Waste Water Treatment Works (WWTW) (SEU);
- Ground water desalination plant (SRO/BWRO) and sea water desalination plant (SWRO); and
- The Storm Water System (SEO).

The bulk of these mentioned systems discharge to the KCWOB, however due to the engineering design of the plant few of these systems discharge to the KCWIB. As discussed in section 3.1.1, this discharge point is considered insignificant, however the characteristics of the effluent have been included in this report and the potential impact these constituents may have on the environment have been assessed in the relevant specialist studies.

An overview of these systems or effluent sources is provided in the tables below. Systems have been grouped together according to whereto the discharge is released. Furthermore, it should be noted that many of the above listed systems are upstream of the main discharge systems.

Table 5: Effluent sources from KNPS discharged into the KCWOB

Waste Stream	Main Effluent Discharge System	Brief Overview of Discharge and source (i.e. systems upstream)
A	The Main Circulating Water System (CRF) (as highlighted in **blue**, Figure 4)	Return of abstracted seawater/cooling water, which is characterised as heat-sink and may contain residual free chlorine resulting from dosing with biocide. This source is the most significant discharge in terms of volume, ranging from 81 972 - 327 888 m^3/h depending on plant configuration.
B	The Essential Service Water System (SEC) (as highlighted in **red**, Figure 4)	Return of abstracted seawater/cooling water from the nuclear island/primary loop, which is characterised as heat-sink and may contain residual free chlorine resulting from dosing with biocide. This source is the second most significant discharge in terms of volume, average of 12 700 m^3/h depending on plant configuration.
C	The Secondary Releases System (SEK) (as highlighted in **green**, Figure 4).	Industrial effluent from operations within the conventional island/secondary loop. Upstream systems include: ▪ ATE; ▪ APG. Although this system is mainly a non-radiological effluent system, it also contains radiological effluent which is included in this application.
D	Radiological Effluent Discharge System (KER) (as highlighted in **pink**, Figure 4).	Industrial effluent from operations within the nuclear island/primary system. Although this system is a radiological effluent system, it also contains non-radiological effluent which is included in this application.
E	The Waste Water Treatment (SEU) and Stormwater System (SEO-S) (as highlighted in **yellow**, Figure 4)	Treated domestic effluent (SEU) from operations within the wastewater treatment works. The WWTW receives sewage and grey water from across KNPS. Stormwater collected from the southern half of the plant. Upstream systems include: ▪ Industrial effluent from Unit 2's Electrical Building Ventilation System (DEL).
F	The ground water desalination effluent (SRO/BWRO) and sea water desalination effluent (SWRO) (as highlighted in **blue** and **yellow**, Figure 4).	Effluent from filter backwashing, brine from reverse osmosis membranes and chemicals associated with water treatment. This includes water production for the plant as well as excess water produced for the City of Cape Town supply. The SRO/BWRO effluent will be discharged via SEO-S or the CRF outfall, while the SWRO will be discharged via the CRF outfall.

Section 3.1.1 mentions systems which discharge via the KCWIB, an overview of these are provided in the table below.

Table 6: Effluent sources from KNPS discharged into the KCWIB

Waste Stream	Effluent Source	Brief Overview
G	The Northern Stormwater System (SEO-N)	Stormwater collected from the northern half of the plant. Upstream systems include: Industrial effluent from Unit 1's Electrical Building Ventilation System (DEL); ▪ Industrial effluent from operations within the auxiliary boilers plant (XCA); ▪ Industrial effluent from operations within the demineraliser plant (i.e. sumps [SDX] and filters [SDA]); and ▪ Industrial effluent from operations within the chlorination plant (CTE).

Flow from the circulating water system is the largest ranging from 81 972 - 327 888 m^3/h depending on plant configuration, followed by the essential water system (12 700 m^3/h), with the rest of the effluent sources contributing minor volumes (<400 m^3/h)[13] in comparison to the aforementioned.

4.3 Simplified Description of the Systems / source of effluent at KNPS

4.3.1 The Main Circulating Water System (CRF)

This cooling water system is independent of the primary and secondary loops, and is an open (or once through) system.

The CRF system's main purpose is to act as a heat exchanger by providing cooling water to the main condenser and to remove excess heat produced by the steam generators, which cannot be re-used by the system. A complex system within the turbine hall maximises the energy that can be recovered from the steam which in turn minimises the amount of heat that cannot be recovered. The discharged water therefore has a higher temperature (~11 ºC) than that abstracted.

In addition to heat, the CRF cooling water discharged contains residual oxidants as a result of chlorination, which is used to prevent biofouling. The abstracted water that is used for cooling purposes contains a range of entrained species, including both micro and macro-organisms (such as biofilms and juvenile mussels, respectively). The build-up of these species could reduce the efficiency of the condenser or cause damage. Therefore, the dosing of sodium hypochlorite has been introduced as an abatement measure to prevent biofouling within KNPS plant systems.

[13] PRDW, 2017 (Table 4-1: Summary of flow scenarios).

KNPS has two reactor units each requiring its own independent pump trains, in addition each unit is provided with a stand-by pump with the same characteristics as the main operating pumps (i.e. with a mean flow rate of 81 972 m^3/h).[6] The CRF discharge is shown in Figure 4, depicted in blue.

In a non-routine event (such as the trip of one CRF pump) the ΔT in the second train of the unit may increase from ~11 ºC to ~22 ºC. It is predicted that the duration of this state is ~12 hours, i.e. estimated time required for the stand-by pumps to kick-in and reach full operation.

Table 7 presents the characterisation of the CRF discharge during operation at full capacity, during refuelling outages and during an accidental pump trip.

Table 7: Characterisation of CRF discharges (source: PRDW, 2017)

Parameter	Unit	Value		
		Full capacity: 2 Units CRF	Refuelling Outage: 1 Unit CRF	1 Unit CRF, 1 Pump Trip
Discharge	m^3/h	327 888	163 944	81 972
Duration	h	Continuous	Continuous	12
Frequency	-	-	-	Abnormal conditions
ΔT	°C	11.7	11.7	22.7
Free Chlorine	mg/kg	0.5	0.5	0.5
Bromoform	mg/kg	0.05(1)	0.05(1)	0.05(1)

1) Bromoform is expected to be formed as a by-product of the chlorination of seawater.

4.3.2 The Essential Service Water System (SEC)

The SEC system's main purpose is to provide cooling water to, and in addition has a safety function within, the nuclear island. As indicated above, the loops are operated independent of each other mostly for safety reasons.

Similar to the CRF system, seawater is abstracted from the intake basin and is dosed with chlorination to prevent biofouling. However, the SEC system is subject to routine shock chlorination and therefore experiences variability in free chlorine concentrations above that of normal levels experienced in the CRF system. The characterisation of the SEC discharge is provided in the Table 8.

The SEC discharge is shown in Figure 4, depicted in red. As indicated in Figure 4, the SEC system is discharged directly below the CRF trains, on the north-western wall of the KCWOB.

Table 8: Characterisation of SEC discharge (source: PRDW, 2017)

Parameter	Unit	Value	Value

Parameter	Unit	Value	Value		
			Full capacity: 2 Units CRF	Refuelling Outage: 1 Unit CRF	1 Unit CRF, 1 Pump Trip
Discharge	m^3/h	12 700	-	-	-
Duration	h	Continuous	-	-	-
Frequency	-	-	-	-	-
ΔT	°C	12	-	-	-
Free Chlorine	mg/kg	1	2[(1)]	8	Once per week
			25[(2)]	0.5	Once every 2 weeks
Bromoform	mg/kg	0.1[(3)]	-	-	-

1. Approximation of the variability in normal chlorine levels.
2. This characterisation of the shock chlorination is extremely conservative, since in reality only one of four SEC trains would be shock chlorinated at a time.
3. Bromoform is expected to be formed as a by-product of the chlorination of seawater.

4.3.3 The Secondary Releases System (SEK)

The SEK system is a tank receiving system designed to collect, monitor and discharge liquid effluent produced both within the conventional island and as a back-up discharge and storage system to the nuclear island. Although this system is mainly a non-radiological effluent system, it also contains radiological effluent which is included in this application. The main non-radiological contaminants include phosphate used in closed cooling water systems, ammonia, ETA and hydrazine which is used to condition systems for corrosion protection. Finally, the SEK system is also used to discharge chemicals used for regenerating ion exchange media.

During normal operations, the SEK system is designed to bypass the SEK collection tanks and discharges continuously to the KCWOB. As a safety measure the bypass line is fitted with volume/flow counters and in instances where the pre-determined radioactive threshold (as prescribed by the NNR AADQ limits) is exceeded, the discharge is automatically diverted to the SEK collection tanks. Here the effluent is monitored; measured and not discharged from the tanks, until the cause of the abnormal condition is remedied.

The SEK discharge is shown in Figure 4, depicted in green. As indicated in Figure 4, the SEK system is discharged directly into the CRF trains, at the northern end of the KCWOB.

Note that the radiological release from this system is regulated by the NNR and does not form part of this application.

The discharge rate from the SEK collection tanks are either 300 m^3/h or 20 m^3/h (depending on which pump is used). During normal operations (i.e. via the bypass line) the discharge rate may also vary, however the maximum rate is 80 m^3/h per pump (three pumps).

The characterisation of the SEK discharge is provided in the Table 9. These releases may occur during plant operation at full capacity or during refuelling outages.

Table 9: Characterisation of the SEK discharges (source: PRDW, 2017)

Parameter	Unit	Value	Abnormal Value
Discharge	m^3/h	80	300
Duration	h	6	-
Frequency	-	Daily	-
Temperature	°C	55	-
pH	-	5.0 – 11.7	-
Total Suspended Sediment (TSS)	mg/kg	75	-
Hydrazine	mg/kg	0.2	-
Ammonia	mg/kg	20	100(1)
Ethanolamine	mg/kg	6	-
Phosphates	mg/kg	550(3)	-
Nitrates	mg/kg	15	-
Nitrites	mg/kg	3	-
Aluminium	mg/kg	2	-
Copper	mg/kg	0.04	-
Chromium	mg/kg	2	-
Iron	mg/kg	0.2	-
Manganese	mg/kg	0.2	-
Nickel	mg/kg	2	-
Lead	mg/kg	1.5	-
Zinc	mg/kg	1	-
Sulphate	mg/kg	8 000	-
Sodium	mg/kg	4 000	-
Detergents – Linear Alkylbenzene Sulfonate (LAS)	mg/kg	7(2)	-
Detergents – Alcohol Ethoxysulfates (AES)	mg/kg	280(2)	-
Detergents – Alcohol Ethoxylates (AE)	mg/kg	35(2)	-
Biochemical Oxygen Demand (BOD)	mg/kg	568	-
Chemical Oxygen Demand (COD)	mg/kg	1410	-
Oil/grease	mg/kg	154	-

1. The abnormal ammonia value corresponds to the upper pH limit. It has never occurred, but is possible.
2. Maximum allowable concentration not exceeding the relevant ecological guideline at the end of the KCWOB.
3. The phosphate releases occur only during outages, daily for three days.

In addition to the aforementioned discharges, exceptional hydrazine releases from the draining of vessels under wet-layup occur via SEK during refuelling outages. During normal operational state, the discharge (via the bypass line) is at a maximum discharge rate of 80 m^3/h per pump (3 pumps). During refuelling outages, the steam generators under layup conditions are drained with high levels of hydrazine at 60 m^3/h. The secondary feed train and condenser may also be drained in outages when under high hydrazine concentration layup conditions at varying flow rates.

Depending on the concentration of the SEK tanks; discharges from the SEK collection tanks (during exceptional/abnormal circumstances) can be pumped at a lower discharge rate of 20 m^3/h when the hydrazine concentration is more than 50 mg/l. The discharge characterisation for both exceptional and normal operational releases is summarised in Table 10.

Table 10: Characterisation of exceptional SEK discharges (hydrazine discharges associated with outages) (source: PRDW, 2017)

Parameter		Unit	Value
Release 1	Discharge	m^3/h	80
	Duration	h	0.5
	Frequency	-	Daily
	Hydrazine	mg/kg	187.5
Release 2	Discharge	m^3/h	80
	Duration	h	1.67
	Frequency	-	Weekly
	Hydrazine	mg/kg	187.5

4.3.4 The Radiological Effluent Discharge System (KER)

Similar to the SEK system, the KER system is designed to collect (to three collection tanks), monitor the volume and radiological activity of effluent from the nuclear island, treat and then finally discharge should this effluent be to acceptable limits. The concentration of release to the environment depends on the radioactivity level of the effluent; the dilution capacity of the cooling water and the environment; and regulatory standards (NNR Standards).

KNPS also has treatment systems for effluent which contains radioactive contaminants, by means of at-source abatement techniques. The treatment systems are designed, depending on their specific function, to remove radioactive and non-radioactive contaminants from the primary loop and effluent prior to discharge to its collection tanks.

Although the KER system is mainly a radiological effluent system, it also contains non-radiological effluent. The main source of non-radiological contaminants includes boron (from boric acid used for reactivity control), phosphate used for controlling corrosion of closed-loop cooling circuits and laundry effluent. The release of non-radiological effluent may occur during normal operational state or during refuelling outages. The characterisation of the KER discharges is presented in Table 11. Although, the layup condition chemicals of the steam generators are drained to SEK (see above) it is possible, although not usually performed, to drain the steam generators to KER. Given that the KER discharge is at a lower flow rate than SEK, the SEK discharge will envelop KER in this case. For this reason, we have not added this scenario to Table 11.

Table 11: Characterisation of the KER discharges (source: PRDW, 2017)

Parameter	Unit	Value
Discharge	m^3/h	25
Duration	h	5
Frequency	-	Once every 2 days
Temperature	°C	55
pH	-	5.0 – 11.7
Total Suspended Sediment (TSS)	mg/kg	150
Boron	mg/kg	188
Lithium Hydroxide	mg/kg	3.5
Phosphates	mg/kg	1 250(3)
Detergents – Linear Alkylbenzene Sulfonate (LAS)	mg/kg	63
Detergents – Alcohol Ethoxysulfates (AES)	mg/kg	280
Detergents – Alcohol Ethoxylates (AE)	mg/kg	250
Aluminium	mg/kg	2
Copper	mg/kg	0.2
Chromium	mg/kg	2
Iron	mg/kg	2
Manganese	mg/kg	0.2
Nickel	mg/kg	2
Lead	mg/kg	1.5
Zinc	mg/kg	1
Ethylenediaminetetraacetic acid	mg/kg	1 500

Parameter	Unit	Value
(EDTA)		
Citric Acid	mg/kg	3 000
Zinc Acetate as Zinc	mg/kg	0.005
Total Zinc	mg/kg	1
Chemical Oxygen Demand (COD)	mg/kg	1 410
Biochemical Oxygen Demand (BOD)	mg/kg	568
Oil/grease	mg/kg	154
Nitrates	mg/kg	15
Nitrites	mg/kg	3
Ammonia	mg/kg	18

1. The phosphate releases occur only during outages and are limited to two releases, two days apart.

The KER discharge is shown in Figure 4, depicted in pink. As indicated in Figure 4, the discharges from KER are released directly into the CRF train at the northern end of the KCWOB.

In addition to normal operational discharges an exceptional boron release occurs approximately five times per year, the exceptional release is characterised in Table 12.

If required, KER effluent can be released via SEK but this is highly unusual. Should this occur, the concentrations in Table 11 will be adjusted in proportion to the discharge rate to that of the concentrations in the final CRF effluent.

Table 12: Characterisation of exceptional Boron releases via KER (source: PRDW, 2017)

Parameter	Unit	Value
Discharge	m^3/h	25
Duration	h	13.5
Frequency	-	5 times per year
Boron	mg/kg	2 700

4.3.5 The Waste Water Treatment and Storm Water System (SEU)

The existing WWTW receives domestic sewage and grey water from various sources across the plant. The wastewater then undergoes secondary treatment via an activated sludge system, which includes an aeration tank without a dedicated anoxic zone. The treated effluent is further sanitized with chlorine prior to mixing with the CRF cooling water, further diluting the discharge. This final effluent stream meets the statutory water quality standards (refer to Water Permit and Exemption, Appendix A:).

The SEU discharge is shown in Figure 4, depicted in yellow. The SEU system discharges into the SEO-S system, before it is discharged directly below the CRF trains on the south-eastern wall of the KCWOB.

The WWTW is designed to accommodate a peak flow of 28 m^3/h. The characterisation of the SEU discharge is presented in Table 13.

Table 13: Characterisation of SEU discharges (source: PRDW, 2017)

Parameter	Unit	Value
Discharge	m^3/h	28
Duration	h	Continuous
Frequency	-	-
Temperature	°C	20
pH	-	4.5 – 9.5
Total Suspended Sediment (TSS)	mg/kg	90
Ammonia (NH3-N)	mg/kg	60
Free Chlorine	mg/kg	5
Chemical Oxygen Demand (COD)	mg/kg	140
Biochemical Oxygen Demand (BOD)	mg/kg	65
Faecal Coliforms	Counts/100 ml	1 000
Detergents – Linear Alkylbenzene Sulfonate (LAS)	mg/kg	20
Detergents – Alcohol Ethoxysulfates (AES)	mg/kg	95
Detergents – Alcohol Ethoxylates (AE)	mg/kg	85

4.3.6 The Unit 2 Electrical Building Ventilation System (DEL)

The DEL system provides ventilation to unit 2's electrical equipment and components housed in the electrical building. This system is a closed water-filled pressurised system, which uses compressed refrigeration gas to maintain temperatures. This system is also dosed with phosphate to prevent the various system components from corrosion. Any leaks or draining of this system for maintenance purposes is discharged to the SEO-S system, before it is discharged directly below the CRF trains on the south-eastern wall of the KCWOB. The characterisation of Unit 2 DEL discharges is presented in Table 14.

Table 14: Characterisation of Unit 2 DEL discharges (source: PRDW, 2017)

Parameter	Unit	Value
Discharge	m3/h	20
Duration	h	2
Frequency	-	Once per year during an outage of Unit 2
Phosphate	mg/kg	1 250

4.3.7 The Desalination Plants

4.3.7.1 Reverse Osmosis Plant (SRO) / Brackish Water Reverse Osmosis Plant (BWRO)

KNPS has an existing, but disused ground water reverse osmosis plant (SRO) system which is being replaced by a brackish water reverse osmosis plant (BWRO), as an alternative freshwater source for the plant.

The BWRO will be designed to produce up to ~75 m^3/h (i.e. ~1.8 ML/day) of freshwater for use at the power station. Due to the current drought conditions experienced in the region, it is proposed that a temporary BWRO plant will be installed with the intention of a permanent plant constructed and operational in 2018.

The BWRO system will extract brackish groundwater from the Atlantis aquifer, and prior to treatment the abstracted water will be pre-treated to remove suspended solids and metals by means of filtration. The pre-treatment process includes oxidation of metals (Al, Fe and Mn), dosing of coagulants (e.g. ferric chloride) and filtration. Both the pre-treatment and treatment processes produces brine and process effluent which will be discharged directly into the CRF system either upstream of the condensers or downstream of the condensers in the KCWOB or both.

The characterisation of the BWRO effluent (pre- and post-treatment) has been estimated from the characteristics of similar facilities,[14] and the discharge is presented in

[14] PRDW, 2017; Lwandle, 2017; Pulfrich & Steffani, 2014; Van Ballegooyen, et al., 2007; and CSIR, 2016.

Table 15 and Table 16. The constituents of the BWRO discharge are not considered to pose any significant environmental risks and has been screened from further analysis, in addition the dispersion plume resulting from the discharge is considered to be negligible.[15]

[15] PRDW, 2017 (refer to Table 4-10 and Table 4-11).

Table 15: Characterisation of BWRO plant discharge (source: PRDW, 2017)

Parameter	Unit	Value
Produced freshwater	m3/h	75
Recovery rate	-	0.75 to 0.85
Feed water	m^3/h	100(1)
Discharge	m^3/h	25(1)
Temperature	ºC	20
Salinity	psu	15(2)
Nitrite (NO_2)	mg/l	7.33
Nitrate (NO_3)	mg/l	9.33
Silica (SiO_2)	mg/l	66
Sulphates	mg/l	2500
Phosphonate antiscalant	mg/l	31.3(3)
Chlorine	mg/l	0.002 – 0.1(4)
Sodium metabisulphate(5)	mg/l	3
Peroxyacetic acid	mg/l	1.55
Low pH cleaner	mg/l	4.13
High pH cleaner	mg/l	4.13
Total residual dibromonitrolopropionamide (DBNPA) (6)	mg/l	1.15 - 2.475(7)

1. Maximum value (based on minimum recovery rate of 0.75).
2. Maximum salinity during discharge of Cleaning In Place (CIP) effluent.
3. Based on the maximum recovery rate of 0.85 and a dose rate of 4.7 mg/l into the feed
4. Usually low because of reactions with sodium bisulfate (neutralised). A maximum value of 0.1 mg/l was assumed in (Van Ballegooyen, et al., 2007).
5. For the neutralisation of chlorine. May lead to reduction of dissolved oxygen if overdosed.
6. Alternative to chlorine.
7. (Van Ballegooyen, et al., 2007).

Table 16: Characterisation of BWRO plant pre-treatment discharge (source: PRDW, 2017)

Parameter	Unit	Value
Discharge(1)	m^3/h	40
Temperature	°C	20
Aluminium	mg/l	32
Iron	mg/l	22
Manganese	mg/l	5.5
Total Suspended Solids (TSS)	mg/l	400
Total Organic Carbon (TOC)	mg/l	150
Coagulant: Ferric Chloride (as Fe)(2)	mg/l	20.6
Ferric Chloride (as $Fe(OH)_3$)	mg/l	39.4
Anionic Polymer(3)	mg/l	3

1. Discharge expected to occur for approximately 6 minutes every hour.
2. Ferric Chloride (FeCl3) will precipitate into Ferric Hydroxide, which will contribute to the TSS of the discharge. The Ferric Hydroxide may cause a discolouration of the pre-treatment effluent.
3. Alternative to Ferric Chloride.

4.3.7.2 Seawater Reverse Osmosis Plant (SWRO)

In addition to the BWRO, the City of Cape Town Metropole Municipality has identified KNPS precinct for the installation of a seawater reverse osmosis plant (SWRO), which will serve as an alternative water source for the city.

The SWRO will be designed to produce up to 20 ML/day. The plant will extract seawater from the KNPS intake basin, while the effluent will be discharged directly into the CRF system either upstream of the condensers or downstream of the condensers in the KCWOB or both.

The characterisation of the SWRO effluent has been estimated from the characteristics of similar facilities,[16] and the discharge is presented in Table 17. The constituents of the SWRO discharge are not considered to pose any significant environmental risks and has been screened from further analysis, in addition the dispersion plume resulting from the discharge is not considered to be significant.[17]

Table 17: Characterisation of SWRO plant discharge (source: PRDW, 2017)

Parameter	Unit	Value
Produced freshwater	m3/h	833
Feed water	m^3/h	2 083(1)

[16] PRDW, 2017; Lwandle, 2017; Pulfrich & Steffani, 2014; Van Ballegooyen, et al., 2007; and CSIR, 2016.
[17] PRDW, 2017 (refer to Table 4-10 and Table 4-11).

Parameter	Unit	Value
Brine Discharge	m^3/h	1 250[(2)]
Salinity	psu	665[(3)]
Increase in temperature (ΔT)	°C	2
pH	-	7.3-8.2
Suspended Solids	mg/l	11.76
Coagulant: Ferric Chloride (as Fe)[(4)]	mg/l	3.33
Coagulant: Ferric Chloride (as Fe(OH)3)[(4)]	mg/l	6.37
Total Suspended Solids	mg/l	18.04(5)
Phosphonate antiscalant	mg/l	4.7[(6)]
Chlorine	mg/l	0.002 – 0.1[(7)]
Sodium metabisulphate[(8)]	mg/l	3.14
Peroxyacetic acid	mg/l	1.55
Low pH cleaner	mg/l	4.13
High pH cleaner	mg/l	4.13
Total residual dibromonitrolopropionamide (DBNPA) [(11)]	mg/l	1.15 - 2.475[(12)]
Anionic polymer (alternative to Ferric Chloride)	mg/l	1.67

1. Assuming 40% of feedwater is converted to freshwater.
2. Assuming 60% of feedwater is discharged as brine.
3. An intake salinity of 35 psu and a freshwater recovery of 40% results in a brine salinity of 58.3 psu. A brine salinity of 66 psu is thus conservative and takes into account variations in the intake salinity and variations in the concentration of the brine.
4. Ferric Chloride (FeCl3) will precipitate into Ferric Hydroxide, which will contribute to the TSS of the discharge. The concentrations presented here assume that the pre-treatment effluent is blended with the brine. The Ferric Hydroxide may cause a discolouration of the pre-treatment effluent. Options to limit the metal discharges in the filter backwash effluent shall be considered. If found to be necessary, these options may include a Dissolved Air Floatation system or diversion of the primary filter backwash for clarification and sludge disposal.
5. Including Ferric Hydroxide precipitant.
6. Typically dosed into feedwater at 3 mg/l which results in ~5 mg/l in effluent.
7. Usually low because of reactions with sodium bisulfate (neutralised). A maximum value of 0.1 mg/l was assumed in (Van Ballegooyen, et al., 2007).
8. May lead to reduction of dissolved oxygen if overdosed.
9. Generally sulphuric acid. Effect would be reduction in pH, therefore pH guidelines apply.
10. Alkaline cleaner. Effect would be on pH, therefore pH guidelines apply.
11. Alternative to chlorine.
12. (Van Ballegooyen, et al., 2007)
13. SA Water Quality Guideline suggests values between 0.035 – 0.07 mg/l.

4.3.8 The Stormwater System – South Side (SEO-S)

The SEO-S system drains stormwater from across the southern half of the plant. Stormwater is also collected from various buildings which introduces the possibility of hydrocarbon contamination. The operational practice dictates the water is directed to an oil skimmer or weir where a filter is used to skim off all the oil, after which the resulting effluent is discharged to the KCWOB. The remaining oil fraction that has been separated is sent for final disposal at an appropriately licenced waste management facility. In addition, in the areas where hydrocarbons are used the drainage systems are segregated from the stormwater drainage systems, which also reduce the possibility of contamination. During normal operational state, the effluent released from this system is essentially uncontaminated stormwater and treated effluent from the WWTW (SEU).

In exceptional circumstances or during outages, the Unit 2 DEL system (as discussed above) is drained into the SEO-S system. The characterisation of this discharge is therefore presented in Table 14. Furthermore, the SEO-S system is also used for the draining of the SEU system, the characterisation of which is presented in Table 13. The SEO-S discharge is shown in Figure 4, depicted in yellow. The SEO-S system discharges directly below the CRF trains on the south-eastern wall of the KCWOB.

4.3.9 The Auxiliary Plant System (XCA)

In exceptional circumstances, should both reactors be shut down and steam is required for plant start-up and de-aeration of feed water, one of the three auxiliary boilers is required to produce steam. These are conventional diesel fired boilers with three modes of operation, namely steam production; stand-by and shutdown. In a means of preventing corrosion, the boilers are dosed with ammonia to increase pH and hydrazine for oxygen scavenging.

As the boilers spend most of the time in shutdown mode, they are periodically started up for maintenance purposes and kept in stand-by mode when one or both reactors are shut down. A change in the operational state of KNPS will result in a change to the boiler water levels which in turn will result in an effluent release from the XCA system to the SEO-N system.

The characterisation of XCA discharges is presented in Table 18.

Table 18: Characterisation of XCA discharges (source: PRDW, 2017)

	Parameter	Unit	Value	Abnormal Value
Release 1	Discharge	m^3/h	60	-
	Duration	h	0.42	-
	Frequency	-	Monthly	-
	Temperature	°C	60	-
	Ammonia	mg/kg	15	100(1)
	Hydrazine	mg/kg	300	-
	Total Suspended Sediment	mg/kg	10	-

	Parameter	Unit	Value	Abnormal Value
	(TSS)			
	pH	-	7.5 to 10.5	-
	BOD	mg/kg	100	
	COD	mg/kg	800	-
Release 2	Discharge	m^3/h	60	-
	Duration	h	1.17	-
	Frequency	-	Once per outage	-
	Temperature	°C	20	
	Ammonia	mg/kg	15	
	Hydrazine	mg/kg	300	-
	Total Suspended Sediment (TSS)	mg/kg	10	
	pH	-	7.5 to 10.5	
	COD	mg/kg	800	-
	BOD	mg/kg	100	

1. The abnormal ammonia value corresponds to the upper pH limit. This level is not reached during normal operation, but could occur approximately once per year.

4.3.10 The Chemical Effluents System (SDX)

It is a requirement of nuclear power plants to have access to almost pure water, as this type of water helps to limit deposits within the various system components. KNPS has an onsite demineraliser plant which provides demineralised water to the plant. The SDX system consists of carbon filters and ion exchange resins. The effluent produced from this system consists of filter backwashing and ion exchange regeneration. Sulphuric acid and sodium hydroxide are used within this SDX system to regenerate ion exchange media, which after neutralisation generates quantities of sulphate and sodium as an effluent. The characterisation of SDX discharges is presented in Table 19.

Table 19: Characterisation of SDX discharges (source: PRDW, 2017)

Parameter	Unit	Value
Discharge	m^3/h	400
Duration	h	1
Frequency	-	Twice per week
Temperature	°C	20
pH	-	7.5 – 9.5

Parameter	Unit	Value
Total Suspended Sediment (TSS)	mg/kg	60
Sulphate	mg/kg	8 000
COD	mg/kg	90
BOD	mg/kg	12
Sodium	mg/kg	4 000

The SDX system discharges via the SEO-N system into the KCWIB.

4.3.11 The Demineralised Water Production Plant (SDA)

Similar to the SDX system, the SDA system is contained within the demineraliser plant. The SDA system however consists of active charcoal filters before the ion exchange resins. Aluminium sulphate is injected as a flocculent prior to this filter.

The effluent produced from this system consists of filter backwashing, aluminium and solids concentrated from the potable water feed. The characterisation of SDA discharges is presented in Table 20.

Table 20: Characterisation of SDA discharges (source: PRDW, 2017)

Parameter	Unit	Value
Discharge	m^3/h	100
Duration	h	1
Frequency	-	Weekly
Temperature	°C	20
Aluminium Sulphate	mg/kg	150
COD	mg/kg	240
BOD	mg/kg	30
Total Suspended Sediment (TSS)	mg/kg	80

The SDA system discharges via the SEO-N system into the KCWIB.

4.3.12 The Chlorination Plant (CTE)

The CTE system is used for the dosing of cooling water (CRF and SEC) with chlorination as a mitigation measure to prevent biofouling. The CTE system is designed to produce sodium hypochlorite by using electrolysers in sufficient quantities to ensure the CRF and SEC discharge water contains excess free chlorine. The system also uses hydrochloric acid to clean system electrolysers on a regular basis. The acid is neutralised with sodium hydroxide producing sodium chloride and some un-neutralised acid or sodium hydroxide prior to release. The characterisation of CTE discharges is presented in Table 21.

Table 21: Characterisation of CTE discharges (source: PRDW, 2017)

Parameter	Unit	Value
Discharge	m^3/h	6
Duration	h	2
Frequency	-	Monthly
Temperature	°C	20
pH	-	7.5 – 9.5
Chloride	mg/kg	120 000
Total Suspended Sediment (TSS)	mg/kg	5
Sodium	mg/kg	80 000
Salinity	psu	200

The CTE system discharges via the SEO-N system into the KCWIB.

4.3.13 The Unit 1 Electrical Building Ventilation System (DEL)

The DEL system provides ventilation to unit 1's electrical equipment and components housed in the electrical building. This system is a closed water-filled pressurised system, which uses compressed refrigeration gas to maintain temperature. This system is also dosed with phosphate to prevent the various system components from corrosion. Any leaks or draining of this system for maintenance purposes is discharged via the SEO-N system, into the KCWIB. The characterisation of Unit 1 DEL discharges is presented in Table 22.

Table 22: Characterisation of Unit 1 DEL discharges (source: PRDW, 2017)

Parameter	Unit	Value
Discharge	m^3/h	20
Duration	h	2
Frequency	-	Once per year during an outage of Unit 1
Phosphate	mg/kg	1 250

4.3.14 The Stormwater System – Northern Side (SEO-N)

The SEO-N system drains stormwater from across the northern half of the plant. Stormwater is also collected from various buildings which introduces the possibility of hydrocarbon contamination. Similar to SEO-S oil skimmers or weirs are used as a mitigation measure. In addition, the areas where hydrocarbons are used the drainage systems are segregated from the stormwater drainage systems, which also reduce the possibility of contamination.

The SEO-N system collects uncontaminated stormwater and the various effluent discharges from the XCA, SDX, SDA, CTE and the unit 1 DEL systems before discharge to the KCWIB. The characterisation of the discharges is therefore presented in Table 18 to Table 22.

4.3.15 The Radiological Releases

Only the SEK and KER systems produce radiological effluent releases from KNPS. This section has been included for information purposes only.

The dispersion of radionuclides and their accumulation in seabed sediment have been modelled by PRDW[6], while the radiological impact on marine biota have been modelled by Eskom using the ERICA tool (refer to section 6.1).

The characterisation of the radiological releases is therefore presented in Table 23.

Table 23: Annual load of radionuclides released at KNPS

Element	Radionuclide	Annual Load [Bq/y]
Silver (Ag)	Ag-110m	1.28E+09
Carbon (C)	C-14	2.05E+10
Cobalt (Co)	Co-58	5.10E+09
	Co-60	1.62E+09
Caesium (Cs)	Cs-134	5.18E+08
	Cs-137	1.26E+09
Iron (Fe)	Fe-55	1.15E+10
Hydrogen (H)	H-3	4.14E+13
Iodine (I)	I-131	1.06E+08
Manganese (Mn)	Mn-54	2.29E+08
Nickel (Ni)	Ni-63	1.54E+10
Tellurium (Te)	Te-123m	5.18E+08

4.4 Simplified Overview of the final discharge - KCWOB

An overview of the various effluent streams discharged into the KCWOB is presented in Figure 4 and a simplified description of the source provided in section 4.3.

Figure 4: Layout of effluent streams released into the KCWOB (source: PRDW, 2017)

For each reactor unit (KNPS has two), the CRF cooling water infrastructure comprises of the KCWIB (universal for all systems), the Forebay, and Pumping Station. From the Forebay the seawater is transported to the Pumping Station after which the water is dosed with sodium hypochlorite. Once the water has been used, it is transported to the outfall basin via an onshore outflow pipe which terminates at the northern end of the KCWOB. As mentioned above the CRF cooling water dominates the effluent produced from KNPS and is discharged via two 3 m diameter pipes with invert levels at -2.2 m CD.[6] There is a total of four CRF trains (2 per unit) equally spaced horizontally housed in a concrete structure.

For further details to hydraulic design refer to section 3.2.1 of the PRDW study (Appendix B:2).

4.4.1 The Key Buildings / Facilities where the discharge is generated

For the purposes of this application, the key buildings/facilities/structures of KNPS where effluent is generated have been grouped together, which are as follows:

- Nuclear Island Building(s) (refer to Figure 1);
- Turbine Hall and Auxiliary Building(s) (refer to Figure 1 and Figure 5); and
- Waste Water Treatment Plant (refer to Figure 5, ID No. 7).

Figure 5 provides a simplified overview of the various industrial systems which generates effluent at KNPS.

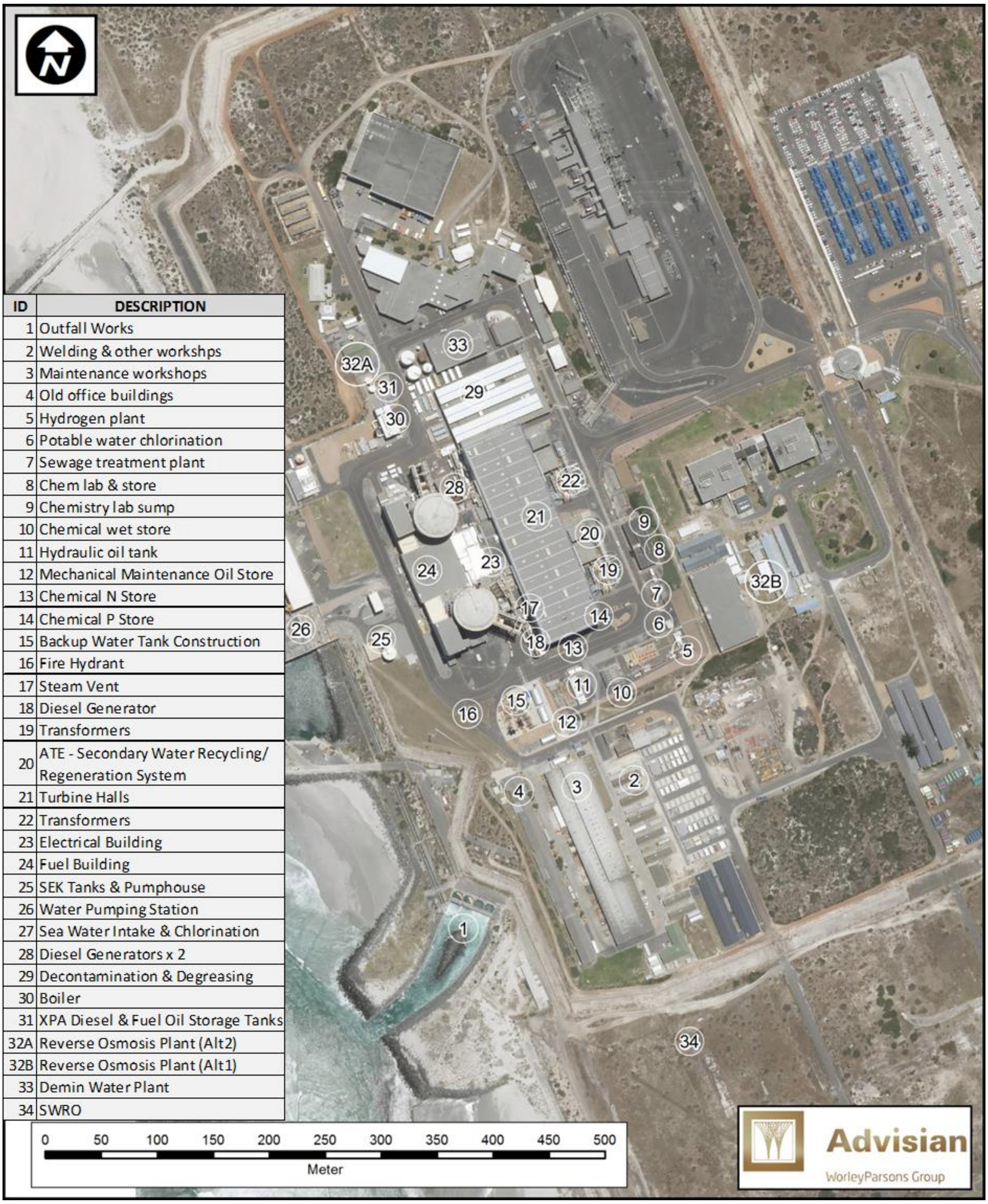

Figure 5: Simplified overview of the various industrial systems which generate effluent at KNPS.

5 POLLUTION ABATEMENT MEASURES IMPLEMENTED AT KNPS AND THE APPLICATION OF BAT FOR THE SELECTION OF THOSE MEASURES

This section defines the use of appropriate abatement measures for effluent discharge activities and the application of BAT for cooling water abstraction. This chapter is structured as follows:

- Application of the open cycle cooling water system;
- Consideration of all industrial and domestic effluent produced by KNPS against the waste minimisation hierarchy:
  - The possibility of avoiding discharge to coastal waters;
  - Process design and effluent treatment;
  - Re-use of water;
  - Selection of raw materials used within the processing systems;
  - Minimising the use of materials; and
  - Contamination prevention of effluents and surface water run-off.

5.1 Application of the Open Cycle Cooling Water Systems

5.1.1 Open Cycle Cooling Systems

The CRF and SEC systems provides cooling water to both the secondary and primary loops respectively; with SEC's main purpose being nuclear safety. Various site specific aspects particularly environmental constraints were taken into consideration with the design of KNPS as a coastal nuclear plant. Open cycle cooling is standard industry practice.

The main reasons for the selection of an open cycle cooling system were as follows:

- Closed cooling water systems with cooling towers have significant visual and noise impacts;
- Closed cooling water systems with seawater make-up require large-scale water treatment facilities and a desalination plant may be necessary due to the quality of water abstracted at KNPS. This design would require the disposal of large volumes of effluent water and waste, these releases have major operational and environmental implications;
- A closed cooling water system with a seawater make-up design is weather sensitive and thus the quality of water produced would be highly variable, this would have operational implications;
- Cooling water towers and a water treatment plant capable of handling the large volume of water abstracted, could require a very large footprint;
- The operating experience on coastal open circuits is far greater than on closed cooling systems.

The following negative environmental impacts are associated with open cycle cooling systems:

- Fish entrainment;
- Marine discharge thermal plume; and
- Discharge of chlorinated cooling water.

Nuclear operating experience recognizes these mentioned negative environmental impacts; however the design provisions developed within the industry indicates these impacts are considered minor in comparison to the challenges presented for closed systems.

5.2 Discharge Location Considerations

In any discharge scenario presented, the option of appropriate effluent treatment prior to discharge is considered the preferred environmental option. The alternative to discharging to coastal waters is discharging to a sewerage network system and final treatment at a municipal WWTW. The issue with this option is that there is no suitable municipal network connection capable of accepting and transporting the large volume of water discharged from KNPS. This is supported by the current arrangement of KNPS, where cooling water is discharged directly to the sea. In addition the plant uses an on-site WWTW before discharging treated effluent to coastal waters.

Furthermore, the nearest municipal WWTW is the Melkbosstrand which has a plant capacity of 5.4 Mℓ per day, where KNPS discharges at a minimum ~80 m^3/s (6 912 Mℓ per day) of cooling water. The construction of a suitable network and pumping such volumes of effluent to the WWTW would be prohibitively expensive. The Melkbosstrand WWTW discharges its treated effluent to the Berg and Dwars Rivers, which are in comparison to the Atlantic Ocean, far more sensitive receiving environments.

5.3 Nuclear Island Industrial Effluents

The following abatement measures are implemented to the nuclear island industrial effluent streams:

- The primary loop is a pressurised closed system where water is passed through a recycling plant which maximises the re-use of water, minimises water consumption and the generation of effluent. The recycling plant has an additional function of reducing the consumption of boric acid, which in turn minimises the release of boron;
- The primary loop's cooling water is dosed with chemicals to prevent corrosion of the plant, which results in the reduction of radioactive and non-radioactive metal releases;
- The various liquid effluent streams generated within the nuclear island are managed in a manner that prevents cross contamination with clean waste streams;
- Treatment of nuclear island effluent is optimised by treating at source, thus reducing radioactive and non-radioactive contaminants.

5.4 Conventional Island Industrial Effluents

5.4.1 Plant Design and Effluent Treatment

The following abatement measures are implemented to the conventional island industrial effluent streams:

- The secondary loop is a closed system and by means of the steam generator blowdown system maximises the re-use of water, minimising water consumption and the generation of effluent;
- The secondary loop's water is dosed with chemicals to prevent corrosion of the plant, which results in the reduction of radioactive and non-radioactive metal releases;
- This system is treated with filtered and demineralised water, therefore maximising recycling of water to the secondary loop and also produces a high quality effluent;
- The effluent generated may be contaminated with tritium, but is unlikely to contain other radioactive constituents. All effluent streams generated are isolated from each other, which prevents cross contamination prior to and post treatment;
- The effluent is collected in tanks when appropriate, and it is monitored, analysed and released only when the water is unsuitable for re-use. When in tank by-pass mode, the release is monitored but usually only after release due to its lower environmental risk than the KER system.

5.4.2 Raw Materials Used in the Secondary System

For corrosive protection, the secondary loop is dosed with ammonia and ethanolamine to control pH levels. Corrosion of plant may cause the following:

- Reduced efficiency of the plant, which ultimately impacts the receiving environment;
- Production reliability;
- Increased discharges of metals from the corroded material; and
- Reduces the life expectancy of the plant which leads to high replacement of parts and increased waste production.

In addition, feedwater is dosed with hydrazine, which acts as an oxygen scavenger and prevents the corrosion of metals within the steam generator. There are alternative chemicals available; however hydrazine is preferred as it does not bio-accumulate within the receiving environment and in fact tends to decompose in aquatic environments under certain environmental conditions.

5.5 Oily Water Treatment

The generation of oily water, or water contaminated with hydrocarbons is an operational hazard of the industry. The following abatement measures are implemented to reduce emissions and the associated impacts of this waste stream:

- Contaminated water is passed through an oil skimmer or weir where the oil is filtered off and the remaining clean water is discharged.

5.6 Demineraliser Plant Industrial Effluent

5.6.1 Plant Design

Abatement measures implemented within the demineraliser plant is an ion exchange system, which reduces emissions and associated impacts.

The following effluent is generated within the demineraliser plant:

- Ion exchange treatment results in discharges of sodium, sulphates and chlorides when the resins and membranes are regenerated and/or treated with sulphuric acid and sodium hydroxide; and
- The effluent produced in the plant is neutralised with either sulphuric acid or sodium hydroxide, which a final effluent discharge of sulphates and sodium.

5.7 Dosing of Cooling Water with Chlorine

5.7.1 Need for Chlorination

Dosing of the cooling water is essential to the maintenance of KNPS. The buildup of biofouling could reduce the overall efficiency of the plant, which may lead to an increase in environmental impacts such as the generation of radioactive waste, for every unit of electricity produced. Options in terms of biofouling are limited, and may include:

- The use of specific paints and coatings for anti-fouling; and
- Chemical dosing, usually with sodium hypochlorite.

The pros and cons of these options have been considered within the nuclear industry, and it found that the more effective types of paints and coatings which could be used for biofouling purposes contain substances which are particularly hazardous to the environment (e.g. tributyl). Therefore the more preferred is the use of chlorination dosing of the cooling water. KNPS prefers the chemical dosing approach as it is more effective in preventing the buildup of biofouling within its plant systems.

5.7.2 Chlorine Minimisation

The following approach is adopted for the minimisation of chlorine:

- Effective screening and cleaning are the first lines of defence. Screening and filtration help prevent the buildup of biofouling, but in addition to this cleaning of the systems will be required. Chemical dosing is only one fraction of the line of defense and will not be relied on solely. Dosing will be carried out in conjunction with screening and cleaning; and
- Chlorination frequency is closely linked to monitoring protocols for fouling, environmental monitoring of organisms in the receiving environment, examination of growth in the loops and in addition the monitoring of the condenser efficiency.

5.8 WWTW Effluent

The bulk (80%) of domestic effluent is routed to the Melkbosstrand WWTW but a small portion (20%) that may contain low levels of radioactivity is treated on-site.

The following abatement measures are implemented to reduce effluent and the associated impacts of this waste stream:

- The use of appropriate techniques which are proportionate to the risk associated with domestic effluent;
- The application of the waste hierarchy, specifically the isolation of the various drainage systems to ensure that uncontaminated surface water is not contaminated; and
- The implementation of appropriate monitoring, control and maintenance of the WWTW to ensure its effective operation.

5.9 Storm Water Drainage System

The following abatement measures are implemented to reduce emissions and the associated impacts of this waste stream:

- As mentioned above the various drainage systems at KNPS are segregated to ensure stormwater is not contaminated by domestic sewage or hydrocarbons;
- Generally, the stormwater system does not pass through the WWTW, which is an important measure for ensuring that the WWTW's is not adversely affected during periods of high rainfall;
- Uncontaminated stormwater runoff will not pass any other 'treatment facility' before its discharge to the KCWIB and KCWOB;
- In areas exposed to hazardous materials, containment techniques have been implemented such as bunding and kerbing. In addition oily water collected from these areas will pass through an oil-water interceptor before being discharged.

5.10 BWRO and SWRO Systems

The following abatement measures shall be implemented to reduce emissions and the associated impacts of this waste stream:

- The effluent stream flow rate in the BWRO effluent is restricted to 40 m^3/h in order to ensure that the ecological guidelines are met at the end of the KCWOB especially from filter backwashing activities.
- The iron content from the use of ferric chloride can increase iron loading and lead to an increase in turbidity. Blending of backwash effluent with the brine discharge will be considered and the use of alternatives to ferric chloride or sludge capture for solid waste disposal.

6 Environmental Impact and Risk Assessment

6.1 Radiological Effluent

As mentioned in section 2.2, the main focus of this application is on non-radiological effluent; however, for a holistic assessment of the potential impacts on the marine environment, an assessment of the radiological discharge on the marine environment has also been included for information purposes. The findings of this assessment are provided below.

6.1.1 Assessment of the Radiological Impact of normal operational discharges from KNPS on non-human species in the marine environment

Historically, it has been generally accepted that adequate protection of humans against radiation exposure will, on the whole, also ensure the adequate protection of non-human species. This widely held principle remained unchallenged, to some extent because there was no internationally agreed criterion or policies that explicitly required that, or detailed how, the protection of the environment (in particular non-human species) be demonstrated. However, significant progress has been made in recent years, as viewpoints, methodologies, and practices to assess the impact of ionising radiation on non-human species have converged. This convergence has led to the development and publication of internationally accepted guidelines for conducting such assessments. International Commission of Radiation Protection (ICRP) publications 103, 91, 108 and 124 provide comprehensive principles, frameworks, and concepts, on the protection of biota from the harmful effects of radiation, aimed at ensuring conservation; maintaining biological diversity; and protecting the health and status of the natural habitats, communities and ecosystems.

The International Atomic Energy Agency (IAEA) has established international standards and mechanisms for their worldwide application, to restrict releases of radioactive materials into the environment over time in order that not only humans, but also the non-human component of the environment, is protected adequately.

Eskom has conducted an assessment of the impact of normal operations on marine organisms in the environment around KNPS using an IAEA endorsed tool for conducting such assessments. The Environmental Risks from Ionising Contaminants: Assessment and Management (ERICA) tool was designed to fulfil the IAEA safety standard objective of protecting people and the environment from harmful effects of ionising radiation. The ERICA tool, which automates the radiological environmental impact assessment (REIA) process, has been developed by more than sixty specialists from varied interest areas such as scientific institutions, regulators, policy makers and environmental agencies. The ERICA integrated approach comprises three elements related to; environmental management, risk characterisation, and impact assessment. It provides a methodology for assessing the environmental exposure and risks and effects from ionizing radiation on marine biota. The tool also guides the user through the assessment process, performing the necessary calculations to estimate dose rates to selected biota.

The ERICA tool was used to conduct an assessment for the specific marine environment around KNPS. The input data for the ERICA tool includes radioactivity concentrations in seabed sediment of principal radionuclides discharged from KNPS. These concentration values were modelled using an advanced marine dispersion software code (a three-dimensional MIKE 3 Flow Flexible Mesh Model coupled to the MIKE ECO Lab Model). The dispersion model for the Koeberg marine environment was calibrated against the results of laboratory radioanalysis of sediment samples. These samples were collected at locations where the highest radionuclide concentrations were predicted by the model.

The ERICA tier one assessment was performed using 1 Bq/kg for sediment concentration for purposes of a conservative screening assessment activity. This is above the predicted activities which were below 1 Bq/kg.

The results of the radiological dose assessment for marine biota indicate no significant radiological risk. The radiation doses to reference organisms, are below the screening value of 10 µGy/h.

6.2 Non-Radiological Effluent

This section summarises the specialist studies (its methodologies and findings) completed by PRDW[6] (Dispersion Modelling Study) (refer to Appendix B:2) and Lwandle[9] (Marine Ecology Study) (refer to Appendix B:1).

6.2.1 Screening of Constituents

6.2.1.1 Screening Methodology

As presented in the individual effluent characterization, refer to section 4, it can be concluded that KNPS whole effluent discharge is complex and no one-set methodology can be applied.

For this reason, the specialist team has developed a pragmatic approach for the application assessment. They have also developed a methodology to determine the concentration of constituents within the effluent discharge which do not pose a significant threat to the receiving environment. This exclusion process then highlights the constituents which do not pass the screening tests and that would require further assessment. The results of the assessment are presented below. The screening process is outlined in the flow diagram below.

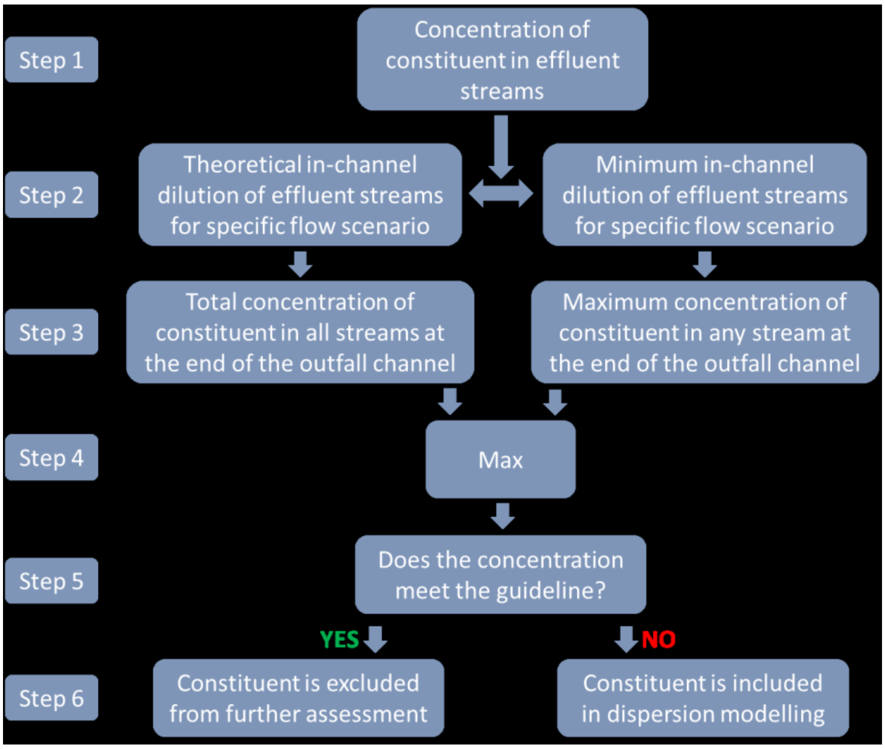

Figure 6: Flow chart describing the screening process used to identify constituents discharged at KNPS which do not pose a significant risk to the receiving environment, and can therefore be excluded from further assessment. (Source: PRDW, 2016).

For further details pertaining to the screening process conducted, refer to section 4 of the PRDW study (Appendix B:2). Further to this, PRDW[6] conducted the chemical dispersion modelling of the discharged constituents presented in section 4.2. Refer to section 5 of the PRDW study (Appendix B:2)[6] for further details pertaining to the dispersion modelling.

6.2.1.2 Dispersion Modelling

The screening process has identified the following constituents, as not meeting the relevant ecological guidelines at the end of the outfall channel:

- Temperature;
- Free Chlorine (TRO);
- Hydrazine; and
- Phosphate.

The assessment of these constituents has thus been included in the dispersion modelling. The model was run for a full year in order to capture seasonal trends in environmental conditions. The year 2009 was selected for modelling purposes, as it covers all the datasets required as input and those necessary for proper calibration of the model.

As presented in the section 4, certain effluent discharges are released continuously while others are released in batches. Therefore the model results were post-processed to calculate the duration that the ecological guideline was exceeded in the modelled year. Since batch releases occur infrequently and only for short durations, the total annual duration of the releases is generally well below 5% of the time; therefore, although the post-processed results are the same for continuous and batch releases, the result for batch releases is presented in units of hours per year rather than percentage of time per year. This result is more easily interpreted than a very low percentage.

A number of sensitive receptor locations have been identified by Lwandle.[9] At these locations, time series of near-surface and near-seabed concentrations are presented for the continuous release scenarios only.[18]

The hydrodynamic dispersion modelling of thermal, chemical, sediment and radionuclide discharges from KNPS Station predicted the extent of and fluctuations in constituents of the discharges.[6] The modelling results were interpreted to predict impacts in the receiving environment (water column and seabed) according to constituent concentrations and distributions. In addition, times series data was used to identify exposure risks at selected receptor sites. These include two subtidal reefs (Blinders), the inter- and sub-tidal zones of the intake basin breakwater, a site at 1 000 m from the discharge and inter- and a sub-tidal site to the south of KNPS at Melkbosstrand. The locations of these five sites are within a 5 km radius of the discharge, as shown in Figure 7.

[18] PRDW, 2017 (Time series figures presented in Annexure B of that report).

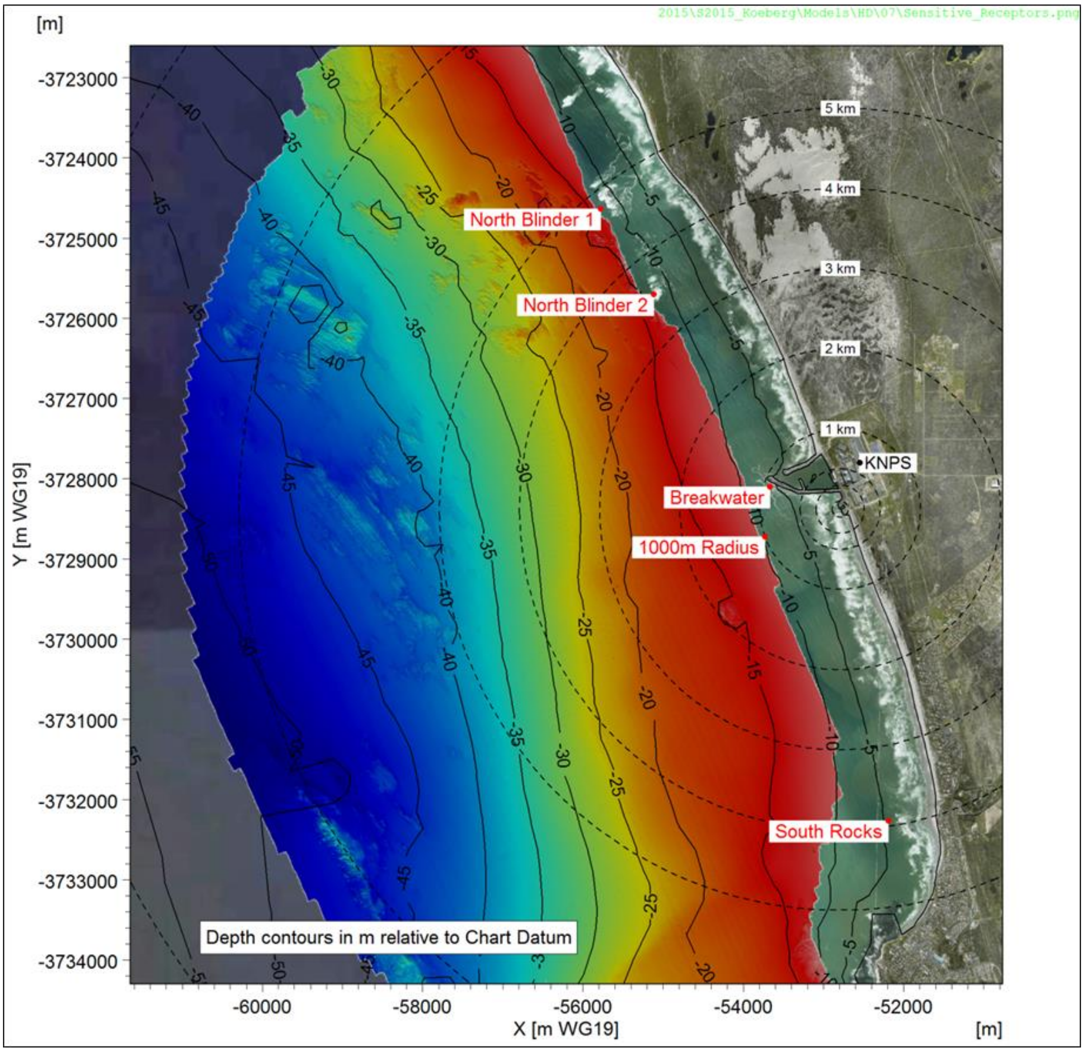

Figure 7: Locations of sensitive receptors within a 5 km radius of KNPS discharge (Source: PRDW, 2016)

All of the hydrodynamic modelling results and plots are presented in the PRDW Study.[6] For completeness discharge distribution plots in the receiving environment that are pertinent to the assessments of the impacts are provided in the relevant sections below. In each case the specific sources of the plots are indicated for ease of reference, should this be required.[6]

6.2.1.3 Impact Assessment Methodology

The impact assessment follows a regular procedure of rating the significance of impacts according to the criteria of duration, geographic extent and intensity/magnitude. Table 24 provides the definitions followed.

Table 24: Definitions of Impact Assessment Criteria use in this Study

Criterion	Ratings of Impacts
Duration	**Temporary/ event** = less than 24 hours. **Short term** = > month **Seasonal** = winter/spring and summer/autumn. **Long term** = the impact will cease after the operational life of the power plant. **Permanent**.
Geographic Extent	**Site-specific** = within 1 000 metres of discharge. **Local** = 15 km radius from the discharge point, in the inner continental shelf area of the SW Cape inshore 'bioregion'. **Regional** = Within the marine ecoregion on the inner continental shelf i.e. Southwestern Cape bioregion **National** = beyond the bioregion within South African EEZ. **International** = beyond 200 n.m. (important for migrant whales, turtles, birds, etc.)
Intensity/ magnitude/ power over receptors	Magnitude in the given area, over the given time. Where applicable reference is made to domestic and international law and standards, including critical habitats (IFC6) and levels of successful conservation: **Low** = negligible alteration of natural systems, patterns or processes. i.e. the disturbance affects the environment in such a way that natural functions and processes continue 'normally'. It affects a localised group within a population for a short time period, and does not interfere with other trophic levels. **Medium** = notable alteration of natural systems, patterns or processes. i.e. where the affected environment is altered but natural functions and processes continue, albeit in a modified way. A portion of a population is affected, but not for more than one generation and without threatening the integrity of that population/system or any species/groups that depend on it. **High** = severe alteration of natural systems, patterns or processes. i.e. where natural functions or processes are altered to the extent that they will temporarily or permanently cease. Affects an entire population/species or system causing a decline in abundance/change in distribution/major disruption that exists for several generations.
Significance	Determines whether the impact will cause a notable alteration of the environment, particularly in the broader context, and how this should influence decision making; ratings are: **Low to very low** = The impact may result in minor alterations of the environment and/or can be easily avoided by implementing appropriate mitigation measures, and should not have an influence on decision-making, or **Medium** = The impact will result in a moderate alteration of the environment and can be reduced or avoided by implementing the appropriate mitigation measures, and should only have an influence

Criterion	Ratings of Impacts
	on decision-making if not mitigated, or **High** = The impacts will result in a major alteration to the environment even with the implementation of the appropriate mitigation measures and should have an influence on decision-making.
Confidence	Specifies the degree of confidence in predictions based on available information and specialist knowledge as **Low or Medium or High**, with reasons.

6.3 Impact Assessment

6.3.1 Introduction

The South African water quality guidelines for the coastal zone[19] defines 'beneficial use' as the desired use or uses for a particular marine (or estuarine) water body, and identifies five beneficial uses with associated environmental objectives for the coastal zone water body. These include:

- Suitability as a basic amenity through the environmental objective of prevention of public nuisance from visual degradation and/or odour problems;
- Maintenance of the ecosystem through the environmental objective of ensuring ecological integrity;
- Recreation, including primary and secondary contact, with the environmental objective of protecting human health and aesthetic condition;
- Collection and/or culture of aquatic life for food with the linked environmental objective of maintenance of water quality, and
- Industrial purposes, again with the environmental quality objective of ensuring water quality levels are such that the water body is fit for use.

The concept of beneficial use has an approximate biodiversity equivalent in 'ecosystem services'. These are defined as benefits people derive from functioning ecosystems, including the ecological characteristics, functions, or processes that directly or indirectly benefit human wellbeing.[20] Broad categories of ecosystem services are:

- Supporting (function) – equivalent to the beneficial use of 'maintenance of ecosystems';
- Provisioning (primarily fishing) – equivalent to the beneficial use of collection and/or culture of aquatic life for food;
- Regulating (function) – no apparent beneficial use equivalent, and
- Cultural (function) – equivalent in part to the recreation beneficial use.

Whichever beneficial use or ecosystem service is assigned or assignable to the receiving water body at KNPS, the 'maintenance of the ecosystem/supporting function' can be considered as having the strictest environmental quality objectives, as the CWDP should be protective of both

[19] DWAF, 1995.
[20] Costanza et al. 2011 in Sink et al. 2011.

near and far field ecological integrity.[21] The assessment of the risks to marine ecology linked to KNPS effluent discharge is based on this beneficial use/ecosystem service and associated environmental quality objective of ensuring ecological integrity.

The impact assessment focused on the following:

- The effects of the non-compliant constituents with established water quality guidelines on the receiving environment.

Heavy metals, although compliant, are an exception to this due to their possible role in identifying deposition areas where radionuclides may accumulate with possible effects on biota.

The physical effects of the seawater intake and discharge system infrastructure on the coast are not dealt with as they have been in place for >20 years and have been accommodated within the environmental processes characteristic of KNPS location.[9]

6.3.2 Impact 1 – Effects of Effluent Discharge on the Receiving Environment: Temperature

The study of the effects of effluent discharge (particularly the discharge of cooling water in this case) has been investigated[22], where it was found that the discharge may generate chronic level effects on biota such as alterations in growth, metabolism, reproduction, production, and/ or influence ecosystem level processes through e.g. alterations of the amount of oxygen dissolved in sea water.

Water quality guidelines applicable to the receiving water body have been listed in Table 3.1 (Lwandle, 2016). The South African guideline is extremely conservative allowing a maximum temperature elevation of 1 °C outside of the mixing zone.[23]. The World Bank guideline is set at a maximum temperature elevation of 3 °C at 100 m from the discharge. [24]

The derived site-specific water quality guidelines[25] set the lower absolute temperature limit for chronic (sub-lethal) effects at 25 °C and that for acute (lethal) effects at 30 °C.

The results of the dispersion modelling showed the percentage of time that the DWAFF[19] water quality guideline of +1˚C above ambient is exceeded in the receiving water body at the surface and seabed under normal operating conditions.

Under normal operating conditions, the impact assessment[9] found that the area of non-conformance (in terms of the water quality guidelines[19]) near the sea surface extends from 4 km

[21] DEA, 2009.
[22] Robinson, 2013, and authors cited therein.
[23] For thermal discharges, the temperature deviation from ambient conditions (due to the discharge of heating or cooling water) may not exceed 1 °C in the marine environment, i.e. $\Delta T \leq 1$ °C (based on DWAFF, 1995).
[24] A thermal effluent should not result in a temperature increase of greater than 3 °C at the edge of the zone where initial mixing and dilution takes place. Where such a zone is not defined, an initial mixing zone of 100 m may be used provided that there are no sensitive aquatic ecosystems within this distance (World Bank, 1998).
[25] Lwandle, 2017 (refer to section 3).

to the north of KNPS to approaching 6.5 km to the south and 3.2 km offshore. Near the seabed the area of non-conformance is lower, due to the fact that the discharge plume is buoyant[26], extending from 3.8 km in the north to ~5.5 km in the south and 1.2 km offshore. Alternatively, in terms of the World Bank[27] limits the area of non-conformance at sea surface extends 1.5 km to the north of the discharge, 3.5 km to the south and 1.5 km offshore. At the sea-bed level the area is 0.5 km north, 3.5 km south and 0.8 km offshore. In both cases the areas of non-compliance are extensive and considerably exceed the provisional mixing zone dimensions put forward by DEA (300 m radius from discharge for offshore locations)[28], and the World Bank[27] 100 m distance.

The results of the dispersion modelling showed the percentage of time that the derived site-specific water quality guidelines is exceeded in the receiving water body at the surface and seabed under normal and abnormal[29] operating conditions.

Under normal operating conditions temperature induced chronic effects in the resident biota will be restricted to the immediate area of the discharge in the longshore and extend 100 m offshore. Temperatures above the acute effects threshold are not predicted under this operating scenario. In the abnormal conditions the extent of the area that will experience temperatures in excess of 25 ºC is estimated to be 1.1 km south of the discharge, 0.5 km north and 1.0 km to the west. Temperatures higher than 30 ºC are predicted to occur but to be constrained to the immediate area of the discharge in the longshore and extend 0.2 km offshore. All of these predicted extents are smaller at the seabed.

The impact significance ratings for the various scenarios are summarised in the tables below.

[26] Jury and Bain, 1989.
[27] World Bank, 1998.
[28] Anchor, 2015.
[29] Abnormal conditions include short periods (~12 hours) caused by breakdown/tripping of one of the CRF pumps.

Table 25: Summary of the Impact Assessment on the Effects of Temperature Exceedances on the Receiving Environment under Normal Operating Conditions (Source: Lwandle, 2017)

Nature of negative impact	Compliance with general water quality guidelines
Extent/ geographical area of impact	**Regional:** The heated effluent plume exceeds thresholds beyond provisional and defined mixing zone distances from the discharge and extends into the SW Cape inner continental shelf ecozone.
Duration of impact	**Long term**: Continuously throughout the life of the power plant.
Intensity/ magnitude/ power over receptors	**High:** The discharge is non-compliant with existing and developing policy on marine outfalls in South Africa.
Significance before mitigation	**High**
Mitigation/ management actions	Mitigation would require alternative methods to dissipate the heat produced in nuclear power generation through, e.g. cooling towers or through heated cooling water dispersion through an offshore deep-water discharge with diffusers. The cost benefits of either of the above or other alternatives are moot in terms of the ecological risks posed by the discharge (see below).
Significance with mitigation	**Low** – The discharge would be consistent with policy
Confidence	**High** – the modelled plume behaviour is robust.

Table 26: Summary of the Impact Assessment on the Effects of Temperature Exceedances on the Receiving Environment under Normal Operating Conditions (Source: Lwandle, 2017)

Nature of negative impact	Ecological effects due to exceedances of site-specific temperature guidelines.
Extent/ geographical area of impact	**Site-specific and Local**: The chronic effects threshold is limited to within 100 m of the discharge.
Duration of impact	**Long term:** Continuously throughout the life of the power plant.
Intensity/ magnitude/ power over receptors	**Low**: Effects are sub-lethal and limited to a negligible area.
Significance before mitigation	**Very Low**
Mitigation/ management actions	N/A.
Significance with mitigation	N/A
Confidence	**High** – the modelled plume behaviour is robust

Table 27: Summary of the Impact Assessment on the Effects of Temperature Exceedances on the Receiving Environment under Abnormal Operating Conditions (Source: Lwandle, 2017)

Nature of negative impact	Ecological effects due to exceedances of site-specific temperature guidelines
Extent/ geographical area of impact	**Local:** The chronic effects threshold is limited to within 1000 m of the discharge. The acute threshold is limited to the Site extent.
Duration of impact	**Temporary:** Out of commission durations are <12 hours and events are infrequent.
Intensity/ magnitude/ power over receptors	**Low:** Non-compliance durations are short (<12 hours) and rare
Significance before mitigation	**Very Low.**
Mitigation/ management actions	N/A
Significance with mitigation	N/A
Confidence	**High –** the modelled plume behaviour is robust**.**

6.3.3 Impact 2 – Effects of Effluent Discharge on the Receiving Environment: Total Residual Oxidant (TRO)

As mentioned in section 5.7, chlorine is used as a biocide at KNPS as it is naturally toxic to marine organisms and maintains the build-up of biofouling. Chlorine in itself and in its bromine based primary derivatives is grouped as TRO. Discharge concentrations of TRO (as chlorine) are predicted to be 0.54 mg/l under normal KNPS operating conditions but an order of magnitude higher at 6.29 mg/l under short duration shock treatment conditions. The water quality guideline for chlorine (= TRO) is 0.003 mg/l, which incorporates a precautionary factor of 10 below the NOEC level assessed. To evaluate actual risks to local biota the United Kingdom EQS of 0.01 mg/l is applied here.

The modelled behaviour of TRO post discharge for normal plant operating conditions shows that, at the sea surface, water quality guideline concentration[19] will be exceeded in excess of 95% (5% of the time) in a zone extending 3.25 km north of KNPS discharge, ~4.5 km south and 2.2 km offshore. At the seabed, as expected from discharge plume behaviour, the non-compliant area extends 2 km north, ~4.5 km south and ~1.25 km offshore. Due to the very short abnormal durations of shock chlorine dosing and appreciable intervals between such treatments (0.5 hours every 14 days) abnormal conditions were not modelled separately by PRDW but were incorporated in the overall predictions of plume extents and a time series presented.

The areas of non-compliance are extensive and considerably exceed the provisional mixing zone dimensions put forward by DEA (300 m radius from discharge for offshore locations)[28] and the World Bank[27] 100 m distance.

The derived site-specific water quality guidelines[25] set the lower chlorine (TRO proxy) concentration limit for chronic (sub-lethal) effects at 0.01 mg/l. The dispersion modelling results show this limit will be exceeded in excess of 95% (5% of the time) at the sea surface are 1.5 km north of the discharge, 2.8 km south and 1.5 km offshore (west). At the seabed, these dimensions are 0.8 km north, 2.8 km south and 0.8 km offshore. These dimensions exceed provisional (Anchor 2015) and defined (World Bank 1998) mixing zone dimensions.

The receptor most sensitive to site-specific guideline exceedances is phaeophyte algae (kelp), which may cause compromised growth. Potential habitat for kelp in the marine environment are the reef formations at North Blinder 1 & 2, north of the KNPS discharge, and at south rocks, south of the discharge.

Neither of the North Blinder sites is predicted to experience TRO concentrations exceeding the site-specific threshold of 0.01 mg/l. As expected North Blinder 2 will be exposed to higher TRO concentrations than the site further north but comparison of the plots indicates that the temporal variations are similar. The south rocks site is predicted to experience two events over the calendar year where the site-specific guideline will be marginally exceeded; January and November. In both instances exceedances will be very short at 24 hours or less. The January exceedance is concurrent to the periodic shock chlorine dose modelled for early January, but the November event not so, coinciding with a smaller elevation of ~0.5 mg/l observable in the time series for a site 100 m offshore of the discharge.[30] Due to short exposure durations ecological risks to local kelp bed habitat can be discounted.

General risks of chronic effects to organisms in the receiving water body extend over the areas of non-compliance with the site-specific TRO guideline (above). Affected organisms can include plankton and fish in the water column and benthos on the seabed.

The impact significance ratings are summarised in the tables below.

[30] PRDW, 2017 (see Figure 5-39).

Table 28: Summary of the Impact Assessment on the Effects of TRO on the Receiving Environment under Normal Operating Conditions (Source: Lwandle, 2017)

Nature of negative impact	Compliance with general water quality guidelines
Extent/ geographical area of impact	**Regional**: The TRO plume exceeds the general guideline threshold beyond provisional and defined mixing zone distances from the discharge and extends into the SW Cape inner continental shelf ecozone.
Duration of impact	**Long term**: Continuously throughout the life of the power plant.
Intensity/ magnitude/ power over receptors	**High**: The discharge is non-compliant with existing and developing policy on marine outfalls in South Africa.
Significance before mitigation	**High**.
Mitigation/ management actions	Mitigation through altering the chlorine dosing intensity and dosing frequency should be evaluated for application at KNPS.
Significance with mitigation	**Medium** – Even with altered chlorine treatment it is questionable whether the discharge would meet the provisional or defined mixing zone dimensions.
Confidence	**High** – the modelled plume behaviour is robust.

Table 29: Summary of the Impact Assessment on the Effects of TRO on the Receiving Environment under Normal Operating Conditions (Source: Lwandle, 2017)

Nature of negative impact	Ecological effects due to exceedances of site-specific TRO guidelines.
Extent/ geographical area of impact	**Sub-Regional**: The chronic effects threshold is limited to within the gazetted KNPS security zone.
Duration of impact	**Long term**: Continuously throughout the life of the power plant.
Intensity/ magnitude/ power over receptors	**Low**: Effects on kelp are unlikely and plankton and ichthyoplankton will be exposed to transient effects that diminish in time with dilution of the discharge plume and TRO decay processes. A minor proportion of the benthos regional benthos may be chronically affected.
Significance before mitigation	**Medium**: - The predicted effect area exceeds provisional mixing zone dimensions.
Mitigation/ management actions	Mitigation through altering the chlorine dosing intensity and dosing frequency should be evaluated for application at KNPS.
Significance with mitigation	**Low**: - Non-compliances should be restrictable to within 500 m of the discharge.
Confidence	**Medium** – the modelled plume behaviour is robust but the consequences of intermittent dosing (proposed mitigation) have not been modelled yet.

6.3.4 Impact 3 – Effects of Effluent Discharge on the Receiving Environment: Phosphates

The phosphate concentration in KNPS discharge peaks at 0.54 mg/l. Phosphate is discharged from four sources, two of which are from the Electrical Building Ventilation System (DEL) and are considered minor sources as these occur once per year for two-hour periods.[31] The other sources of phosphate are from the nuclear (KER) and conventional (SEK) island discharges. These sources can supply total annual loads of 625 kg and 396 kg of phosphate to the discharge but with discharges occurring intermittently over short periods (total durations of 20 and 12 hours annually respectively).[31]PRDW[6]modelled abnormal flows.

The specified receiving water quality guideline concentration is 0.053 mg/l. Concentrations above the threshold extend from 4.25 km north of KNPS to 6.5 km south of the plant and 3.0 km offshore at the surface and are more constrained at the seabed extending from 2 km north to the same distance south but are restricted to ~1 km offshore. Peak concentrations >10 mg/l are predicted to occur in the intake basin but will be flushed through the plant with the intake cooling water and discharged at concentrations of 0.5-1.0 mg/l with the cooling water effluent.

Durations of non-compliances with the water quality threshold would be restricted to periods <50 hours per year over all the area of the discharge.[32]

The influence of the elevated phosphorus would be on phytoplankton production. As nitrogen is the limiting nutrient for this in the southern Benguela ecoregion[33] the minor elevation in phosphorus concentration in a minute proportion of the pelagic zone is therefore not predicted to exert any measureable influence in the receiving water body. Consequently, no deleterious effects on marine ecology are predicted.

The significance of the impact is summarised in the table below.

Table 30: Summary of the Impact Assessment on the Effects of Elevated Phosphate Concentrations on the Receiving Environment (Source: Lwandle, 2016)

Nature of negative impact	Ecological effects due to exceedances of site-specific phosphate guidelines
Extent/ geographical area of impact	**Regional**: The chronic effects threshold extends beyond the sub-regional boundary offshore.
Duration of impact	**Long term**: Continuously but intermittently throughout the life of the power plant.
Intensity/ magnitude/ power over receptors	**Low**: Effects on phytoplankton production are unlikely due to nitrogen and not phosphorus being the limiting nutrient in the region. Further the batch releases are considerably shorter than the 12-14 day upwelling/relaxation cycle typical of the region that largely controls phytoplankton production and distribution.

[31] PRDW, 2017 (refer to Table 5-13).
[32] PRDW 2017 (refer to Figures 5-55 and 5-56).
[33] Chapman and Shannon, 1985.

Nature of negative impact	Ecological effects due to exceedances of site-specific phosphate guidelines
Significance before mitigation	**Very Low**: - No measurable effects are predicted.
Mitigation/ management actions	N/A
Significance with mitigation	N/A
Confidence	**High** – the modelled plume behaviour is robust and the local phytoplankton ecology is relatively well understood.

6.3.5 Impact 4 – Effects of Effluent Discharge on the Receiving Environment: Hydrazine

Kelp sporophytes which are located on rocky/reef substrata in the shallow subtidal zone of in the receiving water body are specifically vulnerable to the toxicity effects caused by hydrazine.

Hydrazine in KNPS discharge varies with annual loads of 263 kg at normal operations and 480 kg in reactor outages. These loads result in estimated concentrations in the discharge of 0.11 mg/l and 0.19 mg/l respectively. The specified general water quality guideline is 0.0002 mg/l and the site-specific higher than this at 0.0025 mg/l.[25] The general guideline is based on a NOEC calculated from observed chronic toxicity effects (gametophyte growth) in Macrocystis (giant kelp) and an applied precautionary factor of 10. The site specific guideline is derived from the calculated NOEC.

The modelled behaviour of hydrazine post discharge for normal plant operating conditions shows that, at the sea surface, the specified water quality guideline concentration will be exceeded in a zone extending 10.0 km north of the KNPS discharge, 9.0 km south and 4.0 km offshore. At the seabed, as expected from discharge plume behaviour, the non-compliant area extends 9.0 km north, 9.0 km south and 1.5 km offshore. During short-term outages these dimensions increase to 12.5 km north, 17.5 km south and 5.0 km offshore at the sea surface and 12.5 km north, 17.5 km south and 4.0 km offshore near the seabed.[6] Hydrazine release durations under this scenario are very short at <2 hours.

The areas of non-compliance in both normal operating and abnormal outage scenarios are extensive and considerably exceed the provisional mixing zone dimensions put forward by DEA (300 m radius from discharge for offshore locations),[28] and the World Bank[27] 100 m distance. However, in all cases the amount of time in any one year that exceedances of the guidelines may occur is ≤100 hours for normal plant operations and ≤300 hours during short-term outages in all affected areas except for the immediate area of the discharge (<100 m) and in the cooling water intake basin.

The derived site-specific water quality guidelines[25] set the hydrazine chronic effect threshold at 0.0025 mg/l. The results of the dispersion modelling show the distribution of the proportion of time that this limit is exceeded in the receiving water body. The spatial extents where the modelled concentrations exceed the site-specific guideline at the sea surface are 2.5 km north of the discharge, 4.5 km south and 1.5 km offshore (west). At the seabed, these dimensions are 0.8 km north, 2.5 km south and 1.0 km offshore. These dimensions exceed provisional (DEA 2013) and defined (World Bank 1998) mixing zone dimensions but the overall durations of exceedance over a calendar year are ≤100 hours.

The specified water quality guideline is the NOEC of 0.0025 mg/l for chronic effects (growth) on *Macrocystis gametohytes*. As stated above potential kelp habitat near the KNPS is at North Blinder 1 and 2, and at South Rocks, south of the discharge. These sites would be affected by hydrazine contained in bottom waters. Under normal operating conditions, hydrazine at concentrations in excess of 0.0025 mg/l is not expected to extend to either of the North Blinder sites and that if the South Rocks site is impacted the duration of the exceedance will be ≤2 hours. Under abnormal conditions associated with refuelling this exposure increases to ≤10 hours.[34]

Kelp gametophytes can delay sporophyte generation by seven months or longer in unfavourable conditions such as low nutrient concentrations or unfavourable light conditions.[35] In the southern Benguela Current region such conditions may develop in the relaxation phase of the upwelling cycle when inorganic nutrient specifically may be reduced in the upper water column due to take-up by phytoplankton. Upwelling replenishes these so the duration of dormancy controlled primarily by unfavourable nutrient conditions is that of the local upwelling cycle (12-14 days in late spring through summer). The annual duration of exposure to possible growth inhibiting concentrations of hydrazine at the South Rocks site is <0.5 that of a single upwelling cycle. It is unlikely that such exposures can cause any measurable ecological effect in kelp gametophyte growth at this site.

Hydrazine chronic level toxicity (EC_{50}) to other taxa such as fish exceeds 3 mg/l[36], which is greater than the predicted discharge concentration for this compound.

The significance of the impact is summarised in the tables below.

Table 31: Summary of the Impact Assessment on the Effects of Hydrazine on the Receiving Environment under Normal Operating Conditions (Source: Lwandle, 2017)

Nature of negative impact	Compliance with general water quality guidelines
Extent/ geographical area of impact	**Regional**: The hydrazine plume exceeds the general guideline threshold beyond provisional and defined mixing zone distances from the discharge and extends into the SW Cape inner continental shelf ecozone.
Duration of impact	**Long term**: Continuously but intermittent short-duration exceedances throughout the life of the power plant.
Intensity/ magnitude/ power over receptors	**High**: The discharge is non-compliant with existing and developing policy on marine outfalls in South Africa.
Significance before mitigation	**Medium** – The short non-compliant durations reduce the significance of non-compliance with policy.

[34] PRDW 2017, Figure 5-52.
[35] Carney, 2009
[36] CERI, 2007.

Nature of negative impact	Compliance with general water quality guidelines
Mitigation/ management actions	Mitigation through altering the hydrazine release practices from semi-batch discharge to more frequent blending of the constituent into the combined discharge from the KNPS
Significance with mitigation	**Low - Medium** – The required mixing zone will reduce but may not comply with existing and developing policy on marine outfalls in South Africa.
Confidence	**Medium** – the modelled plume behaviour is robust but factors that should reduce hydrazine in the effluent (residual BOD demand and oxidation by TRO) may not have been adequately addressed.

Table 32: Summary of the Impact Assessment on the Effects of Hydrazine on the Receiving Environment under Normal Operating Conditions (Source: Lwandle, 2017)

Nature of negative impact	Ecological effects due to exceedances of site-specific hydrazine guidelines
Extent/ geographical area of impact	**Regional**: The chronic effects threshold is may affect the South Rocks site outside of the gazetted KNPS security zone.
Duration of impact	**Long term**: Continuously but intermittent throughout the life of the power plant.
Intensity/ magnitude/ power over receptors	**Low**: Effects on kelp are unlikely as are effects on other biota in the receiving water body.
Significance before mitigation	**Very Low for** ecological effects but **Medium** for area of exceedance non-compliance with defined mixing zone limits.
Mitigation/ management actions	Mitigation of the mixing zone apparent non-compliance can be through altering the hydrazine release practices from semi-batch discharge to more frequent blending of the constituent into the combined discharge from the KNPS.
Significance with mitigation	**Very Low** for ecological effects; and **Low-Medium** for mixing zone extent which although probably restricted to within 500 m of the discharge still exceeds contemplated limits.
Confidence	**Medium** – the modelled plume behaviour is robust but the consequences of intermittent dosing have not been modelled yet.

6.3.6 Impact 5 – Effects of Effluent Discharge on the Receiving Environment: Build-up of Heavy Metal Concentrations in Deposition Areas

KNPS effluent discharge contains very low concentrations of heavy metals. This discharge poses no toxicity risk to pelagic organisms as the concentrations are below the respective DWAF[19] receiving water quality thresholds. Dissolved heavy metals can adsorb to suspended inorganic and organic particles in the water column and find their way to the seabed through sedimentation.[37] This preferentially occurs in quiet water areas in wave and current affected inner continental shelf zones, or in deeper water off the continental shelf edge. Over time sediment heavy metal concentrations in these depositional areas can build up through continued supply, such as may be from a continuously operating discharge, e.g. KNPS, and local remineralisation of organic matter and associated biogeochemical processes. This can generate heavy metal concentrations approaching those considered to cause toxicity effects in benthos with ecological consequences of modification to benthic communities.[38]

Candidate depositional areas that may be influenced by KNPS discharge have been identified by PRDW[6] as KNPS seawater intake basin, Murray Harbour on Robben Island and entrance to the port of Cape Town. These sites, including the open sandy seafloor in the vicinity of KNPS have been measured in 2015. The result of this survey is presented in Appendix A: of the Lwandle[9] report.

Heavy metal concentrations were low at or near the analytical detection limit in the non-depositional sites but were elevated but variable in the KCWIB. This is linked to elevated aluminium (proxy for clay minerals) concentrations in this location. Copper and lead concentrations measured at KCWIB site IB 1 and cadmium at site IB 3 exceeded the respective SQGs but the mean values for the KCWIB did not. Accordingly, KCWIB sediments do not classify as being contaminated to the extent that they constitute toxicity risks.

Samples within the KCWIB show variable heavy metal concentrations with high levels of arsenic, chromium, copper, iron and lead at site IB 1 relative to the other three sites within the KCWIB. The observed heavy metal concentration gradients may be ascribable to the proximity of site IB 1 to the northern KCWOB at KNPS.

The significance of the impacts of discharges of heavy metals in KNPS effluent are summarised in the table below.

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[37] Libes, 2011.
[38] Gray and Elliot, 2009.

Table 33: Summary of the Impact Assessment for the Build-up of Heavy Metals in the Receiving Environment (Source: Lwandle, 2017)

Nature of negative impact	Compromised sediment quality
Extent/ geographical area of impact	**Local** – Heavy metal build-up does not extend beyond the KNPS cooling water intake basin.
Duration of impact	**Long term**
Intensity/ magnitude/ power over receptors	**Low** for most metals as average heavy metal concentrations fall within sediment quality guideline even within the depositional environment of the KNPS cooling seawater intake basin, but **Medium** for iron due to potentially increased build-up from the high annual loads generated by the RO plants.
Significance before mitigation	**Medium** for seawater intake basin sediments; **Very Low** for non-depositional areas
Mitigation/ management actions	If monitoring shows build up in sediment iron concentrations in the seawater intake basin, exclude ferric hydroxide coagulant from the discharge by rerouting to settlement ponds and ultimately land fill or employ an alternative particle removal process such as dissolved air flotation
Significance with mitigation	**Low**
Confidence	**High** – for the adjacent open inner continental shelf area but Medium for the intake basin sediments due to uncertainty on the sources of the heavy metals in this location.

6.4 Impact Assessment Summary

The impact assessment evaluated the potential risks associated with the effluent discharge to the marine ecology within the receiving environment. The study was relied on the following:

- The hydrodynamic modelling[6] showed the behaviour of the discharge plume and constituents;
- Published information on the ecology characteristics of the receiving environment and region; and
- Known toxicity effects of the discharge constituents.

The main conclusions of the impact assessment are that:

- The discharge plume is not compliant with established water quality guidelines in that specified limits for temperature, total residual oxidant (TRO), phosphate and hydrazine were predicted to be transgressed outside of mixing zone boundaries contemplated by DEA (2013) and in developing policy;
- Risks to organisms within ~2 km of the discharge are limited to chronic effects;

- All predicted ecological impacts associated with the discharge were graded as being of low to medium significance;
- All predicted exceedances of water quality guideline concentrations were rated as high or medium significance due to large mixing zones indicated by the simulation modelling; and
- Identified mitigation options for reducing the medium to high significance impacts should be subject to feasibility assessments, including simulation modelling, and cost/benefit analyses as the associated ecological risks are not rated as highly significant.

The results of the environmental impact assessment conducted for the purposes of this evaluation of the KNPS discharge are summarised in (Table 34).

The major uncertainties that exist are:

- The possible existence of synergistic or additive effects on effluent toxicity due to constituents in the effluent discharge; and
- Whether the predictions of low toxicity levels based on assessments of the risks posed by individual constituents are robust, particularly for inhabitants of the water column.

A monitoring programme encompassing whole effluent toxicity tests, discharge plume behaviour in the field, field based toxicity investigations in the receiving environment and inorganic contaminant build-up in sediments is recommended to reduce these uncertainties. Further, the established intertidal beach monitoring should be continued to identify any effects on this component of the natural environment, should these arise. In addition, the KNPS should investigate whether there are benefits from modifying chlorination procedures and hydrazine discharge practices to reduce their level of non-compliance with the emerging policy and regulations on the extents of effluent mixing zones for marine discharges.

Table 34: Impact Summary Table (Source: Lwandle, 2017)

#	Impact Type	Extent	Duration	Intensity/ magnitude	Significance before mitigation	Mitigation	Significance post mitigation	Confidence in prediction
1	Temperature guideline exceedance – normal operations	Regional	Long-term	High	High	Alternative cooling	Low	High
2	Temperature elevation: Ecological risk – normal operations	Site specific	Long-term	Low	Very Low	N/A	N/A	High
2	Temperature elevation: Ecological risk –	Local	Temporary	Low	Very Low	N/A	N/A	High

#	Impact Type	Extent	Duration	Intensity/ magnitude	Significance before mitigation	Mitigation	Significance post mitigation	Confidence in prediction
	abnormal operations							
3	TRO guideline exceedances	Regional	Long-term	High	High	Modify Cl dosing	Medium	High
4	TRO discharge: ecological risk	Sub - Regional	Long-term	Low	Medium	Modify Cl dosing	Low	Medium
5	Phosphate discharge: ecological risk	Regional	Long-term	Low	Very low	N/A	N/A	High
6	Hydrazine discharge guideline exceedances	Regional	Long-term	High	Medium	Modify discharges	Low - Medium	Medium
7	Hydrazine discharge: ecological risk	Regional	Long-term	Low	Very Low & Medium	Modify discharges	Very Low & Low Medium	Medium
8	Discolouration of sea surface foams by $Fe(OH)_3$	Local	Long-term	Low	Low	Divert flows	Very Low	Medium
9	Heavy metal build-up including iron in deposition areas	Local	Long-term	Low & Medium	Medium & Very low	Divert flows to reduce iron	Low	High & Medium

7 Monitoring Programme

7.1 Monitoring of the Aqueous Systems

KNPS is a complex plant made up of various aqueous systems, each with its individual monitoring systems and monitoring programme. All radiological waste effluent is under permanent monitoring and surveillance, before being discharged from the site. System instrumentation continuously logs data on digital recorders or paper and sends electronic notification to the operators located within the control room.

Over and above this, manual monitoring is undertaken according to a specific regimen to ensure the quality of the individual systems (and waste streams in this case); this is undertaken at the various individual outlets throughout the plant, rather than at the final discharge point. The outlets have been grouped according to their discharge points, and are discussed below. The following KCWOB outlets are monitored (refer to Figure 4 and to Figure 8):

- CRF;
- SEC;
- KER;
- SEK;
- DEL
- SRO/BWRO and SWRO; and
- SEU.

The following KCWIB outlets are monitored:

- XCA;
- SDA;
- DEL
- SDX; and
- CTE.

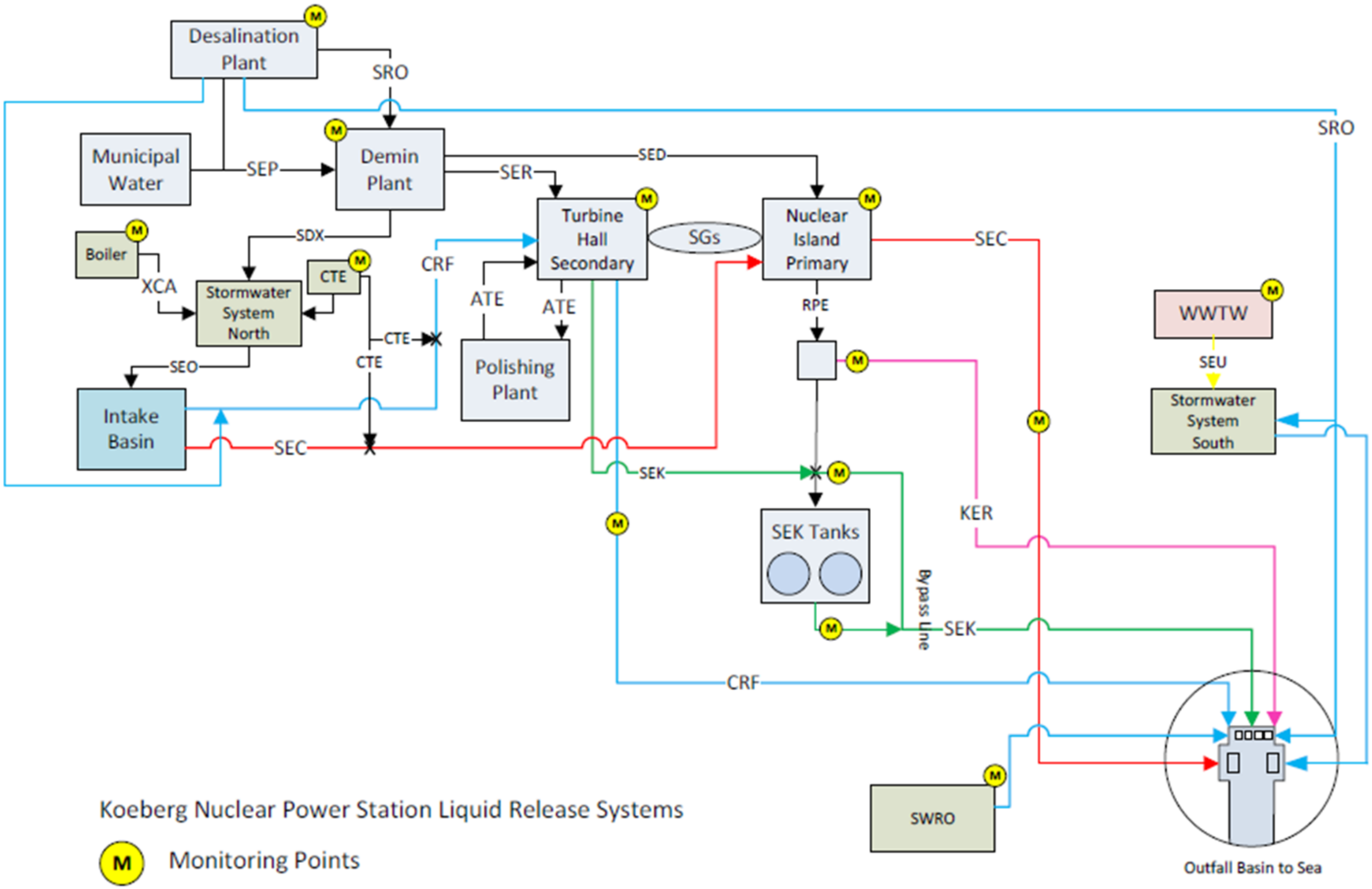

Figure 8: Schematic Flow Diagram of KNPS Liquid Release Systems and Monitoring Points

7.1.1 Monitoring of the Main Circulating Water System (CRF)

The main circulating water is monitored post discharge from the condenser.

The flow[39] rate and temperature of the main circulating water system is continuously monitored. In addition, the cooling water is dosed with chlorine to protect the system against biofouling. The addition of this chemical produces residual oxidants, and other chlorination by-product wastes.

During the dosing period:

- The chlorine concentration required in the cooling system is limited by the size of the installations and by the periodic measurement of the hypochlorite concentration produced; and
- The TRO concentration is measured post discharge from the condenser. This measurement, together with the volume of water discharged, allows the loadings of residual oxidants to be calculated.

Free chlorine is monitored once every shift (i.e. once every 8 hours).

7.1.2 Monitoring of the Essential Service Water System (SEC)

Similar to CRF, the essential service cooling water is monitored post discharge from the nuclear island but before the discharge to the KCWOB.

The flow rate and temperature of the essential service water system is continuously monitored. In addition, the cooling water is dosed with chlorine to protect the system against biofouling. The addition of this chemical produces residual oxidants, and other chlorination by-product wastes.

During the dosing period:

- The chlorine concentration required in the cooling system is limited by the size of the installations and by the periodic measurement of the hypochlorite concentration produced; and
- The TRO concentration is measured post discharge from the heat exchanger. This measurement, together with the volume of water discharged, allows the loading of residual oxidants to be calculated.

Free chlorine is monitored once every shift (i.e. once every 8 hours).

The following manual chemistry monitoring is conducted:

- Radioactive Iodine-131 - once every 7 days;
- Radioactive Tritium– once every 31 days;
- Radioactive Gross Alpha - once every 31 days; and
- Radioactive Total Strontium– once every 92 days.

[39] The motor current of CRF is measured, which is a function of flow.

7.1.3 Monitoring of the Radiological Effluent Discharge System (KER)

The volume and chemical concentration is measured before effluent is discharged to the CRF outfall. During abnormal conditions, discharge is diverted to the SEK storage tanks, where further monitoring is undertaken.

The release of radioactive effluents is regulated by the National Nuclear Regulatory Act, 47 of 1999. Regulation code Licensing Document "LD 1020" sets criteria for the discharge of radioactive liquid releases to the environment. This code specifies the monitoring and measurement of released activity. Annual Authorised Discharge Quantity (AADQ) (of radioactive effluent) is determined in agreement with the NNR.

Before a release is approved from the KER tanks, each tank is recirculated to ensure the contents have homogenised, a manual sample is taken and analysed by gamma spectrometry. Releases are controlled by ensuring that the gamma activities comply with the AADQ. In addition, gross alpha and tritium analyses are periodically performed on composite samples.

Furthermore, the outlets of the KER tanks (all three of them) are equipped with instrumentation for continuous radiological activity monitoring during batch releases, with an alarm in the control room and automatic termination of the release should the pre-set threshold be exceeded. When discharge is terminated, additional manual monitoring is conducted on each tank during recirculation. The following manual chemistry monitoring is conducted:

- Boron – prior to any action (i.e. release, transfer, etc.);
- Radioactive Gamma Spectrum – prior to any action (i.e. release, transfer, etc.);
- Radioactive Iodine-131 - prior to any action (release, transfer, etc.);
- Radioactive Tritium – once every 31 days;
- Radioactive Gross Alpha OTS - once every 31 days; and
- Radioactive Total Strontium OTS – once every 92 days.
- Phosphate – at least once per every 31 days in systems that discharge to KER;
- pH - prior to any release;

Provision exists as a backup to divert KER to SEK for further monitoring and treatment.

7.1.4 Monitoring of Secondary Releases System (SEK)

Within the SEK system, Radiation and Chemistry monitoring is continuously applied, which must also comply with the above mentioned NNR radiological established limits. A system for continuous measurement of gross gamma activity is installed on the sampling lines of the steam generator blowdown, for each unit with alarming and recording in the control room. If contamination is detected, the effluent discharge is diverted to storage within the one of the two storage tanks. Similar to the KER system, manual monitoring is conducted on the tanks prior to release and manual monitoring is performed post release when in SEK tank bypass mode.

The following manual chemistry monitoring is conducted on the tanks:

- Boron - prior to any action (release, transfer, etc.).

The following manual chemistry monitoring is conducted on the SEK Bypass:

- pH - once every 7 days;
- Ethanolamine – once every 7 days;
- Ammonia – once every 7 days;

The following manual chemistry monitoring is conducted on the SEK Bypass (continuous release/batch release from tanks):

- Radioactive Gamma Spectrum – prior to any batch action (release, transfer, etc.) and weekly for SEK tank bypass;
- Radioactive Iodine-131 - prior to any action (release, transfer, etc.) and weekly for SEK tank bypass;
- Radioactive Tritium – once every 31 days;
- Radioactive Gross Alpha OTS - once every 31 days; and
- Radioactive Total Strontium OTS – once every 92 days.

The following manual chemistry monitoring is performed on relevant systems that discharge to SEK on a periodic basis:

  - Hydrazine – periodic sampling which varies between systems that discharge to SEK; and
  - Phosphate – at least once every 31 days on relevant systems that discharge to SEK.

7.1.5 Monitoring of WWTW Effluent (SEU)

Final treated effluent is monitored post discharge from the WWTW.

The following manual chemistry monitoring is conducted (but not limited to):

- Free Chlorine – once every 7 days; and
- Suspended solids - once every 14 days;

The following radioactive sampling is conducted on the final effluent:

- Radioactive Gamma Spectrum – once every 7 days;
- Radioactive Tritium – once every 31 days;
- Radioactive Gross Alpha – once every 31 days; and
- Radioactive Total Strontium – once every 92 days.

In addition to the chemical analysis of the final effluent, flowmeter readings are taken and recorded daily.

7.1.6 Monitoring of Auxiliary Plant System (XCA)

The following manual chemistry monitoring is conducted after dosing and on a regular basis:

- pH; and
- Hydrazine at least once every 14 days.

7.1.7 Monitoring of Demineralised Water Production Plant and Chemical Effluents System (SDA and SDX)

The following manual chemistry monitoring is conducted after neutralization of the sulphuric acid and sodium hydroxide prior to release:

- pH.

7.1.8 Monitoring of Chlorination Plant System (CTE)

The following manual chemistry monitoring is conducted after neutralization of the acid prior to release:

- pH.

7.1.9 Monitoring of the Electrical Building Ventilation System (DEL)

The DEL system is dosed with phosphate within the intermediate circuit and CFCs in the outer circuit, both of which are continuously monitored prior to discharge.

7.2 Monitoring Equipment

All discharges of liquid effluents are monitored for flow and concentration of the chemical parameters expected to be present in the effluent tanks for the various systems mentioned above. All of the samples taken from the various storage tanks of the systems are analysed at the onsite laboratory. The sampling system allows for samples to be taken that are representative of the contents of the tanks once their contents have mixed.

All sampling and monitoring equipment is subject to a programme of preventative maintenance, involving a periodic check of their operation and a periodic calibration. Records of all maintenance and calibration is kept secure and made available to the NNR or any other state department when required. Reports are also submitted to the NNR on a quarterly basis, as per the license requirements.

7.3 Monitoring Procedures

7.3.1 Analysis Prior to Discharge:

Involves the analysis of the physico-chemical parameters of the effluent from the tanks prior to discharge. A representative once-off sample is carried out in each tank with laboratory analysis undertaken prior to the effluent being discharged from the tank. The type of analyses performed is dependent on the system being monitored.

7.3.2 Analysis Post Discharge:

Involves the analysis of the other physico-chemical parameters of liquid effluent within the discharge pipeline at continuous discharge. In addition, a sample from each tank is retained for a composite sample which is analysed periodically, for certain constituents, to complete the account of releases.

7.4 Current Marine Environmental Monitoring

Scientific research has been conducted over the last 34 years to assess the marine environmental impacts associated with KNPS discharge.

Preliminary studies were conducted in the late 1970's, and further studies have focused on three distinct time phases i.e. preoperational (1981 to 1984), transitional (1985) and operational (1987 to present).

Refer to Appendix E: for a summary of the various marine ecology studies conducted over the years.

7.4.1 Overall Impact of KNPS on the Marine Environment

In the final report compiled by Dr. PA Cook, which culminated the Marine Environmental Impact studies with the operational phase of the study, most of the earlier predictions (pre-December 1989) regarding the extent of the Koeberg plant pollution impact were proved incorrect. The main findings can be summarized as:

- No reduction in the species diversity index was recorded. In fact the index rose during the operative period;
- Overall community structure of beach animals was very variable from year to year, but the dominance of a few key species was maintained throughout the experimental period;
- The predication colonization of the area by opportunistic warm water species did not occur;
- The breeding cycle of the main indicator species, *Donax serra,* appeared to be significantly influenced by water temperature. Although the cycle was fairly variable before KNPS began operation, it appeared to be even more unpredictable during the operative phase. There was no evidence however, that this affected the overall number of mussels on the beach. In 2005 it was established that over the long terms this mussel has maintained its dominance and the population appears unaffected;[40]
- Phytoplankton biomass was reduced by an average of about 53% due to entrainment in KNPS cooling system whilst zooplankton mortality averaged 22.3%. Mortality of plankton during entrainment was not, however, considered to be detrimental to the marine environment because of the very localized area affected; and
- The overall conclusion is that KNPS has had very little detrimental effect on the ecology of the local sandy beaches.

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[40] Griffiths, CL and Robinson TB. Koeberg Nuclear Power Station Marine Environmental Report. University of Cape Town. August 2005.

The more recent study conducted by Griffiths[40] confirms most of the above, with the exception of determining that:

- Marine organisms most likely to impact on KNPS cooling water supply are medusa of the phyla Cnidaria and Ctenophora, which have been increasing in density along the west coast of South Africa since the 1970's. High densities may require chemical shock treatment, the impacts of which on the surrounding environment would need to be determined.

7.4.2 Ongoing Programme

Since 1990 emphasis has been placed on *Donax serra* as being the indicator species and most of the ongoing study has concentrated on this beach animal. In conjunction bi-annual total specie samples are being taken for identification and counting of the samples. The annual reports thus far indicate differences, which have little overall biological significance.[40 and 41]

7.4.3 Monitoring Frequency

The following marine environmental monitoring is conducted:

- Marine structures inspection – once annually;
- Coastal survey - once annually;
- Marine samples (radiological programme) – quarterly / 2 monthly;
- Seawater temperature recorders – quarterly / 2 monthly;
- Marine samples (non-radiological) – six monthly; and
- Beach profile survey - once annually.

7.5 Proposed Marine Environmental Monitoring

Section 4 highlights the complex mix of constituents discharged from KNPS to the marine environment. In addition to this, the monitoring programme will have to take into consideration the complex nature of the effluent as well i.e. predominantly warm water which makes the effluent plume buoyant and further limits its influence on the seabed outside the immediate area of discharge. Further, the trajectory of the effluent plume varies with metocean conditions and the axis of flow can be southerly, westerly or north-westerly.

The programme outlined below takes account of these issues while aiming to obtain scientifically defensible information on the plume and associated environmental effects.

The monitoring programme addresses the following:

- Effluent toxicity – The evaluation of the possible effects of the plume set out above has focused on the individual constituents in the discharge. The combined or possible synergistic effects have not been quantified primarily due to a lack of robust information for such plumes;
- Build-up of contaminants in sediments in the receiving environment – The inorganic constituents, primarily heavy metals, can influence sediment biogeochemistry in depositional

[41] Cook, PA. Marine Environmental Reports, 1990 – 1996. Zoology Department, University of Cape Town.

areas in the adjacent receiving environment to the point of generating adverse effects on benthos;

- Distributions and gradients in primarily temperature, as a proxy for other constituents, in the receiving environment; and
- Actual, as opposed to predicted, toxicity effects in the receiving environment.

7.5.1 Whole Effluent Toxicity

- Purpose: Determine the toxicity risk to the receiving environment of the dissolved constituents of the discharged effluent and the required dilutions to reduce these to acceptable levels. Match these dilutions to those predicted for the effluent plume[6] to determine the water body actually at risk from the discharge.
- Sampling: Obtain multiple grab samples of effluent from the end of the discharge channel twice yearly to compile a whole effluent toxicity profile over time to constrain the variation of the toxicity risks in the receiving environment.
- Analysis – Conduct sea urchin fertilization success tests on the dissolved constituents. Include other tests suitable for determining toxicity levels if required (e.g. microtox).
- Reporting: Compile effluent toxicity tests reports for each period and a composite report on the time series focused on determining variability in toxicity levels and the areas predicted to be at risk in the receiving water body.

7.5.2 Sediment Contamination

- Purpose: Determine whether there is a consistent build-up of inorganic contaminant concentrations in seabed sediments in the receiving water body and the seawater intake basin (identified deposition area), to the point where these represent an ecological risk.
- Sampling: Obtain and analyse sediment samples from the station locations occupied in the 2015 sediment and benthos survey[42] at annual intervals.
- Analysis: Test samples for particle size distributions, organic content and heavy metal concentrations and macrobenthos distributions. Predict sediment heavy metal build-up rates in the sediments in the depositional areas and identify levels of disturbance, if any, on benthos community structure.
- Reporting: Compile full, stand-alone scientific reports on each of the surveys and a synthesis of the results when appropriate.

7.5.3 Effluent Plume Distributions in the Receiving Environment

- Purpose: Using primarily temperature distributions quantify the actual distribution of the discharged effluent plume in the receiving environment to validate the hydrodynamic model results. This is required to add confidence to assessments of actual as opposed to predicted effects of effluent toxicity.
- Sampling: Conduct multi-parameter CTD surveys of the effluent plume area twice yearly to obtain synoptic 3D distributions of the plume extent. These should be conducted concurrently

[42] Lwandle, 2017 (refer to Appendix A).

to the whole effluent toxicity testing and logistically coordinated with the measurements required under section 5.14 (Lwandle, 2016).

- Analysis: Analyse the CTD data to obtain representations of the distribution of the effluent plume at the time of sampling. Determine whether there are concurrent distortions to distributions of specifically dissolved oxygen and phytoplankton biomass. Use these variables to place the results of the whole effluent toxicity tests in the environmental context.
- Reporting: Produce monitoring reports at each survey interval and a composite report on the time series for the distributions.

7.5.4 Toxicity Effects of the Discharge Plume

- Purpose: Determine the existence, or not, of toxicity effects attributable to the discharge effluent plume in the receiving water body by monitoring biofouling rates on artificial substrates suspended in (test) and outside (reference) outside of the effluent plume to complement the whole effluent toxicity test results.
- Sampling: Suspend settlement plates at 3-5 m depths at five locations within the discharge plume within 1 000 m of the end of the discharge channel and match these with five locations approximately 1 000 m offshore 5 km north and south of KNPS. Exposure periods should be <90 days and tests should be conducted in upwelling and non-upwelling periods over a multi-year cycle. Temperature sensors will be deployed at all plate positions to measure the exposure of each site to the thermal plume and to validate the hydrodynamic model results.
- Analysis: toxicity effects are to be determined on a comparative basis between test and the reference sites. If differences are detected the presence or absence of the responsible organisms are to be determined to identify a) varying sensitivity levels within the biofouling community, and b) assist in isolating the causative constituents, if possible. Time series temperature records will be evaluated against temperature distributions as currently predicted from the PRDW[6] hydrodynamic modelling.
- Reporting: Report on each deployment and provide a synthesis of the results at the conclusion of the monitoring period.

7.5.5 Effects of the Effluent Discharge on Intertidal Organisms

KNPS has been conducting regular surveys of sandy beach fauna in the vicinity of its discharge. This programme should be continued to add to the long term data set that has been established.

7.5.6 Further Investigations

Chlorine (TRO) and hydrazine discharges were determined to be non-compliant with both general and site-specific guidelines in terms of the spatial extents of their respective plumes in the receiving environment. KNPS has indicated that the chlorine dosing regime and the hydrazine discharge practices can possibly be modified to the extent that this does not compromise power plant operations. But this will need further study and the outcomes are uncertain. The implications for TRO and hydrazine distributions in the receiving environment should be determined by hydrodynamic modelling of the available options to determine whether there are benefits for the receiving environment and evaluate these against the costs that could be generated by altered management practices.

8 Compliance with Environmental Quality Objectives

8.1 Compliance Monitoring and Assurance Programme

A compliance monitoring programme has been established for KNPS, where the monitoring of effluent against discharge limits imposed by the various relevant permits/licenses is conducted. The programme involves a range of compliance tests including flow, concentrations, volumes and flow rate.

Compliance data has been provided (Appendix F:) which proves KNPS has been 100% to all the relevant permit requirements for the last seven years (2010 – 2016).

In addition, a compliance assurance programme is implemented on site, which comprises of inspections, surveillances and audits as well as various forums for interaction with the nuclear authorisation holder. The NNR compliance assurance programme is based on safety goals that were developed from the principal radiation protection and nuclear safety requirements of the SSRP. The NNR compliance assurance programme was established to provide assurance of the state of health of plant, processes, organisation and environment in terms of identified safety goals. Safety practices are achieved by ensuring that the nuclear authorisation holder complies with the conditions of the nuclear installation licence. The NNR conducts independent compliance assurance activities to determine the extent to which holders of nuclear authorisations comply with the conditions of authorisation. An ongoing monitoring and inspection programme is implemented by the licensee, and is regularly assessed by the NNR to ensure compliance with the nuclear authorization and any other relevant authorisations.

As part of that independent verification of the environmental monitoring programme, the NNR conducted environmental sampling around KNPS site. The samples collected were analysed by a radio analytical laboratory and the analysis results verified against those obtained from Eskom.[43] Furthermore, the NNR conducted 48 inspections at the KNPS as part of its compliance assurance activities for 2014.[43]

8.2 Contingency Planning

Contingency plans include the option of rerouting discharges from both the Nuclear Island and Conventional Island to the SEK holding tanks; this is only done during abnormal conditions which include:

- The radiological waste activity is too high for dilution to the receiving environment. In such circumstances, the radiological liquid waste is reprocessed or delayed release depending on the half-life of the contaminant;
- The Radiological Effluent Monitoring and Discharge System (KER) tanks are filled to capacity because of an abnormal condition.

[43] NNR Annual Report, 2015.

8.3 Decommissioning Plans

KNPS units were commissioned in 1983 and 1984 respectively, with an expected operational life of 40 to 60 years. Decommissioning plans are expected to commence between 2024 and 2045. Decommissioning shall be conducted in a phased approach, which includes:

- Phase 1 – Preparation;
- Phase 2 – Plant shutdown and defueling;
- Phase 3 – Implementation of the spent fuel pool cooling separation plan;
- Phase 4 – Decommissioning operations (i.e. demolition of Conventional Island and auxiliaries; safe enclosure preparation; and electromechanical dismantling);
- Phase 5 – Spent fuel removal and electromechanical dismantling of the fuel building and auxiliaries; and
- Phase 6 – Demolition of remaining structures and site rehabilitation.

The decommissioning of marine structures will be part of the decommissioning of the power station after performing an Environmental Impact Assessment for that activity.

8.4 Management Strategies

The regulatory control of KNPS is exercised by means of a nuclear licence that is issued by the NNR and which incorporates the necessary authorisation conditions to ensure that the safety related aspects of the plant design and general operating rules are complied with. The NNR is also responsible for issuing a nuclear licence which controls the operation, decommissioning and closure of KNPS.

In April 2006, the safety regulation was published as Safety Standards and Regulatory Practices. The safety regulations require, amongst others, that the plant be maintained and inspected to ensure the reliability and integrity of the installation, equipment and plant important to nuclear and radiation safety, and that operational safety assessments be performed and submitted to the NNR at specified intervals.

In terms of the NNR Act, the licensee is required to establish and implement an inspection programme to ensure compliance with the requirements of the nuclear authorisation (including other relevant authorisations) and provide any information at a frequency determined and required by the NNR including:

- Reports on problem, incident and accident notification, investigation and closeout;
- Quality assurance and audit reports including closeout reports;
- Environmental monitoring reports; and
- Reports on liquid and gaseous effluent discharges.

In addition, the NNR requires the licensee to develop and maintain a documented safety case which demonstrates compliance with the requirements of the NNR regulations and international standards.

Typical licence conditions included in the nuclear authorisation are:

- The description and configuration of the authorised facility or action;
- Safety Assessment;
- Scope of activities that might be undertaken;
- Controls and limitations on operation;
- Maintenance, testing and inspection requirements;
- Operation radiation protection programmes;
- Effluent management programmes;
- Radioactive waste management programmes;
- Environmental monitoring;
- Emergency planning and preparedness requirements;
- Physical security;
- Transport of radioactive material,
- Decommissioning;
- Financial security;
- Quality management;
- Acceptance and approval; and
- Reporting.

8.5 Reporting

The following requirements are noted in Annexure 1: Generic Assessment Criteria for Coastal Waters Discharge Permits document.

8.5.1 Permit Advisory Forum

At present, there is no formal CWDP forum, however the Public Safety Information Forum (which comprises of relevant Eskom staff; various officials from the Provincial and Municipal Environmental Departments, and other relevant state organisations, including members of public) have been used to disseminate information.

In addition, all monitoring and compliance reporting is done to the NNR as the statutory authority on the compliance assurance programme.

8.5.2 Monitoring Programme Results

In terms of the NNR Act, KNPS is required to establish and implement an inspection programme to ensure compliance with the requirements of the nuclear authorisation and provide any information at a frequency determined and required by the NNR. In addition, the NNR requires the licensee to develop and maintain a documented safety case which demonstrates compliance with the requirements of the NNR regulations and any other relevant licence standards or conditions.

The NNR conducts independent compliance assurance activities to determine the extent to KNPS complies with the conditions of authorisation. An ongoing monitoring and inspection programme is implemented by KNPS, and is regularly assessed by the NNR to ensure compliance with the nuclear authorisation. Records are kept secure and made available to the NNR or any other state department when required.

8.5.3 Review of site processes in terms of the Waste/Water/Energy Hierarchy to ensure best practice

The NNR conducts independent compliance assurance activities to determine the extent to KNPS complies with the conditions of authorisation. Its role is also to ensure that the licensee applies the best practice in terms of the nuclear industry to continuously improve of processes conducted at the plant.

It should also be noted that KNPS is a signatory of the WANO, which exists purely to help members accomplish the highest levels of operational safety and reliability. This is achieved through a series of highly-regarded programmes, such as peer reviews, and access to technical support and a global library of operating experience.

9 Conclusion and way forward

KNPS has been in commercial operation since 1983/4. The disposal of land-derived effluent into coastal waters was previously authorised by the DAFF under the Water Act of 1956. With the promulgation of the NEM: ICMA a CWDP is required by KNPS for the marine discharge.

This technical report and the associated specialist studies have been drafted so that it may be considered in support of the CWDP application to the DEA. Public engagement has commenced where all interested and affected parties have been invited to comment on the application and its supporting documentation as part of the consultation process. The public participation process has been tailored in accordance with the guidelines set by the DEA.

Eskom believes that this document contains sufficient information to enable the DEA to determine whether a CWDP may be granted. The processes and technology currently implemented at KNPS are considered the most appropriate pollution control measures and the application of best available technique (BAT) for water discharge activities in the nuclear industry. Nevertheless, Eskom will review its hydrazine and chlorine practices to determine if it is feasible to further minimise the release.

10 DEVELOPMENT TEAM

Name	Designation or Business area
Kim Pontac	Advisian – Senior Environmental Scientist
Ryan Jonas	Advisian – Project Leader / Senior Environmental Scientist
Michelle Herbert	Advisian – Senior Environmental Scientist

11 ACCEPTANCE AND REVIEW

The following personnel were given the opportunity to provide review comments:

Name	Designation or Business area
Deon Jeannes	Nuclear Environmental Manager, Eskom.
Robert Moffat	Engineer, Integrated Plant Design – Koeberg, Eskom.

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Appendix A: WATER PERMIT AND EXEMPTION IN TERMS OF THE WATER ACT

Appendix B: SPECIALIST STUDIES

B1 - MARINE ECOLOGY SPECIALIST STUDY

B2 – MODELLING SPECIALIST STUDY

Appendix C: COPY OF THE SEA-SHORE LEASES

Appendix D: NNR DOSE REQUIREMENTS HISTORIC COMPLIANCE DATA

Appendix E: SUMMARY OF HISTORIC MARINE STUDIES CONDUCTED AT KNPS

Appendix F: COMPLIANCE MONITORING DATA FOR THE PAST 5 YEARS.

Appendix G: PUBLIC PARTICIPATION REPORT.