KOEBERG NUCLEAR POWER STATION CWDP

Addendum Report:
Assessment of Additional Thermal Discharge Scenarios

PREPARED FOR:

PRDW
Consulting Port and Coastal Engineers

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1 BACKGROUND

The Koeberg Nuclear Power Station (KPS) uses seawater to cool condensers in the production of electricity for the national grid. The seawater is abstracted from an intake basin, flows through the power station and is returned to sea via a shore-based discharge channel. In normal operations the incoming seawater is heated to ~11.8 °C above ambient prior to discharge and the surrounding ocean acts as a heat sink for this. As part of their Coastal Water Discharge Permit (CWDP) application KPS contracted PRDW and Lwandle Technologies (Pty) Ltd (Lwandle) to assess the behaviour of the discharge plume through hydrodynamic modelling and the degree of environmental risk it represents. The scenarios modelled and assessed included normal operations and an abnormal condition which considered a short-term (12 hour) temperature elevation to 22.7 °C. This could occur through a CRF train being out of service resulting in reduced throughput volumes and thus elevated temperatures in the discharge. The results of the assessment are reported in PRDW (2017) and Lwandle (2017).

Subsequent to this assessment it has become evident that abnormal operating conditions could, in fact, have durations extending up to 14 days. In the light of this the KPS commissioned PRDW and Lwandle to provide a further assessment of the environmental implications of this condition. This was to include hydrodynamic modelling of the heated seawater discharge plume in mitigated and non-mitigated scenarios to reduce the temperature elevation and determination of environmental impacts using the impact criteria developed in Lwandle (2017). This addendum to the KPS CWDP application presents the results of the latter.

2 ABNORMAL CONDITIONS ASSESSED

Seven abnormal temperatures conditions were assessed as summarised in Table 2.1. The mitigation that can be applied is to reduce power output from the affected reactor which effectively reduces the delta T in the CRF discharge. This is due to lowered heat production but more or less constant cooling water flow rates. Note that each reactor unit has two CRF trains with approximately equal cooling water flow rates of 81 972 m^3/h. Cases 0 to 5 show predicted delta Ts for cooling water under a range of power outputs with one unit operating through one CRF train whilst cases 6 and 7 show details for two reactor units with three of the four associated CRF trains operating for 100% and 70% power output levels.

Table 2.1: Temperature conditions assessed (from PRDW 2019)

<table>
<tr><th>Case</th><th>Number of reactor units operational</th><th>Power level of affected reactor (%)</th><th>Number of CRF trains in service</th><th>Delta T of CRF (°C)</th><th>Duration (days)</th><th>Comment</th></tr>
<tr><td>0</td><td rowspan="6">1</td><td>100</td><td rowspan="6">1</td><td>22.7</td><td>0.5</td><td>Pump trip previously assessed</td></tr>
<tr><td>1</td><td>100</td><td>22.7</td><td>14</td><td rowspan="5">New scenarios. One train out of service due to reasons other than pump trip that can take up to 2 weeks to rectify</td></tr>
<tr><td>2</td><td>70</td><td>16.0</td><td>14</td></tr>
<tr><td>3</td><td>60</td><td>15.0</td><td>14</td></tr>
<tr><td>4</td><td>50</td><td>14.0</td><td>14</td></tr>
<tr><td>5</td><td>40</td><td>13.0</td><td>14</td></tr>
<tr><td>6</td><td rowspan="2">2</td><td>100</td><td rowspan="2">3</td><td>15.0</td><td>14</td><td rowspan="2">New scenario 2 reactor units 3 CRF trains operating for 2 weeks</td></tr>
<tr><td>7</td><td>70</td><td>13.4</td><td>14</td></tr>
</table>

3 ASSESSMENT

3.1 DISCHARGE PLUME CHARACTERISATION

The site-specific receiving water quality thresholds established for the KPS discharge plume are 30 °C for acute (lethal) effects and 25 °C for chronic (sublethal) effects (Lwandle 2017). The risks to the receiving environment are evaluated according to these thresholds in terms of affected areas relative to a subsection of the regional scale South West Cape Inner Continental shelf area and the sub-regional scale of the KPS marine security area. The regional scale subsection is defined as that area encompassed between North Blinder 1, north of the KPS discharge, and South Rocks to the south and the 25 m water depth isobath; these features are shown in PRDW (2019, Figure 4-1). The assessment areas are shown in Figure 3-1. The areal extents of these are 2 340 Ha and 640 Ha for the regional scale subsection and the sub-regional scale respectively.

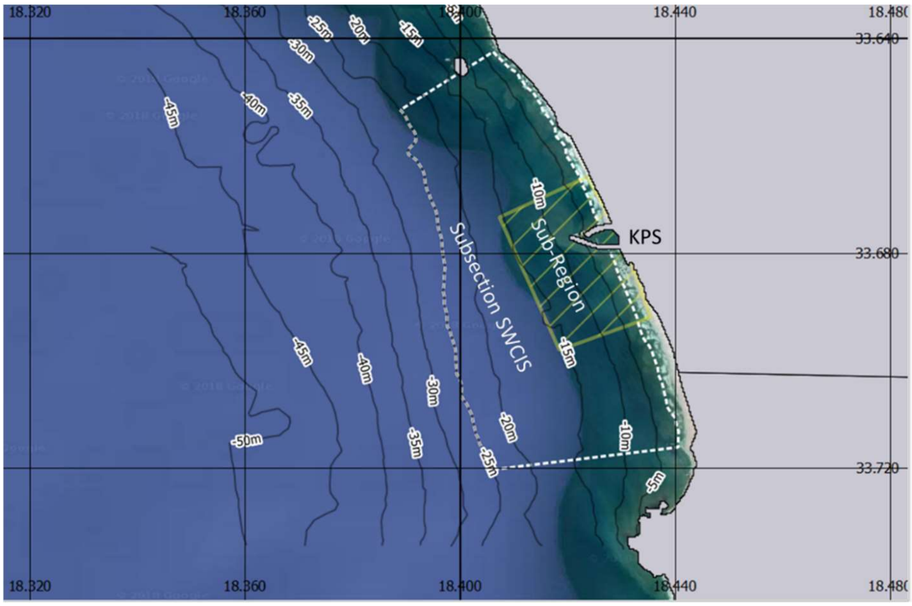

Figure 3-1: Schematic showing extents of the regional scale subsection of the South Western Cape Inner Continental Shelf (SWCIS) area and the sub-regional scales (KPS Security Zone) used in this assessment.

The PRDW (2019) modelling results show the areal distributions of the acute and chronic effects at the seabed and in the upper water column for each of the scenarios modelled for each threshold (PRDW (2019) Figures A-1-A-14), along with temperature time series (PRDW (2019) Figures A-29-A34) at the southern side of the seawater intake basin breakwater, 100 m and 1 000 m distances from the discharge basin (PRDW (2019) Figure 4-1). The areal extents for each of the scenarios are summarised in Table 3.1.

Table 3.1: Areal extents within the KPS discharge plume where water temperatures are predicted to exceed the chronic and acute effects thresholds (from PRDW 2019)

Case #	Operating reactor units	Power outputs (%)	Maximum plume area >30 °C (acute effect threshold) (Ha)		Maximum plume area >25 < 30 °C (chronic effect threshold) for at least 96 hr (Ha)	
			Seabed	Surface	Seabed	Surface
0	1	100	1.2	2.2	N/A[1]	N/A
1		100	3.5	50.4	1.3	8.3
2		70	1.1	9.4	1.1	1.7
3		60	0.8	2.6	1.0	1.2
4		50	0.5	0.7	0.9	1.0
5		40	0.4	0.4	0.7	1.0
6	2	100	4.4	39.5	5.7	19.2
7		70	1.6	4.1	4.8	10.3

[1] This case maximum duration is 12 hours

The temperature time series show that, as expected, the periods of elevated temperatures match those of the durations modelled but that there are gradients with distance from the discharge and declines with reducing power outputs. For cases 1-5 (one CRF train operating with 1 reactor unit) exceedances of the site-specific temperature thresholds are restricted to the 100% and 70 % power output scenarios (#1 and #2) and are variable. In cases 6 & 7 (2 reactor units operating with 3 CRF trains) there is similar variability, but acute effects exercised by temperatures in excess of 30 °C are limited to the 100 m distance time series location. Table 3.2 summarises the exceedance periods at each of the three time series sites.

Table 3.2: Comparisons of the numbers of days in which temperature thresholds are exceeded at the surface and seabed at each of the three modelled time series sites (from PRDW 2019)

Threshold	Case	Time Series Location					
		100 m		Breakwater		1 000 m	
		Seabed	Surface	Seabed	Surface	Seabed	Surface
Acute Effects (Hrs)	1	72	215	0	0	0	0
	2	2	37	0	0	0	0
	3	1	16	0	0	0	0
	4	0	7	0	0	0	0
	5	0	0	0	0	0	0
	6	79	99	0	0	0	0
	7	8	27	0	0	0	0
Chronic Effects (Hrs)	1	267	274	0	9	0	0
	2	177	734	0	4	0	0
	3	151	225	0	4	0	0
	4	128	209	0	3	0	0
	5	107	179	0	2	0	0
	6	303	315	0	23	0	0
	7	290	301	0	15	0	0

3.2 Impact Assessment for the Modelled Scenarios

Impacts on the receiving environment of the abnormal condition cooling water discharges with elevated temperatures above the defined site-specific thresholds were assessed for seabed areas and the volumes of ambient temperature seawater mixed into the discharge plume. Exposures to temperatures at and above the acute threshold (≥30 °C) were considered to be instantaneously lethal for benthic and pelagic organisms. Water temperatures >25 °C <30 °C were considered to generate sublethal effects in such organisms after 96 hours of continuous or intermittent exposure. Extents of the effects were graded according to Lwandle (2017) as was impact magnitude/intensity. The probability of occurrence of the impact (effect, not cause) was rated according to whether it was unlikely to occur, i.e. the impact should probably not occur, or likely, indicating that the impact may occur, or definite, indicating that the impact should occur. Impact significance was graded according to the areal proportions affected whereby proportions less than 1% were rated as Very Low, proportions of 1-5% as Low and proportions in excess of 5% as Medium.

3.2.1 Effects of the abnormal temperature elevation on seabed benthos/sessile organisms

3.2.1.1 Acute (≥30 °C) exposures

The nature of the negative impact is mortality of the benthos/sessile organisms exposed to these temperatures. The effect is considered to be instantaneous. Table 3.3 summarises the impact assessment.

Table 3.3: Impact significance ratings for acute effects of elevated temperatures associated with abnormal operating conditions on benthos and sessile organisms in the receiving environment.

Criterion	Case 0	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Extent	Site	Site	Site	Site	Site	Site	Site	Site
Area (Ha)	1.2	3.5	1.1	0.8	0.5	0.4	4.4	1.6
Duration	Seasonal	Seasonal	Seasonal	Seasonal	Seasonal	Seasonal	Seasonal	Seasonal
Magnitude/Intensity	Low	Low	Low	Low	Low	Low	Low	Low
Probability	Likely	Definite	Definite	Definite	Definite	Definite	Definite	Definite
Significance @ Sub Region	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
Significance @Subsection of SWCIS	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low

3.2.1.2 Chronic (≥25 °C to <30 °C) exposures.

The nature of the negative impact is sub-lethal effects on benthos/sessile organisms exposed to temperatures within this range. Durations of exposure need to be 96 hours or longer to generate the effects. Table 3.4 summarises the impact assessment.

Table 3.4: Impact significance ratings for chronic effects of elevated temperatures associated with abnormal operating conditions on benthos and sessile organisms in the receiving environment.

Criterion	Case 0	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Extent	N/A(b)	Site	Site	Site	Site	Site	Site	Site
Area (Ha)	N/A(b)	1.3	1.1	1	0.9	0.7	5.7	4.8
Duration	Short term	Short term	Short term	Short term	Short term	Short term	Short term	Short term
Magnitude/Intensity	None	Low	Low	Low	Low	Low	Low	Low
Probability	Likely	Likely	Likely	Likely	Likely	Likely	Likely	Likely
Significance @ Sub Region	None	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
Significance @Subsection of SWCIS	None	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low

(b) Case 0 was modelled with a 12-hour duration and thus does not extend into the 96-hour exposure period.

3.2.2 Effects of the abnormal temperature elevation on the pelagic communities in the upper water column

Pelagic organisms that may be affected by the discharged cooling water plume are those that are mixed into it from the receiving environment. Dissimilar to benthos and sessile organisms, pelagic organisms inhabit essentially 3-dimensional environments and therefore assessment of impacts on them is more appropriately done on volumes as opposed to areas affected. This is difficult to conduct as it requires that the actual volumes of the discharge plumes are known or estimated as well from where in the water column the water being entrained into these plumes originates. To simplify this here we assume that all entrained water originates from the sea surface to 5 m water depth, i.e. the upper water column to avoid possible thermocline effects, and the proportions of entrained water are reliably characterised by the highest mixing volume estimate for the respective temperature thresholds. PRDW (2019) provide estimates for the latter as summarised below. Note that this is a conservative method of estimating mixing volumes.

Table 3.5: Percentage entrained water estimates at chronic and acute temperature thresholds within the KPS discharged cooling water plume under the evaluated scenarios for one and two operating units (from PRDW 2019).

Threshold	One operating reactor unit	Two operating reactor units
Chronic	70%	52%
Acute	45%	20%

To compare the discharge plume areas that exceed chronic and acute thresholds against the two extent categories of sub-regional and the subsection of the South West Cape Inner Continental Shelf, the affected areas were combined. The rationale for this is that water volume exchanges on the inner continental shelf are high and probable exposure durations are short at distances >500 m from the discharge as indicated by the time series data in Table 3.2 and the duration contour plots in PRDW (2019). These combined volumes were then converted to equivalent surface areas by dividing by the water depth (5 m).

Table 3.6 summarises the impact assessment.

Table 3.6: Impact significance ratings for combined acute and chronic effects on pelagic organisms through entrainment into the discharge plumes and being exposed to temperatures above set thresholds.

Criterion	Case 0	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Extent	Site	Local	Site	Site	Site	Site	Local	Site
Equivalent Area (Ha)	0.99	28.49	5.42	2.01	1.02	0.88	17.88	6.18
Duration	Temporary	Short term	Short term	Short term	Short term	Short term	Short term	Short term
Magnitude/Intensity	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Probability	Likely	Likely	Likely	Likely	Likely	Likely	Likely	Likely
Significance @ Sub Region	Very Low	Low	Very Low	Very Low	Very Low	Very Low	Low	Very Low
Significance @Subsection of SWCIS	Very Low	Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low

4 CONCLUSIONS

All seven abnormal operating conditions are predicted to generate impacts of Very Low significance at the assessed geographic scales for seafloor benthos/sessile organisms. Of the seven abnormal operating conditions evaluated for pelagic organisms, only case 1 (1 reactor unit operating with 1 CRF train at 100% power) and case 6 (2 reactor units operating with 3 CRF trains at 100% power) are predicted to generate impacts at anything greater than Very Low significance at the assessed geographic scales. Case 1 is predicted to generate Low significance impacts on pelagic organisms through elevated temperature exposures via entrainment into the discharge plume at the sub-region and subsection of the South West Cape Inner Continental Shelf scales. In the latter case the affected proportion is estimated at 1.22% which is only marginally above the threshold between impacts classifying as Very Low and Low (section 3.2 above). Case 6 is also predicted to generate a Low significance impact on pelagic organisms but only at the sub-regional scale.

5 RECOMMENDATION

Each of the elevated impacts can be mitigated by reducing power output from the reactors to 70%. The impact evaluations indicate that further power reductions will not add any material improvement according to the criteria employed in this assessment. However, even though the 30% power reduction should reduce impact significance to Very Low, due to high natural variability in the inner continental shelf pelagic realm it is unlikely that this would be demonstrable by field measurements. Given this and that the unmitigated scenario is classified as a Low significance impact anyway due to restricted spatial and temporal effect scales, from the perspective of deleterious effects on marine ecology in the receiving water body it is not imperative that the mitigation be applied, i.e. no power reduction is required with either one or two reactor units operational.

6 REFERENCES

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