Review of surface water drains and likely mass fluxes to Cockburn Sound

Theme: Water and Sediment Quality

WAMSI Westport Marine Science Program

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WAMSI WESTPORT MARINE SCIENCE PROGRAM

ABOUT THE MARINE SCIENCE PROGRAM

The WAMSI Westport Marine Science Program (WWMSP) is a $13.5 million body of marine research funded by the WA Government. The aims of the WWMSP are to increase knowledge of Cockburn Sound in areas that will inform the environmental impact assessment of the proposed Westport development and help to manage this important and heavily used marine area into the future. Westport is the State Government's program to move container trade from Fremantle to Kwinana, and includes a new container port and associated freight, road and rail, and logistics. The WWMSP comprises more than 30 research projects in the biological, physical and social sciences that are focused on the Cockburn Sound area. They are being delivered by more than 100 scientists from the WAMSI partnership and other organisations.

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DATA
Finalised datasets will be released as open data, and data and/or metadata will be discoverable through Data WA and the Shared Land Information Platform (SLIP).

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Executive Summary

This study addresses the need for more information about baseline nutrient loads to Cockburn Sound from surface water drainage for Project 3.3 “Key Elements of the Groundwater/Surface Water Flux into Cockburn Sound” in contrast to groundwater discharges. The survey of surface water drainage includes discharge from drains located on the beach, shoreline area, and any drainage associated with pipes that might discharge beyond the shoreline directly offshore into the Sound. Marine outfalls of wastewater (effluent), cooling water, and process wastewater are also reviewed as several industries are authorised to discharge wastewater and stormwater into the Sound. The study area extent is the coastline between Woodman Point in the City of Cockburn to Mangles Bay near Cape Peron in the City of Rockingham, Garden Island, and catchment areas within less than a kilometre inland from the coastline that have direct relevance.

Several field trips were made in September 2022 to locate previously documented drains and to note any additional ones that have been installed since a previous survey conducted by the Department of Water in 2007. Information was sought directly from each of the relevant local government areas, i.e., the Cities of Cockburn, Kwinana and Rockingham, and several large commercial/industrial properties. Additionally, information on nutrient discharge limits were collated from the Department of Water and Environmental Regulation licence records for industries that are authorised to discharge process water directly into Cockburn Sound.

Surface water discharges to Cockburn Sound are notionally from 14 stormwater drains with the majority of these used for urban drainage within the City of Rockingham, and 8 ocean outfalls for industries located in the City of Kwinana. The spatial distribution of the urban drainage network for the City of Rockingham was not available to the project and it remains unclear what the contributing area and sources are for the stormwater outfalls. Of the 14 stormwater drains identified during field visits in September 2022, only the Rockingham Main Drain was observed to be consistently flowing into Cockburn Sound and it generally flows from about early June until mid- to late February. The average flow rate measured on 14 September was 360 m^3/day into Cockburn Sound. Aside from the Rockingham Main Drain, flows from urban drains are most likely to be intermittent and associated with rainfall events; however, this is based on limited observations. Very approximate estimates from our field survey suggest that the maximum contribution of nutrients from stormwater could be less than about 0.1 tonnes/year, but there is a high degree of uncertainty due to lack of recent measurements of nutrient concentrations in stormwater from different locations and a lack of stormwater flux measurements throughout the wet season.

For ocean outfalls into Cockburn Sound from industry, water flux data and water quality data were sought from major industries, but no quantitative ocean outflow data were made available by the industries contacted for this study. A review of licence information revealed that only the former BP Refinery Kwinana (converted to a fuel import terminal in 2021) and CSBP have nutrient discharge limits specified for their Cockburn Sound outfall; however, since about 2005, these two industries have mainly used the Sepia Depression Deep Ocean Outfall pipeline, which does not discharge directly into Cockburn Sound. Tronox maintains a submarine discharge pipeline into Cockburn Sound, with the discharge licence indicating that nitrogen is monitored. Other industries including Alcoa, Fremantle Ports and Nutrien Ag Solutions Fertiliser manage stormwater such that it is either used in their processes or infiltrated to groundwater. Electricity generation (Synergy and NewGen Power) utilises seawater for cooling which is returned to the Sound after some level of treatment, but it is unlikely that this will impact the mass loading of nutrients to the Sound. Similarly, the Perth Seawater Desalination Plant discharges brine back into the Sound and while nutrients are concentrated in the brine, they are required to be diluted to background at the edge of the mixing zone (DWER 2014); thus the mass loading impacts are negligible.

The field data are inadequate for quantifying total stormwater flux: a dedicated set of flow and auto-sampling equipment would be needed to make such measurement estimates. Other activities within Project 3.3 aim to quantify groundwater nutrient fluxes into Cockburn Sound and will be reported at a later date when the relevant investigations have been completed. However, previous investigations (Smith et al. 2003, Loveless & Oldham 2010, Donn et al. 2015), suggest that estimates of groundwater total nitrogen fluxes could be more than an order of magnitude higher than surface water fluxes, as indicated by the stormwater nutrient flux estimates obtained in September 2022.

2 Introduction

2.1 Purpose

This purpose of this investigation was to survey potential surface water discharges to Cockburn Sound and to confirm the relative scale of input (water and chemicals) to the Sound from surface water compared to groundwater. The intention is to provide baseline information. Previously documented drain discharge locations and drainage networks were reviewed to assess significant changes.

This report addresses surface water inputs relevant to KP2-4 in the WAMSI Science Project Plan for Project 3.3 “Key Elements of the Groundwater/Surface Water Flux into Cockburn Sound”. Other activities within Project 3.3 aim to quantify groundwater nutrient fluxes into Cockburn Sound and will be reported at a later date when the relevant investigations have been completed.

In this report, rainfall runoff to drains that connect to Cockburn Sound are referred to herein as stormwater drains. Within the Cockburn Sound Catchment there are no surface water bodies such as rivers, streams or lakes that drain directly to Cockburn Sound, except Lake Richmond, which has one outlet drain into Cockburn Sound (Figure 1).

2.2 Scope

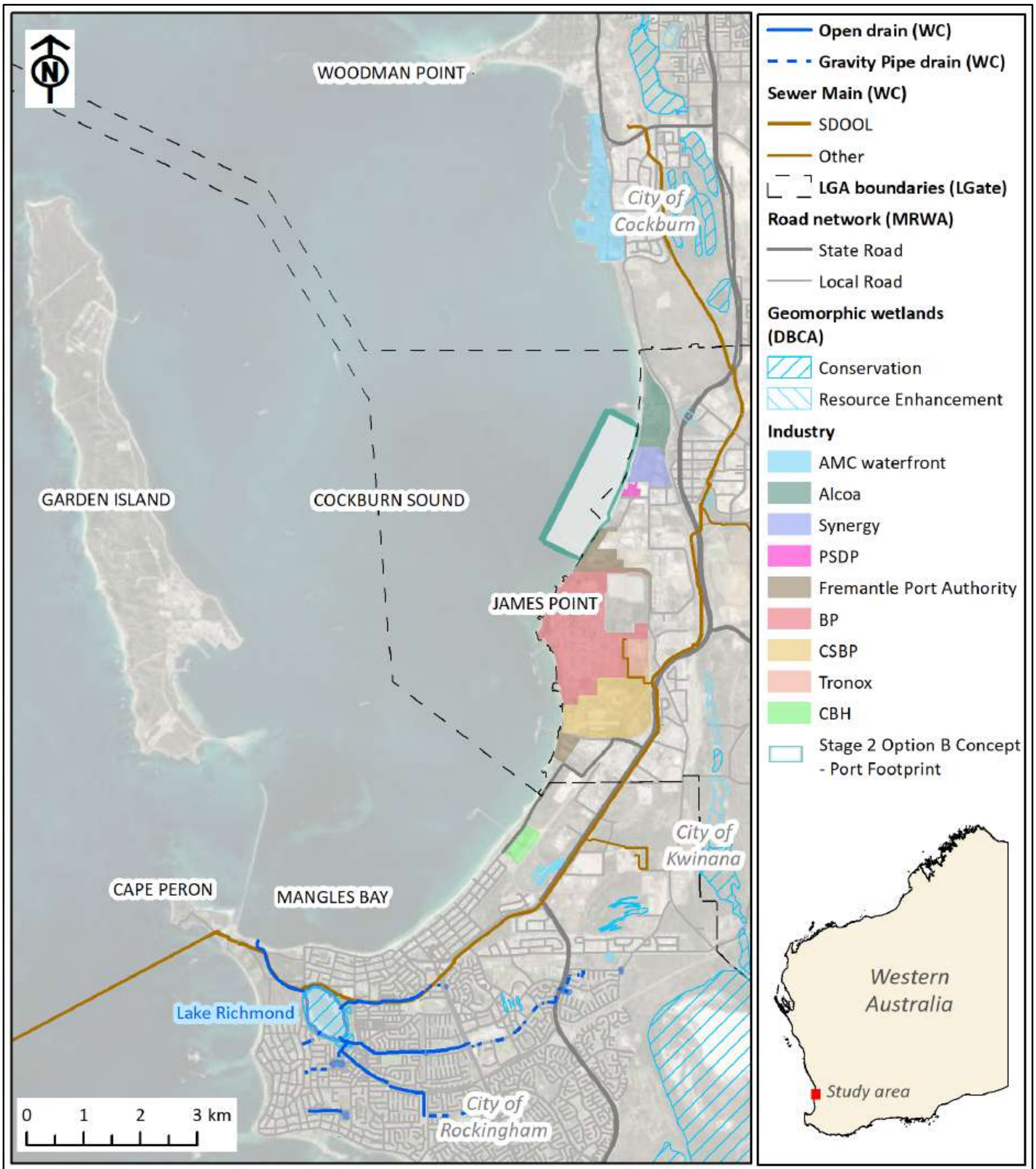
The areal extent of this survey encompasses the coastline between Woodman Point in the City of Cockburn to Mangles Bay near Cape Peron in the City of Rockingham and catchment areas within less than a kilometre inland from the coastline that have direct relevance (Figure 1). Information on the management of rainfall runoff and potential nutrient sources on Garden Island were also collected for this study to evaluate the potential for nutrient flux into Cockburn Sound from the east coast of Garden Island.

The areas described above encompass three local government areas (LGAs) – the Cities of Cockburn, Kwinana and Rockingham, and a number of large commercial/industrial properties. The Water Corporation manages the main drain network, consisting of pressure drains, gravity drains and open channel drains, which were generally installed to control shallow groundwater in urban areas (McFarlane 2019). Within the runoff catchment area for Cockburn Sound, a series of open and piped drains discharge into Lake Richmond in the City of Rockingham (DEC 2010). Inflows into Lake Richmond are balanced by outflow into the Rockingham Main Drain, which discharges into the Sound. Therefore, water flux into the Sound from open channel drains potentially includes a component of groundwater as well as stormwater. There is also a network of stormwater drains managed by Main Roads (associated with ‘State’ roads, Figure 1), but they are located farther inland from the areas described above and none discharge directly into Cockburn Sound.

For the purposes of this investigation, surface water discharge from drains was taken to mean any discharge onto the beach or shoreline area of Cockburn Sound, and any associated with pipes that might discharge beyond the shoreline directly into the Sound offshore. While this report was not intended to include marine outfalls of wastewater (effluent), cooling water, and process wastewater, several industries are authorised to discharge wastewater and stormwater into Cockburn Sound: Appendix 1 contains a record of WA Parliamentary Questions that identified licenced premises discharging into Cockburn Sound, the type of discharge and a record of unauthorised discharges known to have occurred between 2008 and 2016 (Jacob 2016).

There are two ocean outfall pipes in Cockburn Sound for emergency overflow of treated wastewater from Woodman Point WWTP licenced to the Water Corporation (DWER 2019) at Woodman Point and Jervoise Bay (Water Corporation representative, personal communication, 15 September 2022). These outfalls were assessed as not being relevant to this assessment since they are rarely used, with reporting of discharges required under the licence. At industrial sites, stormwater should generally not be discharged into wastewater as it can overwhelm the design capacity of the treatment system (Department of Water 2010).

The inventory of stormwater drains includes drains located on the beach with a clear channel into the Sound, drains located in dune vegetation near the coast that were observed during field trips and information collected on drain outlets managed by commercial properties that exit offshore directly into Cockburn Sound. Marine discharges from the Sepia Depression Ocean Outlet Landline (SDOOL) operated by the Water Corporation are only briefly mentioned in this report in so far as some industries are authorised to discharge treated stormwater using this pipeline (DPC 2004). The SDOOL is primarily used to discharge treated wastewater via a diffuser located 4 km offshore, southwest of Cape Peron into the Sepia Depression, a natural channel approximately 5 km long and 20 m deep (BMT Oceanica Pty Ltd 2014). The southern opening of Cockburn Sound provides a channel between the Sepia Depression and the Sound (BMT Oceanica Pty Ltd 2014).



Data sources:
WC (Water Corporation) - Drainage Open Channel (WCORP-083), Drainage Gravity Pipe (WCORP-080), Sewer Pressure Main (WCORP-069)
LGate (Landgate) - Local Government Area (LGA) Boundaries (LGATE-233)
MRWA (Main Roads Western Australia) - Road Hierarchy
DBCA (Department of Biodiversity, Conservation and Attractions) - Geomorphic Wetlands, Swan Coastal Plain (DBCA-019)
Westport - Stage 2 Option B Concept - Port Footprint

Figure 1. Cockburn Sound catchment showing local government areas (LGA) and potential industrial contributors to surface water inputs into the Sound

2.3 Background

A previous collation of stormwater quality data relevant to this area was published by the Department of Water (2007) in a report that included drains within the City of Rockingham that had outlets on the beach or into unlined sumps in dune vegetation near the coast. Along with additional investigations, these drain locations were re-visited for visual inspection for this study. Although the Department of Water (2007) report includes stormwater nutrient data, this cannot be relied upon as being relevant to current conditions. For example, some drainage networks have been modified by LGAs over time, i.e., combining drains or re-directing flows into sumps that infiltrate to soil and groundwater instead of direct discharge into the Sound.

GHD (2013) conducted a review of contaminant loads to Cockburn Sound for Cockburn Sound Management Council and the Department of Environment and Conservation Environmental Regulation Division. This study produced an historical contaminant loads assessment database that documented annual nutrient loads from atmospheric deposition, groundwater, industrial point sources, shipping and surface drainage into Cockburn Sound between 1950 and 2006. It also produced estimates for contemporary contaminant loads from different land uses in the catchment and cited a lack of recent data as a major knowledge gap. The study identified a lack of published studies on surface runoff from heavy industry and recommended that a visual inspection of the relative size of the drains be conducted to determine which areas discharge the most stormwater to Cockburn Sound (GHD 2013).

In general, unauthorised or uncontrolled discharges from industry into Cockburn Sound have largely been managed or ceased. There have been the occasional reports of unauthorised discharges, for example those documented in Appendix 1 between 2008 and 2016 from different industrial sources and from a vessel at Alcoa Jetty (Jacob 2016). More information about historical direct inputs of contaminants to Cockburn Sound (i.e., boating fuels, anti-fouling, anti-scouring and jetty activities) is available in GHD (2013).

2.3.1 Previous estimates of water and nutrient fluxes for Cockburn Sound

Other activities within Project 3.3 aim to quantify groundwater nutrient fluxes into Cockburn Sound and will be reported on later; however, it is worth summarising previous estimates for groundwater nutrient flux to provide context at this stage.

To estimate nutrient (or chemical) flux, one typically uses the average water flux multiplied by the average nutrient (or chemical) concentration. For surface water, there are no previous estimates of water flux or nutrient flux into Cockburn Sound. There is sparse (likely outdated), nutrient data from stormwater sampling. For groundwater, previous groundwater flow modelling studies have been undertaken to estimate submarine groundwater discharge (SGD) into Cockburn Sound and this, coupled with nutrient sampling data, provides a range of values for total nitrogen: 144 to 585 tonnes/year (Smith et al. 2003) and 655 tonnes/year (Donn et al. 2015) and for total phosphorus: 1.3 to 5.6 tonnes/year (Smith et al. 2003) and 9 tonnes/year (Donn et al. 2015). A range in model-based estimates of SGD nutrient flux are reported due to uncertainty in model parameters (e.g., aquifer hydraulic conductivity, groundwater recharge scenarios) and they also differ between studies because different time periods were modelling under different conditions for groundwater recharge and abstraction. Estimates of nutrient flux into Cockburn Sound at James Point at different times of the year calculated by Loveless and Oldham (2010) using the simple Darcy flux equation and local measurements at the beach face (not model based) ranged from 0.9 to 15.7 tonnes/year for total nitrogen and 0.0015 to 0.29 tonnes/year filterable reactive phosphorous. This approach represents a small portion of the SGD that the previous modelling studies represent, and the nutrient flux estimates are lower. Loveless and Oldham (2010) attribute the lower estimates to natural attenuation induced by biogeochemical reactions specific to the beach aquifer, intertidal zone (Loveless & Oldham 2010).

3 Factors to consider in estimating mass flux of nutrients stormwater

In the absence of stormwater flux measurements, one could use rainfall-runoff models to estimate the volume of runoff to drains as a function of characteristics of the surfaces (i.e., pervious and impervious areas), topographic gradients, vegetation, and rainfall intensity (e.g., see Sitterson et al. (2017) for a review of different models for this purpose). LGAs, such as the City of Kwinana also use tools such as MUSIC[1] (Model for Urban Stormwater Improvement Conceptualisation) to estimate the water flowing specifically from urban sites to design appropriate drainage networks.

The stormwater flux into Cockburn Sound depends on the responsiveness of drainage networks across pipes, sumps and infiltration basins, some discharging direct to the Sound and others draining to groundwater and some open channels that gain or lose water depending on water table fluctuations. Another factor to consider is that LGAs such as the City of Rockingham actively maintain their drainage networks for blockages, such that attempts to predict stormwater flux based on rainfall may vary depending on maintenance schedules. Many of the industrial properties in the City of Cockburn and the City of Kwinana have stormwater management plans that avoid direct surface water discharge into the Sound.

Although it may be possible to use physical aspects of the catchment to predict rainfall-runoff relationships, it was impractical to undertake this exercise to estimate stormwater flux into Cockburn Sound due to the amount of data required and large uncertainty in the characteristics of the network. Nevertheless, physical characteristics of the catchment relevant to stormwater drainage into Cockburn Sound (e.g., land cover and topography) are briefly described as indicative of influences on the scale of inflow.

This report also provides visual observations of stormwater flux into Cockburn Sound in relation to antecedent rainfall during field trips in September 2022, and descriptive information on stormwater management for each LGA and for some of the industrial properties. The field data are inadequate for quantifying total stormwater flux: a dedicated set of flow and auto-sampling equipment would be needed to undertake and make such measurement estimates. The first two visits to site (6- and 9-September 2022) were to survey drain locations, obtain access information, and to observe whether they were flowing. Several drains were flowing following heavy rain on 6-September (following 11 mm of rainfall on the preceding day and whilst raining another ~15 mm on the day of measurement), but no equipment was at hand to measure water fluxes. A third field trip on 14-September was conducted following a rain event (18 mm on the preceding day and dry for the 4 days prior) and although equipment was on hand to measure fluxes, only two of the drains were flowing enough to attempt measurements of flow rate. A float, stopwatch and measuring tape were used to estimate water fluxes (m^3/s): the cross-sectional area of drain filled with flowing water multiplied by the average water velocity. Several measurements of water velocity were obtained by placing the float up-gradient onto the surface of flowing water and its movement to the drain outlet was timed. No water sampling for nutrient/chemical analysis was undertaken.

[1] https://ewater.org.au/products/MUSIC/

4 Overview of surface water and stormwater management

Stormwater management plans for different areas within the Cockburn Sound catchment are in place across multiple agencies, including three LGAs (the City of Cockburn, the City of Kwinana and the City of Rockingham), the Department of Defence for Garden Island, the Water Corporation for the main drains, several industrial properties, including the Australian Marine Complex (AMC), Alcoa, BP Kwinana, CBH Group, CSBP, Fremantle Ports, NewGen Power, Nutrien Ag Solutions Fertiliser, Synergy, Tronox, and the Water Corporation (Figure 1). The list of industrial properties was assembled from those identified near the coastline from a spatial dataset of land tenure cadastre. Contacts from each were sought to interview and confirm the location of any drain outlets to Cockburn Sound. Additionally, a search of licence documents relating to regulated emissions and discharges to the environment from industrial premises was conducted. Licence documents are available online from the Department of Water and Environmental Regulation[2].

4.1 Stormwater drain ocean outlets in local government areas

4.1.1 City of Cockburn

The following description pertains to the drainage catchment for the City of Cockburn section of the study area south of Woodman Point. Along the coast, the physiography varies: to the north there are beaches, parks and reserves with low lying native vegetation near Woodman Point and farther south, there is a seawall below paved surfaces for properties at the AMC. Coastal cliffs bordered by native vegetation and reserves continue farther south along the coastal strip beyond the boundary between the City of Cockburn and the City of Kwinana, ending near Challenger Beach.

There are two north-south trending bands of low topography in the western and central regions of the City of Cockburn. A coastal ridge with an average elevation of 27 m AHD that includes Mt Brown, separates the western low-lying area and its wetlands (i.e., Lake Coogee and Lake Mt Brown) from the ocean. The central ridge located about 4 km from the ocean has an average elevation of 46 m (Divita & Dharma 2017). East of this central ridge are several wetlands that receive drainage from the surrounding areas, but there is no connection with the ocean.

The City of Cockburn drainage infrastructure network is made up of series of pits and pipes, drainage sumps, wetland storages and arterial drainage (Divita & Dharma 2017) as shown in Figure 2. Natural wetlands are used to capture stormwater and provide storage for rainfall events that typically exceed an annual exceedance probability (AEP) of 20% (Divita & Dharma 2017). The only stormwater drain managed by the City of Cockburn into the ocean is a connection to an overflow line (N. Sabaratnam, Drainage Engineer, City of Cockburn). The overflow line is associated with a stormwater sump (near 95 Clarence Beach Road, Henderson) with discharge via a pipeline through the seawall below the AMC hardstand likely only to occur in high rainfall events. Documents provided by the City of Cockburn drainage engineer and a mapping tool to examine the drainage infrastructure[3] were consulted. The sump is between Clarence Beach Road and Cockburn Road and receives drainage from both roads and a carpark on Clarence Beach Road. The drainage source is mostly runoff from road surfaces. To the east of the sump is a large expanse of native vegetation that is part of the western buffer zone for Woodman Point Wastewater Treatment Plant (WWTP). There is no information about stormwater volumes for this sump.

[2] https://www.der.wa.gov.au/our-work/licences-and-works-approvals/current-licences

[3] Drainage Infrastructure is accessible on the City of Cockburn website at: https://experience.arcgis.com/experience/672e8863c58d49eab1338fbc8aa875fb/

4.1.2 City of Kwinana

The City of Kwinana coastline south of the border with the City of Cockburn transitions from a steep, rocky shoreline into long stretches of sandy beach, beginning with Challenger Beach. Similar open sandy beaches continue to the south boundary with the City of Rockingham at Wells Beach. Industrial land use within the Kwinana Industrial Area (KIA) occupies most of the coastline within the City of Kwinana. Stormwater management plans for the industries are described in Section 4.

Documents provided by the City of Kwinana and a mapping tool to examine the drainage infrastructure[4] were consulted (Figure 2). The drainage infrastructure maps indicate an interconnected network of pits and pipes, culverts, stormwater channels and water harvesting devices located mostly in urban areas east of the industrial area. Within the industrial area, the City of Kwinana manages only a limited number of drainage assets which are generally associated with sumps or swales where runoff is infiltrated. For the remainder of roads, runoff is directed to roadside swales for infiltration. There is steep topography at Noots Boat Ramp, Challenger Beach that would allow stormwater runoff from Sutton Road to enter the Sound (R. Ganesha, Coordinator Engineering Developments, City of Kwinana). Overall stormwater runoff from roads in the City of Kwinana does not contribute to direct surface water inputs into Cockburn Sound, but rather contributes to groundwater through infiltration.

For pavement and drainage of non-trafficable areas used for lay down or storage at industrial properties, the City requires drainage by grading the pavement towards permeable areas like swales, sumps or soakwells (City of Kwinana 2020). For unsealed areas, the drainage design should contain flows up to a 20% AEP (1 in 20 year storm), over a 72 duration, within the property (City of Kwinana 2020). Some of the recently developed industrial coastal area is under a different stormwater management scheme. For example, The Flinders Precinct (Stage 1 of Latitude 32 Industry Zone) located 3 km east of the coast, has separate environmental requirements for stormwater treatment, i.e., stormwater generated onsite (excluding roof rainwater) should be treated before direct infiltration on-site (Latitude 32 2012).

[4] Drainage Infrastructure is accessible on the City of Kwinana website at: https://maps.kwinana.wa.gov.au/IntraMaps96/

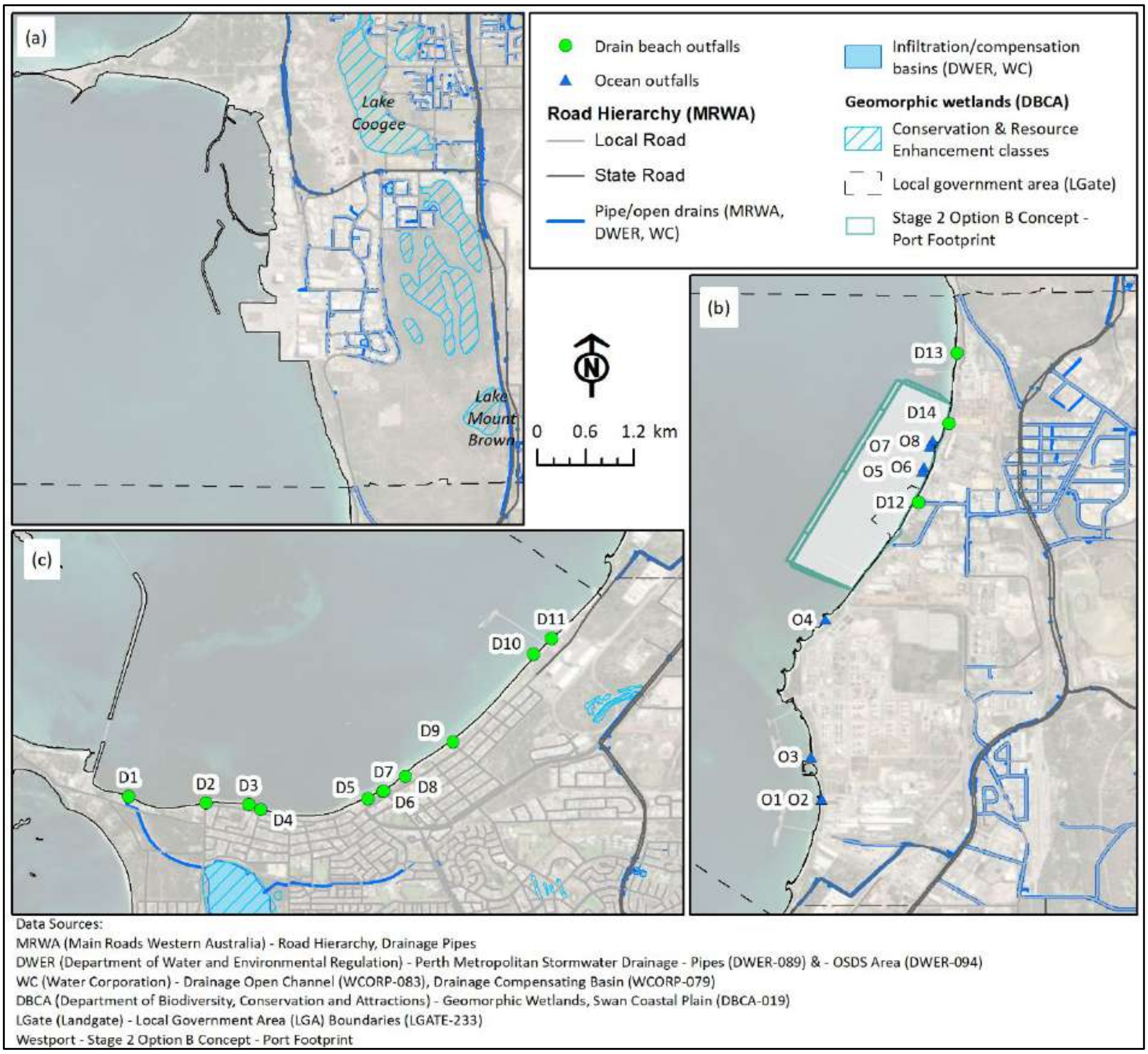


Figure 2 Local government and main roads drainage infrastructure (a) City of Cockburn, (b) City of Kwinana and (c) City of Rockingham. The location of eight ocean outfalls identified from DWER licence documents for industries in this area and 14 stormwater drains identified during field trips (September 2022). D10 and D11 are used by CBH; D12 is used by Water Corporation (Perth Seawater Desalination Plant); D13 is 50 m from Alcoa property. D14 is an unconfirmed drain near Alcoa property.

4.1.3 City of Rockingham

The northern boundary of the City of Rockingham intersects the coastline about one kilometre south of Port Rd and Kwinana Bulk Jetty. Port Rd is the northern extent of the Rockingham Industrial Zone (RIZ). The RIZ coastline is about 2.5 km in length and encompasses CSBP to the northeast to CBH Grain Terminal to the southwest near the intersection of Rockingham Road and Governor Road. The remaining coast from this intersection to Mangles Bay is about 5.5 km of shoreline of mostly broad, flat sandy beaches, bordered by dune vegetation, reserves and public open space. The land cover within 1 km upgradient from the coast is mostly urban residential. Several of the major coastal reserves in the study area are Rockingham Road Conservation Reserve, Governor Road Reserve, Naval Memorial Reserve, Bell Park Reserve and Palm Beach, which are managed by the City of Rockingham, and a large, (27 ha) reserve that is part of the Rockingham Lakes Regional Park system northwest of Lake Richmond, which is managed by the Department of Biodiversity, Conservation and Attractions. Rotary Park, less than 200 m inland from the Mangles Bay, contains a wetland that receives stormwater diverted from Palm Beach (Environmental Health Directorate 2006, Anderson 2009).

In contrast to the other LGAs described above, the City of Rockingham manages many stormwater ocean outfalls (Department of Water 2007). The City has to carefully manage urban drainage to minimise the risk of inundation, particularly in areas of new development that are close to sea level (City of Rockingham 2022b). The City is currently contracting the services of a private company to clean and maintain the existing drainage systems, which involves vacuuming, higher pressure cleaning and underground remote controlled camera inspection of the stormwater drainage system in various catchments and areas of previous flooding (City of Rockingham 2022a).

While there are no recent documents or maps detailing the City's drainage infrastructure network, the drainage network is likely to be associated with urban roads adjacent to the coastline (Figure 2). A report by the Department of Water (2007) shows the locations of many drains and these were re-visited (see Section 5), however a few of the drains no longer exist and some have been combined or converted to underground infiltration cells (City of Rockingham, personal communication, 12 October 2022). Planning policy documents for urban water management specify that no developments should have direct discharge of small rainfall event runoff into wetlands or Cockburn Sound; however, "*runoff from minor and major events is acceptable providing it has been demonstrated that there is appropriate onsite management and treatment of small rainfall events to improve water quality*" (City of Rockingham 2022b). The planning document advises that, "*For frequently occurring small rainfall events up to and including the first 15 mm, lot runoff should be managed within lots and road runoff should be managed within road reserves. Where site conditions do not allow for the full runoff to be managed at source, manage as much as practical at-source. The remaining runoff should be conveyed from a lot or road reserve via piped drainage or overland flow wherever practical*", and that for major rainfall events, "*overland flow paths using the road network must be provided whilst avoiding trapped low points*" (City of Rockingham 2022b).

4.1.4 Rockingham Main Drain (Water Corporation)

The Water Corporation is the responsible authority for the Lake Richmond outlet drain, also referred to as the Rockingham Main Drain (Department of Water 2007) and the Mangles Bay drain (WIR database) that discharges into Mangles Bay (Cranford Pty Ltd and Western Australian Land Authority 2013). Lake Richmond interacts with both surface water and groundwater with a weir above the outlet drain serving to artificially maintain the lake level in winter at an elevation of 0.58 m AHD (Cranford Pty Ltd and Western Australian Land Authority 2013). Lake Richmond water quality varies from predominantly fresh during the winter to saline during summer (Cranford Pty Ltd and Western Australian Land Authority 2013). The drain outlet is about 10 km southwest of the Westport development site. The drainage network associated with Lake Richmond is shown in Figure 1.

Data on stormwater discharge rates and water quality for this drain outlet are lacking. There is a single water quality sampling event from November 2003 recorded in the WIN database. The Department of Water (2007) reported average nutrient concentrations from sampling three times between June and August in 2005. There has been residential sub-division development and likely modifications of the urban drainage surrounding Lake Richmond.

While an early report from 2004 noted that the outlet drain only flowed for a couple of weeks per year (GHD 2013), this has not be re-evaluated in recent times. Observations by a local resident, Mr Ian Steenbhom, retired marine surveyor who regularly walks this area stated that this drain flows from about early June until mid- to late February (I. Steenbhom, personal communication, September 2022).

4.2 Surface water outfalls and stormwater management for industrial sites

Table 1 lists the key industries, information about their purpose to provide background on potential chemical sources, and distance between the farthest extent of each property to the approximate centre of the Westport development site. Eight ocean outfalls were identified and are labelled in Figure 2. Additional details about the stormwater management plans for different industrial premises are provided in this section. The majority of stormwater drains in the study area are managed by the LGAs (see Section 4.1), but a few stormwater drains near industry properties were observed during field trips (Figure 2).

Table 1. Details relating to stormwater assessment for commercial properties near Cockburn Sound. Outfall and drain locations are provided in Appendix 3.

Commercial property or industry	Description of main activity	Approximate location and proximity to development site	Number of marine outfalls into Cockburn Sound	Outfall# or Drain # (Figure 2)
Alcoa	Alumina refinery	1.3 to 2.5 km North	None (unconfirmed)	D14, D13
Australian Marine Complex	Repair, maintenance and construction of naval and commercial vessels, as well as infrastructure for the fabrication and assembly of offshore oil and gas modules	4.4 to 7.4 km North	None (unconfirmed)	--
BP Kwinana	Former crude oil refinery	1.3 to 3.1 km South	None, but 1 beach outfall if SDOOL is unavailable	O4
CBH Group (Kwinana Grain Terminal)	Grain storage and transport by rail and ship	6.2 to 6.8 km South	2 drains (1 of these is managed by the City of Rockingham)	D10, D11
CSBP (a subsidiary of WesCEF)	Chemical (products include sodium cyanide, ammonia/ammonium nitrate) and fertiliser manufacturing	3.9 to 4.4 km South	1 sub-sea pipeline can discharge treated stormwater when the wastewater system is exceeded (non-routine). Also discharge via beach outfall for emergency use only.	O1, O2
Fremantle Ports (Kwinana Bulk Terminal and Jetty)	Loading and unloading of clinker, coal, ore, ore concentrate and any other bulk granular material (other than salt) from vessels	Kwinana Bulk Terminal: 1.1 km South; Kwinana Bulk Jetty: 4.4 km South	None	--
NewGen Power	Gas fired power station	Within the development zone	1 sub-sea pipeline	O6
Nutrien Ag Solutions Fertiliser	Chemical blending or mixing; fertiliser storage	4.5 to 4.8 km South	None	--
Synergy (Kwinana Power Station and Cockburn No 1 Power Station)	Gas fired power station	Within the development zone	2 open channel drains for discharging cooling water, reverse osmosis treated wastewater, and stormwater	O7, O8
Tronox (Pigment Plant)	Titanium dioxide production	No coastline frontage (1.4 km inland from Cockburn Sound); 2.8 to 3.4 km Southeast of WESTPORT	1 sub-sea pipeline for treated process wastewater	O3
Water Corporation (Perth Seawater Desalination Plant)	Seawater desalination	Within the development zone	1 sub-sea pipeline for desalination effluent (brine) and 1 stormwater drain onto beach	O5, D12

4.2.1 *Alcoa Kwinana Refinery*

The Alcoa Kwinana Refinery does not discharge any process water from the site. All stormwater runoff from the refinery is collected and stored in lined ponds for recycling (Alcoa 2012).

4.2.2 *Australian Marine Complex (AMC)*

The AMC has a 3.6 km length of foreshore located between 4 and 7 km north of the Westport development site (Figure 1).

According to a report on the infrastructure of the AMC, which is now managed by Development WA, "Stormwater drainage is provided throughout the AMC via a piped system feeding into a number of sumps for collection and natural infiltration. When flows exceed a certain volume there is a series of overflow paths, into larger sumps. Stormwater is discharged into Cockburn Sound through gross pollutant traps. The City of Cockburn is responsible for the stormwater drainage network within the AMC" (Foster & Blanksby 2020). City of Cockburn drain infrastructure is discussed in Section 4.1.1. Within the 400,000 m^2 area in the southern portion of the AMC, referred to as the Common User Facility, stormwater drainage is managed by the a contracted facility manager responsible for day-to-day operations (Foster & Blanksby 2020).

A search of the DWER database of licenced authorisations of discharges to the environment revealed no entries for the AMC or its individual tenants, except BAE Systems Australia Defence Pty Ltd, which is Australia's second largest ship lifting facility and used for the building, repair of large naval and commercial vessels, abrasive blasting of anti-fouling paints and corroded surfaces and metal coating of ships (DWER 2015). The BAE premises covers 8.4 hectares of land adjacent to Cockburn Sound. The site was classified in 2010 under the Contaminated Sites Act 2003 as 'Possibly contaminated - investigation required' (DWER 2015).

Regarding discharges to the environment, the DWER licence for BAE indicates, "stormwater is captured in a series of pits and pumped into an infiltration pond. The sediment at the bottom of the infiltration pond is collected annually and disposed off-site" (DWER 2015). There are no specified conditions relating to emissions to surface water; however there is a statement advising of an intention to upgrade stormwater management (DWER 2015).

4.2.3 *BP Kwinana*

There are no drains for conveying process water or stormwater into Cockburn Sound from BP Kwinana. According to the current DWER licence for emissions and discharges to the environment for BP Kwinana, stormwater is processed through an on-site wastewater treatment plant and there are limits on process wastewater discharge as shown in Table 2 (DWER 2022a). Treated wastewater from the wastewater treatment plant is discharged to the SDOOL pipeline (routine discharge) or the Cockburn Sound outfall (only when discharge via SDOOL is unavailable) (DWER 2022a). The Cockburn Sound outfall is located on the shoreline. Since the conclusion of refining operations, seawater is no longer used for cooling on site, therefore salt cooling water is no longer discharged to the Sound.

Table 2. Discharge limits for wastewater to Cockburn Sound via outfall

Parameter	Discharge limit	Compliance period
Total nitrogen	200 kg/day	Daily
Total suspended solids	40 mg/L	Monthly average
Chemical oxygen demand	100 mg/L	
Biological oxygen demand	25 mg/L	
Total hydrocarbons	120 kg/day	Daily
Phenolics	20 kg/day	
Sulphides	10 kg/day	
Arsenic	0.4 kg/day	Yearly average
Cadmium	0.08 kg/day	
Chromium	0.16 kg/day	
Cobalt	0.16 kg/day	
Copper	0.16 kg/day	
Lead	0.16 kg/day	
Mercury	0.008 kg/day	
Nickel	0.16 kg/day	
Vanadium	0.16 kg/day	
Zinc	0.8 kg/day	

4.2.4 Co-operative Bulk Handling (CBH)

According to a representative from CBH, there are two stormwater outfalls that service CBH's Kwinana Grain Terminal. One of the drains is scheduled for repair as it is currently in a collapsed state. This drain is part of infrastructure managed by the Department of Transport.

"*The second drain is City of Rockingham infrastructure and CHB worked with the City to redirect it into the dune swale that currently exists due to ongoing erosion effects from tides in the vicinity of the original pipe. Both stormwater pipes have a gross pollutant and chlorine treatment system utilised, and these are housed within the CBH Grain Terminal footprint*" (CBH representative, personal communication, 02 November 2022).

Although not relevant to baseline conditions, there is some information in DWER work approval documents for expansion of the premises in 2021 (DWER 2021f, a). The following statements were provided in the water management description:

"*The stormwater management strategy focuses on managing clean stormwater and stormwater potentially containing nutrients (contaminated stormwater) separately. Stormwater runoff from internal roads where trucks deliver the liquid Urea Ammonium Nitrate (approximately 600 m^2) and the truck washdown area (approximately 1000 m^2) will be directed to an evaporation pond. Uncontaminated stormwater runoff collected from other internal roads, roofs and carpark areas will be collected and infiltrated using downpipes (from roofs), underground cells, drainage swales and soakwells*" (DWER 2021a).

"*The general intent of the stormwater management strategy is to:*

- separate uncontaminated stormwater runoff from potentially contaminated runoff;
- collect and contain all the potentially contaminated runoff using a lined evaporation pond;
- collect and infiltrate the uncontaminated runoff from the first 15 mm event using underground cells, infiltration swales and soakwells; and

- collect and infiltrate the uncontaminated runoff in events greater than the first 15 mm up to 1% AEP (Annual Exceedance Probability) event in underground cells, infiltration swales and soakwells" (DWER 2021a).

4.2.5 CSBP

A review of the CSBP premises before a proposed expansion, identified that as of December 2004 process water and stormwater were routinely discharged via the sub-sea pipeline into the Cockburn Sound at an average rate of 1.5 ML/day (CSBP 2005). However, the planned expansion beginning in February 2005, redirected wastewater and stormwater discharge to the SDOOL.

Stormwater and low-strength effluent generated from the site is routed through wetlands for treatment before being discharged via the SDOOL (Dominigos et al. 2011). When the capacity of the wastewater system is exceeded, discharges can occur via the sub-sea pipeline into Cockburn Sound. According to the current DWER licence for emissions and discharges to the environment for CSBP Kwinana (DWER 2021c) and an e-mail correspondence with the Environment Superintendent of WesCEF, there is one sub-sea pipeline for non-routine use and a beach outflow for emergency discharge of process water into Cockburn Sound.

The effluent discharge limits specified in the DWER licence for CSBP are provided in Table 3 (DWER 2021c).

Table 3. Discharge limits for effluent to Cockburn Sound via sub-sea pipeline

Parameter	Daily concentration discharge limit (mg/L)	Monthly average daily load limit for discharge (kg/day)
Total inorganic nitrogen	--	200
Orthophosphate	--	100
Arsenic (inorganic)	0.1	--
Cadmium	0.036	--
Copper	0.0285	
Free cyanide	0.1	--
Fluoride	--	54
Mercury	0.0014	0.020
Molybdenum	0.25	--
MDEA	16.0	--
Zinc	2.25	--

Note: Total inorganic nitrogen, orthophosphate, and fluoride are calculated as a three-month rolling average

4.2.6 Fremantle Ports

The Fremantle Ports Authority operates two premises in Cockburn Sound the Kwinana Bulk Terminal (KBT) and Kwinana Bulk Jetty (KBJ). According to the DWER licence for KBT, all stormwater from the site is drained to three unlined infiltration basins with no stormwater directly discharged into Cockburn Sound (DWER 2021e). For the KBJ site, the DWER licence indicates that washwater and stormwater are contained (drains, holding tank) on the jetty and that contaminated stormwater/wastewater is either held in a holding tank or pumping into a truck for disposal (DWER 2021b). The following statements are provided for washwater and stormwater management:

"*Vessels and their holds, deck and equipment must not be washed into marine waters. Collect and contain stormwater contaminated with product and washwater that collects on the deck of the wharf,* *so that it does not enter marine waters. Berths bunded and sealed to contain all product contaminated stormwater/wastewater and prevent any material spilt entering the marine environment*" (DWER 2021b).

A representative from Fremantle Ports confirmed the licence information and no further data was provided (personal communication, 13 October 2022).

4.2.7 NewGen Power

NewGen Power operate a gas-fired power station which uses seawater for the cooling process during electricity generation. According to the DWER licence for the NewGen premises, "*cooling water is chlorinated before use and returned to Cockburn Sound via a gravity-fed undersea pipeline which extends approximately 300 m offshore and contains a diffuser array to promote mixing. Some wastewater from the water treatment plant is added to the cooling water prior to entering the sub-sea pipeline. Liquid waste from the demineralisation plant and blowdown is sent to a lined evaporation pond*" (DWER 2016). The licence contains a risk assessment referring to contaminated stormwater runoff within operational areas: there is possible contamination of soil and groundwater through unlined stormwater drainage systems (DWER 2016).

4.2.8 Nutrien Ag Solutions Fertiliser

The Nutrien facility consists of storage bays for fertiliser products, and sheds for fertiliser storage, blending and distribution about 100 to 300 m east of Cockburn Sound. The DWER licence for the Nutrien site shows stormwater drainage lines on one of the sheds, a lined stormwater pond with a permeable reactive barrier and a drainage pit (DWER 2021d). This indicates that stormwater is managed on site with no direct surface water inputs into the Sound.

In 2015, an investigation revealed ammonia present in groundwater concentrations exceeding the environmental quality guidelines and a reactive barrier was installed within the (then) unlined stormwater evaporation pond to attenuate nutrients in 2015. Nutrient impacted soil was excavated and removed from the stormwater evaporation pond in 2016. In 2019, the site was classified as 'contaminated -- remediation required' (DWER 2022b).

4.2.9 Synergy

Synergy operates two electricity generation premises, the Kwinana Power Station (KPS) and Cockburn No. 1 Power Station (C1PS). Two open channel drains, project out into Cockburn Sound.

The DWER licence document for KPS indicates that Synergy is authorised to discharge cooling water and reverse osmosis treated wastewater from both W1 and W2 outfalls from this power station (DWER 2012), while C1PS is licenced to discharge cooling water is discharged from the W1 outfall (DWER 2022c).

A representative from Synergy, clarified that the open channel drains discharge cooling water, reverse osmosis treated wastewater, and stormwater (Synergy representative, personal communication, 01 November 2022).

4.2.10 Tronox – Pigment Plant (formerly Tiwest Pty Ltd)

The Pigment Plant is located about 1.2 km east of Cockburn Sound. According to the DWER licence, Tronox is authorised to discharge treated process wastewaters via a sub-sea pipeline with limits on suspended solids, pH and manganese (DWER (2011); Table 4). There are requirements for wastewater monitoring that indicate maintenance of a flow recorder on the discharge from the on-site wastewater ponds to the sub-marine pipeline and weekly sampling for total nitrogen, but there are no discharge limits.

Table 4. Discharge limits for wastewater to Cockburn Sound via sub-sea pipeline

Parameter	Discharge limit	Average period
Suspended solids	50 mg/L	Monthly
pH	6.5 – 10.0	Daily
Manganese	12 mg/L	Weekly

4.2.11 Water Corporation / Perth Seawater Desalination Plant (PSDP)

According to the DWER licence for the PSDP, the Water Corporation is authorised to discharge desalination effluent, including brine from its PSDP via a 160 m-long sub-sea pipeline with a diffuser at the outflow end in Cockburn Sound (DWER 2014). A minimum of 45 dilutions of the desalination effluent at the edge of the mixing zone is estimated as needed. It is estimated that the concentrated brine discharged back to Cockburn Sound has a salinity of approximately 65,000 mg/L (DWER 2014).

Drainage construction plans for the site indicate that the property has infiltration basins, road gullies, spoon drains, perimeter basins for managing stormwater. There is only one drain onto the beach and there is no water quality monitoring of stormwater (Water Corporation/PSDP representative, personal communication, 29 September 2022).

4.3 HMAS Stirling on Garden Island

The land cover on Garden Island is approximately 90% vegetated and the only major development is Fleet Base West located at HMAS Stirling, the Royal Australian Navy base, which is managed by the Department of Defence. Most of the naval infrastructure is centred around the southeast end of the island near Careening Bay, which is 8 to 9 km west of the WESTPORT development site. There are no natural surface water bodies on the Island (Blackman 2018). A packaged treatment plant replaced legacy treatment ponds for wastewaters and there are two infiltration ponds farther north on the island; however, these rarely see any inflow. Most of the output from the treatment plant is used for irrigation (Department of Defence / Environment and Engineering Branch/ Infrastructure Division representative, personal communication, 08 November 2022). Over much of the island, which is undeveloped, stormwater is likely to infiltrate directly into the sandy soils (Rodolakis 2018).

Stormwater is collected into unlined, open drainage swales for infiltration at several facilities. The stormwater pipe network appears to indicate that runoff from the wharf and some hardstanding areas drains into Careening Bay (Blackman 2018, Rodolakis 2018). This matches the description in early development plans for the stormwater drainage system (Environmental Protection Authority 1989).

One of the Helicopter Support Facility hangers has an enclosed piped stormwater infrastructure, which is connected to an underground storage tank for offsite disposal (Rodolakis 2018).

5 Stormwater drain inventory and visual survey

A visual survey was conducted to inventory existing stormwater drains (Table 5). Photos from the 06 September 2022 survey and a return visit on the 14 September were used to compare the drains under wet conditions and after a few days of drier conditions (Figure 3 to Figure 6).

A previous collation of stormwater data relevant to this area was published by the Department of Water (2007) in a report that included drains within the City of Rockingham that had outlets on the beach or into unlined sumps in dune vegetation near the coast. As described in Section 4.1.3, some of these previously reported drains no longer exist and some have been combined or converted to underground cells (City of Rockingham, personal communication, 12 October 2022). These have been noted in Figure 7 (ROC10, ROC11, and ROC12). Water quality sampling conducted in 2005 for 15 of these stormwater drains is provided in Appendix 2. Total nitrogen concentrations in these stormwater samples varied from 0.086 mg/L to 2.7 mg/L (median 0.36 mg/L) with the N speciation varying both spatially and temporally. Total phosphorus concentrations varied from 0.019 mg/L to 0.20 mg/L (median 0.07 mg/L) and similarly P speciation varied spatially and temporally. However, considering that urban land use has changed little since concentrations of nutrients were measured in 2005, this dataset provides an indication of the potential concentration ranges that may be observed (Appendix 2).

Table 5. Description of stormwater drains visited on different dates. Not all sites were visited each time (--).

Stormwater drain	06 September 2022	09 September 2022	14 September 2022	17 September 2022
D1	high flow	high flow	high flow	high flow
D2	low flow	dry	dry	--
D3	low flow	dry	dry	--
D4	low flow(?) submerged outlet	dry	dry	--
D5	medium flow	dry	dry	--
D6	dry	dry	dry	--
D7	dry	dry	dry	--
D8	medium to high flow	trickling	trickling	--
D9	high flow	dry	dry	--
D10	high flow	dry	dry	--
D11	high flow	dry	small trickle of part of the cross-section	dry
D12	dry	--	dry	--
D13	dry	dry	dry	--
D14	--	--	dry	--
ROC07	--	--	dry	--
ROC08	--	--	dry	--
ROC09	--	--	dry	--

Figure 3. Locations of stormwater drains D1 through D8 identified during trip on 06 September 2022. These drains are all in the City of Rockingham.

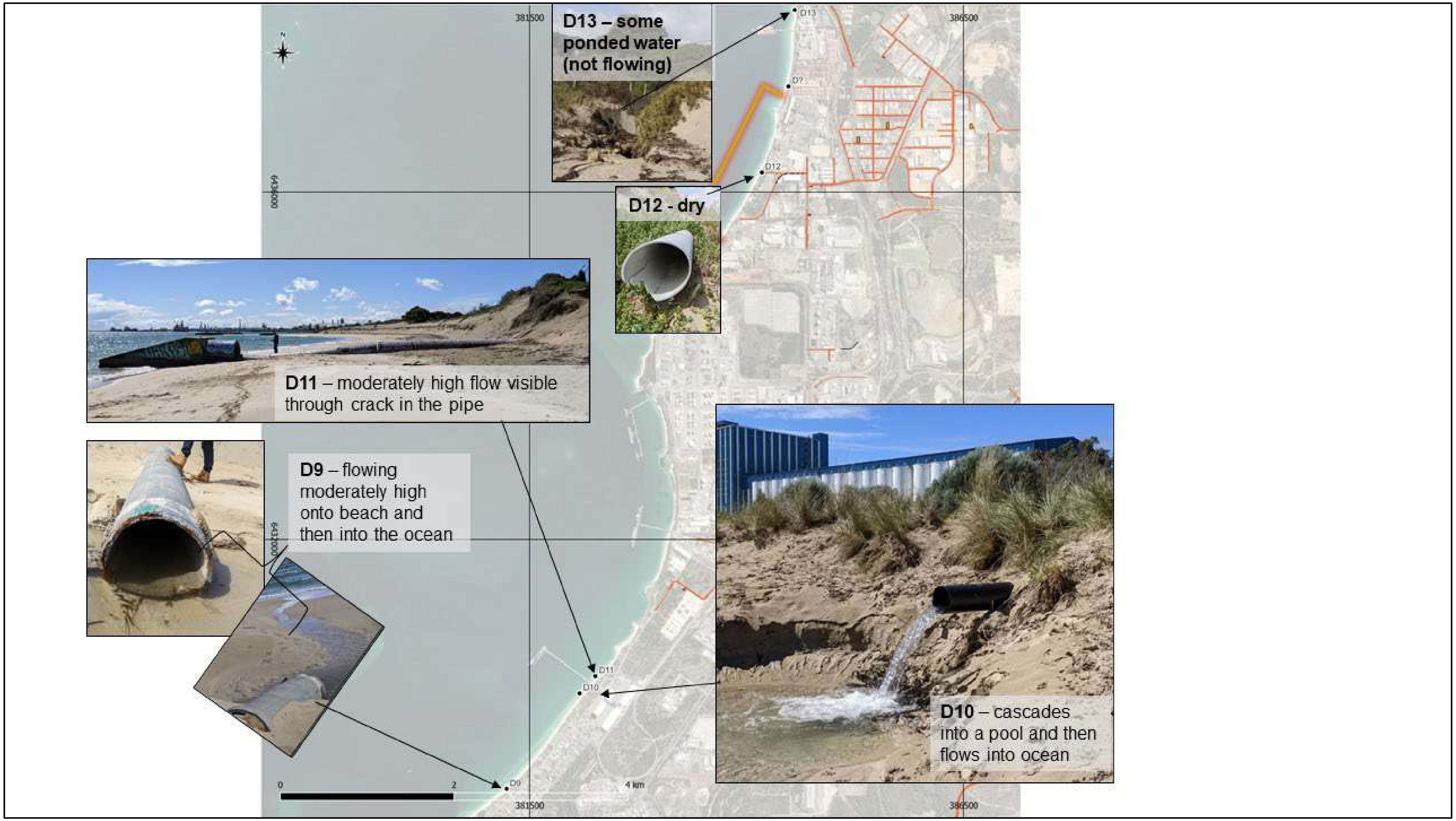


Figure 4. Locations of stormwater drains D9 through D13 identified during trip on 06 September 2022. D9-D11 are in the City of Rockingham; D12 and D13 are in the City of Kwinana.

Figure 5. Stormwater drains D1 through D8 re-visited on 14 September 2022. Compare with Figure 3, which was during wetter conditions.

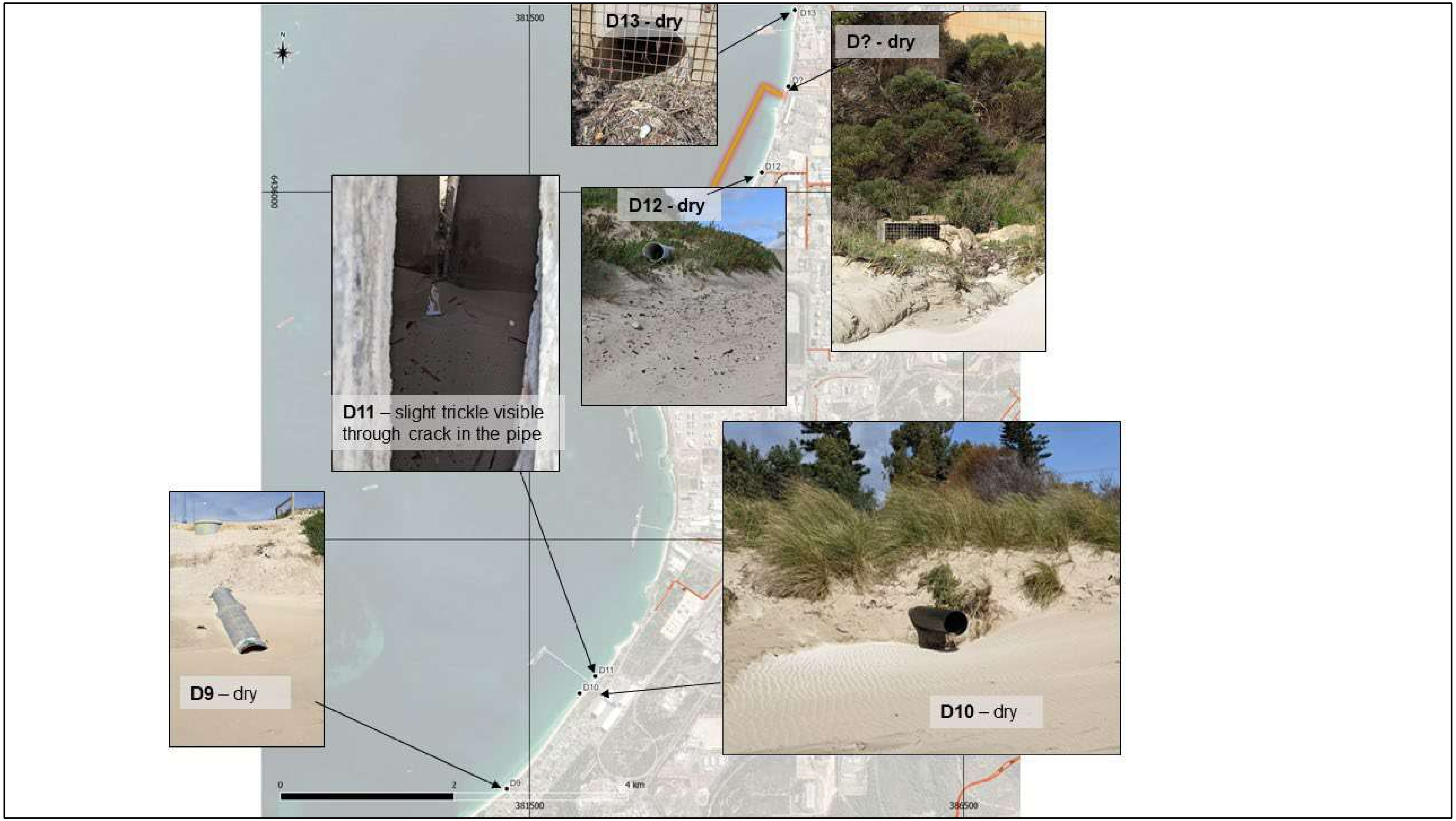


Figure 6. Stormwater drains D9 through D13 re-visited on 14 September 2022. Compare with Figure 4, which was during wetter conditions.

Figure 7. Drains located farther away from the shoreline and closer to roadways in the City of Rockingham, including unlined sumps in dune vegetation (photos from 14 September 2022).

6 Calculated fluxes for stormwater drains

Following a rain event on 14 September, two of the stormwater drains (D1 and D8) were flowing enough to attempt measurements of their flow rates. A float, stopwatch and measuring tape were used to estimate water fluxes (m^3/s): the cross-sectional area of drain filled with flowing water multiplied by the average water velocity. Several measurements of water velocity were obtained using a float placed up-gradient onto the surface of flowing water and its movement to the drain outlet was timed.

For D1, the flowing cross-section was about 0.38 m^2. The average velocity based on timing the float travelling a 1 m length was 0.01 m/s, yielding a water flux of approximately 360 m^3/day.

For D8, the flowing cross-section was about 6.4 m^2. The average velocity based on timing the float travelling a 50 cm length was 0.0185 m/s, yielding a water flux of 10 m^3/day.

7 Discussion

Surface water inputs into Cockburn Sound are derived from two main sources, rainfall runoff or stormwater, and water generated/used for industrial processes. Regionally road runoff is likely to only contribute to surface water inputs into the Sound in the City of Rockingham where stormwater drains discharge directly into the Sound. Aside from the Rockingham Main Drain flows are most likely to be intermittent and associated with rainfall events; however, this is based on limited observations. Since the spatial distribution of the urban drainage network was not available to the project, it remains unclear what the contributing area and sources are for the stormwater outfalls. Flows from the Rockingham Main Drain are likely to be more persistent since the catchment includes Lake Richmond and a network of drains designed to intercept groundwater. No data exist to quantify the surface water flows into the Sound from these stormwater drains or the Rockingham Main Drain.

Limited water quality data (up to 3 measurements) is available for stormwater drain discharge in the City of Rockingham (Department of Water 2007). While this data is from 2005 it may be currently relevant since the area is an established urban area with little land use change. However, without recent flow data, it is not possible to accurately estimate nutrient loading into Cockburn Sound.

Surface water inputs into the Sound from industry located along the coastline have reduced over the past 50 years, through the discharge of treated wastewater via the SDOOL from 1984 (BMT Oceanica Pty Ltd 2014) and subsequent discharge of industrial wastewater to the SDOOL (BP Refinery Kwinana and CSBP fertiliser plant; (DPC 2004)). Pipeline outfalls into Cockburn Sound are still maintained by CSBP and BP Kwinana for emergencies when the wastewater system is exceeded or the SDOOL is unavailable (non-routine) and any discharges are reportable to DWER as enforced by the discharge licences. Tronox maintains a submarine discharge pipeline into Cockburn Sound, with the discharge licence indicating that nitrogen is monitored. Nutrient fluxes could be calculated from the cumulative flow measurements and nutrient concentration data. Other industries including Alcoa, Fremantle Ports and Nutrien Ag Solutions Fertiliser manage stormwater such that it is either used in their processes or infiltrated to groundwater. Electricity generation (Synergy and NewGen Power) utilise seawater for cooling which is returned to the Sound after some level of treatment, but while it may induce localised temperature changes, it is unlikely that this will impact the mass loading of nutrients to the Sound. Similarly, the Perth Seawater Desalination Plant discharges brine back into the Sound and while nutrients are concentrated in the brine, they are required to be diluted to background at the edge of the mixing zone (DWER 2014); thus the mass loading impacts are negligible.

According to the data collected after a rainfall event in September 2022, water fluxes were 10 m^3/day and 360 m^3/day for stormwater drains D8 and D1, respectively as described in Section 6. Based on water quality sampling data published by the Department of Water (2007) and described in Section 5, the maximum measured concentrations of total nitrogen and total phosphorus were 0.54 mg/L and 0.1 mg/L (D8) and 0.7 mg/L and 0.022 mg/L (D1), respectively (Appendix 2). The water fluxes multiplied by the maximum nutrient concentrations suggest the contribution of nutrients from stormwater are less than 0.1 tonnes/year (for D1: 0.09 tonnes/year for total nitrogen; 0.003 tonnes/year total phosphorous).

In comparison, previous investigations to quantify groundwater inflow to Cockburn Sound provide a range of values between 0.9 and 655 tonnes/year for total nitrogen and between 0.0015 and 9 tonnes/year for total phosphorus (Smith et al. 2003, Loveless & Oldham 2010, Donn et al. 2015).

8 Conclusions/recommendations

Based on the work undertaken to complete KP2-4 in the WAMSI Science Project Plan for Project 3.3, it is concluded that:

- Surface water discharges to Cockburn Sound are notionally from 14 stormwater drains with the majority of these used for urban drainage within the City of Rockingham, and 8 ocean outfalls for industries located in the City of Kwinana.
- For ocean outfalls into Cockburn Sound from industry, water flux data and water quality data were sought from major industries, but no quantitative ocean outflow data were made available by the industries contacted for this study (Table 1).
- A review of DWER licence information for industries that are authorised to discharge process water directly into Cockburn Sound revealed that only BP Refinery Kwinana and CSBP have nutrient discharge limits specified for their Cockburn Sound outfall; however, since about 2005, these two industries have mainly used the SDOOL pipeline, which does not discharge directly into Cockburn Sound.
- Of the 14 stormwater drains identified during field visits in September 2022, only the Rockingham Main Drain was observed to be consistently flowing into Cockburn Sound and a local resident stated that this drain flows from about early June until mid- to late February. The average flow rate measured on 14 September was about 360 m^3/day into Cockburn Sound.
- Eight drains were flowing on one field visit following 11 mm of rainfall on the preceding day and whilst raining another ~15 mm on the day of measurement. Some of the LGAs, such as the City of Rockingham, actively maintain their drainage networks for blockages, such that attempts to predict stormwater flux based on rainfall may vary depending on maintenance schedules.
- Rough estimates from our field survey suggest that maximum contribution of nutrients from stormwater could be less than about 0.1 tonnes/year, but there is a high degree of uncertainty due to lack of recent measurements of nutrient concentrations in stormwater from different locations and a lack of stormwater flux measurements seasonally and throughout the year.

To obtain a more accurate assessment it is recommended that comprehensive sampling be undertaken to account for seasonality and spatial variability. The field data are inadequate for quantifying total stormwater flux: a dedicated set of flow and auto-sampling equipment would be needed to make such measurement estimates.

Other activities within Project 3.3 aim to quantify groundwater nutrient fluxes into Cockburn Sound and will be reported at a later date when the relevant investigations have been completed. However, previous investigations (Smith et al. 2003, Loveless & Oldham 2010, Donn et al. 2015), suggest that estimates of groundwater total nitrogen fluxes are more than ten times greater than the stormwater nutrient flux estimates obtained in September 2022.

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10 Appendices

10.1 Appendix 1: WA Parliamentary Questions relating to discharges from industry into Cockburn Sound between 2008 and 2016

The follow text is copied from Jacobs (2016) with investigation/prosecution details removed:

Question On Notice No. 5252** asked in the **Legislative Assembly** on **16 March 2016** by **Mr M. McGowan

*Question Directed to the: **Minister for Environment***
*Question Directed to: **Hon A.P. Jacob***
*Minister responding: **Hon A.P. Jacob***

Question
In relation to Cockburn Sound:
(a) How many licensed premises continue to discharge into the Sound? Please list their names.
(b) What are their authorised discharges?
(c) How many unauthorised discharges are known to have occurred in Cockburn Sound since 2008?
(d) In each case outlined in (c), what was the premise; volume; composition and nature of the discharge? (ii) what action, including prosecution was taken?

Answered on 10 May 2016
(a) Four licensed premises discharge cooling water into Cockburn Sound:
- BP Refinery Kwinana;
- Electricity Generation and Retail Corporation Kwinana Power Station;
- Electricity Generation and Retail Corporation Cockburn Power Station No. 1; and
- Newgen Power Kwinana.

Two licensed premises routinely discharge process wastewater into Cockburn Sound:
- Water Corporation, Perth Seawater Desalination Plant; and
- Tronox (Tiwest) Pigment Plant.

Two licensed premises are authorised to discharge process wastewater to Cockburn Sound but generally discharge via the Sepia Depression Deep Ocean Outfall (SDOOL) and will only discharge to Cockburn Sound in an emergency when discharge to the SDOOL is not possible:
- BP Refinery Kwinana; and
- CSBP fertilizer plant

(b) Authorised cooling water discharges are seawater that has been taken from the sound and returned to the sound. Licenses have limits on temperature and free chlorine which may have been added as an antifouling agent.

The Perth Seawater Desalination Plant is authorised to discharge desalination effluent including brine. Ministerial Statement Nos. 626, 655 and 832 apply to the plant. Ministerial Statement No. 832 includes conditions that require the development and implementation of a marine monitoring plan and management response to declines in dissolved oxygen in the bottom waters of Cockburn Sound.
Tronox is authorised to discharge treated process wastewaters with license limits on suspended solids, pH and manganese. Ministerial Statement No. 452 applies to the plant, which includes conditions (proponent's environmental management commitments) relating to the management and monitoring of wastewater discharge to Cockburn Sound.

BP Refinery Kwinana is authorised to discharge treated process wastewater with limits on hydrocarbons nutrients and selected metals. Ministerial Statement No. 161 applies to the plant but does not include any specific conditions relating to wastewater discharge to Cockburn Sound.

CSBP is authorised to discharge treated process wastewater with limits on nutrients, cyanide and selected metals. Ministerial Statement Nos. 34 and 875 apply to the plant. Ministerial Statement No. 34 includes conditions that relate to discharges of wastewater to Cockburn Sound (monitoring program and reporting arrangements).

(c) 11.
(d)
1. 19 October 2008 - BP Refinery jetty pipeline - estimated 600-800 litres - leak of fire-fighting foam.
2. 12 September 2009 - Kwinana Power Station - estimated leak of 220 litres oil.
3. 27 June 2011 - Alcoa Jetty Kwinana - discharge of unknown volume of fluid from vessel.
4. 22 July 2011 - Kwinana Power Station - emission to air of ash.
5. 14 June 2012 - Alcoa Kwinana Jetty - leak of an estimated 80 litres of hydraulic oil.
6. 31 December 2012 - Kwinana Power Station - discharge of an estimated 100 litres of ash contaminated water.
7. 3 March 2013 - Kwinana Power Station - discharge of an estimated 1000 litres of ash contaminated water.
8. 22 November 2013 - Coogee Chemicals Kwinana - leak of an unknown quantity of diesel fuel.

10.2 Appendix 2: Historical water quality data for Rockingham drains

Apx Table 1. Water quality data for drains surveyed by the Department of Water in their Beach Health Program report (DOW 2007). Source: WIR database (https://www.water.wa.gov.au/maps-and-data/monitoring/water-information-reporting)

Site label (this report)	DOW (2007) report label	Site Ref in WIR database	Collection date	N (sum sol ox) [NOx-N, TON] (ug/L)	N (tot kjel) [TKN] (ug/L)	N (tot) [TN, pTN] (ug/L)	NH3-N/NH4-N (sol) (ug/L)	P (tot) [TP, pTP] (ug/L)	PO4-P (sol react) [SRP, FRP] (ug/L)	Salinity (mg/L)	Suspended Solids (Total) (Gikas & Tsihrintzis) (mg/L)
D10	ROC01	6140015	3/06/2005	250	890	1100	570	110	66	220	1
D10	ROC01	6140015	13/07/2005	160	730	890	490	57	40		3
D10	ROC01	6140015	9/08/2005	100	150	250	150	26	14	34	
D11	ROC02	6140016	3/06/2005	580	2100	2700	1500	200	180	600	3
D11	ROC02	6140016	13/07/2005	95	540	630	440	34	24		4
D11	ROC02	6140016	22/08/2005	270	880	1200	390	120	20	2300	337
D2	ROC16	6141398	21/07/2005	380	410	780	110	80	47		8
D2	ROC16	6141398	9/08/2005	140	270	410	61	120	41		
D2	ROC16	6141398	24/08/2005	82	490	570	32	130	31		44
D3	ROC14	6141397	16/05/2005	31	230	260	75	88	66		3
D3	ROC14	6141397	10/08/2005	49	330	380	130	110	69		
D3	ROC14	6141397	24/08/2005	24	250	270	28	70	36		10
D4	ROC13A	6141395	8/06/2005	30	780	810	52	180	31		180
D5	ROC06	6141388	8/06/2005	34	230	260	49	95	39		119
D5	ROC06	6141388	24/08/2005	91	270	360	<10	110	57		51
D5	ROC06	6141388	20/09/2005	90	290	380	100	110	60		25
D5	ROC06	6141388	20/09/2005	90	300	390	78	110	64		26
D7	ROC05A	6141386	21/07/2005	240	340	570	81	80	42		13
D7	ROC05A	6141386	23/08/2005	33	300	330	45	44	16		75
D7	ROC05A	6141386	20/09/2005	100	160	270	100	75	35		12
D8	ROC04	6140767	13/07/2005	270	270	540	110	55	32	170	49
D8	ROC04	6140767	23/08/2005	19	370	390	32	100	20		78
D8	ROC04	6140767	20/09/2005	39	350	390	49	66	19		11
D9	ROC03	6140766	16/05/2005	64	180	250	<10	47	13		21
D9	ROC03	6140766	3/06/2005	71	290	360	190	22	20	31000	3
D9	ROC03	6140766	22/08/2005	120	320	450	140	50	16	84	17

Site label (this report)	DOW (2007) report label	Site Ref in WIR database	Collection date	N (sum sol ox) [NOx-N, TON] (ug/L)	N (tot kjel) [TKN] (ug/L)	N (tot) [TN, pTN] (ug/L)	NH3-N/NH4-N (sol) (ug/L)	P (tot) [TP, pTP] (ug/L)	PO4-P (sol react) [SRP, FRP] (ug/L)	Salinity (mg/L)	Suspended Solids (Total) (Gikas & Tsihrintzis) (mg/L)
ROC07	ROC07	6141389	16/05/2005	120	220	340	53	80	48		6
ROC07	ROC07	6141389	24/08/2005	22	120	140	26	19	10		69
ROC07	ROC07	6141389	20/09/2005	91	160	250	82	69	41		1
ROC08	ROC08	6141390	8/06/2005	18	240	260	43	38	18		6
ROC08	ROC08	6141390	24/08/2005	73	250	320	33	57	28		9
ROC10	ROC10	6141392	24/08/2005	29	170	200	27	31	19		4
ROC10	ROC10	6141392	20/09/2005	96	160	250	57	62	36		2
ROC10	ROC10	6141392	29/09/2005	11	210	220	54	140	35		6
ROC12	ROC12	6141394	8/06/2005	15	70	86	36	43	27		4
ROC12	ROC12	6141394	24/08/2005	22	170	190	19	33	17		7
ROC12	ROC12	6141394	20/09/2005	35	78	110	58	38	20		2
D1	RMD	6141399	3/06/2005	<10	220	220	45	22	15	31000	4
D1	RMD	6141399	13/07/2005	100	590	700	110	13	5	550	3
D1	RMD	6141399	9/08/2005	89	510	600	51	14	<5	540	

10.3 Appendix 3: Locations of drains, outfalls and other sites referred to in this report

Site	Easting	Northing	Comment
D1	377800	6428395	
D2	378624.5	6428323	
D3	379079.6	6428311	
D4	379203	6428251	
D5	380341	6428403	
D6	380494	6428491	
D7	380507	6428498	
D8	380731	6428683	
D9	381232	6429121	
D10	382075	6430223	
D11	382258	6430422	
D12	384171	6436222	
D13	384553	6438093	
D14	384481	6437214	
ROC07	380273.7	6428353	
ROC08	380102.2	6428259	
ROC09	379986.4	6428179	
ROC10	379964.7	6428177	
ROC11	379667.8	6428131	
ROC12	379468.5	6428162	
O1	383183	6432504	approximate location
O2	383182	6432504	approximate location
O3	383064	6433034	approximate location
O4	383195.4	6434747	approximate location
O5	384206	6436612	approximate location
O6	384222	6436662	approximate location
O7	384280.2	6436927	approximate location
O8	384309	6436991	approximate location

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