Mosquito Risk Assessment and Management Plan

Redbank Power Station
112 Long Point Road West, Warkworth NSW

13 June 2024

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1. Introduction

In Australia, mosquitoes are more than just a seasonal nuisance; they are a significant public health concern. Various species of mosquitoes in Australia are vectors for diseases such as Ross River virus, Barmah Forest virus, Murray Valley encephalitis, and dengue fever. These diseases can lead to severe health complications and place a substantial burden on the community and the healthcare system. Effective management of mosquito populations is therefore crucial to safeguarding public health and ensuring the well-being of Australian residents.

Verdant Earth Technologies Ltd (Verdant) have recently submitted a development application (SSD-56284960) for the restart of Redbank Power Station. As part of the four-week public exhibition of the Environmental Impact Statement (EIS), it is understood that several agencies provided comments for consideration. In particular, Hunter New England Local Health District (HNELHD) has requested that a mosquito risk assessment is carried out to ensure any potential mosquito breeding sites are identified and a mosquito management plan is prepared to reduce both nuisance biting and disease transmission to the local population.

A desktop study has been conducted to review existing data and reports on mosquito populations and habitats, as well an analysis of historical data on mosquito-borne diseases in the immediate area of Redbank Power Station.

An environmental assessment has also been conducted to evaluate factors contributing to mosquito breeding in the area, such as water bodies, vegetation, and waste management practices, as well as assess land use / human activity patterns that may influence mosquito populations in the area.

This analysis has helped evaluate the potential for mosquito-borne disease transmission based on the species likely present. A health risk assessment has been carried out to assess the risk of mosquito-borne diseases to the human population, with particular attention to vulnerable groups and areas with higher risk.

Based on the findings from the risk assessment, targeted mosquito control strategies have been developed. These strategies include source reduction, larvicide, and adulticide, as well as recommendations for integrated pest management (IPM) practices. Public health recommendations have also been provided, offering guidelines for public health education and community involvement, along with strategies for personal protection and behavioural changes to reduce mosquito exposure.

Mosquitoes and the diseases they transmit remain a significant public health challenge in Australia. Comprehensive risk assessments and management plans are essential to protect communities, reduce disease transmission, and promote a healthier environment. By understanding the complex interactions between mosquitoes, the environment, and human populations, targeted and effective strategies can be developed to address this ongoing threat.

1.1. Site identification

The Site is located at 112 Long Point Road West Warkworth NSW.

The Site is located in the Singleton Local Government Area, within the Hunter Valley. The Hunter Valley region is comprised of ten local government areas including Cessnock, Dungog, Lake Macquarie, Maitland, MidCoast, Muswellbrook, Newcastle, Port Stephens Singleton, and the Upper Hunter. It includes Greater Newcastle, the seventh largest urban area in Australia.

The Site is positioned approximately 10 km to the west of Singleton, 10 km northeast of Bulga and 8 km northwest of Mount Thorley. Four open cut coal mines are within 2.2 to 7 km of the Site. The surrounding region also includes rural and agricultural properties and industrial areas.

The location of the Site is shown in Figure 1.1.

Figure 1.1. Site location (Source: NearMap 2024).

2. Mosquito lifecycle, breeding, and disease transmission

Mosquitoes are insects belonging to the order Diptera, and they have a complex lifecycle, unique breeding habits, and are vectors for many serious diseases affecting humans and animals. Understanding these aspects is crucial for effective mosquito control and disease prevention.

2.1. Mosquito lifecycle

Mosquitoes undergo four stages: egg, larva, pupa, and adult (refer to Figure 2.1).

1. Female mosquitoes lay their eggs on the surface of stagnant water or in areas that will later flood. Some species lay their eggs on damp surfaces just above the waterline. The eggs can hatch within days or remain dormant for months until they are submerged in water.
2. Upon hatching, mosquito larvae (also known as "wrigglers") live in the water. They feed on microorganisms and organic matter. Larvae go through four molts (instars), growing larger with each stage. They have a siphon for breathing air at the water surface.
3. The pupal stage (also known as "tumblers") is a transitional phase where the mosquito transforms from a larva to an adult. Pupae are mobile and can respond to light changes and disturbances. This stage lasts for a few days, after which the adult mosquito emerges.
4. Adult mosquitoes emerge from the pupal case and rest on the water surface until their body parts harden and they are ready to fly. Males typically emerge first and form swarms to attract females. Females mate once, storing sperm for future egg batches.

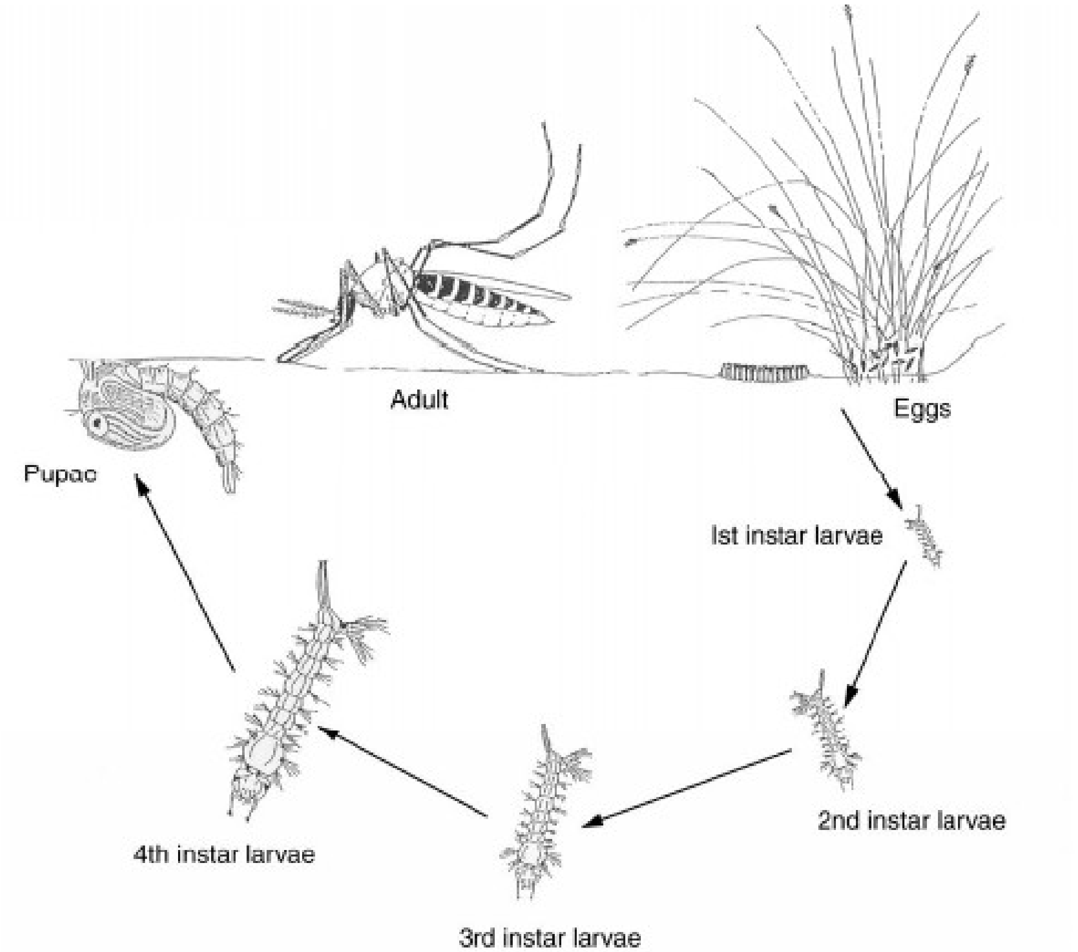

Figure 2.1. Lifecycle of the Mosquito including eggs, four larval stages, pupae and adult (Webb and Russell 2009).

2.2. Breeding

Mosquitoes breed in various aquatic habitats, including natural water bodies (ponds, marshes, swamps), artificial containers (bird baths, discarded tyres), and transient water sources (puddles, ditches).

Each species has specific preferences for breeding sites. For example, *Aedes* species mosquitoes prefer small, temporary water containers, while *Anopheles* species mosquitoes prefer clean, still water.

Warm temperatures and high humidity accelerate the mosquito lifecycle, leading to faster development and increased breeding. Seasonal rains and flooding can create abundant breeding sites, resulting in population surges.

2.3. Disease transmission

Mosquitoes are vectors for several diseases, transmitting pathogens through their bites. Female mosquitoes require blood meals to develop their eggs. When they bite, they inject saliva containing anticoagulants to prevent blood clotting. If the mosquito is infected with a pathogen, the saliva also contains the pathogen, which is transmitted to the host during the bite.

Factors that influence disease transmission include:

- **Mosquito Density**: High mosquito populations increase the likelihood of disease transmission.
- **Human Activity**: Human behaviours, such as storing water in open containers, living near breeding sites, and outdoor activities during peak mosquito feeding times, can increase exposure to mosquito bites.
- **Climate and Environment**: Climate conditions, such as temperature, rainfall, and humidity, significantly impact mosquito breeding and disease transmission. Warmer climates and wetter conditions typically enhance mosquito activity.

3. Major mosquito-borne diseases in Australia

Mosquitoes are a significant public health concern in Australia, primarily due to their role as vectors of various diseases. With over 300 mosquito species across the continent, these insects thrive in diverse environments, from coastal regions and wetlands to urban areas and inland waterways. While not all mosquito species are disease vectors, many pose serious health risks by transmitting pathogens to humans.

Mosquito-borne diseases impose a significant burden on public health in Australia, leading to prolonged illness, increased healthcare costs, and lost productivity. The psychological impact on communities during outbreaks, combined with the need for ongoing mosquito control efforts, underscores the importance of effective management strategies (Healthdirect 2023, NSW Health 2024).

Table 3.1 provides a summary of the major mosquito-borne diseases in Australia.

Malaria has not been included in this table as there are no competent vectors of malaria known to occur in NSW. The risk of malaria occurs when travelling outside of Australia without appropriate protection in malaria-endemic parts of tropical and subtropical areas of Asia, Africa, Central and South America, some Pacific Islands and parts of the Middle East.

Table 3.1. Major mosquito-borne diseases in Australia.

Mosquito-borne disease	Prevalence	Symptoms	Vectors	Impact
Ross River Virus	Ross River Virus (RRV) is the most commonly reported mosquito-borne disease in Australia. It is especially prevalent in NSW	Symptoms include joint pain, swelling, fatigue, and rash, which can last for several weeks to months.	The primary mosquito vectors include *Aedes vigilax* and *Culex annulirostris.*	The virus significantly impacts individuals' quality of life and productivity and can cause prolonged illness (Healthdirect, 2023).
Barmah Forest Virus	Barmah Forest virus (BFV) is the second most common mosquito-borne disease in Australia, found widely across the country, including NSW.	Similar to RRV, BFV causes joint pain, fatigue, and rash. The symptoms are generally less severe but can still be debilitating.	It is transmitted by several mosquito species, including *Aedes vigilax* and *Culex annulirostris*.	BFV leads to significant discomfort and impacts daily activities. Recovery periods are prolonged for those infected (Healthdirect, 2023).
Murray Valley Encephalitis	Murray Valley Encephalitis (MVE) is a rare but potentially fatal mosquito-borne disease found in northern Australia and occasionally in NSW. Outbreaks are sporadic, often occurring in northern and central Australia, especially after heavy rainfall and flooding (SA Health 2023)	It can cause severe neurological symptoms, including encephalitis, which can lead to permanent brain damage or death.	The primary vector is *Culex annulirostris*.	Despite its rarity, the severity of the MVE makes it a significant public health concern (Healthdirect, 2023).

Mosquito-borne disease	**Prevalence**	**Symptoms**	**Vectors**	**Impact**
Dengue Fever	Dengue fever is mainly reported in northern Queensland but can affect travellers returning to NSW from tropical regions. Dengue outbreaks have become more frequent, posing a significant public health challenge.	High fever, severe headache, pain behind the eyes, joint and muscle pain, rash, and bleeding	*Aedes aegypti* is the primary mosquito vector.	Severe cases can develop into dengue haemorrhagic fever or dengue shock syndrome, which can be fatal if not treated promptly (Queensland Health 2023).
Japanese encephalitis	Japanese encephalitis (JE) is an emerging concern in northern Australia, with occasional cases reported in NSW.	Symptoms range from mild fever and headache to severe neurological complications.	*Culex tritaeniorhynchus* is a primary vector.	JE can be fatal or cause long-term neurological damage, making it a serious public health issue despite its rarity (Healthdirect, 2023)

4. Risk assessment

4.1. Vectors

The *NSW Arbovirus Surveillance and Mosquito Monitoring Program* (NSW Health 2024) provides comprehensive data on mosquito populations, habitats, and the incidence of mosquito-borne diseases in NSW.

The *NSW Arbovirus Surveillance and Mosquito Monitoring Program* aims to monitor and manage the risks associated with mosquito-borne diseases. This program, particularly active from November to April, involves regular mosquito trapping, arboviral testing in mosquitoes and sentinel chickens, and environmental condition assessments.

Mosquito abundance for the 2023-2024 season is shown in Figure 4.1 below. This shows all mosquito trapping results by location and species type to date for the current arbovirus season. Newcastle has one of the highest cumulative counts for *Aedes vigilax* and total species of all the regions monitored.

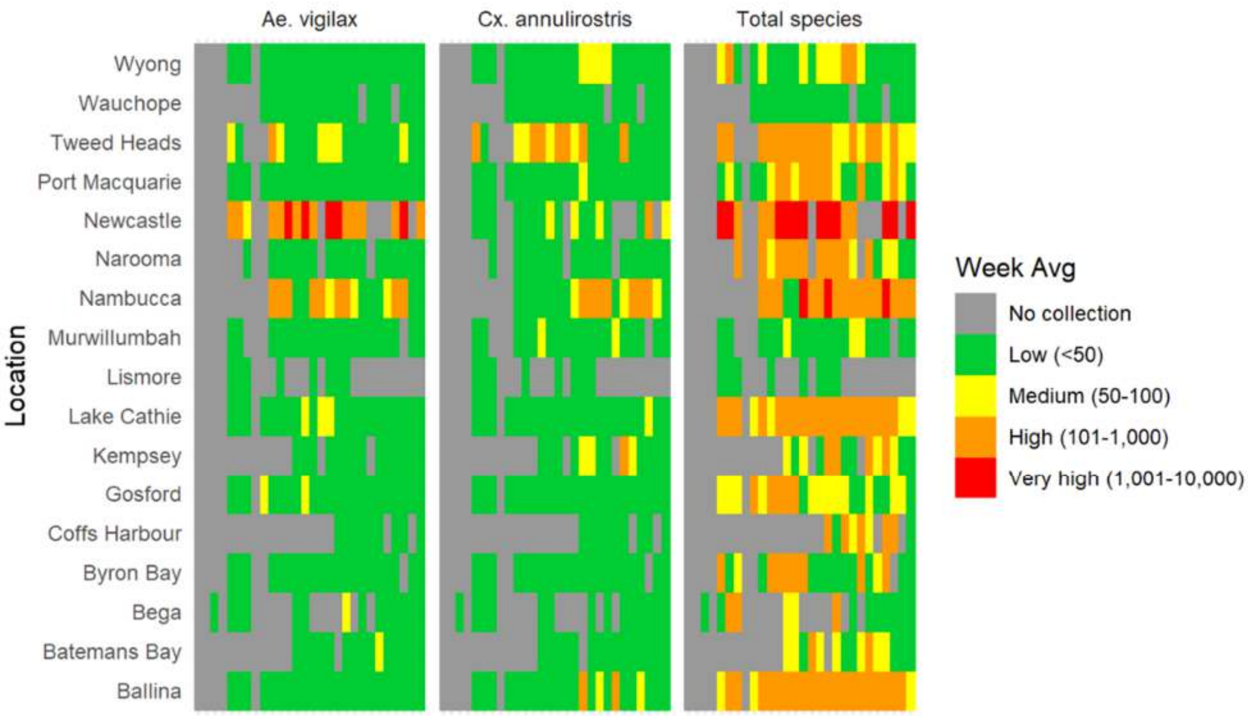

Figure 4.1. Cumulative mosquito abundance table - mosquito trapping results by location and species type to date for the current arbovirus season

Table 4.1 below provides an overview of the mosquito species, and the disease risks they pose in the Hunter Valley region.

Table 4.1. Mosquito species specific to the Hunter Valley.

Mosquito	Habitat	Breeding Sites	Seasonality	Diseases	Image
Aedes vigilax (Saltmarsh Mosquito)	*Aedes vigilax* is one of the most widespread mosquito species in Australia predominantly originating from coastal wetlands like salt marshes, mangroves and swamps.	Breeding sites include saltmarshes, mangrove swamps, and coastal wetlands. Eggs are laid on moist soil and hatch after tidal flooding or rainfall. *Aedes vigilax* can fly many kilometres to breed.	Peak populations occur in summer and after significant rainfall or tidal events.	Ross River Virus Barmah Forest Virus	
Culex annulirostris (Common Banded Mosquito)	Found in a variety of habitats including freshwater wetlands, ponds, and urban water bodies.	Prefers stagnant water with high organic content, such as swamps, puddles, and slow-moving streams.	Population peaks in warmer months and after periods of heavy rainfall.	Murray Valley Encephalitis Ross River Virus Barmah Forest Virus	
Aedes notoscriptus (Australian Backyard Mosquito)	Common in urban and suburban areas.	Breeds in artificial containers such as bird baths, plant saucers, and blocked gutters.	Populations are relatively stable year-round but peak in warmer months.	Ross River Virus Barmah Forest Virus	
Aedes alternans (Scrub Mosquito)	Found in coastal and brackish water habitats.	Prefers tidal pools and marshes.	Populations peak following tidal events and significant rainfall.	Primarily known for nuisance biting rather than disease transmission.	

Mosquito	Habitat	Breeding Sites	Seasonality	Diseases	Image
Culex sitiens (Coastal Saltmarsh Mosquito)	Found in coastal and brackish water environments.	Breeds in saltmarshes, brackish pools, and estuarine areas.	Populations increase during warmer months and after rainfall.	Ross River Virus Barmah Forest Virus	
Coquillettidia linealis (The Fen Mosquito)	Found in freshwater habitats with dense vegetation.	Prefers areas with aquatic plants where larvae can attach to plant roots.	Populations peak in warmer months.	Ross River Virus Barmah Forest Virus	

4.2. Diseases

Under the *Public Health Act* 2010, all arboviral infections are notifiable in NSW. Other notifiable vector-borne diseases are malaria and epidemic typhus. NSW laboratories report cases to NSW public health units. Notifiable disease data are routinely entered by public health unit staff into the NSW Notifiable Conditions Information Management System (NCIMS).

In the 2018-2019 monitoring period, the highest number of notifications for Barmah Forest Virus infection were in the Northern NSW, Mid North Coast and Hunter New England Local Health Districts (LHD), with few notifications in other LHDs. The highest population notification rates were in the Northern NSW and Mid North Coast LHDs.

Ross River Virus notifications were highest in the Hunter New England, Western NSW and Northern NSW LHDs, while Ross River Virus population notification rates were highest in the Far West and Western NSW LHDs (NSW Health 2024).

Table 4.2 below shows that the Hunter New England LHD had the highest Ross River Virus notifications in NSW for 4 of the past 5.5 years (January 2019 to May 2024).

Table 4.2. Ross River Virus notifications in NSW residents, by year of disease onset and Local Health District of residence.

Year	Central Coast	Far West	Hunter New England	Illawarra Shoalhaven	Mid North Coast	Murrumbidgee	Nepean Blue Mountains	Northern NSW	Northern Sydney	South Eastern Sydney	South Western Sydney	Southern NSW	Sydney	Western NSW	Western Sydney	Total
2019	39	10	**158**	23	72	50	12	77	24	9	5	26	7	68	13	593
2020	80	7	**641**	24	400	55	83	430	73	26	12	17	12	111	22	1,994
2021	15	12	120	17	83	**175**	4	96	11	9	4	30	3	77	0	656
2022	26	33	153	25	39	**210**	11	44	25	9	3	19	3	122	6	728
2023	4	17	**96**	7	33	78	3	40	5	4	7	7	2	45	6	354
2024	7	4	**105**	4	46	14	8	98	10	6	4	19	7	20	4	357

Ross River virus is the most reported mosquito-borne disease in Australia with more than 4,000 cases reported yearly.

5. Environmental factors

5.1. Surrounding land uses

Australia's diverse climate and environment play a crucial role in the proliferation of mosquito populations. Tropical and subtropical regions, with their warm temperatures and high humidity, provide ideal conditions for mosquito breeding. Seasonal rainfall, particularly in the northern parts of Australia, creates temporary water bodies that serve as breeding grounds for mosquitoes. Urbanisation and changes in land use also contribute to the spread of mosquito habitats, as standing water in artificial containers and poorly managed waste areas become breeding sites (Mackenzie et al 2017; World Mosquito Program, 2023).

Mosquito abundance is dictated principally by rainfall patterns and irrigation practices in inland regions, while in coastal regions tidal inundation along with rainfall is important. Temperature and/or day-length are often critical in determining the initiation and duration of mosquito activity for species in temperate zones. Hence, observation of environmental parameters, especially rainfall, is a crucial component of the management of mosquitos.

The land uses surrounding Redbank Power Station are diverse, encompassing agricultural, industrial, residential, and natural areas. Each of these land uses contributes to the environmental conditions that can influence mosquito populations. A land use map is provided in Figure 5.1. Figure 5.2 provides an aerial photograph of the surrounding land uses.

An evaluation of the environmental factors that contribute to mosquito proliferation in the area surrounding Redbank Power Station is provided below and summarised in Table 5.1.

The area surrounding Redbank Power Station features significant agricultural activity. This includes grazing lands for livestock, cropping areas, and other forms of primary production. Agricultural activities can create various water bodies such as irrigation channels and farm dams, which can serve as breeding sites for mosquitoes.

The Hunter Valley region, including Warkworth, is known for its extensive coal mining operations. The area is home to several large-scale open-cut coal mines. Mining activities can lead to the creation of artificial water bodies such as retention ponds and disturbed land areas. These can become breeding grounds for mosquitoes if not properly managed.

The region also includes areas of natural vegetation, riparian zones along watercourses, and patches of bushland. Natural water bodies and dense vegetation provide ideal habitats for various mosquito species.

5.2. Human activity patterns

Scattered residential properties are present around Redbank Power Station. These include both rural homesteads and more concentrated residential communities in nearby towns. Residential areas contribute to mosquito breeding through poorly maintained gardens, standing water in containers, and other domestic water sources.

Human activities, such as watering gardens, filling bird baths, and using irrigation systems, can inadvertently create standing water that supports mosquito breeding.

Increased human activity near water bodies, such as fishing, hiking, and picnicking, can influence mosquito populations. These activities can disturb natural habitats and create temporary water sources.

Ongoing construction and land development in the area can alter natural water flow and create new breeding sites for mosquitoes. Temporary pools of water in construction sites can become mosquito habitats.

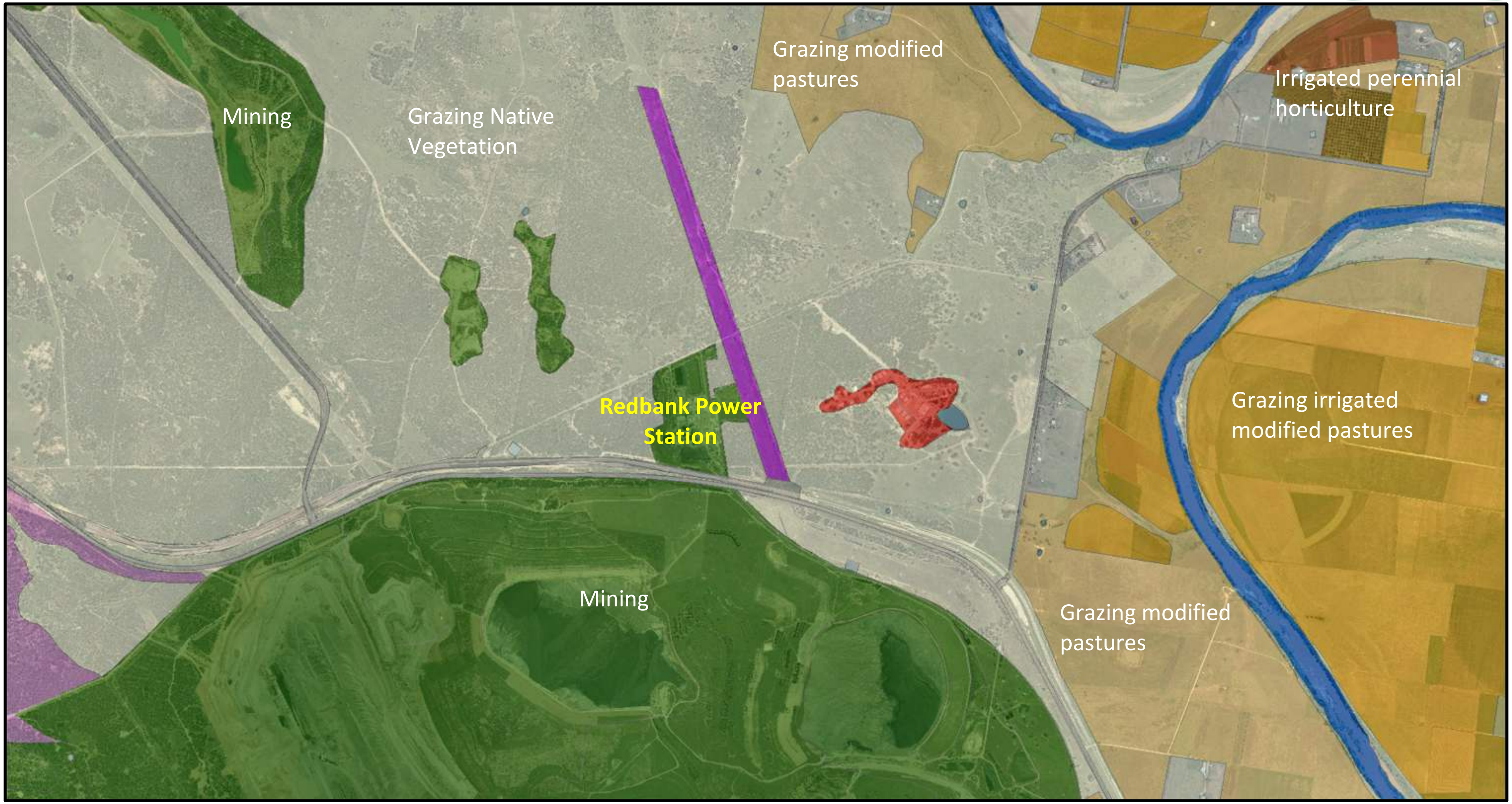

Figure 5.1. Surrounding land use (Source: NSW Government 2023).

Figure 5.2. Aerial view of surrounding land uses (Source: NearMap 2024).

Table 5.1. Environmental factors that contribute to mosquito proliferation in the area surrounding Redbank Power Station.

Environmental Factor	Description	Vector(s)
Creeks and rivers	The area around Redbank Power Station is influenced by the Hunter River and its tributaries, such as Sandy Hollow Creek which runs adjacent to the western boundary of the Site. Stagnant or slow-moving sections of these water bodies can become prime breeding grounds, especially after rainfall.	These water bodies provide ideal breeding sites for mosquitoes, particularly species like *Culex annulirostris*.
Irrigation channels and dams	Agricultural activities in the area involve the use of irrigation channels and farm dams, which can create standing water conditions conducive to mosquito breeding.	These water bodies can harbor mosquito species like *Culex sitiens*, which breed in both freshwater and brackish environments.
Mine dams	Mine dams, used for water storage, waste management, and tailings in mining operations, can inadvertently create favourable conditions for mosquito breeding.	*Aedes vigilax* prefer coastal and estuarine areas but can adapt to other stagnant water bodies like mine dams. *Culex sitiens* breeding sites include saltmarshes, brackish pools, estuarine areas, and mine dams. *Anopheles* spp. prefer freshwater bodies with clean, still water but can be found breeding on the edges of mine dams, ponds, and wetlands.
Stormwater drains	Inadequate maintenance of stormwater drains and culverts can lead to the accumulation of stagnant water, providing breeding sites for mosquitoes.	*Culex annulirostris* prefers stagnant freshwater habitats with high organic content such as stormwater drains.
Riparian vegetation	The presence of dense riparian vegetation along creeks and rivers provides sheltered breeding sites for mosquitoes. Vegetation such as reeds and grasses can trap water and create microhabitats for mosquito larvae.	Species like *Coquillettidia linealis* benefit from attaching their larvae to the roots of aquatic plants within this dense vegetation.
Forested and wooded regions	Surrounding forests and wooded areas can provide resting sites for adult mosquitoes. These regions offer shade, humidity, and protection from wind, creating a favourable environment for mosquitoes to thrive.	Adult mosquitoes, including *Aedes alternans*, may rest in these areas during the day and become active at dusk.

5.3. Site specific factors

Redbank Power Station, like many industrial facilities, utilises various water bodies for its operations. These water bodies play crucial roles in the functioning of the power station but also have the potential to create habitats conducive to mosquito breeding if not properly managed. These water bodies include the following, which are shown in Figure 5.3:

- Wastewater holding pond
- Raw water holding pond
- Primary containment back-up fuel (coal) storage dam
- Sedimentation/oily water separator
- Raw water clarifier tank
- Sludge thickener tank
- Wastewater clarifier tank

It is important to note that the volume of the raw water holding pond is turned over approximately twice per day and therefore it is unlikely that stagnant water would occur in this pond. The waste water clarifier is only used when preparing for discharge into the river otherwise it remains empty and dry.

These other ponds/tanks can hold water for varying lengths of time, depending on rainfall and the power station's water management practices. The presence of organic matter and nutrients can make them suitable habitats for mosquito larvae.

Stagnant water in drainage channels, bunded areas and informal ponds can also become breeding grounds for mosquitoes, especially if they contain organic debris.

Figure 5.3. Redbank Power Station water bodies with the potential to create habitats conducive to mosquito breeding.

6. Summary

Redbank Power Station is situated in a diverse landscape characterised by agricultural, mining, residential, and natural land uses. It faces risks from mosquito-borne diseases due to the presence of various water bodies, both internally and externally, that can serve as mosquito breeding sites. The specific mosquitoes and their associated diseases pose a notable public health concern for the power station and its surrounding areas.

The specific mosquito risks for Redbank Power Station include:

- *Aedes vigilax* (Saltmarsh Mosquito):
  - Likely to breed in temporary or permanent pools of water within wastewater and storage dams, especially after rainfall.
  - Primary vector for Ross River Virus (RRV) and Barmah Forest Virus (BFV).
- *Culex annulirostris* (Common Banded Mosquito):
  - Prefers stagnant water with organic matter, commonly found in wastewater and sedimentation ponds.
  - Major vector for RRV, and BFV.
- *Aedes notoscriptus* (Australian Backyard Mosquito):
  - Could breed in smaller artificial water bodies found around the power station.
  - Potential vector for RRV and BFV.
- *Aedes alternans* (Scrub Mosquito):
  - May breed in temporary standing water within the power stations.
  - Known for nuisance biting but can contribute to overall mosquito population pressure.
- *Coquillettidia linealis* (The Fen Mosquito):
  - Prefers freshwater habitats with dense vegetation, possibly utilising areas around wastewater treatment ponds and storage dams.
  - Potential vector for RRV and BFV.

6.1. Disease risks

The presence of these mosquito species at Redbank Power Station and its surroundings poses a risk of mosquito-borne diseases, including:

- **Ross River Virus:** Commonly transmitted by *Aedes vigilax* and *Culex annulirostris*, causing debilitating symptoms like joint pain, fatigue, and rash; and
- **Barmah Forest Virus**: Similar in transmission and symptoms to RRV, spread by several mosquito species.

A typical workplace health and safety risk assessment considers the likelihood and the consequence of an incident occurring (following the implementation of control measures) to determine the overall risk. Using a standard risk matrix, the overall likelihood of a worker contracting a mosquito-borne disease is assessed to be “unlikely to occur but could happen”. The consequence is considered “major” whereby the consequence could include permanent or extended illness requiring prolonged hospital stays. This leads to an overall risk rating of “medium”.

7. Mosquito control and management

Efforts to control mosquito populations and mitigate disease spread in Australia involve a combination of strategies. These include environmental management to eliminate breeding sites, chemical control using larvicides and adulticides, biological control methods, and public health campaigns to educate workers and the surrounding community about personal protection measures. Integrated Pest Management (IPM) approaches, combining multiple control methods, are widely used to achieve sustainable and effective mosquito control (SA Health, 2023).

To effectively manage and mitigate mosquito breeding and reduce the associated health risks at Redbank Power Station, the mitigation measures provided in Table 7.1 should be implemented.

By implementing these strategies, the Mosquito Risk Assessment and Management Plan aims to significantly reduce mosquito populations and minimise the risk of disease transmission. Public health education and community involvement will be integral to the plan's success, empowering residents to take proactive measures in their homes and communities.

Ultimately, this Mosquito Risk Assessment and Management Plan is a vital tool for protecting the health of workers and the surrounding community. It will enhance the quality of life for residents, support the sustainability of local ecosystems, and promote a safer and healthier environment.

Table 7.1. Proposed mitigation measures for mosquito control.

Area of Management	Type of Mitigation Measure	Mitigation Measures
Water Management	Inspection	**Regular site inspections** Conduct site inspections to check for: • Areas of stagnant water including within artificial containers, bunded areas and storage containers • Flooded areas after heavy rainfall • Mosquito larvae (small wriggly creatures) on water surfaces
	Maintenance	**Water storage** Conduct regular inspections of ponds and water storage areas to ensure water is circulating properly and not becoming stagnant. Use aerators or fountains to keep water moving.
		Stormwater drains and channels Inspect and clean stormwater drains and channels frequently to ensure they are free-flowing and not accumulating stagnant water. Ensure proper grading to facilitate drainage.
		Wastewater clarifiers Maintain wastewater clarifiers to prevent stagnation. Implement a schedule for regular cleaning and monitoring to ensure water flow is maintained.
	Water treatment	**Larvicides**[1] Where site inspections identify mosquito larvae or potential breeding sites, apply larvicides, such as *Bacillus thuringiensis israelensis* (Bti) or Methoprene. These should be used in compliance with regulatory guidelines to minimise environmental impact (refer to Table 7.2).

[1] Larvicides are chemicals used to control mosquito larvae in water bodies before they mature into adult mosquitoes.

Area of Management	Type of Mitigation Measure	Mitigation Measures
		Biological control Consider introducing native fish species, such as Australian smelt (*Retropinna semoni*), into permanent water bodies to naturally reduce mosquito larvae populations. For mosquito management in Australia, it is preferable to use native fish species to avoid potential ecological issues associated with introduced species. Encourage microbats through the implementation of bat houses or planting trees that will provide habitat for local microbat species. Microbats are known to consume adult mosquitoes. An ecologist should be consulted to establish the most viable means of encouraging microbats to the area.
Vegetation Management	Clearing and trimming	**Regular maintenance** Regularly clear and trim vegetation around ponds and dams to reduce mosquito breeding sites. Ensure that grass and other vegetation are kept short and do not provide shelter for mosquitoes.
		Buffer zones Establish buffer zones of maintained vegetation around water bodies to reduce the likelihood of mosquitoes finding suitable breeding sites.
Chemical Control	Larvicides and adulticide[2]	**Fogging and spraying** If identified during site inspections, apply adulticides to identified breeding sites. Fogging / spray should be carried out during peak mosquito activity periods. Conduct fogging and spraying operations during early morning or late evening when mosquitoes are most active. Use chemicals such as Malathion, ensuring minimal impact on non-target species.
Structural Modifications	Covering water bodies	**Installation of covers** Install covers or mesh screens over water storage areas, clarifiers, and other open water bodies to prevent mosquitoes from accessing these areas for breeding.
		Drainage improvements Enhance drainage systems to prevent water from stagnating. Implement design modifications to existing infrastructure to facilitate better water flow and reduce potential breeding sites.

[2] Adulticides are chemicals used to control adult mosquitoes.

Area of Management	Type of Mitigation Measure	Mitigation Measures
Health and Safety	Personal protection	**Protective gear** Provide workers with protective clothing, such as long sleeves and pants, to minimise skin exposure to mosquitoes. Supply and encourage the use of insect repellents.
		Workplace practices If possible, adjust work schedules to limit outdoor activities during peak mosquito activity times (dawn and dusk). Encourage workers to take precautions and report any signs of breeding sites or mosquito-borne illness.
	Education and training	**Awareness Programs** Include mosquito awareness in site inductions. Conduct regular training sessions to educate workers about the risks of mosquito-borne diseases and the importance of personal protection measures. Provide informational materials and updates on mosquito control efforts. Public health campaigns focus on educating residents about mosquito breeding prevention and personal protection measures. Initiatives like "Fight the Bite" are prominently featured.
Reporting	Regular reporting	**Record keeping** Maintain records of site inspections and any control measures implemented. Report any incidents of mosquito-borne diseases among workers to HNELHD.
		Communication with authorities Report significant findings to local health authorities and collaborate on regional mosquito control initiatives.

Table 7.2. Larvicides and adulticides.

Larvicide/adulticide name	Type	Brand Name	Description	Application	Environmental Impact
Bacillus thuringiensis israelensis (Bti)	Larvicide	VectoBac	A bacterial larvicide that specifically targets mosquito larvae, causing them to stop feeding and die.	Can be applied to standing water, ponds, marshes, and other mosquito breeding sites.	Safe for humans, pets, and wildlife when used as directed. It specifically targets mosquito larvae and does not harm other aquatic organisms.
Methoprene	Larvicide	Altosid	An insect growth regulator that disrupts the development of mosquito larvae, preventing them from maturing into adults.	Applied to water bodies such as ponds, wetlands, and containers where mosquitoes breed.	Low toxicity to non-target organisms, including fish and birds. Safe for use in drinking water sources.
Pyriproxyfen	Larvicide	Sumilarv	Another insect growth regulator that interferes with the development of mosquito larvae and pupae.	Applied to water where mosquitoes are known to breed.	Minimal impact on non-target species, making it suitable for integrated pest management programs.
Permethrin	Adulticide	Coopex	A synthetic pyrethroid insecticide effective against a wide range of insects, including mosquitoes.	Can be applied as a space spray, residual spray on surfaces, or fogging for large areas.	Toxic to fish and aquatic organisms, so care must be taken to avoid contamination of water bodies.
Deltamethrin	Adulticide	K-Othrine	Another synthetic pyrethroid, effective for controlling adult mosquitoes.	Used in residual sprays, space sprays, and fogging operations.	Toxic to fish and aquatic life. Appropriate measures should be taken to prevent contamination of water sources.
Malathion	Adulticide	Fyfanon	An organophosphate insecticide used for adult mosquito control.	Can be applied as an ultra-low volume (ULV) spray or fogging.	Moderate toxicity to wildlife and beneficial insects. Proper application techniques should minimize non-target exposure.
Bifenthrin	Adulticide	Talstar	A synthetic pyrethroid used to control a variety of insects, including mosquitoes.	Used in residual sprays and barrier treatments around homes and other structures.	Toxic to aquatic organisms and bees. Should not be applied directly to water bodies.

8. Limitations

This report has been prepared by Opterra with all reasonable skill, care, and diligence, and taking account of the manpower and resources devoted to it by agreement with the Client. Information reported herein is based on the interpretation of the visual assessment and has been accepted in good faith as being accurate and valid.

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Opterra's professional opinions are based upon its professional judgement, experience, and training. These opinions are also based upon the assessment described in this report. Opterra has limited its investigation to the scope agreed upon with its Client. Opterra believes that its options are reasonably supported by the visual assessment that have been done, and that those opinions have been developed according to the professional standard of care for the environmental consulting profession in this area at this time. That standard of care may change, and new methods and practices of exploration, testing, analysis, and remediation may develop in the future, which might produce different results. Opterra's professional opinions contained in this document are subject to modification if additional information is obtained, through further investigation, observations, or validation testing and analysis during remedial activities.

In addition, this report does not, and does not purport to, give legal advice as to your actual or potential liabilities, or draw conclusions as to whether any particular circumstances constitute a breach of relevant legislation. You will appreciate that this advice can only be given by qualified legal practitioners.

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Finally, Opterra does not make any other warranty, expressed or implied, as to the professional advice contained in this report.

9. References

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