2015

# Review of mosquito control program Wyndham/East Kimberley Shire.

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# 1.0. INTRODUCTION.

The first part of a review of a mosquito control program should be a mosquito survey to determine the extent and type of mosquito problems in an area. This can be sometimes done from an aerial examination of an area, but with a complex and extensive area such as the Shire of Wyndham East Kimberley, and particularly the population centres of Kununurra and Wyndham, a ground mosquito survey was deemed vital to determine those problems that will need to be addressed.

The mosquito survey deals with the mosquito sampling and inspections carried out from 27 September to 3 October 2015. The survey involved visiting selected areas of interest in and in close proximity to both Kununurra and Wyndham for likely mosquito breeding sites as assessed from Google earth, problem areas mentioned in previous reports and publications, and inspecting recent problem areas as outlined by Louis Franks, the Shire of Wyndham /East Kimberley Environmental Health Officer (EHO). Representative potential mosquito breeding sites were inspected for the presence of water, and assessed for their potential for mosquito breeding.

This survey was not meant to be exhaustive to locate all mosquito breeding sites. It was rather a survey to determine the type of situations that will both need to be examined in more detail, and to consider a relevant surveillance and control program in order to afford some practical control of potential pest and mosquito borne disease problems in the Shire of Wyndham /East Kimberley.

Photos of potential sites were taken and notes made on potential problems sites in relation to mosquito breeding and possible control options. Most potential breeding sites inspected were sampled for larvae using a standard soup ladle, with samples placed in 70% alcohol that evening for later examination and identification. The results of the larval collection are mentioned in sections dealing with those locations and are presented in Appendix 1.

Adult mosquito traps were set at a small number of locations in each town that were considered to represent the major sources of potential mosquito problems close to the towns at this time of the year. The inspection of the breeding sites also considered the placement of future adult mosquito traps for an ongoing mosquito monitoring program. The results of the adult mosquito collections are mentioned in sections that deal with those locations and are presented in full in Appendix 1.

The potential breeding sites inspected were mainly representative of breeding sites in the Shire, and are by no means an exhaustive list of all the actual or potential sites around these towns. They do however represent the types of major mosquito breeding sites that can be expected to result in pest and potential vector mosquito problems. Other similar sites would have similar breeding potentials and control options. The photos of the potential mosquito breeding sites are presented below, together with a brief outline of their potential for breeding and possible control options.

The potential breeding sites, pest problems and disease potential posed by various species for the NT is attached as Appendix 2. Similar pest and disease potentials will be relevant for North West WA.

The second part of this review deals with an examination of the present mosquito and arbovirus surveillance and mosquito control program in each town. An outline of the present surveillance and control program was primarily gained by having meetings and discussions with local Shire officers who have carriage of the present programs, as well as officers of other local organisations whose area of responsibility or operations can impact on mosquito breeding or vector control.

The findings from these meetings and discussions were backed up by various reports and investigations dealing with the mosquito breeding sites or disease data. Not the least was a detailed draft mosquito management plan (MMP) being prepared by the Shire which has already addressed many aspects of a mosquito surveillance and control program. These documents are listed in the references or Appendices where appropriate.

The third part of the review outlines the findings and conclusions from the survey, the discussions, and an examination of various source documents, as well as the result of various comments or advice from principal players in the Shire or the Western Australia Health Department who play a vital role in planning and delivery of the programs. These conclusions incorporate various recommendations for the future mosquito surveillance and control program.

# 2.0. MOSQUITO SURVEY.

## 2.1. KUNUNURRA TOWN AREA.


**Figure 1. Kununurra overview.**

The town of Kununurra is closely associated with Lily Creek, Lily Creek Lagoon and Lake Kununurra.

A large area of the residential section is situated east of Lily Creek Lagoon in the Lakeside area. The other main residential area is north of Lily Creek Lagoon and extends to the north side of the town. The nearest irrigation area is on the north-west side of the town and extends from Ivanhoe Road northwards. The main irrigation channel starts at the old Pump House on Lake Kununurra and extends north to cross Ivanhoe Road just north of the town.

The main section of the town is separated from the Lakeside area by the large Lily Creek Lagoon, which has a narrow opening to Lake Kununurra at the southern end of the Lagoon.

### 2.1.1. Kununurra Town and Lily Creek Lagoon.


**Figure 2. Kununurra town area.**

The commercial and industrial section of the town is adjacent to Lily Creek Lagoon in the middle of the image above. Messmate Way leads from the Victoria Highway near the Lagoon to the commercial centre of the town. Ivanhoe Road leads to the nearest irrigation areas to the west and north of the town.

Many of the hotels and two of the caravan parks are sited around Lily Creek Lagoon on the RHS of the image. The Lagoon has margins of Typha reeds (olive green) in many sections, with some sections (RHS of the arm of the Lagoon above) with wide margins of reeds, while others (LHS of arm above) have relatively narrow margins of reeds, and in some places (at the head of the Lagoon) there are relatively bare margins, where there has been Typha removal. The presence of Typha reeds is an indication of a relatively high potential for mosquito breeding for species such as **Culex annulirostris**, **Culex palpalis**, **Anopheles annulipes**, **Anopheles bancroftii**, **Mansonia uniformis** and **Coquillettidia xanthogaster** (Appendix 2).

### 2.1.2. Lakeside Resort and Caravan Park.


**Figure 3. Suburb east of Lakeside, east edge of Lily Creek Lagoon.**

**Figure 4. End of drain on east side of Lakeside Resort.**

**Figure 5. Clean margin of Lagoon. Little Typha growth.**

Lakeside Resort is on the east side of Lily Creek Lagoon and on the west side of the Lakeside suburban area. On the Lagoon side nearest the town there are relatively bare margins where Typha has been removed or weedicided. These margins are relatively steep and deep.

### 2.1.3. Edge of Lily Creek Lagoon below Messmate Way.

**Figure 6. Edge of Lily Creek Lagoon near Messmate Way.**

**Figure 7. Thick Typha margins in the background.**

Some margins in this area are free of *Typha* after a weed removal program. This is a model for how the lake margin could be in order to reduce potential mosquito problems arising from the margins of the lake. The best method for *Typha* reduction would be to access the lakeside margin with a boat, and spray the emergent plants with a weedicide using a spray rig. This would gradually reduce the width of the reed margin and could still leave a residual narrow reed margin for aesthetic reasons and to reduce wave action erosion of the sides, yet be narrow enough for fish and other aquatic mosquito predator access into the upright stems.

**Figure 8. Section near pump shed and Messmate Way.**

**Figure 9. Wide Typha margin; note house boats on Lagoon.**

Some of these margins are very wide and shallow with extensive *Typha* growth, making any reed reduction program very difficult. However a long term program could still reduce these wide *Typha* margins by weediciding where the margins are closest to the town, and hence any mosquito breeding is likely to impact on the residential areas.

### 2.1.4. Drain from Messmate Way.

**Figure 10. The drain from Messmate Way, upper section.**

**Figure 11. Messmate Way drain, lower section.**

The drain from Messmate Way is an unformed earth drain, which receives long term dry season water flow from overspray of grassed areas on Messmate Way, and drains the commercial area of the town.

During the recent inspection, 4th instar **Cx. annulirostris** were sampled from the drain in the upper section of the drain from an isolated pool, in association with green filamentous algae and grass. The green filamentous algae is an indication of high nutrient levels in this water, probably derived from fertiliser in run off from the grass areas in the median strip on Messmate Way.

The point where the drain enters the lake had thick Typha growth, but appeared to have little mosquito breeding, which is a result of fish predation and other biological control agents. There was however a 4th instar **Culex hilli** larvae recovered from a section of particularly thick Typha which was dead and lodged over. This species is not a human pest but its presence indicates that areas of thick lodged and dead Typha are potential breeding sites for other species.

This drain has the capacity to breed **Cx. annulirostris** and **Cx. quinquefasciatus**. These species can breed in relatively high numbers in the drain, as it is not subject to fish predation and has higher level of nutrients and isolated pools, which are ideal for these species. This site is amenable to a medium term engineering solution by piping the drain water via a subsoil pipe or installing concrete inverts direct to the lake margin.

**Figure 12. Messmate Way; over watering.**

**Figure 13. Messmate Way; over watering.**

**Figure 14. Lakeside area overwatering.**

A short term solution to the excess water discharging to drains involves examining the watering regime and the pattern of watering to reduce the frequency of watering and correct over-spray areas where water discharges to the roadside gutter and hence to open earth drains.

The long term and frequent presence of water from over watering and waste water discharge to open drains encourages reed growth in the open drains, and is hence creating mosquito breeding and adding to maintenance needs, which will require regular silt and weed removal.

### 2.1.5. Lilly Creek Lagoon Boat landing area.

**Figure 15. Boat landing, and thick reed margin (RHS).**

**Figure 16. Observation platform (East of boat ramp).**

There is an extensive Typha reed area on the other side of the Lagoon opposite the boat landing. Also note the thick reed growth on RHS of the boat landing area. This thick reed growth extends around the Lagoon adjacent to the **Kimberleyland Holiday Park**.

Note the dead reeds in the background of the observation platform. These dead reeeds are the result of the recent weed maintenance program.

### 2.1.6. Observation platform area.

**Figure 17. Observation platform.**

**Figure 18. Dead reeds at end of observation platform.**

The reeds appear to have been weedicided by application from the land ward margin. There are calm water areas landward of the dead and lodged reed areas, with green living reeds on the Lagoon side. This type of weediciding pattern can encourage mosquito breeding by keeping fish separate from the shore-side wave protected and nutrient rich water areas. The suggested weediciding program discussed above is also recommended for this area. Land side weedicide application makes it difficult to apply the spray to the outer edge of the Typha, with the result that it will regrow from the untreated outer edges into the treated areas relatively quickly. The presence of these thick reed areas so close to the various camping areas such

as the Kimberleyland Holiday Park camping area, where people are more likely to be exposed to mosquito attack, heightens the potential pest problems and increases the disease potential for diseases such as Ross River virus disease and Murray Valley encephalitis.

### 2.1.7. Lily Creek.

Lily Creek, upstream of the Victoria Highway, is poor draining, with paperbarks and thick grass growth in Lily Creek. This section will need assessment to determine if wet and post wet season ponding occurs and larval sampling to determine if this area is a productive area of mosquitoes.

**Figure 19. Lily Creek downstream of Victoria Highway.**

**Figure 20. Lily Creek further downstream from Victoria Highway.**

Downstream of the Victoria Highway culvert, the creek goes into a sandy area and then a fern area. The creek here has a sandy bed and Pandanus vegetation, with a narrow invert in the upper reaches that is likely to only have short term ponding after the wet season. This creek may add to the silt loads into the Lagoon. This site appears ideal for the installation of a silt trap to prevent silt deposition and further reed expansion into Lily Creek Lagoon. Lower downstream in Figure 19 shows more invert vegetation and probable longer term ponding. This site needs to be investigated during and after the wet season for ponding and mosquito breeding. Likely species breeding here are **Cx. annulirostris** and **Anopheles annulipes**.

The creek widens further downstream nearer to the Lakeside Resort and Caravan Park. The steep bank here has a lot of marginal trees and thick extensive areas of Typha in the wide section of creek. The thick Typha indicates this area may be a productive mosquito breeding site for **Cx. annulirostris**.

### 2.1.8. Lily Creek at the start of Lily Creek Lagoon.

**Figure 21. Lily Creek at edge of Lakeside Resort.**

**Figure 22. Lily Creek meets Lily Creek Lagoon in a wide extensive area of Typha.**

This extensive area of thick Typha is possibly the most important source of **Cx. annulirostris** and **Anopheles species** mosquitoes for the east section of the main town area and the Lakeside suburb area, due to its close proximity to these main residential areas. There is a sparse edge of Typha on the bank adjacent to the Lakeside Resort and Caravan Park (LHS above), indicating purposeful Typha control at the edges, or the effect of depth of water or shading by the adjacent trees. It would be helpful to determine the reed control history of this area. If the sparse reeds are an effect of shading, it indicates a possible environmental and cheap alternative for reed control at the margins. This Typha area needs intensive survey to determine its capacity to breed mosquitoes. If possible, this margin should have reed reduction treatments by weedicide to reduce the reeds margin width.

### 2.1.9. Gardenia Drive drain, Lakeside.

The drain is between Setosa St. and Gardenia Drive. This open drain starts downstream from the Corkwood Street area. The source of the water discharging into the Gardenia St. drain is in the catchment of the Corkwood drain, and includes areas of lawn watered by the Shire, as well as private verge areas watered by sprinklers.

**Figure 23. Discharge into the Gardenia St. drain from the culvert on Hibiscus Drive.**

The Gardenia Street drain has an extended length of water and Typha reed regrowth. The water near the headwall at the end of the subsoil drain and for some distance downstream had green algal growth, indicating relatively high nutrient levels. There were 4$^{th}$ instar and younger instars of **Cx. annulirostris** larvae recovered in relatively high numbers in the upper section of the open drain where dead lodged Typha was present. This was in spite of the relatively clear water and the presence of a lot of biological control agents such as mayfly and dragonfly nymphs.

**Figure 24. Typha and surface water in Gardenia St. drain well downstream from Hibiscus Drive culvert.**

The water areas in this drain were in the process of drying up and leaving isolated pooling, probably as a result of natural water seepage into the drain system being reduced as the dry season progresses. There was no mosquito breeding in this lower section, with more open pools, less nutrients, and less lodged dead Typha. This whole drain has recently been excavated to remove reed growth and silt. The drain needs weedicide application as soon as possible, as the Typha is regrowing and will soon be thick and more difficult to weedicide. This Typha regrowth and the persistence of water in this drain well into the dry season is maintained by the continuing dry season water discharge into this drain. Weediciding as soon as possible will reduce future weedicide needs and silt removal requirements. Insecticide control by repeated methoprene pellets in the short term for 30 day control is warranted while larvae are present, as these locations as so close to residential areas.

**Figure 25. Gardenia Drive drain, upper section**

**Figure 26. Gardenia Drive drain, lower section.**

Gardenia Drive drain upper section (LHS above). Typha regrowth is evident in the still moist drain. Lower down (RHS) it becomes more sandy and there is no surface water in the lower section towards the distant creek line, but there is still Typha regrowth in the drain. The entire drain requires weedicide action to reduce Typha reed regrowth. This drain eventually discharges to the now dry north arm of Little Lily Creek.

### 2.1.10. Argentea St. drain.

**Figure 27. Drain head wall with silt blockage and Typha growth.**

**Figure 28. Lower down Argentea St. drain.**

The Argentea St. drain recieves less dry season water flow compared with the Gardenia St. drain. However the Typa presence indicates there is still dry season discharge into this drain, and the ponding inside the subsoil drain (LHS above) is likely to breed mosquitoes, particularly **Cx. quinquefaciatus**. The Typha growth should be weedicided as soon as possible, and the silt at the subsoil drain end wall, and downstream where necessary, should be removed in preparation for the coming wet season. The Melaleuca regrowth lower down the drain indicates that this growth will evetually catch silt and require added maintence costs. It is reccommeded that this drain is weedicided or slashed as soon as possible so that the regrowth can be handled relatively easily now rather than later, when removal will prove more costly and difficult.

**Figure 29. Lower reaches of Argentea St. drain.**

This section of the drain is sandy but these is evidence of wet season pooling in the drain. This drain should be slashed and weedicided where necessary before each wet season. At the end of this drain, at the corner of Livistona St. and Argentea St., is a nearby culvert that has some minor Typha growth. This Typha should be removed and the silt removed before the wet season to facilitate flow in the drain. The wet season water flow from the culvert enters the now dry north arm of Little Lily Creek. Little Lily Creek is a source of silt that facilitates the extensive Typha growth in the shallow edges of Lily Creek Lagoon. It would be useful to install a sediment/silt trap catchment facility in this locality, as well as other major drains, to prevent additional silt entering the Lagoon. These silt structures would need annual removal of silt and sand.

### 2.1.11. "Wetland area" off Ivanhoe Road.

**Figure 30. Dirt track and vehicle ruts, road without culverts.**

**Figure 31. Depressions and poorly formed drainage lines.**

**Figure 32. Poorly formed drainage line with depressions.**

**Figure 33. Land crab burrows indicating water at depth.**

An area east of Ivanhoe Rd. and west of Button Drive is called the “Wet Land”. The “Wet Land” area is a severely disturbed area of land with previous excavations and disrupted drainage. There are numerous vehicle ruts, and the whole area will be waterlogged in the wet. The severely disturbed areas have been caused by road or track construction and past land clearing. There are numerous crab holes, and various potential ponding areas are evident that do not drain into nearby drains. The whole area needs to be surveyed to guide levelling, filling, and draining to recreate good drainage, with levels taken of the whole area to see the drainage possibilities. It will probably need a drain through the embankment of the main irrigation drain nearby to effectively drain this area.

The insecticide alternative or interim solution is to apply methoprene pellets to established areas of mosquito breeding prior to the onset of the wet season and reassess this application every 4 weeks by larval sampling and reapplication if the larvae are present and are not methoprene affected.

The depressions are probable breeding sites for various ground breeding Aedes species such as **Aedes normanensis**, as well as **Cx. annulirostris**. The crab holes could breed some other specialised Aedes species but these are not likely to be any significance as pest species.

### 2.1.12. Button Drive area.

**Figure 34. Drain into Aboriginal housing area.**

**Figure 35. Drain off Speargrass Road, rear of Button Drive.**

There are considerable drainage problems in this area, with potential ponding in these drains and adjacent non draining areas in the wet season. These small drains needing silt cleaning and reforming work to improve drainage to a main drain and then to the main irrigation channel. Minor lateral drains from depressions to these drains may be necessary if these pooling sites areas cannot be simply filled.

### 2.1.13. Drains off Ivanhoe Rd., industrial area.

**Figure 36. Main drain to east and at 90 degrees to Ivanhoe Rd.**

**Figure 37. Junction of smaller drain, parallel with Ivanhoe Rd.**

These drains off Ivanhoe Rd. have a good mown inverts and are well maintained open earth drains with minor depressions.

### 2.1.14. Drain beside Ironwood Drive.


**Figure 38. Ironwood Drive roadside drain is resonably well formed.**

**Figure 39. The branch drain to the fence in the back ground.**

**Figure 40. Branch of Ironwood Drive drain through fence.**

The Ironwood Drive roadside drain and the drains off Ivanhoe Road are resonably well formed, although there could be some minor pooling in the wet season that could lead to some mosquito breeding, paticularly **Cx. annulirostris**. The drains apear to be annually maintained with mowing. The drains largely appear adequate for drainage to prevent mosquito breeding, but could be improved with some minor silt removal. However if wet season pooling does occur, this could be rectified in these drains by installing a 750mm shallow v shaped concrete invert in the centre of the drains to allow good drainage to the nearby culverts under Ironwood Drive and Ivanhoe Road.

The unformed and unmaintained section of drain that extends through the fence off Ironwood Drive needs reforming with regrading and regular mowing. This area of drain is vegetated and would have relatively deep wet season pools that are likely to persist for long periods in the wet season, and are likely to breed considerable numbers of **Cx. annulirostris**. This drain should be inspected after the first rains and weekly afterwards to determine if it is a mosquito breeding site. If breeding is detected, the recommended insecticide solution is to apply methoprene pellets every 4 weeks.

2.1.15. Barringtonia Ave area.

**Figure 41. Main drain along Greybox Drive.**

**Figure 42. Subsoil pipe end into open drain, Greybox Drive drain.**

**Figure 43. Sub soil pipe end. Greybox drain.**

**Figure 44. Drain junction downstream of sub soil pipe discharge.**

These drain areas have been reported to require regular larviciding. Near the corner of the drain junction there is a sub soil pipe, with water up the pipe; (see Figure 43). This site is likely to breed **Cx. annulirostris** mosquitoes in the open drain and **Cx. quinquefasciatus** mosquitoes up the subsoil pipe during and after the wet season. The drain needs an inspection and treatment during the wet season and post wet season, with methoprene pellets the insecticide of choice to allow 30 day treatment regimens when breeding is detected. The main drain should be cleaned of silt to allow the pipe to drain adequately into the open drain without pooling up the pipe. This drain is another that could be improved in the medium to longer period with concrete inverts to improve drainage.

### 2.1.16. Drain on Coolibah Drive.

**Figure 45. TAFE drain on Coolibah Drive.**

This drain had fish in it and was not breeding any mosquitoes. A sample of the fish was not taken to determine if they are native fish. It appears this is a permanent situation with continuous dry season water discharging to the drain. The nearby source of the water from adjacent properties should be investigated to determine if the flow can be stopped. It is likely that the flow is due to overwatering and run off into culverts and drains. If the dry season flow can be reduced or eliminated, the drain should be regraded to ensure it is free draining. If either of these alternatives is not possible, one solution is to make this site a water feature with a small weir in the drain 5-10 m downstream of the culvert to ensure water remains in the drain and ensure it is always stocked with native fish.

## 2.2. NEAR TO KUNUNURRA LOCALITIES.

### 2.2.1. Southern edge of Lily Creek Lagoon.

At the end of Old Darwin Road at the Munganji locality (see Figure 49) there is a very shallow and extensive margin of Lily Creek Lagoon with Typha, brackish water fern, and other fern species. The edge has Leichardt Pine and River Red Gums, indicating long term water presence. Extensive invasive Neem trees are present landward of the water margin. Numerous wallaby tracks were observed around the water edge. A wide expanse and extensive margin of shallow water with Typha reeds extends out into Lily Creek Lagoon.

**Figure 46. Edge of Lily Creek Lagoon, Munganji locality.**

**Figure 47. Edge of Lily Creek Lagoon, grass, ferns and reeds.**

This margin appears to be a potential productive area for **Cx annulirostris, Ma. uniformis and Cq. xanthogaster** species, although a brief inspection of the margin at the Munganji locality did not reveal any larvae. The margin will need adult mosquito sampling for the latter two species and larval and adult sampling for the first species, during and soon after the wet season, and during the early and mid dry season, to dertmine if and when this type of margin is a productive source of mosquitoes. It is possible that most of the margin area is under biological control agents for mosquito larvae. However those areas physically distrubed by the creation of pools isolated from the main water body, such as the wheel ruts below, may be productive sources of mosquitoes. If this proves so, then vehicle barriers around wet margins to protect these margins may be warranted. The presence of Neem tress offers no protection or repellency for mosquitoes.

**Figure 48. Earth track with wheel ruts at margin at Munganji locality.**

### 2.2.2. Quarantine cattle yard area.


**Figure 49. Drovers Road and Old Darwin Road vicinity.**

The Quarantine cattle yard area is located on Drovers Road south of Kununurra. This cattle drench facility and wash-down bay has earth banks and fenced effluent pits, (see Figure 50). Three pits are present with each overflowing to each other. Green algae growth and duckweed (Elodea species) are present on the surface, but with clean margins, there is little opportunity for mosquitoes breeding at the moment. However the pits need to be checked regularly for mosquito breeding. The pits will need regular margin weed control. These pits are likely to over flow in the wet season and lead to high nutrient water contaminating nearby flood prone areas and allow nutrients to enter the Lagoon and promote algal and reed growth in the Lagoon. One solution is to install a sprinkler dispersal system to disperse the effluent over a wide area, while ensuring there is no additional surface flow into the pits by installing banks to divert surface water flow away from the wash down area and the pits.


**Figure 50. Drench facility with fenced effluent pits.**

**Figure 51. Cattle watering trough.**

The cattle water troughs were dry during the survey, but could be a minor source of native container mosquitoes such as **Ae. notoscriptus**, **Cx. quinquefasciatus** or **Ae. tremulus** in times of use. Emptying the troughs after use would prevent any mosquito breeding. The large above ground-water tanks nearby are probably not sealed.

**Figure 52. Cattle yard on ground tank.**

**Figure 53. Cattle yard on ground tank, gaps in tank roof.**

The large on ground water tank has gaps in its roof (photo above), which could allow the breeding of native container breeding mosquito species. The tanks should be inspected inside for mosquito breeding, and if any is detected, the tanks should be sealed with expandable foam or an alternative method.

Nearby between these facilities and the nearby Lake Kununurra is an extensive poorly drained, flood prone area with large areas of pooling in the wet season that would probably be a productive source of **Cx. annulirostris**. This whole area and the various types of pooling should be checked during and soon after the wet season to establish if there are productive mosquito breeding sites in this area.

### 2.2.3. Race course, rodeo, camping grounds, pistol club, and Drovers Road area.

The race course and rodeo facilities are located further west on Drovers Road near to Lake Kununurra (see Figure 49 above). The area is also used as a temporary camping ground, although this may only be around a few times per year when events are on. The facilities are serviced by septic tanks. Tap water is supplied by tall tanks which are pump filled from the nearby lake. The nearby Lake edge has a lot of Phragmites grass, Typha reeds and Neem trees. There is a nearby sign indicating a Salvinia control area. Exotic Salvinia water plants are ideal breeding sites for **Mansonia** and **Coquillettidia** mosquito species, so any **Mansonia** and **Coquillettidia** pest problems in this area could be exacerbated if these plants are not controlled or eradicated.

The closeness of the thick Typha reed margins of the lake indicates considerable potential mosquito breeding sites and potential mosquito exposure during evening or night time functions, so any function, especially camping use, would be benefited by mosquito avoidance and self-protection messages in advertisements or in public notices when functions are conducted. The presence of considerable numbers of agile wallabies, which are hosts for Ross River virus, indicates a higher potential for transmission of this arbovirus by vectors such as **Cx. annulirostris**.

The pistol club facilities located just south of the junction of Old Darwin Road and Drovers Road is adjacent to an escarpment, which is relatively close to Lake Kununurra. There is little in the way of infrastructure, so night time use and hence exposure to mosquitoes may not be a problem. There is water pumped to a holding tank for toilets that may not be sealed, and septics in this site may not be sealed. It would be useful to inspect these facilities for mosquito breeding, and seal those facilities where necessary.

**Figure 54. Rodeo area and high numbers of agile wallabies.**

## 2.2.4. Discovery Holiday Park, Lake Kununurra.


**Figure 55. Discovery Holiday Park and Old Quarry locations.**

The Discovery Holiday Park near the end of Lakeview Drive is adjacent to Lake Kununurra and a large backwater on the lake, with a nearby backwater lagoon that is a very extensive area separated by the Lakeview Drive road embankment from Discovery Holiday Park. The backwater and the backwater lagoon has a lot of floating algae and dead water weed on the water. This habitat is ideal for **Anopheles** mosquitoes, as well as **Cx. annulirostris**. However **Cx. annulirostris** is likely to be under considerable biological control by fish and aquatic insects in these areas, and will only be productive in cut off pools or dense fallen reed areas.

The Pump House restaurant and the Golf club is nearby at the end of Lakeside Drive. There will be considerable public exposure to mosquitoes in this area due to the presence of patrons of the nearby golf club, the caravan park and the Pump House restaurant. The commercial and public facilities in this area could promote or provide the use of repellents or other devices such as mosquito lanterns to protect patrons or customers. Some mosquito control at facilities such as caravan parks would benefit by bifenthrin or lambda-cyhalothrin barrier spraying low fringing vegetation or installing hedges or erecting shade cloth fencing so these can be used with barrier sprays.

**Figure 56. Discovery Holiday Park. Backwater,Typha margin.**

**Figure 57. Backwater looking to lake and backwater inlet.**

**Figure 58. EVS trap at Discovery Holiday Park.**

**Figure 59. Louis Franks and Ebony Daniell,  Shire EHO's.**

**Figure 60. Isolated lagoon north side of road to Discovery Park.**

**Figure 61. Lake, Discovery Park, Pumphouse, golf club, locality.**

### 2.2.5. Old Quarry area.


**Figure 62. Old Quarry area and access track to Lake Kununurra.**

The Old Quarry road is a dirt track off the Victoria Highway, 100m west of Ivanhoe Road junction, which leads around the Old Quarry area and through a poor draining area to the edge of Lake Kununurra. This rough dirt track will have little or no wet season access. However it provides dry season access to areas that are likely to be important mosquito breeding sites as they are close to the Town area. The first part of the track traverses an area that has been disturbed by past land clearing and excavation, and has numerous poorly drained areas that could provide wet season breeding sites for **Cx. annulirostris**.

This area needs a mosquito ground survey in the wet season and early dry season to determine if productive mosquito breeding sites are in this area. Pre to early wet season application of methoprene pellets to any productive areas of breeding, with repeat inspections during the wet season would provide good larval control, but location of areas to be treated will require extensive and thorough ground surveys to locate breeding sites. Medium term mosquito control should be an engineering rectification of levelling or grading to re-establish good drainage. Any engineering rectification will need to be guided by an aerial topographic survey.

The old quarry excavations were not investigated during this survey because of the lack of access by road, but will need to be investigated as they may receive town drainage and nutrients during the wet season, and may be at least early wet season breeding sites for **Cx. annulirostris.** If the excavations have perennial water and any marginal vegetation and floating algae, they may be appreciable **Anopheles** species breeding sites. The determination of these excavations as mosquito breeding sites will depend on the presence of fish in the excavations. If there are no fish present, the addition of native fish early in the wet season could provide an ideal short to longer term mosquito control method.

**Figure 63. Open water flood prone area at edge of Typha swamp.**

**Figure 64. Grass and Typha swamp land RHS Old Quarry Road.**

Half way along the track on the RHS (see Figures 63 and Figure 64), there is an extensive Typha swamp, with thick grass growth at the landward margins. Some areas have open vegetation free areas that are likely to have shallow wet season ponding that could be productive mosquito breeding sites, and will need checking to determine if breeding does occur there. This area is a good permanent adult mosquito trap site, which could gauge the potential for wet season and post wet season mosquito numbers arising from this or nearby sites. However siting of a trap positon will require investigation of wet season road access.

### 2.2.6. End of Old Quarry Road at edge of Lake Kununurra.

There were extensive neem tree growth and coffee bush thickets nearer the end of the old quarry Road dirt track, with numerous areas that are low lying and probably extensively flooded in the wet season. The drainage lines and depressions in this area should be investigated by a ground mosquito survey. If appreciable mosquito breeding is discovered, the engineering solution will require an aerial topographic survey to see if there is any feasibility to practically provide improved drainage of these areas to Lake Kununurra.

The Lake margin on the town side in this vicinity has a relatively narrow Typha margin with a steep bank that is not likely to be a major mosquito breeding site. The lake margin on the other side of the Lake opposite the end of the quarry track has extensive Typha growth and there appears to be little capacity for a practical engineering solution to this extensive Typha growth and probable mosquito breeding on that side. A temporary wet season to early dry season monthly EVS trap on the opposite side would help to determine if there is appreciable mosquito numbers originating from this area.

## 2.3. IRRIGATION AREAS.

### 2.3.1. Main and minor water channels.

**Figure 65. Main irrigation channel near Pump House restaurant.**

**Figure 66. Minor irrigation channels.**

The main irrigation channel and most of the minor channels appear to have been regularly weedicided and have relatively clean margins, which discourages any mosquito breeding. In addition the main channels have appreciable water flow, further discouraging mosquito breeding. Many of the smaller feeder channels only contain water for a few days, so may not contain water long enough for mosquito breeding to develop. None of the main channel sections or minor channels inspected along Ivanhoe Road or Weaber Plains Road contained any mosquito larvae. However they also appeared to not contain any appreciable numbers of small fish, which indicates that if the channel margins are allowed to be thickly vegetated, they could develop some capacity for mosquito breeding at the margins.

### 2.3.2. Irrigation plantations Ivanhoe Road.

**Figure 67. Flooded sandalwood plantation feeder channel.**

**Figure 68. Road side waste water drain.**

A considerable area of the irrigation areas close to the town are sandalwood plantations. There is currently little or no sugarcane irrigation areas. The plantation areas are periodically flood irrigated with wide bays between the rows of trees from a feeder channel, and the flood bays dry out over a few days, hence

providing little opportunity for mosquito breeding. One area of Sandalwood plantation was observed in the process of irrigation that could have provided longer retention of water. It appears the area was flooded longer than normal by a temporary blockage of the feeder channel. This temporary blockage by dead vegetation was cleared during the inspection by the landowner and water started flowing and draining again. However the capacity for longer term pooling in the irrigation areas during the wet season needs to be investigated to determine if any mosquito breeding is occurring in the irrigation areas. Sandal wood plantation areas more than 5 km from the main residential areas are unlikely to provide appreciable mosquitoes for the town area.

The road side drain water appears to be longer lasting with appreciable vegetation and has more capacity for mosquitoes breeding. If these drains are not flooded for more than a week, they will not have the capacity to breed appreciable numbers of mosquitoes.

### 2.3.3. Irrigation areas along Weaber Plains Road.

**Figure 69. Weaber Plains road and irrigation area.**

**Figure 70. Shallow ponded area along Weaber Plains Road.**

**Figure 71. Shallow ponded area with extensive shallow water.**

**Figure 72. Shallow water with large numbers of magpie geese.**

This shallow ponded area has a high potential to be a mosquito breeding area, both during the wet season and whenever it is purposely flooded. The geese will add organic material to the water which will enable

large populations of mosquito larvae, particularly if there is appreciable areas of thick emergent grasses or floating dead weeds and grasses that prevent appreciable larval control by aquatic predators. In addition, shallow flooding is likely to encourage more emergent vegetation that will offer harbourage and protection for mosquito larvae. This site could breed large numbers of **Cx. annulirostris** and possibly **An. annulipes,** as well as floodwater **Aedes** species such as **Aedes normanensis**, **Aedes lineatopennis** and possibly **Aedes nocturnus** and **Ae sagax.**

This site needs to be investigated to determine if and when mosquitoes breed in it. If this shallow water nature of the bay is not required, more deeply flooding the bay to at least a metre deep would discourage emergent grasses and enable wave action at the margins to discourage mosquito larval survival. However as this bay is more than 10 km from the residential areas of town, any regular mosquito control is not as relevant as any similar area that is within 10 km of the town. These sites will be locally very productive for mosquitoes, and increase the potential for mosquito borne diseases such as MVE and RRV. The land owners and relevant authorities should be made aware of the mosquito breeding potential of these areas.

2.3.4. Waste water from irrigation areas.

**Figure 73. Waste water drain 5km along Ivanhoe Road.**

**Figure 74. Waste water draining s/west of Ivanhoe Rd. 5km mark.**

**Figure 75. Waste water drain downstream 700m s/west of Ivanhoe Road.**

**Figure 76. Waste water feeder drain to main waste drain.**

**Figure 77. Waste drain culvert. Feeder waste drain.**

The waste water drains from irrigation areas are generally over grown with vegetation and are more prone to mosquito breeding. As an example there is a main waste irrigation water drain about 5 km along Ivanhoe Road. There is a lot of water flow into this drain from the adjacent irrigation areas and by the colouration, it appears these waters have high nutrient levels conducive to mosquito breeding. The drain has tallgrass margins at the start of the drain, but about 700m downstream it had stopped flowing as evaporation and infiltration had robbed it of water at the time of inspection. Downstream in the drain, the drying drain and remnant pools are discrete and vegetation free at the edges with no mosquito breeding evident.

The smaller feeder drains are much more overgrown with grasses and weeds on sides and inverts of the drains, with Typha reeds in some areas.

In the wet season and earlier in the dry season when these waste drains are full, they will have thick grass and occasional areas of Typha reeds in the invert of the drains. These waste drains could then be appreciable sources of **Cx. annulirostris**. Particularly important potential areas of mosquito breeding are at the ends of the waste drains where they enter poorly draining creeks or flood out areas and become low lying swamp areas.

All waste drains within 5 km of the town need to be inspected for mosquito breeding in and after the wet season to determine their capacity to breed mosquitoes. If they are significant sources of mosquitoes, they could be relatively easily treated with methoprene pellets. However the medium to longer term control relies on weediciding and drain cleaning, and ensuring all waste water drains flow freely to downstream areas and into the Ord River.

## 2.4. KUNUNURRA FACILITIES.

### 2.4.1. Waste facility, landfill.


**Figure 78. Locations around waste facility.**

The waste facility for Kununurra is located on the Old Darwin Road approximately 1.5km from the Drovers Road junction with the Old Darwin Road. There are extensive deep excavations in sandy soil but there are no potential mosquito breeding sites inside these excavations.

### 2.4.2. Vicinity of Land fill locality.

There is a large flood prone area to the north of the waste facility. This area was dry at the time of the survey but could be an appreciable source of **Cx. annulirostris** and **Anopheles** species during the wet season and in the early dry season. There is also poor draining land south of the waste facility along the Old Darwin Road. Land development has disturbed natural drainage patterns and has led to ill draining areas.

These areas will need to be checked carefully to determine their mosquito breeding capacity during the wet season and soon after on a number of times relating to different water levels and the presence of emergent or marginal vegetation.

### 2.4.3. Kununurra sewage ponds.

**Figure 79. Kununurra sewage pond locality, and main irrigation channel.**

**Figure 80. Secondary Ponds, algae on ponds.**

**Figure 81. Margins clean with numerous ducks.**

**Figure 82. Secondary ponds. Floating duck weed.**

**Figure 83. Sewage ponds, clear margins, floating algae.**

**Figure 84. Floating duck weed windblown to edges.**

**Figure 85. Outlet pipe of effluent to main channel.**

The Kununurra sewage ponds are located west of the town (see locality image Figure 79). The ponds are well maintained, with vegetation free margins that are not conducive to mosquito breeding. Effluent after treatment is piped to the nearby main irrigation channel where it is suitably diluted and there is no marginal vegetation in the receiving channel. The floating algae, and floating and wave piled duckweed (Elodea sp.) were not breeding mosquitoes during the survey. If marginal vegetation becomes established, these ponds could be very productive sources of **Cx. annulirostris**, and possibly **Cx. gelidus** and **Cx. quinquefasciatus**. The presence of numerous water birds also makes this site very relevant for the potential for MVE transmission.

Soil heaps on the west and south west side of pond area caused by past land clearing and development has interrupted surface wet season landward flow of drainage to the main irrigation channel. Many depressions exist throughout the area that could be important breeding places for **Cx. annulirostris,** particularly as this site is so close to residential areas. This poorly draining area needs checking in wet season for mosquitoes breeding. Wet season treatment of any breeding would be by the application of methoprene pellets, but medium to longer term rectification by levelling improved drainage is required.

### 2.4.4. Shire arbovirus surveillance and vector control facilities.

**Figure 86. Sentinels chickens coop in corporation area.**

**Figure 87. Sentinel chickens.**

The sentinel chicken facilities are located in the Ngahluwah Aboriginal development area on St. Martins Way near Button Drive on the north-west side of the main residential area and not far from the “wet land area”. Although well-constructed, and afforded good security by this location, it is not sited for optimal detection of MVE or Kunjin activity arising from wild water birds. The existing site is separated from Lily Creek Lagoon by the main residential area and hence is not likely to act as an early warning method for flavivirus activity. The better site for a sentinel chicken flock is close to aquatic bird habitats such as near to Lily Creek Lagoon, Lake Kununurra or the sewage ponds. The location of an alternative site for this flock is recommended.

**Figure 88. Existing permanent EVS trap site, Shire yard.**

**Figure 89. Existing EVS trap location, Shire yard.**

The existing permanent EVS mosquito surveillance trap sites are located on the fence at the Shire yard on Bandicoot Drive, and at the sentinel chicken site on St. Martins Way. The traps are baited with carbon dioxide gas obtained from cylinders sourced from a local supplier. As stated above the sentinel chicken site, and hence the EVS trap site associated with the chickens, needs to be relocated to optimise both virus detection and relevant mosquito populations. Mosquito populations arising from the Lily Creek Lagoon are not likely to be well represented by trap positons so far from the most important sites of mosquito breeding and water bird activity.

**Figure 90. Vector control equipment, operational fogger.**


**Figure 91. Vector control equipment storage area.**

The current vector control equipment consists of a new Cougar brand ULV fogger. This unit is fully operational and serviced and operated with advice from Dave Walker and Clarke Pest Control. There is also a disused Cougar fogger that can be cannibalised for parts. The foggers use Twilight ULV insecticide and a wetting agent DC Tron is used. The insecticides are stored in an air-conditioned room.

## 2.5. WYNDHAM AREA.

### 2.5.1. The 6 Mile Creek area.

**Figure 92. Aerial view of locality of 6 Mile Creek.**


**Figure 93. Close up of 6 Mile Creek.**

The 6 Mile Creek area has been a location of mosquito complaints in the past. It is approximately 3 miles east of Wyndham town (the 3 mile area), with mileage distances referring to distances from the original port facilities. It is also between the airport and Wyndham town. There is a recreational club nearby on the north side of the Highway and a private residence associated with extensive bird keeping sheds on the southern side of the highway.

Figure 94. Lateral margins of 6 Mile Creek downstrem of highway.

Figure 95. Main channel of 6 Mile Creek just below highway.

Figure 96. Isolated tidal pool in 6 Mile Creek invert, lower reaches.

Figure 97 Lower reaches of 6 Mile Creek, tidal.

The 6 Mile Creek, its tributary creek, and poorly draining areas on the lateral aspects of the creek below the highway and west of the bird sheds are high potential **Aedes vigilax** breeding sites. These sites should be inspected after the first big rains of the wet season and after the highest spring tides to determine specific breeding sites. Control can be by methoprene briquettes. There is little practical engineering control necessary here apart from possible tidal control on culverts on the highway, because there are so few residents affected. However if there is considerable use of the recreation club, and possible outdoor mosquito exposure, some control of high larval populations of **Ae. vigilax** by insecticides at peak periods would be warranted.

2.5.2. Wyndham Town, (3 Mile area).


**Figure 98. Aerial view of Wyndham localities.**

Wyndham town is about 3 miles east of the port area. The residential area is located on both sides of the highway to the port. During the survey, a mosquito complaint was investigated by an inspection of the yard and the placement of an EVS trap in the yard overnight.

2.5.3. Wyndham residence, mosquito complaint location.

**Figure 99. Complaint residence. Septic tank with gap in lid.**

**Figure 990. Complaint residence. EVS trap.**

**Figure 100. Wyndham School. Possible mosquito access to septic holding tanks.**

The complaint residence had a mosquito problem probably originating from artificial containers nearby (see Table1, Appendix 1), with the **Cx. quinquefasciatus** probably originating from the faulty septic tank in the yard. It was not possible to inspect inside the septic tank but a mosquito was observed coming out of the hole. Three species collected in the adult trap are artificial receptacle or tree hole breeding mosquitoes. In the current location and season, all of the species collected probably came from nearby artificial receptacles, and all can breed in functioning or disused septic systems, as well as small purposely filled receptacles.

Most residences in Wyndham have septic tank systems, which are actually septic treatment and holding tanks, where the treated effluent is then gravity piped to the sewage treatment plant near the Highway, rather than fed into an on-site absorption trench. Other locations in Wyndham had sections of their waste systems that were not adequately sealed against mosquito entry (see school system above) and there are probably many septic systems in the town that are breeding mosquitoes, and these are the probable cause of many complaints when they are not related to large outbreaks of salt marsh mosquito hatches originating from tide or rain events. The simple means of control of these mosquito sources is sealing the septics and sealing any damaged inspection lids or grates in pipe or vent systems leading to the septics. Particular care should be given to sealing all gully traps in all houses in Wyndham with fly wire in the grate instead of just having a slit grate. The responsibility for inspecting and rectifying problem septics and grates in the houses in Wyndham will be the owners of the property. The Shire of Wyndham /East Kimberley should undertake an education program to encourage the owners to rectify these problem sites. Generally the breeding of mosquitoes on private or other residential or industry property will be against Health regulations.

### 2.5.4. Wyndham oval.

**Figure 102. Wyndham oval former water reuse facility.**

**Figure 101. Town water supply to water holding tank.**

Effluent was previously used via a concrete holding tank near the oval to irrigate the oval. Now the holding tank contains town water and is only a freshwater holding tank. There was no mosquito breeding in the holding tank, primarily because of the low nutrient levels and the pesence of aquatic insect predators of mosquito larvae. This tank should be periodicaly checked for mosquito breeding.

### 2.5.5. Sentinel chicken site.

**Figure 102. Sentinel chickens, Wyndham.**

**Figure 103. Sentinel chickens in coop, Wyndham school.**

The sentinel chicken flock is in the school grounds and maintained by the school. The adult mosquito EVS trap is not associated with the chickens, but is located within a 1 km in the Anglican Church grounds and is operated and serviced by the vicar. There appears to be little **Cx. annulirostris** potential within or close to Wyndham town, as most of the potential mosquito breeding sites are saline habitats associated with **Ae. vigilax**, so siting of the chickens and the monitoring trap is not so important for this long dispersing species.

However if opportunity allows, the positioning of the EVS trap would be better within 50 m of the chickens, for better indications of mosquitoes associated with the chickens. The church location is also relatively exposed to wind, and there are competing lights from the nearby basketball ground.

### 2.5.6. Wyndham Caravan Park and 3 Mile Creek area.

**Figure 104. Caravan Park dam wall, partly breached overflow.**

**Figure 105. 3 Mile Creek downstream from caravan park dam.**

**Figure 106. 3 Mile Creek, upstream of pedestrian path culvert.**

**Figure 107. Pedestrian path culvert looking upstream.**

The caravan park has a dam in the upper reaches of 3 Mile Creek and is tidal from the salt flat to just upstream of the Great Northern Highway culvert on the highway (above RHS). The 3 Mile Creek flows around the Wyndham caravan park to the highway culvert and then towards the extensive salt mud flats. The caravan park dam may be a source of mosquitoes early in the wet season and post wet season, but may have aquatic predators in it after it fills during the wet season, and may not be a productive source while it flows or is relatively full.

The section of the creek after it overflows from the caravan park dam to the pedestrian culvert is deeply incised and will have residual pools during and after the wet season. This creek line may be a mosquito source early in the wet season but again may have aquatic predators for most of the wet season and early dry season. However both sites will need checking during the early wet when they first fill, particularly if there is thick vegetative grass and reeds at the margins. The area of wet season and post wet season freshwater ponding with thick Eleocharis reeds just upstream from the pedestrian culvert (Fig. 108) is a likely very productive area of **Culex annulirostris** and **Anopheles** species mosquito breeding in the wet and early post wet season.

Figure 108. Pedestian path culvert, with tidal weir effect.

Figure 109. 3 Mile Creek down stream of path, tidal ponding.

The culvert at the pedestrian path has a relatively steep drop on the downstream side and forms a fortunate partial or complete tidal barrier. If any exceptional tide gains access above the pedestrian culvert, this ponding water in the dead Eleocharis reeds may breed **Ae. vigilax** after very high tides and after the first rains. If there is no tide access to this site it will be a very productive site for **Cx. annulirostris**.

Figure 110. Downstream of highway road culvert towards salt flats.

The downstream side of this pedestrian culvert and for the length of the invert of the creek to the salt mud flat is highly likely to breed high numbers of **Ae. vigilax,** and should be checked after exceptional high tides and after first rains. The invert of the 3 Mile Creek after the pedestrian culvert is tidal and non draining. It would be difficult to make it free draining because the invert of the creek is below the level of the receiving mud flats.

An engineering method to afford a partial solution is the have the creek invert filled with gravel and solid fill to the natural ground surface, with erosion prevention gabions after the culverts to slow the wet season flows.

An insecticide option is to use staked methoprene briquettes installed every 5 meters along the invert of creek before the rainy season, or inspection and treatment with methopene pellets or briquettes after high tides and the first rains.

### 2.5.7. Wyndham sewage ponds.

**Figure 111. Wyndham sewage pond, new pond.**

**Figure 112. Wyndham sewage pond, new pond.**

The single new Wyndham sewage pond has good, stable, vegetation free margins. There was no mosquito breeding in the ponds when inspected during the survey.

**Figure 113. Old ponds. Dry but will fill in wet season.**

**Figure 114. Depressions adjacent to old ponds.**

**Figure 115. Creek like depression landward of old ponds.**

**Figure 116. Creek like depression, non-draining.**

**Figure 117. Drain line from ponds area through fence.**

The two older ponds are now disused. The ponds have a residue of organic matter and are edged with thick grass, affording food and shelter for any mosquito breeding. When they are flooded during the wet

season, they are likely to be productive sources of **Cx. annulirostris**. Past land disturbance around these ponds has created many potentially productive mosquito breeding sites. There are depressions with establish grasses and reeds in these depressions, which make them ideal mosquito breeding places. These sites are likely to be very productive sources of **Ae. vigilax** and **Cx. annulirostris** early in the wet season, and may continue to breed **Cx. annulirostris** as long as they remain flooded later in the wet season. These sites will need regular checking for breeding as they are close to residential areas. Any breeding could be controlled with methoprene briquettes or pellets. The old ponds when filled could be less productive by weed and grass removal around the margins.

### 2.5.8. Wyndham sewage effluent disposal area.

**Figure 118. Mud flat with high effluent mangroves on horizon.**

**Figure 119. Altered habitat of Sporobolus grasses and ponds.**

**Figure 120. Ponding effluent and grass margin, 1 October 2015.**

**Figure 121. Extensive area of brackish grasses.**

**Figure 122. Effluent discharge area in tall mangroves.**

The effluent from the old and now the new treatment pond is piped about 700 m south west from sewage ponds across a bare mud flat to a former small mangrove creek line. The continual discharge of effluent to this site has dramatically altered the former habitat over many years, with the result the fresh water component has enabled dense and tall mangove growth, various pooling areas of effluent over a wide area, and an extensive network of salt water tolerant Sporobolus grass to establish around depressions. These depressions and pools will be productive sources of **Ae. vigilax** and possibly **Ae. sagax** and **Cx. sitiens** when flooded by tides or rain. The pools may be fresh enough during the wet season to breed **Cx. annulirostris**. Water samples taken during the wet season should be tested to determine the salinity levels of surface pools in this area to determine if the pools are capable of breeding fresh or brackish water mosquitoes.

Control of any breeding site by insecticides could be achieved by timely instalation of staked methoprene briquettes in and around tidal pools.

**Figure 123. Photo Louis Franks 2/11/15 after spring tide (8.23m).**

**Figure 124. Photo Louis Franks 2/11/15. Tide flooded area. Effluent mangrove forest in background.**

The tide during the inspection survey (7.78m) did not reach the effluent discharge site in the thick mangroves, or any of the surrounding drying pools of effluent. However the high tide the following month on 29/10/2015 (8.23m) did flood the area (photos Fig 125 and 126, 2/11/15), and hence indicates the tidal threshold for flooding the pools near this effluent area that will lead to mosquito breeding is about 8 m. This tide threshold should be refined during late dry season tides in coming years.

This site is likely to be a most productive source of mosquitoes for the Wyndham town and should be rectified as soon as possible. Rectification of this new habitat could be achieved relatively quickly by prevention of discharge to this site. Temporary reduction of effluent discharge could be achieved by bringing the old ponds back into operation to give an increased holding capacity, and to reduce the discharge volume by allowing more evaporation. The effluent could also be used to irrigate the oval using the infrastructure already in place, if the effluent is of sufficient quality to use for this purpose. However such use of these old ponds will only be temporary, and a more permanent solution could be to installing a new pipeline to pipe the effluent to a larger creek-line further down the tidal reach that is regularly flushed by tides.

In the short term, if possible, the effluent should be stored in the ponds or reused by spray dispersal in the dry season and released in the wet season, when it will be diluted and more likely to drain away with flow on the mud flats and mangrove creeks.

## 2.6. WYNDHAM PORT AREA.


**Figure 125. Wyndham port area.**

### 2.6.1. Tidal flats and culverts.

**Figure 126. Drains from high mud flats areas to road culverts.**

**Figure 127. Culverts partially blocked with debris and silt.**

**Figure 128.Tidal creeklines from road culverts.**

**Figure 129. Road culverts blocked by vegetation and silt.**

There are many culverts between the airport area and the port area that lead to downstream tidal areas, or connect tidal areas. Some have downstream inverts that have residual tidal pools, while other are partially blocked with vegetation and silt and retain storm or tidal water. Some areas are potential **Ae. vigilax** mosquito breeding sites. During the current survey many sites were inspected after a high tide and most of the culverts directly connected to tidal flats were not breeding mosquitoes. This was apparently because the tidal flow in many is frequent enough or does not remain long enough to become a mosquito breeding site. However all were not inspected. The ones inspected and others should be inspected a few days following high tides, both early in the wet season and at the end of the wet season, to determine those that breed mosquitoes and need rectification. In many instances rectification could be simple measures such as removal of bocking vegetation or silt. Others may require measures such as resizing or correcting culvert levels to facilitate adequate drainage. Those that are breeding mosquitoes can be treated with methoprene briquettes or pellets in the short term.

### 2.6.2. Mud dump areas.

**Figure 130. Mud dumping area, downstream is free draining.**

**Figure 131. Mud dumping blocking drainage.**

**Figure 132. Retained pool formed by mud dump LHS background.**

**Figure 133. Extensive retained tidal water with Ae. vigilax larvae.**

The recent dumping of mud on a tidal flat in the port area has disrupted tidal drainage. During the present survey, **Ae. vigilax** larvae were found in the retained water after recent high tides. These dump areas need to be organised to prevent retained water after high tides. Dumped mud needs to be from upper margins of tidal areas and drainage pathways need to be created to allow free drainage from any dump areas.

### 2.6.3. Port facilities areas.

**Figure 134. Non draining drainway near tank farm, Port area.**

**Figure 135. Partially blocked tidal creekline in port area.**

The port area has a number of poorly draining depressions or poorly constructed drains that will retain tidal or rainwater. Many of them will be **Ae. vigilax** breeding sites after rain. These sites all need to be located and referenced, and a plan drawn up to rectify them. In many instances this rectification can be performed with a backhoe to clear slit or create new drainage pathways, or to install new culverts or partially fill small low lying areas.

### 2.6.4. Old crocodile farm area.

**Figure 136. Old crocodile farm area.**

**Figure 137. Crocodile farm. Filled and levelled area of old ponds.**

**Figure 138. Recently levelled crocodile ponds areas.**

**Figure 139. Downstream of crocodile farm showing depressions.**

The former crocodile farm was reported to be a mosquito breeding area in the recent past. During the current survey the site was observed to be partially rectified, with all the crocodile holding ponds filled in and most of the ground surface levelled to prevent the retention of surface water. However in the lower reaches of the area there is still some further filling and levelling required to remove all potential ponding areas that could breed mosquitoes.

**Figure 140. Deep tidal excavation associated with crocodile farm.**

**Figure 141. Outlet of deep excavation pit to tidal areas.**

The deep excavation was not breeding mosquitoes during the survey. It appears to be reached regularly by tides and hence is not conducive to mosquito breeding. However it should be checked at other times of the year to detemine if it does breed mosquitoes under certain circumstances of low water or low tides.

### 2.6.5. Wyndham Hotel Area.

Figure 142. Wyndham hotel. Bird water.

Figure 143. Wyndham Hotel. Disused swimming pool.

The Wyhdham Hotel has an old internal drainge system and various possible receptacles that could breed domestic mosquitoes such as **Ae. notoscriptus** and **Cx. quinquefasciatus.** No mosquito breeding was located during the current inspection. However as the international port is so close to the hotel, it would be appropriate, from a Quarantine viewpoint, to ensure the possible domestic breeding sites in the hotel site are rectified. The hotel site should be inspected afer the start of the rain season for ponding and mosquito breeding. If the pool it is to continue in an unmaintained state, it should be cleaned of debris such as leaves and treated with methoprene briquettes as per label for the volume of water retained.

The general area around the hotel and other nearby properties or faclities includes some stormwater drains and depressions that could breed mosquitoes at other times. A general mosquito survey should be conducted around the public and private facilites in the general port area during the early wet season to determine the localty of any other actual or potential mosquito breeding sites.

**2.6.6. Pioneer cemetery and Wyndham Port area, tidal flats.**

Figure 144. Between Pioneer cemetery and port.

Figure 145. Recently flooded tidal flats with good tide drainage.

There are extensive tidal flats between Wyndham and the port area, with mangrove creeks in the middle of the flats that are relatively frequently reached by tides. The tidal flats are flooded by high tides but drain back to the mangrove creek-lines soon after a tide event. The mangrove areas and the extensive tidal

flats between the Pioneer Cemetery and the main port area are not likely to breed mosquitoes unless there is some artificial disturbance in margin area that retains tide water from the highest tides.

**Figure 146. Pioneer Cemetery tidal flat a few hours after tide**

**Figure 147 Pioneer Cemetery a few hours after tide**

The tidal flat near Pioneer Cemetery has a mangrove creek that is relatively close to the highway. An inspection one day and two days after the tide indicated there was no mosquito breeding in the water retained on the flat or in the creek-line. Some retained water was retained in Sporobolus grass pools, which is generally an indicator of **Ae. vigilax** breeding site. However it appears the tide water is not retained long enough on the flats or in the grass pools in these sites to become mosquito breeding sites.

# 3.0. MEETINGS AND DISCUSSIONS

Various meetings and discussions were undertaken with various officers in Kununurra.

These included;

## 3.1. Meeting 1. - Meeting with Wayne Richards (A/Director Shire of Wyndham /East Kimberley), Louis Franks (EHO Shire of Wyndham /East Kimberley) and Peter Whelan (Mosquito Consultant) Monday 28 September 2015.

After introductions and aims of the review, the general Shire of Wyndham /East Kimberley mosquito surveillance and control program was discussed. The program is briefly outlined in part in the selected parts of the draft Shire of Wyndham /East Kimberley MMP at Appendix 5.

**Larval control.**

Wayne and Louis listed the various locations where larvicides were applied last wet season. These included the various drains that were already established as having mosquito breeding, including Barringtonia drain, TAFE entrance on Coolibah drain, Wetland off Ivanhoe Road, Gardenia St. drain, Argentea St. drain, and Ghost Gum St. drain. All these sites were treated with methoprene pellets after routine inspections.

**Mosquito borne disease cases.**

These are more fully listed in the complete version of the draft Shire of Wyndham /East Kimberley MMP, but are not detailed in Appendix 5.

Briefly there were 13 cases of RRV in the Shire of Wyndham /East Kimberley in 2015, and most were in January. Most were from out of town locations around Kununurra with only 1 case from Wyndham. Cases occurred in the locality of River Farm, Airport Farms (locality near airport), Packsaddle Plains, and Mills Road. On a per capita basis, few were from Kununurra itself and most were in longer term residents rather than tourists.

**Arbovirus surveillance.**

New EVS traps had just arrived and will enable a more comprehensive trap program from now on. During the survey period traps were only set in 2 locations at the permanent sites in Kununurra (sentinel chicken site at Ngahluwah community area) and the Shire yard on Bandicoot Drive) and 1 site in Wyndham (Anglican church on Koolama St. near Shire offices).

As at February 2016 the EHO's are setting traps in Kununurra at 4 locations; at Kununurra airport, sewage ponds, Lakeside Caravan Park, and Shire Gardens. Traps are also being set as at February 2016 in 4 locations in Wyndham; at Dulverton St, Koolama St., Reginal St and the Sewage Ponds.

There are two sentinel chicken flocks with one in Kununurra at the Ngahluwah community area and one in Wyndham at Wyndham School. Chickens are bled fortnightly by the EHO's in the wet season and monthly in the dry season if there are no seroconversions.

**Adult mosquito control.**

There is a fogging program in the Wyndham area when the trigger indicators of mosquito borne disease indicate a disease transmission problem. This is generally significant seroconversions to MVE or Kunjin virus in sentinel chickens, human cases of MVE, or a demonstrated outbreak of RRV. Fogging is undertaken by the Shire of Wyndham /East Kimberley in consultation with the WA Department of Health. The current fogging routes and program are outlined in Appendix 3.

## 3.2. Meeting 2. Discussions between Louis Franks and Peter Whelan.

**Long term data**

There is little long term data on mosquitoes for Kununurra. This is primarily due to the difficulties in local identification of mosquitoes and the practicalities of setting and retrieving routine traps in various locations with a small workforce.

**Wyndham sewage ponds**

The manager of the ponds is Mike Boyes of Water Corporation.

**Vector control equipment**

The foggers and insecticides are stored in the shed at the Shire of Wyndham /East Kimberley yard in Kununurra. The insecticides are stored in an air conditioned portion of this shed. Other field equipment is stored in a garden shed behind the Shire offices, and includes a ladle, some boots and sample equipment .

**Roads**

Main Roads WA are responsible for main roads including culverts on these roads. The Shire of Wyndham /East Kimberley is responsible for roads in most town areas except for main roads such as Highways sections through towns. In Wyndham, Main Roads are responsible for the Great Northern Hwy through the town area and to the port and hotel locality up to Gully Road, and then it is the Port Authority responsibility.

**Mosquito publicity.**

There is a media program orgamnised by the Shire (see Appendix 4). This appears to be appopriate and well conducted. The tourist radio has mosquito messages, but while they are unlikely to reach many of the local audience, they may have some impact on tourist behaviour in relation to self-protection against mosquitoes.

**Availability of mosquito self-protection products in local outlets.**

Peter Whelan made an inspection of local stores and found a good range of mosquito self-protection products.

Coles had plug in devices containing allethrin and “Clip On” repellent devices containing metofluthrin, as well as standard repellents.

Mitre 10 had “Raid” DIY bifenthrin for barrier spraying, “Thermacell” mosquito repellent and control lanterns, and “Thermocell” hand held gas powered pad repellent devices.

## 3.3. Meeting 3. John Piercy (Shire of Wyndham /East Kimberley Asset Management Officer), Nav Rajeha (Shire of Wyndham /East Kimberley Senior Technical Officer), Louis Franks (Shire of Wyndham /East Kimberley EHO), and Peter Whelan (Entomology Consultant), 2 October 2015.

The agenda items and discussions included;

**Drains in suburb areas of Kununurra.**

Peter Whelan indicated his findings of mosquito breeding in the drains and overwatering as the probable reason for sustained flow and aquatic reeds in the drains, and drain and weed maintenance needs. The Shire of Wyndham /East Kimberley will look into any possible contribution to watering regimes and flow in drains. The Shire will look at possible maintenance needs in drains.

**Lake and Lagoon margins.**

Lake and Lagoon margins with Typha reeds and probable mosquito breeding sites were discussed. The possible contribution to mosquito breeding by areas of dense reeds, and particularly dead weeds from the weedicide program were outlined. The Department of Waters has responsibility for Lake maintenance issues and previously carried out reed removal with a machine. The aspect of weed control will need to be followed up with the approptiate officers in the Shire of Wyndham /East Kimberley and the Department of Water.

**Sewage ponds.**

The sewage ponds in Kununurra were in excellent condition and were not breeding mosquitoes. The findings on the Wyndham effluent discharge to the tidal area was outlined. Peter Whelan stated that this was possibly the most important artificial mosquito breeding site in Wyndham, which is adding to the potential Murray Valley encephalitis and Ross River virus disease transmission in the town. The points raised about suitable effluent disposal will need to be addressed by the Water Corporation staff in Wyndham.

# 4.0 CONCLUSIONS AND RECCOMENDATIONS

## 4.1. Mosquito breeding, and larval surveillance and control.

Larval control should only be undertaken in locations where larvae have been just located or a larval monitoring program indicates the timing and location where larvae are expected in the short term. Adult trapping records should be examined to aid in determining locations where mosquito larvae can be expected, particularly the locations where roving adult traps indicate unknown breeding sites.

Larval surveys for tidal influenced areas are required around 3 to 4 days after rain or tide events. Timing of larval surveys in tidal areas is more critical than freshwater sites, when tidal species larvae may only be present in pools up to 4 days after tide inundation before they moult into pupae, which makes control very difficult. Larval surveys for freshwater species should be made around 6 days after rain events for temporary rain filled or recently flooded sites, as the most common species, **Cx. annulirostris** can develop from recently laid egg rafts to pupae in 6 to 7 days during the wet season. Larval inspections of selected and known freshwater sites during the wet season should be made in regular locations at the start of the wet season and at least monthly up to June in locations where methoprene pellets are used. More extensive larval surveys should be undertaken twice per year; just after the first appreciable rains of the wet season in January and mid-way through the wet season in February a week after rain, to look for new sites that develop because of new civil or agricultural developments, or other changes in habitats that lead to mosquito breeding.

The sampling of sites for the location of larvae should be made with a standard dipper, sample bottles, and a pipette. Larval dipping should be made in vegetation or other physical locations where larvae can be expected, and numerous dips should be made in each location to cater for the probable uneven distribution of larvae and their preference for certain locations. Fourth instar larvae should be searched for in particular, but a sample of all instars and any different looking larvae should be made. An estimate should be made of the type of instars and the approximate number per dip so later comparisons between location and time can be made. All collection details should be entered on the sample bottle, including location, date, number of larvae per dip, and presence of fish or other predators. A sample of larvae should be made and taken to the laboratory or office for formal identification. All sample data and identification should be entered into a data base.

The procedure for larval surveillance and larval sampling is outlined in Appendix 6.

Generally the threshold for larval control in fresh water sites should be around 2 fourth instar larvae per dip. In permanent or perennial freshwater sites with semi aquatic vegetation and fish and other aquatic predators present, there may continuous egg laying and relatively stable numbers of early instars, but very few or no 3$^{rd}$ or 4th instars, indicating that biological control is achieving sufficient control and larvicides may not be required. It is helpful in freshwater sites with thick aquatic or semi aquatic vegetation to take more dips or use a bucket for sampling, to get an estimate of the number of larvae per square metre to gain an indication of possible production of larvae over the whole area of habitat, which will help determine whether larval control is warranted.

Temporary freshwater breeding sites are generally transient, have higher temperatures, and take longer for predators to appear, and development of larvae to pupae may proceed within 7 days, so the presence of early instar larvae only in these sites may require larval control, before they proceed to develop to later instars and pupae.

In tidal sites with larvae, there are usually few effective predators, and early instars will generally proceed to develop to later instars and pupae, so a detection of any larvae in a large uniform habitat area indicates control is warranted. In tidal sites with thick vegetation, the presence of 2 larvae per dip on average warrants control, as sampling is generally under-estimated in these sites.

Larval control can be by a range of measures, with the most practical and appropriate in the Shire being the application of methoprene pellets or briquettes, and the rectification of small sites by physical or engineering measures. Pellets are useful in habitats that may last for a week up to 30 days. If the habitat is likely to remain for over 30 days, briquettes are more useful and will generally give 90 days control. Any breeding site with pale looking larvae in comparison to untreated sites indicates the pellets or briquettes are still effective and re-treatment is not required. Briquettes are very useful in pre-treatment of perennial and productive sites such as the invert of tidal creeks or tidal depressions, where the briquettes can be applied in sites a week before high spring tides occur and retreatment of these sites will not usually be required until after 90 days. For briquettes in these tidal situations, it is useful to attach the briquettes to stakes in a net bag with a float and cable ties so that the briquette is not covered by mud and is not displaced. Note that many tidal sites that are productive in the late dry season or early wet season are generally unproductive in the mid wet season if continuous freshwater is present and flowing, as there is no available damp mud microhabitat for egg-laying, and fish predators will usually be present.

Many of the principles for mosquito surveillance and control can be found in detail in the WA Health Mosquito Control Manual 2015, (see References). The specific sites and control options are detailed below.

### 4.1.1 Drains.

There are a number of storm drains in Kununurra that are breeding mosquitoes or have a varying potential to breed mosquitoes. Most of the locations of potential mosquito breeding located in drains during this survey are related to higher nutrient levels or vegetation in the drains, and these locations are generally where there is longer term dry season flow in the drain with waste water from over irrigation of lawns, park areas, footpath verges, or wash down operations. Possible over watering on grass verges and parks is leading to aquatic reed growth in some drains, which will promote extended and higher mosquito breeding. The breeding in drains is relatively important in Kununurra, as the drains are within or close to urban residential areas, and people will be their closest sources for blood meals.

The present control of breeding with methoprene pellets is satisfactory. However the present inspection and control of larvae in drains needs to be examined to determine if the inspections and control can be expanded to include more drains. All the drains throughout Kununurra need to be located and indicated on a vector control map. The aspect of vector control maps is outlined in Appendix 6. Each drain needs to be sampled for mosquito breeding at various times of the year and given a priority reference for when they should have repeated inspection or control.

Some of the dry drains have well maintained inverts by mowing and have little capacity to breed mosquitoes during the dry season. However these drains still need to be inspected during the wet season to determine if they are capable of breeding mosquitoes.

Many drains require some form of rectification. All suburban drains should be examined for silt and weed removal requirements. The drains with Typha reed growth, in particular Gardenia St. drain and to a lesser extent the Argentea St. drain need application of weedicide such as glyphosate a number of times throughout the year.

While weedicide applications to water appear contrary to the Guiding Principle 6 of the Vegetation Management Plan, which states “use of chemicals in and close to water is to be avoided” (see Reference),

it is suggested that the use of glyphosate is the most practical method, which is also the least disruptive to the invert of the drains, particulary if it is applied when water is not flowing in the drains, or the drain invert is dry. While Guiding Principle 7 of the Vegetation Management Plan states that "riparian vegetation and cumbungi around drainage outlets will be retained unless it can be shown to be contributing to upstream flooding", it is clear that riparian vegetation in drains increases the management needs of the drains, and contributes to mosquito breeding in the drains, which appears to be a more considered approach to vegetation removal in drains. The object should be to eliminate the reeds so that maintence requirements are reduced, and they have less capacity to breed mosquitoes. Some drains such as those near the "wetland" area and Button Drive area will need reforming to promote better flow during the wet season.

Those drains that have dry season flow should be examined to determine the source of the dry season flow. If this flow is caused by over watering or waste water from other sources, there shoud be an examination of the watering patterns or frequency to determine if the additon of water to nearby drains can be substantialy eliminated or reduced. Drains with longer term retained water such as Gardenia St. drain, and drains off Ivanhoe Road, Greybox Drive and Ironwood Drive could be considered for small concrete inverts to promote flow away from residential areas to other drain or water infiltration areas.

### 4.1.2. Freshwater depressions and poorly draining areas.

There are a number of poorly draining areas close to urban areas of Kununurra. These need to be inspected at the appropriate time of the year for a better evaluation of their mosqutio breeding capacity. As well, any possible and practical rectification methods need to be determined. Particular areas include the area beween the sewage ponds and the main irrigation channel, the "wetland" area, and the Old Quarry and areas bordering the Old Quarry Road.

Other flood prone areas further from residential areas should also be considered for drainage enhancement if they prove to be appreciable mosquito breeding places. These sites include the flood area between the cattle yards and Lily Creek Lagoon, and the extensive flood prone area n/w of the dump.

The depressions and poor draining areas around the tank farm at Wyndham port area and the depressions around the Wyndham sewage ponds would be productive soures of **Ae. vigilax** in the early wet season, and possibly **Cx. annulirostris** in the mid to later wet season. All the Wyndham area should be surveyed for similar non draining areas with a view to rectifying them by filling or draining. The short term insecticide solution to control any breeding in similar areas in Kununurra and Wyndham is to install staked briquettes of methoprene in mesh bags or floats so that control can be achieved over a few months.

In some instances, an assesment of the drainage needs will involve either on ground or aerial topographical surveying, as well as on ground assesment during the wet season. Some small areas may need small filling operations, while others may need simple drains constructed with a backhoe or front end loader.

### 4.1.3. Lake and Lagoon margins.

Lake Kununurra and Lily Creek Lagoon have extensive areas of Typha reeds around their margins and in creek line entry point to Lily Creek Lagoon. A proper assessment of the capacity of these Typha areas

should be conducted to determine their seasonal capacity as sources of mosquitoes. A specific investigation will be needed to determine whether these reeds are sources of **Mansonia** or **Coquillettidia** mosquitoes, as these species will not be detected in normal surface larval sampling because they are usually attached to underwater roots and stems of reeds and grasses. It is possible that large areas of Typha are not as important as artificial drains and depressions, particularly those drain sites with thick vegetation and higher nutrient levels.

Typha reeds reduction should be discussed with the Department of Water and the Department of Environment and Conservation. Appropriate Environmental approvals will be needed for any Typha removal around Lake Kununurra and Lily Creek Lagoon. In the Vegetation Management Plan, it is stated that there needs to be a "long term weed removal and rehabilitation plan" for the lake and lagoon. Consideration of mosquito breeding in such vegetation should be an additional guiding principle in a weed removal plan. Reed reduction should be attempted where possible around certain points of Lily Creek Lagoon, particularly those margins closest to urban areas. Weedicide of margins around Lily Creek Lagoon, if possible by approval, should be attempted from the Lagoon side by boat, rather than the land side.

### 4.1.4. Creeks entering Lily Creek Lagoon.

Both Little Lily Creek and Lily Creek have silt and sand loads that can promote shallow and extensive areas of reeds in their lower reaches. It would be beneficial to install silt traps in the lower reaches of these creeks at sites before the creeks enter Typha areas, to prevent the further expansion of these Typha areas. These silt traps can be relatively simple, but need to be at sites where they can be cleaned of silt on an annual basis.

Clearing of cumbungi in these areas is supported in Principle 3 of the Vegetation Management Plan, which states that "clearing of cumbungi will be limited to areas defined for recreation and amenity, or areas defined as having experienced large increases in cumbungi growth. There can be no argument that these areas have experiened appreciable cumbungi growth and continue to expand, and if they are confirmed as appreciable mosquito breeding sites, will have a serious detrimental effect on recreation and amenity.

### 4.1.5. Sewage and waste water ponds and effluent.

The sewage ponds in Kununurra are in good condition with vegetation free margins, and were not breeding mosquitoes at the time of the survey. This was despite areas of floating duckweed and banks of dead algae that can sometimes provide breeding sites for mosquitoes. These ponds need to be maintained in their present condition to prevent mosquito breeding, with periodic checks at other times of the year to determine if any mosquito breeding occurs.

The cattle yard waste water ponds require periodic inspections to determine if they become sites of mosquito breeding. The installation of a sprinkler dispersion system or an inflitration area appears to be warranted to prevent high nutrient water from contaminating nearby flood prone areas, and to prevent nutrients entering the Lagoon and promoting algal and reed growth.

The new sewage pond in Wyndham was in good condition with vegetation free margins and was not breeding mosquitoes. The old ponds were dry during the survey. These will flood in the wet season. When

they first flood, they will become substantial sources of a number of species of mosquitoes, and will need inspection and control.

The sewage effluent release site from the Wyndham ponds onto the salt flat and mangrove area should be investigated for its seasonal capacity to breed mosquitoes. The treatment pond should be assessed to reduce effluent release. There should be due consideration to install a new pipe to deliver effluent further down stream from the present disposal site to a daily flushed tidal site.

The possibility of bringing the old ponds back into operation as short term or dry season holding ponds to reduce effluent release to the mud flat disposal site should be investigated. Filling these ponds to capacity is better that leaving them intact to flood in the wet season. Further effluent release reductons in the dry season may be possible by effluent reuse on the oval using existing infrastructure. If the old ponds can not be used as holding ponds, they should be levelled and the area made free draining.

### 4.1.6. Irrigation plots around Kununurra.

At the time of the survey, no mosquito breeding was detected in irrigation plots or the main or minor irrigation channels. The lack of breeding in irrigation plots during the current survey was primarily a function of the dry season, when any irrigation water infiltrates quickly. However the site on Weaber Plains Road where there were numerous geese could be a highly productive site for mosquto breeeding. Any such sites, within 5 km of urban residential areas or concentrations of rural houses, where irrigation water stays on site for more than 7 days, should be investigated for mosquito breeding and to determine methods to prevent longer term flooding that promotes mosquito breeding.

There are a number of situations where mosquito breeding could develop in irrigation areas. This would primarily involve shallow vegetated feeder channels or irrigation bays where water is retained for periods longer than a week. This water retention would allow **Cx. annulirostris** mosquitoes to develop. This could occur in the wet season, or in situations where channels are blocked by silt or vegetation. Any such areas should be located and investigated by periodic inspections of the irrigated areas in the wet season, and to promote the reporting of such areas to the EHO for advice.

### 4.1.7. Waste water from irrigation areas.

The highest capacity for mosquito breeding in the irrigation areas is in the waste water after irrigation. The waste water drains are not maintained in the same manner as the feeder channels, and hence they contain varying amounts of grass or reeds. In addition the waste water receiving areas are usually flood out areas where artificial swamps could develop, which could be very high sources of mosquitoes. These waste water channels and disposal sites will have high nutrients and be capable of breeding high numbers of **Cx. annulirostris**.

All waste water channels should be inspected and marked on a vector control map. They should be periodically inspected through the year to determine whether they become appreciable mosquito breeding sites. Priority should be given to those channels and drains that are within 5 kms of urban residential areas of Kununurra or concentrations of rural residences. If appreciable mosquto breeding is detected in relevant waste drains, they should be subjected to mosquito control by methoprene in the short term. In the medium to longer term, they should be subject to maintenace procedures of weed

removal and wedicide spraying. They should be reformed or reconstructed where appropriate to drain directly to the Ord or other large free flowing creeks or rivers. Any silt blockages that act to retain water in the drains should be removed to ensure all drains are free flowing.

### 4.1.8. Roadside culverts.

There are many culverts on roads and tracks that are partially blocked or have flow reduced, which can cause upstream retention of storm water, and lead to mosquito breeding.

The retention of tidal or saline water is a particular problem in the Wyndham area, both on main roads roads and roads in the Port area of responsibility.

All road culverts should be located and listed on a checklist, with rectification needs and possible solutions brought to the attention of the relevant body responsible for the relevant roads.

### 4.1.9. Tidal flats and Tidal creeks.

In general most of the tidal flats around Wyndham town and the Port area are not appreciable breeding sites for **Ae. vigilax**. The main salt marsh mosquito breeding sites are likely to be associated with the various drains and creeks that lead to the salt flats. These creeks are generally incised by erosion to invert levels below the natural surface of the upper salt flats, with the result that they retain salt water after very high dry season tides. From the survey evidence and a post survey inspection by Louis Franks, it appears that tides over 8.0 m are necessary to flood the major potential tidal mosquito breeding areas. Potential creeks that are likely to be large sources of **Ae. vigilax** are the tidal sections of the incised inverts of 3 Mile Creek and 6 Mile Creek.

Control of mosquito breeding in the creeks in the Wyndham area could include the short term application of methoprene pellets 2 to 3 days after tidal or rain flooding of these creeks, or the pre-emptive installation of staked methoprene briquettes just prior to the high tide or rain periods. In some locations, such as 3 Mile Creek at the pedestrian pathway culvert, the enhancement of tidal barrier weirs could prevent tides from entering further upstream areas of creeks. There may be other sections of drains or creeks where the installation of low rock tidal gabions with appropriate erosion protection could prevent tidal ingress into the upper section of creeks.

There are also many poor-draining areas around the high tide limit in the Wyndham area. An inspection of all tidal margins in the general Wyndham area should be made at appropriate tides and after rain to locate these potential mosquito breeding sites. Larval mosquito control will depend on available personnel, and it may only be possible or practical to treat the major sources closer to urban areas. At least 5 indicator sites should be selected as appropriate sites to regularly monitor for larvae after tides or rain. Generally around 15 mm of rain is sufficient to lead to ponding in tidal depressions, but this will need ongoing validation and checking. Surveys for larvae after spring tides over 8 m will need to be made 10 days after the highest tides each month from November to March. Tide charts will need to be examined before each late dry season to select dates for tidal larval site surveys. If possible a tide pest chart should be prepared to advise the public when expected Ae. vigilax pest problems are likely to occur (See web site; NT Disease Control, Medical Entomology , pest mosquito periods).

### 4.1.10. Urban septic systems.

The septic system of on property holding tanks in Wyndham is likely to be causing appreciable dry season mosquito problems. All property owners with septic treatment and holding systems on all properties in Wyndham should be targeted by the Shire of Wyndham /East Kimberley for an education program for faulty septic lids, unscreened gully traps, vents, or inspection points.

## 4.2. Exotic vector surveillance.

Both Kununurra and Wyndham have a potential for importations or introductions of exotic mosquito species from either overseas or from Queensland, with species such as **Ae. aegypti** or **Ae. albopictus** being a particular threat. While Quarantine authorities have carriage for detections within port areas, there is no program for exotic detections just outside port areas in Wyndham, and there is no specific exotic detection program for Kununurra town. It is considered that the Shire, as a receptive area for these species, should operate a limited exotic vector surveillance program with a limited number of tyre traps and ovitraps (suggested 2 tyre traps per town and 3 ovitraps per town) , perhaps operated on a season basis during the wet season from January to March inclusive. If possible the new Gravid Aedes Trap (GAT, see Ritchie et al 2014 Reference) developed in Queensland should be trialled in SWEK as a replacement for ovitraps, as these traps will collect adults, which will be quicker to collect and identify. The principles of operating an exotic mosquito surveillance program are illustrated in the paper on the successful eradication of **Ae. aegypti** from Groote Eylandt in the NT in Whelan et al 2009 (see References). Identification or forwarding for identification of any larvae or adults from GAT traps should be done at least weekly.

## 4.3. Adult Vector monitoring.

It is understood that the number of EVS traps are to be be increased, and some roving traps will be set to determine better permanent mosquito monitoring points. It is necessary to have full year and long term mosquito population data to be able to better anticipate mosquito control needs and to understand disease tansmission cycles. It would be optimal to carry out fortnightly adult mosquito monitoring during the wet season at a range of sites, subject to personnel availability, and particulary at the new permanent sites. The previous permanent mosquito trap sites should be augmented with additional traps close to appreciable potential mosquito breeding sites. During the dry season, monthly trapping would be sufficient, in recognition of the probable EHO personnel limitations in the Shire.

Suggested sites in Kununurra include the end of Lily Creek in the vicinity of Lily Creek Lagoon and the Lakeside Caravan Park, the Old Quarry Road area, the vicinity of the Kimberleyland Caravan Park, the Discovery Holiday Park, and near where Little Lily Creek enters Lily Creek Lagoon. At least 4 trap positions would be advisable. Other roving traps (at least 3 per month) are required in the rural area where RRV transmission has been recorded and other sites near swamp-land and reed areas within 5 km of Kununurra, to determine if there are locations with high populations of vectors that are not being detected by the permanent trap positions. Trap positions should be well away from competing lights.

In Wyndham the trap site at the Anglican church is unsuitable. Other trap site locations could include Dulverton St. at the rear of a house on the edge of the suburban area, a site near the sewage ponds, one near 3 Mile Creek and one in the port area. If the suggested 4 traps in Wyndham cannot be set fortnightly during the wet season, they should be set at least monthly in relation to high tide and rain events. Ideal periods are 10 days after the highest monthly tides of the late dry season, and 10 days after the first appreciable wet season rains that lead to localised pooling in creeks and depressions. Traps set before 9

days and after 17 days after high tides or rain will not collect peak numbers of mosquitoes arising from tide or rain. Again at least 3 roving trap should be set at potential breeding places to determine possible sites that have high vector numbers that are not being detected by the permanent trap sites.

Trap collections of more that 100 **Ae. vigilax** or 200 **Cx. annulirostris** per night at locations within 500m of residential areas would be likely to pose pest problems for residents, and the results of trapping over these thresholds should be included in timely public advice in relation to self protection messages. Trap collections of over 500 **Cx. annulirostris** in the wet season from December to May inclusive within 500 m of residential areas would be regarded as posing a severe pest problem and a potential vector disease risk, and should be included in public messages as posing a public health risk for MVE or RRV, and adult fogging of selected harbourage areas should be considered.

## 4.4. Sentinel chickens.

The existing sentinel chicken site in Kununurra should be relocated to a site nearer to Lily Creek Lagoon, as the existing site is too far from aquatic bird habitat and seasonal mosquito populations to act as an early warning sysem for MVE transmission. Chickens in Kununurra should be bled fortnightly from the first rains in the wet season to at least the end of May in the early dry season, with monthly bleeds during the remainder of dry season until the start of appreciable rains or December, unless seroconversions occur in the previous bleed. Longer term data should be examined to determine if this is still the appropriate bleeding period.

The flock in Wyndham at the school is relatively close to the sewage ponds and the effluent disposal site on the mud flats, so is located in an appropriate place at the moment. Chickens in Wyndham need to be bled from the first rains of the wet season until the early dry season (May) or until **Cx. annulirostris** numbers become very low.

## 4.5. Adult Mosquito Control.

Adult mosquito control should only be undertaken when adult vector monitoring indicates there is a mosquito problem. Any fogging program or ad hoc fogging should be referred to the WA Health Medical Entomology team for advice and assistance.

The adult mosquito control program in Wyndham has appropriate fogging routes. However more adult surveys need to be undertaken to determine where appreciable mosquito harbourage sites are located, and more emphasis should be made on fogging these places in preference for prescriptive fogging residential areas.

The equipment and insecticides are located in Kununurra and can be resourced at appropriate times. Fogging should only be conducted during the evening or early night when appropriate triggers are reached for mosquito borne disease risks, or for severe nuisance problems from potential vector mosquitoes during the period of mosquito disease risk.

The fogging program in Kununurra will need to be investigated as per route, timing and triggers. Fogging should only be conducted when sentinel chickens seroconvert to MVE or Kunjin virus during the high MVE risk period from March to May, or soon after human cases of MVE or Kunjin disease occur, or during periods when relatively high RRV transmission is occurring, or when high to very high vector numbers at appropriate times indicate a significant disease risk. Fogging should preferably be undertaken in appreciable mosquito harbourage areas, and these will usually not be in urban residential areas.

## 4.6. Mosquito Publicity.

As many of the mosquito breeding situations in and around Kununurra and Wyndham cannot be controlled with insecticides or rectified in the short to medium term, the present public awareness program should be retained and revised to see if more methods of public communication can lead to changing people's behaviour to better protect themselves from mosquito attack. Alerts to people of the risk periods of both high mosquito numbers and disease transmission risk periods should be based on current mosquito trapping results, sentinel chicken results, and disease transmission risk periods derived from past transmission periods.

There will be regular pest problems from tidal mosquitoes in the Wyndham area due to the extensive tidal areas around the various sections of Wyndham and the very long range of **Ae. vigilax** of up to 50 km from large breeding sites. Residents of both Wyndham and Kununurra should be alerted to the fact that periodic nuisance and potential vector mosquitoes will occur in pest numbers and they may not be amenable to practical insecticide or rectification control. The public will need to be advised to take effective self protection measures against mosquito bites during these periods when mosquitoes are appreciable pests.

The public should be made aware of the regular and ad hoc mosquito control or rectification measures undertaken by the Shire, and the results from vector monitoring and sentinel chickens. The Shire should organise appropriate publicity of the Shires approach to the mosquito and disease reduction strategy, and this may include information sheets, community meetings at appropriate times, or through local media.

## 4.7. Activity Chart

The various elements and timing of the mosquito surveillance and control program are presented in the Activity Chart below.

Activity Chart

| Activity | Where | How Many | How often | When | When completed | Thresholds | Follow up action |
|---|---|---|---|---|---|---|---|
| Sentinel Chicken bleeding | W. and K. flocks. | All chickens | Fortnightly<br><br>Monthly | Start of Wet. June | May<br><br>Dec. | Flavi + ve | Publicity. Reporting. Fogging discussion. |
| Tidal Larval survey | W | 5 Indicator sites | Monthly 10 days after 8m tides or 15mm rain in wet | Nov | March | >2 per dip any site | Extensive larvicide pellets or briquettes all reg sites. |
| Freshwater larval survey | W and K | 5 Indicator sites K | Monthly in wet | Dec. 6 days after 15 mm rain | June | >2 per dip any site | Examine all regular f/w control sites. |
| Seasonal larval survey | W and K | 5 roving sites K<br>3 roving sites W. | One day per month | Jan | Feb | After regular rain | Add new sites to regular vector control map |
| Regular adult trap setting | W and K | 4 traps K.<br>4 traps W | Monthly | Dec | June | 200 Cx ann.<br>100 Ae. vigilax | Publicity re pest.<br>>500 Cx. ann.<br>Fogging discussion. |
| Ad Hoc adult traps | W and K | 3 traps per month. | Monthly | Dec | April | 100 any species | Evaluate vector control map |
| Larval control freshwater | W and K | All regular sites | Monthly | Dec | June | 2 of 4th instar per dip | Evaluate survey data |
| Larval control methoprene pellets | W and K | Recc rate. All positive sites. | 30 days | Tide sites, week before 8 m. F/W 2 days after 15 mm rain | 4 day after 8m tide or 10 days after rain. | Larvae present, no white larvae | Review vector map |
| Larval control briquettes | W and K | 1 briquette per 3 m length of site, or indiv pools | Every 90 days | Set before 1st 8 m tide Oct | Tide sites become fresh and full. | >2 per dip. Larvae present, no white larvae | Review vector control map |
| Ovitrap and tyre survey | W and K | 3 ovitraps.<br>2 tyre traps. | Sample every two weeks for two months. | January | March | When exotics detected | Id larvae. Report to WA Health, Quarantine. |
| Adult Fogging | W route.<br>K route. | All determined harbourage sites. | Once to twice in one week when required. | V high vectors. MVE cases or sent+ve after discuss. | No more new MVE cases. No more new ch +ves. Vect nos normal. | MVE, case or chicken seroconvt. RRV >10 cases per month. | Pre fog publicity. Evaluate adult trapping data. |

W = Wyndham K= Kununurra

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# 6.0. ACKNOWLEDGMENTS.


## 6.1 Field survey

The EHO, Louis Franks, accompanied me on much of the field exercise and his local knowledge and helpful experience are gratefully acknowledged. Ebony Daniell assisted in trap setting and field inspections.

## 6.2 Discussions

Wayne Richards (A/Director Shire of Wyndham /East Kimberley), Louis Franks (EHO Shire of Wyndham /East Kimberley)

John Piercy (Shire of Wyndham /East Kimberley Asset Management Officer), Nav Rajeha (Shire of Wyndham /East Kimberley Senior Technical Officer),

## 6.3 Comment and Review

Louise Gee, Director SWEK, who provided detailed comment on editorial aspects and very helpful comments on fogging and vegetation control, and in particular information on the Lake Kununurra and Lily Creek Lagoon Vegetation Management Plan 2008.

Ebony Daniell, and Chiquita dos Reis, EHO's, SWEK who provided helpful comment on the draft including fogging and larval control and editorial comment.

Dr. Peter Neville of WA Health who made constructive comments on the draft, including fogging and monitoring, and who suggested the inclusion of the Activity Chart.

## 6.4 Report Preparation

Gwenda Hayes who assisted in report layout and editorial comment.

# 7.0 APPENDICES

## Appendix 1 Results of mosquito surveys.

### Table 1: Mosquito adult collections, Kununurra and Wyndham 30/9-1/10 2015

| Date | Location | Trap type | Number of mosquitoes | *Genus* | *Species* | Sex |
|---|---|---|---|---|---|---|
| 01/10/2015 | Wyndham Anglican church | EVS CO2 baited | 1 | *Culex* | *quinquefasciatus* | male |
| 30/09/2015 | Wyndham Dulverton St. | EVS $CO_2$ | 10 | *Culex* | *quinquefasciatus* | female |
| | | | 4 | *Aedes* | *tremulus* | female |
| | | | 1 | *Aedes* | *tremulus* | male |
| | | | 1 | *Tripteroides* | *punctolateralis* | female |
| 30/09/2015 | Kununurra Lakeside resort | EVS $CO_2$ | 2 | *Culex* | *quinquefasciatus* | female |
| | | | 2 | *Culex* | *annulirostris* | female |
| | | | 1 | *Culex* | *hilli* | female |
| | | | 1 | *Coquillettidia* | *xanthogaster* | female |
| | | | 1 | *Coquillettidia* | *xanthogaster* | male |
| 30/09/2015 | Kununurra Discovery caravan park edge of lagoon | EVS $CO_2$ | 4 | *Culex* | *annulirostris* | female |
| | | | 1 | *Culex* | *hilli* | female |
| | | | 3 | *Coquillettidia* | *xanthogaster* | female |
| | | | 1 | *Mansonia* | *uniformis* | female |
| | | | 1 | *Uranotaenia* | *sp* | female |
| | | | 13 | *Aedeomyia* | *catasticta* | female |
| | | | 7 | *Anopheles* | *annulipes* | female |
| | | | 17 | *Anopheles* | *bancroftii* | female |

### Table 2: Mosquito larval collections, Kununurra and Wyndham 1-2 October 2015

| Date | Location | Habitat | Number | Genus | Species | Instars | Vegetation |
|---|---|---|---|---|---|---|---|
| 01/10/2015 | Kununurra Messmate Way, lagoon edge | lagoon edge clear water | 1 | *Culex* | *hilli* | 4th | Dead Typha reeds |
| 01/10/2015 | Kununurra Messmate Way, lagoon edge | storm drain | 10 | *Culex* | *annulirostris* | 1st ,2nds,3rds,4ths pupae | Green filamentous algae |
| 01/10/2015 | Kununurra drain Lakeside | storm drain clear water | 6 | *Culex* | *annulirostris* | 1st,2nds,3rds,4ths pupae | Dead Typha reeds |
| 01/10/2015 | Wyndham port, mud dump | tidal pool | 3 | *Aedes* | *vigilax* | 3rds | Sporobolus grass, Samphire herbs |
| Total | | | 20 | | | | |

## Appendix 2 - Common mosquito species in the Top End of the NT.

**Their biology and disease significance**

**Peter Whelan,**

**Medical Entomology Branch**

**Department of Health and Community Services**

**January 2004**

### Culex annulirostris "The common banded mosquito".

**Breeding sites**

This species exploits temporary ground pools, poorly draining grassy wet season depressions and shallow reed swamps. Potential breeding sites include seasonal grass floodways, low-lying areas adjacent to creeks, as well persistent reed swamps and other wetlands. The perennial sections of swamps and creeks are relatively open, well defined, and do not contain significant areas of semi aquatic or aquatic vegetation, are generally not appreciable breeding sites.

The greatest potential for increased breeding of this species will be in impeded or blocked floodways and drainage floors, storm drainage and sewage facilities and artificial water features. The capacity of these sites to breed mosquitoes should be rectified by engineering means.

Any new dams and ponds have the potential to be colonized with freshwater *Eleocharis* and *Typha* reeds which can provide ideal breeding sites for *Cx. annulirostris.* If these impoundments are not maintained free of thick grass and reed growth at the margins, they will become appreciable sources of *Cx. annulirostris* mosquitoes over the medium to long term.

**Seasonal abundance**

The highest numbers are expected in mid-dry season (July) and early wet season (January).

The pattern of abundance is expected to be an increase in numbers coinciding with the start of the wet season in temporary wet season filled depressions, followed by a steady post wet season rise to a peak in July. Breeding will occur in longer lasting creeks and floodways as grass growth and receding water levels hinder the impact of aquatic mosquito predators and isolated pools emerge at the margins.

Perennial creeks and swamps are unlikely to be significant source of this species by the mid dry season as the water retreats to open water or narrow channels with fish and other aquatic predators.

**Dispersal**

Although *Cx. annulirostris* can disperse up to 10 km from highly productive sources (Russell 1986), there is a usually a significant drop in *Cx. annulirostris* numbers up to 2 km away from significant sources (Whelan, et al. 1997b).

**Pest numbers**

The pest threshold for *Cx. annulirostris* near the Leanyer Swamp area adjacent to the northern residential suburbs of Darwin is approximately 600 per $CO_2$ trap per night trapped at a point between the urban areas and the breeding sites (DHCS & DCC 1989). *Culex annulirostris* is not as significant a pest as some of the *Ochlerotatus species* due to its habit of biting only after sundown, and being less persistent in the presence of lights, personal protective clothing and repellents.

Trap collections within development areas of approximately 100 would probably represent a pest threshold for exposed people in the 1-2 hours before sundown.

**Disease significance**

*Culex annulirostris* is the most important vector of arboviruses in the NT (Whelan & Weir 1993). It is a recognized and good vector of Murray Valley encephalitis virus (MVEV), Kunjin virus, Ross River virus (RRV), and Barmah Forest virus (BFV) (Merianos et al. 1992, Whelan et al. 1993*)*. Many other arboviruses have been isolated from this species (Whelan & Weir 1993).

However even relatively small numbers may be responsible for transmitting viruses with the risk primarily a function of suitable vertebrate hosts, reservoirs and vector numbers. As this species bites primarily after sundown, self-protection measures can be relatively easily employed to give a good degree of protection against mosquito bites.

However if new mosquito breeding sites are created by interference with natural drainage patterns and contamination of creeks and floodways with organic wastewater or the disruption of fish populations, a significant increase in vector numbers could increase the disease risk.

## Culex quinquefasciatus "The brown house mosquito"

**Breeding sites**

This species breed in polluted water and artificial receptacles filled by rain or purposefully filled. Unsealed septic tanks and poorly designed sewage facilities are particularly productive breeding sites. Breeding sites of *Cx. quinquefasciatus* may be more productive during, and for the few months following, the wet season depending on wastewater persistence. Septic tanks are required to be installed such that they are completely mosquito proof. An inspection of any septic tanks by an Environmental Health Officer is recommended when first installed and then annually to ensure that they remain mosquito proof and do not cause surface pooling of contaminated water.

**Seasonal abundance**

Locally present depending on breeding sites that tend to be more productive in the dry season.

**Dispersal**

Probably disperses in the order of 200m to 1km for very large breeding sites.

**Pest numbers**

Pest threshold is probably in the order of 30 to 50 per CO2 trap. It is generally under-represented in CO2 traps

**Disease significance**

It can be a minor pest for humans but is not regarded as a potential disease vector in Australia at present.

## Coquillettidia xanthogaster, “The golden mosquito”.

**Breeding sites**

*Coquillettidia xanthogaster* breeds primarily in association with semi aquatic reeds such as *Typha* and *Eleocharis.* The extent of these reeds in dams and drains will be dependent on the water management and maintenance of the margins of the drains and impoundments. The extent of these reeds in impoundments will largely be dependent on the depth of water and the inside slope of the impoundments. Any dams or pits should be constructed with steep internal sides to reduce the extent of these reeds.

**Seasonal abundance**

This species has a larval stage in the order of three weeks compared to many other species that have a larval duration of 1 week. Adults tend to emerge in a sharp peak around the full moon. This species can be expected to be abundant from February to August with a peak around June and July.

**Dispersal**

This species can disperse relatively long distances and probably up to 10 km.

**Pest numbers**

This species will bite humans readily. The pest threshold is probably similar to *Cx. annulirostris,* and would be around 100 per CO2 trap. The pest aspect of this species is elevated because of its habit of biting in the day as well as in the evening and night.

**Disease significance**

*Coquillettidia xanthogaster* is not a vector of human disease in the NT.

## Mansonia uniformis "The water hyacinth mosquito"

**Breeding sites**

This species is closely associated with semi-aquatic and aquatic vegetation, particularly thick floating aquatic vegetation.

**Seasonal abundance**

It is generally abundant near extensive breeding sites from March to July.

**Dispersal**

This species does not tend to disperse very far from its breeding site and probably less than 500 meters.

**Pest numbers**

This species is an appreciable pest species and tends to bite readily in the shade in the day as well as during the evening and night. The pest threshold is probably between 50 to 100 per CO2 trap in the vicinity of people.

**Disease significance**

This species is not a vector of human disease in the NT.

## Anopheles annulipes s.l. "The common Australian Anopheline"

**Breeding sites**

*Anopheles annulipes s.l.* breeds in open sunlit pools and swamps, often with vegetation. In the NT it breeds primarily in shallow margins of long lasting pools with some or little vegetation. Appreciable breeding sites are likely to exist in seasonally flooded areas associated with creeks and extensive swamps.

**Seasonal abundance**

Post wet season peaks corresponded to the period after the waters begin to recede, leaving large areas of isolated pools where biological control agents do not persist.

**Dispersal**

The effective flight range of this species is from 1.6 to 2 km.

**Pest numbers**

The pest threshold is in the region of 100 per CO2 trap in the vicinity of exposed people.

**Disease significance**

This species is a potential vector of malaria, and productive sites within the development should be eliminated or reduced.

### Anopheles farauti s.l. “The Australian malaria mosquito"

**Breeding sites**

*An. farauti s.l.* breeds in either brackish or freshwater pooling in vegetated swamps. It is a sibling species with at least three species present in the NT. One species is brackish breeding while the other two are freshwater species. New breeding places could be provided by the development of dams or impoundments, particularly if isolated pooling with dense reed growth occurs.

**Seasonal abundance**

It was most numerous from May to July.

**Dispersal**

The effective flight range is in the order of 1.6 km.

**Pest numbers**

The pest threshold is in the order of 50 to 100 in a CO2 trap.

**Disease significance**

This species is the most important potential vector of malaria. It is of medical significance if a case of imported malaria occurred in the vicinity of medium to high densities.

### Aedes reesi “The black floodwater mosquito”

**Breeding sites**

*Aedes reesi* is a floodwater species and breeds in fresh to slightly brackish, vegetated ground pools often in association with *Cx. annulirostris, Ve. funerea* or *Ae. normanensis*. It is favoured in low-lying grassy drainage floors with artificial depressions and seepage.

**Seasonal abundance**

It was most abundant in the late wet to post wet period in April.

**Dispersal**

Probably disperses in the order of 1 to 2 km.

**Pest numbers**

Pest threshold is probably in the order of 50 to 100 per CO2 trap. It will probably not be a significant pest here unless new breeding sites are created.

**Disease significance**

It can be a minor pest for humans and is probably capable of transmitting Ross River virus and Barmah Forest virus.

### Aedes normanensis “The floodwater mosquito”

**Breeding sites**

*Aedes normanensis* is a floodwater species and breeds in open ground pools with or without vegetation and sometimes in association with *Cx. annulirostris.* Breeding sites are likely in the floodways and drainage floors particularly in impeded and blocked drainage floors.

**Seasonal abundance**

It has a wet season abundance. At Woodcutters mine south of Darwin it was most abundant in January.

**Dispersal**

The effective dispersal distance is in the range of 2 to 4 km.

**Pest numbers**

The pest threshold is likely to be around 50 in a CO2 trap. It is likely to be a pest from January up to March.

**Disease significance**

It is a pest for humans and is capable of transmitting Ross River virus and Barmah Forest virus. Personal protection measures will be required when it is present in pest numbers.

## Aedes vigilax "The salt marsh mosquito"

**Breeding sites**

The most extensive and productive breeding sites will be the upper tidal section of the mangrove areas around the coast, in brackish swamps where extensive reed growth occurs, or in flood plains associated with tidal rivers. The larvae are usually absent from the mid wet to the mid dry season in the major habitats, as the habitats are either flooded and have high numbers of aquatic predators such as fish, or are dry.

**Seasonal abundance**

*Aedes vigilax* is likely to be most abundant in the late dry season and the early wet season (August to January). Generally the numbers increase after each succeeding spring tide from August to December and reach their highest numbers after the early heavy rains in December or January. The pattern and levels of abundance can vary from one year to another, due to the variable height of the spring tides each year and the amount and timing of rain in relation to the tides.

There can be a sudden appearance of adult saltmarsh mosquitoes seeking blood 9 days after flooding of the breeding site. They are likely to pose an appreciable pest problem for 7 to 10 days per month over the late dry season and early wet season.

**Dispersal**

The dispersal of *Ae. vigilax* from a breeding area is related to the distribution, area and productivity of their specific breeding sites, as well as the specific dispersal characteristics of this species. Large numbers can disperse over long distances to cause a pest problem at remote areas.

*Ae. vigilax* has a long flight range. Relatively high populations have been recorded at Katherine in the early wet season, which is up to at least 100 km from the nearest tidally influenced breeding site.

**Pest numbers**

Public complaints regarding *Ae. vigilax* and corresponding collections in $CO_2$ baited light traps placed between the residential area and the swamp near the suburbs bordering Leanyer Swamp in Darwin indicated that pest numbers occur at levels in excess of 50 *Ae. vigilax* per $CO_2$ trap per night (DHCS and Darwin City Council 1989, P. Whelan unpublished data).

A $CO_2$ trap collection of 50 *Ae. vigilax* per night is approximately equal to a biting rate of 50 mosquitoes per hour at the peak biting period on an unprotected person (DHCS and Darwin City Council, 1989, P. Whelan unpublished data). This species is regarded as the most important pest mosquito in the Darwin area because of its aggressive biting habits, its ability to bite during the day as well as the night, and its sudden emergence in plague proportions.

**Disease significance**

*Aedes vigilax* is a vector of Ross River virus disease in the Top End of the NT (Tai et al. 1993, Whelan & Weir 1993). It is also a vector of Barmah Forest virus disease (Merianos et al. 1992, Whelan, et al. 1993). The greatest potential transmission period of these viruses in the Top End of the NT is in December and January, when *Ae. vigilax* occurs in relatively high numbers, and during humid months when the longevity of the mosquito population is likely to be extended.

Relatively new arrivals that may be non-immune to these arbovirus diseases are more vulnerable. The potential disease aspects, together with the probable pest problems, emphasize the need for personal protection when this species is present.

### Other species of mosquitoes

The pertinent characteristics of species likely to be minor pest species other than those dealt with above are outlined briefly below.

### Anopheles meraukensis "The freshwater reed Anopheles mosquito"

*Anopheles meraukensis* breeds in similar sites to *An. annulipes s.l.*, although often in clearer unpolluted water with reeds and grasses. It occurs in highest numbers in the late wet and early dry season when the water levels are high. Breeding sites may be associated with the flooded grass and reed areas in freshwater swamps, particularly Melaleuca swamps.

### Anopheles bancroftii "The black malaria mosquito"

*Anopheles bancroftii* breeds in shaded freshwater swamps, often in association with paperbark and *Eleocharis* reeds. It is often in relatively high numbers in the post-wet season near breeding areas. It is a potential vector of malaria but is not as efficient as some of the other species because of its relative short longevity.

### Aedes elchoensis "The tree hole mosquito"

Aedes elchoensis breeds in rain filled tree holes. It is a common species but generally does not reach large populations because of the limited availability of breeding sites. It is highest where there are dense stands of Eucalyptus trees that probably include older individuals with rot hole breeding sites. It is a very minor pest for humans and is only seasonally present. It is not known as a vector of human disease.

### Aedes notoscriptus "The receptacle mosquito"

*Aedes notoscriptus* breeds in artificial containers filled by rain or in natural rain filled tree rot holes. It was only present at very low numbers during the current survey. However if artificial receptacles such as old tyres and drums are filled with rainwater, new breeding places will be provided. It is a suspected minor vector of Ross River virus and Barmah Forest virus. A management plan should be in place to remove or adequately store receptacles so that they do not become breeding places for these mosquitoes.

### Aedes kochi "The Pandanus mosquito"

*Aedes kochi* breeds in *Pandanus* leaf axils filled by rain. Appreciable *Pandanus* areas associated with creeks and floodplains. This species does not disperse far and usually only causes a minor and transient localized pest problem. This species is not known to be a vector of arboviruses in the NT.

### Potential Introduced species

There are a number of species that are not present in the NT but could be imported and become pests or present a serious public health problem.

### Aedes aegypti "The dengue mosquito"

*Ae. aegypti* breeds in artificial receptacles such as tyres, tins, drums, rainwater tanks, wells, pot plant drip trays, roof guttering and anything that will hold rainwater. It is only found in close association with human habitation.

It is a vector of Dengue Fever (*Ae. aegypti*) but is not present in the NT. However it has the potential to be imported from Queensland in tyres or other containers that may have held water that are sourced from areas where *Ae. aegypti* occurs (e.g., Charters Towers, Townsville, Cairns), (Whelan and Tucker 1998). It is therefore recommended that all receptacles that can hold rainwater including old machinery and tyres in particular be stored under cover, holed or filled with sand or soil to prevent the retention of rainwater.

No used tyres should be sourced from Queensland unless they have been super chlorinated or sprayed with a suitable insecticide to kill any dormant *Ae. aegypti* eggs. Additional items that should not be sourced from Queensland include pot plant drip trays and other vessels capable of holding water.

Any mosquito larvae found in receptacles imported from the relevant areas of Queensland should be submitted to the MEB in 70% alcohol or methylated spirits. If *Ae. aegypti* are found, the MEB will then need to initiate elimination measures as a public health measure.

Appendix 3 Fogging program Wyndham area.

| | |
|---|---|
| **WORK INSTRUCTION** | **Mosquito Fogging Wyndham** |
| **RESPONSIBLE DIRECTORATE** | Community Development |
| **RESPONSIBLE OFFICER/S** | Louis Franks, Ebony Daniell (EHO's) |
| **MANAGER APPROVAL** | Louise Gee |
| **REVIEWED/MODIFIED** | Date:22/05/15 |
| **REVIEW DUE** | Date: |
| **RELATED ORGANISATIONAL DIRECTIVES** | Mosquito Program Brief WI/HTH-5767 |

**INSTRUCTION:**

OSH

- The Cougar fogger must be used with a ute that is the same height as the trolley it is stored on (Ranger Land cruiser and the Wyndham Leading Hand Hilux are compatible).
- When the fogger unit is moved on/off the ute, a minimum of two persons are required.
- The fogger unit must only be taken on/off the ute using the trolley or a crane.
- The fogger unit must be strapped down when in the back of the ute and when stored on the trolley.

Chemical application

- Tank capacity is 55 litres. Chemical ratio: 1 litre of Twilight: 20 litres of DC Tron. When level drops to where the tank sits in the machine (the green metal part of machine) then this ratio should be re-filled.
- Rotary switch 'target rate' should be set to **.200** This setting delivers approximately 15ml per Ha.
- 'Fog' has a drift area that has been taken into account on the map/route, there is no need to re-fog areas. Wind speeds must be between 5-16 kph to operate the fogger. Outside of this range, the fogging is not effective.
- Flush the spraying system after each day of use.
- Current cost of Twilight per 5 litre container: $545, DC Tron per 20 litre drum: $85

**These chemicals must be stored in a ventilated area and be locked up when in storage**.

**DIRECTIONS FOR FOGGING IN WYNDHAM**

**FIRST RUN – RESIDENTIAL AREA**

**DRIVE AT 15KM/HR**

**Do not respond to public requests to re-fog or fog areas not detailed on map. Fogging must not be done on private property.**

***Residential Area (part A)***

Start the fogger on the back road behind the District High School (Welch Street)

Fog up past the school and turn left onto Great Northern Highway

Turn Right onto the small road that joins onto Koolama

Turn left at Koolama Street

Right onto Kangaroo Drive

Right onto Kabbarli Street

Right onto Civic Way

Left onto Koolama

Left onto St. Pauls Way

Right onto Kabbarli St. and immediately turn right onto St. Peters Way

Drive to the end of St. Peters Way

Turn Right onto Koolama and drive along in front of the Shire office

Turn left onto the small side street that meets Great Northern Highway

Turn left onto Great Northern Highway and drive along in front of the shops

Turn left onto Bonaparte Street

**Turn off the fogger at the end of Bonaparte St.**

*Distance Travelled: 3.5km*

*Time Taken: 17.5 minutes*

***Residential Area (Part B)***

Drive to the Hospital entrance on Mindaroo Street

Turn the fogger on at the entrance to the hospital and drive up Mindaroo Street

Turn Left at Koojarra St.

Follow Koojarra Street all the way around

Turn left at Dulverton

Drive up to the end and turn left at Delamere

Left onto Kwinana Street

Left onto Dorrigo

Left onto Delamere and finally

Left onto Denman

Turn the fogger off at the end of Denman.

*Distance Travelled: 3.2km*

*Time Taken: 16 minutes*

**SECOND RUN – INDUSTRIAL AREA, PORT & COMMUNITY CLUB**

**DRIVE AT 15KM/HR**

***Industrial/Commercial Area***

Start the fogger at the depot and depart up Coverley Street

Turn left onto Murphy Street

Right onto Kimberley Street

Left onto Ord Street

Right onto Sharpe Street

Turn left onto Great Northern Highway then

Right onto Baker Street

Drive to the end of Baker Street and enter Wyndham Caravan Park

Do one loop around the caravan park

Turn left outside the Caravan Park

Travel on the dirt road and take the first right which eventually joins with Koolama street

Turn right at the intersection with bitumen (Kangaroo Drive)

Turn left onto Great Northern Highway and travel up to Kimberley Street

Turn right back onto Kimberley Street

Left onto Flinders Street

Left onto Coverley Street

Right onto Cato Court and then back out to Coverley Street

Right onto Coverley Street and finally

Left onto Martin Place

Turn the fogger off at the end of Martin Place.

*Distance Travelled: 3.5km*

*Time Taken: 17.5 minutes*

**Drive to Wyndham Community Club (9 Mile) and fog for approx. 2 minutes**

*Distance Travelled: -*

*Time Taken: 2 minutes*

**Drive to the Wyndham Port**

***Wyndham Port***

Drive out to the Port and start the fogger just before the first house on O'Donnel street (red roof).

Drive up O'Donnell Street

Turn right onto McPhee, which them turns into Reginald Street

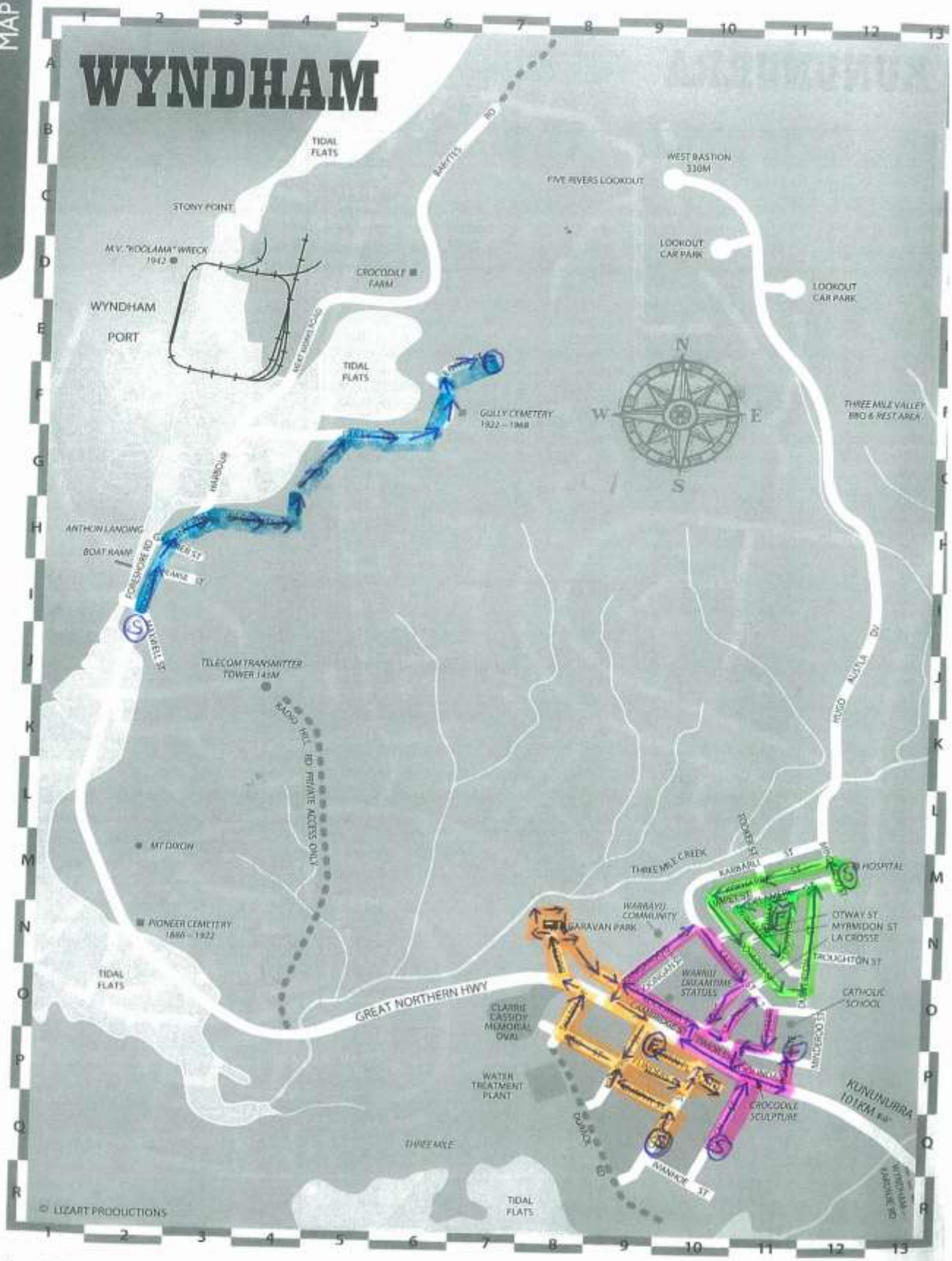
Turn Right onto Gully Rd

Follow up to George Street

Turn fogger off at the end of George Street

*Distance Travelled: 2.3km*

*Time Taken: 11.5 minutes*


WYNDHAM
TIDAL FLATS
STONY POINT
M.V. "KOOLAMA" WRECK 1942
WYNDHAM PORT
CROCODILE FARM
BAKITES RD
FIVE RIVERS LOOKOUT
WEST BASTION 330M
LOOKOUT CAR PARK
LOOKOUT CAR PARK
TIDAL FLATS
GULLY CEMETERY 1922 – 1948
THREE MILE VALLEY BBQ & REST AREA
N
W
E
S
HARBOUR
ANTHON LANDING
BOAT RAMP
FOREMORE RD
TELECOM TRANSMITTER TOWER 145M
ROAD HILL RD PRIVATE ACCESS ONLY
MT DIXON
PIONEER CEMETERY 1886 – 1922
TIDAL FLATS
GREAT NORTHERN HWY
THREE MILE CREEK
HOSPITAL
WARWAYU COMMUNITY
CARAVAN PARK
OTWAY ST
MYRMIDON ST
LA CROSSE
TROUGHTON ST
WARWAYU DREAMTIME STATUES
CATHOLIC SCHOOL
CLARRIE CASSIDY MEMORIAL OVAL
WATER TREATMENT PLANT
CROCODILE SCULPTURE
KUNUNURRA 101KM
THREEMILE
IVANHOE ST
TIDAL FLATS
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## Appendix 4 Media and Advertising

**INFORMATION**

**Title: Warning to protect against mosquito bites for the Kimberley**

The Department of Health has reiterated its warning to residents and travellers to take precautions to avoid mosquito bites during the school holiday period following further detections of the mosquito-borne Murray Valley encephalitis (MVE) and Kunjin (KUN) viruses throughout the Kimberley.

These viruses have been detected in a number of sentinel chicken flocks across the Kimberley, which are used as an early warning system for virus activity by the Department of Health and the University of Western Australia.

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“While the risk of being infected and becoming unwell is low, the illness caused by these viruses can be severe and even fatal. The only effective protection is to take precautions to avoid mosquito bites,” Dr Neville said.

“Initial symptoms of MVE include fever, drowsiness, headache, stiff neck, nausea and dizziness. People experiencing these symptoms should seek medical advice quickly. In severe cases, people may experience fits, lapse into a coma, and may be left with permanent brain damage or die.

“In young children, fever might be the only early sign, so parents should see their doctor if concerned, particularly if their child experiences drowsiness, floppiness, irritability, poor feeding, or general distress.”

Dr Neville said Kunjin virus usually caused a milder illness than MVE, but in rare cases also causes severe symptoms, including headache, neck stiffness, fever, delirium and coma.

No human cases of MVE or KUN disease have been reported so far this year, but the viruses have now been detected in four sentinel chicken flocks in the Kimberley including in Kununurra.

People do not need to alter their plans to visit the Kimberley region but it is important to avoid mosquito bites by taking a few simple steps when camping, fishing or undertaking other outdoor activities:

- avoid outdoor exposure around dawn and early evening
- wear protective (long, loose-fitting, light-coloured) clothing when outdoors

apply a personal repellent containing diethyl toluamide (DEET) or picaridin to exposed skin or clothing. The most effective and long-lasting formulations are lotions or gels.

Due to the current weather conditions, the Department of Health have advised the Shire that fogging is not necessary.

Please contact the Shire Environmental Health Department on 9168 4100 if you would like further advice.

## FOR MEDIA COMMENT PLEASE CONTACT:

**John Moulden, President, Shire of Wyndham East Kimberley (08) 9168 4100**

## Appendix. 5 Selected Extracts from draft of 2015 Shire of Wyndham East Kimberley Mosquito Management Plan (Draft). Strategic Community Plan 2012-2022.

### Strategic Community plan

Goal 3: Protection and enhancement of lifestyle values, community facilities and the environment to provide safe and inviting communities

Objective 2.4: High standard of health and community facilities and services available to all residents

Strategy 2.4.1: Advocate for improved health and community services

### Community Engagement

The Shire of Wyndham East Kimberley's CP/GOV-3100 Community Engagement Policy has been considered in relation to this plan.

Engagement will take place in accordance with the Shire's Community Engagement Guidelines and will include:

A community mosquito survey has been undertaken to assess concerns from residents and local stakeholders. If fogging occurs a one week notice period will apply.

### Goal

To reduce the numbers of nuisance or disease vector species through management practises to ensure an adequate quality of outdoor amenity can be achieved, and educate the community of their personal responsibilities.

### Aims

To meet the requirements of Section IX of the Health Act 1911 with respect to vector borne diseases.

To meet the requirements of the residents to have a reasonable quality of outdoor life.

### Objectives

The Shire of Wyndham /East Kimberley aims to minimise the likelihood of people being bitten by nuisance and disease carrying mosquitoes by implementing a mosquito management plan that includes:

Educating the public the risks of mosquito borne disease, to take action to minimise their contact with mosquitoes and to encourage measures that can be taken to reduce numbers around the home.

Coordinating the chicken sentinel program within the Shire of Wyndham /East Kimberley

Application of larvicide in mosquito breeding areas

Larvae and mosquito surveillance

Mosquito fogging in appropriate circumstances

To ensure the ongoing research and application of emerging practices, technologies and treatment options.

To review the effectiveness of this plan and continue to make alterations to ensure best practise is followed and results are optimised.

### Statutory Requirements

Department of Health:

*Health Act 1911*

Shire of Wyndham East Kimberley:

*Health Act 1911 – Shire of Wyndham East Kimberley Health Local Laws 2003*

### Public Education & Awareness

The public are a vital stakeholder for this MMP and have a responsibility in any integrated program to manage mosquitoes. Due to the high transient residential population in the region it is important that educational programs are ongoing to ensure information is received by all residents. It is also essential to consider the large number of tourists that visit the region in the dry season months and convey public health messages to these people wherever possible.

The education program is centred around but not limited to the following –

- Information displays at local events such as Christmas Markets, Barra Bash, Brown Water Classic fishing events. Fishing is the number one recreational activity where people are bitten by mosquitoes in the Kimberley
- Letter PO Box drops.
- Display information posters on all local notice boards.
- Promotion of the program through local media such as local radio station Waringarri 6WR, ABC Kimberley, and the Kimberley Echo newspaper.
- Disseminate warnings when environmental and mosquito monitoring indicate a risk of mosquito-borne disease is likely through local media.
- Advise the public of planned chemical and physical mosquito control activities. Ensure while out in the field conducting monitoring or treatment that the appropriate signage is put up.
- All telephone and written complaints will be recorded.
- Inform and educate the public about their responsibilities for personal protection measures and backyard mosquito control such as -

1. Avoiding exposure in areas of high mosquito activity, especially during dawn and dusk.
2. Ensure insect screens on houses are intact to prevent mosquitoes entering.
3. Wear long, loose fitting clothing when outdoors.
4. Use personal repellents containing diethyl toluamide (DEET) or picaridin.
5. Locating potential containers, emptying the water out and leaving the container inverted.
6. Fitting mosquito proof cowls to septic tank system vent pipes. Ensure septic tanks lids are sealed to prevent mosquito access.
7. Screen and seal rainwater tanks to prohibiting mosquito access;
8. Filling in depressions in the ground with soil or sand to eliminate a breeding site;
9. Ensure pools are well chlorinated and filtered and free from dead leaves.

### Mosquito Surveillance - Larval Survey

All identified breeding sites will be monitored regularly during the mosquito season or after large tides or floods to determine the larval activity. The survey involves taking a water sample with a larval dipper to establish the approximate number of larvae per $m^2$, and the stage the larvae have reached in their life cycle. Water depth and

temperature also have an effect on the frequency of the surveys. Both of these factors influence the numbers of larvae and potentially the number of mosquitoes and how quickly they breed. The findings of these surveys will determine if there is a need for the application of larvicide to prevent the emergence of adult mosquitos.

### Mosquito Surveillance - Trapping of adult mosquitoes

Adult mosquito traps are used to monitor the numbers and species of adult mosquitoes found in particular areas. The traps that are used by the Shire of Wyndham /East Kimberley rely on $CO_2$ (regulator attached to cylinder), a light source to attract mosquitos and a small fan to keep the adult mosquitos contained. These traps can be placed in various areas around town sites and in particular in areas that are reporting higher than usual numbers of mosquitos. The mosquitoes caught in the traps are counted and identified.

Once the mosquitos have been trapped and identified Environmental Health Officers can target the program to the relevant species of mosquitos and their breeding sites.

### Land use

Ideally, residential developments should be located well away from mosquito breeding sites to minimise contact and impacts with mosquitoes and residents. This is however not usually practical or achievable in the Kimberley region due to the magnitude of the natural environment in comparison to the size of the town sites.

### Sentinel Chicken Program

There is currently one flock of chickens in Kununurra and one flock in Wyndham that are part of the WA Sentinel Chicken Surveillance Program. This program is run by the Department of Health and the University of Western Australia (UWA).

The program is used to provide an early warning of an increased level of flavivirus activity in WA, whereby fortnightly blood samples are taken from the chicken flocks and the blood is sent to UWA for analysis for MVE, and Kunjin Virus. Should elevated numbers of positive results be confirmed the Department of Health issues a media release to urge people to take personal protective measures against mosquitoes.

### Vegetation

Physical control methods are measures taken to reduce the potential for mosquito breeding and harbourage through adapting the natural or built environment. Breeding sites can be reduced by decreasing the amount of vegetation within drains, marsh or other known breeding sites.

### Chemical control using larvicides

Larvicides kill mosquito larvae and prevent the emergence of the larvae into pupa and ultimately adult mosquitos. Larvicides can be used successfully to treat specific areas that are known breeding sites. As these known breeding sites can be specifically targeted this means that the effectiveness of the treatment is high, which can greatly reduce the number of adult mosquitos in the environment.

The following larvicides are currently used as part of the Shire's mosquito management program:

S-methoprene ProLink XR Briquettes and pellets are an insect growth regulator. S-methoprene is absorbed by the larvae and prevents the larvae from emerging from the pupal stage. The Shire will apply this product in accordance with the required application rates throughout the mosquito season. This product is available in several different

formulations, including the slow-release briquettes, which ensure ongoing reliance of the larvicide into inundated marsh land, providing ongoing control.

VectoBac G - contains spores and endotoxins of naturally occurring bacterium. The spores and endotoxins are concentrated by filter feeding other purpose. VectoBac G is toxic only to the larvae of certain diptera. It does not harm other aquatic, marine or terrestrial fauna. Maruyama machines which have a long throw rate are used to distribute Vectobac G

### Adulticides

Adulticiding refers to the killing of adult mosquitoes, and is the only form of chemical control once the mosquitos reach adulthood. Adulticiding is not target specific and works like a large scale insect spray, killing other insects, including predators and beneficial insects. Adulticiding can only be utilised when weather conditions are fine and there is no wind or rain. It should be noted that the environmental impact, particularly on natural wetland/marsh areas can be significant and is undesirable.

In particular adulticiding can be particularly useful during times of flood or during times where there is an outbreak of mosquito borne disease and decreasing the adult population quickly is vital.

Residual surface treatment chemicals are now available that have similar mode of action to traditional adulticides, however are applied to internal and external surface areas at or around known breeding sites/harbourage areas, and kill mosquitos that land on the surfaces.

The following adulticides are currently used as part of the Shire's mosquito management program:

Twilight – this chemical is used in the ULV Cougar fogger and is a phenothrin and piperonyl butoxide based insecticide concentrate used for the control of adult mosquitoes and flies.

Biflex Aqua Max – is a bifenthrin insecticide that is used as a barrier treatment. The chemical is sprayed on surfaces such as trees and fences to kill mosquitos that land on the surface.

### Record Keeping

It is critical that good record keeping practices are carried out. The following records but not limited to should be kept on the Shire's system -

- Annual complaint register
- RRV/BFV/MVE notifications and interview documentation
- Adult and complaint based trapping results
- Larval sampling surveys
- Chemical/bio-larvicide treatments
- Reports
- Product labelling/MSDS
- Media releases

Maintaining this standard of record keeping should ensure current staff and any future employee/s involved with delivering the MMP have access to background knowledge.

### Contiguous Local Authorities Group (CLAG)

State Government funding of mosquito control activities is available to adjacent local governments to form a CLAG, with the grouping being based on considerations of geography and management of disease vector mosquitoes. As the Shire of Wyndham East Kimberley is so geographically remote, it can be considered as one CLAG group.

The Shire applied for funding in 2015-2016 for contribution by the State government for treatment chemicals and equipment.

### Staff training

It is essential that personnel involved in the operational aspects of the MMP are suitably qualified, trained and/or supervised. Skills required to carry out the requirements of the MMP safely and effectively are -

1. Basic mosquito ecology
2. Principles of integrated mosquito management
3. Surveillance/monitoring techniques
4. Collection and recording of mosquito samples
5. Standard operating procedures for equipment
6. Safe storage, handling and application of chemicals/larvicides in accordance with product labelling and MSDS
7. Use of appropriate PPE in accordance with product labelling, MSDS and environmental conditions
8. Calibration techniques
9. Information technologies/geographical information systems
10. Budget management

The Department of Health offer an in depth mosquito management course approximately every two years which teaches most skills and competencies required. Specific skills and local knowledge can be attained under direct supervision and field work with EHO Specialist.

The Department of Health is also available to offer advice and assistance to regarding the MMP and its implementation.

## Appendix 6. Mosquito surveillance and monitoring techniques.

Whelan PI. 'Mosquito surveillance and monitoring techniques.' Mosquito Management Manual, Department of Health, Western Australia 2015.

**LIST OF CONTENTS**

## 1.0 INTRODUCTION

Mosquito surveillance is the process of providing information on aspects of mosquito populations by carrying out surveys. It is a vital part of any mosquito control program and should be started before any direct control begins. The underlying aim of carrying out any surveillance program is to determine the what, where, when and why of any possible mosquito problem. When it has been established that a control program is necessary, the ongoing surveillance program will assess whether the mosquito populations are being reduced and, more importantly, if the control program is achieving reductions in pest problems or mosquito borne disease. The results of the mosquito surveys are used to;

Determine the need for a mosquito control program.

Plan the program by providing adequate information to allow decisions on the type and extent of control.

Guide the day to day activities of the program.

Permit evaluation of the effectiveness of the control program.

Mosquito surveillance can be separated into four phases corresponding to the four periods of a control program. These stages are the preliminary phase, the base line data phase, the operational phase and the evaluation phase. The object and the details of mosquito surveys are different for the different stages of a control program.

## 2.0 THE PRELIMINARY PHASE

The object of the preliminary phase is to define the nature and extent of the mosquito problem. This will indicate whether a control program is necessary and if so, the extent of the area to be controlled and particular areas of priority. The preliminary phase should be completed before the base line data phase is put into operation, although sampling during the preliminary phase can provide some of the base line information. The preliminary phase should incorporate three elements that include an information search, drawing vector control maps and initial sampling of adult and larval mosquitoes.

### 2.1 Information Search

The first step in the initial survey is to gather together all the relevant files, literature and references that will be relevant to a mosquito control program in a particular area. All the information should be organised and accessible for ready reference.

Contacts should be established with Local, State and Federal Authorities for information and help. The information needed should include:

a. What species of mosquitoes are potential problems in your particular area? Is it a pest problem or a potential disease problem?

b. When do the mosquito problems occur? Is it a seasonal problem and what is a likely reason for seasonality? What data is available from medical records and reports on previous mosquito borne disease outbreaks, including seasonal distribution and the spatial distribution of cases?

c. What information and equipment is needed to carry out mosquito surveys and control operations in your area?

d. How can the mosquitoes be identified?

e. What is the relevant biological information on the problem species, including habitat preferences and seasonal abundance?

f. What are the local climatic/environmental variables that may affect local mosquito populations?

g. What is the distribution of the major mosquito habitats?

h. Is there any mosquito collection data from past records?

## 2.2 Vector Control Maps

The next step is to draw up a preliminary vector control map. This map should be updated as the preliminary surveys progress. The vector control map should show all the relevant details of the nature and extent of the mosquito problem and enable the planning of mosquito surveys and future control operations.

Vector control maps usually relate to a town and should extend at least 2 km and ideally up to 10 km from the urban boundary. All maps of the local area for at least 10 kilometres around the town should be assembled, including vegetation maps, topographical maps and maps of built-up areas. These should be incorporated onto one map. The map should show the location and nature of actual and potential mosquito breeding sites, such as rivers, creeks, lakes, dams, marshes, storm water drains, borrow pits, depressions, sewage ponds, mangroves and dense forest. Maps can be hard copies or electronic interactive maps. Examples of a stylised vector control map is shown in Figure 1.

Incorporated on the map should be the residential areas, night recreation areas, roads, railways, access routes, industrial sites, concentration of animals, areas of pollution, and tidal influenced areas. Google earth images and aerial photographs are of particular value in an initial survey, so that vegetation zones can be used as a guide to mosquito habitats and access to particular habitats can be planned. This map can be updated by additional information as it becomes available and by a reconnaissance survey, to verify the accuracy of the details.

Marked on the vector control map should be a buffer zone around urban areas based on the flight range of the most important species of mosquitoes in that area.

Generally the buffer zone will be in the order of 1.6 to 4 kilometres from the perimeter of the urban residential development. The buffer zone should expand at breeding sites or points of dense vegetation which are continuous with areas inside the buffer zone. Most of the mosquito monitoring and control activities should be carried out within the buffer zone unless the initial monitoring indicates a need to expand the area of operation.

## 2.3 Preliminary Sampling

For vector control operations, the initial larval and adult sampling sites are determined from the vector control map. The various methods and detailed procedures for larval and adult sampling are dealt with in Section 6.0.

When a complete picture of the mosquito fauna of an area is required, every available type of breeding sites including crab holes, plant axils, receptacles, creeks, swamps, water filled depressions and any other water accumulation should be considered and examined for mosquito breeding. However for well-established pest and disease problems, it is only necessary to examine and sample the potential breeding sites of the principal problem species.

With preliminary surveys, there is no substitute for a lot of legwork, and a determined effort to penetrate into all vegetation zones or areas of likely mosquito breeding. The golden rule of larval surveys is to sample around the entire boundary of any potential mosquito breeding area. This is very important, at least initially, to determine if a particular habitat or part of a habitat is more prolific than others, and to find the source or sink of the water in the breeding site. The initial larval sampling should be carried out in the likely mosquito problem period, and be completed in a few weeks, with initial adult sampling being conducted at the same time to detect possible undetected sources.

During preliminary sampling, consideration should be given to the selection of suitable permanent sampling stations for larvae and adult mosquitoes. This choice will be based on a quantitative assessment of the breeding sites and on the relative numbers of adults or larvae present.

The preliminary adult sample sites should be many as possible near all the probable breeding sites located during the initial larval survey and at relevant points in and around the buffer area as determined from the information on the vector control map. The number of trap sites can then be reduced down to a manageable number for routine sampling. The most productive and the most informative trap sites are chosen for routine sample sites. Once the routine adult sample sites are chosen, usually within the first two months, these should not be changed, so that base line information can be gathered to allow accurate assessment of changes over the season and years, and to asses control measures.

The initial survey must note the particular habitats where mosquitoes are found, so that knowledge of the preferred habitat for each species can be compiled. Note that mosquito populations can change dramatically in a few weeks, both in size and species composition. These changes can occur with variations in tides, rainfall and vegetation, or due to other factors that are less obvious.

## 3.0 BASE LINE DATA PHASE

During the base line data phase the permanent larval and adult sampling situations selected during the preliminary phase are regularly sampled.

All climatic data is collected and organised, including information on rainfall, tides, temperature and any other climatic variable that is likely to affect mosquito populations. During this phase there will be dynamic changes occurring in the mosquito habitats and all of these changes should be noted and correlated with the larval and adult sampling. Base line data on mosquito complaints and details of mosquito borne disease should also be compiled for later comparison.

This phase should last at least 12 months to cover the major habitat changes and seasonal variations. It is during this phase that plans for a control strategy should be formulated. Strategies for disease control or vector control should be examined so that an integrated control program can be drawn up.

## 4.0 OPERATIONS PHASE

When a mosquito control program is implemented, it needs to be guided by regular larval and adult sampling of the selected sample points of the area being controlled. Sampling should be from the same points and with the same regularity as the base line data phase. These regular and ongoing surveys will indicate the current status of adult and larval populations in the control area. Changes in habitats can occur seasonally or with artificial influences and give rise to mosquito population fluctuations. Usually the adult sampling program or the larval sampling will show the response to the changes.

Sometimes there will be public complaints that may not tie in with the sampling data and require additional or supplementary larval or adult sampling. At other times, the adult sampling data will show increases that are not obvious in the larval sampling data. Additional larval surveys are then required to locate any additional mosquito breeding or to determine the reasons for the increased adult levels.

The regular operations survey should allow areas of mosquito breeding to be defined and quantitatively assessed so that ongoing priorities for control can be decided.

## 5.0 EVALUATION PHASE

After control measures have been carried out, it is most important to assess their effectiveness and to identify any remaining problems.

### 5.1 Larval Evaluation

Evaluation of larval insecticide control operations should be done on the day or the day after control, with the results compared with a pre-control survey. Areas that have been missed can be re-treated and any operational and technical difficulties should be reviewed and rectified.

### 5.2 Adult Evaluation

Evaluation of larval control includes the comparison of adult population indexes before and after larval control. Evaluation of larval control using adult mosquito information is generally imprecise because the adult population will take some time to decrease, and there may be dispersal into control areas from other areas. In assessing the efficiency of adult control programs, it may be necessary to carry out age determination assessments on the sampled females to determine whether emergence or re-invasion has occurred.

### 5.3 Engineering Evaluation

The assessment of engineering measures such as draining and filling should include a comparison of twelve months sampling data before and after the completion of the engineering measures. The evaluation of engineering measures will usually require a short and longer term assessment to cope with possible gradual habitat changes in the years after engineering measures.

### 5.4 Disease Evaluation

Disease evaluation will reflect the real benefits of the mosquito control program. Different parameters of disease can be compared with the base line data after control measures have been completed. If disease parameters are not decreasing, the original hypothesis and vector control strategies need to be critically evaluated.

## 6.0 MOSQUITO SAMPLING TECHNIQUES

## 6.1 Larval Surveys

### *6.1.1 General*

The purpose of larval surveys is to find out where and when the mosquitoes are breeding and what type of habitat they are breeding in. Generally we can divide the sampling procedures into the sampling of ground water habitats and artificial receptacle sampling. Most mosquito control operations are concerned with ground water habitats, while receptacle sampling is a more specialised survey to gain information on receptacle breeding *Aedes* species.

### *6.1.2 Ground Water Habitats*

For field sampling of ground water habitats, it is important to traverse the entire margins of the breeding site to determine the entry or exit points and possible source of the water. Permanent indicator sample points that represent the habitat should be chosen after extensive initial sampling. Sampling should then be quantitative so that the relative importance of all the breeding sites or habitats can be assessed.

In an extensive breeding site, this may include a point in each vegetation or water type known to be a breeding site. These permanent points should be at sites where there is year round access. These permanent larval sampling sites should be sampled at least once per month over the twelve month period, using the same sampling techniques, and recording all the important variables as shown on the larval collection form. For tidally affected areas, these sampling frequencies will have to be coordinated with the tides. Increased frequency of sampling is necessary for transition periods between times of little mosquito activity and times of increased activity, such as the start of summer or the start of the wet season.

All sample sites should be marked on the vector control map. Additional larval samples should be taken at different points throughout the year to make sure the permanent points are efficient indicators of larval breeding sites.

The sampler must be careful not to change the nature of the sample site itself by repeated sampling. These permanent larval sampling sites will enable an assessment of how the breeding habitat and the species and numbers of mosquito larvae changes over a 12 month period. It will pin-point those important factors in the habitat that lead to fluctuations in mosquito numbers.

### *6.1.3 Artificial Receptacle Sampling*

Artificial receptacle sampling is primarily to detect the presence of *Aedes aegypti* or other related *Aedes* species in an area, or to determine the receptivity of an area for *Aedes* species introduction. The presence or receptivity is assessed by recording all the available information on the number, type, and characteristics of various receptacles in each particular area. The detection of these *Aedes* species can be assisted by adult sampling techniques, but usually the specialised techniques such as ovitraps or receptacle surveys are required.

Ovitrap sampling is a specialised sampling technique using special egg laying substrates dipping into water in a dark coloured receptacle. The ovitraps are usually left out for a week and then the paddles or ovi-strip are inspected for eggs. The eggs can be hatched, and either the larvae or the emerged adults are examined for species determination.

An artificial receptacle breeding survey is carried out to determine all the relevant particulars of receptacle breeding mosquitoes in a certain area. The primary aim of a receptacle survey is to examine artificial receptacles, but natural receptacles are also examined.

The priorities for receptacle sampling can be guided by the initial ovitrap data. Detailed receptacle surveys can then be carried out in certain suburbs or limited areas.

*Aedes* receptacle surveys record all the relevant receptacle information for each premise. If the number of premises is very large, as in a large town, a sample of premises can be made by selecting a number of streets at random and then sampling each property in that street. If the town is small, as many premises as possible should be sampled for receptacles.

For exotic *Aedes* species, particular attention should be given around airports, seaports, boat berthing facilities, dry dumps and industrial areas.

### *6.1.4 Equipment for Larval Sampling*

a. An enamel dipper painted white on the inside with a relatively long handle. A deep soup ladle is ideal. A long piece of wood can be attached to the dipper for difficult to reach situations. (see Figure 2)

b. White enamel pans, trays or pale coloured buckets. These have the advantage that more water can be sampled at one time when larval populations are not particularly concentrated. They are not convenient in shallow water or where there is a lot of vegetation obstruction.

c. A pipette or dropper. Ensure that the tip of the pipette is wide enough to allow large larvae and pupae to be sucked up.

d. Small stoppered or topped vials. These can be glass or plastic. Mosquito larvae can be collected live into these small vials or into vials of 70% alcohol (ethanol) or 70% methylated spirits.

e. Note book, labels and pens. Labels are best written in pencil and placed inside the collection receptacle with larvae.

f. A bulb pipette. This is a large bulb with flexible tubing that can be utilised for sucking water plus larvae out of crab or tree holes or plant axils.

g. A pale bucket, a long piece of rope and a powerful torch for examining wells and rain-water tanks.

h. If you have an inaccessible area, a 4 wheel drive vehicle is an advantage. An all-terrain vehicle such as the Argo is extremely useful in large swamp situations.

i. Suitable clothing, such as hat, overalls, rubber boots and carry bags.

### *6.1.5 Procedures for Ground Water Habitat Sampling*

Mosquito larvae are usually found where surface vegetation or debris are present. In larger bodies of water, larvae are generally confined to marginal areas or floating surface materials.

a. Before looking for larvae, examine the data of the adult catches to see what species you are looking for. This will give you an idea of the preferred habitats of your species, with its water type and vegetation requirements.

b. Examine the vector control map and aerial photographs for vegetation patterns and likely areas of mosquito breeding. Plan the access route and plan your specific search sites. If a large

area is of uniform vegetation then examination at selected points only can reduce the amount of work.

c. When searching for mosquito larvae, the searcher must be prepared to walk and to penetrate through thick vegetation into the selected points chosen on the aerial photographs. There is no substitute for legwork and perseverance.

d. When approaching a margin of a water body, it is important to note the vegetation patterns. The different types and habit of grass, reeds, or other vegetation may be clues to deciding exactly where the mosquitoes are likely to be and which habitats must be sampled.

e. When you have selected particular habitats look at the water first before disturbing it with the feet, the ladle or by shadows. Note the presence of fish and other predators and look for larval activity.

f. Use the dipper at likely places. If looking for *Anopheles* larvae let the top layer of water run into the dipper or skim the top layer of water. Very shallow water at the extreme edges or the water on the top of floating algae is also a source of *Anopheles* larvae. With *Culex* larvae the dipper sample will need to be deeper and next to clumps of vegetation or grass. When sampling for larvae, proceed carefully, as disturbance and shadows cause larvae to go to the bottom. Let water run into the dipper from vegetation clumps and scoop the dipper up just before it fills up with water. With *Aedes* larvae you need a quicker motion as they will dive rapidly to the bottom, (see O'Malley 1995).

g. Record the number of dips made. Usually these are in multiples of ten, with dips being made only in likely places (after you have established the types of habitat where the larvae are).

h. Transfer the larvae to the vial with the aid of the pipette. Take a water sample in another vial for salinity and pH examination.

i. Record all habitat information on a notebook or form with a code label inside the vial. The degree of pollution, vegetation, degree of shade, water colour, possible salinity and predators present should be noted.

j. Note the larval instars present and relative proportion of each instar. *Culex* species eggs should also be searched for, especially at the side of pools or where scum has been blown by the wind. Note all larval information on collection forms. Set forms for direct larval recording are more convenient for information gathering, identification records and later compilation. An example of a set larval form is shown in Figure 3.

k. Surveys of larvae should be made at least once per month, with increased frequency during the breeding season or major habitat changes, to establish the time required between surveys.

l. For mosquito species such as *Mansonia and Coquillettidia*, larvae may be found by pulling up aquatic and semi aquatic plants and washing them in a pale coloured bucket to dislodge them from the vegetation, or pumping out water from a bottomless isolation drum placed over emergent vegetation and pouring all the sampled water though a fine sieve.

m. Sometimes there may be a need to muddy up pools and sit and wait for larvae to rise to the surface.

n. Some species, such as tree hole breeders or crab hole breeders require sampling with a piece of flexible tubing or more specialised equipment. Trees such as figs and *Poinciana trees* that have areas between the main branches capable of holding water are productive sites. Other trees such as boabs, mangroves and eucalypts can have hollow broken branches with water inside the hollow. These sites need to be looked at a few days after rain.

o. With salt marsh mosquitoes, it is important to time the search for larvae two to three days after the highest tides of the month or rain.

p. For fresh flood water *Aedes*, inspection of rain filled depressions is needed two to three days after rain.

### *6.1.6 Ovitraps and Procedures for Aedes Ovitrap Sampling*

Ovitraps or egg traps are special traps used for detecting the presence of *Aedes* receptacle breeding mosquitoes. There are a number of types of ovitraps, using various materials as the receptacle and various substrates used for egg laying.

The types range from sticky ovitraps for adult sampling as the mosquitoes lay eggs, lethal ovitraps which aim to impart insecticide to adults as they lay eggs, and general ovitraps which sample eggs.

General ovitraps use glass jars or plastic buckets as receptacles. Generally glass jars have the advantage of being clear to allow ease of inspection of the sides and bottom for eggs or larvae. The glass is unsuited to egg laying, so very few eggs are attached to the sides, reducing the loss of eggs for analysis.

The disadvantage of glass is the need for painting or encasing black protectors for a dark background to prevent breakages. Other disadvantages are the fragility, weight and additional space required in transportation.

Plastic buckets are generally light, stackable, cheap, and do not need painting or enclosure in a black cover. Plastic buckets can be black but red is seen by mosquitoes as dark and allows ease of inspection of scum and eggs on the sides. The disadvantage of plastic is that *Aedes* tend to lay eggs on the sides, as well as the paddle or ovi-strip.

The types of paddles or ovi-strips include ‘Masonite’ paddles, red velour strips, or red painted tongue depressors. Generally ‘Masonite’ paddles have the advantage of roughness, grooves and a wide wet wick zone favouring egg laying. Red velour has the advantage of a wide coverage of the receptacle, good wick area and ease of observation for counting eggs. It can also be impregnated with an insecticide to act as a lethal ovitrap to kill adults as they lay. Tongue depressors need to be roughened and painted red to improve suitability for egg laying.

***Standard ovitrap procedure***

a. A standard ovitrap consists of a black receptacle with a ‘Masonite’ paddle attached to the inside of the receptacle in a vertical position, with the rough side facing inwards. The paddle has a white painted line half way up the paddle as a water level indicator.

b. Ovitrap sites should be secluded, shaded, low to the ground, near vegetation and protected from rain and animal disturbance. If possible the ovitraps can be placed between two bricks or stones, or behind or under a suitable object such as a wash trough.

c. The ovitrap should be placed near or within fifty (50) metres of human habitation.

d. Water is added to the ovitrap to the white line on the paddle or receptacle. The water should be fresh and can be either tap water left to stand for a few hours or rainwater. Ovitraps should also have a food source for the larvae, with aged grass infusion water or fish flakes ground fine to provide suitable food for both young and older larvae. Ovitraps for Quarantine purposes should have a methoprene pellet added each month to prevent any possible adult escapees.

e. The ovitrap should be numbered, and the number, town, location, the date placed, and the date retrieved should all be recorded in a record book or an information system.

f. The ovitrap should be left for a week and then reinspected.

g. On inspection, it should be noted in the record whether the trap is tipped over, dry or otherwise disturbed by ants, frogs or polluted.

h. If there is any remaining water in the trap, pour it into a clear glass jar and inspect if for mosquito larvae. Larvae are collected alive into a small receptacle for rearing or identification.

i. If there are only fourth instar larvae present, then all the larvae can be put into a vial of 70% alcohol and labelled with an identification number.

If there are any younger larvae they should be reared to fourth instar, together with larvae reared from the eggs on the paddles. The identification number should correlate with information in the record, including the ovitrap number and the location. The labelled vials should be filled to the top with alcohol and stored adequately to prevent breakage until they are submitted to specialists for identification, along with the records or form.

k. The paddles with attached eggs are left in a plastic bag for one day and allowed to dry out gradually. They are then placed in fresh water in trays, together with any young larvae from the ovitrap collection in step h. The eggs can then hatch and the larvae are reared to fourth instar for identification. Hatched paddles should be inspected for unhatched eggs under the microscope and then dried and re-flooded if necessary. The paddles are then sterilised and scrubbed to remove any old hatched eggs.

l. The replacement ovitrap is refilled, with a new paddle, fresh water, and the ovitrap replaced for later inspection. If the ovitrap cannot be inspected within one week, the ovitrap should be collected and replaced with a fresh ovitrap or left in position until dry and then collected for inspection. The ovitrap and paddle should both be identically labelled and attached together.

m. For regular ovitrap monitoring purposes, all ovitraps should be collected every six months, and taken to the laboratory where they should be filled completely with fresh water to hatch all eggs and examined after one week. Then the ovitraps should be thoroughly cleaned with boiling water and scrubbed to remove any old eggs, and then repositioned.

### *6.1.7 Procedures for Receptacle Sampling*

a. If possible, contact the person responsible for the property and inform them of your intentions and reason.

b. Examine the entire premises, both indoors and outdoors for any receptacles, and note the type of receptacle and the presence of water or larvae in each receptacle.

c. Each receptacle should be sampled for larvae.

d. The first step in sampling larvae is to look carefully at the surface of the water for larvae or pupae.

e. With a ladle, gently lower the ladle deep into the receptacle so that larvae can be seen against the white background of the ladle. The ladle can then be slowly extracted with the larvae and water.

f. The receptacle can then be emptied carefully into a white bucket or tray for further examination.

g. Tyres can be prised open and the inside water can be scooped with a ladle, ensuring that the ladle makes contact with the bottom of the tyre.

h. In rainwater tanks, the bucket and a length of rope can be used, with the bucket lowered down into the water to provide a pale background for detecting larvae. The torch should be used to examine for the presence of larvae. Water should also be extracted from the tap into a bucket and examined.

i. Blocked roof gutters can be checked for breeding by using a ladder or a long stick with a mirror attached to one end. A sure sign of a blocked gutter is a dripping down pipe a few days after the last rain.

j. The axils of trees and other plants with leaf axils such as bromeliads and lilies can be sampled with a bulb pipette.

k. All the larvae found should be collected and put in the vials with an identification number. The identification number should correspond to notebook information on the town, street, premises number, date, type and water characteristics of the receptacle. The vials should be filled with 70% alcohol. If there are many larvae, all stages of larvae should be collected, with different looking larvae included.

l. If there are only first and second instar larvae, they should be collected into a clean receptacle with original water, labelled, and reared to a later instar.

m. The larvae can be reared by taking the sample in a sealed receptacle back to a base, loosening the top of the receptacle, and leaving the receptacle in a cool shaded place until the larvae develop.

n. For overseas arrival boats, and in other areas where exotic *Aedes are* suspected, receptacles can be sampled by looking for the presence of eggs. Scrapings can be made from just above where the water line would have been in the receptacle. The scrapings can be made by a paint scraper or a chisel and collected into a receptacle. The scrapings are put into a labelled sterile receptacle for later microscope examination or rearing of the eggs.

o. If a return trip to an area is anticipated in three to four days, fresh water can be added to any dry receptacles or tree-hole axils where *Aedes* eggs are suspected, and the water can be collected after a few days for examination.

p. The labelled larval samples, together with records should be submitted to recognised experts for species identification or confirmation.

## 6.2 Adult Surveys

### *6.2.1 General*

The purpose of adult sampling is to get an indication of a mosquito species presence or population fluctuations in time or space. For regular adult sampling during control programs, the method chosen may not necessarily be the method that catches the most number of mosquitoes, as long as it accurately reflects population changes.

Once-off adult sampling rather than regular sampling from the same trap sites is of limited value in a mosquito control program, but is useful to determine the presence of various species in initial surveys or to locate particular areas of high mosquito activity. Once-off surveys need to be timed

during potentially productive periods and include as many methods as possible to increase the accuracy of species records.

There are a number of ways to collect adult mosquitoes, and the method used will depend upon the aim in making the collection. All of the adult collection methods have a bias that will be more or less applicable for certain species. Direct quantitative comparisons cannot be made between species from different trap type collections unless the bias of each trap is known. If there is little information on the mosquito fauna in an area, it is best to use as many different methods as possible to ensure that you collect as many species as possible.

For routine monitoring purposes, a single method is usually most convenient. Once a method is chosen, it is important that the method and equipment is standardised, so that comparisons actually reflect the variations in the mosquito population and are not the result of a change of trap type or location. The types of adult trapping methods are outlined below. Examples of adult collection record forms are shown in Figure 4 and Figure 5.

### *6.2.2 Human Biting Collection*

These collections are usually the simplest and most direct way to sample a mosquito problem. It involves collecting the mosquitoes that are about to bite a person. If you wish to find out which mosquitoes are causing a problem for people, the obvious and most accurate method is to carry out a human biting collection. The collection site must be selected out of the wind, near vegetation, in the area to be assessed. If this is in a town or near a residence it should not be in a lit area or under street lights.

Most biting collections are carried out at night, just after sundown for a defined period, but there are variations for different species. The collector sits quietly with one or both legs exposed and collects mosquitoes that are about to bite. The mosquitoes are usually collected by the use of a mouth aspirator (sucking tube) (see Figure 2) or a specialised vacuum mechanical aspirator. A dull or red light torch is necessary for night collections. The mosquitoes are transferred from the sucking tube to a mesh covered paper cup or collected in the detachable receptacle on the mechanical aspirator. They can be killed prior to being identified by placing the receptacle in the freezer for 10 minutes.

The freshly killed specimens can be pinned or placed between layers of loose tissue paper in pill boxes or small tins. Pinned specimens should be correctly labelled and forwarded for identification in special pinning boxes (see Figures 6 and 7).

The choice of the time to conduct biting catches in any particular area should be made on the basis of catches of 10-20 minutes duration every hour over a 24 hour period. This will establish peak biting times for each species so that standardised time catches can be made from week to week or season to season. Generally the first hour after sunset is used as a standard period for man biting collections and collections are usually made for 20 to 30 minutes. If the adult mosquito population is very high, the collection time can be shortened. Collection should be recorded on standardised collection forms (see Figure 4) for later comparison and analysis.

A variation of this technique is the human attraction collection, where the collector uses an aspirator or wide net to collect mosquitoes attracted to the vicinity of collector before they attempt to bite. This is useful for rapid surveys for day biting species, where the mosquitoes can be relatively easily seen. Human attraction collections are usually made in sheltered vicinities where adult mosquitoes tend to harbour during the day. For dengue vector *Aedes*, these collections can be made using a sweep net around the legs over a 5 minute period.

### *6.2.3 Animal Collections*

Mosquitoes can be collected from tethered animals. This method involves collecting mosquitoes that are attracted to a particular animal and does not necessarily include those mosquitoes that are attracted to humans. This method, using a mechanical aspirator and protective clothing for the collector, can be used safely and painlessly to catch large numbers of mosquitoes.

### *6.2.4 Animal Bait Traps*

For animal bait trap collections, the animal can be enclosed in a trap set out for a night time collection. The trap is designed so that mosquitoes can enter easily but can't find their way out. Mosquitoes can be collected from the trap the following morning by the use of a mouth or mechanical aspirator such as a small car vacuum with a catching attachment. Magoon traps are large specially built animal bait traps housing an animal inside a net protected cage and surrounded by a trap body that allow mosquitoes easy access but limited egress.

Animal bait collections do not give the same results as human biting collections. There are variations in the attractiveness of various mosquito species to different animals, and animal bait collections may be less suitable to assess the relative numbers of various species of mosquitoes that prefer to bite people in particular. They are however safer than human biting collections when there is a risk of mosquito borne disease, and are usually more convenient than direct animal collection.

### *6.2.5 Window Traps*

These traps are mounted on windows in houses or special experimental huts, and rely on trapping mosquitoes as they enter or leave via a limited route. They are mainly used in programs such as malaria programs, where an assessment of the numbers and species that enter and leave houses is used to determine likely vectors.

### *6.2.6 Net Traps*

Net traps are used around a person or an animal and rely on the habit of mosquitoes approaching low to the ground and then trying to leave by flying up. Mosquitoes enter under the net to feed on the bait animal and are then restricted in their escape by the insect net. A collector catches the mosquitoes from the inside of the net. This method can be used to collect large numbers of mosquitoes, especially when a large bait animal is utilised. It can provide good specimens and can be used with little risk of the collector getting bitten. A person can be substituted for a bait animal and if further protected by an inner net, this can be a safe and convenient way to assess species specifically attracted to people.

### *6.2.7 Carbon Dioxide Traps*

Dry ice will attract some species of mosquitoes. Cylinder traps with entry funnels utilising carbon dioxide are constructed so as to allow entry to insects attracted to the carbon dioxide but restricting their exit. This method is used when relatively clean catches of mosquitoes are required and but will only catch certain species of mosquitoes that are both attracted to CO2 and will enter the funnel.

A variation of this method is the passive trap developed by Scott Ritchie and colleagues in Queensland. The passive trap uses no mechanical suction, with mosquitoes attracted to below the

trap by cylinder delivered CO2. The mosquitoes tend to fly up into the open bottom of the trap and are killed and retained on the inside of the trap with insecticide impregnated honey baits on the walls as they feed. The baits can be used as a virus surveillance tool by analysis for arboviral RNA expectorated by the feeding mosquitoes. The advantages of this trap is that it requires no battery power, and can be regulated by timers to the cylinder regulators to catch large number of mosquitoes over certain periods of the day for up to a week between services.

### *6.2.8 Light Traps*

Light traps are the most commonly used adult surveillance technique. There are many different types of light traps that can be used to attract and trap mosquitoes. Light can be used by itself or in combination with carbon dioxide. There is a variation in species and numbers collected using light alone or light plus carbon dioxides as attractants. The advantages of these traps are that they can be operated all night and can sometimes collect large numbers of insects. They can be permanent or simple and portable, and there is a variety of power sources available.

Light traps can be used to obtain the relative numbers of some species of mosquitoes that are active at night. The CDC light trap is usually made up of a small incandescent bulb, a fan and a catching receptacle (Figure 8). It is suspended about 2 m above the ground in a sheltered position but with a wide range of view. It should be placed in a position where it does not compete with other light sources and care may have to be taken to prevent ants from devouring the catch. Traps are set before sunset and collected after sunrise. To increase trap catches, a supply of "dry ice" or gas from a bottled source can be discharged near the trap entrance.

Other modifications can be made to increase the trapping efficiency, such as the CFG trap that incorporates counter flow geometry where modified air flow increases the catch.

The Mozzie Magnet trap utilises counter flow geometry and a propane gas bottle to both power the trap and supply the CO2, and catches mosquitoes continuously into alcohol or dry over a period of days to weeks. The advantage of traps like the Mozzie Magnet trap is longer term and larger catch trapping without an operator, but has disadvantages in sensitivity to movement, fungus in the catches, and technical difficulties in operating continuously.

Special carbon dioxide baited light traps are commonly used as a standard adult mosquito monitoring technique in Australia. The EVS (Encephalitis Virus Surveillance) trap consists of an insulated can that contains the dry ice, a small battery driven fan incorporating a "grain of wheat" light suspended below the can, and a collecting receptacle attached to the trap body. Various wavelengths of light can be used to attract different species of mosquitoes.

If light alone is utilised, trapping should be done on similar moon phases, as attractiveness of the light will vary considerably. When a permanent trap site is chosen, it should not be changed during a program. Trap results can vary markedly from one site to another due to the proximity of the vegetation, exposure to wind, the effect of lights and other less obvious factors. Trap results are recorded on the standardised collection forms (see Figure 5).

### *6.2.9 Truck Trapping*

A large rectangular mouthed funnel shaped vehicle mounted insect trap can be used to collect only flying insects. This is a direct sample of what is flying and has no bait bias that may be present in the trap methods. This method can be used to indicate the times of flight activity of different species of mosquitoes. Collections are usually made over a fixed route at regular intervals. It can also be useful in assessing the efficiency of adult vector control treatments by comparison of pre and post control sampling. One disadvantage is the height of the mouth of the trap on the vehicle, which gives a bias to a certain height of collection.

*6.2.10 Spray Catches*

Aerosol spray catches inside houses can be carried out to determine what species and numbers are inside houses. Mosquitoes are collected from sheets laid on the floor.

*6.2.11 Resting Station Collections*

Most adult mosquitoes rest in the day in cool, dark, humid places. Careful searching may locate particularly productive resting places, from which regular collections can be made. These collections can then give an idea of the relative mosquito population. These particular sites are usually productive for only one and two separate species. Some typical sites include wells, under bridges, in storm water drains, verandas, hollow logs, dense fern patches, overhangs on creek banks, and caves. The mosquitoes are collected with an aspirator, small hand held adapted vacuum collector, or a large powered suction sampler.

*6.2.12 Fay Traps*

The Fay trap is a day-time trap which is quite specific for *Aedes aegypti* adults of both sexes. It is based on the attraction of contrasting gloss black and white panels and involves a wind orientated cover and a cylinder, housing a battery operated suction motor and a suspended collection bag. The trap is placed near a suspected *Aedes aegypti* breeding location to establish the presence of *Aedes aegypti*.

*6.2.13 BG Traps*

This trap was originally designed to attract the dengue mosquito *Aedes aegypti*. However, this trap also attracts other *Aedes, Culex* and *Anopheles* mosquitoes. The trap consists of a collapsible white cylinder with white mesh covering the top. In the middle of the mesh cover is a black tube through which a down flow is created by a 12V DC fan that causes mosquitoes in the vicinity of the opening to be sucked into a catch bag. The catch bag is located above the suction fan. The air then exits the trap through the mesh top. This design generates ascending current and it is claimed to be similar to that produced by a human host, both in its direction, geometrical structure, and chemical composition of the attractants. Attractants, a combination of lactic acid, ammonia, and fatty acids are given off by the BG-Lure®. The lure releases the long-lasting attractant for up to five months. There have been reports that the lure is not very effective for some species. The trap can be made much more effective for Aedes species by the addition of solid dry ice or CO2 gas from a cylinder and regulator. Models can vary in size and there are 240v power models for continuous operation. Other lures such as octanol could be used.

*6.2.14 Gravid Traps*

This is a trap designed to collect gravid *Culex* mosquitoes and is most effective for the collection of mosquitoes of the *Culex pipiens* complex. The trap consists of a pan over which is suspended a suction trap similar to a standard CDC miniature light trap. An attractant such as hay infusion is added to the water in the pan and the attracted gravid mosquitoes are sucked into the collecting receptacle by the battery operated fan. The trap can be set over night or all day. Collecting gravid mosquitoes increases the chance of collecting mosquitoes infected with pathogens.

*Sticky ovitraps*

Sticky ovitraps are composed of acetate sheets with an adhesive facing inwards to the inside of the ovitrap and placed inside an ovitrap suitably baited with water and feed or organic rich water. Female receptacle breeding mosquitoes are attracted to the ovitrap and are caught on the adhesive. This method is useful in exotic *Aedes* sampling to determine the presence of adults that come to lay eggs, or to remove them from the population.

## 7.0 RECORDING DATA

The results of all collections should be entered on standardised collection forms. Examples of collection forms are shown in Figures 3, 4 and 5. Essential items to be recorded are locality, date, collector's name, sampling station, type of collection, number of mosquitoes, sex of mosquitoes, species of mosquitoes, population index (larvae per dip, number of adults biting per hour), and meteorological and habitat data.

All collection forms should be collated and kept in date order as permanent records of the program. In addition, ongoing tabulation and graphing of all results should be maintained on a weekly basis so that a quick visual inspection will show the current status of mosquito populations. Other variables such as tide data, river height, temperature, control operations, and any other locally important characteristic, should be incorporated into the visual presentation or analysed with the monitoring data to gain an insight into the reasons for population fluctuations. The monitoring data should also be analysed with information on pest thresholds or cases of mosquito borne disease to determine whether the control program is achieving the ultimate aims.

The surveillance results should be critically examined at least once per month to determine underlying causes for variations and whether the variations can be attributed to any of the measured variables. Indications of variation that can be attributed to one particular variable should be critically examined and tested wherever possible, either in the field or the laboratory.

Each year the whole program should be examined to determine annual patterns of abundance and any reasons for annual variation. Annual Reports should be compiled outlining all aspects of the program and include up to date vector control maps, changes in procedures and equipment, and details of all control operations. Assessments and conclusions about the surveillance program and the overall control program should be made so that annual progress can be assessed.

If the surveillance programs and an integrated control program have been properly planned and carried out, you should see reductions in mosquito populations and corresponding reductions in potential or actual mosquito borne disease.

## 8.0 LIST OF FIGURES



## 9.0 REFERENCES


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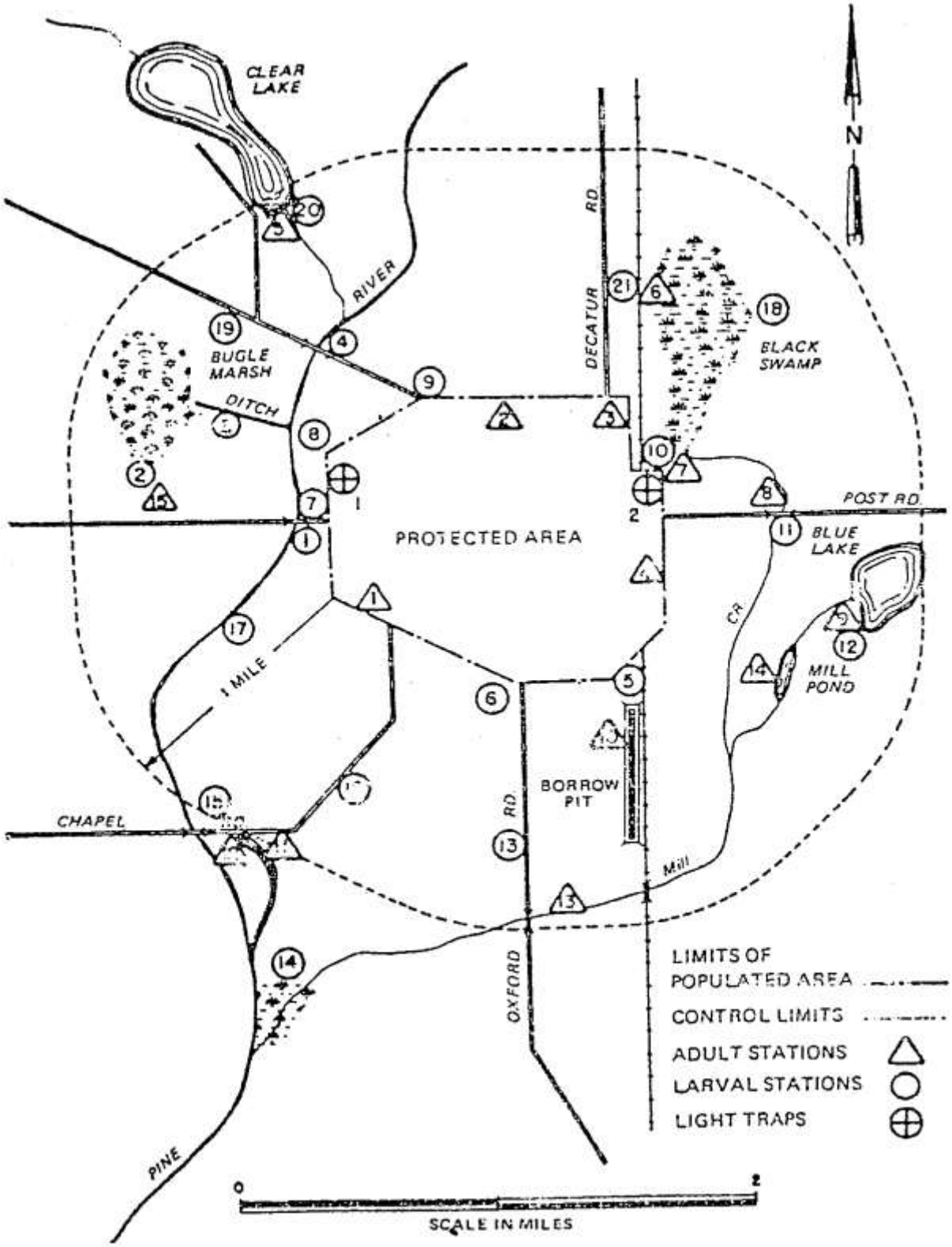


Schematic Map Showing Mosquito Sampling Stations

Figure 1: **Vector control map**

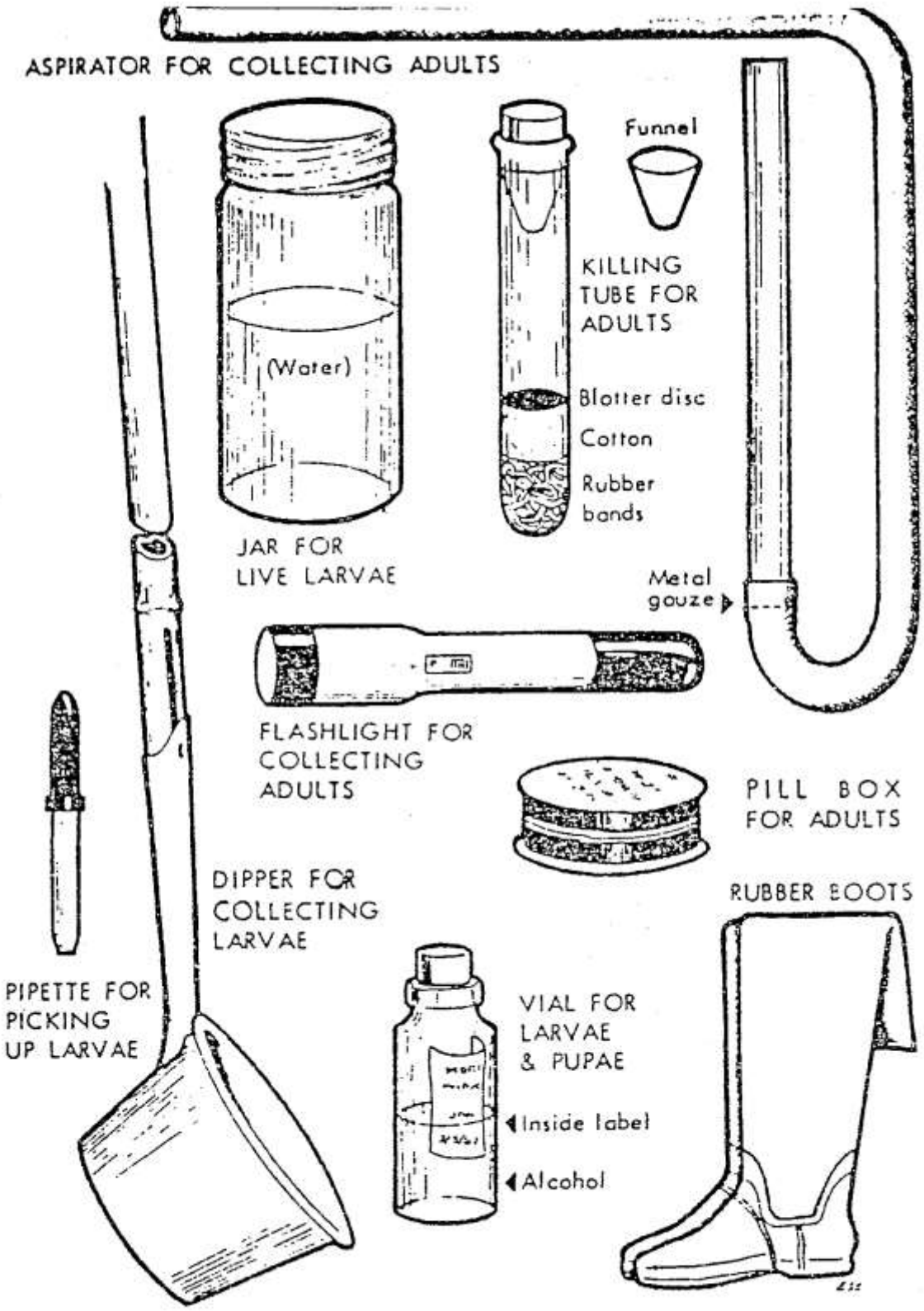


**Figure 2**: Equipment for mosquito surveys

## Fig 3 : Mosquito larval collection form

| SHIRE OF: | PRE-TREATMENT LARVAL SURVEY REPORT | | | | | | | | | | | | | | | | | | | | | | Date:_____ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WATER DEPTH | | | | WATER QUALITY | | | LARVAL DENSITY ( /m²) | | | | | DISTRIBUTION | | | | | INSTARS (%) | | | | | |
| Site name or number | 0-10 | 10-25 | 25-50 | >50 | Temp (°C) | pH | Conductivity (mS/cm) | <10 | 10-100 | 100-1,000 | 1,000-10,000 | > 10,000 | estimated total area of site ($m^2$) | Edge (use '1' to indicate) | Widespread (use '1' to indicate) | estimated % of site with larvae | area requiring treatment ($m^2$) | I | II | III | IV | Pupae | Total |
| | | | | | | | | | | | | | | | | | | | | | | | |
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| **Total** | | | | | | | | | | | | | | | | | | | | | | | |
| **Mean** | | | | | | | | | | | | | | | | | | | | | | | |
| **%** | | | | | | | | | | | | | | | | | | | | | | | |

**COMMENTS:** insert comments about field observations, weather conditions and other factors (e.g. larval development rates, water level fluctuations, evaporation, infiltration, etc) that may assist with or be relevant to determining need and best timing for

**Rainfall** (during 3 weeks prior to survey)

| | | | |
|---|---|---|---|
| Date(s) | | Amount (mm) | |
| Date(s) | | Amount (mm) | |
| Date(s) | | Amount (mm) | |
| Date(s) | | Amount (mm) | |
| Date(s) | | Amount (mm) | |

**High tides** (during 3 weeks prior to survey)

| | | | |
|---|---|---|---|
| Date(s) | | Height (m) | |
| Date(s) | | Height (m) | |
| Date(s) | | Height (m) | |
| Date(s) | | Height (m) | |
| Date(s) | | Height (m) | |

Fig 4 : **Adult survey form (man biting collection)**

ADULT SURVEY

MAN BITING COLLECTION : INDOORS/OUTDOORS

AREA No: ..... COLLECTION SITE:.....

STATION No: ..... .....

SEASON: TEMPERATURE: START ..... END .....

WET ☐ DRY ☐ HUMIDITY : START ..... END .....

CLOUDY ☐ FINE ☐ RAIN ☐ WIND SPEED: START ..... END .....

DIRECTION: START ..... END .....

No. Of COLLECTIONS:..... HOME: LOW LEVEL ☐ PIERS ☐

COLLECTION METHOD: ..... SCREENED ☐ UNSCREENED ☐ SCREENING FAULTY ☐

PAROUS RATE:..... WALLS: BRICK ☐ TIMBER ☐ BLACK VENEER ☐

| TIME | TOTAL No. | | CUP No. | No.FEED | SPECIES | | |
|---|---|---|---|---|---|---|---|
| | An | C | | | ANOPHELINE | CULICINE | |
| 6-7 | | | | | | | |
| 7-8 | | | | | | | |
| 8-9 | | | | | | | |
| 9-10 | | | | | | | |
| 10-11 | | | | | | | |
| 11-12 | | | | | | | |
| 12-1 AM | | | | | | | |
| 1-2 | | | | | | | |
| 2-3 | | | | | | | |
| 3-4 | | | | | | | |
| 5-6 | | | | | | | |

TOTAL

No. per M/H

COLLECTION DATE

SIGNATURE OF COLLECTOR

Fig 5 : **Adult mosquito trapping record**

| | | | |
|---|---|---|---|
| Trap site: | | | |
| Trap location details: | | | |
| Time set: | | | |
| Time collected: | | | |
| Overnight weather conditions: | | | |
| | | | |
| | Females | Males | Total |
| Collection number: | | | |
| | | | |
| | | | |
| **Details of identified mosquitoes** | | | |
| Species | | | |
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Figure 6: **Killing and mounting of mosquito adults**


Figure 1. Chloroform tube; A. rubber bands; B. cotton plug; C. tissue plug.

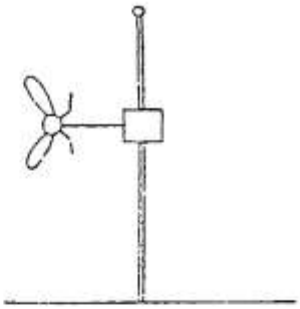

Figure 2.

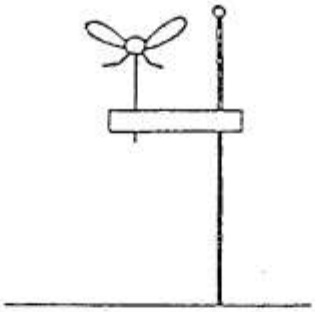

Figure 3.

Mounting mosquito adults on minuten nadeln.

Figure 4. Point to head of insect pin.

Figure 5. Apply polish to point.

Figure 6. Touch polish to pleural aspect.

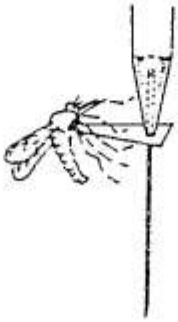

Figure 7. Adjust height of point with setter.

Figure 7: **Preparation of insects for shipping**