Northern Territory Government

DEPARTMENT OF
NATURAL RESOURCES, ENVIRONMENT, THE ARTS AND SPORT

Guidelines for Preparation of an Environmental Impact Statement

OLYMPIC DAM EXPANSION (NT TRANSPORT OPTION) PROJECT

- BHP Billiton -

November 2008

TABLE OF CONTENTS

1 INTRODUCTION

BHP Billiton Olympic Dam Corporation Pty Ltd (BHP Billiton) is proposing to expand its existing mining and minerals processing operation at Olympic Dam in South Australia to increase the production of copper and associated products including uranium oxide, gold and silver.

The Olympic Dam Expansion Project is currently being jointly assessed by the Australian Government and the South Australian Government at the level of an Environmental Impact Statement (EIS). A draft EIS is being prepared by BHP Billiton in accordance with EIS guidelines that were published in January 2006, and then recently updated, to satisfy the requirements of both jurisdictions.

BHP Billiton is assessing a number of options for transport and shipment of product. One option that was developed after the joint government guidelines were published is to export copper concentrate, as well as uranium oxide, via the Port of Darwin. These guidelines deal with only the **NT Transport Option** of the Olympic Dam Expansion Project.

The Northern Territory Minister for Natural Resources, Environment and Heritage (the NT Minister) has determined that the Olympic Dam Expansion NT Transport Option of the Olympic Dam Expansion Project (NT Transport Option) requires formal assessment under the NT *Environmental Assessment (EA) Act* at the level of an EIS. Issues of concern contributing to this decision include:

- A high level of public interest in the mining of radioactive materials in general;
- A high level of public scrutiny in the transport of radioactive materials close to residential areas;
- A high level of public interest in the environment, health and social implications of a loading and storage facility operating for radioactive products close to habitable areas;
- Wastewater management at Port of Darwin (particularly rail wagon wash down water); and
- Air emissions (particularly radioactive dust particles).

The NT Government has agreed to work collaboratively with the Australian and SA Governments to enable the NT Transport Option to be considered within the current joint assessment process framework. These guidelines therefore supplement the *Guidelines for an Environmental Impact Statement on the proposed expansion of the Olympic Dam operations at Roxby Downs*, published jointly by the Australian Government and SA Government and henceforth termed the **Joint Assessment Guidelines**. The original document and a recently updated version can be accessed on the SA Government's website at http://www.planning.sa.gov.au/go/olympic-dam.

Information about the proposal and its relevant impacts, as outlined in this document, is to be provided in the EIS. This information must be sufficient to allow the NT Minister to make informed recommendations to the responsible (consent) Minister in accordance with the EA Act.

Responsibilities within the assessment process are divided among the jurisdictions as follows:

- The Australian Government is responsible for assessing all aspects of the proposal including aspects relevant to matters of National Environmental Significance (NES);
- The South Australian Government is responsible for all aspects of the proposal within its jurisdiction in South Australia; and
- The Northern Territory Government is responsible for assessing all aspects of the proposal within its jurisdiction in the Northern Territory (The NT Transport Option).

The guidelines only apply to the NT Transport Option. Where the word “action” or “proposal” is used in these guidelines, its interpretation is limited to the NT Transport Option.

2 GENERAL ADVICE ON EIS

2.1 GENERAL CONTENT, FORMAT & STYLE

A full description of the content required in the EIS is contained within Sections 2, 3 and 4 of the Joint Assessment Guidelines.

Information requirements specific to the Northern Territory as set out in these NT Transport Option guidelines must be included as a separate Appendix to the EIS to allow stakeholders and other interested parties to easily locate NT-specific matters in the EIS documentation. These matters should also be summarised within the relevant sections of the main body of the EIS.

2.2 ADMINISTRATION

Three ‘preliminary’ copies of the draft EIS should be lodged with the Environment, Heritage and the Arts (EHA) Division of the Department of Natural Resources, Environment, the Arts and Sport (NRETAS) for internal review prior to the public review.

Once the internal review is complete and the proponent implements any necessary changes, 10 bound copies of the draft EIS should be lodged with the NT Minister care of the EHA Division for distribution to NT Government advisory bodies.

The EIS should be provided on CD/DVD in ADOBE *.pdf format for placement on the NRETAS internet site (Executive Summary, Chapters and Appendices separate). The NRETAS site will also provide a link to an electronic, interactive version maintained by the proponent. This should be done at least 4 days before notice is provided by newspaper. Additionally, two Microsoft Word copies of the Draft EIS should be provided to facilitate production of the Assessment Report and Recommendations.

The draft EIS is to be advertised for review and comment in the *NT News, The Advocate (Alice Springs),* and *Katherine Times*.

The EIS should be made available for public review at:

- Environment, Heritage and the Arts Division (Dept. Natural Resources, Environment, the Arts and Sport), 2nd Floor, Darwin Plaza, 41 Smith Street Mall, Darwin;
- Development Assessment Services (Dept. Planning and Infrastructure), Information Desk, Ground Floor, Cavenagh House, Cnr Cavenagh and Knuckey Streets, Darwin;

- Minerals and Energy Information Centre, Department of Regional Development, Primary Industry, Fisheries and Resources, 3rd Floor, Paspalis Centrepoint,
  48 Smith Street Mall, Darwin;
- Northern Territory Library (NTL), Parliament House, Darwin;
- Casuarina Public Library (e-mail citylibrary@darwin.nt.gov.au ,
  Ph: 89300230);
- Palmerston City Library, Goyder Square, Palmerston
  (Contact tree.malyan@palmerston.nt.gov.au or phone 8935 9993);
- Darwin City Council Libraries (Casuarina, Darwin City, Karama, Nightcliff);
- The Environment Centre NT, Unit 3, 98 Woods St, Darwin (two copies requested with supporting documentation);
- Northern Land Council, 45 Mitchell St, Darwin;
- Litchfield Shire Council office – 7 Bees Creek Road, Fred's Pass, NT (email council@lsc.nt.gov.au; Ph: 8983 1912);
- Environment Hub, Rapid Creek (Shop 9 Rapid Creek Business Village, Pearce Place, Millner);
- Katherine Town Council Public Library (telephone: 8972 5500);
- Alice Springs Town Council Public Library (telephone: 8950 0500);
- Tennant Creek Public Library (telephone: 8962 0050).

3 GENERAL INFORMATION

This should provide the background and context of the action including:

- The title of the action;
- The full name and postal address of the designated proponent;
- A clear outline of the objective of the action;
- Legislative background for the proposal, including the relevant NT legislation that applies to the project;
- The background to the development of the action;
- How the action relates to any other proposals or actions (of which the proponent should reasonably be aware) that have been or are being taken, or that have been approved in the region affected by the action;
- The current status of the action; and
- The consequences of not proceeding with the action.

4 DESCRIPTION OF THE PROPOSAL

This section must describe the **NT Transport Option** proposal to allow an understanding of proposed infrastructure design and engineering. All construction (including site preparation), operation and management elements of the proposed action must be described. Where applicable, this information should be described separately under the appropriate headings.

Details should include the proposed location/s of the NT Transport Option components, works to be undertaken, date or time period over which construction, operation and management is expected to take place, any structures to be built, and elements of the action that may have impacts on identified environmental factors.

Aspects to be covered include:

- An explanation of the objectives, benefits and justification for the action;

- A description of the proposal's location indicating distance from Alice Springs, Katherine and Darwin, and the proposal in relation to the Stuart Highway and the Adelaide to Darwin Railway. The proximity of nearby residential areas and communities, pastoral leases and any major watercourses that may be impacted must also be indicated;
- An overall layout of the proposed action;
- Schedule for the proposal;
- Location and design criteria for each component of the proposal including design limitations imposed by site characteristics;
- Land requirements, land tenure, acquisition requirements (permits, rezoning and Native Title), and the tenures under which the proposal would be held including details of relevant legislative processes required to grant proposed tenure;
- Infrastructure requirements and specifications (permanent and temporary), and ancillary activities;
- Employment and business opportunities (direct and indirect), including sources of workforce, skill levels required and opportunities for local people and businesses;
- Methods for storage, handling, containment and emergency management of chemicals and other hazardous substances (including fuel and explosives); and
- Decommissioning planning with objectives for the site.

5 ALTERNATIVES

Alternative proposals for the NT Transport Option must be discussed in sufficient detail to enable an understanding of the reasons for preferring certain options and rejecting others.

Alternatives to be discussed must include:

- Not proceeding with the proposal;
- Transport options;
- Storage and handling facility locations;
- Environmental management technologies, particularly for dust and waste water management.

6 RISK ASSESSMENT

6.1 RISK ASSESSMENT APPROACH

This EIS should be undertaken with specific emphasis on identification, analysis and treatment of risks through a whole-of-project risk assessment. Through this process, the EIS will:

- Acknowledge and discuss the full range of risks presented by the proposed NT Transport Option including those of special concern to the public;
- Quantify (where possible) and rank risks so that the reasons for proposed management responses are clear;
- Acknowledge levels of uncertainty about estimates of risk and the effectiveness of risk controls;
- Extend risk assessment to problems in realising benefits; and

- Discuss the residual risks and their consequences expected to be borne by the community, providing better understanding of equity issues.

Levels of uncertainty with the impact assessment should be identified and addressed by the risk assessment. Steps taken to reduce uncertainty or precautions taken to compensate for uncertainty should also be identified and their effect/s demonstrated.

Information provided should permit the reader to understand the likelihood of the risk, its potential severity, and any uncertainty about the effectiveness of controls. If levels of uncertainty do not permit robust quantification of risk, then this should be clearly acknowledged.

The risk assessment should be based on international best practice. Processes for risk management are formalised in Standards Australia / Standards New Zealand (eg. AS/NZS 4360:2004; HB 436:2004; HB 158:2006).

BHP Billiton is expected to work with close regard to community expectations and concerns and to respect that the community may perceive the level of risk for this proposal differently to the proponent. In the interest of achieving a balanced risk assessment, it is expected that the proponent will place a high priority on communicating with the local community throughout the EIS process.

6.2 HAZARDS AND RISKS TO HUMANS AND FACILITIES

The EIS should include an assessment of the risks to people and nearby facilities associated with the construction, operation and maintenance of the various components of the NT Transport Option, and the storage and transport of materials within the NT. The aim of this assessment is to demonstrate that:

- The proponent is fully aware of the risks to human health and safety associated with all aspects of the development;
- The prevention and mitigation of risks to human health and safety are properly addressed in the design specifications for the facility; and
- The risks can and will be managed effectively during the construction, commissioning, operation, and decommissioning of the development.

Sufficient analysis should be provided to indicate whether risks are likely to be acceptable compared with similar ventures in Australia and Internationally. Assumptions used in the analyses should be explained. Relevant standards, codes and best practice methodologies that minimise risks should be discussed.

The proponent must discuss how the relevant authorities will be engaged to ensure emergency response capacity is adequate and emergency management is coordinated.

Section 5.9 (Hazard and Risk) of the Joint Assessment Guidelines provides more specific requirements, some of which are relevant to the NT Transport Option.

7 KEY RISKS OF THE NT TRANSPORT OPTION

7.1 DESIGN, CONSTRUCTION AND OPERATION OF THE STORAGE AND LOADING FACILITY

The proponent is to demonstrate how the storage and loading facilities would be designed and operated to achieve no detectable contamination of the

surrounding environment. It is also to discuss the potential likelihood and consequence of product spillage from unplanned risk events.

7.1.1 Context

The nature of the material being handled at East Arm Port requires special measures to be put in place to prevent airborne emissions of particulates from the facility and contaminated stormwater from entering the receiving environment.

7.1.2 Information requirements

Detailed information requirements for this key risk can be found in the *Air Quality, Surface Water* and *Waste Materials Management* sections of the Joint Assessment Guidelines. A summary of these and other requirements specific to the NT Transport Option are included below:

- Describe the existing air environment that may be affected by the proposal having regard for particulates, gaseous and odorous compounds, particularly radioactive dust and any other radiation hazards.
- Describe the surface water drainage systems that may be affected by the storage and handling of copper concentrate and the likely fate of stormwater from the site.
- Sufficient data on local meteorology and ambient levels of pollutants are to be gathered to provide a baseline for later studies.
- Describe the pollutant exposure sources, likely exposure receptors and potential levels of exposure, including potential levels of ionising radiation.
- Define and describe the objectives and practical measures for protecting environmental values for air and water, and how these objectives will be achieved and monitored.
- Include an outline of the stormwater and wash-down water management system designs associated with the likely storage facility location scenarios.
- Discuss the air filtration and ventilation system in the storage facility and how any particulate emissions will meet the National Environment Protection Measure for ambient air quality at the site boundary.
- Discuss wastewater treatment at the site.
- Detail the measures to prevent product losses to the environment during ship loading.
- Outline plans for decommissioning and rehabilitation of the storage and port facilities.

7.2 TRANSPORT OF PRODUCT

The proponent must demonstrate that fugitive product losses to the environment will be prevented as far as reasonably practicable and that any incidental product losses to the receiving environment can be managed with no significant environmental harm (including to human health).

7.2.1 Context

- There are risks associated with the transport of product that cannot be managed through engineering alone.
- The railway and many of the roads that are proposed for use are shared with the community, or pass through private land or close to dense residential

areas, and traverse waterways. Ships will pass through Darwin Harbour and shipping activity will increase.
- Potential impacts of concern associated with the transport of product include radiological contamination of air, soil and water. Sources of impact could include dust generation, accidents such as product spills or vehicle collisions/derailment, unsecured loads, etc.

7.2.2 Information Requirements

From a risk perspective, examine aspects of product transport including, but not limited to:

- Details of any new or upgraded roads and rail infrastructure and facilities;
- An outline of the regulations, guidelines and procedures specific to operating the NT Transport Option;
- Details of how high risk elements of the transport route will be managed (such as road intersections, river crossings, driver fatigue, port activities);
- Details of product containment, and how risks of spillage, fugitive product losses and other risks associated with the product in transit will be managed;
- Emergency procedures in the event of an accident such as a train derailment; and
- A discussion of rolling stock and vehicle wash-down practices and how the waste water will be managed.

7.3 PUBLIC INTEREST IN ENVIRONMENTAL AND SOCIAL IMPACT

Environmental, social and health impact assessment is necessary to help citizens, communities and community leaders understand and quantify social and health implications of a project. This allows the community to collectively plan for and deal with the consequences of a proposed development.

The proponent needs to demonstrate that the communities potentially affected by this proposal will not bear significant costs in terms of social, economic and health impacts and can maximise the benefits that may be associated with the proposal. Community perceptions need to be managed sensitively.

7.3.1 Context

- There is strong public concern about the health impacts related to the exposure of humans to radioactive material.
- There is strong public interest in the mining of uranium, and the fate of the product.
- There is public concern that radioactive wastes (in this case, the fate of wastes recovered in wash down water and dust residues) could create “legacy” issues after the mining company has finished with the site.

7.3.2 Information Requirements

The Joint Assessment Guidelines require a thorough social impact assessment to be conducted as well as an economic assessment. In addition to these considerations, the proponent must assess the potential social and health impacts (including wellbeing) associated with the **NT Transport Option**. Relevant requirements include:

- A discussion of the costs and benefits of the proposal to the community;

- Any potential impacts on the health of the surrounding port users and community, and management measures to prevent impacts;
- A summary of the perceptions expressed by individuals and groups within the community;
- A considered response to these perceptions; and
- A community consultation program to engage the community and keep them informed about the proposal, as well as providing a conduit for complaints and expression of concerns.

8 OTHER ENVIRONMENTAL RISKS

The Joint Assessment Guidelines contain detailed information requirements on the following risk areas and environmental factors:

- Roads, Rail and Infrastructure (Section 5.10 Land Use and Planning)
- Greenhouse emissions and Climate Change (Sections 5.11 Meteorological Environment and Climate, and 5.12 Air Quality);
- Erosion and sediment control (Section 5.13 Topography, Geology and Soils);
- Flora and fauna (Sections 5.14 Flora and 5.15 Fauna);
- Water management (Sections 5.16 Groundwater and 5.17 Surface Water)
- Noise (Section 5.18 Noise and Vibration);
- Cultural heritage (Section 5.19);
- Social Impact Assessment (Section 5.20)
- Visual Amenity (Section 5.21);
- Waste management (Section 5.22 Waste Materials Management);
- Economic Assessment (Section 5.23); and
- Rehabilitation and Decommissioning (Section 5.24)

In addition to the relevant requirements outlined in the above sections of the Joint Assessment Guidelines, the proponent must consider the following advice with respect to the NT Transport Option:

- NT Environmental Assessment Guide - Greenhouse Gas Emissions (Attachment 1) or (http://www.nt.gov.au/nreta/publications/environment/index.html);
- Any receptacles or depressions with the potential to store water for more than 3 days should be avoided, and stormwater drains must be kept clear of vegetation and free-draining to avoid formation of mosquito breeding habitat. See 'Construction Practice Near Tidal Areas of the Northern Territory – Guidelines to Prevent Mosquito Breeding' (Attachment 2);
- NT Erosion and Sediment Control guidelines (http://www.nt.gov.au/nreta/natres/soil/management/index.html);
- Any discharge of wastewater from the premises in to Darwin Harbour will require a Waste Discharge Licence under the *Water Act 1992*. Guidance and application forms can be found at the following site: (http://www.nt.gov.au/nreta/environment/licences/guides.html#water);
- A licence to possess will be required for copper concentrate under the *Radiation Protection Act* and the *Radiation (Safety Control) Act*. The 'Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing' will be a condition of licence;
- A licence under the *Radioactive Ores and Concentrates (Packaging and Transport) Act* and approval for a store will be required.

9 ENVIRONMENTAL MANAGEMENT

Specific safeguards and controls, which are proposed to be employed to minimise or remedy environmental impacts identified in Section 7, are to be included in a draft Environmental Management Plan (EMP).

The draft EMP should be strategic, describing a framework for environmental management for construction and operational phases of the proposal; however, as much detail as is practicable should be provided to enable adequate assessment during the public exhibition phase. Where possible, specific management policies, practices and procedures should be included in the draft EMP.

Where practicable, the draft EMP should include:

- The proposed management structure of the construction, operational and decommissioning phases and its relationship to the environmental management of the site;
- Management targets and objectives for relevant environmental factors;
- The proposed measures to minimise adverse impacts and maximise opportunities;
- Performance indicators by which all anticipated and potential impacts can be measured;
- Proposed monitoring programs to allow early detection of adverse impacts;
- A summary table listing the undertakings and commitments made in the EIS, including clear timelines for key commitments and performance indicators, with cross-references to the text of the Statement; and
- Provision for the periodic review of the management plan itself.

Reference should be made to relevant legislation, guidelines and standards, and proposed arrangements for necessary approvals and permits should be noted. The agencies responsible for implementing and overseeing the management plan should be identified. Proposed reporting procedures on the implementation of the management plan, independent auditing or self-auditing and reporting of accidents and incidents should also be included.

The EMP would continue to be developed and refined following the conclusion of the assessment process, taking into consideration the proposed timing of the NT Transport Option, comments on the EIS and incorporating the Assessment Report recommendations and conclusions.

10 PUBLIC INVOLVEMENT AND CONSULTATION

The EIS has an important role in informing the public about this proposal. It is essential that the proponent demonstrate how public concerns were identified, and will influence the design and delivery of the proposal. Public involvement and the role of government organisations should be clearly identified. The outcomes of any surveys, public meetings and liaison with interested groups should be discussed including any changes made to the proposal as a result of consultation. Details of any ongoing liaison should also be discussed.

An outline of negotiations and discussions with local government and the Northern Territory Government should be provided.

A stakeholder communication plan must be included in the EIS to facilitate consultation, information sharing and involvement with Government and the local

community during the planning, construction, operation and decommissioning of the proposal.

Attachment 1

Northern Territory Government

DEPARTMENT OF
NATURAL RESOURCES, ENVIRONMENT, THE ARTS AND SPORT

NT ENVIRONMENTAL IMPACT ASSESSMENT GUIDE:

GREENHOUSE GAS EMISSIONS AND CLIMATE CHANGE

PURPOSE

The Northern Territory Government's objective for managing greenhouse gas emissions from new and expanding operations is to minimise emissions to a level that is as low as practicable. This will help fulfil the objective of minimising greenhouse gas emissions from the NT into the future.

The Northern Territory Government's objective for considering future climate change in the assessment process is to ensure projects and developments are planned taking climate change science and projections into account, to minimise future environmental, social and economic costs and take advantage of any opportunities.

This Guide aims to assist proponents in providing the information needed by the Department of Natural Resources, Environment, the Arts and Sport (NRETAS) to assess the impact of greenhouse gas emissions from proposed projects and assess other potential impacts from proposed projects under projected future climatic conditions under the *Northern Territory Environmental Assessment Act 1994*.

GUIDANCE

Emissions estimates

Note that the Australian Government is establishing a national greenhouse gas emissions trading system, which may have implications for some proponents. More information on a national emissions trading scheme is available at
http://www.climatechange.gov.au/emissionstrading/index.html

Proponents should detail the following in their environmental impact assessment documentation:

1. An estimate of the greenhouse gas emissions for the construction and operation phases:

(a) in absolute and carbon dioxide equivalent figures (refer to the Glossary in this Guide) for each year of the project;
(b) identified on a gas by gas basis; and

(c) by source (including on site and upstream sources such as emissions arising from land clearing and the production and supply of energy to the site).

Emissions estimates are to be calculated using the methodology developed and periodically updated by the National Greenhouse Gas Inventory Committee or another national or internationally agreed methodology. See http://www.climatechange.gov.au/workbook/index.html for access to the National Greenhouse Accounts Factors which may assist.

For emissions from clearing of vegetation, emissions estimates are to be calculated using the National Carbon Accounting System, or another nationally recognised methodology. For more information see http://www.climatechange.gov.au/ncas/index.html

2. Details of the project lifecycle greenhouse gas emissions and the greenhouse gas efficiency of the proposed project (per unit and/or other agreed performance indicators).

Lifecycle emissions and greenhouse gas efficiency should be compared with similar technologies producing similar products.

To provide an understanding of the broader impact of the proposal, proponents are encouraged to place the estimated greenhouse gas emissions from the proposal into a national and global context. Information on Australia's national emissions profile can be obtained from the Department of Climate Change at http://www.climatechange.gov.au/inventory/2005/index.html. International emissions can be seen at the United Nations Framework Convention on Climate Change (UNFCCC) website at http://unfccc.int/ghg_emissions_data/items/3800.php

Measures to minimise greenhouse gas emissions

Proponents must demonstrate consideration of a wide range of options and indicate the intended measures and efficient technologies to be adopted to minimise total greenhouse gas emissions from the proposed project, including:

(a) identifying energy conservation measures, opportunities for improving energy efficiency and ways to reduce fugitive emissions where applicable;
(b) indicating where potential savings in greenhouse gas emissions can be made through the use of renewable energy sources, taking into account fossil fuels used for supplementary power generation; and
(c) whilst recognising the likely commencement of an emissions trading scheme in 2010, their commitment to offsetting greenhouse gas emissions.

The design measures to maximise efficiency and minimise emissions should represent best practice at the time of seeking project approval.

Proponents are to advise whether they will join the Commonwealth Government's Greenhouse Challenge program. For more information on the program see http://www.climatechange.gov.au/challenge/index.html

Offsets

Emission offsets include activities that remove carbon from the atmosphere or reduce the greenhouse gas intensity (output per unit product) from current or future activities. No Australian standards for offsets currently exist, although the Australian Government has committed to the development of an Australian standard for offsets by the end of 2008. The Australian Government

does currently approve Greenhouse Friendly carbon credits under the Greenhouse Friendly initiative, more information about which can be found at http://www.greenhouse.gov.au/greenhousefriendly

Measures that offset emissions within the NT are encouraged, and NRETAS staff can discuss possible options with proponents. Proposed emissions offsets projects should include an estimate of greenhouse gas emissions savings that will be achieved through implementation.

Emissions monitoring and reporting

Consistent with the principles of continuous improvement, a program is to be outlined in the proponent's Environmental Management Plan which includes ongoing monitoring, investigation, review and reporting of greenhouse gas emissions and abatement measures.

The Australian Government is developing a nationally consistent framework for greenhouse and energy reporting by industry. Projects with significant emissions may be required to report their emissions under the National Greenhouse and Energy Reporting Act 2007. Data reported through the system will underpin the National Emissions Trading Scheme. For more information see http://www.climatechange.gov.au/reporting/index.html

Impacts of climate change

Climate change is projected to result in changes to sea level, land and sea temperatures, cyclone intensity, frequency of fire weather, and frequency of extreme weather events including storms, drought and flood.

Proponents should discuss how projected climate change has been taken into account in planning the proposal, and how climate change is expected to affect the proposal over its stated lifetime. Proponents should discuss how climate change-related risks (for example, risk of failure of project infrastructure during potential extreme weather events) will be managed.

Potential impacts of climate change on the surrounding environment including water, land, biodiversity and ecosystems, coastal zones, and the social environment should also be taken into account in proposal planning.

In assessing climate change risk, proponents should be guided by recent projections published by organisations such as the CSIRO, the Bureau of Meteorology (BoM), and the Intergovernmental Panel on Climate Change. For the latest CSIRO and BoM projections for Australia, see: http://www.climatechangeinaustralia.gov.au

GLOSSARY OF GREENHOUSE TERMS

Abatement: Limiting, abating, avoiding or sequestering greenhouse gas emissions through source reduction, fuel displacement or switching, carbon stabilising techniques or sink enhancement.

Absolute emissions: Refers to the total emissions of greenhouse gases expressed in terms of the actual mass of each individual gas emitted over a specified time period.

Best Practice: A best practice is a process, technique, or use of technology, equipment or resource that has a proven record of success in minimising energy use and greenhouse gas emissions. A commitment to use best practice is a commitment to use all available knowledge and technology to ensure that greenhouse gas emissions are minimised.

Carbon Dioxide Equivalent: A unit of greenhouse gas emissions calculated by multiplying the actual mass of emissions by the appropriate Global Warming Potential. This enables emissions of different gases to be added together and compared with carbon dioxide (see Table 1 below).

Commonwealth Government's Greenhouse Challenge program: A cooperative effort by industry and the Commonwealth Government to reduce greenhouse gas emissions through voluntary industry action. See: http://www.climatechange.gov.au/challenge/index.html

Greenhouse Gases: Table 1 lists the greenhouse gases proponents are required to report on.

Global Warming Potential (GWP): The warming potential of a gas, compared to that for carbon dioxide. GWPs are revised from time to time as knowledge increases about the influences of different gases and processes on climate change. Refer Table 1.

Project Lifecycle Greenhouse Gas Emissions: Those greenhouse gas emissions measured cumulatively over a defined period. Typically this period is from the point of extraction of the raw materials to either the beginning of the consumer phase of a product or the final disposal or recycling stage of a product, depending on its nature. Proponents should justify their choice of the defined period.

National Greenhouse Gas Inventory Committee: A committee comprising representatives of the Commonwealth, State and Territory Governments that oversees the development of greenhouse gas inventory methods and compilation of inventories for Australia.

Sequestration: Removal of greenhouse gases from the atmosphere by vegetation or technological measures. Sequestration is not yet precisely defined for the purposes of recognised trading or offset schemes. Accordingly, NRETAS will take a common sense approach on a case by case basis in the interim. To assist proponents, NRETAS regards sequestration as a process that results in the isolation of carbon dioxide from the atmosphere for a period which is significant in terms of influencing the global warming effect.

Source: Any process or activity that releases a greenhouse gas into the atmosphere.

Table 1: Greenhouse gases and respective Global Warming Potential (GWP) factors

Greenhouse Gas	Global Warming Potential
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
Perfluorocarbons (CF_x)	6,500 – 9,200
Hydrofluorocarbons (HFCs)	140 - 11,700
Sulphur hexafluoride (SF_6)	23,900

Greenhouse gas emissions expressed in carbon dioxide equivalent (CO_2-e) are calculated by multiplying the actual mass of emissions for each greenhouse gas by its respective GWP factor. GWP factors listed are those published by the International Panel on Climate Change in its 4th Assessment Report, 2007, see http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_Ch02.pdf

Attachment 2

Northern Territory Government
Department of Health and Community Services

CONSTRUCTION PRACTICE NEAR TIDAL AREAS IN THE NORTHERN TERRITORY

GUIDELINES TO PREVENT MOSQUITO BREEDING

NORTHERN TERRITORY COASTAL MANAGEMENT COMMITTEE JUNE 1988

Minor update 13/08/02
Minor update 25/8/05

For more information contact:

Department of Health and Community Services
Medical Entomology Branch
PO Box 40596
Casuarina NT 0811

Telephone: 08 8922 8901
Fax: 08 8922 8820

CONSTRUCTION PRACTICE NEAR TIDAL AREAS IN THE NORTHERN TERRITORY

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P. I. Whelan
Medical Entomology Branch
Department of Health & Community Services

for the
Coastal Management Technical Advisory Group

CONTENTS

Construction Practice Near Tidal Areas in the Northern Territory

Guidelines to Prevent Mosquito Breeding

1.0 **Introduction**

There have been many instances of construction in or near tidal areas in the Top End of the Northern Territory that have resulted in ecological disturbance and subsequent mosquito breeding. Many of the deleterious disturbances have been the result of little or no recognition of the ecological consequences of construction practices, either during the construction period or on completion of the project. Much of the deleterious ecological disturbance can be avoided or minimized by consultation between engineers or construction authorities and people with ecological expertise.

One of the most significant impacts of construction in or adjacent to tidal areas is the creation of new sources of pest and potential disease causing mosquitoes. The creation of new mosquito breeding sites can have an enormous bearing of the quality of life, land values, costly rehabilitation measures, mosquito control programs and most importantly, the health and legal implications involved in an outbreak of mosquito-borne disease.

2.0 **Aim of Guidelines**

These guidelines are intended as a checklist for planners, engineers or any supervisory officers, responsible for the planning or implementation of any construction activity near tidal areas, in order to prevent the creation of mosquito breeding sites.

They are also intended to be used as a checklist in the preparation and evaluation of any Preliminary Environment Report or Environmental Impact Statement. In this way it is hoped that the 'potential for additional. mosquito breeding areas will be recognized and avoided in the planning or implementation phases of any construction project, so that later costly or environmentally disruptive rectification works will not be necessary.

It is proposed to circulate these guidelines to the relevant construction or advisory authorities. Any doubts on the potential for creating mosquito breeding sites on any project can be referred to the Senior Medical Entomologist of the Department of Health and Community Services or any COMTAG member.

3.0 **Mosquitoes of Public Health Importance**

Background information on mosquito biology, breeding sites, potential diseases and specific control measures can be found in "Mosquitoes of Public Health Importance in the Northern Territory and their Control" (1984), available from the Department of Health and Community Services. Of the 100 species of mosquitoes in the Northern Territory, fifteen (15) species can breed in the intertidal zone, at least at certain sites and some times of the year. These include the principal vectors of malaria, epidemic polyarthritis, and a number of other virus diseases, as well as those species regarded as the most important pest species.

Salt Water Mosquitoes	**Common Name**	**Importance**
Anopheles hilli	Saltwater Anopheles	Potential disease vector
Culex sitiens	Saltwater Culex	Localized pest species
Aedes alternans	Scotch Grey	Negligible pest
Aedes vigilax	Saltmarsh mosquito	Major pest and disease vector

Brackish Water Mosquitoes

Anopheles farauti s.l.	Australian malaria mosquito	Major malaria vector
Verrallina funerea	Brackish water mosquito	Important local pest

Brackish to fresh water mosquitoes

Culex annulirostris	Common banded mosquito	Major pest and disease vector
Anopheles bancroftii	Black malaria mosquito	Potential malaria vector and pest
Anopheles annulipes s.l.	Australian Anopheles	Potential malaria vector
Anopheles meraukensis	Water reed Anopheles	Pest species
Coquillettidia xanthogaster	The orange mosquito	Important pest species
Mansonia uniformis	Water hyacinth mosquito	important pest species

3.1 **Malaria**

Malaria was only eradicated in the Northern Territory in 1962 and many communities in the Northern Territory remain vulnerable to malaria reintroduction, particularly those communities which are near large sources of *Anopheles* mosquitoes. Each year up to thirty malaria cases are imported into the Top End from overseas, and the Department of Health and Community Services investigates and follows up each case. With increasing numbers of people living in remote areas with large mosquito populations, or adjacent to mosquito sources in expanding urban areas, the potential for malaria reintroduction is increasing. In particular circumstances, adult mosquito control measures near urban areas may be necessary, but problems due to lack of access, thick vegetation, or the proximity to urban areas, may prevent or reduce the effectiveness of these measures. We need to reduce these potential problems by reducing the mosquito breeding areas adjacent to urban areas.

3.2 **Arbovirus Diseases**

Each year there are up to 20 cases of epidemic polyarthritis reported in the Top End. These are laboratory confirmed cases only, and it is thought the number of clinical cases is very much higher. All of these cases have been investigated and the likely sites of transmission were frequently in towns adjacent to particularly productive mosquito breeding areas. With a tropical lifestyle and an expanding population, it is becoming increasingly necessary to provide mosquito free urban areas.

4.0 **Mosquito Breeding Sites in Coastal Areas**

The breeding sites of the various mosquito species are illustrated in Fig. 1. The area of greatest potential for mosquito breeding lies within the upper high tide zone (from 7. 3m to 7. 9m A. C. D. in the Darwin area). In addition, the region up to 1.0m above maximum high tide can be a significant mosquito breeding area, as this region is usually the recipient of seepage, rain water and silt inputs being transported to the tidal areas. These regions have the capacity for both natural and human disturbances that can lead to significant increase in mosquito breeding.

The intertidal areas of wide expanse, thick vegetation, very flat topography, and fresh water inflows are the largest sources of mosquitoes. These large tidally influenced marshes (e. g. Leanyer Swamp) have variable salinity water which is shallow and thickly vegetated and is the ideal breeding habitat for most of the important mosquito species. Natural tidal marshes such as these can be extended and made much more productive sources of mosquitoes with increased silt, nutrient and water inputs from urban and industrial developments.

Any construction practice that increases the flow of water, silt or nutrients, or interrupts or prolongs the drainage through these areas, has the capacity to increase the amount of mosquito breeding. This is particularly so in the upper high tide area, where the often naturally self draining margin of the mangroves can be easily disturbed and result in the pooling of tidal water. Such sites can be quite small, but extremely productive in the numbers of salt water mosquitoes such as *Ochlerotatus vigilax.*

At present the Northern Territory Government and the Darwin City Council have a continuing mosquito engineering control program around urban Darwin, to rectify past poor

construction practices. The annual expenditure for the three years 1985-1987 has been in the region of $180 000.

This annual expenditure included funds for the construction of drains and a proportion to permanently upgrade those drains that repeatedly breed mosquitoes. The program will need to be relatively long term to rectify all the past poor construction practices and achieve a relatively mosquito free city, particularly when poor construction practices are still proceeding. In contrast, planners of the new satellite city of Palmerston considered the potential for mosquito breeding at an early stage. The siting of the urban areas, the rectification of existing mosquito breeding areas, the design and endpoints of the storm drains, and reclamation works in Palmerston have resulted in a relatively mosquito free urban environment. This consideration in the planning stage has been a very cost effective solution.

5.0 **Construction practices that can** result in **mosquito breeding**

Mosquito problems created by previous construction practices are detailed in Appendix I.

5.1 **Sand Extraction**

Deposits are usually found in low lying areas along swamps and creeks or close to the tidal areas. Any sand extraction activity has the capacity to produce wet season flooded depressions or waterfilled borrow pits that quickly become colonized with aquatic or semi aquatic vegetation and result in new mosquito breeding areas. These areas can be extremely productive, particularly if the borrow pits have some tidal influence, as this can eliminate may of the freshwater aquatic predators of mosquito larvae. Those sand extraction areas that are deep enough to penetrate the water table can become perennial mosquito sources.

5.2 **Storm Water Drainage**

Storm water drain construction can produce mosquito breeding sites by poor placement of berm material and the disruption of normal drainage patterns. If the disruption of drainage is in tidal areas it can create extreme mosquito problems.

Open unlined storm drains with relatively permanent dry season flows can be mosquito sources, particularly if the drain receives organic nutrients from urban run off or industrial processes.

If storm drains with considerable dry season flows are directed into low lying areas, particularly in the upper high tide zone, considerable ecological disturbance can result in dramatic increases in mosquito breeding.

5.3 **Road embankments and Access Roads**

Road embankments and access roads can result in impoundments or impedance of normal drainage patterns and frequently cause at least wet season pooling. Detailed topographic and vegetation surveys are usually necessary to avoid such disturbances.

5.4 **Water Retention in Tidal Areas**

The construction of water retention features can result in altered vegetation patterns that can give rise to mosquito breeding. Water retention in standing mangrove areas which

results in the death of mangroves can create extremely productive sources of the salt marsh mosquito, the salt water *Anopheles* or the salt water *Culex* mosquito. Inundation of disturbed tidal areas by high tides, rain or waste water can result in emergence of large numbers of mosquitoes. Meticulous planning or water retention features is necessary to avoid creating mosquito breeding sites. Aspects that need particular attention include the final water level, the quality and salinity range of the impounded water, the maintenance drainage capability, the potential vegetation growth in or at the edges, and the inflow of silt.

5.5 **Land Fill Operations**

Land fill in tidal areas can disrupt previously self draining areas and result in pooling of water. This is particularly so if the land fill has silt laden run off and is sited in a complex drainage pattern. Pollution and vegetation growth at the edge of land fill operation in water can eliminate or restrict the normal activity of aquatic predators and give rise to mosquito problems.

5.6 **Sewage Pond Construction**

The siting of sewage ponds is one of the most important factors in reducing potential mosquito problems. Recent siting of ponds in Darwin has been excellent, as disruption of mangrove drainage patterns has been avoided, and access and service embankments have not resulted in the inadvertent impoundment of water.

Maintenance needs, such as emptying certain ponds, can cause extreme mosquito problems unless the pond contents can be channelled or discharged directly to a daily flushed tidal area. These maintenance practices need to be considered in the planning stages and should be important factors in the choice of a site.

The type of ponds, particularly the depth, size and bank material can have a large bearing on whether the ponds are mosquito sources.

5.7 **Urban Subdivisions**

When urban subdivisions are poorly sited near pre-existing mosquito sources, or sites that have the potential to become sources, it is very likely that there will be public pressure at a later date to rectify the mosquito breeding. Sometimes the rectification works can be extremely expensive, or severely disrupt natural features such as swamplands. It is logical to avoid such costly rectification works or possible destruction of animal and fish habitats, by the correct siting of urban subdivisions.

The Health Department has recommended avoiding large and uncontrolled tidally influenced mosquito breeding areas by having a 1.6km buffer between the breeding areas and the proposed urban development.

This buffer is very relevant for those large salt marsh swamps with fresh water input such as Leanyer Swamp and Howard Swamp, but it is of little relevance for very small areas that are not very productive, or that can be easily controlled or rectified.

If urban areas are built near these large and at present uncontrollable mosquito breeding areas, then attempts will be necessary to control the breeding. Examples of types of physical control methods recommended include:

1. Swamp drainage by a system of channels

2. Tidal bunds, tide gates and an internal drainage system

3. Steep sided relatively deep (greater than 2. Om) excavated fresh water lake

4. Salt water lake.

Insecticide control for extended periods should not be contemplated as a control measure around urban areas, as there can be no certainty that such methods will be effective in the longer term.

6.0 Guidelines for Construction Practice

6.1 Borrow Pits and Excavations

6.1.1 No borrow pits, extractive industry or excavation should be conducted within the tidal zone, unless provision is made to prevent ecological changes.

6.1.2 Borrow pits or extractive operations should not excavate to a base level below maximum high tide level.

6.1.3 Cover material and vegetation should not be pushed into the tidal zone. There should be no impedance of overland flow into the tidal zone.

6.1.4 All borrowing or extractive areas should be rehabilitated immediately upon completion of the operation such that all operational areas are completely self draining.

6.1.5 Vehicle disturbed areas such as wheel ruts and compacted soil areas should be rectified as soon as practical to prevent water ponding.

6.2 Storm Water Drainage

6.2.1 Drains should be constructed to discharge direct into regularly flushed tidal areas, such as tidal creeks or a formalized channel dug back from a tidal creek. In Darwin 100 year flood drains should be constructed to the 3.7 AHD level and low flow drains to the 3. 0 AHD (or below this level if silt accumulation is a potential problem).

6.2.2 Drains through tidal areas need to be of dimensions that will not result in silt accumulation in or near the drain. Low flow drains should be installed wherever there is the possibility of longer term dry season flows. Such drains can be either impervious above ground inverts or sub soil pipes.

6.2.3 Low flow drains should be installed wherever there is the possibility of longer term dry season flows. Such drains can be either impervious above ground inverts or sub soil pipes.

6.2.4 Access along all drains is necessary for regular maintenance.

6.2.5 Drains through tidal areas should follow the course of existing creeks or flow lines wherever possible.

6.2.6 Drains for mosquito control purposes should be only of dimensions that are necessary to drain over a period of 2 to 3 days for tidal areas, and 4 to 5 days for fresh water, unless there are other considerations requiring larger drains.

6.2.7 Silt traps should be installed in drains that are likely to carry considerale silt loads. This is particularly necessary in large urban drains during subdivision construction.

6.3 Embankments and Access Roads

6.3.1 No embankments should be constructed across tidal areas unless provision is made for sufficient tidal exchange to prevent any considerable ecological change. If upstream impoundments of tidal water are completely flushed at least once in 7 days, there is usually no significant mosquito breeding in the impounded tidal water.

6.3.2 Embankments should have provision for complete drainage of upland areas at least over a period of less than five days after flooding. This particularly applies to areas near the tidal limit, which would only be reached by tides once in 10 to 14 days.

6.3.3 Embankments for land reclamation purposes should have an internal drainage system with tide valves at the embankment. If upland flows are diverted around the reclamation area, the diverted flow should be discharged direct to the major tidal drainage line immediately seaward of the embankment.

6.3.4 Vehicle access along the upper high tide zone should be restricted as much as possible, to prevent the creation of vechile disturbed areas that could pond tide and rainwater.

6.4 Water Retention in Tidal Areas

6.4.1 An ecological and hydrological study should be undertaken before any water retention feature is constructed in a tidal area.

Those aspects that are considered critical to the success of an aquatic feature include:
the levels and seasonal fluctuations in salinity; the possible aquatic and semi aquatic vegetation changes likely to occur; the effect on aquatic animal life; the number of days under tidal influence; the depth of the retained water; inputs of organic and other pollutants into the system; the' source., amounts. and quality of possible top up water; the provisions for periodic maintenance; possible ecological effects seaward of the retention.

6.4.2 If the tidal regime in the water feature is significantly reduced or eliminated, all existing mangroves in the retention area should be removed.

6.4.3 Silt traps should be constructed at all significant silt entry points.

6.4.4 Regular vegetation maintenance or control programs will be necessary. The provision of 1:1 side slope or impervious margins should be considered to reduce maintenance needs.

6.4.5 There should not be any small cut off areas at any height level of the water.

6.5 Land Fill in Tidal Areas

6.5.1 Land fill operations should not impede any established drainage patterns, either by the land fill operations, or possible erosion from the fill area.

6.5.2 There should be drainage provisions all around the base of sanitary land fill operations, and these drains should discharge direct to a daily flushed tidal system.

6.6 Sewage Pond Construction.

6.6.1 Sewage ponds should be sited preferably on bare mud flat areas in preference to existing mangrove areas to minimize ecological disturbances.

6.6.2 The siting of ponds should not result in any impedance to pre-existing drainage lines,either landward or within the tidal area.

6.6.3 Pond drainage during maintenance should be direct to daily flushed tidal areas.

6.7 Urban Subdivision

6.7.1 A mosquito buffer zone for the exclusion of urban residential development is recommended within 1.6km of large and uncontrolled tidally influenced mosquito breeding areas.

6.7.2 No urban residential developments are recommended within 1km of mangroves, unless biting midges are not likely to be a significant problem.

6. 7. 3 Any subdivisions bordering tidal areas should incorporate a buffer distance between the high tide level and property boundaries, so that access is possible for management purposes, and to prevent the creation of new mosquito breeding sites.

7.0 Consultation

The Medical Entomology Branch of the Northern Territory Department of Health and Community Services is available for advice on what may constitute a potentially significant mosquito breeding site. In some instances where detailed entomological investigations are necessary, 12 months entomological monitoring may be required before the detailed planning stage. For significant entomological investigations, it may be necessary for the developer to engage an entomological consultant.
Consultation for any project within a tidally affected area may be required with the Northern Territory Department of Lands, the Environment Unit of the Conservation Commission, or the Coastal Management Technical Advisory Group (C. O. M. T. A. G) .

Appendix I

Previous mosquito problems in the Top End of the Northern Territory created by Construction Practice

1.0 Sand Extraction

Bynoe Harbour

Sand extraction on a beach area in Bynoe Harbour resulted in an area of mangroves being bulldozed and pushed further into a tidal area to form a retarding barrier. Fresh water inflow into the retarding basin resulted in an area of impounded water varying from brackish to salt, depending on tidal movement. The large quantities of dead and dying mangroves contributed to high levels of organic matter and flotsam. The area proceeded to breed very large numbers of salt marsh mosquitoes and a range of other pest and potential disease carrying mosquitoes.

Casuarina Beach

Sand mining at Casuarina Beach was carried out behind the frontal dunes, to a depth below high tide level. Although initially the pits only collected freshwater, the weakened frontal dunes soon collapsed, allowing tidal entry into the pits.

The result was a range of fresh, brackish and tidal water pools, with mangroves and dense salt water couch grass, providing ideal habitats for a large range and huge numbers of mosquitoes. These mosquitoes seriously disrupted the recreational use of the nearby park, and affected nearby residential areas and the hospital area.

2.0 Storm Water Channelization Ludmilla Creek

During the installation of storm water drainage in the Ludmilla area, a large channel was constructed through the upper reaches of the Ludmilla mangroves to convey the increased storm water further downstream. The spoil from the channelization was thrown up on the sides of the channel to form a continuous embankment. This embankment disrupted the free drainage of the nearby mangrove and mud flat areas, resulting in cut off tidal depressions throughout the upper reaches of mangroves. These depressions created the breeding sites for hordes of salt marsh mosquitoes that plagued the general area for many years until rectified by the re-establishment of a drainage system under the combined mosquito engineering control group.

3.0 Storm Water Discharge, Sandy Creek, Tiwi

The construction of storm water drainage in the Tiwi area resulted in the discharge of storm water into the upper reaches of Sandy Creek along Rocklands Drive. With residential development, this extensive drainage system had considerable dry season flows from overwatering and wash down activities, which transformed the seasonal drainage line into a permanently flowing creek. Ecological changes occurred in the creek and for a considerable distance downstream into the

mangrove areas of Sandy Creek. Fresh water and brackish water reeds began growing beneath mangroves and on former bare mud flat areas.
Silt accumulation caused drainage pattern changes and pooling of both fresh and tidal waters over considerable areas. Some areas of mangroves died while others colonized new areas. These ecological changes led to the creation of a range of mosquito breeding habitats and serious mosquito pest problem.

4.0 Road Embankments and Access Tracks

Tiger Brennan Drive

During the construction of the Tiger Brennan Drive extension, a large area of mangroves was cut off from regular tidal influence by an earth embankment. Some areas of the mangroves were flattened and left in situ, while other areas were bulldozed clear, leaving deep machinery tracks. Inadequate temporary drainage pipes were installed which were too small to allow sufficient drainage of impounded water, sited too *high to* allow complete drainage, and yet sufficient to allow tidal ingress and water level fluctuations. This situation led to a stagnant brackish water impoundment, with periodic tidal flooding of sheltered shallow water and artificial depressions. The resultant emergence of salt marsh and other species of mosquitoes required regular surveys and mosquito control operations in areas of inaccessible swamp. Notwithstanding that the affected area will soon be landfilled for future commercial development, even short-term impoundment of brackish water provides an unacceptable environment that promotes mosquito breeding.

Access Tracks

Access tracks, particularly those constructed by Electricity or Sewerage authorities, are frequently just above tidal reach, due to the positioning of many of their facilities. These tracks sometimes have inadequate drainage provisions which can interupt overland water flow into tidal areas or disrupt tidal drainage patterns. This can result in the retention of water in drainage lines and creeks, creating swampy areas, or cause pooling on the uphill sides of the track. In some instances, when drainage is constructed under the road, scouring on the downhill side of the drain can result in depressions that can fill after rain or high tides.

5.0 Water Retention Features in Tidal Areas

Examples of the range of problems created by water retention in tidal areas can be illustrated by the construction of the Frances Bay Mooring Basin, the old Fannie Bay Golf Club dam, the Gove alumina final retention pond and Palmerston Lake on the Darwin City Council Golf Course. All of these projects had water retained either permanently or temporarily during construction, and were periodically under water level fluctuations by tidal or storm water influence. Each impoundment exhibited a range of salinities and resulted in vegetation changes which included either death of mangroves, growth of fresh or brackish water reeds, death of fish or other aquatic mosquito predators or prolific algal growth.

Any of these factors can result in prolific breeding of mosquitoes. The ecological modifications caused by the construction has usually been considerable and the mosquito breeding can only be alleviated by expensive or critically timed water management procedures.

In the mooring basin, the mangrove death and coincident mosquito breeding was caused by the embankment of an area of mangroves upstream of the mooring basin, with inadequate provision for stormwater drainage from the impounded area.

The Old Fannie Bay Dam mosquito problems arose from the creation of a non draining tidal depression which was periodically flooded by high tides.

Extensive algal growth and colonization by dense reeds in the Palmerston Lake resulted from infrequent tidal entry, inadequate pumping capacity for top up sea water, inflow of organic rich storm water and the insufficient side slope and depth of the impoundment.

The Gove waste water retention pond was created by impounding a large area of mangroves behind an embankment. The low salinity and high PH of the impounded water caused the death of a large area of dense mangroves and destroyed all aquatic life except for periodic pulses of enormous numbers of mosquito larvae. The periodic plagues of salt marsh mosquitoes from this area precipitated industrial problems and ushered in a mosquito control program which was frequently inefficient. The large area of mosquito breeding and the inaccessibility of the breeding areas by a tangle of dead mangroves hindered larval control, and adult mosquito control by fogging was restricted by the lack of all around access to cope with varying wind directions.

6.0 **Sanitary Land Fill, Leanyer Dump**

Urban refuse fill into the edge of a salt marsh resulted in areas of polluted marsh becoming significant mosquito breeding sites as the normal aquatic predators such as fish beetles and bugs were eliminated. Other areas became breeding sites by poor placement of the fill creating cut off pools or silt runoff interrupting surface drainage patterns. Additional problems were created by depressions left by the operation of machinery on the salt marsh floor. In one instance, the stockpiling of a large number of tyres without a covering of soil led to appreciable numbers of artificial container breeding mosquitoes affecting nearby suburbs.

7.0 **Sewer Line Construction**

The installation of sewer lines, by the nature of gravity flow requirements, are invariably installed near the tidal zone. The creation of mosquito breeding has been caused by the construction of embankments to carry pipes across tidal areas, the subsidence of excavations, or the pushing of earth and debris into the mangroves. An embankment across a former tidal creek in Coconut Grove resulted in changing a free draining section of tidal creek into a dense swampy fresh water reed swamp. The ecological changes were not confined to upstream of the embankment. Continued seepage through the embankment caused mangrove species change in the tidal area below the embankment and the resultant root growth and silt accumulation created a series of brackish and saline cut off pools. A section of the control zone sewerage scheme bordering tidal areas of Fannie Bay created depressions by machinery disturbance and subsidence of earth cover. More recent installations for the Trade Development Zone created additional mosquito breeding sites by pushing earth and mangroves into the tidal zone.

8.0 **Construction of Leanyer Sewage Ponds**

The siting of the Leanyer Ponds and associated embankments led to severe disruption of mangrove drainage patterns. One embankment had provision for drainage but the culvert was not installed with any consideration for possible ecological consequences. This area retained fresh water in the wet season, but was still subject to very high tides. Mangroves within the embankment died and the previous mud flat was transformed into a dense brackish water reed swamp. In addition, the maintenance of certain ponds could only be achieved by effluent release into the impounded area. In the tidal area, the drainage pattern disruptions led to very large areas of mangrove channels and flow lines without the capacity to drain freely at low tides. Subsequent mangrove vegetation growth further aggravated the disruption and resulted in large areas of tidal pooling. The consequences of these practices led to enormous populations of a range of mosquito species, severely affecting nearby residential areas.

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