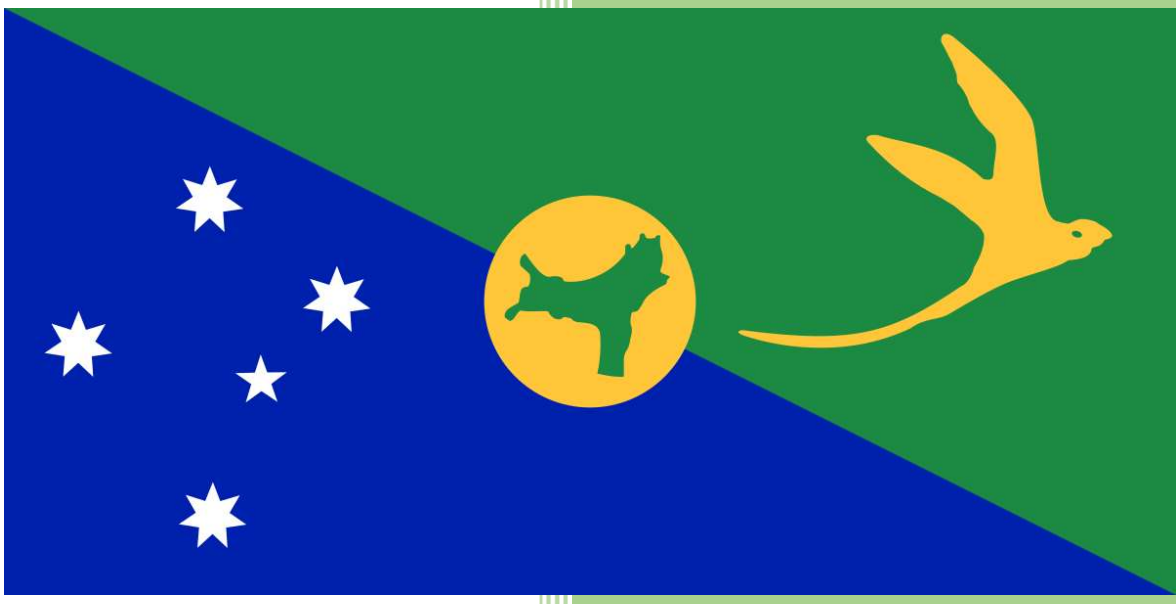
2025

Landslide Risk Management Plan

Endorsed for Use – December 2025



Emergency Management Committee
Christmas Island

Adoption by the EMC

The Christmas Island Rockfall Risk Management Plan (RRMP) was a result of the 1997 Parliamentary Standing Committee on Public Works report on the Implementation of Rockfall Risk Reduction Strategies on Christmas Island (Appendix C). The RRMP recognised the Commonwealth's commitment to reducing rockfall risk across Flying Fish Cove.

To reflect the impact of debris flow landslides on Flying Fish Cove, the RRMP was significantly updated in 2025 and has been renamed the Landslide Risk Management Plan (LRMP) (this document).

The LRMP is maintained by the Indian Ocean Territories Administration (IOTA) Emergency Management Officer as secretariat to the EMC.

The Landslide Risk Management Plan is adopted by the Emergency Management Committee to ensure a coordinated response to rockfall risk on Christmas Island. As Chair of the EMC, the Administrator signs on behalf of the Committee recognising their commitment to the strategies within the LRMP.

The Christmas Island Landslide Risk Management Plan is hereby adopted by the Christmas Island Emergency Management Committee.

17 December 2025

Administrator Farzian Zainal
Chair
Christmas Island
Emergency Management Committee

Date

Contents

Amendments

Proposals for amendment or addition to the contents of the Plan are to be forwarded to:

Emergency Management Officer
Indian Ocean Territories Administration
Department of Infrastructure, Transport, Regional Development, Communications, Sport and the Arts
PO Box 868
Christmas Island 6798

Or via email to operations@infrastructure.gov.au

Document history and status

Revision	Prepared by	Approved by	Date approved	Date Issued
Original	GHD Pty Ltd			2001
Review	DOTARS -			2004
Draft	DOTARS -			2005
Full	DOTARS - Karen Singer	Administrator - Neil Lucas	16 June 2006	2006
Draft	DOTARS – Chris Dunn			2007
Draft	AGD – Chris Dunn			2009
Final	AGD- Chris Dunn			2009
Review rainfall triggers	IOTA – Mark Slattery	Administrator - Jon Stanhope		2013
Review of actions	IOTA – Chantelle Powell	Administrator - Barry Haase		2016
Updated Level 1 action table	IOTA – Jessica Sullivan	EMC Executive		2016
New format & incorporated flowchart	IOTA – Jessica Sullivan	Administrator - Natasha Griggs		2017
Review	IOTA- Brad Stringer	----------	----------	---------
Review of rainfall triggers, review of actions.	GHD Pty Ltd			2024
Review of all actions	IOTA David Young	EMC		2025
Endorsed for Use	**EMC**	**Administrator – Farzian Zainal**	**11 Dec 2025**	**17 Dec 2025**

Interpretation

"Administrator" means the Commonwealth Official appointed to administer the Territory of Christmas Island on behalf of the Commonwealth of Australia under the *Administration Ordinance 1968.*

"Administration" means the Indian Ocean Territories Administration which is the on-island branch of the Department of Infrastructure, Transport, Regional Development, Communications, Sports and the Arts

"AFP" means the Australian Federal Police.

"BoM" means the Bureau of Meteorology.

"Department" means the Department of Infrastructure, Transport, Regional Development, Communications, Sports and the Arts responsible for the Indian Ocean Territories.

"EMO" means the Emergency Management Officer appointed by the Indian Ocean Territories Administration.

"PWC" means the Parliamentary Standing Committee for Public Works, which conducted the hearing on Implementation of Rockfall Risk Reduction Strategies on Christmas Island in July 1996.

"LRMP" means the Landslide Risk Management Plan,

"The Cove" means Flying Fish Cove and Road to Smith Point.

"SOCI" means Shire of Christmas Island.

"Stevedores" means the Complete Stevedoring and Freight Services.

"Territory Controller" means the Officer in Charge, Australian Federal Police, who is responsible to the Administrator for the conduct of counter disaster operations.

"6RCI" means Christmas Island Community Radio Station.

Actions in the Event of a Landslide Warning

Landslide Yellow Alarm

Rainfall: Cumulative **30-day rainfall total exceeds 500 mm** or

Rockfall Events: In the order of **2 m³ aggregate** or greater seen to occur or

Debris Flow Event: In the order of **5 m³ aggregate** or greater seen to occur.

This condition lasts until the cumulative 30-day rainfall total falls below **400 mm OR** as advised by geotechnical experts.

Landslide Yellow Alarm Actions

Responsible party	Action
Immediate Actions	
AFP **EMO/ IOTA**	1. Activate Yellow lights at ALL 5 locations (Appendix B) and place the ROCKFALL/LANDSLIDE sign on all co-located posts. 2. Increase frequency of inspections along landslide barriers to weekly. 3. Instigate monthly drone flights of cliff faces, weather permitting.
Actions During Yellow Alarm Period	
EMO/ IOTA	1. Monitor cumulative 30-day rainfall. 2. Contact 6RCI and request Yellow Advice Radio Message 1A (Appendix A). 3. Yellow Advice Message 1A to be posted on Emergency WA and IOT News. (Appendix A). 4. Monitor BOM forecast for upcoming rainfall or wind events that may trigger an Amber Alarm.
Actions at the conclusion of a Yellow Alarm Period	
EMO/ IOTA **AFP**	1. Contact 6RCI and request Yellow Advice messages be stopped. 2. AFP turn off Yellow Alarm lights (5 locations).

Landslide Warning Amber Alarm

Rainfall - Cumulative: Cumulative **30-day rainfall total exceeds 500 mm** or

Rockfall Events: In the order of **2 m³ aggregate** or greater seen to occur or

Debris Flow Event: In the order of **5 m³ aggregate** or greater seen to occur or

Plus

Rainfall – Event: **50 mm in any hour** or a BoM forecast indicating this may occur or

Rainfall – Event: **100 mm in 12 hours** or a BoM forecast indicating this may occur or

Rainfall – Event: **150 mm in 24 hours** or a BoM forecast indicating this may occur or

Seismic event: Any observable seismic event

Wind event: Wind speeds corresponding to a Category 1 cyclone
Maximum mean wind speed 63 – 88 km/h.
Typical strongest gust up to 125 km/h.

This condition lasts until the cumulative 30-day rainfall total falls below **400 mm OR** as advised by geotechnical experts.

Landslide Amber Warning Actions

Responsible party	Action
Immediate Actions	
AFP	1. Turn on the Amber Alarm lights at all 5 locations (Appendix B) and place the ROCKFALL/LANDSLIDE sign on all co-located posts. 2. Restrict access to Flying Fish Cove and Smith Point using barrier installed at the AFP Boat shed. 3. Evacuate the Cove of ALL personnel from the AFP boat shed to Smith Point and close the boat ramp to the public. Access only granted for essential personnel as approved by the EMC Executive. 4. Inform the Harbour Master of your actions. 5. Smith Point users (Water Corporation, Indian Ocean Oil Company and Tai Jin House) are to inform AFP when All PERSONS have exited their site and should access be required during the alert period, approval from AFP must be sought. 6. Place Rockfall/Landslide alert signs at the roundabout. 7. Inform Emergency Management Officer of actions undertaken.
EMO/ IOTA SOCI	1. Post Amber Warning message on Emergency WA and IOT News Facebook page. 2. Contact 6RCI and request the broadcast of Amber Warning message 2A (Appendix A). 3. Inform Works and Services Manager, Shire of Christmas Island, to implement temporary speed reductions of 40kmh along Murray Road between Silver City Road and Gaze Road. 4. Following advice from AFP, inform Administrator of commencement of Amber Alarm and actions undertaken.

Responsible party	Action
Actions During Amber Alarm Period	
EMO/ IOTA	1. After 24 hours from last initiation, inspect the rockfall fence for signs of rockfall or subsidence. Report to the AFP regarding the condition of the barrier fencing and findings of the inspection. 2. Monitor cumulative 30-day rainfall.
EMC Exec	1. EMC Exec to provide approval on request for essential personnel to enter the area beyond the AFP boat shed.
Actions at the conclusion of Amber Alarm Period (de-escalation to Yellow)	
EMO/ IOTA	1. Determine if it is safe for the alarm to cease, considering the outcome of the inspection of the rockfall fence by the Emergency Management Officer and the cumulative 30-day rainfall. 2. Inform Works and Services Manager Shire of Christmas Island, to remove temporary speed reductions of 40kmh along Murray Road between Silver City Road and Gaze Road. 3. Post information on Emergency WA and IOT News Facebook page. 4. Contact 6RCI and request Yellow Advice Downgrade message 1B for 24 hours (Appendix A). 5. Inform Administrator of cessation of Amber alert.
AFP	1. Remove barrier to the Cove. 2. Change warning lights to Yellow for a period of 24 hours. 3. Remove Rockfall/Landslide signs from the roundabout.

Rainfall - Cumulative: Cumulative **30-day rainfall total exceeds 650 mm** or

Rockfall Events: In the order of **5 m³ aggregate** or greater seen to occur or

Debris Flow Event: In the order of **10 m³ aggregate** or greater seen to occur or

Plus

Rainfall – Event: **65 mm in any hour** or a BoM forecast indicating this may occur or

Rainfall – Event: **130 mm in 12 hours** or a BoM forecast indicating this may occur or

Rainfall – Event: **200 mm in 24 hours** or a BoM forecast indicating this may occur or

Seismic event: Any observable seismic event

Wind event: Wind speeds corresponding to a Category 2 cyclone
Maximum mean wind speed 89 – 117 km/h.
Typical strongest gust up to 164 km/h.

This condition lasts until the cumulative 30-day rainfall total falls below **500 mm OR** as advised by geotechnical experts.

Landslide RED Alarm Actions

Responsible Party	Action
Immediate Actions	
AFP	1. Turn on the RED Alarm lights at all 5 locations (Appendix B) and place the ROCKFALL/LANDSLIDE sign on all co-located posts. 2. Restrict access to Flying Fish Cove and Smith Point using barrier installed at the AFP Boat shed (if not already done on Amber alert). 3. If not already done, evacuate Smith Point users (Water Corporation, Indian Ocean Oil Company and Tai Jin House). AFP are to be informed when ALL persons have exited their site. *Should access be required during the alert period, approval from EMC Exec must be sought before entering the restricted area. 4. Evacuate the Marine building, AFP Boat shed, Al Baraka supermarket and Madrassa. Access only granted for essential personnel as approved by the EMC Executive. 5. Inform Harbour Master of actions.
EMO/IOTA	1. Post Red Warning message on Emergency WA and IOT News Facebook page. 2. Contact 6RCI and request the broadcast of Red Warning message 3A (Appendix A). 3. Inform Works and Services Manager, Shire of Christmas Island, to implement temporary speed reductions to 40kmh/hr along Murray Road between Silver City Road and Gaze Road (if not already done on Amber alert).

Responsible Party	Action
	4. Close carpark behind Block 403 (if not already done on Amber alert). 5. Following advice from AFP, inform Administrator and EMC of commencement of Red Alarm and actions undertaken.
SOCI	1. Close road access to the fence line and Catholic Church. 2. Restrict access to Kampong to local and essential traffic.
Actions During RED Alarm Period	
AFP	1. Maintain closure of access to the Cove area. * If access is required for essential services, this will need to be authorised by the EMC Exec. 2. Monitor closed road access to the fence line, Catholic Church and Madrassa. 3. Monitor public's movement in Kampong area during shifts. 4. After 48 hours and when deemed safe to do so, inform Al Barakah Supermarket Manager– shop can reopen with occupancy restricted to 8 persons at all times, including staff. 5. Madrassa to remain CLOSED during RED Alarm Period.
EMC Executive	1. To meet daily.
Actions at the conclusion of Red Alarm Period (de-escalation to Amber)	
AFP	1. In consultation with the EMC Executive, determine if it is safe for the alarm to be downgraded to Amber, considering the outcome of the inspection of the rockfall fence and the cumulative 30-day rainfall. 2. If so determined, deactivate Red Alarm lights and switch on Amber lights. 3. Cancel Red Alarm conditions and resume Amber Alarm conditions.
EMO/ IOTA	1. Contact 6RCI and request the broadcast of Amber Decrease Broadcast 2B (Appendix A). 2. Inform Administrator cessation of Red Alarm and return to Amber Alarm conditions. 3. Inform Al Barakah Supermarket, Madrassa and Marine Building occupants that restrictions no longer apply. 4. Open carpark behind Block 403. 5. Update information on Emergency WA and IOT News Facebook page.
SOCI	1. Open Road access to the Fence Line and Catholic Church.

Landslide Amber Warning Actions (De-escalation from Red Alarm)

Actions at the conclusion of Amber Alarm Period (de-escalation to Yellow)	
AFP	1. In consultation with the EMC Exec, determine if it is safe for the alarm to cease, considering the outcome of the inspection of the rockfall fence and the cumulative 30-day rainfall. 2. If so determined, remove barrier to the Cove. 3. Change warning lights to Yellow for a period of 24 hours. 4. Remove Rockfall/Landslide signs from the roundabout.
EMO/ IOTA	1. Contact 6RCI and request Yellow Advice downgrade message1B (Appendix A). 2. Inform Works and Services Manager, Shire of Christmas Island, to remove temporary speed restrictions of 40kmh along Murray Road between Silver City Road and Gaze Road. 3. Inform Administrator of cessation of Amber Alarm and moving into Yellow Alarm for 24 hours. 4. Post information on Emergency WA and IOT News Facebook page.

Auto-Dialler Warning System

When triggered, the Drumsite rain gauge will SMS, Email and auto-dial pre-set recipients to advise that a rockfall alarm has been activated, notifying the recipients through a pre-formatted message. The following actions are to be taken on receipt of this warning:

For Auto Dialler:-

1. The Auto Dialler will call all numbers in the system in order and will continue until a number on the telephone key pad is pressed. The current programming includes AFP, Territory Controller, EMO and IOTA Senior Ops Manager.
2. When you receive the first message, **hang up** (press the red button, NO, or stop on your telephone key pad) so that the call will go on to the next person.
3. The computer will continually call phone numbers until someone acknowledges the call by pressing any number key on the telephone key pad. When you hear the call for the second time press a number on the key pad. **Do not press the keypad on the first call**, otherwise the chain will cease and not all parties will be alerted. You need to make sure that all parties have been alerted and action commences under the Landslide Risk Management Plan for the level of alert.
4. Transition from Level 1 (Yellow) to Level 2 (Amber) or Level 2 (Amber) to Level 3 (Red) alarm and back again will initiate a new SMS, Email and auto-dialler sequence for evacuation. This should be acknowledged as above.

1 Overview

A Landslide Risk Management Plan (the Plan) was developed for the Flying Fish Cove area of Christmas Island in March 1997 and was revised by GHD Pty Ltd at the request of the Department in August 2001. It has since been updated to incorporate information from annual inspections, exercises and rockfall incidents.

The Plan details the strategies and actions to:

- Reduce the risk of rockfall impacting upon the individuals, community and facilities.
- Increase the community awareness of the rockfall hazard, its causes, mitigation efforts and methods.

A series of consultations with the community and authorities were held between 5 and 12 November 1996 and reference was made to the past studies and reports about the rockfall risk at Flying Fish Cove.

The March 1997 Management Plan included requirements for the construction of fencing and warning signs and the erection of rockfall barriers to the areas at higher levels of risk. These were completed.

A further review of landslide risks was undertaken in July 2000.

Following this the rockfall barriers were extended to the length of the Kampong and a secondary barrier comprising an earth berm was constructed in the areas subject to a greater risk of rockfall.

In 2006 a review was undertaken to assess the landslide risk and recommend risk reduction measures along Jalan Pantai, where it extends from Flying Fish Cove to Smith Point.

In 2012/13, a review was undertaken using records and data to assess the accuracy of the Level 1 and Level 2 triggers.

It was recommended that the Landslide Risk Management Plan be updated to reflect the possibility of a catastrophic tank failure due to an identified issue of the water tank foundations at Drumsite and George Fam. This measure is no longer required as the foundations of the water tanks have been strengthened.

In 2016 a review was undertaken of the Actions/Responses, with updates made to the Level 1 Action Table in the Plan.

In 2017 a flow chart laying out the process for the cancellation of Level 1 or 2 restrictions produced by Bowden Geological in 2015 was added to the plan.

The last issued version of the LRMP was 2018 (Reference 1).

Revision of the LRMP to include the risk of debris flow landslides and to review the trigger levels has been recommended in the Annual Inspection reports since 2017. A rewrite of the LRMP (this document) was commissioned by the Department in 2024 by GHD Pty Ltd.

1.1 Revised Nomenclature

A significant change to the Plan has been the inclusion of the risk of debris flow landslides, in addition to rockfalls, to the residents, visitors, structures and infrastructure of Flying Fish Cove. To reflect this the Plan has been renamed the **Landslide Risk Management Plan (or LRMP)** as the term “landslide” better reflects both debris flow and rockfall hazards.

1.2 Management Plan Structure

The Management Plan has been structured around the following:

i. **Control of Population Exposure to Hazard** by land use planning and reductions in activity on the foreshore, either permanently or during periods of high risk.

ii. **Warning Mechanisms** leading to appropriate responses at times of greater risk. Monitoring of rainfall, seismic activity and landslide incidents are the factors with potential for warning of rockfall. These factors have been grouped under three levels of warning conditions:

- Level 1 condition (Yellow Alarm) – elevated risk period.
- Level 2 condition (Amber Alarm) – possibility of an event.
- Level 3 condition (Red Alarm) – probability of an event.

iii. **Community Awareness and Education Programs** to inform, involve and educate the community to increase the perception of the hazard, its causes, mitigation efforts and methods. Develop a broader awareness of the Level 1 and Level 2 warning conditions and the expected response to them by the community.

iv. **Research** to collect data over time to improve the understanding of the slope processes and refine the risk analysis.

v. **Review** of the plan to ensure that recommendations made by specialist personnel and those involved with the plan are updated, and improvements to the plan are made.

Each of these strategies is developed by the plan to provide a series of actions with responsibilities.

It should, however, be realised by all concerned that a risk management plan can reduce but never entirely remove the risk of injury/fatality due to a landslide event.

The main stakeholders and participants in the implementation of this management plan are:

- Administrator.
- The Department.
- Shire of Christmas Island.
- Australian Federal Police.
- Kampong Residents.
- Harbour Master.
- Complete Stevedoring & Freight Services.

Other stakeholders include:

- National Emergency Management Agency.
- The Bureau of Meteorology.
- Water Corporation.
- Indian Ocean Oil Company.
- Radio Station 6 RCI.
- Australian Border Force.
- Royal Australian Navy.

2 Introductory Provisions

2.1 Background

By resolution on 17 June 1996, the House of Representatives referred the proposed implementation of rockfall risk reduction strategies on Christmas Island (Reference 1) to the Parliamentary Standing Committee on Public Works for consideration and report to parliament. Included in the strategies was a requirement to have in place a Landslide Risk Management Plan before December 1996. Accordingly, a Landslide Risk Management Plan was commissioned by the Department responsible for the Indian Ocean Territories on 31 October 1996 and prepared by Works Australia during November-December 1996. Advice on the plan was provided by Consulting Engineering Geologist Dr Fred Baynes. The Plan was revised in 2001, updated in October 2004, September 2005, June 2006, March 2013, 2016 and March 2017. The last issued version of the Plan was dated 2018 (Reference 2).

This document presents a major revision to the LRMP (i.e. the inclusion of debris flow landslides as a hazard) and the renaming of the plan as the Landslide Risk Management Plan (LRMP) to reflect that change.

The Plan is administered by the Department responsible for the Indian Ocean Territories (the Department) through the Indian Ocean Territories Administration.

2.2 Title and Purpose

This management plan shall be referred to as the Landslide Risk Management Plan – Flying Fish Cove and Road to Smith Point (LRMP). The purpose of the LRMP is to reduce the risk of injury or death to individuals and the risk of damage to property, from landslide in the Flying Fish Cove and along the road to the Smith Point area of Christmas Island.

2.3 Objectives of the Plan

The objectives of the LRMP – Flying Fish Cove and Road to Smith Point are:

- To detail those strategies and actions that should be implemented to reduce the risk of landslides impacting upon the individuals, community and facilities.
- To increase the community awareness about the landslide hazard, its causes and mitigation efforts.

The Plan does not address actions required in the event of a significant landslide. If this were to occur the Territory Controller would assume responsibility, under the Christmas Island Emergency Management Plan.

2.4 Scope

The Plan relates to the Flying Fish Cove and the road to the Smith Point area of Christmas Island, Indian Ocean, and seeks to involve the Community as well as those authorities that use and have responsibility for the control of land, buildings, infrastructure, services and activities at Flying Fish Cove and Smith Point.

2.5 Activation & Termination of the Plan

The LRMP commenced in December 1996 in accordance with the recommendations of the Parliamentary Standing Committee on Public Works. The LRMP is superseded by the Landslide Risk Management Plan (LRMP) in 2024. The Plan shall be continuously maintained and can only be deactivated by the Minister with responsibility for the Territories

2.6 Authority

The Administrator of Christmas Island is appointed by the Governor-General under the *Administration Ordinance 1968*, and Chairs the Emergency Management Committee

The Plan is authorised and executed by the Administrator of the Territory of Christmas Island.

2.7 Technical Review

The Technical Review of the Plan shall be carried out by the Emergency Management Committee.

The Committee shall discuss landslide risk twice a year, specifically addressing the following:

- To consider each prescribed management action and determine whether or not it is being carried out.
- To evaluate the performance of each prescribed management action in relation to the objective or objectives it is intended to serve.
- To determine the cause of any prescribed action not achieving its objective/s.
- To report to the Administrator the results of the review.
- To identify and recommend any amendments to the Plan.

Meetings should be held prior to the wet season (approx. October) and subsequent to the wet season (approx. April).

2.8 Related Documents

The Plan is to be considered in conjunction with the Christmas Island Emergency Management Plan.

3 Hazard Identification

3.1 Background

At Flying Fish Cove a series of thickly vegetated cliffs and steep intervening slopes form an amphitheatre about 200 m high above the Cove. The residential locality of the Kampong, and various other buildings and facilities, have been developed at or close to sea level on the relatively even ground at the base of the slope. The extent of this land, between the base of the cliffs and the shore, is limited and relocating the facilities is not considered viable.

Debris flows, rockfalls and the movement of boulders of various sizes down the slope are a natural process of the slopes of Flying Fish Cove and have been occurring throughout the recorded history of the area.

Whilst many of the boulders stop before they reach the lower slopes, occasionally boulders weighing several tonnes roll down onto the lower slopes and onto the base of the slope. Though there is no evidence of fatality or injury during the last 100 years there is a record of damage to infrastructure (old Boat Club and rockfall fences) and there is a risk that residents and facilities could be hit by boulders.

Debris flow landslides occur on the slopes and in recent times have reached the fences, causing significant damage to the fences and occasionally flowing out into public areas such as the Boat Ramp car park area. A risk exists that people using the public areas, residents of the buildings or infrastructure/facilities could be hit and/or engulfed by a debris flow landslide.

Rockfall risks at Flying Fish Cove were assessed in 1995 by Golder Associates (Reference 3). This report contained a summary of all of the various previous rockfall risk studies, and included detailed observations of conditions on the slopes of Flying Fish Cove, analyses of rockfall risks, and quantitative assessment of the risk of fatality. The risks were summarised in a submission to the PWC dated July 1996 (Reference 4) and that summary formed the basis for the PWC deliberations dated 19 September 1996. It should be noted that debris flow landslides did not form part of the 1995 Golder Associates risk assessment. This was largely due to a debris flow landslide not having been formally recorded since 1935.

The landslide risk along the section of Jalan Panti between Flying Fish Cove and Tai Jin House was assessed in 2006 by GHD Pty Ltd (Reference 5). That report found the slopes around Flying Fish Cove, including the road to Smith Point, are subject to ongoing slope instability and landslide events, particularly during periods of high and/or sustained rainfall events or seismic activity. The greatest risk to life and property along the road was considered likely to be large rockfalls, while the risk due to debris slides and undercutting of the toe of the slope by wave action were considered to be relatively low. The 2006 GHD report concluded that complete and effective mitigation of the risk of rock fall or debris flow landslides along the roadway would not be practical or economical, due largely to the extent of the very steep slopes and cliffs above the road. However, it was noted that implementation of a number of treatment measures and controls, as an extension to the Landslide Risk Management Plan, would assist to reduce the risk from landslides.

Landslide risk at Flying Fish Cove was reassessed by GHD Pty Ltd in a Qualitative Risk Assessment (QRA) completed in 2018 (Reference 6), with the datasets developed in the assessment updated to include all rockfalls and debris flow landslide events that had been recorded since 1995, plus the debris flow landslides recorded to have occurred since 1935. The risk assessment was further updated in April 2024 (Reference 7) to include the large rockfall that occurred above the '408' barrier fence in March 2021 (Arup, 2021). This landslide destroyed part of the '408' rockfall barrier and the largest block (approximately 100 m^3 in volume) came to rest not far from rockfall berm '2a'.

The damage to rockfall barrier fence 408 caused by the March 2021 landslide has been repaired in 2023. In addition, the boat ramp trailer parking section of rockfall barrier has been demolished and was replaced with a significantly larger, more modern flexible barrier design in 2022.

3.2 *Landslide Risk Terminology*

The terms used to describe landslide risk throughout this Plan are as defined by the Australian Geomechanics Society (AGS) (2007c – Reference 8). The main terms that are used throughout the Plan and their AGS definitions, are presented below:

- **Acceptable risk:** A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.
- **Consequence:** The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.
- **Elements at risk:** The population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by the landslide hazard.
- **Frequency:** A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.
- **Hazard:** A condition with the potential for causing an undesirable consequence (the landslide). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material and the probability of their occurrence within a given period of time. Landslide hazard includes landslides which have their source in the area or may have their source outside the area but may travel on to or regress into the area.
- **Individual risk to life:** The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.
- **Landslide:** The movement of a mass of rock, debris, or earth (soil) down a slope. The AGS landslide risk management publications use the term 'landslide' to broadly describe all forms of mass movement.
- **Likelihood:** Used as a qualitative description of probability or frequency.
- **Quantitative risk analysis:** An analysis based on numerical values of the probability, vulnerability and consequences and resulting in a numerical value of the risk.
- **Risk:** A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability and consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form. Risk is further defined as:
    - **For life loss:** The annual probability that the person most at risk will lose his or her life taking account of the landslide hazard and the temporal spatial probability and vulnerability of the person.
    - **For property loss:** The annual probability of the consequence or the annualised loss taking account of the elements at risk, their temporal spatial probability and vulnerability.

- **Societal risk:** The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental and other losses.

- **Tolerable risk:** A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.
- **Vulnerability:** The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

3.3 Landslide Nomenclature

The classification of landslides in this report follows the scheme of Cruden and Varnes (1996) (Reference 9). The following landslides are commonly referred to in this report:

- **Debris Flow:** A very rapid form of mass movement in which loose soils, rocks and organic matter combine with entrained air and water to form a slurry that then flows downslope. The flow is a broken-up mass of material that no longer retains its original structure or fabric.
- **Rockfall:** Abrupt movement of rocks that become detached from steep slopes or cliffs. Mass in motion travels most of the distance through the air and includes free fall, bouncing and rolling.
- **Slide:** A downslope movement of soil or rock mass occurring dominantly on surfaces of rupture or on relatively thin zones of intense shear strain.

3.4 Elements at Risk

3.4.1 Population

The site was divided into six areas based on the locations of buildings and infrastructure (elements at risk) situated along the toe of the escarpment. These areas along with the elements at risk in each area are summarised below.

Area	Elements at risk
Boat ramp trailer Area / carpark	Individuals in carpark (in open) Individuals in vehicle Vehicle driving along Jalan Pantai Road (north of traffic lights)
Marine Building	Individuals working in Marine Building Individuals working in Federal Police Building
Block 413 Area	Individuals in Block 413 Individuals in storage shed behind Block 413 Individuals in carpark (in open) west of Berm 2
Block 411 Area	Individuals in Block 411 Individuals on basketball court
Block 409 Area	Individuals in Block 409 Individuals in carpark (in open) west of Berm 1

Area	Elements at risk
	Individuals in storage shed behind Block 409
Madrasa / Shop Area	Individuals in Madrasa Individuals in shop
Block 403 Area	Individuals in carpark behind Block 403 Individuals in Block 403

3.4.2 Infrastructure

Power

The risk to electrical supplies to the Kampong has been mitigated by the replacement of all overhead power lines with underground cables in 1997. The network has been designed to allow for a ring feed to the area. In the event of a direct hit on a substation it could be isolated and the remaining network restored. This work would require access by electrical staff of the Indian Ocean Power Service (IOTPS) to equipment located in the area.

The power supply to the Kampong is divided across three transformers. In the event of a loss of one substation from a rockfall event it would leave either the marine building or approximately half of the residential population without power until the fault is rectified. If this is not possible for an extended period of time placement of a portable genset for emergency power to the area would be provided. A genset for events of this nature is maintained on Island by the Administration.

The power cable section along the roadway to Smith Point is vulnerable to damage from impact by a rockfall and would result in loss of the ring capacity to the Kampong and Settlement areas until the damage could be repaired. The cable construction and protection by its location beneath the other pipelines were considered at its time of installation. Any impact on the cable should not result in an exposed live cable as it would automatically be disconnected.

Waste Water

Waste Water Treatment Plant (WWTP)

The Waste Water Treatment Plant (WWTP) on Christmas Island is located at Smith Point. The plant is manned during the week and the operator may visit it on a number of occasions during the weekend.

In the event of a rock fall alarm or incident, the WWTP may not be accessible and the plant may be evacuated. The WWTP can operate automatically for a period of 24 to 48 hours if there is power supply, but after this time a manual sludge decanting and a visual check of all equipment is required. As a rule, the maximum interval between checking the plant would-be 24-hour intervals.

If the power supply was cut at the WWTP due to rock fall, then the WWTP will continue to receive waste water, but it could not be treated. The aeration tank would continue to fill, but decanting could not occur, and eventually the WWTP would overflow. An auxiliary generator is on site to maintain power to the WWTP

There are no facilities available on Christmas Island to clean up a waste water spill in the marine environment. The spill would mix with the seawater and eventually be dispersed. If access to the WWTP was permitted, action could be taken to prevent further spillage and to avoid contamination into the environment, both terrestrial and marine. The Water Corporation would inform the relevant Health and Environment authorities who will advise what precautions need to be taken.

Waste Water Pump 1

The No. 1 Waste Water Pump Station (PS1) is located along Jalan Pantai behind the Kampong units. PS1 is always heavily loaded during periods of heavy rainfall.

Equipment failure will result in an almost immediate overflow of waste water into the Cove. In the event of a breakdown of the PS1 and or genset, the Water Corporation would require, if possible, access to the site to carry out repairs.

Overflow storage tanks are installed at PS1. These tanks, when installed, will give approximately three hours of waste water storage before the waste water overflows into the Cove. The major concern of a fall occurring in this area would be the loss of power. A genset has been installed at PS1 which would automatically start should this occur. If the rockfall hit the pump station building, it would need to damage the electrical wiring, the switchboard or the genset before the pump station would fail to work. There is no contingency in place if the pump station failed due to a rockfall.

Pipelines

Two pipelines are located along the side section of the concrete road to Smith Point.

Water

The water main has approximately 166 m of exposed, above ground, ductile iron pipe. Should this pipe be ruptured due to a rockfall, then it could be isolated at the boat ramp trailer parking and outside the Smith Point fuel tanks. It could then be fed back to the other fuel tanks and refuelling jetty from the water pipe on the pipe rack. Services off the main between the closed valves (i.e. Tai Jin house and the WWTP) would not have any water supply.

Waste Water

The waste water pipe is also approximately 166 m of exposed, above ground, ductile iron pipe. This pipe is used for pumping wastewater from PS1 to the WWTP. With the exception of the southern end of Drumsite and the new IRPC, all waste water collection from Christmas Island is pumped through this pipe. A rupture of this pipeline would result in immediate waste water overflow into the bay, either direct or by flowing down the concrete section of the road and then into the bay. Ruptures to the waste water pipe would not be identified until such time as the pipe is inspected. The length of time it would take to repair the pipe would depend on the extent of damage, how much soil and rock would need to be cleared and how quickly Water Corporation can gain access to the pipe. The repair timeframe would be measured in days rather than hours.

Telecommunications

There are no active services in the area and as such there is no danger to telecommunication services from a rockfall**.**

3.5 Hazards

3.5.1 Landslide Volume Classification

The magnitudes of landslides discussed in this report have been classified according to the estimated volume of material reaching or passing the existing rockfall barrier. A breakdown of the classification is presented below. It should be noted that landslide events with volumes classified as 'large' or greater can involve both soil and rock failures and may be associated with 'complex' landslides according to the Cruden and Varnes (1996) classification (Reference 8).

Volume of Debris Reaching or Passing Rockfall Fence (m^3)	Volume Classification	Typical Dimensions of Landslide	
		Debris (m)	**Rockfall Blocks (m)**
<0.1	Very small	-	0.25 x 0.4 x 0.3
0.1 – 1	Small	-	0.6 x 0.6 x 0.6
1 – 10	Medium	4 x 2 x 1 (such as the February 2002 CI Club Fence landslide)	2 x 1.5 x 1 (such as the April 1999 old Boat Club rockfall)
10 -100	Large	9 x 4 x 1.5 (Such as the debris reaching the fences during the Basketball Court landslide)	Multiple blocks (such as March 1972 rockfall) with a range of block sizes up to about a few metres across or single blocks (similar to the March 2021 rockfall) with dimensions of up to about 4 m x 5 m x 5 m.
100 – 1000	Very large	Such as the October 2016 old Boat Club landslide	Multiple blocks (such as the March 2021 rockfall). The largest block in the 2021 rockfall had dimensions of about 4 m x 6 m x 6 m (nominally 100 m^3). Historical rockfalls such as the rockfall at the northern end of the site adjacent to the Christmas Island Club Fence suggest individual blocks up to about 590 m^3.
> 1000	Extremely large	A number of large and very large landslides, such as April 1935 landslides	As per very large events

3.5.2 Rockfall Hazard

Rockfalls are defined as abrupt movement of rocks that become detached from steep slopes or cliffs, with the mass once in motion travelling part of the distance through the air, including free fall, bouncing and rolling.

The areas of Flying Fish Cove identified to be at risk due to rockfalls from the upper cliff line are indicated in Figure 1 and Figure 2 and from the intermediate cliff line in Figure 3 and Figure 4. It should be noted that a rockfall could conceivably extend beyond the probable limit of rockfall defined in the figures, but that the risk of this happening is considered to be negligible.

Level of Risk from Rockfall

GHD 2024 have created a rockfall landslide volume frequency model. The rockfall landslide volume frequency model predicts the long-term average number and volume of rockfall landslides reaching the toe of the escarpment per year. The Flying Fish Cove model is based on knowledge and interpretation of the documented rockfall landslides in the landslide inventory (see Appendix A).

Average annual number landslides, category volume and average annual volume per year in each volume category

Average landslides per year	Very small	Small	Medium	Large	Very Large	Extremely Large	Totals
Volume (m^3)	0.2	0.5	0.3	0.6	3.8	0	5.4
Number	5.2	1.7	0.12	0.04	0.02	0	7.1

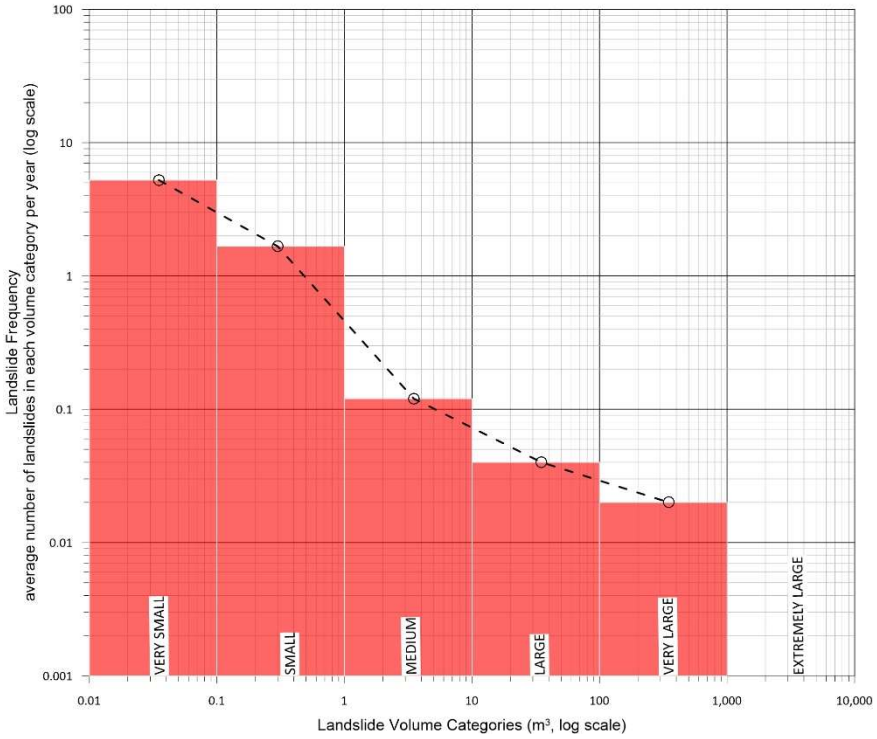


Plate 1 - Updated Landslide Volume Frequency Model for Rockfalls at Flying Fish Cove

The most obvious hazard is that individual boulders, or groups of boulders, might roll down onto the lower slopes and impact upon the community, possibly causing injury or death to individuals and/or damage to facilities including buildings, vehicles and services.

Compound events (very large or extremely large events), where numerous boulders originating from several different sources around the Cove simultaneously roll down to the lower slopes, are conceivable but very much less likely than single events.

3.5.3 Debris Flow Landslide Hazard

Debris flow landslides are a very rapid form of mass movement in which loose soils, rocks and organic matter combine with entrained air and water to form a slurry that then flows downslope. The flow is a broken-up mass of material that no longer retains its original structure or fabric.

The areas of Flying Fish Cove identified to be at risk due to debris flow landslides are indicated in Figure 5 (with barriers). It should be noted that a debris flow could conceivably extend beyond the probable limit of defined in the figures, but that the risk of this happening is considered to be negligible.

Level of Risk from Debris Flow

GHD have created a debris flow landslide volume frequency model. The debris flow landslide volume frequency model predicts the long-term average number and volume of debris flow landslides reaching the toe of the escarpment per year. The Flying Fish Cove model is based on knowledge and interpretation of the documented debris flow landslides in the landslide inventory (see Appendix A).

Average annual number landslides, category volume and average annual volume per year in each volume category

Average landslides per year	Very small	Small	Medium	Large	Very Large	Extremely Large	Totals
Volume (m^3)	0	0	0.1	0	24.2	111.5	135.8
Number	0	0	0.02	0	0.04	0.023	0.1

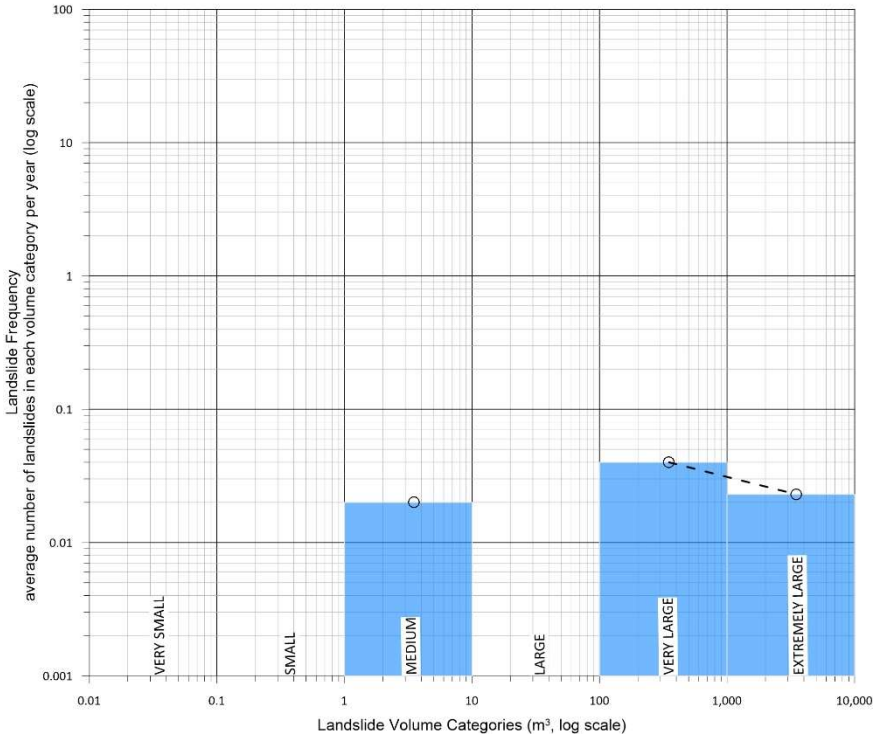


Plate 2 – Updated Volume Frequency Model for Debris Flows at Flying Fish Cove

Debris flows are likely to occur with little warning; they travel long distances and often involve large volumes of soil and rock. The greatest hazard presented by a debris flow landslide is a large uncontrolled flow of slurry being deposited against or over (engulfment) a structure, item of infrastructure, vehicle or person, potentially causing injury or death to individuals and/or damage to facilities including buildings and services.

Compound events, where numerous debris flow landslides originating from several different sources around the Cove simultaneously flow down to the lower slopes, are conceivable, and have occurred in the past (e.g. April 1935), but very much less likely than single events.

3.6 Potential for Warning of Landslides

3.6.1 Landslide Triggers

Significant evidence exists that landslides in general, including those in the slopes above Flying Fish Cove, are triggered by several external events, these include:

- **Water infiltration:** This is the most common cause of landslides and may be caused by natural phenomena such as heavy rain, or by human activities such as removal of vegetation, interference with natural drainage, the channelling of surface water over/into a slope or leaking water mains. On Christmas Island, the relationship between water infiltration and slope failure is better established for debris flow landslides than for rockfalls.
- **Earthquakes:** Ground motions caused by earthquakes are considered to be a potential trigger of rockfalls, and under the right circumstances debris flow landslides. This trigger has the potential to initiate rockfalls, but is only likely to initiate a debris flow landslide if the impacted slope has already received significant prolonged rainfall and is nearing saturation.
- **Wind:** Following Cyclone Gillian in March 2014, wind was identified as a trigger for rockfalls. Strong and/or turbulent winds cause trees to move excessively (including the roots) and fall. The movement is believed to act to loosen and release rockfalls, particularly where trees grow on or near cliff edges.
- **Tree roots:** Tree roots can both bind a slope together and stabilise a rock or soil mass, but can also act to "jack open" joints and cracks in the rock. Tree roots growing in a rock joint forces the joint open, removing the rock on rock contact at the joint face. Death of a tree and the decomposition of the binding roots can remove the stabilising mesh of roots and lead to a rockfall or contribute to a debris flow.
- **Ravelling of dry soil:** This is a recently identified mechanism on Christmas Island, however this trigger may become more common if the Island continues to experience long dry periods. The tropical soils of Christmas Island become friable (easily crumbled or reduced to powder; crumbly) as they dry, meaning that they lose cohesion, become weaker, and in some cases become like coarse sand and able to ravel (movement of individual particles down a slope) from a rock mass or from below individual boulders within the scree slope above the Cove.

Based on current understanding of the mechanisms of slope failure on Christmas Island the potential contribution of each trigger event to a slope failure has been ranked.

Trigger	Debris Flow Landslide	Rockfall
A single intense rainfall event	Unlikely	Possible
Cumulative rainfall and build-up of water within the slope	Likely	Possible
Cumulative rainfall and water build-up followed by a single intense event	Very likely	Possible
Earthquake	Possible	Possible/likely
Wind	Unlikely	Possible/likely
Tree roots – jacking	Unlikely	Possible/likely
Tree roots – dying	Possible	Possible/likely
Ravelling of dry soil	Unlikely	Possible

3.6.2 Landslide Warning Signs

Loose boulders and potentially unstable parts of cliffs are widespread on the slopes above Flying Fish Cove and to Smith Point, and any one of them might be the source landslides in the future. It is not feasible to physically monitor the stability of each boulder or all parts of each cliff, however, some warning of landslide might be provided by monitoring those factors which are known to trigger landslide events or are observed to be associated with them in some way. A summary of some of the warning signs that may precede landslide activity is given below.

Debris Flow Landslide	Rockfall
Moderate to heavy rainfall over an extended period (say > 15 days of the past 20 days).	Small areas of fresh, white limestone appearing on cliff faces where they have not previously appeared – this is an indication that material has fallen from a face exposing unweathered limestone.
Springs start to flow from the talus slope between the toe of the middle cliff line and the rockfall barriers.	An increased number of smaller rocks being found along the rockfall barrier fences.
An increased number of smaller rocks being found along the rockfall barrier fences.	Seismic events tend to occur without warning, however a series of minor seismic events may precede more significant events.
	Areas of disrupted or toppled vegetation.
Prolonged periods of little or no rainfall (3 – 4 months) followed by a high volume, very intense rainfall event as the first rain of the wet season.	Dead trees on the cliff crest, near the top of a cliff face or elsewhere on the cliff – longer term the decay of the root system may lead to a rockfall.

3.6.3 Landslide Alarm Settings

It is proposed that the factors that might precede a landslide incident be grouped into three levels of warning conditions.

- **Yellow Alarm** - elevated risk period.
- **Amber Alarm** – possibility of an event.
- **Red Alarm** – probability of an event.

Red alarm indicators are therefore considered as being more likely to be followed by a landslide event than the Amber indicators. However, it should be noted that there are no indicators which can be reliably used as absolute warning of a landslide.

Alarm Yellow Alarm

Trigger or Warning Sign	Debris Flow Landslide	Rockfall
Cumulative 30-day rainfall	Cumulative 30-day rainfall total in excess of 500 mm.	NA
Accumulation of small rocks along rockfall barriers	A debris flow incident greater than 5 m^3 in aggregate may be a precursor to further landslide.	A rockfall incident greater than 2 m^3 in aggregate may be a precursor to further rockfall.

Alarm Amber Alarm

Trigger or Warning Sign	Debris Flow Landslide	Rockfall
Alarm Level 1 trigger/warning signs i.e. >500mm rainfall PLUS		
Single rainfall event	50 mm in any hour. 100 mm in 12 hours. 150 mm in 24 hours. OR – A BoM forecast of any of the above.	50 mm in any hour. OR – A BoM forecast of the above.
Wind event	NA	Wind speeds corresponding to a Category 1 cyclone (i.e. maximum mean wind speed 63 – 88 km/h. Typical strongest gust up to 125 km/h).

Alarm Red Alarm

Trigger or Warning Sign		Debris Flow Landslide	Rockfall
Cumulative 30 day rainfall		Cumulative 30-day rainfall total in excess of 650 mm.	NA
Single rainfall event		If occurring at the same time as a cumulative 30-day rainfall total in excess of 500 mm. 65 mm in any hour. 130 mm in 12 hours. 200 mm in 24 hours. OR – A BoM forecast of any of the above.	200 mm in 24-hour period. OR – A BoM forecast of the above.
Accumulation of small rocks along rockfall barriers		A debris flow incident greater than 10 m^3 in aggregate may be a precursor to further landslide.	A rockfall incident greater than 5 m^3 in aggregate may be a precursor to further rockfall.
Wind event		NA	Wind speeds corresponding to a Category 2 or worse cyclone (i.e. maximum mean wind speed 89 – 117 km/h. Typical strongest gust up to 125 – 164 km/h).

Note: The trigger levels above are based on a comparison of the landslide inventory (Appendix A) with recorded data such as rainfall, seismicity and wind speed. Given the relatively recent installation of the Drumsite weather and seismic monitoring station, it is envisaged that the trigger levels should be revisited at least every two years or following a significant landslide event in order to ensure they are valid.

4 Assessed Level of Risk

The Australian Geomechanics Society (AGS) 2007d (Reference 10) provides discussion and gives the AGS recommendations in relation to tolerable risk for loss of life. The AGS recommended levels are summarised below.

Situation	Suggested Tolerable Loss of Life Risk for the Person Most at Risk
Existing slope / existing development	10^{-4} per annum (1E-4 pa) or 1 in 10,000 pa
New constructed slope / new development / existing landslide	10^{-5} per annum (1E-5 pa) or 1 in 100,000 pa

It is important to distinguish between 'acceptable risks' and 'tolerable risks'. AGS (2007c) (Reference 8) states that tolerable risks are risks within a range that society can live with so as to secure certain benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if practicable. Acceptable risks are risks which everyone affected is prepared to accept. Acceptable risks are usually considered to be one order of magnitude lower than Tolerable risks.

The assessed individual risk to static elements (buildings and the occupants of buildings) in Flying Fish Cove are tabulated in Appendix B. The assessed individual risk to mobile elements (individuals walking in the open air and vehicles driving on the roads) are tabulated in Appendix C. A summary of the estimated annual risks of 'loss of life' to individuals most at risk that exceed the AGS suggested tolerable risk criteria are given below.

Area	Elements at risk	Hazard	Estimated Loss of Life Risk for the Person Most at Risk (per annum)
Marine Building	Individuals working in Marine Building	Extremely large debris flow	5×10^{-4}
		Extremely large debris flow (site wide event)	1.1×10^{-4}
		Medium rockfall	1.4×10^{-4}
		Large rockfall	1.8×10^{-4}
Marine Building	Individuals working in Federal Police Building	Extremely large debris flow	1.2×10^{-4}
Madrasa / Shop Area	Individuals in Shop	Medium rockfall	1.2×10^{-4}
Madrasa / Shop Area	Individuals in Shop	Large rockfall	1.3×10^{-4}
Block 403 Area	Individuals in Block 403	Medium rockfall	2.6×10^{-4}
		Large rockfall	2.4×10^{-4}

Note: The risk levels summarised above take into account the presence of the existing rockfall barriers and berms, but not the proposed replacement barriers.

5 Risk Management Policy

The original LRMP (The conclusions and recommendations from the July 1996 hearing of the PWC (Reference 1) are attached at Appendix E.

The PWC report details those actions that the Golder Associates report of 1995 (Reference 10) recommended should form part of the risk management plan, which may be summarised as follows:

- Long term land use planning aimed at restricting access to those areas at greater risk of rockfall.
- Establishment of a response to extreme rainfalls.
- Establishment of a response to minor rockfalls and seismic events.
- Education of the community and visitors on the impact of rockfall events.
- A research program.

6 Prescribed Management Actions

6.1 Overview

The Prescribed Management actions required by the Plan are within the four following basic strategies:

i) Monitoring of Rainfall, Rockfall and Seismic Activities leading to appropriate responses at times of greater risk.

ii) Control of Population Exposure to Hazard by land use planning and restricting access to areas at risk, either permanently or during periods of high risk.

iii) Community Education programs to increase the awareness of the hazard, the nature of the Yellow, Amber and Red warnings and expected response from the community.

iv) Research to collect further information on rockfall mitigation, the slope processes and rockfall risks etc.

v) Review of the LRMP and prescribed actions to ensure effectiveness and currency.

6.2 Monitoring of Rainfall, Wind, Seismic and Landslide Activities

Background

Landslides have been associated with events of heavy rainfall, high winds and seismic activity (earthquakes). It is also widely recognised that the occurrence of foreshocks is the most reliably established precursor to large earthquakes. Small landslide events can be precursor events to larger landslide events. Monitoring these factors and using them as warning indicators forms an important strategy in the LRMP.

Objectives

- To set in place a mechanism to collect data about rockfall events.
- To set the threshold intensities to determine warning conditions for rainfall.
- To set in place a warning – response mechanism for heavy rainfall events.

Prescribed Actions

No.	Prescribed Action	Responsibility
6.2.1	**Monthly Inspections of Landslide Barriers/Berm** Carry out monthly inspections of the landslide barriers and berms behind the Kampong and the Jalan Pantai Road to the traffic lights at Smith Point. Monthly inspections are not to take place during periods of heavy rainfall nor for at least 24 hours after the cessation of Yellow and Amber alarms and 48 hours after Red alarms. During each inspection: • Record the location and size of all significant landslide (individual rocks or debris flow) activity. • Examine the cliff and slope immediately above the barrier and note any unusual geological activity or events (such as fallen or broken trees). • Document all events, including photographic records, to maintain a detailed record that will be useful to predict future behaviour. • Mark the rocks with paint and move them away from the fence. Monthly inspections are to be undertaken by the EMO or a suitably briefed delegate. **Post-Landslide Event Inspections** Post-event inspections are not to take place during periods of heavy rainfall nor for at least 24 hours after the cessation of Yellow and Amber alarms and 48 hours after Red alarms. Inspections and clearing are to be undertaken with great care by two persons, one being the EMO or equivalent. One person is to approach the landslide or rockfall from undisturbed ground and the other remaining on undisturbed ground to warn of any further movement of rocks or soil in the vicinity. Do not approach any major landslides or rockfalls or areas that appear unstable. Arrange for consultation with an experienced Engineering Geologist to discuss any significant events or geological activity and determine if any immediate, short term or long term action is required.	**IOTA**

No.	Prescribed Action	Responsibility
6.2.2	**Barrier Maintenance** In conjunction with 5.2.1, inspect the fence, anchorages, posts and base plate, wire ropes and nets and report any changes or obvious wear and tear. Arrange for maintenance of the fence in accordance with manufacturers specifications. Ensure no vegetation is growing from the berms. If present it should be slashed and poisoned.	**IOTA**
6.2.3	**Cliff Face Inspections by Drone** Carry out 6 monthly drone inspections (including video capture) of the middle and upper cliff faces from the upper set of traffic lights at Smiths Point and around Flying Fish Cove to Club Road / the Catholic Church. Following the drone inspection: • Compare the collected video footage to the video footage collected in the previous 12 months. • Note changes in the cliffs (including location), particularly areas where material is no longer present (usually indicated by whiter areas of rock) or where cracks in the rock appear to be wider than previously observed. Other indicators can include tilting or dying trees. • If changes are small, compile a list of changes (including location) and supply to the Engineering Geologist making the Annual Inspection. • If large changes are observed, arrange for consultation with an experienced Engineering Geologist to discuss. **Post-Landslide Inspections by Drone** Following a landslide event (either a rockfall or a debris flow) use the done to video the origin of the failure. Arrange for consultation with an experienced Engineering Geologist to discuss the event and determine if any immediate, short term or long term action is required.	**IOTA**
6.2.4	**Maintenance of Alarm Warning System** Maintain and check monthly the rain gauge warning system for correct operation and setting for Yellow, Amber and Red rainfall conditions. The person/s testing and maintaining the electronic computer and telemetry systems must be appropriately experienced / qualified, preferably a telecommunications technician. IOTA are to inform the AFP and SOCI of any problems with the alarm warning system.	Prime: **IOTA**

No.	Prescribed Action	Responsibility
6.2.5	Each time an alarm is triggered, check equipment and confirm that it is not a false trigger and record details accordingly. The AFP is to notify IOTA and SOCI of false alarms. IOTA / DIRD to arrange rectification of alarm system.	Prime: **AFP** Support: **SOCI and IOTA**

6.3 Control of Population Exposure to Hazard

Background

The area covered by the Plan is being used for a diverse range of activities. Apart from the Kampong residential and other community buildings (such as the Madrassa and the Al Barakah supermarket), the area includes the boat trailer parking area, BBQ facilities and the beach. The Marine Building and the building next to it are workplaces. The Golder Associates Report of 1995 recommended long term land usage planning aimed at restricting access to these areas. This recommendation was supported by GHD Pty Ltd.

Objectives

- To limit exposure of the residents, workers and visitors to risk.
- To define actions to reduce risk in specific circumstances.

Prescribed Actions

No.	Prescribed Action	Responsibility
5.3.1	Continue the general planning principles of not increasing the residential population in the areas of the Kampong at greater risk from rockfall.	**SOCI**
5.3.2	Activities at the Cove resulting in an increase of people in the area, are to be minimised in the event of heavy and sustained rainfall (i.e. Level 1 (Yellow) alarm and above).	**SOCI**
5.3.3	In the event of an alarm follow procedures outlined under Section 6.	**AFP**

6.4 Community Awareness Program

Background

The perception of the risk by the community in relation to damage, injury or loss of life from a major landslide is relatively low. To ensure an appropriate response to an emergency, the community level of understanding of the implications of a major landslide needs to be improved.

Objectives

- To increase the community perceptions of the landslide hazard and the potential causes.
- To involve and encourage the community to informally monitor the landslide conditions in the Kampong and report events as they occur.
- To advise on the reason for and nature of the warning conditions and the reasons for the required action.
- To advise on the actions to be undertaken subsequent to a warning condition being issued.

Prescribed Action

No.	Prescribed Action	Responsibility
5.4.1	At the commencement of each wet season, prepare and circulate information in local languages advising the community of the landslide hazards, the impact of seismic activity and rainfall, the importance of vegetation to stabilise the slopes and the safety and emergency procedures to be undertaken in the event of Level 1, 2 and 3 warning conditions.	**IOTA**
5.4.2	As part of the pre-wet season briefings/education sessions, make the community aware of the changes to the LRMP, particularly the changes in the risk levels associated with each level of alarm and the differences between the new alarm levels and those previously set in the LRMP.	**IOTA**
5.4.3	Using community communication systems e.g. the Islander and 6RCI, raise the importance of the community reporting landslide events, seismic activity and any unusual geological activity on the cliff face or slopes above the Cove.	**IOTA**

6.5 Research

Background

The Public Works Committee lists in its conclusions and recommendations that the risk management plan requires “continuous research”. Accordingly the research should be related to the data gathered over time in the regular inspections of the cliff face, slopes and landslide barriers as part of the monitoring and maintenance regimes.

Objectives

The objective of the research activity is to increase the current understanding of the natural processes controlling the development of landslides and options for arresting the motion of the rocks, soil and vegetation which is dislodged in a landslide event. The research will also provide a database to better characterise the landslide hazard and thus improve the assessment of both rockfall and debris flow risk. The research process will also provide a feedback mechanism for the evaluation of the Landslide Risk Management Plan.

Prescribed Action

No.	Proposed Action	Responsibility
6.5.1	**Annual Inspection:** Arrange for an experienced Engineering Geologist to inspect the cliff face and slope below annually, review the collected data and provide a written report on the geological state of the cliff/slope with any recommendations on modifications to the Landslide Risk Management Plan.	**The Department**
6.5.2	**Five Yearly Inspection and LRMP Review:** Arrange for a review of the research program at the end of the five year period by an experienced Engineering Geologist, including the preparation of a report which comments on the nature of the rockfall activity, the existing slope processes, any evidence of changes in conditions, any discernible trends in the changes and an assessment of any major landslide events that might have occurred during the 5 year period, including an updated of the landslide inventory (Appendix A). The report should also include an evaluation of the costs and benefits of the research, a review of future strategy and any changes required to the Landslide Risk Management Plan.	**The Department**
6.5.3	**Update Alarm Levels:** Following each landslide event or every 2 years if no landslides occur, complete a review of the rainfall, wind and seismic levels that trigger each Alarm level. This review should be undertaken by an experienced Engineering Geologist.	**The Department**

6.6 Review

Background

Following from the research program, the Advisory Committee should assess and update technical points in the plan, and to ensure management actions are being carried out.

Objectives

The objectives of the review are:

- To draw together recommendations received from specialists and those involved in the plan, to ensure the plan is current and improvements are made.
- To undertake an exercise to ensure the effectiveness of the plan in the event of a rockfall warning.

Prescribed Action

No.	Proposed Action	Responsibility
6.6.1	**Annual Exercise:** An exercise to examine the effectiveness of the actions and response for a landslide event is to be conducted annually. The exercise is to be based on a large or very large rockfall or debris flow event and is to involve all personnel specified in the LRMP for that event. The exercise should occur prior to the wet season (around October) each year.	Prime**:** **The Department** Support: **All with responsibilities under the Plan.**

6.6.2	**Update Alarm Levels:** Following each landslide event or every 2 years if no landslides occur, complete a review of the rainfall, wind and seismic levels that trigger each Alarm level. This review should be undertaken by an experienced Engineering Geologist.	**The Department**
6.6.3	**Annual Review:** The EMC is to discuss and review the LRMP every six months. This should take into account outcomes of the annual exercise, inspections by the Engineering Geologist and any rockfall alarms and events.	Prime: **The Department** Support: **All with responsibilities under the LRMP.**

7. Closure

It should be noted that extensive use of earlier studies on landslide risk at Flying Fish Cove has been made in the preparation of the LRMP. These earlier studies were based on limited site investigations and only those landslide events recorded in historical records or reported to the authorities. It is thus essential to review the LRMP at regular intervals as more and more knowledge is acquired, further data is collected from the new weather and seismic monitoring station at Drumsite and risk levels are reassessed.

It should also be noted that the risk levels summarised in the submission to PWC in July 1996 were put forward by a consultant commissioned for that purpose. The results of any particular risk assessment will be dependent upon the assumptions underlying the particular method used. There are examples in the technical research literature of how several independent risk assessments on the same problem differed widely in assumptions, presentation, and resulting conclusions. Thus, the risk assessment previously stated may by itself only provide a partial view, and any decisions solely based on that assessment could be erroneous when viewed in the light of future actual events. Therefore everyone concerned should realise that any risk prediction should always be complemented by sound strategies for ongoing management of risk mitigation in the area. This has been the underlying philosophy in the preparation of this plan.

8. References

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5. **GHD Pty Ltd** (June 2018). Department of Infrastructure & Regional Development and Cities, Flying Fish Cove, Christmas Island, Quantitative Landslide Risk Assessment.
6. **GHD Pty Ltd** (April 2024). Interim Rockfall and Landslide Risk Review, Flying Fish Cove, Christmas Island (Draft report). Department of Infrastructure, Transport, Regional Development, Communications and the Arts.
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Figures

FIGURE 1 – Rockfall Susceptibility, 3 m^3 Block, Upper Cliff line Initiation (With existing barriers)

FIGURE 2 – Rockfall Susceptibility, 100 m^3 Block, Upper Cliffline Initiation (With existing barriers)

FIGURE 3 – Rockfall Susceptibility, 3 m^3 Block, Intermediate Cliffline Initiation (With existing barriers)

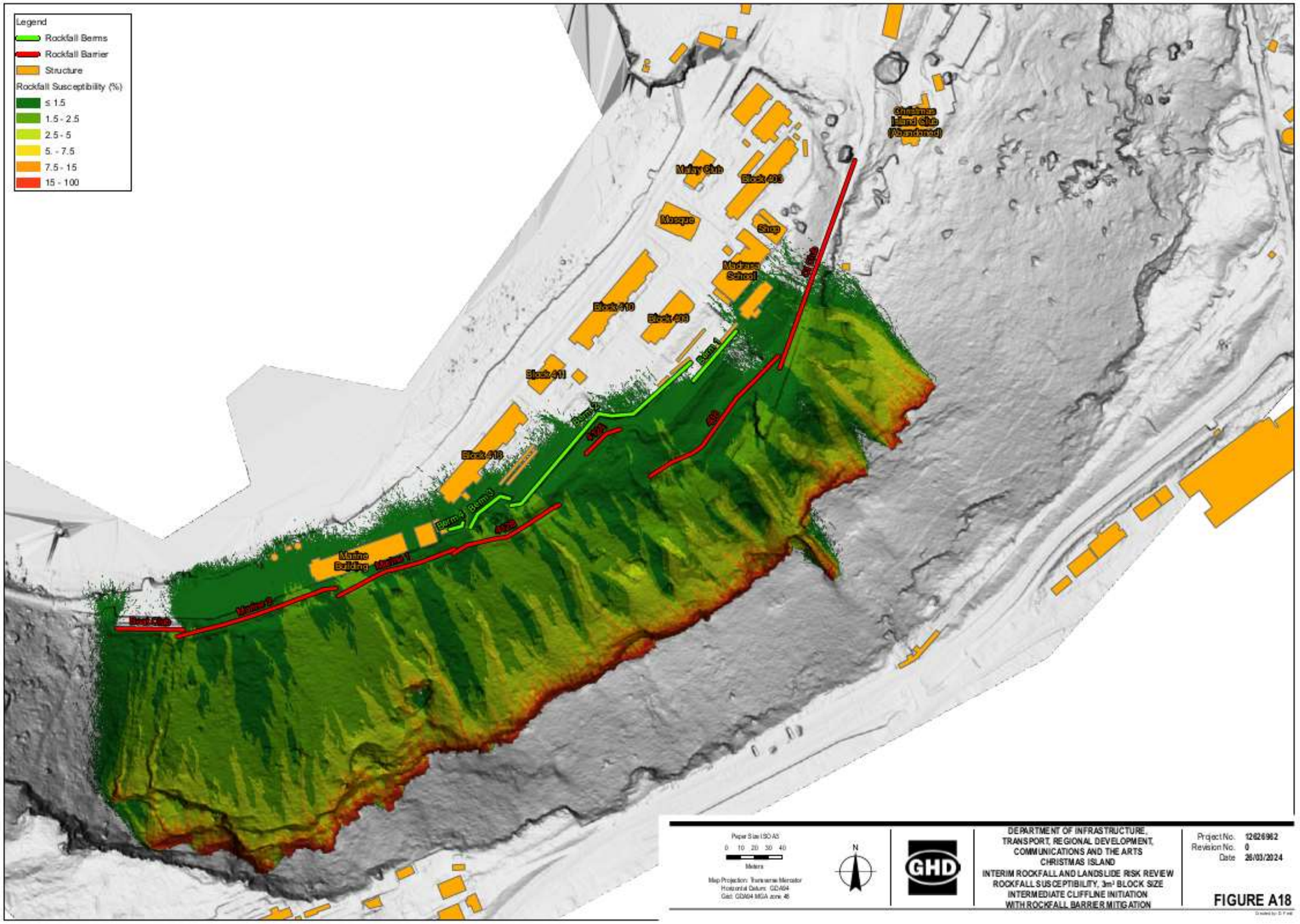

FIGURE 4 – Rockfall Susceptibility, 100 m^3 Block, Intermediate Cliffline Initiation (With existing barriers)

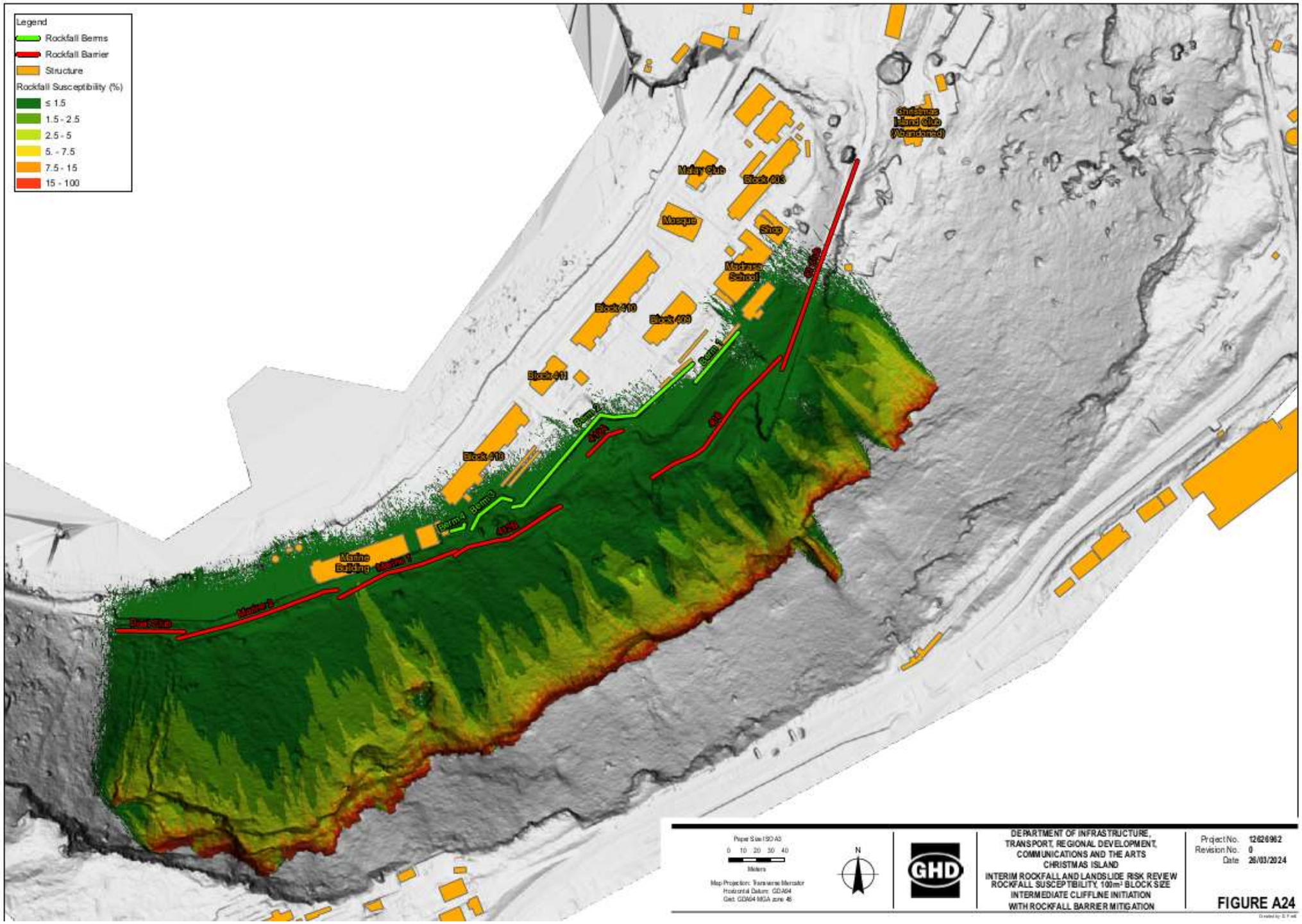

FIGURE 5 – Areas of Debris Flow Landslide Susceptibility

Appendices

Appendix A

Broadcast Warnings

Broadcast Warnings

Introduction

Standard words are to be used in the event of a rockfall warning due to high rainfall or seismic activity.

The AFP or EMO will advise 6RCI when to broadcast Warning Messages and which message to broadcast.

These are to be broadcast by radio 6RCI every hour between 7:00 hours and 21:00 hours in English, Chinese and Malay, unless otherwise instructed by the AFP. It is envisaged that these words will be held in a pre-recorded format in English, Chinese and Malay by 6RCI enabling early broadcasting.

Words in the event of a rockfall warning due to high rainfall or Seismic activity:

6RCI RADIO MESSAGES LANDSLIDE/ROCKFALL EMERGENCY WARNING

1A YELLOW WARNING (Public Awareness) Played every 2 hours

- Natural Hazard triggers have been met, and the Emergency Management Committee is closely monitoring all weather conditions.
- Please use caution when entering known Rockfall areas along Murray Road.
- Currently there are no restrictions in place for the public.
- Continue to listen to 6RCI and monitor the Emergency WA app for updates.

2A AMBER WARNING (Escalation) Played every 2 hours

- Due to an increased Natural Hazard risk, there is now restricted entrance to Flying Fish Cove.
- Access West of the Australian Federal Police Boatshed towards Tai Jin House is now restricted to emergency personnel and essential staff only. The boat ramp is now closed to the general public.
- A high Rockfall risk exists between Flying Fish Cove and Smiths point.
- A high Rockfall risk exists along Murray road between Silver City Road and Gaze Road.
- Speed limits between these two points have been reduced to 40 kilometers per hour.
- Continue to listen to 6RCI and monitor the Emergency WA app for updates.

3A RED WARNING (Escalation) Played hourly

- Natural hazard risks have significantly increased which may trigger Landslides and Rockfalls.
- A high Rockfall risk exists between Flying Fish Cove and Smith Point.
- There is now restricted entrance to Flying Fish Cove.
- Access West of the Police Boatshed towards Smith Point is now restricted to emergency personnel only.
- Madrassa school is now closed until further notice.
- There is no Access to the Catholic church.
- There is no access to the Al Barakah supermarket.
- A high Rockfall risk exists along Murray road between Silver City and Gaze Roads.
- Speed limits between these two points have been reduced to 40kms per hour.

3A Continued

- Continue to listen to 6RCI and monitor WA Emergency app for updates.
- Urgent enquiries only to the Police on 9164 8444.

3B RED WARNING (Al Barakah Update) Played hourly

- Natural hazard risks have significantly increased which may trigger Landslides and Rockfalls.
- A high Rockfall risk exists between Flying Fish Cove and Smith Point.
- There is now restricted entrance to Flying Fish Cove.
- Access West of the Police Boatshed towards Smith Point is now restricted to emergency personnel only.
- Madrassa school is now closed until further notice.
- There is No Access to the Catholic church.
- The Al Barakah supermarket is now able to operate.
- A high Rockfall risk exists along Murray road between Silver City and Gaze roads.
- Speed limits between these two points have been reduced to 40kms per hour

2B AMBER WARNING (Threat Reducing from Red) Played every 2 hours

- The risk of a Landslide or Rockfall has been reduced but not eliminated.
- Access West of the Australian Federal Police Boatshed towards Tai Jin House is still restricted to emergency personnel and essential staff only.
- The boat ramp is closed to the general public.
- We ask everyone to exercise caution when entering rockfall prone areas.
- Speed restrictions along Murray road are still in place.

1B YELLOW WARNING (Reduced) Played every 2 hours

- All restrictions have now been removed.
- Please continue to use caution around Rockfall prone areas.
- Report any rockfalls to the Police on 91648444

Appendix B

Warning Light Locations

WARNING LIGHT LOCATIONS (5)

1.OUTSIDE POST OFFICE KAMPONG.

2. MOSQUE KAMPONG.

3. MURRAY RD CNR GOLDEN BOSUN RD DRUMSITE.

4. COMMUNITY HALL MURRAY RD POON SAAN.

5. GAZE RD FUEL DEPOT.

Appendix C

Conclusions and Recommendations of the Parliamentary Standing Committee for Public Works in July 1996

Conclusions and Recommendations of the Parliamentary Standing Committee for Public Works in July 1996

1. The Commonwealth has a responsibility to implement measures designed to reduce the risk of fatality at various locations in Flying Fish Cove.
2. Before December 1996, the Department of Environment, Sport and Territories should have ready a rockfall risk management plan for Flying Fish Cove which identifies events, documents responses, assigns responsibilities, requires continuous research and monitoring, and increases community awareness of risks and dangers. Simulated exercises should be undertaken.
3. Ficus microcarpa trees should be planted upslope from the rockfall barrier to provide extra protection in the longer term.
4. As is evident from the major rockfall in 1972, the Committee believes that the Boat Club should be demolished and a new safe site, proximate to water frontage, and consistent with the Town Plan, be found. *[Boat club has been demolished prior to 2005]*
5. The Department of the Environment, Sport and Territories and Christmas Island Shire Council should give favourable consideration to construction costs of a new club building being wholly or partially funded from the community Benefit Fund.
6. Land for private development is the most pressing need on Christmas Island. *[Land has been released for private development prior to 2005]*
7. Block 408 in the Kampong should be demolished at the end of its economic life, expected to be in three to five years' time. *[Demolished prior to 2005]*
8. Following the construction of the rockfall barrier and the implementation of a general rockfall risk reduction management plan, the future of Block 412 should be re-evaluated at the end of the same period. However, the Committee favours the eventual removal of Block 412. *[Demolished prior to 2005]*
9. Dwelling units at the south-west corners of both blocks, considered to be at greatest risk, should be progressively and permanently vacated. *[Blocks 408 and 412 have been demolished prior to 2005]*
10. The Department of the Environment, Sport and Territories, in conjunction with Christmas Island Shire Council, should identify parcels of land for residential and other developments that comply with the Draft Town Plan. *[Land has been released for private residential development]*
11. Land for private housing development should be offered without delay. *[Land has been released for private residential development prior to 2005]*
12. The future use of the site of Block 408, post demolition, should not preclude its use as a revegetated area to provide nesting sites for the Christmas Island Frigate bird. If Block 412 is demolished, the same uses could apply. *[incorporated into Kampong residential area]*
13. Potential trade-offs between the use of the sites as recommended and the use of land containing vestiges of primary rainforest, at present not favoured for development by the Australian Nature Conservation Agency, should be investigated.