Assessment and Planning for Tsunami Vertical Evacuation

Director's Guideline for Civil Defence Emergency Management Groups [DGL 21/18]

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Authority
This guideline has been issued by the Director Civil Defence & Emergency Management pursuant to s9(3) of the Civil Defence Emergency Management (CDEM) Act 2002. It aims to provide a nationally consistent approach to assessing and planning for tsunami vertical evacuation.

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Foreword

All New Zealand coasts are at risk from tsunami. As New Zealand matures in its approach to tsunami risk management, we continue to address some of the more difficult challenges we face in managing tsunami risk.

We have a comprehensive range of guidance and arrangements in place to support CDEM Groups in managing their tsunami risk, including the development of tsunami evacuation zones; public education for tsunami risk; mass evacuation; welfare services, and public alerting. However, for some communities, local environmental or demographic factors create barriers to evacuating all people in evacuation zones in the time available before tsunami waves arrive.

This guideline is intended to support CDEM Groups in assessing whether there may be a need for tsunami vertical evacuation in their areas as a method of last resort. It also includes the wide range of considerations CDEM Groups need to address before implementing tsunami vertical evacuation. Using a risk-based approach, the guidance provides a step-by-step method for CDEM Groups to ensure they are implementing the most appropriate and practical tsunami risk management measures, when considering tsunami vertical evacuation in their areas.

This guidance describes the assessment and planning for tsunami vertical evacuation (Phase One). The Phase Two guidance, due for publication in 2019, is being led by the Ministry of Business, Innovation & Employment (MBIE) and will complement this guideline. It will describe the design criteria for tsunami vertical evacuation structures.

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Introduction

Tsunami risk management in New Zealand involves a broad range of activities at the national, regional and local level. A critical tsunami risk management measure for life safety is the timely evacuation of people when a tsunami threat is identified. Civil Defence Emergency Management (CDEM) Groups are responsible for coordinating local evacuation planning and all associated activities, including public education.

Some CDEM Groups face particular challenges with regard to timely community evacuation; therefore, additional measures such as tsunami vertical evacuation may need to be considered. This guidance offers a tool to support a CDEM Group that is considering tsunami vertical evacuation as an additional measure (of last resort) to manage tsunami life-safety risk.

Tsunami vertical evacuation is the use of structures as short-term refuge sites for those at risk from tsunami inundation. Their use is most appropriate during local source tsunami events, when available evacuation time can be minutes. It is important that tsunami vertical evacuation is recognised as a supplementary risk management measure of last resort, to meet a clear need, when all other risk management measures have been assessed and implemented. Tsunami vertical evacuation structures are intended for those people who may live, work or recreate in inundation zones, where timely evacuation is not possible. For example:

- On coastal plains, tsunami inundation can extend several kilometres inland, making rapid evacuation on foot impractical.
- Some central business districts in coastal locations have high-density populations living and/or working in high-rise structures, making evacuation out of zones complex due to congestion.
- Some coastal communities are physically isolated from nearby high ground by waterways or barriers such as walled motorways.

Phased guidance

This guideline is Phase One of two; each phase constitutes a separate phase of work related to tsunami vertical evacuation planning.

Phase One presents a risk-based approach for a CDEM Group to determine whether tsunami vertical evacuation should be considered for their area, or for specific at-risk communities.

Phase Two will describe the design criteria and engineering performance considerations for tsunami vertical evacuation structures. This will include, but is not limited to, design-specific considerations for tsunami inundation depth and velocity, tsunami and earthquake loads and related structural criteria. It will include an appendix that covers the cost considerations associated with retrofitting existing buildings, or for constructing a purpose-built tsunami vertical evacuation structure.

Purpose and audience

The purpose of this Phase One guidance is to provide a nationally consistent approach for assessing, identifying, planning and designing for tsunami vertical evacuation in New Zealand. The audience for this document is all CDEM Groups (because of their specific emergency management functions) and local authorities (for example because they have building compliance and land management roles).

Structure of this guidance

The key considerations presented and described in this document are summarised in the Tsunami vertical evacuation decision-making tool on page 4. This tool is a step-by-step resource, designed to support a CDEM Group to apply a risk-based approach to assessing the need for tsunami vertical evacuation within its area, or for at-risk communities. The guidance includes detailed explanations for each step of the risk-based approach.

The steps shown in the decision making tool are summarised in the following sections of this guidance:

- Step 1 Tsunami hazard risk assessment provides information on the requirements and methods for completing tsunami risk assessments.
- Step 2 Tsunami residual life safety risk assessment and risk management describes the process and provides methods for assessing, evaluating and managing tsunami residual risk.
- Step 3 Tsunami vertical evacuation describes the key principles and considerations for implementing tsunami vertical evacuation. This also includes an overview of the Phase Two guidance, which is expected to be available in 2019.

Other guidance

Relationship to other plans and guidelines

In order to properly understand the context of this Guideline users are strongly encouraged to read it in conjunction with:

- *Director's Guideline: Mass Evacuation Planning [DGL 07/08]*
- *Director's Guideline: Tsunami Evacuation Zones [DGL 08/16]*
- *Director's Guideline: CDEM Group Planning [DGL 09/18]*
- *Director's Guideline: Strategic Planning for Recovery [DGL 20/17]*
- *Technical Standard: Tsunami Warning Sirens [TS 03/14]*
- *Technical Standard: Tsunami National Signage [TS 01/08]*
- *Supporting Plan: National Tsunami Advisory and Warning Plan [SP 01/18]*

Use of icons

The icon shown to the right is used in this guideline and indicates more information is available in another document or website. The icon includes a link to the digital version or online location of the document referenced.

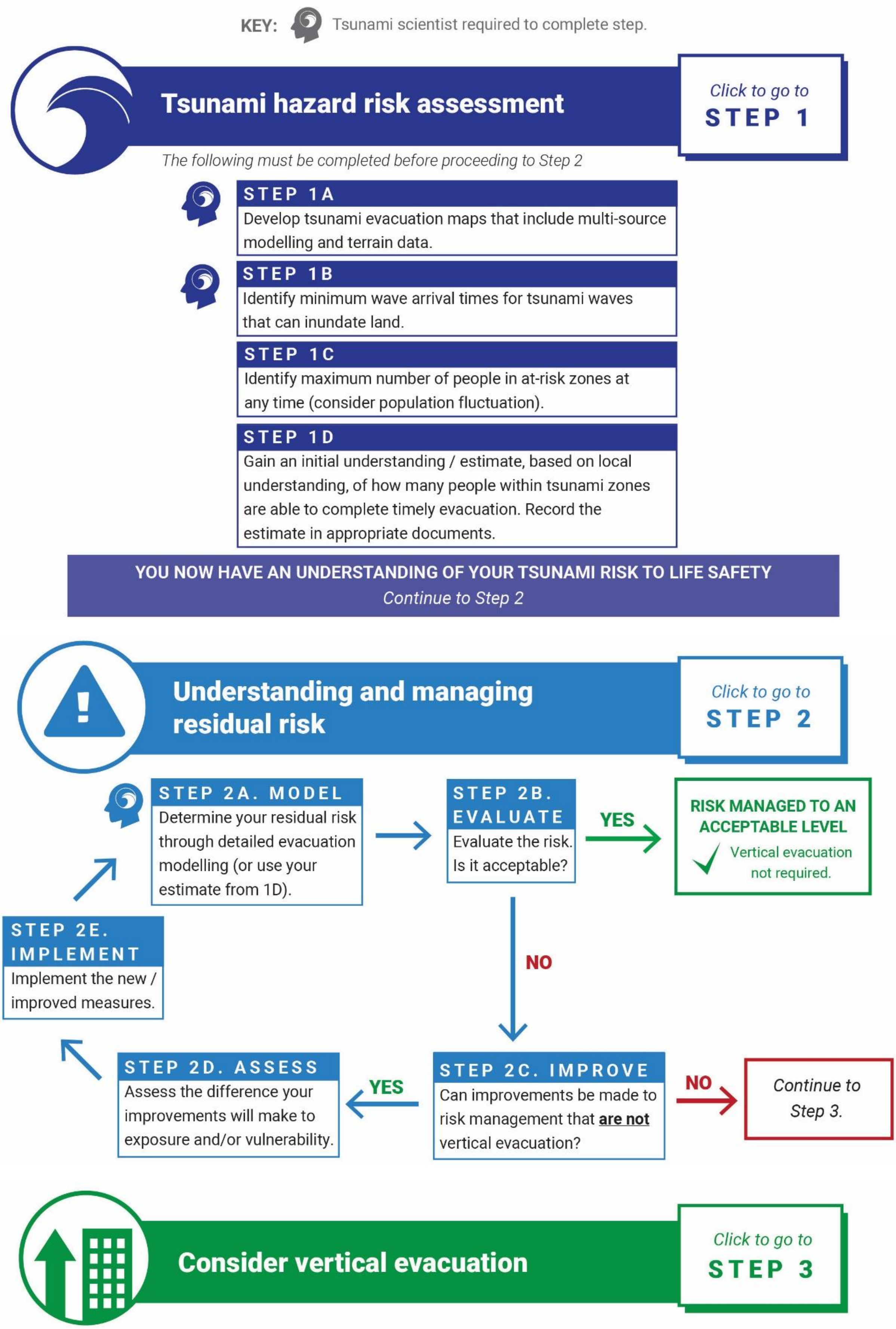
The icon shown to the right indicates an action and/or documentation step for a CDEM Group as they follow the process shown in the tsunami vertical evacuation decision-making tool.

Key terms and definitions

Below is a list of key terms and associated definitions used throughout this document:

Tsunami	A natural phenomenon consisting of a series of waves generated when a large volume of water in the sea or in a lake is rapidly displaced.
Distant source tsunami	A tsunami originating from a remote source, generally more than 3 hours travel time from the New Zealand coast.
Regional source tsunami	A tsunami originating from a source 1-3 hours travel time from the nearest New Zealand coast.
Local source tsunami	A tsunami originating from a source less than 1 hour travel time from the New Zealand coast. Note travel times may be as short as a few minutes.
Tsunami Inundation	Flooding of land by tsunami waves.
Maximum Credible Scenario	A tsunami scenario large enough to, at a minimum, encompass the 2500-year tsunami inundation at the 84% confidence level. In some cases, this may need to be a composite event that combines the inundation from more than one scenario.
Tsunami Evacuation Zones	Areas identified by CDEM Groups as at risk of tsunami inundation, taking into account all considered tsunami sources and developed as per the evacuation zone guidance [DGL 08/16].
Risk	Risk means the likelihood and consequence of a hazard as defined in Section 4 of the *Civil Defence Emergency Management Act 2002*.
Residual tsunami life safety risk	The risk to people remaining after tsunami risk reduction measures have been implemented. That is, the risk to the people who may not realistically be able to evacuate before tsunami waves arrive, despite existing plans and systems.
Travel time	The time required for the first tsunami wave to propagate from its source to a given point on a coast.
Arrival time	The time of arrival of the first tsunami wave at a given point on the coast.
Vertical evacuation structure	A structure that has sufficient height to elevate evacuees above the level of tsunami inundation, and is designed and constructed with the strength and resiliency necessary to resist the forces of tsunami waves, preceding earthquakes and aftershocks that may occur during the period in which the refuge is occupied A tsunami vertical evacuation structure is not a Civil Defence Centre (CDC).
CDEM Group	Refers to a Civil Defence Emergency Management (CDEM) Group.
Civil Defence Centre (CDC)	Is a facility in a community that is set up during an emergency to support individuals, family/whānau, and the community. A CDC is not a tsunami vertical evacuation structure.

Tsunami vertical evacuation decision-making tool



Step 1 Tsunami hazard risk assessment

Effective tsunami risk management begins with assessing tsunami risk through the process of identification, analysis and evaluation. This section relates to Step 1 of the tsunami vertical evacuation decision-making tool, and provides a standard approach to tsunami risk identification and analysis.

Undertaking this step will determine the current tsunami life safety risk for an area of interest such as a community or CDEM Group's area. Each of the steps in the risk assessment process is outlined and links provided to supporting documents and resources where appropriate.

The risk assessment process is outlined in Step 1, and the following steps in this document, are based upon the ISO 31000 International Risk Management Standard.

1.1 Understanding tsunami risk to people

Establish the risk assessment context

Sometimes referred to as agreeing the scope of the risk assessment, this step involves identifying:

- the purpose of the risk assessment
- the geographic boundaries of the area of interest
- the criteria (i.e. range of consequences) that will be assessed
- the information required to undertake the risk assessment e.g. tsunami hazard, population exposure, terrain
- the expertise and technical requirements for the risk assessment
- stakeholder identification – which agencies and others i.e. private sector, communities should be involved, and
- other information that may be relevant e.g. timelines and budget for completing the assessment.

The purpose of this assessment is to understand total tsunami life safety risk in terms of population exposed on land to tsunami hazard. This understanding is then used to determine the effectiveness of mitigation options.

All other context considerations are decided by the agency responsible for applying this guideline.

Agree and document the context of your tsunami risk assessment. This should be outlined in your CDEM Group Plan, or other applicable documents of record.

Identifying tsunami hazard

Areas of tsunami hazard in New Zealand are identified as publicly available tsunami evacuation zones, For the purposes of calculating tsunami risk, robustly determined tsunami evacuation zones are required. These zones are ideally a representation of the combined hazard from all credible tsunami sources, noting these are conservative due to current constraints as identified in the *Tsunami Evacuation Zones Director's Guideline [DGL 08/16]*.

This guideline (linked left) includes detailed explanations of the range of scenarios that should be included to get a thorough understanding of tsunami hazard.

In general terms, tsunami hazard can be summarised as the depth, velocity and landward extent of inundation possible from all sources. For each CDEM Group, a local source is defined as a tsunami with potential travel time of approximately one hour from source to anywhere on the coast within the CDEM Group's area. A local source for one CDEM Group is likely to be a regional source for other CDEM Groups. Each CDEM Group needs to consider whether a tsunami source is local, regional or distant relative to its own coast.

To determine tsunami hazard, scientific advice on possible sources and modelling is required. Detailed topographic information is required to understand patterns and limits of tsunami inundation.

Tsunami sources that are included must be characterised to ensure understanding of their contribution to tsunami hazard. The following information about tsunami sources is required for various steps within this guideline:

- The local, regional and distant sources that contribute to the tsunami hazard for the area under consideration. For example, determining which sources can create possible land inundation.
- The minimum travel time from tsunami generation to the arrival of the first wave at a given point at the coast, within the area under consideration.
- The local (or close regional) maximum credible (or "worst-case") scenarios for your region. This means the scenarios that could result in the greatest inundation.

This is important for understanding the range of velocities, depths and inundation extents associated with this worst-case scenario. This information will also be required for structural requirements in the vertical evacuation Phase Two guidance. It is therefore useful to collect this information as part of the initial hazard assessment, so it is noted as part of the scientific advice sought during hazard identification.

> Develop tsunami evacuation zones for your area, including consideration of all appropriate tsunami sources and the hazard associated with these sources. Evacuation zone modelling should follow the process outlined in DGL 08/16. Step 1A and 1B.

Likelihood, magnitude and consequence

The Civil Defence Emergency Management Act (CDEM Act) 2002 defines risk as “the likelihood and consequences of a hazard”. In applied terms, this means understanding the likelihood of a particular hazard occurring at a given scale or magnitude, in a given location, and the type of and severity of consequences that can be expected. Both likelihood and consequences are important for evaluating whether risk is acceptable and which risk management measures are appropriate.

For tsunami risk evaluation, understanding the likelihood of sources that could generate tsunami of a magnitude that can inundate land is essential. The consequences of land inundation are that people’s safety will be at risk. It is not possible to change the likelihood or magnitude of tsunami hazard. Risk management therefore focuses on managing the consequences through reducing population vulnerability and exposure.

Exposure to tsunami hazard

The following should be taken into account when determining the maximum exposed at-risk population:

- Day-time and night-time fluctuations on the number of people in the area of interest (e.g. tsunami hazard zone). For example, people moving into and out of the zone during day-time to large employers or schools, or home at night-time to coastal residences.
- Seasonal influxes for holiday locations and whether the location sometimes hosts large crowds (e.g. events and festivals).

Calculating total exposure is an essential part of tsunami risk assessment to determine total risk. *Mapping* of population exposure (e.g. mapping the number of people by building or meshblock) is required for Step 2 Tsunami residual life safety risk assessment and risk management on page 10.

> Calculate the total population exposure for your tsunami evacuation zones. Map the spatial distribution of people exposed within your tsunami evacuation zones. A GIS specialist may be required for this step. Step 1C.

Vulnerability

Population vulnerability describes the inherent factors that influence the degree of harm experienced by people exposed to a hazard. People are physically vulnerable to tsunami hazard, due to the high energy of tsunami waves and entrained debris.

Vulnerability also includes the degree to which individuals are able to undertake actions for reducing or avoiding the risk. For example, evacuating people from exposed areas is the most fundamental method for managing the risk to life. Any conditions or characteristics of the people exposed that reduce their inherent ability to evacuate, makes them more vulnerable. For example, if people cannot:

- understand there is a threat (either from natural or official warnings)
- make informed decisions on what to do, or do not know how to follow official instructions, e.g. knowing where to go to reach safety
- move freely and rapidly out of evacuation zones.

There are a range of reasons why these vulnerabilities may be present in individuals or parts of the population, such as age, impaired mobility, language barriers, cultural barriers, people in institutional care, those caring for less mobile dependents, and people new to an area unfamiliar with hazards and warning systems.

Understanding the vulnerabilities of your exposed populations is important for Step 2 Tsunami residual life safety risk assessment and risk management on page 10.

Identify vulnerable populations in your evacuation zones. Document where they spend time within the evacuation zone in your Community Response Plans, and CDEM Group Tsunami Contingency or Response Plans. Step 1D and Step 2A.

1.2 Understanding tsunami life safety risk

Calculating total tsunami risk

In the simplest terms, the total tsunami life-safety risk can be considered as equivalent to all people exposed in all evacuation zones. This is because evacuation zones ideally represent the combined inundation areas from all significant sources.

This total risk is number of people anywhere within all tsunami evacuation zones who could be killed or injured if no tsunami risk management measures are in place.

This is because:

- evacuation zones ideally represent the combined inundation areas from all significant sources and all probabilities;
- during a tsunami evacuation, all people within a zone are expected to self-evacuate or, if advised in an official warning, leave the area; and
- the actual extent and depth of inundation cannot be known until waves arrive and are unlikely to match modelling exactly.

For calculating total risk, CDEM Groups need to have completed tsunami evacuation zone modelling following the guidance in the *Tsunami Evacuation Zones Director's Guideline [DGL 08/16]* including consideration of multiple sources and their expected inundation depths and extents (Step 1A).

> Determine tsunami life-safety risk in appropriate areas as an input to a residual risk assessment (see Step 2 Tsunami residual life safety risk assessment and risk management on page 10).

Local knowledge

A CDEM Group is likely to have local knowledge and/or experience of which locations might not be able to evacuate fully within the time available. This could be based on issues such as:

- congestion in densely populated areas;
- distance required to reach safe locations where evacuation zones extend kilometres inland, or
- where vulnerable populations are present etc.

This initial assessment allows a CDEM Group to identify locations that could benefit from further improvements in risk management. For these areas, the next step is to undertake detailed risk assessment as described in Steps 2A-2E. A CDEM Group may determine all those at risk will be able to reach safety before initial wave arrival. This initial assessment may indicate that a more detailed assessment and consideration of tsunami vertical evacuation is not required.

> Using the evacuation zone and population information (including vulnerability information) from Steps 1A, 1B and 1C, identify priority locations, towns or cities for detailed assessment. These will be the locations a CDEM Group determines could possibly benefit from tsunami vertical evacuation and therefore further assessment is required (using Step 2) to confirm this. Step 1D.

Step 2 Tsunami residual life safety risk assessment and risk management

This section relates to Step 2 of the tsunami vertical evacuation decision-making tool, and describes the process for considering tsunami residual risk assessment and managing residual risk management to acceptable or tolerable levels (see *Section 2.2 Residual risk evaluation: acceptable, tolerable and intolerable risk*). This includes:

- modelling residual risk
- determining risk acceptance levels
- evaluating the level of residual risk
- evaluating options for improving risk management
- and implementing new risk management measures.

Following implementation of any risk management measure, it is recommended that the change to residual risk is re-modelled and the acceptability of residual risk re-evaluated. This process of assessment, evaluation, and reducing residual risk continues until risk is tolerable, or all achievable risk management improvement measures are in place.

2.1 Modelling residual risk

Residual life safety risk

Residual risk is the risk remaining after risk management measures have been implemented. Determining residual risk requires a clear understanding of the effectiveness of risk management measures currently in place. In the case of tsunami risk management, residual risk modelling is a quantitative process. This process involves comparing evacuation modelling results with the minimum wave arrival time of waves capable of inundating the land, to determine the number of people who cannot evacuate before the first wave arrives at the coast.

International experience has shown that even in the most prepared communities, where comprehensive risk management is in place, it may be difficult to achieve 100% evacuation, regardless of the time available (Fraser et al., 2012). Full effectiveness requires all those at risk to understand natural warnings for tsunami in the case of a local earthquake, and in regional or distant earthquakes, to take appropriate action immediately (i.e. follow official warnings). As tsunami is a relatively unfamiliar hazard to most New Zealanders, this understanding and readiness to act, requires long-term, societal behavioural change. The “LONG or STRONG, GET GONE” campaign is part of the national public education programme to achieve this change.

Evacuation models calculate the time required for all people within an evacuation zone to reach safety. This takes into account a number of behavioural and physical elements, including:

- The time taken to begin evacuating including time to understand the threat and make a decision to evacuate. This includes the duration of ground shaking (for felt, local source earthquakes), plus personal assessment, contacting relatives and joining up with family to evacuate. This may contribute additional time to the overall evacuation time (Fraser, 2014). This additional time should be considered in any estimate of the evacuation time required. Note, that for unfelt, local earthquakes or regional earthquakes this decision-time also includes, the time required by authorities to identify a threat, and generate and issue a warning to the public.

- Different movement rates, route availability and terrain by incorporating data on terrain, population exposure, and population vulnerability
- Variability in population behaviour and movement rates based on time of day (diurnal/nocturnal rates)

Scientific expertise and evacuation modelling software is required to complete this process robustly. More detail is provided in the following sub-sections on evacuation modelling data and types of evacuation modelling.

Evacuation modelling data

The following data are essential or important for robust evacuation modelling.

- A model of the hazard zone – in this case, a model showing tsunami evacuation zones and all areas outside the zones i.e. safe locations.
- A digital elevation model of terrain and land cover to calculate maximum walking (and possibly vehicle) speeds. This can include tracks, walkways, roads and waterways.
- Demographic data, particularly age distribution (which can represent reduced mobility in the very young and very old), people with disabilities and other demographic data that may influence pedestrian travel speeds.
- The maximum number of people exposed in tsunami evacuation zones, distributed spatially and temporally. This may be done by assigning people to buildings (building footprint data required), or by distributing numbers of people to small spatial aggregation units (e.g. census meshblocks). Day-time and night-time distributions may be required.
- An estimate of the percentage of the population that can realistically be expected to comply with official warnings or understand and respond to natural warnings, following a natural or official tsunami warning (note in either case this is not likely to be 100%).

Conduct a data stocktake to determine if your CDEM Group has the data required for evacuation modelling, based on the level of sophistication you will use (see *Types of evacuation modelling* below). Required for Step 2A.

Types of evacuation modelling

Evacuation modelling can be undertaken with increasing levels of sophistication, to improve the accuracy and quality of the modelled results. All evacuation modelling requires the following basic inputs:

- An identification of the distance that people must travel to reach safety. This is best determined by using available evacuation zone boundaries. Distance assessment could include evacuation routes via roads, walking tracks, or cross-country routes.
- The number of people within evacuation zones including an understanding of their population distribution.
- The travel speeds of people on foot (and those using vehicles or bicycles)

The following methods may be used to estimate the time required for all those at risk to evacuate. They are described in order of sophistication and robustness.

Time-distance models

The simplest methods for calculating the above use time-distance formulas to estimate travel time (for example the travel times shown on Google Maps). These do not account for the number of people evacuating or individual movement rates and have high levels of uncertainty and inaccuracy. This method will not produce results that are sufficiently robust for determining tsunami residual risk.

Drills and simulations

Real-life simulations or drills such as “tsunami hīkoi” exercises can indicate real-world travel speeds and time to reach safety. However, they are typically not conducted in the most challenging circumstances, including night-time and inclement weather. Regardless, exercises and drills can supplement all types of tsunami evacuation modelling, from the least to the most sophisticated. Pre and post exercise surveys may be undertaken to identify barriers to evacuation and test assumptions about the ease of evacuation.

Least-cost distance models

“Least-cost-distance” modelling is based on time, distance, terrain complexity and the method determines the minimum path from every location in the hazard (evacuation) zone to the nearest point of safety. These give an indication of realistic evacuation times for evacuees (see Lukovic et al, 2017, or Fraser et al, 2014 for an example of this method being applied in Wellington and Hawke’s Bay). For this method, any pre-evacuation additional time must be added after determining the least-cost-distance.

Agent-based modelling

Agent-based modelling takes into account people’s behaviour and complex movement. That is, it simulates the movement of individuals (agents) during an evacuation. This modelling can include the additional time spent before evacuation begins, e.g. time taken to understand a natural warning or for an official warning to be issued and received. This modelling approach can include the varying speeds people move at depending on their mobility, and how their movement changes when they meet barriers or other evacuees en route. Result can include the number of individuals reaching safety within a given time and the number of expected casualties (i.e. the residual risk). Note: agent-based modelling for tsunami evacuation is an emerging science in New

Zealand and is not yet readily available. It is expected to become more commonplace in the future.

Combining modelling methods

CDEM Groups are encouraged to determine their residual risk through combining the types of real world testing provided by exercise simulation and drills, with least-cost distance or agent-based modelling. Real world drills are useful for testing assumptions about terrain and mobility, whereas computer models can consider all possible routes and large populations.

Additional evacuation considerations

The efficiency of evacuation may also be hampered by environmental factors such as:

- the capacity of evacuation routes (congestion in high density areas, narrow routes or bridges)
- temporary use/time of day fluctuations, which increase exposure i.e. festivals, tourists, and seasonal workers
- potential damage and debris to evacuation routes (building damage, landslide debris, fallen trees, power lines)
- hazardous substances or floods from burst pipes or spills.

Maximum evacuation time available

The maximum evacuation time available is determined by the minimum wave arrival time, which is the estimated time between tsunami generation and the first arrival of a tsunami wave at the coast.

Residual risk calculation

Residual risk is then determined as the number of people remaining in an evacuation zone at the minimum wave arrival time.

With the assistance of an evacuation modelling expert, calculate your residual risk. Compare your minimum arrival time with the evacuation modelling time for all to reach safety. The number of people still in an evacuation zone when the first wave arrives is the residual risk.

Assess possible additional time, hazards and barriers to evacuation in your evacuation zone. Use scientific advice to determine whether these are significant in terms of total time taken for the at-risk population to evacuate. Estimate or model your evacuation time for all those at risk and compare it with the minimum wave arrival time. All those remaining within hazard (evacuation) zones represent the residual risk for your area. Document your residual risk assessment. Step 2A.

2.2 Residual risk evaluation: acceptable, tolerable and intolerable risk

Risk levels

Risk acceptance levels are aligned to benefits and trade-offs. Any risk management measure is likely to have some kind of trade-off whereby some opportunities or benefits will not be realised, as activities are curtailed or controls are put in place to protect people or property. For example, work commuting choices will involve trade-offs between cost, time, distance, convenience of routes, availability of options and the ability to take passengers or bulky objects. Depending on which benefits a commuter would like to realise and which are lower priorities, the transport choice could be car, bicycle, motorcycle, walking, ferry, bus or train. In the tsunami risk management context, there is social and economic benefit to be gained from living, working and recreating on the coast.

The introduction or improvement of any risk management measure will include consideration of the specific benefits and trade-offs relative to the residual tsunami risk. Trade-offs are likely to arise between (for example) increased use and development of coastal areas and the resulting increase in the population requiring evacuation during tsunami warnings. Any long-term restrictions on the population in at-risk areas to improve evacuation times (e.g. through land use planning) will need to be balanced against the trade-offs (e.g. lower economic activity) from not using the land.

A CDEM Group may choose to model, or otherwise quantitatively assess the improvements in life-safety measures. For example, land-use planning changes that involve a plan change process, legal advice, policy writing and extensive consultation. See *Section 2.3 Means of managing residual risk* for more detail on risk management options.

Residual risk to life is evaluated to determine if it is acceptable, tolerable or intolerable. It is almost certain that some residual risk will remain, regardless of the effectiveness of tsunami risk management and the preparedness of the local population. This is because (for example):

- every tsunami event is different
- the population is variable in terms of overall number during a day, week or season, e.g. numbers of visitors or commuters present
- variability in local familiarity with the tsunami hazard and the location of evacuation zone
- factors outside the control of those at risk may hamper evacuation (e.g. injuries).

Therefore, it is likely that some residual risk must be accepted.

Agreeing risk acceptance levels is fundamental to determining the appropriate risk management measures to be used. The following definitions from the Natural Hazards Risk Communication Toolbox[1] are provided to guide decision-making on risk acceptance levels.

Acceptable risks Where positive or negative residual risks are negligible, or so minimal that no mitigation measures are required.

Tolerable risks Where opportunities (benefits) are balanced against potential adverse consequences (losses). Tolerable residual risk is a willingness by society (although perhaps not by specific individuals) to live with risk in order to gain certain benefits, and requires the risk to be managed in some way.

[1] Auckland Council (2014) Natural Hazards Risk Communication Toolbox

Intolerable risks

Where the residual risks are intolerable regardless of the benefits the activity may bring, and risk reduction measures are essential.

Determine your tsunami risk tolerance

As part of CDEM Group planning, tsunami residual risk will be considered alongside other hazards and risks to determine acceptable levels. At what point is the residual risk intolerable? Risk tolerance is likely to vary among individuals, iwi, hapu, communities and agencies. Factors to consider when determining local risk acceptance levels include:

- who bears the risk
- who manages the risk and bears the cost
- a process for how risk acceptance levels will be agreed and who will be involved in this process
- the opportunity realised or lost as a result of the accepted tsunami risk
- acceptance levels of risk to life from other hazards that could result in multiple, widespread fatalities
- is the goal to reduce residual risk to tolerable levels or is it to ensure residual risk is acceptable to all?

CDEM Groups may wish to refer to the *Director's Guideline on Strategic Planning for Recovery [DGL 20/17]* for more detail on engaging communities in conversations about risk tolerance and understanding local values and local risk management priorities.

Determine levels of acceptable, tolerable and intolerable residual risk for tsunami using the methods agreed by stakeholders. External facilitation may be useful. Required for Step 2B.

Determine the tsunami risk management baseline by documenting the current tsunami risk management measures in place and critically assessing the completeness and effectiveness of these various. This baseline will be used to evaluate the effectiveness of new and improved measures that are implemented. Required for Step 2C.

Residual risk to life is within acceptable limits

If tsunami residual life-safety risk is within acceptable limits, additional risk management measures are not required, but may be beneficial in the long term. Tsunami risk should be monitored to determine that changes in the tsunami hazardscape (e.g. new sources discovered), or changes in population exposure and/or vulnerability do not result in residual risk increasing to intolerable or decreasing to tolerable levels. If residual risk levels change, they should be evaluated against risk acceptance levels and risk management measures should be reviewed as necessary.

An example of how acceptable risk could be determined for a community is "*if land inundation is only likely from distant sources, and sufficient evacuation time is available for all those at risk, before first wave arrival",* then the risk may be acceptable to emergency managers and the community. These conditions allow for timely evacuation of at-risk communities. Acceptable risk levels should be agreed through consultation with stakeholders and should be appropriate for the community at-risk.

Monitor residual risk levels to account for changes in tsunami hazard knowledge or population change, and promote to avoid any increase to residual risk. Re-evaluate residual risk against acceptable levels as appropriate. Ongoing requirement for Steps 2A and 2B.

Residual risk is tolerable

Tolerable residual life safety risks are those that a society is generally willing to live with, after risk management measures have been put in place to reduce the worst impacts. Tsunami risk in New Zealand is for the most part managed to tolerable levels, because most risk management is undertaken to protect human life. That is, we accept that if a tsunami occurs there is likely to be damage to buildings and infrastructure. However, the risk to people is reduced through a range of interventions, such as public education on the correct action to take on natural warnings, and evacuation zone mapping.

If residual tsunami risk is determined to be tolerable, some additional risk management measures are likely to be required. This can be due to factors including:

- Risk is not static and risk levels may increase (see explanation in the 'residual risk is within acceptable limits' subsection).
- Risks are uncertain – there is inherent uncertainty in hazard and risk modelling, allow for this uncertainty using a precautionary approach.
- Risk management measures in place cannot be assumed to be 100% effective – consider the difference between expectations of public behaviour and what people will actually do on a given day; i.e. is all of the population, including visitors and culturally diverse communities, prepared with the information to receive warnings and take the correct action?

Consider improving or introducing new tsunami risk management measures to reduce residual risk levels. If no further action is taken to reduce tsunami risk, document the reasons for this decision in the CDEM Group risk assessment documentation.

If new or improved risk management measures are implemented then their effectiveness in reducing the residual risk should be evaluated (during or after implementation) to determine the new level of residual risk. Following new evacuation modelling, this new residual risk level should then be compared with risk acceptance levels to determine if further risk management measures are required.

Monitor residual risk levels to account for changes in tsunami hazard knowledge or population change and ensure that they do not increase the residual risk. Re-evaluate residual risk against tolerable levels as appropriate. Record this as part of the CDEM Group risk assessment documentation. Step 2C.

Residual risk is intolerable

If tsunami life-safety risk is determined to be intolerable, new or improved measures to reduce the risk should be implemented. Measures for managing residual risk are discussed in *Section 2.3 Means of managing residual risk*.

The expectation should be that residual risk will be reduced to at least tolerable, and ideally acceptable levels. If all other practical options for reducing residual risk are in place and risk is intolerable, then tsunami vertical evacuation may be considered as a risk management measure.

Evaluate and implement risk management options to reduce residual risk. Following or during implementation, the effectiveness of the new measure(s) in reducing the residual risk should be evaluated to determine the new level of residual risk. Following new evacuation modelling, this new residual risk level should be compared with risk acceptance levels to determine if further risk management measures are required.

Monitor residual risk levels to track any changes in tsunami hazard knowledge or population change that may increase residual risk. Re-evaluate residual risk against tolerable levels as appropriate. Record this as part of CDEM Group risk assessment documentation. Step 2D.

2.3 Means of managing residual risk

Risk management measures

This section provides examples of the measures available for reducing residual risk before CDEM Groups consider tsunami vertical evacuation. Tsunami vertical evacuation should only be considered when all other practical measures for managing risk have been implemented and evaluated. The most effective method to ensure the safety of people is to remove them outside of hazard zones to safe locations. Tsunami vertical evacuation is a measure that is designed to offer temporary refuge, however people will still be physically located within the hazard inundation zone, and are therefore susceptible to being isolated in an inundated hazardous area, so it is considered a measure of last resort.

Tsunami risk is the product of the likelihood and the consequences of a tsunami. We cannot change the likelihood of a tsunami occurring; therefore, risk management must focus on reducing the consequences. The measures for managing tsunami risk to people fall into two main categories: reducing the exposure of people to tsunami hazard, and reducing the vulnerability of people exposed to tsunami hazard.

This section also describes the importance of critically assessing the effectiveness of the measures already in place, prior to the implementation of any new or improved risk management measures. This may be done through public surveys, exercises, assessment by specialists, modelling or other impartial methods and provides a baseline for understanding changes to residual risk.

Tsunami risk management measures span various functions of councils (e.g. emergency management, regulatory, policy planning, finance and community engagement) and it is important that <u>all appropriate functions</u> are included in decision-making for risk management measures.

Reduce long-term exposure

In this guidance, a change to long-term exposure means a permanent change to the number of people exposed to tsunami, rather than the temporary change provided by evacuation during tsunami events.

Below are two options that <u>may</u> reduce long-term exposure: (1) land use planning, and (2) more sophisticated modelling to refine the size of tsunami evacuation zones.

Land use planning

(1) Land use planning is where development is limited or controlled to reduce the type of activities situated within buildings in hazard zones. However, some natural hazard risks are more commonly managed through land use planning measures than others. For example, many councils use rules and policies to control land use in flood hazard zones. This is because flood hazard zones are generally easily identified and floods are a relatively frequent hazard.

For tsunami, the case for land use planning controls is not so straightforward. The likelihood of damaging and life-threatening events is generally low, our coasts are already intensely developed, and very few significantly damaging tsunami have occurred in recent historical times. Public acceptance of restrictions on use of the coast will be evaluated against coastal amenity and the social and economic benefits gained from existing coastal land use. A low likelihood can translate into a lower desire for restrictions when there are significant trade-offs involved.

Any land use planning rules for tsunami should be appropriate to the acceptability of risk. It may be practical and appropriate to adopt new land use planning rules for tsunami in the following conditions, but such decisions should be made with community consultation on whether rules should apply for:

- areas exposed to local sources capable of producing very large tsunami (e.g. offshore plate subduction zones)
- certain types of land use activities that result in concentrations of vulnerable populations (e.g. early childhood education centres or aged care facilities)
- greenfield coastal developments only, or for greenfield developments and intensification of existing coastal developments
- design and layout of new subdivisions (notably roads, public footpaths and reserves) to facilitate quicker evacuation to higher ground
- critical infrastructure (excluding ports)
- areas where tsunami risk is intolerable
- other locally significant factors.

Note: a combination of the above conditions may be required for land use planning rules to be a risk management measure. These should be accepted by the majority of stakeholders.

Consider land use policies and rules for managing exposure to tsunami hazard. Are there compelling reasons why such measures should be considered in the at-risk area? Document all steps of the process required for implementation. Document benefits and opportunity costs of land use planning measures in the analysis of tsunami risk management measures. Step 2C.

Modelling refinements

(2) Evacuation zone modelling is often completed conservatively to account for the uncertainties in understanding tsunami sources and the modelling equations used. Total population exposure is based on the number of people in these conservatively-modelled zones. In some cases, this can mean the population exposed to tsunami is overestimated, and the time required to reach safety, is overestimated. Improvements in evacuation zone modelling can include better characterisation of sources, improvements in wave modelling, or improvements in inundation modelling. In general, as the modelling becomes more accurate, the cost also increases. The most detailed models require the greatest accuracy of base data and expertise. A trade-off between precision and cost is often employed to ensure evacuation maps can be developed in the knowledge that they may be an overestimation of the at-risk areas, to account for the

modelling uncertainties. Improved data or more accurate modelling can reduce uncertainties and in some cases, reduce the landward extent of the evacuation zones. Factors to consider regarding more detailed modelling include:

- Detailed modelling may not (significantly) reduce the size of evacuation zones – discuss with tsunami modelling scientists how uncertain and conservative current modelling is before undertaking further modelling.
- Cost – is there budget available for more detailed modelling, requiring scientific expertise and specialised software?
- Population density – it may be more effective to focus on improving modelling in the most densely populated areas, as a small change in the evacuation zone extent can potentially remove thousands or hundreds of people located within an evacuation zone.
- Maximum credible scenarios – modelling the maximum credible scenarios from all sources will produce the greatest inundation extents. Any reduction in the modelling uncertainties evacuation zone extent, than models that include reduced uncertainties for smaller, more likely scenarios.

Consider the current models used to develop local evacuation zones. Determine whether improved modelling is a possibility based on a cost-benefit assessment. Record the results of these considerations as part of evacuation zone mapping supporting documentation. Steps 1A, 1C and 2A.

Reduce short-term exposure

In this guidance, a change to short-term exposure means the temporary change in the exposed population that is provided by evacuation during tsunami events.

The alternative to land use planning that reduces the number of people within hazard zones is to improve the current evacuation plans and routes in place. These improvements make it easier for those at risk to move to safe locations during any imminent tsunami threat of land inundation. A suite of measures is available to support the timely and/or improved evacuation of at-risk communities. The ideal is that through these measures, residual risk can be reduced to acceptable levels or be sustained within tolerable limits.

Improve evacuation routes and efficiency of movement

The following measures, if implemented, could contribute to more timely evacuations:

- Improving the capacity or quality of routes e.g. widening “pinch-points” such as bridges and building boardwalks across uneven terrain or installing solar-powered lighting.
- Building new routes where none are present, for example, steps up a steep hillside or new bridges spanning impassable waterways.

- Implementing and maintaining public education on using alternate means of transport in evacuation to reduce traffic congestion, including walking and cycling for those who can, and motorised vehicles only for those who require them.
- Identifying any likely hazards on evacuation routes and mitigating the hazard. For example, stabilise slopes adjacent to evacuation routes or have a long-term plan to move electricity network cables underground.
- Ensure clear signage on evacuation routes, and ongoing education to improve awareness of the routes.

Consider the capacity and ease-of-use of identified evacuation routes. Determine whether improvements to increase capacity and/or reduce travel time are possible.

Reduce vulnerability

Reducing vulnerability means decreasing the environmental factors and/or inherent population and individual factors that inhibit timely evacuation.

The measures below, if implemented, could increase people's awareness, decision-making capability and evacuation ability, therefore reducing vulnerability. Guidance is available on the inclusion of people with disabilities (link left) and including culturally and linguistically diverse communities in planning (links provided, left, below). CDEM Groups may find these useful when considering barriers to evacuation these vulnerable communities may face.

Public education to increase tsunami awareness and decision-making capability:

- Improved/targeted/more effective public education and engagement on natural warnings for local source tsunami and the correct actions to take.
- Improved/targeted/more effective public education on official warnings, when they will be used, how they will be used and appropriate public response actions.
- Develop public education materials in a number of formats and deliver through a wide range of channels, e.g. different languages or pictures-only for non-English speakers, resources for businesses or school, reach the public via social media, community radio, posters in campgrounds, public events in tourist season etc.

Training, exercises, planning and drills with at-risk populations:

- Regular public drills to reinforce familiarity with evacuation routes and test assumptions about the time required for evacuation.
- Organised transport for lower mobility groups (note: this likely provides the most value for near-regional source events, this may not be practical for local source events unless the vehicle and driver is on site at all times for the group in need).

- Evacuation planning with large institutions (e.g. schools) and workplaces (see *'Working towards tsunami safer early learning services and schools'* – published by East Coast LAB (linked left), for further information).
- Community response planning to identify people who may require additional help to evacuate (e.g. a sole parent with young children or a caregiver of a dependent adult).

Improvements in capability and capacity:

- Improvements in public alerting systems for official warnings with special consideration for hard to reach pockets of people (e.g. tourists in isolated areas) and high-density areas.
- Improvements in emergency management planning and procedures for tsunami warning and evacuation. These should be based on exercises and other methods that identify opportunities for improvement.
- Professional development of response staff – improved knowledge of tsunami hazard and risk, planning and procedure development and engaging with the public.

Consider the range of improvements possible in public education, in reaching and supporting vulnerable or hard to reach groups, and in civil defence emergency management training, planning and procedures. Determine which measures would be appropriate for improving local tsunami risk management. Document any changes that will be adopted in the CDEM Group's analysis of tsunami risk management measures.

Select and implement risk management measures

Select the measures to be implemented from that are most appropriate to improving management of the local tsunami risk. Consider:

- local priorities (e.g. schools in tsunami zones or communicating with large numbers of tourists)
- the speed and proportion of evacuation observed from drills
- budget
- opportunity costs and opportunities realised.

Document the decision-making process and which measures will be implemented. Undertake all the necessary steps for implementation of these measures.

2.4 Review effectiveness of implemented risk management improvements

New or improved risk management measures are introduced to reduce residual risk. Following implementation of these it is important to assess the effectiveness of each measure. Changes to exposure or vulnerability can then be included in a revised evacuation model, to determine the new residual risk value. The new residual risk value must then be compared against risk acceptance levels.

Determine changes to exposure or vulnerability

Use the methodologies applied in Step 2 to determine the tsunami risk management baseline (exposure, vulnerability and risk management in place) for the region or community of interest. Use this baseline to track changes to exposure or vulnerability. It may be more practical to group risk management measures together, rather than assess each measure individually. For example, all measures that have been implemented to reduce long-term exposure (such as land use planning or improved hazard modelling), could be assessed simply as the change in total exposed population, based on the number of people in the newly mapped evacuation zone.

Changes to vulnerability are likely to be more difficult to quantify, especially measures to improve decision-making and action intentions. Surveys are one method that may be used. However, care must be taken to ask the same survey questions before and after the implementation of measures. It is also important to note that increased awareness about tsunami hazards is not the same thing as increased preparedness for tsunami evacuation.

> Determine changes in exposure and vulnerability against the baseline. Seek expert advice on evacuation modelling and whether the changes are significant. Record these changes as part of CDEM Group risk assessment documentation. Step 2D.

Recalculate residual risk

The new residual risk must now be calculated and compared with risk acceptance levels.

> Return to the start of Step 2A and repeat the residual risk assessment and residual risk evaluation using the new exposure and vulnerability information. If residual risk cannot be reduced to tolerable levels, consider vertical evacuation.

Step 3 Tsunami vertical evacuation

This section relates to Step 3 of the tsunami vertical evacuation decision-making tool and discusses the considerations needed for implementing tsunami vertical evacuation in New Zealand. This includes understanding the principles of implementation, different structure types, public education and messaging, and planning considerations.

This step does not provide design requirements for tsunami vertical evacuation structures. This will be presented in the Phase Two guidance, to be developed in 2019, by the Ministry of Business, Innovation & Employment (MBIE) and MCDEM.

Step 3 should only be considered if all other means to reduce the residual risk have been implemented, and the residual risk is still deemed intolerable, i.e. where, tsunami vertical evacuation is the only option remaining to reduce the residual risk to tolerable levels. This step will need to be understood by all stakeholders involved in planning for tsunami vertical evacuation. To ensure expectations are managed, it is important for all stakeholders, decision makers and at-risk communities to be aware of the factors that may prohibit the designation and use of tsunami vertical evacuation structures. These factors may include:

- the cost to build a new, or retrofit an existing structure, becomes prohibitively expensive
- the available locations for a structure are unsuitable for the at-risk community
- the community or stakeholders do not want to use vertical evacuation as a measure to reduce the residual risk.

There are two types of tsunami vertical evacuation structures (1) purpose-built, and (2) retrofitting and use of existing structures, such as carparks and high-rise buildings. Purpose-built structures are specifically designed and built to withstand earthquake shaking and tsunami forces. Retrofitting existing structures requires the assessment and enhancement of existing structures to a standard that allows them to retain structural integrity following earthquake shaking, and subsequent tsunami impact forces and wave heights. Both new and retrofitted structures will need to meet the structural standards outlined in the Phase Two guidance.

3.1 Considerations and principles when planning for tsunami vertical evacuation

The following section describes a range of topics to be considered when planning for tsunami vertical evacuation. These are based on existing international frameworks and academic research on tsunami vertical evacuation.

The following principles of implementation apply to the use of tsunami vertical evacuation structures in New Zealand. Structures are:

- designed and built to provide a short-term refuge from tsunami, for the purpose of life safety only and are unable to provide long-term refuge and are not Civil Defence Centres
- considered a last resort option, if timely evacuation out of tsunami evacuation zones is not possible. Evacuation out of all tsunami evacuation zones should always be the first option.

3.2 CDEM specific considerations

CDEM Group Plan and CDEM arrangements

As part of the CDEM Group Planning process (as described in Section 4.1 of the *CDEM Group Planning Director's Guideline [DGL 09/18]*), each CDEM Group should describe their 4Rs risk management for prioritised risks. CDEM Groups must state and provide for the hazards and risks to be managed by the CDEM Group and the emergency management necessary to manage these hazards and risks (refer s.49(2)(b-c) of the CDEM Act).

If tsunami is a priority risk, the CDEM Group Plan should include the rationale for tsunami risk management measures in place, and those that will be adopted in the future. This includes the key considerations and decision-making process underlying the use of tsunami vertical evacuation, if it is to be adopted as a risk management measure (as described in Steps 1 and 2 of this guideline).

The rationale should also include how tsunami vertical evacuation has been evaluated against other risk management priorities for other hazards. Tsunami vertical evacuation is likely to be a resource intensive and costly option to reduce residual risk, the rationale should clearly make the case for why this measure is prioritised over other hazards and associated measures.

Existing plans and arrangements for tsunami risk management will need to be reviewed and updated if the decision is made to use tsunami vertical evacuation. Many arrangements will be context-specific to the CDEM Group, and therefore the CDEM Group is best placed to know what will need to be amended. Below is a list of plans, arrangements or activities that should be reviewed, and are likely to require updating to incorporate tsunami vertical evacuation considerations:

- public education programmes and community engagement strategies
- evacuation plans, including mass evacuation planning
- maps and signs
- response plans/contingency plans
- standard operating procedures (SOPs)
- exercising/testing activities
- public alerting messages and arrangements
- community response plans
- welfare plans
- recovery plans.

Public education and messaging

Public education is a catch-all term for the engagement, resources, campaigns, training, exercises and activities designed to raise awareness and improve the readiness and response of at-risk communities. Public education is a critical component of tsunami risk management, and this is especially so for local source tsunami. If tsunami vertical evacuation is to be adopted as a risk management measure, then challenges are likely to arise over the alignment of local and national tsunami safety messaging and campaigns.

To avoid public confusion, a CDEM Group should carefully develop tsunami safety communication strategies, public education campaigns, and resource materials to ensure any inconsistencies are well-managed.

In New Zealand, the advice to those near the coast during a long or strong earthquake is to DROP, COVER and HOLD during the shaking, and then, follow the LONG or STRONG, 'GET GONE' advice. This means immediately moving inland or to the nearest high ground, outside of tsunami evacuation zones. The messaging for tsunami vertical evacuation may be inconsistent with several components of public education for tsunami already in place.

CDEM Groups have put significant effort into developing and promoting tsunami evacuation zones, including placing information boards and route signs, producing printed materials, and in some cases marking safe locations and boundaries. This work has been undertaken to align with the *Tsunami Signage Technical Standard [TS 01/08]* and the *Tsunami Evacuation Zones [DGL 08/16]* (link provided, left). The DGL recommends the following text on information signs and materials "In the case of a large earthquake (that is hard to stand up in), unusual noises from the ocean, or changes in the ocean (e.g. the ocean rushing in or out), or you feel a weak earthquake that lasts for a minute or more: Evacuate ALL zones."

Messaging for using tsunami vertical evacuation will conflict with this advice and will have to be carefully developed to ensure at-risk communities understand the implications of evacuating to a site that is still technically within an evacuation zone. Additionally, it must be made clear that evacuation vertically within an evacuation zone is a last resort option and where possible, it is always preferable to leave the at-risk area completely.

Nationally consistent messaging for use of tsunami vertical evacuation structures will be developed during Phase Two of this guidance.

Community engagement plan

Before the implementation of tsunami vertical evacuation, a CDEM Group should develop a communication plan/community engagement plan to ensure the context, use and limitations of tsunami vertical evacuation are understood. The plan should include the following:

- Why a tsunami evacuation structure is required in a location(s) and the wider context for evacuation (i.e. the local tsunami hazard context, including minimum wave arrival times).
- That the best option is always to leave all at-risk areas before tsunami waves arrive, but this may not be possible for all people.

- Which communities it is designed to serve, including any vulnerable groups or people present between the coast and the structure (i.e. it is preferable and safer to travel inland than to travel coastward towards a tsunami vertical evacuation structure).
- When it is appropriate to use a tsunami vertical evacuation structure for evacuation (i.e. only to be used in certain circumstances where timely evacuation is not possible).
- What triggers the use of the structure (i.e. 'natural' or 'informal' warnings or from an official warning).
- Descriptions of the signs, maps and other resources that have been updated or developed to support use of the tsunami vertical evacuation structure.
- That the tsunami vertical evacuation structure's purpose is to provide short-term refuge and it will not provide the resources that are usually associated with long-term shelters, and it is not a Civil Defence Centre (CDC).

Tsunami evacuation zones, signs and maps

The *National Tsunami Signage Standard [TS 01/08]* provides the requirements for tsunami signs in New Zealand. A template for tsunami vertical evacuation signage is provided in this standard as well as recommendations on sign placement. The standard includes the template for signs used on the outside of structures (see page 15) and additional signs designating which floor should be reached for safety if the structure is multi-level (see page 17). Tsunami maps show evacuation zones, safe locations and recommended routes.

CDEM Groups will be required to align with these standards and ensure maps have clear symbols that differentiate tsunami vertical evacuation structures from other features (such as natural features or landmark buildings). The map legend should summarise the key considerations for use of the structure, for example that these structures should only be used following natural warnings or explicit official messaging to do so.

Exercises and drills

Exercises and drills are a part of a continuous process to test emergency planning, raise public awareness and increase familiarity with the correct actions to take during emergencies. Exercises and drills also provide valuable opportunities for interactive education including the discussion of hazards, appropriate actions and the refinement of evacuation plans (Fraser, 2014). Conducting exercises or drills using tsunami vertical evacuation structures for distant source tsunami scenarios will be unnecessary as tsunami vertical evacuation structures should only be used when timely evacuation is not possible (i.e. for local source tsunami or in some circumstances regional source tsunami).

Arrangements should be made by CDEM Groups to regularly test their tsunami vertical evacuation structure(s) through exercises and drills. CDEM Groups could consider using existing frameworks or systems for exercises or drills to conduct a tsunami vertical evacuation specific exercise or drill.

For example, activities aligned with *ShakeOut*[2] (New Zealand's national earthquake drill and tsunami hīkoi) could include a tsunami vertical evacuation drill.

Wellbeing

In this context, wellbeing refers to the conditions and resources that contribute to the comfort of people present in tsunami evacuation structures. As the primary purpose of these structures is for short-term refuge above tsunami inundation levels, wellbeing considerations are supplementary to the life-safety considerations such as access and structure height (note: building-specific considerations will be covered more fully in the Phase Two guideline).

A tsunami vertical evacuation structure is not a Civil Defence Centre and does not require provisions for long-term shelter. CDEM Groups are best placed to consider what facilities will be available. Local information on the at-risk population and likely duration of occupancy will assist with these considerations.

Occupancy duration is difficult to estimate, as each event will be different. Evidence from the 2011 Tohoku Tsunami in Japan suggests that it is reasonable to expect that a structure could be occupied for at least 24 hours and possibly 48 hours. Ideally, tsunami vertical evacuation structures should have shelter, sanitation, and food and water sufficient for several days (Fraser, 2014). CDEM Groups should consider documenting the decisions made on wellbeing facilities in any tsunami vertical evacuation cost/benefit documentation. Wellbeing facilities *could* include the following:

- Shelter – for protection of evacuees from environmental factors such as rain, wind or sun.
- Food and water – could be considered based on the expected occupancy capacity and duration.
- Sanitation – evacuees may be occupying a tsunami vertical evacuation structure for an extended period. To mitigate risks to human health, sanitation facilities could be provided.
- Communications – communications equipment can provide links to emergency services involved in the response.
- Emergency lighting – emergency lighting such as torches or battery/solar lighting to support safe evacuation within/upon structures.
- First aid supplies – evacuees may be injured during the initial earthquake or during evacuation.
- Facilities for those with additional requirements e.g. people with disabilities, infants or the older people.
- Safe and secure spaces – the safety and security of individuals could be considered and particularly how people can remain safe during occupancy.

[2] https://www.shakeout.govt.nz/

- A secure area for companion animals (pets) – although wellbeing facilities are not typically expected to accommodate pets, people often do not want to leave them behind when evacuating.

The security of, and access to, facilities will also need to be considered. This is particularly the case for a structure that is not multi-purpose, as it may be unoccupied or unused for long periods of time.

3.3 Structure specific considerations

Location of a tsunami vertical evacuation structure

The location of a tsunami vertical evacuation structure, within the tsunami inundation zone, is one of the most important considerations for both purpose-built and retrofitted structures.

A detailed location(s) assessment should be completed as part of the planning process, and should involve all stakeholders. The assessment should ensure a number of locations are evaluated with the main objective of ensuring timely, safe and efficient evacuation. The location of a tsunami vertical evacuation structure should not pose further risk to evacuees, who will be using the structure for refuge. The assessment and planning for location(s), should include:

- Region/area specific tsunami evacuation modelling which includes an assessment of the terrain and wave arrival times. This information will support the assessment of best available routes to the structure(s) by estimating:
    a) Mapped tsunami evacuation zones and routes, alongside terrain information to determine which locations within zones face the greatest challenges to timely evacuation.
    b) Locations that allow evacuees to reach the site(s) within the time available between tsunami warning (natural and/or official) and tsunami wave inundation.
    c) An estimation of travel time from all relevant locations within evacuation zones to determine whether evacuees can reach the site and the safe height within or on the structure, within the time available between tsunami warning (natural and/or official) and tsunami wave inundation.
- Consideration of the most efficient path to the tsunami vertical evacuation structure, noting the number of at-risk people in the tsunami hazard zone, and the directions travelled to reach safety.
- How many people can get to the structure(s), and for each location under consideration, the maximum number of people who will likely use the site. This is especially important where multiple structures may be required, in order to optimise access and capacity.
- The demographics and intentions of the local at-risk community, including how those communities can best travel to a given site.

- A review of potential hazards along the access routes, and areas where there may be a need to improve the quality of the routes or mitigate potential hazards (e.g. potentially unstable slopes).
- A review of additional hazard sources near the structure or its nearby location e.g. power stations/fuel stations may pose a risk of fire, or nearby earthquake prone buildings may suffer partial or full collapse and block evacuation routes with debris.

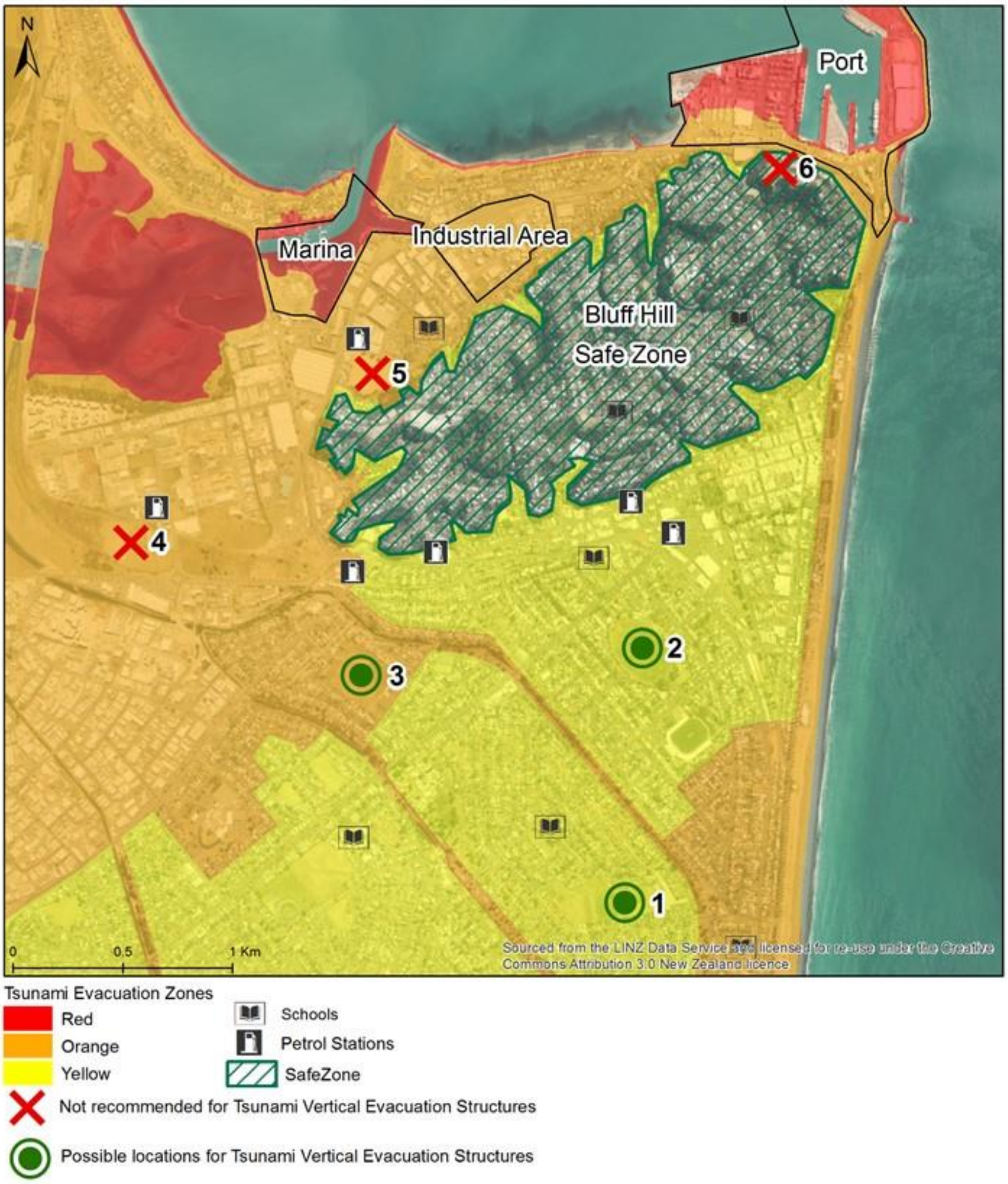
Tsunami evacuation modelling (as described in Step 2A) can assist with identifying locations that are optimal or less suitable.

- A review of possible waterborne hazard sources from the surrounding area, e.g. ports where shipping containers or boats can become waterborne debris.
- Any advantages and disadvantages of different structure types at each location.
- Located to take advantage of the natural direction of travel inland or to higher ground, outside of the evacuation zones, rather than towards the coast. If unforeseen circumstances occur and access to the tsunami vertical evacuation structure becomes blocked, or the structure reaches capacity, evacuees can continue moving inland or to higher ground away from the area of risk.

Figure 1 on the next page is an indicative tsunami vertical evacuation structure(s), options map. Napier City has been used to provide an example of an area in New Zealand where significant land inundation from a local source tsunami is possible. The map clearly identifies the modelled evacuation zones (red, orange and yellow). The maximum credible scenario for this area of Hawke's Bay could result in land inundation of up to 6km inland, in a highly populated area. In this instance, vertical evacuation could potentially save hundreds of lives.

The indicative map has been developed for visualisation purposes, to demonstrate a method for choosing optimum, safe location(s) for tsunami vertical evacuation structure(s). For example, the indicative options map could be used for selecting or ranking sites based on the following criteria:

- population density distribution (based on building density)
- proximity to vulnerable populations (location of schools)
- site accessibility for different parts of the at-risk area (extent of the zone and access routes within the zone)
- distance from other natural vertical evacuation structures/refuges (in this case the Bluff Hill Safe Zone)
- location of identified hazard sources (e.g. petrol stations, industrial areas).



This is an indicative map only, and has been developed for visualisation purposes in support of Section 3 of the 'Assessment and Planning for Tsunami Vertical Evacuation Guidance'. This is not a map that can be used for the designation of tsunami vertical evacuation structures, and does not show assessed locations. The evacuation zones identified in this map are current as of June 2018.

Figure 1 Indicative example of a tsunami vertical evacuation structures, location options map

Access

Accessibility to a vertical evacuation structure is an important consideration and not only includes the structure's 'business as usual' usage (private vs public), but anything that may prohibit use of the structure in times of an emergency. Ideally, a tsunami vertical evacuation structure should:

- must be accessible 24/7, 365 days of the year.
- be built for the varying access needs of at-risk communities. For example, structures should be designed for people with impaired mobility.

- have the capacity of the structure clearly identified i.e. how many people can safely fit in or on the structure.
- have additional multi-purpose benefits, where applicable. This could include educational posters/installations or recreational facilities.
- have multiple access points and have access maps clearly displayed, clearly identifying the safe height or level within or on the structure (e.g. "*Tsunami safe location - Floors 4 and higher*").

Ownership

The owner(s) of tsunami vertical evacuation structure(s) will be required to oversee the facility taking into consideration its emergency purpose and any other purpose(s) it may have. Facility management considerations include:

- longevity/durability of a structure and ensuring it is fit for purpose over time
- any new official advice specific to tsunami risk and engineering requirement, ensuring the structure continues to meet performance requirements
- maintenance of the structure's facilities to ensure they meet an appropriate standard and ensuring 24/7 access
- regular communications with the likely users of the structure during non-emergency times so they are aware of its use and purpose
- scheduling regular drills and exercises to maintain public awareness and testing of the facility
- ensuring processes are in place for CDEM Groups to incorporate any changes to the structure's name or ownership in maps, plans and/or usage agreements
- an evaluation process after any tsunami event for which the structure has been used for its intended purpose.

Funding for a tsunami vertical evacuation structure

Funding the design and build of a new tsunami vertical evacuation structure or retrofitting an existing structure could be a significant cost to a CDEM Group. The Phase Two guidance will provide indicative costs in this regard, specific to New Zealand engineering design, manufacturing and construction costs. When considering funding tsunami vertical evacuation structures, CDEM Groups must consider the end-to-end process of scoping, assessment, evaluation, options assessment, consenting, construction, and implementation including public education signage, drills and long-term maintenance.

If a CDEM Group has identified the need for a tsunami vertical evacuation structure, the cost-benefit analysis and decision-making process will need to be documented and the budgeted analysis be attached to the appropriate financial reporting mechanisms. Long-term plans and budgets can then adequately reflect the full considerations for, costs of, and funding mechanisms available for, tsunami vertical evacuation.

Overview of Phase Two guidance

Building design and performance for tsunami vertical evacuation structures

Phase Two of this guidance series will provide design and performance considerations for tsunami vertical evacuation structures in New Zealand. The Ministry of Business, Innovation & Employment (MBIE) and MCDEM will jointly develop the Phase Two guidance. It will include a review of current international frameworks such as 'Guidelines for Design of Structures for Vertical Evacuation from Tsunamis' (FEMA, 2012) and 'Tsunami Loads and Effects Chapter in Minimum Design Loads and Associated Criteria for Buildings and Other Structures' (ASCE, 2016). The guidance will not include a review of the existing New Zealand building code, but will align with current frameworks for managing building performance in New Zealand.

The scope of the Phase Two guidance includes considerations for the design of purpose built structures, and retrofitting existing structures. This includes content on how a structure must withstand tsunami forces, and the load combinations that should be considered. For example, seismically triggered ground acceleration and shaking, hydrostatic and hydrodynamic forces, waterborne debris accumulation and impact loads, scour effects, and potential load combinations.

The Phase Two guidance is due for completion in 2019.

References

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