This section presents the results of the risk analysis and discusses the evaluation of the identified risks. However, before presenting the results it is important that the criteria be established against which the risks will be evaluated. Therefore, the following section (Section 5.1) discusses the risk criteria considered appropriate for this study. Further details are provided in Appendix A. The estimated lives risks (Sections 5.2 to 5.5) and financial risks (Sections 5.6 and 5.7) are then presented and evaluated in light of the suggested criteria.

5.1 Risk Evaluation Criteria

There are currently no published guidelines on evaluating financial risk. Therefore, the evaluation of financial risks must be conducted within the context of an organisation's internal financial policies and procedures. For this study the financial risk evaluation is conducted as part of assessing benefit cost ratios for risk mitigation works. For lives risks there are published guidelines on risk criteria for individual risk and societal risks. These are discussed in the following sections. However, it is emphasised that the criteria should only be used as a guideline since to date there are no lives risk criteria for natural hazards such as flooding that are widely endorsed by any regulatory agency in New Zealand.

5.1.1 Individual Risk

Suggested guidelines for individual risk have been published by several organisations (e.g. AGS, 2000 and ANCOLD, 1994) and are discussed in more detail in Appendix A. In the Netherlands a limit of between 1×10^{-3} and 1×10^{-6} has been suggested by the Dutch Technical Advisory Committee on Water Defences (TAW, 1988). The lower value is used in cases where the elements at risk (i.e. people) have no control over their exposure to the event or the hazard itself, which can be thought of as an imposed risk situation. The highest value is used in cases where the element at risk has complete control i.e. recreational activities such as sky diving or mountaineering. For this risk assessment we suggest that the following guidelines be used:

- For the individual most at risk the intolerable limit is 1×10^{-4} ; and
- The target (objective) should be 1×10^{-5} .

These values are consistent with the suggested limits in the Netherlands for flooding (TAW, 1988) and guidelines used for evaluating lives risks due to dam safety issues (ANCOLD, 1994).

5.1.2 Societal Risk

Annualised Lives Risk

There are limited cases where criteria have been published for ALR. The USBR suggest a limit of 0.01 fatalities per annum for ALR (USBR, 1997). This guideline is used in the dams industry where flooding is a significant dam safety hazard. A major dam owner in British Columbia (BC Hydro) is reported to use a guideline of 0.001 for ALR (Jonkman and van Gelder, 2002).

F-N Criteria

The latest published ANCOLD societal risk criteria (1994 and 1998) are presented on a F-N chart, which plots the frequency F of N or more fatalities against the number of fatalities (N). On the F-N chart a threshold is defined above which the level of annualised risk is generally regarded by society as unacceptable and measures should be put in place to reduce the risk (refer Appendix A). A lower threshold is also defined, below which the risk is generally regarded by society as acceptable. The intermediate zone, labelled "ALARP" (**A**s **L**ow **A**s **R**easonably **P**racticable), represents a risk level where the risk should be reduced where practical risk reduction measures are available, in consideration of such things as operational and financial constraints. The lower threshold is currently under review by ANCOLD and it is proposed that the "acceptable" zone is removed and the entire area on the graph below the "unacceptable" threshold be referred to as ALARP (ANCOLD, 2001).

Comparison of suggested societal lives risk criteria with other risks experienced in society indicates that the suggested unacceptable threshold is lower than many societal risks reported for America and the UK (Ashby, 2002). This would be expected given that in general people expect to be exposed to significantly lesser levels of risk when the risk is imposed on them rather than when they choose to undertake an activity that exposes them to a risky situation. The UK Health and Safety Executive (HSE) has also published guidelines (HSE, 1991) for societal risk in terms of F-N criteria. The HSE guidelines are slightly higher than the ANCOLD criteria and were developed during a study of the transport of hazardous goods in the UK.

5.2 Risk Profile

Figure 5-1 (at the end of this section) presents the risk profile based on the calculated Annualised Lives Risk (ALR) for each community. The profile has been ranked from highest ALR to lowest.

5.3 Individual Risk

The individual risk, which is the annualised probability of a particular individual being killed by a flood, has been calculated for each of the cases listed in Section 4.1.5 and presented in Table 5-1.

Table 5-1: Estimated Individual Risks

Case	Individual risk
A resident within a high hazard area.	5×10^{-5} (50 per million years)
A resident within a medium hazard area.	8×10^{-6} (8 per million years)
School pupil* (assuming flood occurs during school time).	5×10^{-6} (5 per million years)
Tourist at camping ground (tent/caravan site) in "very high" hazard area.	1×10^{-5} (10 per million years)
Tourist at camping ground (tent/caravan site) in high hazard area.	4×10^{-6} (4 per million years)

* In this case the individual risk is calculated for the Coromandel township where the school is located within a low hazard area.

5.4 Annualised Lives Risk

Figure 5-2 (see end of section) presents the contributions to the ALR for each site due to the various activities at each of the subject communities. From this figure it can be seen that the largest contributor to the ALR comes from the camping grounds and the largest of these is for Waiomu, which has the largest potential population at risk out of all the sites considered. This indicates that risk mitigation measures aimed at reducing the risk at the camping grounds should have considerable benefits in reducing the overall ALR for each of these communities.

5.5 Cumulative Frequency of N or More Deaths

Figure 5-3 (see end of section) shows the societal risk in terms of a F-N Chart, for each subject community. This figure also indicates that the potential LOL has an upper bound, which ranges from 1 to 2 fatalities for Tararu and Coromandel up to 15 to 25 fatalities for the other communities. The higher potential LOL values are associated with camping grounds where during holiday season the population at risk is greatest.

5.6 Financial Exposure Profile

Figure 5-4 (see end of section) presents the estimated financial exposure profile for assets and infrastructure at each of the communities based on the economic elements at risk in Table 4-3. This profile represents the estimated financial consequences given that an event occurs and presents real dollar values. The estimates have been generated using Monte Carlo simulation based on the consequential costs developed from the table given in Appendix C. Estimates at the 50th and 95th percentile have been shown for various categories, namely “activities”, “local agency costs, “regional agency costs” and “State highways”.

Activities represent consequential costs associated with residential housing, schools, retirement villages, campgrounds and hotels and motels. Within the model, these costs have been presented as the product of a damage ratio (a fraction between 0 and 1) and an asset value, both with probability distributions applied to reflect the likely range and uncertainty in financial consequences.

Local agency costs include costs associated with TCDC assets such as local roads, water supply and wastewater systems, channel clearing costs, damage repairs etc and cost to provide and support civil defence services. Regional agency costs represent the costs carried by Environment Waikato including some channel clearing for EW assets, event response costs etc. These costs have been represented as distributions for each category. The exposure values are tabulated in Appendix C (Table C-1).

While the above reflects the main costs likely to be directly incurred as a result of flooding, there are usually a number of indirect and often less tangible costs associated with such an event. These include, for example, impacts on property values, social costs, disruption to daily routines and longer term effects on business and tourist activity, and will generally be harder to quantify. These are briefly discussed in relation to assessing the benefits of flood protection and mitigation works in Section 5.10.5.

5.7 Financial Risk Quotient

The financial risk quotients (financial consequences multiplied by the event probabilities and vulnerabilities) are shown in Table 5-2. Like the ALR, the risk quotients represent the expected annual cost (as opposed to the expected annual number of fatalities) based on the 100-year flood event – in simple terms, the cost of a 100-year event divided by 100. While the risk quotients are shown here as dollars, they are not in fact "real" dollar values, but "risk dollars" (effectively dollars per annum), which can be used as direct inputs to a benefit-cost model.

Table 5-2: Financial Risk Quotients

Location		Activities	Infrastructure	Lives	Total
Tararu	Mean	$850	$920	$10,800	$12,560
	95%	$1,510	$1,230	$10,800	$13,310
Te Puru	Mean	$2,450	$910	$58,560	$61,920
	95%	$3,880	$1,210	$58,560	$63,370
Waiomu-Pohue	Mean	$2,640	$1,480	$40,080	$44,210
	95%	$3,820	$2,050	$40,080	$44,470
Tapu	Mean	$980	$890	$29,000	$30,880
	95%	$1,410	$1,190	$29,000	$31,370
Coromandel	Mean	$3,090	$1,050	$23,200	$27,340
	95%	$5,030	$1,450	$23,200	$29,320

The lives risk quotients are calculated using a fixed value of NZ$4M for a life. The basis for this is discussed in more detail in Section 5.10.4.

5.8 Risk Management Strategy

It is neither possible nor practical to eliminate risk entirely. Sound risk management should recognise this and aim to identify those risks that can be significantly reduced and those that need to be managed. A documented risk management strategy should clearly and concisely set out the corporate risk management policies addressing how these risks will be dealt with. These policies would be expected to set the levels of tolerable and unacceptable risk that can be used as the organisation's criteria against which the identified risks can be measured. This strategy should set the framework for a risk management plan that will set out the specific activities needed to achieve the strategy objectives.

Therefore, pragmatic risk management requires identification and prioritisation of the locations and extent of risk treatment works over the entire risk inventory. These prioritisation decisions need to be transparent and defensible and where possible measured against published guidelines or criteria. The identification of the flood risks for each community is one input into the process of developing a strategy to efficiently manage the flood risks. There are likely to be many other factors that will contribute to the overall strategy, including corporate, political and operational aspects that are beyond the scope of this QRA. However, the QRA does provide valuable tools to help in the decision-making process.

Several criteria for the evaluation of risks have been presented above. These criteria should be considered when setting risk reduction targets (limit of tolerability), which are the cornerstone of a comprehensive risk management plan. Current trends in the development of risk criteria for hazardous industries and dams are moving away from setting specific and fixed limits of risk acceptability. Instead, organisations are adopting a level of risk above which is unacceptable (intolerable limit) and below this level the decision on whether or not the risk is tolerable is being made based on the ALARP principle. The acronym ALARP stands for ***As Low As Reasonably Practicable***. In essence this means that risk reduction measures should be implemented until no further risk reduction is possible without very significant capital investment or other resource expenditure that would be grossly disproportionate to the amount of risk reduction achieved.

The application of the ALARP test implies that risk reduction is an ongoing process that should be frequently reviewed and considered in line with other business and operational systems used in managing community assets. It also means that there will generally not be a hard and fast level of risk that can be considered acceptable. It will be up to the organisation to ensure that it identifies and evaluates the risks systematically and in a manner that is documented, transparent and that clearly communicates the basis for decisions regarding the risk management measures to be implemented. This also allows for considerable flexibility in the way that an organisation undertakes risk management.

In addition to specific risk reduction targets other considerations that will influence the scope of a risk management plan include:

- The amount of funding available for the works.
- The extent of environmental disturbance caused the works (primarily the amount of land impacted by the works).
- The possible impacts on the environment due to the anticipated construction activities.
- The anticipated complexity and time required by the environmental approvals process.
- The pragmatic desire to implement risk reduction works at as many sites as possible to increase the level of risk reduction achieved over the whole risk inventory, rather than reduce the risk by larger amounts at only a small number of hazard sites.
- Achieving a balance between physical works to reduce hazard frequencies or the likelihood of an adverse consequence and other non-engineering type measures. Such measures include emergency response plans, contingency planning, documented risk management plans, insurance to transfer risk to other parties, reputation management and public relations strategies, monitoring and inspections.

Depending on the final objectives of the risk management strategy, various methods of risk treatment include:

1. Alternative methods to prevent or reduce potential consequences include the implementation of detection systems or possibly an early warning system (EWS). An EWS may increase the possibility of people avoiding the potential outcomes of a hazardous event.

2. Consultation with those parties potentially affected by the identified hazards could be considered to gauge the level of risk which people are willing to tolerate. This could help to establish target risk reduction levels and is a common exercise in risk management.

3. Acceptance of certain risks may be appropriate for some sites; most probably if the level of risk is assessed to be tolerable or acceptable to the organisation.

4. Transferring risk is a common part of risk management strategies, when considering assets. This can be achieved by accepting the presence of risks but having insurance to cover the potential outcomes if an event were to happen.

5. Ensuring an effective Asset Management Plan for capital works is a means of documenting the processes and methods for the maintenance of the asset. This should help to ensure that the works perform according to the intended function for the design life.

5.9 Evaluation of Identified Risks

5.9.1 Individual Risk

The individual risks calculated for this assessment are presented on Figure 5-5 (see end of section) along with examples of other individual fatality risks reported from research carried out in New South Wales. Figure 5-5 also demonstrates three guideline levels. The lowest level (1×10^{-6}) is the tolerable limit used by the Department of Urban Affairs and Planning (DUAP) in New South Wales (DUAP, 1992) for guiding the development of hazardous industry in relation to residential elements at risk. This guideline is for continuous occupancy. The middle level of 1×10^{-5} is the guideline used by ANCOLD (1994) as the objective individual risk level for dam safety assessments. The upper level (1×10^{-4}) is the intolerable limit used by ANCOLD (1994), which means that risks above this level are considered to be unacceptable for individuals most at risk when evaluating dam safety risks. These three levels also correspond to guidelines published in the Netherlands (TAW, 1988). From Section 5.1.1, the lowest individual risk level (IR = 1×10^{-6} per year) corresponds to situations where the individual at risk has no control over the hazard and their exposure. The guideline then increases depending on the level of control that the individual has on their risk exposure (i.e. whether the risk is voluntary or involuntary).

From Figure 5-5, all of the calculated individual risks are less than the intolerable limit (ANCOLD, 1998) and considerably lower than some risks of fatality in the community such as smoking and travelling by motorcar. Only two cases are above the ANCOLD objective guideline, namely residents in high flood hazard zones and campers (caravans and tents) in the “very high” flood hazard zones. This indicates that flood risk mitigation measures should be directed at reducing the risk for individuals in these categories, as a higher priority than some other categories.

The ANCOLD objective guideline corresponds to that published in the Netherlands (TAW, 1988) where the element at risk as some control over their exposure. To some degree this may be the case with flood hazard along the Thames Coast where residents can exercise some choice over where they decide to live and flooding is a known hazard. This suggests that applying the lower DUAP limit is certainly not appropriate to this situation. The upper limit used in the Netherlands (IR = 1×10^{-3}), which is applicable in situations where the individual has total control over their exposure is also not considered suitable in this case. Rather, the ANCOLD objective guideline (IR = 1×10^{-5}) is more suitable and the application of this guideline indicates that some risk mitigation is warranted for residences in high hazard zones.

For visitors to camping grounds and in particular people using caravan or tent sites, again there is some degree of choice that visitors exercise on where they decide to stay. However, unless they were informed of the potential risks due to flooding, they would have very little control over their exposure to the hazard and the lower risk guideline (1×10^{-6}) is considered appropriate.

5.9.2 Annualised Lives Risk

Comparison of the ALR for the various communities with published criteria from the USBR indicate that, based on Figure 5-1 there is only one site (Te Puru) where the calculated ALR is greater than 0.01 (USBR, 1997). This indicates that risk mitigation should be examined for these this site as a priority to reduce the level of flood risk that the community is exposed to. Three other sites comprising Waiomu-Pohue, Tapu and Coromandel have total ALR values greater than 0.005, and the total ALR for Tararu exceeds 0.001. Application of the BC Hydro guideline of 0.001 would suggest that the flood risk should be reduced at these four communities as well. From Figure 5-2, the activity contributing the most to the ALR is campgrounds followed by residences in the high hazard zones in Coromandel, Te Puru and Tararu. Therefore, the strategy developed to address the identified risks should include consideration of these higher priority risk levels.

5.9.3 F-N Criteria

The societal risks for each community are presented on a F-N Chart (Figure 5-6). This figure also shows various risk guidelines (ANCOLD, 1998 and HSE 1991) as well as the societal risks from two other studies in New Zealand and Australia pertaining to flood risk. The risk criteria presented on this figure were not necessarily developed for assessing natural flood hazards. However, they do represent criteria that are currently used for assessing societal risk and they can be used as a guide for this study.

Inspection of Figure 5-6 indicates that the calculated societal risks for the subject communities due to flooding are lower than the HSE guideline but the towns of Te Puru, Tapu and Waiomu-Pohue all exceed the intolerable limit used by ANCOLD to assess dam safety risks. In this case risk mitigation measures for these communities are considered to be warranted.

Comparison of the societal risks for the Thames Coast with, for example, the selected case from an Australian dam and the Waiho River near Franz Josef, indicates that the level of risk calculated in this study is significantly less than in these other cases. Therefore, although the risk level for Te Puru, Tapu and Waiomu-Pohue is higher than some guidelines, it is not extreme and risk mitigation should be planned in a controlled and transparent manner.

The evaluation of the level of lives risks calculated for the Thames Coast area indicates that risk reduction measures should be implemented at least for Te Puru, Tapu, Waiomu-Pohue and Coromandel to reduce the lives risks to these communities to more tolerable levels. Presentation of the lives risks in the forms reported above allows the identification of specific areas within the communities where risk reduction should be targeted and prioritised. In any event, the identified risks should be reduced until it can be demonstrated that the residual risk level is as low as reasonably practicable, given the level of available resources for flood alleviation.

5.10 Risk Mitigation Works

5.10.1 General

There is a range of options available to address the identified risks. In general terms these can be grouped into the following actions:

Avoid – e.g. land use controls to discourage development within flood prone areas.

Reduce – e.g. apply appropriate building standards to reduce the likelihood of flood waters causing significant damage such as elevating the floor levels in houses, constructing stop banks, installing flood detention structures, installing pumps to discharge flood water, increase the flow capacity of channels, reduce flow impediments within channels such as associated with bridges and culverts.

Retreat – installing flood warning systems can increase the probability that people within the flood prone areas can be informed of the hazard and take appropriate steps to evacuate or otherwise safeguard themselves.

Transfer – risk can be transferred through insurance (for assets at risk) and also by consultation with affected parties so that they can exercise greater control over their own exposure to the risk and less stringent risk criteria may be applicable.

Accept – the potential consequences due to flooding are acceptable to those that may suffer harm (either to themselves or their assets) that usually requires risk education and consultation.

Specific risk treatment measures include:

- Build stop banks (could be purpose built or incorporated into roads, noise bunds or the like.
- Increase the floor level of habitable buildings using stilts or elevated piles.
- Remove or relocate assets from the flood path.
- Further investigations to better quantify hazards and/or consequences
- Monitoring and detection systems including early warning systems
- Emergency Actions Plans
- Contingency planning, recovery plan and business continuance plans
- Risk management plan
- Asset maintenance planning
- Accept the risk (do nothing)
- Stakeholder management
- Public information such as posting warning/information signs, issuing information pamphlets etc.
- Reputation management
- Insure for economic losses
- Risk Assessment Review

Of the above measures some would reduce the risk, such as engineering remedial works that reduce the specific consequences from an event, and the risk reduction can be quantified. Such measures are often referred to as tangible risk treatment measures. In some cases the effect of some measures may not be readily quantifiable. Examples of these include review and update of the risk profile or implementing an asset management plan. Such measures provide valuable information for managing the risk but the effect cannot be readily calculated. Such measures are often referred to as intangible risk treatment measures or simply as risk management measures (compared to risk reduction measures).

For this study two broad cases have been considered to help evaluate the level of benefits that could be gained from risk mitigation works. The first case involves the upgrading of flood warning and evacuation procedures. This involves the installation of rainfall gauges for catchments that are currently not monitored and stream flow monitoring for each of the communities. This would be complimented by systematically developing and documenting data gathering, transfer, evaluation and reporting systems to enable effective flood warnings to be conveyed to the potential population at risk. Evacuation plans for the various activities within each community would also need to be formalised, documented and implemented. This would have particular risk reduction benefits when applied to the camping grounds, which have been shown to contribute the most to the level of lives risk. Specific risk mitigation measures for campgrounds should include:

- Implementing robust warning and evacuation plans to reduce the potential consequences of a flood event.
- Discouraging camping in higher risk areas of the camping ground, thereby avoiding the risk, and/or

- Providing potential visitors with information to increase their awareness of the hazard (and also their potential understanding of warning and evacuation systems).

The second broad case involves specific engineering works to reduce the potential flooding impacts at each community. Details of these measures including estimated costs and typical risk reduction benefits are provided in Appendix D. The following sections discuss the estimated lives risk reduction for each of these cases. The calculated reduction in economic risks for these cases is discussed in Section 5.10.3, which also compares their benefits.

For this study we have looked at two levels of engineering risk reduction works, which were developed by staff at Environment Waikato. Generally these comprise engineering works designed to alleviate flooding due to events ranging between a 5% AEP (20 year event) and 1% AEP (100 year event), which are discussed further in Section 5.10.3. There are other mitigation options that could be considered, however, the detailed assessment of various “options within options” is beyond the scope of this present study but could readily be carried out given that the risk models are set up for each community.

5.10.2 Upgrading Flood Warning and Evacuation Systems

The effectiveness of improved flood warning and evacuation systems is difficult to assess objectively. However, using the values given in Section 4.1.1 as a starting point, revised probabilities have been assigned, as summarised below, taking into account the listed factors (original figures shown in brackets):

Table 5-3: Probabilities of Level of Warning Available with Upgraded Flood Warning and Evacuation Systems

Level of warning	Day	Night
Adequate warning	0.8 (0.5)	0.6 (0.4)
Little warning	0.15 (0.4)	0.3 (0.4)
No warning	0.05 (0.1)	0.1 (0.2)

The result of improved systems is roughly a 40 to 50% reduction in ALR for each community, achieved at relatively modest cost. This is also reflected in the F-N curves, which move closer to the ANCOLD limit of tolerability, but not below this guideline level. Although these probabilities are based on judgements and cannot necessarily be confirmed analytically, such actions can be relatively easily implemented for modest cost and should be considered a priority risk treatment measure. Figure 5-7 (see end of section) illustrates the reduction in ALR attributed to upgrading the flood warning and evacuation systems.

5.10.3 Engineering Risk Reduction Works

The proposed engineering works are designed to alleviate the effects of the 1 in 100-year flood event. The estimated lives risk reduction benefits from implementing the engineering works have been quantified by adjusting the appropriate input parameters for the risk model to reflect the likely impacts of the works. In some cases this involves reducing the PAR within a flood hazard zone and/or downgrading the flood hazard zone and hence the potential fatality rates in some areas. Specific details of possible engineering works and their corresponding effects on reducing the flood hazard are listed in Appendix D. Two schemes have been examined. The first scheme comprises works design to alleviate flooding impacts up to a 5% AEP event (referred to as Option 2 in Appendix D). In this situation flooding due to a 1% year AEP is likely to occur, but to a lesser degree than is currently the case. The second scheme comprises works designed to alleviate flooding up to the 1% AEP event (referred to as Option 3 in Appendix D).

The lives risks after implementation of the Option 2 works as well as upgrading the flood warning and evacuation systems are shown in the following figures, with Figure 5-7 demonstrating the reduction in the ALR for each of the sites and Figure 5-8 shows the annualised lives risk per activity. These figures reflect the combined effect of both engineering works and improved warning and evacuation systems.

Specific details are given in Appendix D, but in general the effect of the engineering works is that:

- Dwellings in potential medium flood hazard zones are protected from the full force of the floodwaters and the depth and velocity of floodwaters outside of the river channel will be significantly reduced, thereby downgrading the flood hazard zone to low.
- Dwellings in potential low flood hazard zones will also have their rating reduced to very low.
- For camping grounds the proposed reduction measures reduce the flood hazard zones to the next lowest rating.
- In some cases the proposed risk reduction works are also likely to enhance the flood warning and potential for people at risk to escape the floodwaters. For example, constructing stop banks adjacent to the lower portion of the Tapu campground is expected to provide additional time for rising river levels to be detected, warnings to be issued and evacuation of campers in high hazard areas to be evacuated. This has also been included in estimating the risk reduction afforded by the works.

Figures 5-7 and 5-8 show that considerable risk reduction can be achieved by implementing the proposed engineering risk treatment measures and in most cases the lives risk can be reduced below intolerable levels.

The implementation of Option 3 works further decreases the level of lives risk, as shown in Figure 5-9.

5.10.4 Catchment Works

Additional measures are also proposed for each catchment to control erosion, reduce sediment loads and stabilise slopes. These works include riparian fencing, planting and pest control. The impact of these measures will take several years to be fully realised, and so these benefits, and the associated costs of the catchment works, have not been included in the risk assessment at this stage.

5.10.5 Benefit Cost Ratios

The reduced flood severity ratings for residences, schools etc. also reduces the potential damage due to the floodwater, which reduces the consequential costs and the financial risk. The reduction in financial risk quotient has been used to generate benefit cost ratios for the risk treatment works. Details of the benefit cost ratio calculation are provided in Appendix D and summarised in Table 5-4, following.

Table 5-4: Benefit Cost Ratios (BCR)

Community	BCR		
	Flood warning and evacuation systems only	Warning and evacuation systems + capital works (Option 2 – Appendix D)	Warning and evacuation systems + capital works (Option 3 – Appendix D)
Tararu	0.7	0.07	0.05
Te Puru	5.3	0.2	0.2
Waiomu-Pohue	3.7	0.3	
Tapu	2.7	0.8	0.4
Coromandel	4.2	0.2	0.1

Given the magnitude of the economic consequences due to the hazard event and the number of potential fatalities for the subject communities the BCR tends to be dominated by the contribution to the financial risk quotient from the estimated fatalities. Consequently, the calculated BCRs from the risk reduction works are sensitive to the value adopted to represent the cost of a life used in the financial risk model, which was $4M. This value of $4M corresponds to that used in the Transfund New Zealand Project Evaluation Manual for estimating the benefits from accident reduction measures. If a value of, say, $2M is used then the BCRs would typically reduce by about 50%. If the contribution to the financial risk from fatalities is excluded from the BCR calculation then the proposed risk reduction works would give BCRs of the order of 0.01 to 0.05. Economic justification for capital works based on a BCR of this magnitude would be difficult. However, the BCR could be used as a prioritisation tool to help evaluate an optimal risk treatment works programme.

It is noted that at this stage, only direct benefits (such as the reduction in the costs of flood damage, clean-up and repair, loss of business and costs incurred by local and regional agencies in emergency response, as set out in Table 4-3) are included in the BCR analysis. Other indirect, and perhaps less tangible benefits, such as improved property values, greater peace of mind for residents and reduced disruption in the event of a flood have not been quantified at this stage, but could be considered in future. Quantification of these benefits, would require significantly more input from the local communities.

Figure 5-1: Lives Risk Profile

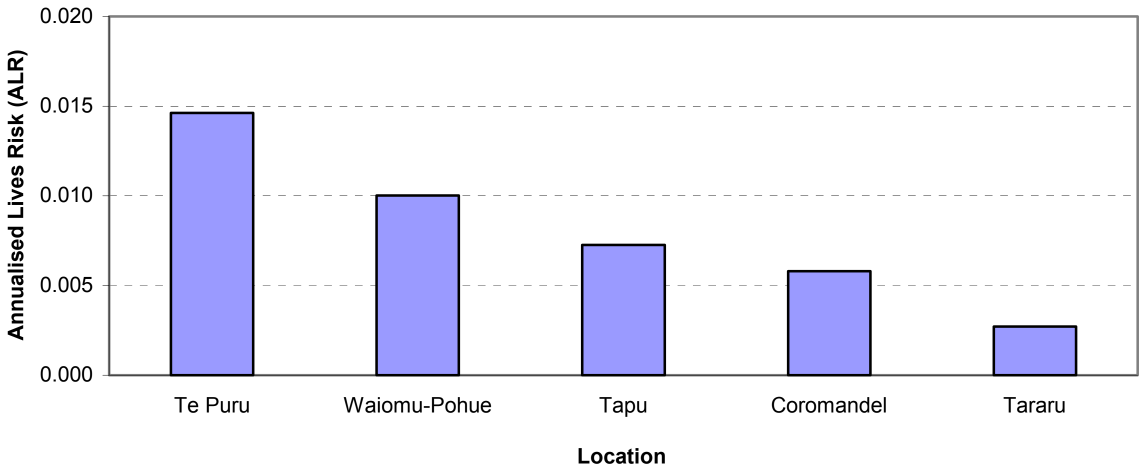


Figure 5-2: Fatalities per Year by Activity for Each Community

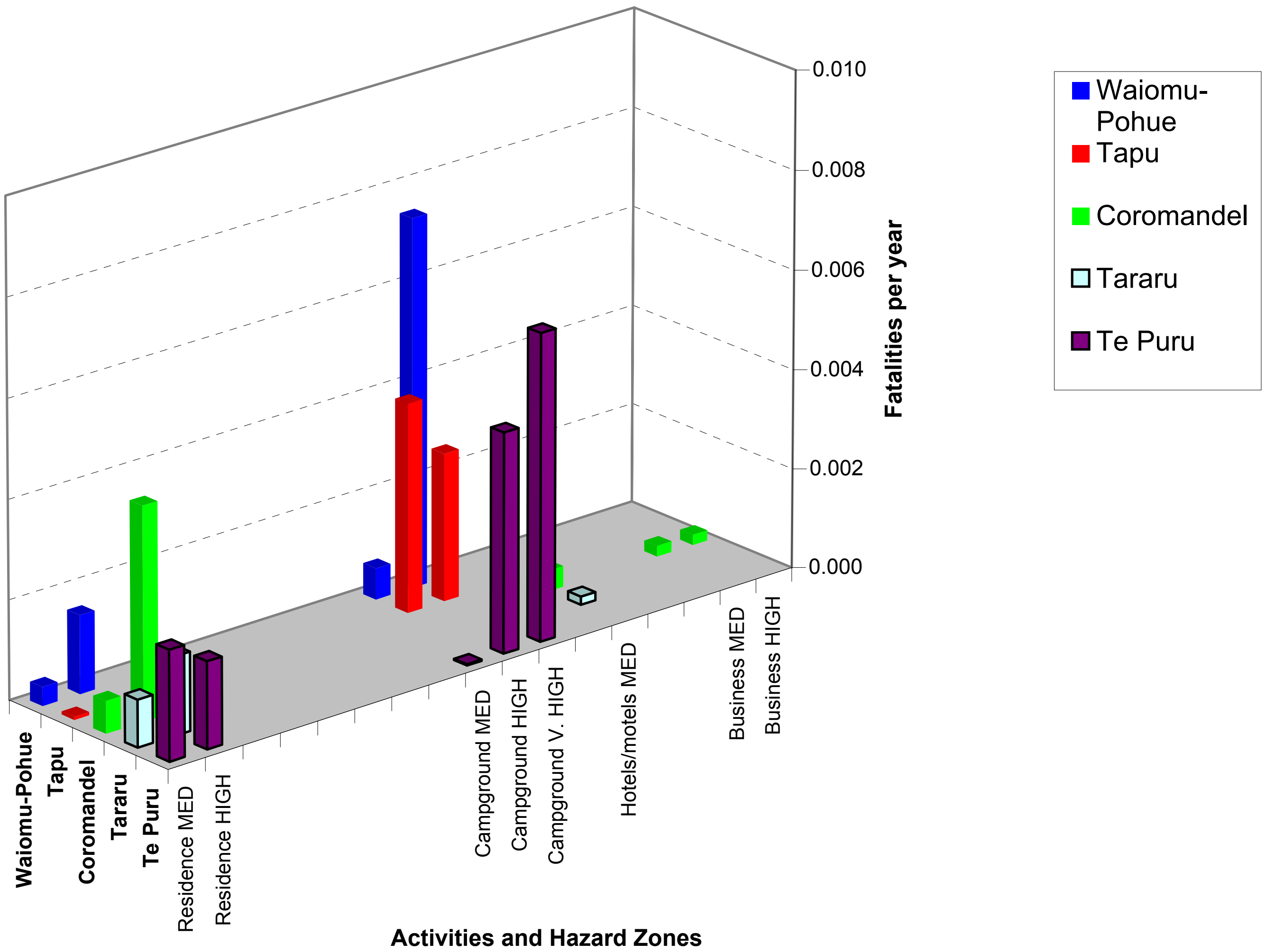


Figure 5-3: F-N Chart for Thames Coast

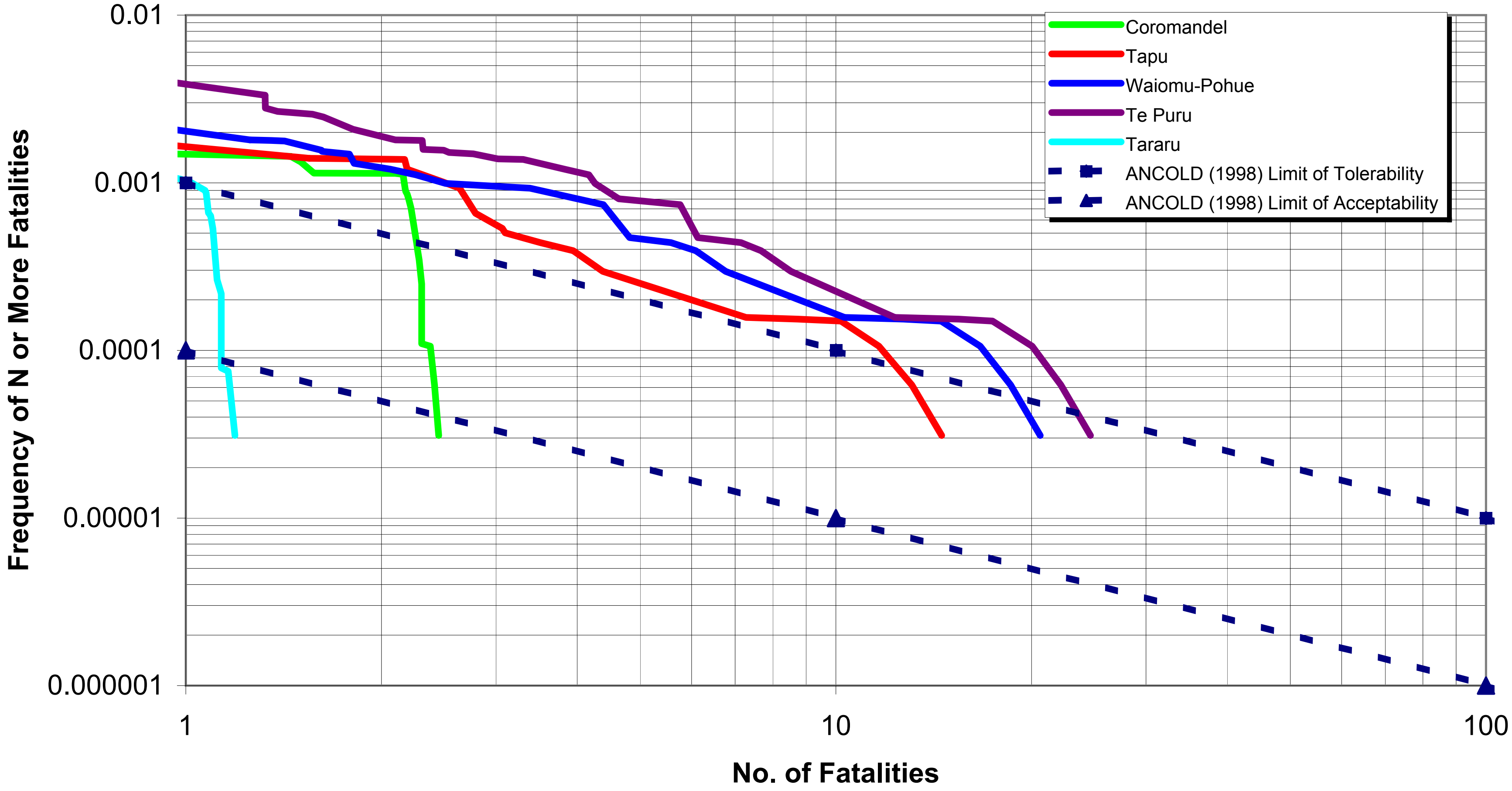


Figure 5-4: Exposure Profile

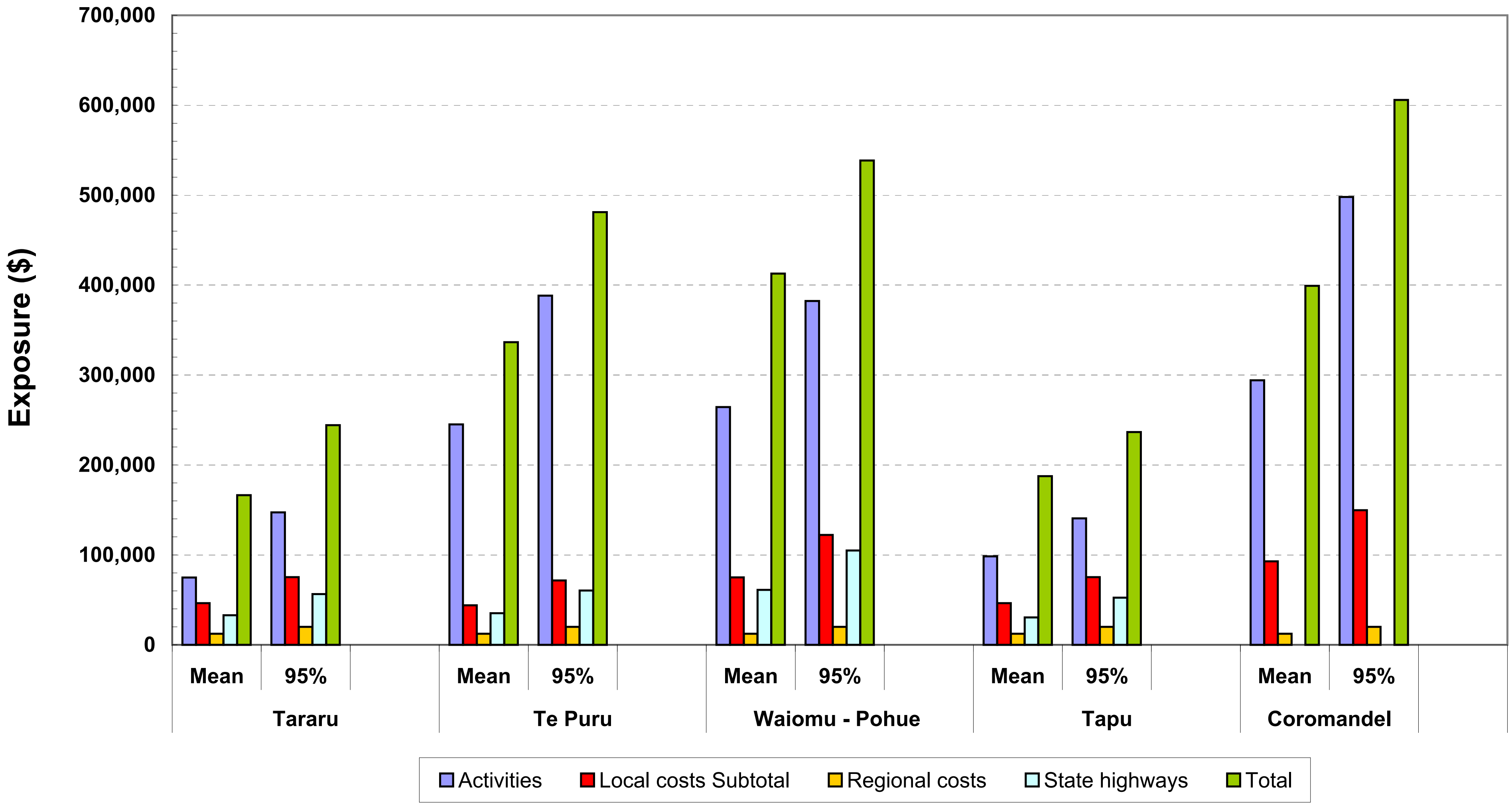


Figure 5-5: Evaluation of Individual Risk of Fatality

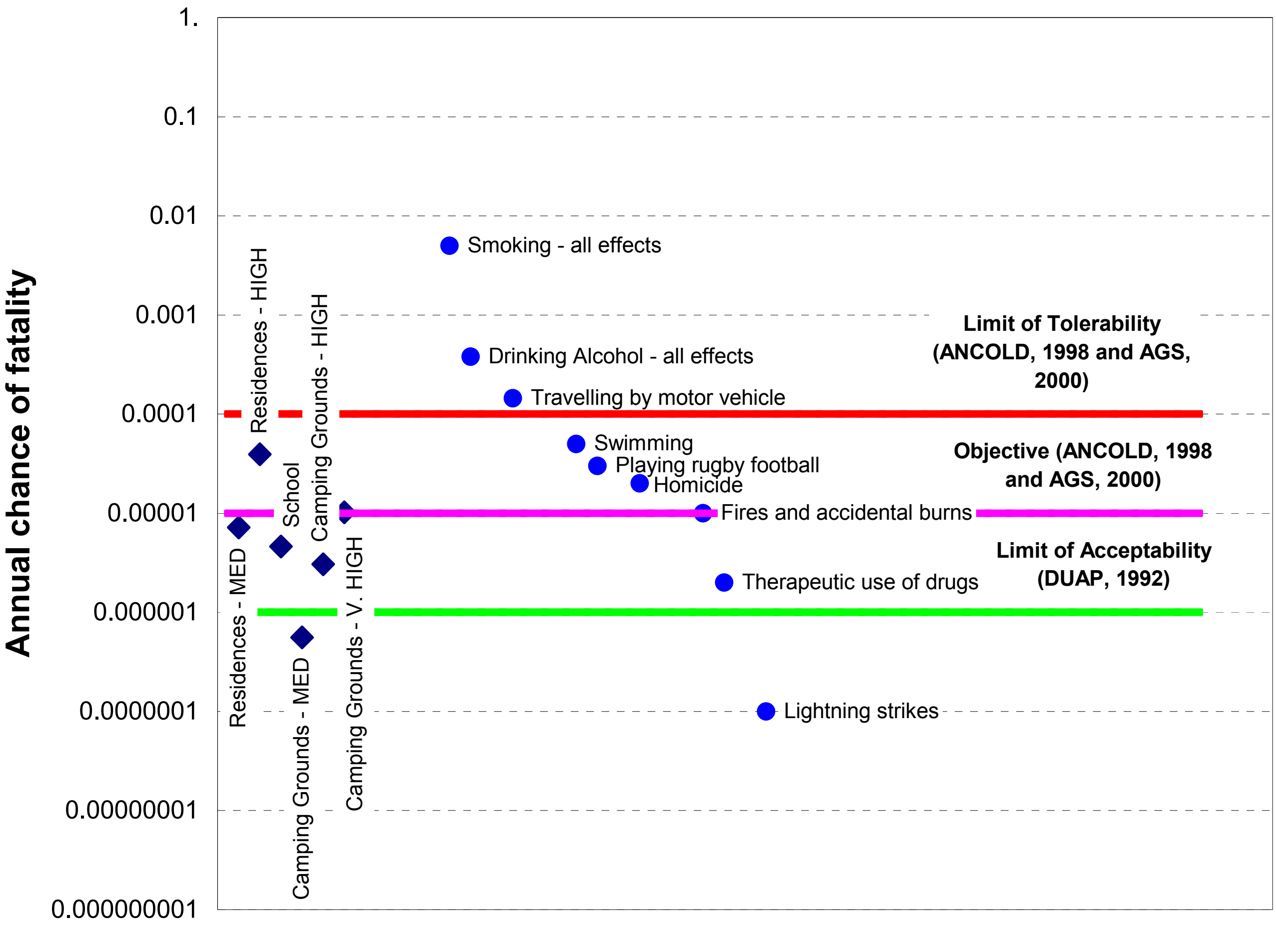


Figure 5-6: Evaluation of Societal Risk on F-N Chart

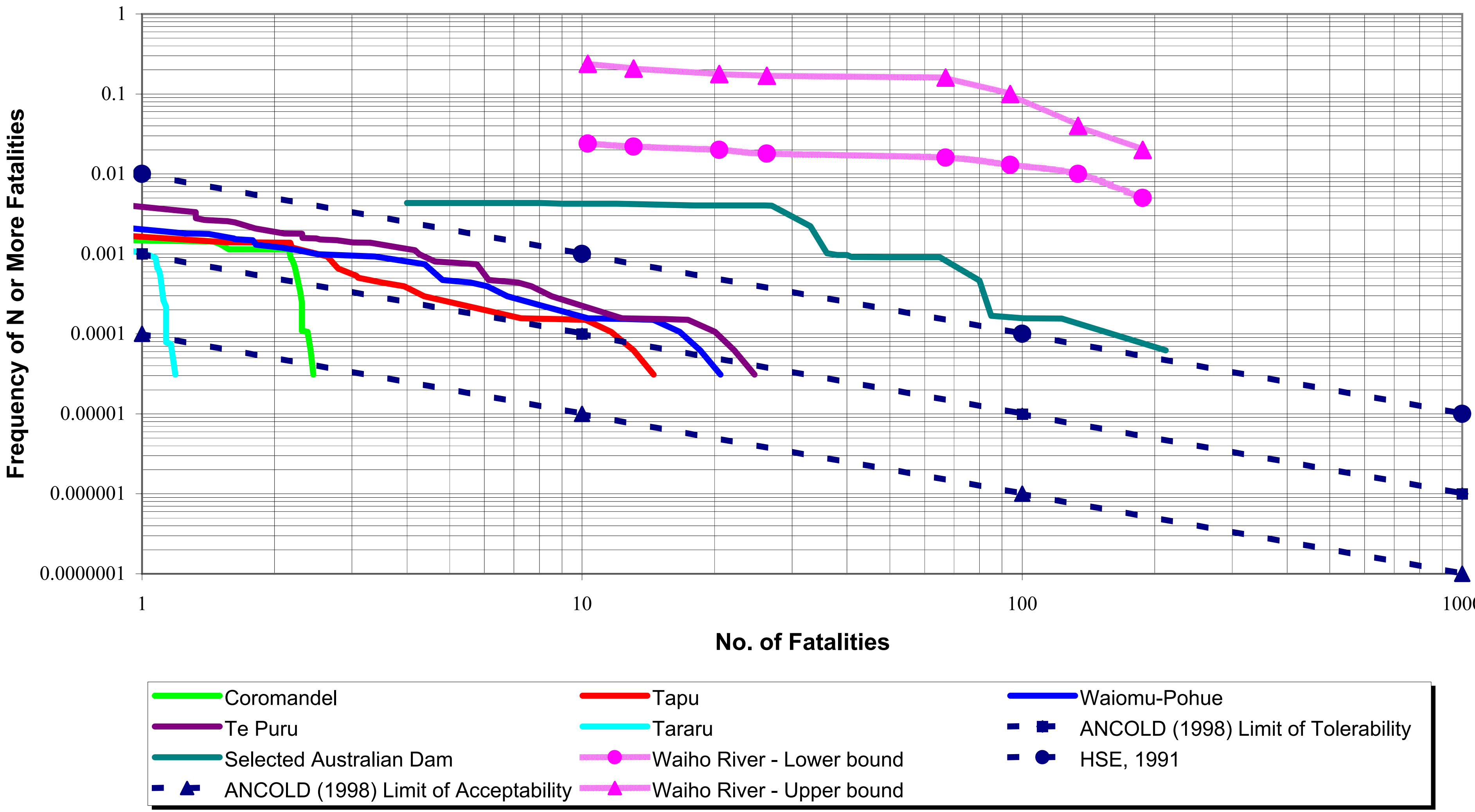


Figure 5-7: ALR Summary Following Risk Treatment (Option 2)

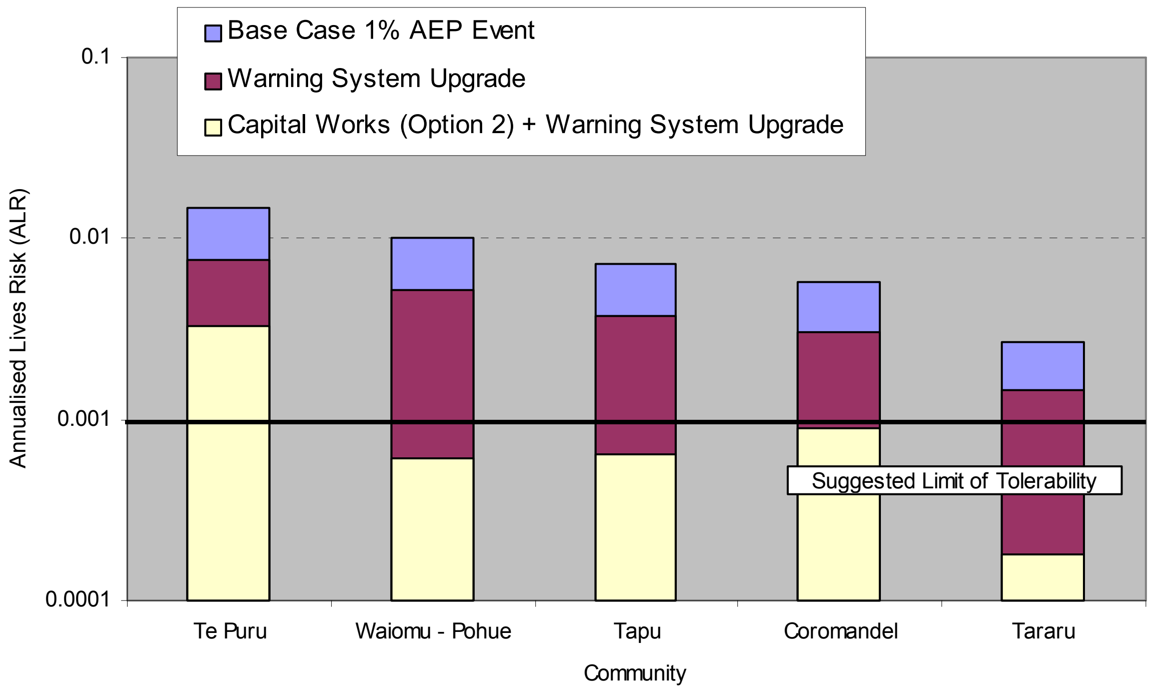


Figure 5-8: Fatalities per Year by Activity Following Risk Treatment (Option 2)

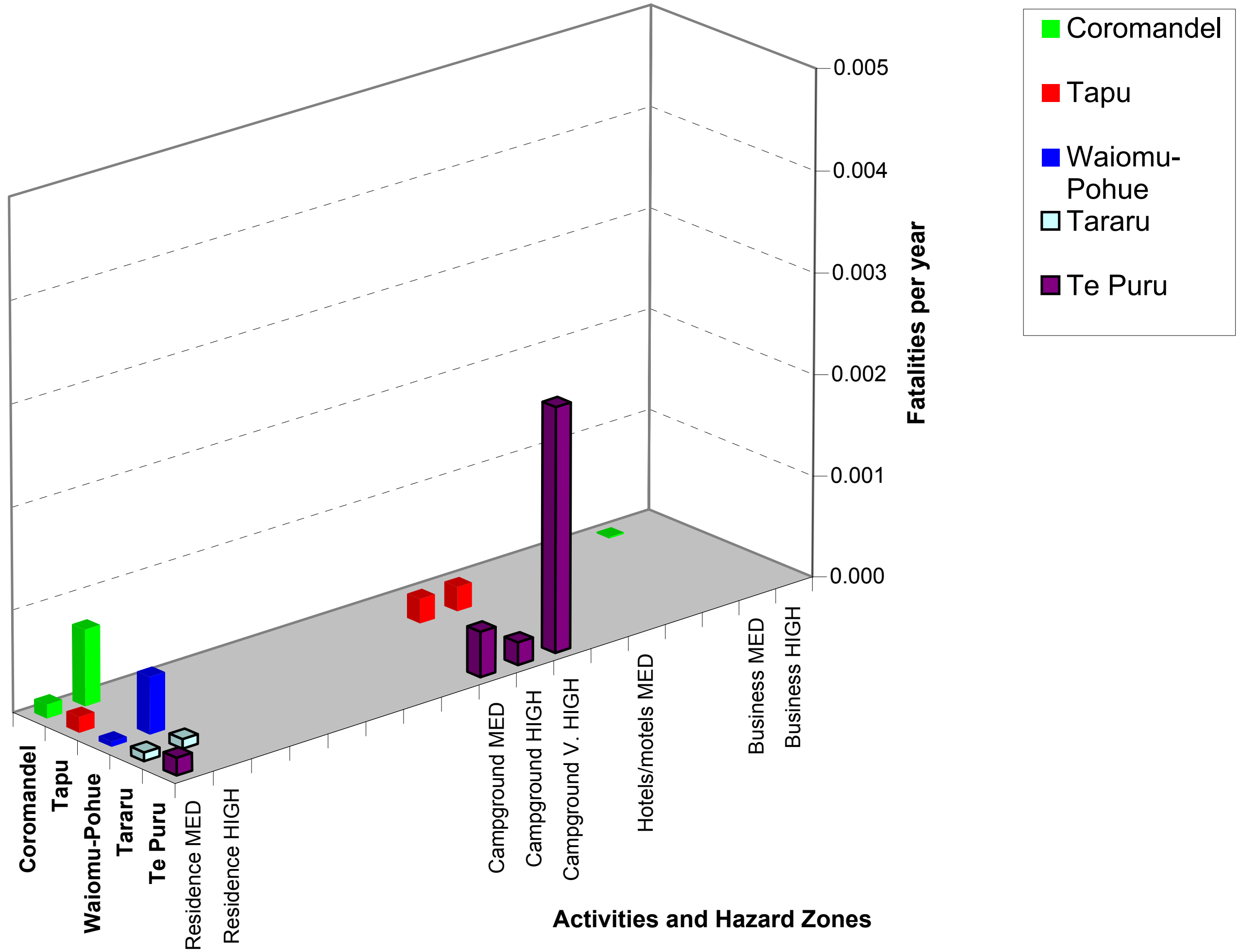
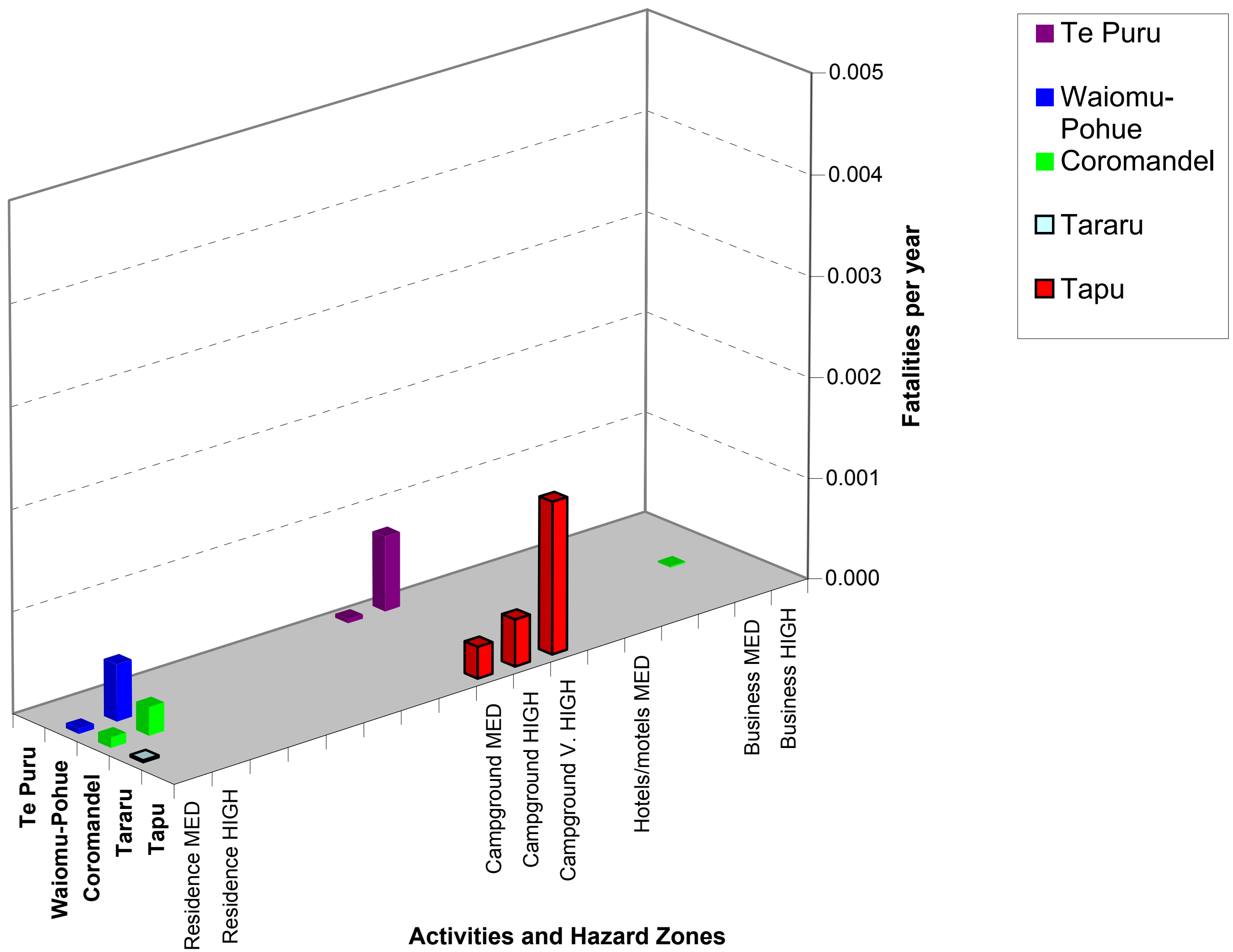


Figure 5-9: Fatalities per Year by Activity Following Risk Treatment (Option 3)



6.1 Conclusions

Based on the results of this risk assessment the following conclusions are drawn:

- The calculated annual individual risks for the various cases examined are less than the intolerable limit of 1×10^{-4} (equivalent to 100 per million years). By comparison, risks of fatality in the community such as from smoking and travelling by motorcar are 5000 per million years and 145 per million years respectively.
- Although less than intolerable, the level of individual risk for individual residents and campers (in caravans and tents) in high flood hazard zones is above desirable levels. Flood risk mitigation measures should be directed at reducing the risk for individuals in these categories, as a priority.
- The total calculated Annualised Lives Risk is highest at Te Puru (0.015) followed in order of descending risk by Waiomu-Pohue (0.010), Tapu (0.007), Coromandel (0.006) and Tararu (0.003). This is higher than suggested guidelines, which vary between 0.01 and 0.001. The ALR ranking is also reflected in the societal risks for each community represented on a F-N chart.
- Evaluation of the level of societal lives risks calculated for the Thames Coast area indicates that risk reduction measures should be implemented at least for Te Puru, Waiomu-Pohue, Coromandel and Tapu to reduce the lives risks at these communities to more tolerable levels.
- Although the calculated lives risks are in many cases above suggested risk guidelines, comparison of the risk levels with other flood studies in New Zealand and overseas, as well as other risks commonly tolerated in society, indicates that the risk level at the subject communities is not extreme and any risk mitigation plans should be developed in a careful, systematic and transparent manner.
- In light of current risk management practices the identified risks should be reduced until it can be demonstrated that the residual risk level is as low as reasonably practicable, given the level of resources available within the local communities for flood alleviation.
- Considerable risk reduction can be achieved by implementing various engineering and non-engineering risk treatment measures, and in most cases the lives risk can be reduced below generally intolerable levels.
- The enhancement of flood warning and evacuation systems provides a significant reduction in the level of lives risks for relatively modest investment, which is reflected in benefit cost ratios typically greater than 2.5. However, this does not affect the risk to property and community assets.
- Given that the overall level of property damage due to the nominated flood hazard is relatively moderate and engineering mitigation works require considerable investment, the benefit cost ratios calculated for the various mitigation options are less than 1 in all cases. The benefit cost ratios are also very dependent on the value of a life adopted for the financial risk calculation.

6.2 Recommendations

We recommend that this risk assessment be used as the basis for developing a strategic flood risk management plan for the subject communities that incorporates the risk prioritisation and evaluation tools presented in the report, along with consultation with stakeholders.

Specific recommendations include:

- For the campgrounds at Te Puru, Waiomu and Tapu we recommend the following risk treatment measures be implemented as a priority:
  - Provide information for campground users on the flood hazards associated with various areas within the campground, such as signposts, leaflets etc.
  - Formally document flood warning and evacuation plans including routes for safe access and egress, muster points etc. These should include physical flood monitoring protocols, trigger levels and associated response actions.
  - Ensure appropriate communication between regional and local authorities, emergency authorities and the campground owners/operators to co-ordinate flood risk management activities.
- Engineering mitigation measures should be implemented to reduce flood hazards for residential areas within high and medium flood hazard zones at Coromandel, Te Puru, Waiomu-Pohue and Tararu.
- Initially, risk mitigation works should be designed to reduce the Annualised Lives Risk at the identified locations and for those recommended activities to at least 1 in 1,000 (0.001). Further risk mitigation should then be planned in accordance with the ALARP principle across the whole risk inventory.

Limitations

URS New Zealand Limited (URS) has prepared this report for the use of Environment Waikato and the Thames-Coromandel District Council in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated December 17, 2002.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared in the first half of 2003 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners. Further details on the limits and interpretation of this risk assessment report are provided in Appendix A.

Ashby, G.L. 2002. *Development of a Risk Management Strategy for Part of State Highway 73 in the South Island of New Zealand.* New Zealand Society for Risk Management Conference, Wellington.

Australian Geomechanics Society (AGS) Sub-committee on Landslide Risk Assessment. 2000. *Landslide Risk Management Concepts and Guidelines*. Journal and News of the AGS, Volume 35, No. 1. March.

Australian National Committee on Large Dams (ANCOLD) Working Group on Risk Assessment. 1998. *ANCOLD Guidelines on Risk Assessment Position Paper on Revised Criteria for Acceptable Risk to Life*. ANCOLD. August.

ANCOLD. 1994. *Guidelines on Risk Assessment. Australian National Committee on Large Dams Inc*. Sydney, 116p.

ANCOLD. 2001. *Guidelines on Risk Assessment*. Draft report issued by the Australian National Committee On Large Dams Inc., Sydney. July.

Barneich, J, Majors, D, Moriwaki, Y, Kulkarni, R and Davidson, R. 1996. *The Reliability Analysis of a Major Dam Project. Uncertainty in the Geologic Environment*, Proceedings of Uncertainty'96 pp1367-1382.

Technische Adviescommissie voor de Waterkeringen. 1988. Some considerations of an acceptable level of risk in the Netherlands.

Fell, R. and Hartford, D. "*Landslide Risk Management*". Landslide Risk Assessment (eds Cruden, D. and Fell, R.), Balkema pp51-109. 1997.

Finlay, P.J. and Fell, R. 1997. *Landslides: Risk perception and acceptance*. Canadian Geotechnical Journal.

Health and Safety Executive. 1988. *The tolerability of risk from nuclear power stations*. HMSO, London, UK.

Health and Safety Executive. 1989a. Risk criteria for land-use planning in the vicinity of major industrial hazards. HMSO, London, UK.

Health and Safety Executive. 1989b. Quantified risk assessment: Its input to decision making. HMSO, London, UK.

Health and Safety Executive. 1992. *The tolerability of risk from nuclear power stations (revised)*. HMSO, London, UK.

Hong Kong Government Planning Department (HKGPD). 1994. Chapter 11: *Potentially hazardous installations*. In Hong Kong Planning Standards and Guidelines. Hong Kong Government, Hong Kong, pp12-19.

IUGS Working Group on Landslides, Committee on Risk Assessment. 1997. *Quantitative risk assessment for slopes and landslides* - the State of the Art. February.

Jonkman, B., and van Gelder, P. H. J. 2002. *An overview of quantitative risk measures and their application for calculation of flood risk*. European Safety and Reliability International Conference, Lyon, France, March 2002.

Land Transport Safety Authority (LTSA). 2000. Road Safety Strategy 2010. National Road Safety Committee, Wellington, New Zealand. October 2000.

Moon, A.T., Olds, R.J., Wilson, R.A. and Burman B.C. 1992. Debris flow zoning at Montrose, Victoria. In Landslides, Proc. Sixth Int. Symp. on Landslides, February (Ed. D.H. Bell), Christchurch, New Zealand. A.A. Balkema, Rotterdam, The Netherlands, Vol 2, pp1015-1022.

Morgan, G.C. 1992. Quantification of risks from slope hazards. Open File Report No. 1992-15, Geological Survey of Canada.

New South Wales Department of Urban Affairs and Planning (DUAP). 1992. Risk criteria for land use safety planning.

New South Wales Department of Urban Affairs and Planning (DUAP). 1994. Risk Assessment.

Optimx Limited. 2002. Waiho River Flooding Risk Assessment. Report 80295/2 prepared for the Ministry of Civil Defence and Emergency Management, Wellington, New Zealand, August 2002.

Standards Australia and Standards New Zealand AS/NZS 4360:1999 Risk Management.

TTAC Limited. 2002. Ruapehu Lahar Residual Risk Assessment. Report prepared for the Ministry of Civil Defence and Emergency Management, Wellington, New Zealand, October 2002.

US Department of the Interior Bureau of Reclamation (USBR). 1999. A Procedure for Estimating Loss of Life Caused by Dam Failure. Dam Safety Office, Colorado, September 1999.

US Department of the Interior Bureau of Reclamation (USBR). 1997. Guidelines for achieving public protection in dam safety decision making. Dam Safety Office, Colorado.

Whitman, R.V. 2000. Organising and evaluating uncertainty in geotechnical engineering. *Journal of Geotechnical and Geoenvironmental Engineering*, pp 583-593.