STUDY REPORT

SR 252 (2011)

Sprinklers For Community Buildings and Places of Special or Historical Interest

E. Soja

The work reported here was jointly funded by BRANZ from the Building Research Levy, and the New Zealand Fire Service whose logos are shown above.

ISSN: 1179-6197

Preface

This report describes a project that investigated the design of a sprinkler system for community buildings, which would otherwise not require a sprinkler system, to be installed as part of the building consent process. For the purposes of the report community buildings are defined as Marae, community halls and historic places. The report discusses the fire incident statistics, current New Zealand and international sprinkler specifications, and costs for sprinkler systems and components. It also proposes the framework for a specific sprinkler system applicable to those buildings.

Acknowledgments

This work was jointly funded by the New Zealand Fire Service Commission from the Contestable Fund and the Research Fund Building Research Levy.

The author would like to thank the following for their assistance:

Staff at Orongomai Marae (Upper Hutt), Waiwhetu Marae (Lower Hutt), Gear Homestead (Porirua), the minister at St Alban's Church (Pauatahanui), and the Christ Church Preservation Society (Inc) for access to Christ Church (Taita, Lower Hutt). Geoff Ward in Wellington, Darren Moses, Brandon Koolen and Warwick Taylor in Christchurch, Chris Mak and David Hipkins in Auckland, and Paul Van Weerden in Hamilton for their help in viewing sprinkler system installations. Piki Thomas (New Zealand Fire Service) (Pou Herenga Maori/National Maori Advisor) for general guidance on Maori buildings.

Note

This report is intended for standards developers, regulators, researchers, engineers and others interested in sprinklers for community buildings.

Sprinklers for Community Buildings and Places of Special or Historical Interest

BRANZ Study Report SR 252

E Soja

Reference

Soja E. 2011. 'Sprinklers for Community Buildings and Places of Special or Historical Interest'. *BRANZ Study Report 252*, BRANZ Ltd, Judgeford, New Zealand.

Abstract

The buildings studied in this report were defined as community halls, churches and Marae. Fire incidents in these buildings were investigated over a period of approximately five years from 2005 to 2010. In New Zealand there were 266 fires in these buildings, with 27 being destroyed. The total number of fires represents 0.79% of all structure fires in all buildings in New Zealand and 24% of all assembly buildings fires. Assembly building fires are 3.2% of all structure fires. International data gives a similar order of results for all assembly buildings, with assembly fires representing 3-5% of all building fires.

In New Zealand, alarms were present in churches and community halls alarms in 25% of the buildings and sprinklers in 1-2%. In Marae, the figures for alarms and sprinklers were 8% and 0% respectively. Because of the low number of fire incidents this does not represent the percentage of alarms and sprinklers in all those buildings. Internationally, for all assembly buildings, the presence of alarms was 46% UK (compared to 15% Australia) and sprinklers varied (20% USA compared to 2.3% Australia).

Other than the USA, where there are standards applying to churches and historic places, there is little information on other countries. The buildings used in this study are treated as any other building with the same activities that apply to general assembly buildings. In some countries there are guidance documents issued by organisations responsible for historic buildings to assist in determining the fire protection of historic buildings.

Using this as the basis, assembly buildings in New Zealand and internationally vary in the number of occupants, floor area and number of floors before sprinklers are required. In New Zealand, this is essentially 500-1,000 occupants with floor heights from single floors to a maximum of 10 floors. In other countries, single-floor buildings may have 18,000 occupants or 5,000 in a shop.

The most onerous design requirement was found to be in the USA where there was a maximum area of 557 m² for a single-floor building with up to 300 occupants. The USA figure is based on a structure with no fire-resistance rating. Adding up to three hours for fire-resistant construction for walls and floors will increase these numbers. In New Zealand the floors and supporting structure must also be fire-resistant construction for multi-floor buildings.

Taking into account the range of buildings which do not require sprinklers by any of the regulatory documents or standards studied, for the purposes of this report the buildings of interest are defined as those with up to three floors, with a maximum of two floors with no fire separation, and an area of 500 m² per floor in multi-floor buildings and 1,000 m² for a single-floor building. This would apply to most existing buildings of the types which are the subject of this study.

Historic buildings take many forms and may not be public assembly buildings. Many are museums, although they may have previously been private dwellings or had other uses. These are all included in this study. The type of fire protection for those buildings would therefore depend on their use.

Fire sprinkler standards apply to different buildings which can be broadly defined as for: (a) domestic dwellings (houses); (b) residential (apartments, motels, hotels, hospitals) with limited floor area and height; and (c) all buildings in increasing level of complexity and detail. Within the standards for all buildings, buildings are given different classifications depending on the perceived fire hazards in the buildings, which then defines the nature of the sprinkler design based on water application rate (discharge density) and area of operation.

Domestic dwelling sprinkler standards (e.g. NZS 4517) and residential sprinkler standards (e.g. NZS 4515) offer the least onerous design requirements. This reduces the cost, but the standards are not necessarily applicable to the buildings in this study unless they meet the building requirements permitted by their scope. In many cases that will not be the case and an alternative sprinkler system must be considered. While the residential standard is less onerous than the full standard, there are still aspects of the design parameters which can be varied to provide a less costly sprinkler system.

For those buildings which are neither domestic nor residential, at present the only standard specified in the New Zealand Building Code (NZBC) Compliance Document C/AS1 is the full sprinkler standard NZS 4541. Within that standard most buildings would be considered as extra low hazard (ELH) or ordinary hazard 1 (OH1). In a few cases, depending on the activity, the building could be classified as ordinary hazard 3 (OH3). The latter includes shops, stages, theatres and museums. They are considered by the standard to provide the same hazard as the processing and production of fabrics, wood products and certain plastics.

In order for a more economical sprinkler system to be specified, restrictions must be placed on the buildings considered in this study so that the fire hazard is able to be controlled. Parameters for the sprinkler system to be used in the target buildings were derived from the current sprinkler standards and the hazards identified by the nature and location of the buildings.

Certain compromises, mostly in the reliability of the sprinkler system, are discussed. These are not considered to sufficiently reduce the effectiveness of the sprinkler system to control a fire in those building, provided restrictions which are recommended in this report are placed on the buildings.

This report and the sprinkler parameters may be used as the basis of a new standard or an Appendix to NZS 4541. This is so that the sprinkler industry may have guidance on the installation of sprinklers in the buildings discussed in this document.

The proposed floor area and height limits on the buildings are as set out below.

> Historic buildings, community and school halls, churches, Wharenui (limited to 40 sleeping spaces), Wharekai, early childhood centres (Te Kohanga Reo) with an escape height less than or equal to 4 m (2 floors). The buildings may include museums and shops with limited combustible materials (e.g. no extensive clothing sales). Country schools may also be suitable subjects. The limits are:

- Three-floor building, with no more than two floors not separated by fire-rated construction:
    - 500 m² on any floor of a multi-floor building
- Single-floor building:
    - 1,000 m².

The floor limits are essentially the same as the building limits specified in NZS 4515 for a system with a 20 minute water supply and with an increase in the floor area of a single-storey building, and the 500 m² applies to any single-floor area. Other variations are:

- Sloping ceilings greater than 37.5° are permitted
- Ceiling height greater than 3 m (up to 6 m) are permitted.

Separate mattress stores in Wharenui not to exceed 54 m², with storage not to exceed 20 m², and stored to no greater than 2 m.

Proposed sprinkler parameters are given in Table 33.

Contents **Page**

Figures **Page**

Tables	Page

1. INTRODUCTION

The overall aim of this project is to develop a framework for the development of a standard for sprinklers to be used in Marae, community halls, churches and other places of special or historical interest. The intention is that these sprinklers will be of lower cost than sprinklers fully complying with current full commercial sprinkler standards e.g. NZS 4541 (SNZ, 2007).

The specific objectives of this project are:

1. To collate information on fire risks associated with Marae, community halls, churches and other places of special or historical interest based on current data and knowledge.
2. Analyse current fire sprinkler concepts and application relating to potential low-cost sprinkler systems.
3. Propose a framework for a sprinkler standard for low-cost sprinkler systems in the buildings identified by the study as likely to benefit from such a system.

The purpose of this document is not to justify the use of sprinklers in the target buildings, nor to discuss some of the practical issues of installing sprinklers in those buildings. It is to give an overview of the fire incidents, regulatory requirements, applicable standards and costs, and hence to recommend a suitable sprinkler specification.

2. SCOPE OF BUILDINGS INVESTIGATED

The buildings in this study are those which may be used by the community for meetings or to visit, such as historic places, but which would not be required by the NZBC Compliance Document C/AS1 for fire safety (DBH, 2010a), to have any form of sprinkler system. Although some of these types of buildings may be large enough or have a sufficient occupant load to require sprinklers, this study is limited to those which do not require sprinklers.

The buildings subject to this study can have a range of activities. Some activities may be classified as follows and include, but are not limited to:

Marae:

- Meeting/crowd activity (Wharenui)
- Sleeping – occasional (Wharenui)
- Cooking/eating/crowd (Wharekai)
- Educational (Te Kohanga Reo, early childhood centre)

Historic Place: (not necessarily registered with the Historic Places Trust)

- Houses used as museums
- Museums, either purpose-built or converted for other activities e.g. a historic Post Office, mill, blockhouse
- Churches
- Buildings which are classified as crowd occupancy but may have an office or café

Community buildings:

- Halls
- Theatres
- Churches.

NZBC Compliance Document C/AS1 (DBH, 2010a)

The buildings may be classified as shown in Table 1.

Table 1: C/AS1 Building classification

Halls, theatres, museums, Marae buildings, churches	CS or CL
Wharenui	SA
Shops, exhibition halls	CM
Te Kohanga Reo	CS or CL
Residential	SH or SR

(This report does not apply to buildings used as hotels, motels and similar buildings.)

Whether a building requires sprinklers depends on the occupant load, which can be used to determine total area of the building, and escape height (distance from highest floor level to highest final exit) which determines the number of floors. The fire-resistance rating of the separation between floors is also a criterion for shops and exhibition halls.

From the requirements of C/AS1 Part 4: Requirements for Firecells, Table 4.1, the following parameters can be derived for buildings which do not need sprinklers:

- Any single-floor building or two-floor building with or without fire separation between floors, which is not a supermarket or other store, with bulk storage/display over 3 m high, where the occupant load is less than 1,000
- Halls, theatres etc (CS or CL) of approximately three floors with an occupant load over 500 but not exceeding 1,000
- Halls, theatres etc (CS or CL) of approximately eight to 10 floors with an occupant load not exceeding 500
- Shop and exhibition halls not including any supermarkets or other stores with bulk storage/display over 3 m high with 60 minutes fire separation between floors:
    - approximately three floors with an occupant load over 500 but not exceeding 1,000 per floor
    - approximately eight to 10 floors with an occupant load not exceeding 500 per floor
- Wharenui with no more that 40 sleeping spaces (special case)
- Early childhood centres with an escape height less than or equal to 4 m (two floors)
- Houses.

The above apply as of the date of publication of this report. There are proposals to amend the Compliance Document for fire safety C/AS1 (DBH, 2010b).

The proposed classes of buildings are given in Table 2:

Table 2: Proposed 2011 C/AS1 Building classification

Halls, theatres, museums	CA
Shops, exhibition halls	CA
Te Kohanga Reo	CA
Houses	SH
Wharenui, hotels, motels, other residential	SM

Similar requirements with regard to sprinklers exist in the proposed amended Compliance Documents, although shops have been brought into the same category as halls and churches and the requirements have been simplified. Shopping malls are now outside the scope of the proposed C/AS1.

The proposed document will not require sprinklers in these buildings if they contain less than 1,000 occupants and have an escape height of less than or equal to 25 m (approximately eight to 10 floors).

2.1 Occupant load and building area

At this point it is worth discussing the relationship between building area and occupant load, as a description of the size of a building is best given by floor area rather than occupant load.

One criterion which determines the need for a sprinkler system in a building is occupant load, and to define the area of a building from occupant load the activities in the building need to be known. Taking the occupant load on its own does not define the area of the buildings as many unoccupied spaces, or spaces with multiple uses, would not be included in the determination of floor area for calculation of occupant load.

Advice is given in C/AS1 Part 2, paragraph 2.3, Occupant Load, and the proposed C/AS1 (DBH, 2010b) states that duplication should be avoided so corridors, toilets etc are not included in the calculation of area although the occupant density includes permanent fixtures and partitions. Calculating an area requires the percentage of the building which would not be included to be estimated.

Occupant densities have been used from NZBC Compliance Document C/AS1, Table 2.2, is given in Table 3 as follows:

Table 3: Occupant density for crowd occupancies

Crowd activity	**Occupant density users/m²**
Area without seating or aisles	1.0
Space with loose seating	1.3
Lobbies and foyers	1.0
Art galleries, museums	0.25
Dance floors	1.7

Shop spaces	0.3

For community halls with loose seating an occupant density of 1.3 users/m² would be the largest value to be used. If this were used for all other buildings it would give a conservatively low value for building area. However for community buildings and Marae buildings, such as Wharenui and Wharekai, 1.3 users/m² is reasonable considering that loose seating could be used in those areas.

For historic buildings the occupant density would very much depend on the activities. Table 4 gives the selected occupant density for the buildings considered in this study.

Table 4: Occupant density in the studied buildings

Building Type	Occupant density users/m²
Marae buildings	1.0
Historic*	0.3
Community including places of worship	1.3

*Other than those defined as Marae or community buildings

The percentage area that can be taken for calculations of occupant load will vary with the type of building. For example, a community hall or Wharenui will have a large space for the occupants whereas a historic building will have toilets, corridors and lobbies which would not be included. As an estimate of occupancy the following, given in Table 5 below, can be used.

Table 5: Estimated percentage occupancy and building areas

Building type	Occupant load users	Occupant density users/m²	Occupied area m²	Occupancy %	Total building area m²
Community halls Wharenui (not used for sleeping) Places of worship	1,000	1.3	770	70	1,100
Historic building (based on a house)	1,000	0.3	3333	50	6,666
Shop	1,000	0.3	3333	60	6,666

The building areas given in Table 5 above are greater than typical buildings considered in this study as shown in Table 6.

Table 6: Typical areas of buildings

Building	Area (approximate) m²
Orongomai Wharenui, Upper Hutt	135
Orongomai Wharekai	240
Waiwhetu Wharenui, Lower Hutt	250
Waiwhetu Wharekai	200
Upper Hutt College School Wharenui	72
Upper Hutt College School Wharekai	115
Te Kauri, Wharenui, Huntly	128
Te Kauri, Wharekai, Huntly	185
St Alban's Church, Pauatahanui	121
St Mary's Holy Trinity, Parnell	893
Ohariu Valley Hall, Wellington	142
Mungavin Hall, Porirua	770
Gear Homestead, Porirua (two floors)	180 per floor
Historic Cottage, Porirua	61
Rawhitiroa Hall, South Taranaki	200
Stone Store, Kerikeri (3 floors)	*104 per floor
Kemp House, Kerikeri (2 floors)	*85 per floor
Antrim House (three floors)	350 max floor area on one floor

Note: * BRANZ estimate

A local community hall and places of worship, including ancillary spaces, may have an area of approximately 700-1,000 m², with Marae buildings significantly less. St Mary's Holy Trinity, Parnell has been included although it is a "cathedral" type of church. Most community churches have a smaller area.

A floor area of 1,000 m² would cover most community halls, churches and Marae buildings and be within the floor area of buildings not requiring a sprinkler system in the Compliance Documents for fire safety (DBH, 2010a). In multi-floor buildings the area is limited to 500 m².

The examples above give a range for small to large buildings of the types identified.

Figure 1 and Figure 3 show plans of a community hall and a small church, and Figure 2 and Figure 4 show the outside of the same buildings respectively.

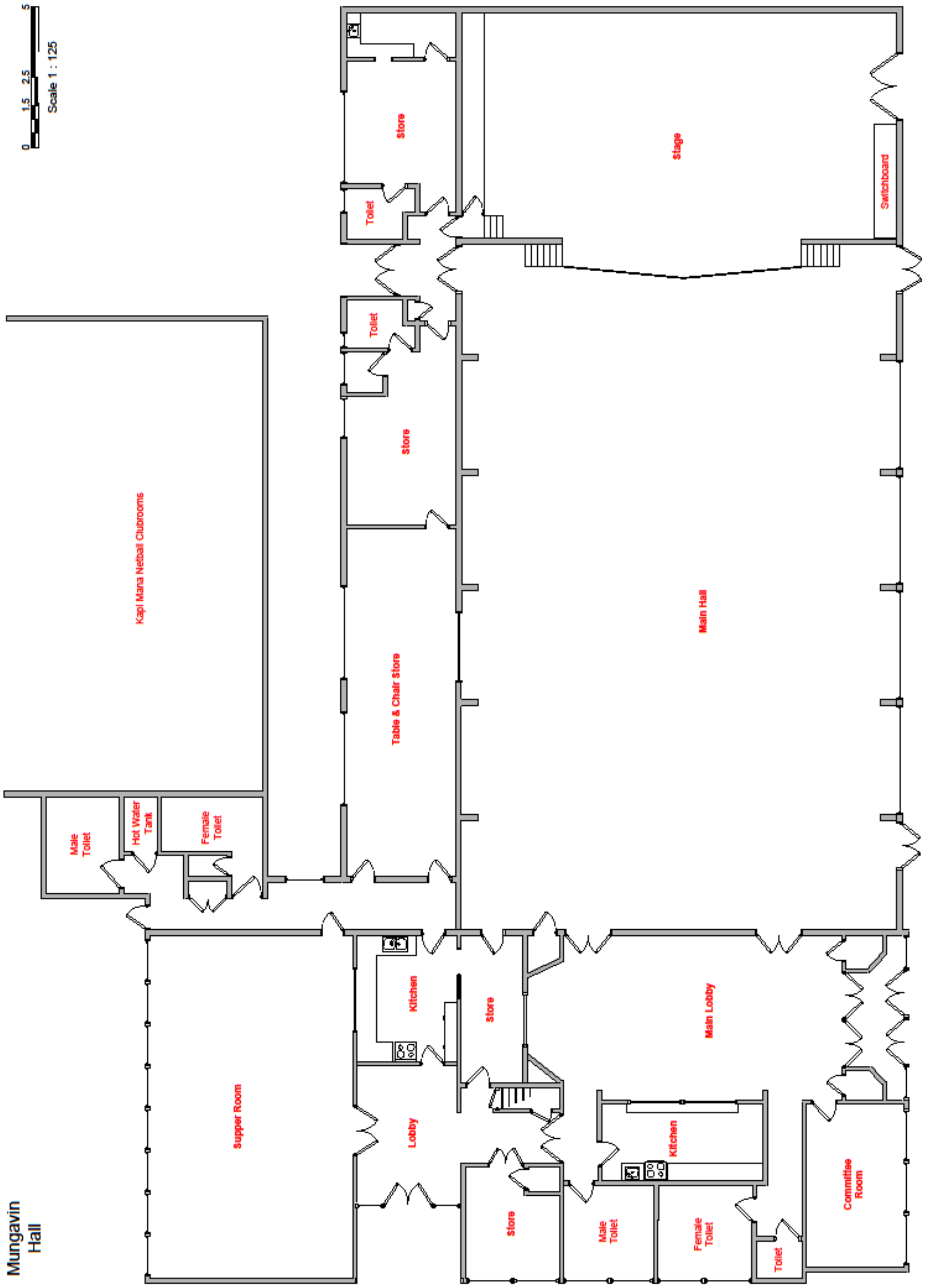

Figure 1: Plan of Mungavin Hall, Porirua

Main hall 24 m x 14 m, 336 m²
Total area, excluding Kapi Mana Netball Clubrooms, approximately 770 m²

Figure 2: Mungavin Hall, Porirua

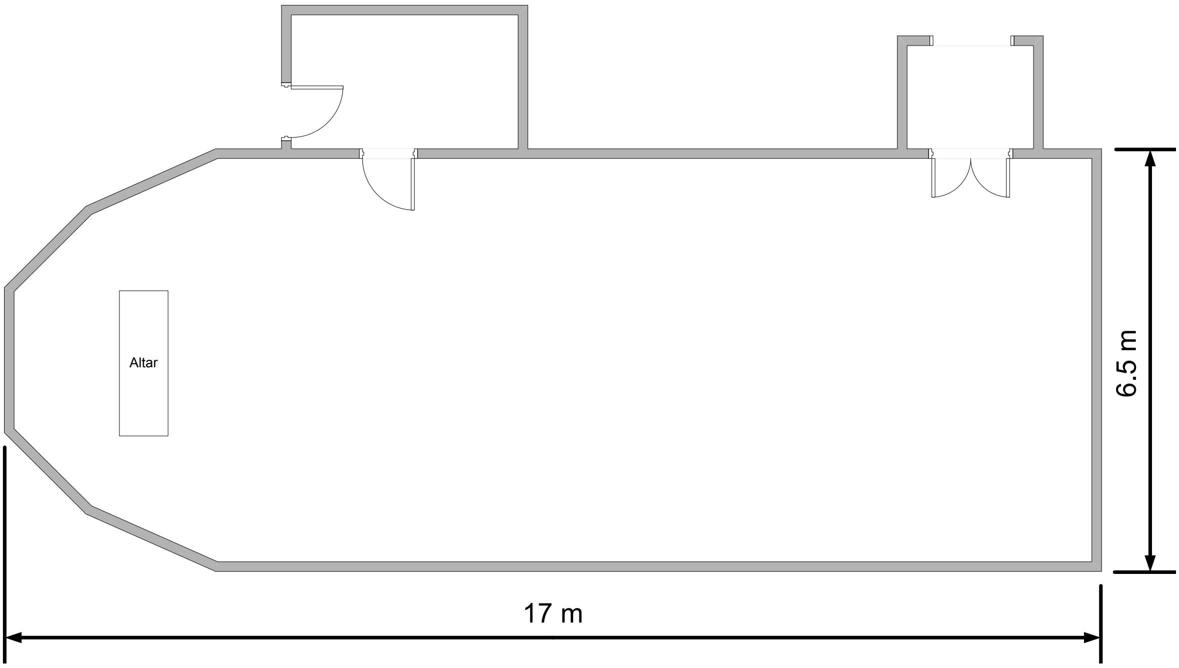

Figure 3: Plan of St Alban's Church, Pauatahanui, Porirua

Dimensions taken from sprinkler block plan, total area of 121 m²

Figure 4: St Alban's Church, Pauatahanui, Porirua

2.2 Building definition

The numbers of buildings within this floor area range being considered in this study, which are not required to have sprinkler systems, is extensive. They range from single-floor buildings to up to 10 floor buildings with occupant loads from 500 people to 1,000 people on any floor.

This means that the buildings can be quite large with a floor area of over 700 m² on any one floor.

Many of the buildings will fall into the category of CS, CM, CL (or proposed CA) i.e. halls, churches, museums and shops. Wharenui are considered as accommodation buildings, SA (or proposed SM), and may have a maximum sleeping occupancy with a limit of 40 occupants irrespective of floor area. However if it is only used as a meeting hall the full occupant load, based on floor area, may be used. Wharekai can be considered as a hall.

In most cases, e.g. community halls and Marae buildings, there will only be a single floor. In historic buildings two-floor buildings would be common. The proposals in this report must therefore include multi-floor buildings. A feature of multi-floor buildings is whether there are fire separations, floors and doors, between each level. For the purposes of this report it is considered that only two floors may be treated as such, with any subsequent floors being fire separated by fire separation with a FRR of at least 30/30/30.

Based on the Compliance Documents C/AS1, and bearing in mind the proposed changes, the following parameters are considered to be appropriate:

> Historic buildings, community and school halls, churches, Wharenui (limited to 40 sleeping spaces), Wharekai, early childhood centres (Te Kohanga Reo) with an escape height less than or equal to 4 m (2 floors). The buildings may include museums and shops with limited combustible materials (e.g. no extensive clothing sales). Country schools may also be suitable subjects. The limits are:

- Three-floor building, with no more than two floors not separated by fire-rated construction:
  - 500 m² on any floor of a multi-floor building
- Single-floor building:
  - 1,000 m²

Historic buildings take many forms and include family homes, museums, Post Offices, courthouses, store houses and buildings which may take similar forms, now operated as museums. These are all included.

3. FIRE STATISTICS

3.1 General

An in-depth statistical analysis of fires in the target buildings is not part of the scope of this study. The purpose of the statistical investigation is to determine the general extent of fires in such buildings. Data is only used where an administration specifically publishes such data or indications of fires are given in published reports. New Zealand and the USA do provide such information and this is recorded in this report.

3.2 New Zealand

New Zealand data has been sourced from the New Zealand Fire Service (NZFS), the New Zealand Historic Places Trust (NZHPT) and New Zealand denominational websites.

The following is a list of sources:

Anglican Church: www.anglicansonline.org/

Baptist Churches of New Zealand: http://www.baptist.org.nz

Catholic Church of Aotearoa New Zealand: http://www.catholic.org.nz

Jackson N. 2011. *Personal Communication*. National Heritage Policy Manager, NZHPT, Wellington, New Zealand.

Methodist Church of New Zealand: http://www.methodist.org.nz

New Zealand Fire Service (NZFS). 2009. *Emergency Incident Statistics: 1 July 2007-30 June 2008.* NZFS, Wellington, New Zealand.

Presbyterian Church of Aotearoa New Zealand: http://www.presbyterian.org.nz

Quigan G, 2010. *Personal Communication*. SMS/SMART Application Support, NZFS, Wellington, New Zealand

Table 7 gives the total number and number per year of fires in churches, community halls, Marae and historic buildings. Table 8 gives the number of buildings destroyed. Destruction of the building given in Table 8 is taken from the category of up to 20% of the property saved from the NZFS service data and statement of "building demolished" in the NZHPT data.

Table 7: Fires in buildings

03/01/2005 to 26/05/2010*					2005 to 2010¥
Type of fire	**Church**	**Community hall**	**Marae**	**Historic building**	**Historic building**
Structure	108	141	13	4	13
Average/year	**20**	**26**	**2**	**0.7**	**2.4**

Table 8: Buildings destroyed

03/01/2005 to 26/05/2010*					2005 to 2010¥
Type of fire	**Church**	**Community hall**	**Marae**	**Historic building**	**Historic building**
Structure	8	14	4	1	6
Average/year	**1.5**	**3**	**0.7**	**0.2**	**1.1**

*(NZFS, 2010)
¥ (NZHPT, 2011;Jackson, 2011)

The difference in data between the NZFS and the NZHPT may be attributed to the classification of buildings in the NZFS database. Some buildings classified as "churches and Marae" may also be historic places.

Data from the NZFS and a brief analysis shows that there were very few fires in such buildings. Over the period 2005/2007 (NZFS, 2008), which is within the date range of the above data in Table 7, there were an average of 6,230 structure fires. This indicates fires in the target buildings represented 0.79% of all structure fires in New Zealand based on the supplied data.

The published statistics do not classify buildings to the same extent as the supplied data. However taking the numbers for structure fires in community halls, places of worship, auditorium and concert halls, which previously (NZFS, 2007) included Wharenui, the percentage of fires is 2.3%. This includes all fires and not just structure fires. Structures fires represent approximately 25% of all fires, which gives the percentage of structure fires in the target buildings at approximately 0.6% from the published data. This is similar to that of the supplied data. The data is summarised in Table 9.

Table 9: Summary of structure fires

03/01/2005 to 26/05/2010*						2005 to 2010¥
Type of fire	**church**	**Community hall**	**Marae**	**Historic building**	**Total**	**Historic building**
Structure	108	141	13	4	266	13
Average/year	**20**	**26**	**2**	**0.7**	**49**	**49.3**
Percentage of all structure fires (6,230)	**0.32**	**0.42**	**0.04**	**0.01**	**0.79**	**0.04**
Percent of buildings destroyed	**0.01**	**0.02**	**0.05**	**0.05**	**0.004**	**0.01**

The percentage of all structure fires in these buildings is low. Of the total number of church, Marae and historic buildings, the percentage of fires varies from 0.13% for historic buildings to 1.7% for churches. Although this is greater than expressed as a percentage of the total structure fires for any building, the percentage of fires in these buildings is still low. No figures are available for the total number of community halls in New Zealand. Table 10 gives a summary of this data.

Table 10: Structure fires as a percentage of number of buildings

Building	Total Number	Fires/year	%/year of structure fire
Church	1,300	20	1.5
Marae	800	2	0.25
Historic building	10,000	13	0.13

It may be considered that with this low number of fires, sprinkler protection may not be cost-effective This view however does not necessarily take into account any cultural or historic value in the buildings. Buildings such as historic churches or Wharenui may represent a considerable value to the community and would benefit from sprinkler protection.

3.2.1 All public assembly buildings

In 2007/2008, 25% of all fires (structure and non-structure) occurred in all public assembly buildings. From data supplied by the NZFS (Quigan, 2010) there were 202 structure fires in assembly buildings in 2007/2008, which means that 3.2% of all structure fires occurred in assembly buildings. This number is used for the comparison proposed below. The data for buildings which form the basis of this study shows that 49 were involved in a structure fire, which is 24% of all assembly building fires.

3.2.2 Fire protection

There were 120 sprinkler systems and 795, smoke, heat and flame detectors in 6,230 structure fires in 2007/2008 (NZFS, 2009). In historic buildings fires (NZHPT, 2011) there was one sprinkler system fire that saved the building over the period 2005 to 2010.

More specifically, for the target buildings where fires occurred, the data supplied directly from the NZFS (Quigan, 2010) is given in Table 11.

Table 11: Fire protection in the target buildings

Type of protection	Church	Community hall	Marae	Historic building
Domestic smoke alarm	5	4		
Heat detector	2	2		
Manual alarm	1	4		
Smoke detector system (monitored)	14	21		1
Smoke detector/security system	2	5	1	
Smoke sampling system	1			
Sprinkler system	2			1
Domestic (home) Sprinkler		1		
Alarms total	25	36	1	1
Alarms%	**23%**	**26%**	**8%**	**25%**
Sprinklers total	2	1	0	1
Sprinklers%	**2%**	**1%**	**0%**	**25%**
Total structure fires	108	141	13	4

This data shows that there are very few sprinkler systems installed in the target buildings where fires occurred. The data is not conclusive on whether the fire protection generally contributed to limiting the damage in the building as a large number of buildings with no recorded fire protection resulted in 91-100% of the property being saved. The greatest number of fire protection methods involved some form of fire alarm, with 23% and 26% in churches and community halls respectively. The presence of sprinklers and alarms in historic buildings is not conclusive because of the low number of incidents.

Where the sprinklers were installed the extent of the property saved was 91-100%.

3.3 UK

Data is taken from *Fire Statistics United Kingdom 2008* (DCLG, 2010), the most recent data available from the UK.

In 2008 there were 88,560 building fires, of which 27,500 were in buildings other than dwellings. Of those 5% occurred in buildings providing recreational and other cultural services. This is as close a definition as can be obtained for the types of buildings considered in this study. This is greater than the 3.2% for all public assembly buildings in New Zealand, but is approximately of the same order of magnitude.

In buildings other than dwellings, smoke alarms were present in 46% of buildings. No data is given for sprinklers.

3.4 Australia (NSW)

Data is taken from the NSW Fire Brigade's *Annual Statistical Report 2006/2007* (NSWFB, 2009).

In 2006/2007 there were 6,257 building fires reported, which is similar to the 6,230 structural fires in New Zealand over the period 2005 to 2010, albeit with a population of nearly twice that of New Zealand.

The closest classification in the data is public assembly property which is defined as "Place where people gather for amusement, recreation, social, religious, civic, travel and similar purposes". Although this is a greater range of buildings than the target buildings, the data can give an indication of the extent of fires. There were 347 fires in such buildings, which is 5.5% of all building fires. This is similar to the UK data of 5% and of the same order of magnitude of 3.2% in New Zealand for all public assembly buildings.

In those buildings in NSW there were 51 smoke detection systems (15%) and eight sprinkler systems (2.3%).

3.5 USA

Data is taken from: Karter, Michael J. 2010. *Fire Loss in the United States During 2009*. NFPA, USA.

An assembly building (NFPA 101, 2009) includes churches, mosques, places of worship, convention centres, exhibit halls, auditoriums, concert halls, movie theatres, television studios, gymnasiums and many more buildings. This is more extensive than the target buildings, but is similar to that used in New Zealand.

In 2009, (Karter, 2010), there were 480,500 structure fires, of which 14,500 were in public assembly buildings. This is 3% of all structure fires and compares similarly with data from New Zealand, the UK, Australia and NSW.

Although not available from the 2009 data (Karter, 2010), information given in a FEMA report for 2006 (FEMA, 2010) indicates that sprinklers were present in 20% of assembly building fires and smoke alarms in 37% of unconfined fires in assembly buildings.

3.6 International comparisons summary

There was insufficient detail in international data to identify fire incidents for the target buildings. However data for assembly buildings provides a useful comparison.

The data from New Zealand, the UK, NSW and the USA shows that the incidence of fires in assembly buildings is similar at 3-5% of all structure fires.

Table 12: Summary of percentage fire protection

Fire protection	NZ	UK	Australia NSW	USA
Alarms %	8.0-26.0	46.0	15.0	37.0
Sprinklers %	1.0-2.0	No data	2.3	20.0

Table 12 gives the percentage of alarms and sprinklers in assembly buildings. Because this is based on buildings in which a fire occurred, the data may be inconclusive. However it does show that (apart from the USA) sprinklers are not prevalent and a greater proportion of buildings have alarms installed.

4. INTERNATIONAL APPLICATION – LITERATURE REVIEW

4.1 Introduction

There are no specific requirements for sprinklers for special buildings such as churches (which are identified as assembly buildings), nor historic buildings in the main building codes. However guidance is given in various published documents which are listed in Table 13.

Table 13: Guidance documents

Document/authority	Description	Reference
NFPA 914	NFPA 914 *Code for fire protection of historic structures* (2010 Edition)	(NFPA, 2010a)
NFPA 909	NFPA 909 *Standard for the protection of cultural resource properties – museums, libraries, and places of worship* (2010 Edition)	(NFPA, 2010b)
NZFS, NZHPT	*Protecting and Preserving What We Value*	(NZHPT, 2003)
NZFS, NZHPT	*Protecting Marae from Fire*	(NZHPT, 2003)
NZHPT	*Guidelines for Fire Safety*	(Caldwell C & MacLennan H, 2000)
NZHPT	*Sustainable Management of Historic Heritage Guidance Series: Fire Safety and Heritage Buildings (draft for consultation).* Update of *Guidelines for Fire Safety* (Caldwell C & MacLennan H, 2000).	(McClean R, 2010)
Technical Conservation Group, Historic Scotland	*Fire Safety Management in Traditional Buildings*	(Historic Scotland, 2010)

Where sprinklers are specified for these buildings the appropriate sprinkler standards are called up.

Domestic dwellings will use NZ 4517 (SNZ, 2010), AS 2188.5 (SAI, 2008), NFPA 13D (NFPA, 2010a) or equivalent. Residential buildings will use NZS 4515 (SNZ, 2009), NFPA 13R (NFPA, 2010b), BS 9251 (BSI, 2005) and AS 2118.4 (SAI, 1995b). All other buildings require a full sprinkler standard: NZS 4541 (SNZ, 2007), NFPA 13 (NFPA, 2010c), AS 2118.1 (SAI, 1999) or BS EN 12845 (BSI, 2009) as appropriate to the jurisdiction, with all design, verification and inspection requirements.

The emphasis varies between standards, with NZS 4517 essentially for life safety and NZS 4541 for property protection.

4.2 Code compliance requirements

Fire protection of the target buildings is addressed by application of the relevant building codes and Compliance Documents (DIA, 2009; DBH 2010a). The New Zealand requirements have been discussed in section 2 above.

The following gives the requirements for the requirements in Australia, England and Wales, and the USA as given in the International Building Code (ICC, 2009).

4.2.1 Australia

The Australian requirements for assembly buildings, Class 9b, are given in the Building Code of Australia 2010 (ABCB, 2010).

Sprinkler systems must be installed in:

- All buildings over 25 m in height.
- Shops with a floor area exceeding 3,500 m² or volume of 21,000 m³.
- A theatre, public hall or similar building unless the stage, back-stage area and accessible under-stage area are separated from the audience by a proscenium wall which has a fire resistance of one hour and is fitted with a non-combustible curtain. This applies to a school assembly hall, church or community hall with a stage and any back-stage area with a total floor area of more than 300 m², or otherwise has:
  - a stage and any back-stage area with a total floor area of more than 200 m²; or
  - a stage with an associated rigging loft.

For theatres etc where these conditions do not apply, then sprinklers are not required e.g. any hall with a back-stage area of less than 200 m, which would be the case with any small community halls and churches. There is no limit on general floor area. There is no specification for number of floors or building height.

Large isolated buildings of the same class can have an area of 18,000 m^2 in one firecell before sprinklers are required.

The applicable standard is AS 2118.1 (SAI, 1999) and is equivalent to NZS 4541. For residential properties AS 2118.4 (SAI, 1995) may be used.

4.2.2 England and Wales

The data given in Section 3 above is for the entire UK i.e. England, Wales and Scotland. The requirements herein are given for England and Wales only.

The England and Wales requirements for houses and assembly buildings are given in the Building Regulations 2000, Fire Safety, Approved Document B (DCLG, 2007). Part 1 applies to dwellings which are single family homes or those containing no more that six residents. Part 2 applies to buildings other than dwellings and includes assembly buildings.

In Part 1 sprinklers are optional. Concessions are given for boundary separation and requiring fire resistance separation of stairs where the building has upper floors above 7.5 m from ground level.

In Part 2 requirements for sprinklers are based on building height and floor area.

In Part 2 there is no height limit for either sprinklered or non-sprinklered assembly, recreational, shops and commercial buildings.

In single-storey buildings there is no floor area limit other than shops, which have a 2,000 m² limit.

In multi-storey buildings of any height there is a floor limit of 2000 m² for non-sprinklered buildings and 4,000 m² in sprinklered buildings. Concessions are given for various building design features, such as boundary separation and reductions in fire-resistance ratings.

Where sprinklers are installed they must comply with BS 9251:2005 *Sprinkler systems for residential and domestic occupancies* (BSI, 2005), or BS 5306-2:1990 *Fire extinguishing installations and equipment on premises* (BSI, 1990). The specifications for sprinkler systems standard is BS EN 12845:2004 *Fixed firefighting systems. Automatic sprinkler systems. Design, installation and maintenance* (BSI, 2009) which is equivalent to NZS 4515 (SNZ, 2009) and NZS 4541 (SNZ, 2007) respectively.

4.2.3 USA

In the USA there is no federal building code. Various organisations publish model building codes which are then adopted in whole or in part by individual states and cities.

The most common building code in the USA is the International Building Code (ICC, 2009), the current edition of which was published in 2009. As at 1 April 2011, 22 states and three USA territories have adopted the 2009 version.

The buildings of interests are assembly group A-3 defined as (ICC, 2009):

> Assembly uses intended for worship, recreation or amusement and other assembly uses not classified elsewhere in Group A including, but not limited to:
>
> - Amusement arcades
> - Art galleries
> - Bowling alleys
> - Community halls
> - Courtrooms
> - Dance halls (not including food or drink consumption)
> - Exhibition halls
> - Funeral parlours
> - Gymnasiums (without spectator seating)
> - Indoor swimming pools (without spectator seating)
> - Indoor tennis courts (without spectator seating)
> - Lecture halls
> - Libraries
> - Museums
> - Places of religious worship
> - Pool and billiard parlours
> - Waiting areas in transportation terminals.

Area and height limits for assembly buildings (Group A-3) are determined by the fire-resistance ratings of external and internal walls and structural elements. With sprinklers, the heights and floor areas may be increased and any one-hour fire-resistance rating can be removed except for external walls. In the latter case the increase in floor areas cannot be applied.

The different wall constructions are designated Types I to V, A or B. A building with Type IIB, and heavy timber roof beams and joists, and Type VB construction has no requirements for fire-resistance ratings. This allows a two-floor building with Type IIB construction to have a floor area of 9,500 ft² (880 m²) and a single-floor building of Type VB construction to have floor area of 6,000 ft² (557 m²). Type IIA and B construction are essentially of non-combustible materials, with some concessions for the use of fire-retardant treated wood, insulation, interior finishes and other similar component. Type V may be of any material.

If a sprinkler system is installed, the floor areas may be increased by 200% for multi-storey buildings and 300% for single-storey. Also the height may be increased by 20 ft (6.1 m) and the maximum number of floors increased by one.

Specific requirements for sprinkler systems in these occupancies arise when:

1. The fire area (firecell) exceeds 12,000 square feet (1,115 m²).
2. The fire area (firecell) has an occupant load of 300 or more.
3. The fire area (firecell) is located on a floor other than a level of exit discharge serving such occupancies.
4. The structure exceeds 12,000 square feet (1,155 m²), contains more than one fire area containing exhibition and display rooms, and is separated into two or more buildings by fire walls of less than four-hour fire-resistance rating without openings.

These requirements appear to supersede the previous specification based on construction type. Taking the most onerous requirement gives a limit with no sprinklers of 557 m² for a single-floor building with an occupant load of 300.

The sprinklered standard referenced in the IBC 2009 is NFPA 13 (NFPA, 2010c) which is equivalent to NZS 4541 (SNZ, 2007).

4.3 Summary of requirements

Table 14 is a summary of the limit which would apply to the target buildings when no sprinklers are required. For houses there are no area, occupant or height limits.

Table 14: Summary of building code requirements

	NZ	Australia	England and Wales	USA€
Area, m^2	Aprox.1,000	18,000¥ 200*	2,000	557
Floors	3-10	Not specified	1 for shops Unlimited for others	1
Occupant load, Persons	500 to 1,000	Up to 5000 in a shop	2,000 to 4,000	300

€ Applies to buildings with no fire-resistant construction

¥ Large isolated building

* Back-stage area

4.4 International and New Zealand standards

4.4.1 Residential

Table 15, Table 16 and Table 17 show the essential parameters for sprinkler design for residential buildings. They are all similar, with the New Zealand standard, NZS 4515, in Table 17 having the most onerous conditions and limits on floor area. Other parameters, such as discharge density and number of design sprinklers, are similar.

These standards apply to a building classed as residential and meeting the floor area and floor numbers specified in the tables below. NZS 4515 specifically excludes domestic occupancies, i.e. homes, which are addressed by reference to NZS 4517.

These standards have application to the target buildings, which can be appropriately designated as residential and would mostly apply to historic buildings.

The design is on a room-by room basis with four sprinklers being the maximum number of design sprinklers in any one room. Where the building has rooms only with a lesser number of sprinklers, these are taken as the design number. That is, for a building where the maximum number of sprinklers in any room is two, then the design will be based on two sprinklers activating, regardless of the total number of sprinklers in the building. This has the advantage of reducing water supply requirements in those buildings where that applies.

Table 15: NFPA 13D

Application	Area m^2	Floors no.	Sprinklers no.	Discharge density mm/min	Water supply duration min
Residential	4,831	4	4	2.04	30

Notes to Table 15:

a) Applies to apartment buildings, lodging and rooming houses, board and care facilities, and hotels, motels, and dormitories.

b) Floor area is per floor.

Table 16: AS 2118.4

Application	Area m^2	Floors no.	Sprinklers no.	Discharge density mm/min	Water supply duration min
Residential	5,000	4	4	2.04	30

Notes to Table 16:

a) Residential is not defined, but can include the residential portions of buildings such as clubs, hotels, motels and apartment buildings.

b) Floor area is per floor.

Table 17: NZS 4515

Application	Area(a) m²	Floors no.	Sprinklers no.	Discharge density mm/min	Water supply duration min
1	≤ 500	≤ 3	4	2.04	20
2	≤ 2000(b)	≤ 4	4	2.04	60

Notes to Table 17:

a) The floor area is the sum of all floors.

b) Where the floor area exceeds 500 m² there are additional requirements for fire brigade alarms and fire sprinkler inlet.

c) Applies to rooms arranged for the purposes of habitation or co-habitation, other than those defined as a domestic occupancy. These include hospital ward areas, rest homes, care institutions, prisons, police cells, motels, hotels, hostels, residential boarding schools, flats and apartments.

4.4.2 Assembly buildings and other residential

The hazard classification for assembly and residential buildings other than specified in 4.4.1 above, which defines the type of sprinkler system, are given by the hazard classification. Table 18 gives the hazard classifications from the various standards reviewed in this report.

Table 18: Hazard classification identifiers

Standard	Classification	Abbreviation
NFPA 13 and AS 2118-1	Light Hazard	LH
	Ordinary Hazard	OH
NZS 4541	Extra Light Hazard	ELH
	Ordinary Hazard	OH

Ordinary hazard is further divided into group 1 and group 2 in NFPA 13, and 1 to 3 in AS 2118-1 and NZS 4541.

Table 19 gives the types of buildings which are given the lowest hazard classification, and these have been selected as similar to the types of buildings which are the subject of this report. Table 20 gives those buildings which are similar to those that are the subject of this report, but with a higher hazard classification.

Table 19: Occupancies of Light Hazard classification

NFPA 13	AS 2118-1	NZ 4541
Churches	Churches and chapels	N/A
Libraries (excluding large stack rooms)	Libraries (excluding stack rooms)	Libraries (excluding stack rooms)
Educational	Schools, colleges, universities	Schools, universities
Hospitals, including animal hospitals and veterinary facilities, nursing or convalescent homes	Hospitals, orphanages, homes and asylums, medical and dental consulting rooms	Hospitals
Residential	Boarding houses, lodging houses, residential portions of buildings (such as clubs, hotels, motels and apartment buildings)	Boarding houses, hotels and motels (residential portion), residential clubs, youth hostels
Institutional	Prisons	Prisons
Offices, including data processing	Offices	Offices, staff amenity and cafeteria areas
Museums	Museums (low-combustible loading)	
Restaurant seating areas	Art galleries	Art galleries
Theatres and auditoriums (excluding stages and prosceniums)		

Table 20: Occupancies of higher than Light Hazard

NFPA 13	AS 2118-1	NZ 4541
	Restaurants and cafes	Churches OH1
Stages OH2	Sports pavilions and stands OH1	Museums (unless otherwise approved) OH3
Mercantile, Post Office OH2	Showrooms OH3	Retail shops and malls OH3
	Theatres, cinemas and public entertainment areas OH3	Theatres, cinemas OH3
	Clubs/hotels/motels OH1	Restaurants and cafes OH1

There are broad similarities between the different sprinkler standards, with some exceptions. Theatres excluding stages and prosceniums are included as LH in NFPA13, but are OH3 in AS 2118-1 and NZS 4541. NFPA makes a distinction between auditoriums and stage areas. This is likely to be because stages and back-stage areas may have a higher fire load than the auditorium or are more complex spaces.

Community halls are not specifically listed and could be included as theatres, although they are not considered to provide the same level of hazard where the stages and back-stage areas do not contain permanent materials used in theatrical productions. Community halls typically do not have a fly system (theatre rigging system) for scenery, but could include light battens. With the low levels of fire load in community halls it is considered they can be classified as OH or ELH. Figure 5 shows a school hall, which would be typical of a community hall and Wharekai.

Figure 5: School hall typical of community halls

For hotels and motels distinctions are made in AS 2118-1 and NZS 4541 between residential and non-residential portions. These may exist as part of the buildings considered in this study, particularly as historic buildings or as Wharenui.

Museums are low hazard in NFPA 13 and AS 2118-1, but OH3 in NZS 4541, and can be varied. Museums can be part of a historic building. For the purposes of this standard, taking into account the limitations on building size given in 2.2 above, museums are considered to be OH or ELH buildings.

Shops are OH2 or OH3. Again these are part of a historic building and for the same reasons as museums are considered to be OH or ELH buildings

Churches are considered by all standards to be low hazard, so an ELH or OH can apply. Figure 6 shows a large church and Figure 7 a small church, both with timber interanl lining and both with an NZS 4541 OH1 sprinkler system.

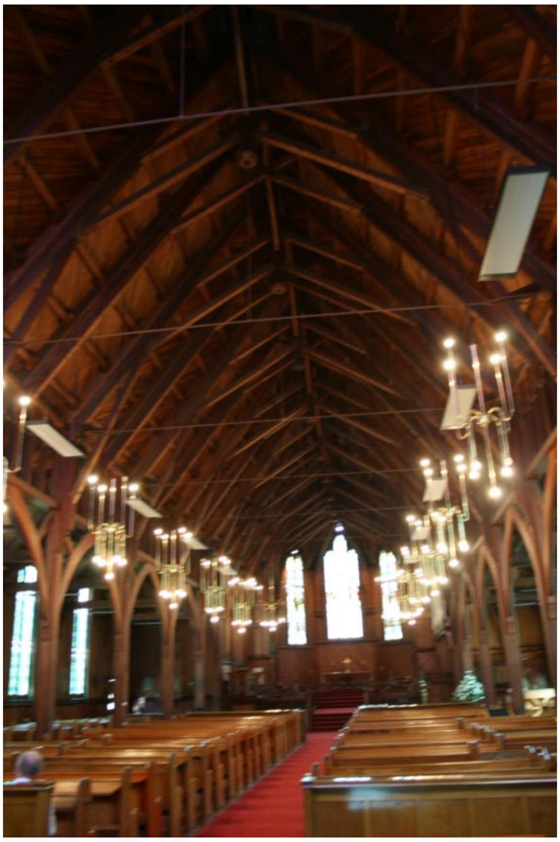

Figure 6: Example of a large timber church building

Figure 7: Example of a small timber church building

Marae complexes contain many different buildings. Except for Wharenui and mattress stores, the Marae buildings, Wharekai etc have no more hazardous contents than a community building and can be given the hazard classification of ELH or OH. Figure 8 shows a Wharekai interior with low fire load.

Figure 8: Wharekai interior

The Wharenui is the more varied construction from a simple hall with no more hazardous material than a community hall as shown in Figure 9 and Figure 10. In Figure 10 mattresses are shown stored in the corner of the Wharenui. This is not considered good practice.

Figure 9: New Wharenui

Figure 10: Small Wharenui with no adornments

More intricate Wharenui can have tukutuku panels on walls and toetoe kakaho panels on the ceilings. Figure 11 shows a Wharenui with no tukutuku panels on the walls and Figure 12 shows a Wharenui with tukutuku panels on the walls. These panels are constructed as a lattice using horizontal timber slats over toetoe kakaho upright stems. Interwoven through the lattice are the fibre elements of either with harakeke, kiekie, or pingao plant material. Toetoe kakaho ceiling panels are constructed from the toetoe plant stems, the kakaho, as shown in Figure 13. This information is taken from BRANZ Study Report 128, *Fire Protection of New Zealand's Traditional Māori Buildings* (Duncan et al, 2004). Figure 12 has tukutuku panels on the walls and fluted timber boards on the ceiling.

Figure 11: Wharenui with plain ceiling

Figure 12: Wharenui with plain tukutuku panels on ceiling

Figure 13: Toetoe kakaho on ceiling (Duncan et al, 2004)

Each form of lining can provide a different level of fire hazard so the hazard classification of a Wharenui can vary. The Wharenui with the unadorned ceiling, except for some timber beams, as shown in Figure 11, may be ELH or OH1.

BRANZ Study Report 128 (Duncan et al, 2004) describes work carried out on fire protection of New Zealand's traditional Māori buildings. That report stated that a sprinkler system would provide the greatest level of property protection and that a fully compliant system would be monitored, automatically calling out the fire service when the sprinkler system is activated. The hazard classification and type of sprinkler system, OH1 etc, was not discussed in that report.

The principle of sprinkler protection is based on the activities and contents. Unless the ceiling is lined with foamed plastics (see clause 203.6 of NZS 4541), no specific requirements are made in NZS 4541 about ceiling linings. It is generally assumed that ceiling linings meet the requirements of the NZBC (DIA, 2009). However this is achieved by compliance with NZBC Compliance Document for fire safety C/AS1 (DBH, 2010a) in any building. Wharenui are unlikely to comply.

Although not specifically exempt from meeting the surface finish requirements of C/AS1, for Wharenui it is recognised that they may not meet them, and in those circumstances are required to have their escape width doubled and path lengths halved. Where the ceiling does not comply with the NZBC or is not determined, the OH1 criteria may still apply. This is because it is usually the contents which create the fire hazard.

Ceiling involvement is secondary and the sprinklers controlling the content fire will control any fire development on the ceiling. Table 21 give the proposed hazard classifications for the buildings included in this study. These hazard classifications are given in recognition of the limitations that are placed by the proposals in this study on building size and hence occupancy.

Table 21: Summary of proposed hazard classifications

Building	**NZS 4541 hazard classification**
Churches	OH1
Community halls	OH1
Historic buildings	OH1 or as otherwise determined by the activity in the building meeting specific sprinkler standards definition
Wharekai or similar	OH1
Wharenui	OH1

4.4.3 Mattress storage in Wharenui

This classification of the building assumes that no mattresses will be stored in the Wharenui and that a separate room will be used for the exclusive storage of mattresses and not shared by other functions of the building. In keeping with clause 903.6 of NZS 4541, these rooms must not exceed 54 m² with a storage not exceeding 20 m², and the mattresses must not stored to a height greater than 2 m. Figure 14 shows an example of inappropriate mattress storage.

Figure 14: Example of inappropriate mattress storage

4.5 Sprinkler parameters

Once the hazard classification is identified the sprinkler parameters, as specified in the relevant standards, can be determined.

The design performance of a sprinkler system is defined by:

a) Design density of discharge

b) Design number of sprinklers operating

c) Total area of discharge

d) Area of discharge of sprinklers

e) Sprinkler spacing

f) Total water flow

g) Water flow per sprinkler.

Not all parameters need be specified and what is specified depends on the hazard classification. For an NZS 4541 ELH system the water flow per sprinkler, number of sprinklers and area per sprinkler are specified. For an OH1 system, the discharge density, number of sprinklers and sprinkler spacing are specified. The actual sprinkler design parameters for various standards and hazard classifications are given in Table 22 and individual sprinkler operation is given in Table 23.

Table 22: Sprinkler design parameters

Standard/ occupancy	Max area of coverage (m^2)	Minimum flow per sprinkler (L/min)	Minimum design sprinkler (No)	Total (L/min)	Max design area (m^2)	Design discharge density (mm/min)	Duration (min)
NZS 4541 ELH	11,000 per set of valves	57	6	342	126	2.7	60
NZS 4541 OH1		60	6	360	72	5.0	60
NZS 4541 OH3		60	18	810	216	5.0	60
AS 2118-1 LH	9,000 per firecell	48	6	288	126	2.3	30
AS 2118-1 OH1		60	6	360	72	5.0	60
NFPA 13 LH	4,831 per firecell	86	6.65	570	139	4.1	30
		62	13	781	279	2.8	30

Table 23: Sprinkler area of operation

Standard/ occupancy	Maximum design area per sprinkler (m^2)
NZS 4541 ELH	21
NZS 4541 OH1	12
NZS 4541 OH3	12
AS 2118-1 LH	21
AS 2118-1 OH1	12
NFPA 13 LH	21

In NZS 4541, an OH1 system is specified as six sprinklers over a minimum area of 54 m², which gives 9 m² per sprinkler. Clause 802.2.1 of NZS 4541 specifies an area of 12 m² per sprinkler, which gives a total area of 72 m². It is common practice in New Zealand (Mak, 2011) to use the 12 m² limit and hence a greater total water flow.

Areas of sprinkler discharge and numbers of sprinklers are similar across all standards and hazard classifications. NFPA 13 has the most onerous requirements requiring the greatest amount of total water flow, but discharge area per sprinkler and design discharge density are similar.

For adequate control of a fire all the relevant parameters must be applied. In this case the basic design parameters of an NZS 4541 OH1 system are used.

For an economical sprinkler design the important parameter is the design discharge density, total water flow in the system and pressure at the sprinkler, as this will control the pipe sizing and required pressure at the control valves. NZS 4541 OH1 gives the best solution with total flow of 360-400 L/min. Further discussion on the proposed parameters will take place in section 5 below.

5. NEW ZEALAND SPRINKLER STANDARDS

5.1 Introduction

This section discusses the various New Zealand sprinkler standards applicable to the buildings considered in this report. The scope and design parameters have been discussed in relation to international standards in section 4 above. This section will summarise these and review other aspects of the specifications.

Current New Zealand sprinklers standards, given in order of decreasing complexity, are:

a) NZS 4541:2007 *Automatic fire sprinkler systems* (SNZ, 2007)

b) NZS 4515:2009 *Fire sprinkler systems for life safety in sleeping occupancies (up to 2000 m²)* (SNZ, 2009)

c) NZS 4517:2010 *Fire sprinkler systems for houses* (SNZ, 2010).

From the discussions in section 4 above, the comparison in Table 24 uses the requirements for an NZS 4541 OH1 system.

Table 24: Comparison between NZS 4541 OH1, NZS 4515 and NZS 4517

Feature	NZS 4541 OH1	NZS 4515	NZS 4517
Scope of application	Residential and assembly (see Section 4)	Residential. See Section 4	Single family dwellings
Extent of fire sprinkler protection	Entire building	Entire building with some cupboards exempt	Sprinklers may be omitted from some areas
Sprinkler types	Conventional, spray and residential	Conventional, spray and residential	Spray and residential
Discharge density	5 mm/min	2.04 mm/min in sleeping areas. Greater in stores etc.	2.04 mm/min
Maximum number of fire sprinklers activating	6	4	2
Minimum water demand	Max. 360 L/min	Max. 240 L/min	Max 120 L/min
Duration of fire sprinkler action	60 minutes	20 minutes or 60 minutes	10 minutes
Water supply	Class C1	Any	Any meeting water demand
Alarms	Fire sprinkler operating alarm and an evacuation alarm	Fire sprinkler operating alarm and an evacuation alarm	Smoke alarms, no connection to fire service
Fire sprinkler valve installation	Installation control valves	Installation control valves	Standard ball valve or similar, no special requirements
Verification of design	By fire Sprinkler System Certifier (SSC)	By SSC	None, but a peer review sometimes requested
Verification of installation	By SSC	By SSC	On commissioning by installer, thereafter owner's responsibility
Inspections	Monthly, six-monthly, quarterly, annually, biennially, quadriennially by listed contractor	Monthly by owner, six-monthly and annually by listed contractor	No formal requirements, annual owner's inspection recommended yearly
Listing requirements	Required for all critical equipment	Required for all critical equipment	Fire sprinkler heads only
Installer requirements	Listed contractor	Listed contractor	None
Pipe work	Mild steel Copper CPVC Stainless steel Any other pipe listed and meeting the requirements of AS 4118.2.1	Mild steel Copper CPVC Stainless steel Any other pipe listed and meeting the requirements of AS 4118.2.1	Any pipe appropriate for domestic water reticulation but must be protected
Provision for external exposure risk	Required	Required	None (optional)
Obstructions	Required separation	Required separation	Required separation
Tanks	Engineered	Engineered	Any
Backflow prevention	Yes	Yes	Not if combined system otherwise required
Pumps	Diesel	Diesel	Any

5.2 Sprinkler parameters

The major parameters in the standards are in relation to:

a) Maximum number of fire sprinklers activating and water demand
b) Extent of fire sprinkler protection
c) Duration of fire sprinkler action
d) Water supply
e) Alarms
f) Fire sprinkler valve installation
g) Verification of design
h) Verification of installation
i) Inspections
j) Listing requirements
k) Installer requirements
l) Pipework
m) Provision for external exposure risk
n) Obstructions
o) Tanks
p) Backflow prevention
q) Pumps.

5.2.1 Maximum number of fire sprinklers activating and water demand

The number of design sprinklers is: six for NZS 4541; four for NZS 4515; and two for NZS 4517 (with 360 L/min, 240 L/min and 120 L/min water demand respectively). These, along with the design discharge and area of operation, define the capabilities of the sprinkler system to control a fire of buildings with the hazard classification for which they were designed.

NZS 4541 OH1 design is for residential and assembly buildings with no control of area and number of floors other than the limiting value of 11,000 m² for a sprinkler system controlled by one valve. The area of the proposed application in community and historic buildings is significantly less, but does not limit the fire hazard, although it does limit the extent of damage.

5.2.2 Extent of fire sprinkler protection

Other than NZS 4517, sprinklers are required in all spaces except for some concealed spaces and cupboards in NZS 4515. Sprinkler locations in NZS 4517 have been deliberately selected to provide life safety in spaces which show a high risk of fire occurring, thereby reducing the cost. In the buildings subject to this study there may be opportunities to reduce the number of sprinklers for small cupboards, otherwise sprinklers in all spaces would be recommended.

Many of the buildings may not have significant smaller rooms and spaces so there should be no issue here. Roof spaces are excluded form NZS 4517, but as the purpose of the proposed sprinkler system is for property protection, roof spaces and any cupboards containing equipment and materials which provide a fire hazard should be included. Mattress storage rooms in Wharenui will not be exempt from sprinkler coverage.

5.2.3 Sprinkler types

Sprinklers specified in the standard are conventional, spray and residential. Each has its uses with different spray patterns and discharge properties. Residential sprinklers can only be used in residential occupancies. Within residential occupancies there may be locations where residential sprinklers are not advised such as in a roof space, although this is not mandatory in NZS 4517, and garages. In any situation residential sprinklers should not be used in non-residential applications. In Wharenui, conventional or spray pattern sprinklers should be used because the coverage area is larger than would normally be expected in a residential space, and the fire hazard is atypical of a residential occupancy for which the residential sprinklers have been tested and approved.

5.2.4 Duration of fire sprinkler action

Duration of fire sprinkler action is most critical where the water supply is from tanks and other water storage such as swimming pools. At present an NZS 4541 OH1 requires 60 minutes duration at 360 L/min which requires a tank of at least 21,600 L capacity. A tank of this size or slightly larger, say 30,000 L, is not considered to be excessive, particularly where the building is in a remote location and fire service attendance times may be protracted. In non-remote locations the duration may be reduced to 30 minutes, but would depend on fire service attendance times. This can reduce the costs of a tank.

The size of buildings considered herein would require a 20 minute water supply in NZS 4515, with a tank size of 7,200 L when water usage is in accordance with NZS 4541 OH1. This volume of water is not considered to be very high (however NZS 4515 is for life protection). A longer supply would be advisable, so 30 minutes would be the minimum.

NZS 4517 requires a 10 minute supply which is considered to be insufficient to provide property protection to the buildings considered in this report.

5.2.5 Water supply

In NZS 4541 various water supplies are described. The minimum supply is a Class C1 and applies to OH1 occupancies. The Class C1 supply is an approved primary supply which can be a town main, supplemented by a diesel pump, an elevated (gravity) tank or a tank and diesel pump. This is the same as for NZS 4515 and NZS 4517, although in the latter an electric pump can be used.

The issue here is the co-operation of the local water authority to permit a suitable connection to the town mains and the use of the diesel pump. These are discussed later.

5.2.6 Alarms and fire sprinkler valve installation

NZS 4515 and NZS 4541 require various alarms and connections to the fire brigade. In the first place this can make valve systems more complex than a simple on/off or automatic release system. NZS 4515 has a simpler valve arrangement than NZS 4541 and has features which may be useable for the proposed buildings in order to reduce costs. External alarm gongs, low pressure alarms, flow switches and jockey pumps to maintain the system pressure above an alarm level and detect any leaks all add to the cost.

NZS 4517 has no alarm requirements other than a recommendation to install a smoke alarm.

5.2.7 Verification of design, installation and inspections

Other than NZS 4517, the sprinkler standards require an SSC and listed contractors to design, install, inspect and maintain the systems. This is a cost item, particularly to the ongoing inspections. For the buildings in this study this is considered necessary to maintain the reliability of the system.

5.2.8 Pipework and listing requirements

In NZS 4517 any pipe is permitted and only the sprinkler needs to be listed. NZS 4515 and NZS 4541 specify specific pipe materials or compliance with a piping test standard for sprinklers. Listing is a cost on a sprinkler system, although it is considered important to maintain the reliability of the system. Pipes have to meet high temperature and limited fire conditions during testing. This is important where pipes may be exposed in a room, which is more the case with commercial properties than residential or domestic.

Correct selection of pipework is important and unless the pipes meet the relevant standards (AS4118.2.1 Part 2.1: *Piping – general* being an example), the pipework must be protected behind fire-resistant construction. In retrofit situations pipework may be exposed and would need to be in accordance with NZS 4541. In that standard the SSC may approve pipe materials not specifically listed in NZS 4541.

5.2.9 Provision for external exposure risk

NZS 4541 and NZS 4515 require external sprinklers where fire hazards exist in close proximity to the sprinkler-protected building. NZS 4517 has no such requirements. External exposure risks are controlled through the building regulatory procedure if neighbouring buildings are not under the same ownership as the protected building. External sprinklers may be installed for other reasons, such as mitigating the effects of arson on a timber-clad building, and would increase the cost of a system. This must be borne in mind by the building owner who can make the choice.

For the buildings considered in this study, external exposure protection is not considered necessary.

5.2.10 Obstructions

Obstructions on ceilings can affect the spray distribution of a sprinkler and hence its ability to provide water to the fire source. Except for NZS 4517, where conventional sprinklers are not permitted, all the standards have similar requirements for the distance away from and below an obstruction where a sprinkler can be placed.

5.2.11 Tanks and seismic restraint

Although used for water storage, plastic tanks are not commonly used for storage of sprinkler water. They are not specifically excluded from the sprinkler standards. They are limited in their storage capacity, with 30,000 L being a maximum. For the purposes of providing water to the buildings in this study, 30,000 L is considered sufficient and could enable the use of plastic water tanks and lower the costs.

5.2.12 Backflow prevention

All stand-alone sprinkler systems will be required to have backflow prevention as is specified by the water authorities. Even in an NZS 4517 sprinkler system, which is combined with the domestic water supply, some water authorities may require a backflow preventer. In most cases this is unavoidable unless the sprinkler system is supplied from a tank and pump.

5.2.13 Pumps

Except for NZS 4517, if water has to be pumped then a diesel pump is required for the primary water supply. A pump, and especially a diesel pump, can add significant cost to a sprinkler system. This is discussed below.

5.3 Choice of fire sprinkler standard

For the purposes of this report, the buildings which are used in this study fall into the first category of no more than 500 m² or greater than three storeys, which is essentially the scope of application for NZS 4515. This indicates that some of the parameters of NZS 4515 can be used with modifications to cater for a different or increased hazard classification.

However aspects to be resolved are:

- Reliability
- Discharge density
- Location of fire sprinklers
- Alarm systems
- Verification of design and installation
- Inspection regimes
- Type of property.

6. DESIGN PARAMETERS

From the discussions in the preceding sections the following parameters are proposed.

6.1 Building types

Historic buildings, halls, churches, Wharenui (limited to 40 sleeping spaces), Wharekai, early childhood centres (Te Kohanga Reo) with an escape height less than or equal to 4 m (two floors):

- three-floor building, with no more than two floors not separated by fire-rated construction:
  - 500 m² on any floor of a multi-floor building
- single-floor buildings:
  - 1,000 m².

The buildings may include museums and shops with limited combustible materials (e.g. no extensive clothing sales).

The floor limits are essentially the same as the building limits specified in NZS 4515 for a system with a 20 minute water supply, and with an increase in the floor area of a single-storey building and the 500 m² applies to any single-floor area. Other variations are:

- Sloping ceilings greater than 37.5°are permitted
- Ceiling height greater than 3 m (up to 6 m) are permitted.

6.2 Sprinkler system

Table 25 gives the proposed sprinkler design parameters.

Table 25: Proposed sprinkler design parameters

Parameter	**Value**
Discharge density	5 mm/min
Number of sprinklers	6
Area of operation m²	72
Sprinkler	Quick response spray pattern 15 mm
Duration	30 minutes
Valveset	Residential
External exposure	Not required
Pipes	Any subject to protection of non-listed pipes or SSC approved pipes
Design, verification, installation, inspection, maintenance	SSC and listed contractor
Tanks	Any
Pump	Electric, directly supplied from the mains board and routed externally from the building
Seismic restraint	Required
Alarms	Flow or pressure switch only to alert fire brigade

Discharge density, number of sprinklers and area of operation are the NZS 4541 OH1 specifications. They are considered to be able to provide sufficient water to control a fire in the properties specified in section 6.1 above.

The proposed number of sprinklers of six has been found to activate in 98% (USA) and 93% (Australia/New Zealand) of structure fires as shown in Table 26.

The data for the USA is more recent than that for New Zealand. The USA data show an improvement in sprinkler control of fire, which would also be the case in New Zealand due to more rigorous application of monitoring the design and installation and improvement in alerting the fire service. The 93% in New Zealand may now be a higher figure.

Table 26: Percentage of sprinkler fires where the specified number of sprinklers or fewer were operated

	Percentage of fires		
Number of sprinklers operating	**USA 2004-2008**	**USA 1925-1964**	**Australia/NZ 1886-1986**
1	78	43	65
2 or fewer	89	62	80
3 or fewer	93	71	87
4 or fewer	97	77	90
5 or fewer	97	81	92
6 or fewer	98	84	93
Reference	(Hall, 2010)	(Marryatt, 1988)	

Pipe materials, design and verification etc are as specified in NZS 4541.

The valveset is proposed to be the residential sprinkler valve as specified in NZS 4515. This includes an activation alarm and includes a fire sprinkler inlet.

For the buildings specified in this study, external exposure is not considered necessary, provided the building complies with Compliance Document C/AS1 for external fire spread. External exposure sprinklers are optional.

Any tanks may be used with appropriate seismic restraint as specified in NZS 4541.

A pump, if required, may be an electric pump directly supplied from the mains board and routed externally from the building. In accordance with NZS 4541 and NZS 4515, a diesel pump would be specified but this is a major cost item as discussed in section 7 below.

7. COST BENEFITS

7.1 Introduction

Sprinklers system can be a major expense ranging from $13,000 for a small historic building of 61 m² to approximately $300,000 for a remote Marae complex. To determine where costs may be reduced it is important to identify essential components which are necessary for the correct operation of the sprinkler system. A sprinkler system must perform its design function of controlling a fire. For of the purposes of this study, that will be for property protection as this has more stringent requirements than life protection. The requirements of NZS 4541 are therefore more relevant than NZS 4517 or NZS 4515 which are both for life protection.

In this section costs for fully compliant and alternative systems will be presented and a proposal made where costs may be reduced. The costs have been obtained from contractors in the North and South Islands and have been rounded.

Aspects of sprinkler costs which have not been included are special provisions for installing sprinklers to, for example, conceal sprinklers, pipes and valves. These would be additional costs and variables, dependent on the nature of the building and form of concealment.

No account has been taken of the possible variations in cost due to the size and finance structure of the contractor and the overhead they charge, although similar costs for components have been found irrespective of the size.

7.2 Sprinkler system costs

Table 24 gives costs for a sprinkler system in churches and Marae designed in full compliance with NZS 4541. These costs are indicative and are expected to be installed costs.

Table 27: Budget cost for church and Marae sprinklers

	Marae – Manukau City	Baptist Church	Church	Remote Marae	Church
Installation	$39,100	$33,500	$17,000	$62,600	$30,000
Valves/gauges	$6,500	$10,800	$7,600	$55,200	$8,400
Tanks				$95,600	$60,000
Pumps				$45,200	$49,000
Town main	$13,300	$4,800	$18,000.00		
Design/certification	$17,700	$14,000	$13,300	$39,000	$14,000
Total	**$76,600.00**	**$63,100.00**	**$55,900.00**	**$297,600.00**	**$161,400.00**
Approximate area m^2	1400	200	200	700	200

These costs are based on budget figures obtained from a sprinkler contractor and have been rounded. The table shows that costs can vary greatly and that a tank and pump can represent a large proportion of the cost.

Table 28 and Table 29 show further costs for churches, community halls and historic buildings. These include sprinkler systems with alternative design options to the water supply.

Table 28: Budget costs for historic building, Marae and community hall

	Small historic house	Marae	Community hall
Cost $	18,000	60,000	13,000
Water supply	Town main	Tank and electric pump	Tank and electric pump
Sprinklers	8	154	24
Area m^2	61	529	200
Design	NZS 4517	4541 OH1*	4541 OH1*

* Alternative solution to NZS 4541 for water supply which includes a tank and electric pump connected to the normal electrical supply board.

Table 29: Budget costs for a church and community hall

	Church	Community hall
Cost $	60,000	32,700 / 60,700
Water supply	Town main	Gravity tank/diesel pump
Sprinklers, number	25	29
Area m²	180	142
Design standard	NZS 4541 OH1	NZS 4541 OH1

In Table 29 the cost for the community hall was based on a gravity tank and 180 m of supply pipes. If a diesel pump were to be included this would be an additional cost of $28,000 taking the total to $60,700 (cost of a diesel pump is $33,000).

7.3 Analysis

There are various aspects of a sprinkler system design, which are unchangeable, and will be determined by the size of the building and hence not amenable to reduction in cost. These are:

a) Number of sprinklers

b) Type of sprinklers

c) Design discharge

d) Associated pipework

e) Water demand

f) Alarms

g) Design approval, verification etc.

Components which can be varied and hence reduce the costs are:

a) Water supply and pumps

b) Tanks

c) Control valve arrangement.

In selecting an OH1 system and proposing a 30 minute sprinkler system duration, this can reduce costs by reducing the size of tanks (if any) and the pipe diameters, particularly for the water supply.

7.3.1 Water supply and pumps

To determine where cost can be varied the percentage of the total cost of the system that a component provides will give an indication. That is, if a component represents a high percentage of the sprinkler cost, then there is more scope for cost reduction than for a component which represents a low percentage of the total sprinkler costs.

Table 30 shows the average percentage costs of various parts of the systems given in Table 27 divided into those supplied by town mains and those supplied by a tank and pump.

Table 30: Percentage cost of sprinkler system components

	Town mains	Tank and pump
Installation	45%	20%
Valves/gauges	13%	12%
Tanks		35%
Pumps		23%
Town mains	19%	
Design/certification	23%	11%
Total	100%	100%

The data show that a tank and pump (diesel) can make up a significant percentage of the cost of the sprinkler system (in this case 58%). The figures for installation, valves and gauges and design/verification are correspondingly lowered because of the high cost of providing a tank and pump. The town mains connection represents 19% of the cost of the system which is significantly less than a tank and pump. This shows that significant savings can be made if the cost of the tank and pump are reduced for those systems which require them. Table 31 shows the range of costs associated with various water supply options.

Table 31: Water supply and pump costs

Type of supply	Town mains (a)	Electric	Electric plus UPS (b)	Diesel
Cost $	5,000 to 18,000	3,000 to 10,000	13,000	35,000 to 45,000

Notes:

a) The cost for town mains water supply is mostly for the water authority connection fee and varies with the size of connection.

b) The electric pump plus the uninterruptable power supply (UPS) includes a battery pack, which will supply power in the event of a disconnection of the mains electricity supply.

c) Electric and diesel pumps require additional tanks at approximately $3,000 for a plastic tank and $15,000 for a concrete tank with full seismic restraint.

Significant savings can be made if an electric pump is used. From Table 31 the marginal saving of an electric pump over a diesel pump is about $20,000 to $30,000. For town mains connections this can be of the order of $30,000. A diesel pump therefore is a significant cost item. Using an electric pump can significantly reduce cost of a sprinkler system. Figure 15 shows a single electric pump arrangement and Figure 16 shows a double pump arrangement.

]

Figure 15: Single electric pump

Figure 16: Double electric pump system

Figure 17 shows a battery back-up which can be used with either the single or double pump. It can give 10 minutes to 120 minutes duration depending on the number of batteries and size and duty of the pump. Batteries can be a significant cost varying from approximately $3,000 to $17,000, but can make the power supply more secure.

Figure 17: Example of a battery back-up (UPS)

Water supply cost can be reduced by using electric pumps instead of a diesel pump, but connection to the town mains is the least expensive option.

Using a battery back-up can increase the reliability of the system in the event that the mains power is cut-off by the fire. It can be a significant cost but lower than a diesel pump.

7.3.2 Tanks

Figure 18 shows a typical 30,000 L plastic storage tank, which costs approximately $3,000 to $4,000. In Table 27 the cost to supply a tank is given as approximately $60,000 to $95,600. Using the plastic tanks can therefore reduce the cost of a sprinkler system significantly, in this example by $50,000 to $90,000.

Figure 18: Plastic storage tank – 30,000 L

7.3.3 Valves

The choice of valves depends on the type of system which can be domestic, residential or full (NZS 4541). Figure 19 shows a domestic system valveset, Figure 20 shows a residential valveset and Figure 21 shows an NZS 4541 OH1 valveset.

Figure 19: Domestic valveset

Figure 20: Residential valveset

Figure 21: NZS 4541 OH1 valveset

The cost of each valveset is given in Table 32. This shows that a residential valveset is $6,000 less than an NZS 4541 valveset. Whilst for larger systems this may not represent a significant cost saving, where say a sprinkler system may cost $60,000 this is 10% of the total cost. Combined with other cost reductions it can contribute to a lower cost sprinkler system.

Table 32: Valveset costs

	Cost ($)	Marginal cost over NZS 4541 valveset ($)
NZS 4541 OH1	10,000 to 14,000	-
NZS 4515 Residential	4,000 to 6,000	6,000 to 8,000
NZS 4517 Domestic	1,800	8,200

7.4 Discussion

A few areas of a sprinkler system have been found where savings can be made. These are in the provision of the water supply, particularly where a tank and pump are required and in the valveset.

Using an electric pump instead of a diesel pump can reduce the cost of a sprinkler system by $30,000, although this can be reduced by $15,000 when a battery back-up system is included.

The use of plastic tanks can also reduce the cost of a sprinkler system which can be at least $50,000, although will vary when seismic requirements are included.

A valveset offers the least reduction at a minimum of $6,000, but if included with other cost reductions can be a factor in the installation of a sprinkler system.

8. COMPROMISES

The proposed sprinkler system has variations to a full sprinkler design. Bearing in mind that the scope of application to the buildings considered in this report are limited by the size of the buildings, the variations are considered to be insufficient to reduce the value of the sprinkler system in providing protection to the buildings.

Data in Table 26 show that in 98% of structure fires, six or fewer sprinklers activated. This is the number of sprinklers proposed in this study and is considered suitable for the buildings in this study.

For sprinklers supplied from a town mains there are no proposed changes. Where a tank and pump are required, it is considered that the proposed electric pump system is suitable with the reliability increased if the pump has a battery back-up as discussed in section 7 above.

The sprinkler system will be required to undergo design and installation verification by an SSC and installation and maintenance by a listed sprinkler contractor, so there is no compromise in this respect.

The proposed sprinkler system is essentially an NZS 4515 system with increased design density and number of sprinklers activating. Compromises are therefore considered to be minimal.

9. SUMMARY

The results of this study show that fires in community halls, Marae, historic buildings and similar buildings represent a small percentage of all fires in buildings in New Zealand and internationally. This does not mean that those buildings do not need a sprinkler system and for cultural and heritage reasons a sprinkler system may be installed. This is currently happening in New Zealand where churches, Marae and historic buildings have a sprinkler system.

Although sprinkler systems may not be required by building regulations, where such sprinklers are installed they must meet the full requirements or the appropriate standards, for example NZS 4541 in New Zealand. Compliance with those standards can result in sprinklers having a high cost, particularly where the sprinkler system relies on a tank and pump to provide water.

It is considered that cost savings can be made in sprinklers for community halls, Marae and historic buildings by appropriate selection of water supply arrangements and to some extent the valveset. To this end recommendations are made below for a proposed application and sprinkler system. Any compromises are considered to be negligible in that the sprinkler system will provide protection where none previously existed.

Cost savings can be made in the provisions for water supply if a tank and pump are required and in the choice of valveset. Although cost reductions on some individual components may not be large, e.g. valvesets, the cumulative saving may make a sprinkler system more viable.

In addition to reviewing costs, an outcome of this study will be to better define the buildings and the type of sprinkler system to be applied to those buildings.

10. RECOMMENDATIONS

10.1 Application

Historic buildings, community and school halls, churches, Wharenui (limited to 40 sleeping spaces), Wharekai, early childhood centres (Te Kohanga Reo) with an escape height less than or equal to 4 m (2 floors). The buildings may include museums and shops with limited combustible materials (e.g. no extensive clothing sales). Country schools may also be suitable subjects. The limits are:

- Three-floor building, with not more than two not separated by fire-rated construction:
    - 500 m² on any floor of a multi-floor building
- Single-floor buildings:
    - 1,000 m²

The floor limits are essentially the same as the building limits specified in NZS 4515 for a system with a 20 minute water supply and with an increase in the floor area of a single-storey building and the 500 m² applies to any single-floor area. Other variations are:

- Sloping ceilings greater than 37.5°are permitted
- Ceiling height greater than 3 m (up to 6 m) are permitted.
- Separate mattress stores in Wharenui are not to exceed 54 m², with storage not to exceed 20 m² and stored to no greater than 2 m.

10.2 Sprinkler system

Table 33: Proposed sprinkler parameters

Parameter	Value
Discharge density	5 mm/min
Number of sprinklers	6
Area of operation m²	72
Sprinkler type	Quick response spray pattern, 15 mm
Duration	30 minutes
Valveset	Residential
External exposure	Not required
Pipes	Any subject to protection of non-listed pipes, or SSC approved pipes
Design, verification, installation, inspection, Maintenance	SSC and listed contractor
Tanks	Any
Pump	Electric, directly supplied from the mains board and routed externally from the building Battery back-up power supply optional
Seismic restraint	Required
Alarms	Flow and pressure switch to remote monitoring to alert fire brigade

10.3 Application to standards

This report and the sprinkler parameters may be used as the basis of a new standard or an Appendix to NZS 4541, so that the sprinkler industry may have guidance on the installation of sprinklers in the buildings discussed in this document.

APPENDIX A REFERENCES

Australian Building Codes Board (ABCB). 2010. *BCA 2009 Building Code of Australia, Class 2 to 9 Buildings, Volume One*. ABCB, Canberra, ACT, Australia.

British Standards Institution (BSI). 1990. BS 5306-2:1990 *Fire extinguishing installations and equipment on premises: specification for sprinkler systems*. BSI, London, UK.

British Standards Institution (BSI). 2004. BS EN 12845:2004+A2:2009 *Fixed firefighting systems. Automatic sprinkler systems. Design, installation and maintenance.* BSI, London, UK.

British Standards Institution (BSI). 2005. BS 9251:2005 *Sprinkler systems for residential and domestic occupancies: Code of practice.* BSI, London, UK.

Caldwell C & MacLennan H. 2000. *Guidelines for Fire Safety*. New Zealand Historic Places Trust, Wellington, New Zealand.

Department for Communities and Local Government (DCLG). 2007. *The Building Regulations Fire Safety Approved Document B, Part 2: Buildings Other Than Dwellings.* DCLG, Newcastle Upon Tyne, UK.

Department for Communities and Local Government (DCLG). 2010. *Fire Statistics*: *United Kingdom 2008.* DCLG, Newcastle Upon Tyne, UK.

Department of Building and Housing (DBH). 2010a. *Compliance Document for New Zealand Building Code Clauses C1, C2, C3, C4: Acceptable Solution C/AS1 (Amendment 8).* DBH, Wellington, New Zealand.

Department of Building and Housing (DBH). 2010b. *Proposed Changes to Building Code Requirements and Associated Documents for Protection from Fire.* DBH, Wellington, NZ.

Department of Internal Affairs (DIA). 2009. *Schedule 1 of the Building Regulations 1992 (SR 1992/150).* Reprinted as at 1 February 2009. DIA, Wellington, New Zealand

Duncan CR, Whiting P, Wade CA, Whiting D & Henderson A. 2004. 'Fire Protection of New Zealand's Traditional Māori Buildings'. *BRANZ Study Report 128.* BRANZ Ltd, Judgeford, New Zealand.

Hall JR. 2010. *US Experience With Sprinklers and Other Automatic Fire Extinguishing Equipment.* National Fire Protection Association, USA.

International Code Council (ICC). 2009. *International Building Code*. Country Club Hills, IL, USA.

Jackson N, National Heritage Policy Manager, New Zealand Historic Places Trust (NZHPT). 2011. *Personal Communication*. NZHPT, Wellington, NZ.

Karter, Michael J. 2010. *Fire Loss in the United States During 2009*. NFPA, USA.

Marryatt HW. 1988. *Fire: A Century of Automatic Sprinkler Protection in Australia and New Zealand, 1886-1986.* Australian Fire Protection Association, VIC, Australia.

McClean R. 2010. *Sustainable Management of Historic Heritage Guidance Series (draft for consultation): Fire Safety and Heritage Buildings.* New Zealand Historic Places Trust Pouhere Taonga, Wellington, New Zealand.

National Fire Protection Association (NFPA). 2010a. NFPA 13D *Standard for the installation of sprinkler systems in one- and two-family dwellings and manufactured homes.* NFPA, Quincy, MA, USA.

National Fire Protection Association (NFPA). 2010b. NFPA 13R *Standard for the installation of sprinkler systems in residential occupancies up to and including four storeys in height*. NFPA, Quincy, MA, USA.

National Fire Protection Association (NFPA). 2010c. NFPA 13 *Standard for the installation of sprinkler systems.* NFPA , Quincy, MA, USA.

National Fire Protection Association (NFPA). 2001a. NFPA 914 *Fire protection of historic structures.* NFPA, Quincy, MA, USA.

National Fire Protection Association (NFPA). 2001b. NFPA 909 *Code for the protection of cultural resources*. NFPA, Quincy, MA, USA.

New South Wales Fire Brigade (NSWFB). 2009. *Annual Statistical Report 2006/2007.* www.fire.nsw.gov.au (accessed on xxx).

New Zealand Fire Service (NZFS). 2008. *Emergency Incident Statistics: 1 July 2006-30 June 2007.* NZFS, Wellington, New Zealand.

New Zealand Fire Service (NZFS). 2009. Emergency Incident Statistics:1 July 2007-30 June 2008. NZFS, Wellington, New Zealand.

New Zealand Fire Service (NZFS) and New Zealand Historic Places Trust (NZHPT). 2005. *Protecting and Preserving What We Value*. NZFS and NZHPT, Wellington, New Zealand.

Quigan G. 2010. *Personal Communication*. SMS/SMART Application Support, NZFS, Wellington, New Zealand.

SAI Global. 1995. AS 4118.2.1: 4118 *Fire sprinkler systems Part 2.1: Piping – general.* Standards Australia, Sydney, Australia.

SAI Global. 1995b. AS 2118.4 *Automatic fire sprinkler systems – residential*. Standards Australia, Sydney, Australia,

SAI Global. 2008. AS 2118.5 *Automatic fire sprinkler systems – home fire sprinkler systems.* Standards Australia, Sydney, Australia,

SAI Global. 1999. AS 2118.1 *Automatic fire sprinkler systems – general requirements*. Standards Australia, Sydney, Australia ,

Standards New Zealand (SNZ). 2006. *Fixed Fire Protection Group Interpretation Maraes – Final:* FI-066. SNZ, Wellington, New Zealand.

Standards New Zealand (SNZ). 2007. NZS 4541 *Automatic fire sprinkler systems.* SNZ, Wellington, New Zealand.

Standards New Zealand (SNZ). 2009. NZS 4515 *Fire sprinkler systems for life safety in sleeping occupancies (up to 2000 m²).* SNZ, Wellington, New Zealand.

Standards New Zealand (SNZ). 2010. NZS 4517 *Fire sprinkler systems for houses.* SNZ, Wellington, New Zealand.

US Fire Administration (FEMA). 2010. *Non-Residential Building Fires*. USFA, (city), USA.