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29 April 2002

Ms. Karyn Bosomworth
Community Safety Directorate
Country Fire Authority
P.O. Box 701
Mt. Waverley, Victoria, Australia 3149

Dear Ms. Bosomworth:

Enclosed is our report entitled Minimisation of Contamination from Structural Fire-fighting on Water Quality. It was written at Country Fire Authority Headquarters during the period 12 March through 29 April 2002. Preliminary work was completed in Worcester, Massachusetts, before our arrival in Australia. Copies of this report are simultaneously being submitted to Professors Arthur Gerstenfeld and Susan Vernon-Gerstenfeld for evaluation. Upon faculty review, the original copy of this report will be catalogued in the Gordon Library at Worcester Polytechnic Institute. We very much appreciate the time that you have devoted to us.

Sincerely,

James Pietrovito

Stephanie Carney

Ari Magder

Report Submitted to:

Dr. Arthur Gerstenfeld

Dr. Susan-Vernon Gerstenfeld

Melbourne, Australia Project Centre

By

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In Cooperation With

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Country Fire Authority

MINIMISING THE POTENTIAL IMPACT OF STRUCTURAL FIRE-FIGHTING ON WATER QUALITY

April 29, 2002

Abstract

This report, prepared for Country Fire Authority of Victoria, focuses on the potential contamination of local water resources by structural firewater runoff. When water that is used to fight structural fires mixes with hazardous material from certain structures, a potentially dangerous runoff can result. This runoff may flow into sensitive ecosystems, threatening aquatic life and human drinking water. This project provides recommendations for Country Fire Authority for minimisation of environmental contamination as a result of structural firewater runoff.

Executive Summary

Water is a precious resource that is being abused in Australia and around the world (www.waterwatch.org.au). Water supplies become polluted in many different ways. Among these potential causes of water contamination is structural fire-fighting. While structural fires have potential to be harmful to the environment, the water that is used to fight them is not always seen as a direct threat. When this water combines with chemicals from a blaze, however, the result can be a harmful runoff that may lead to polluted water sources. Decontamination of the water sources near a fire can potentially be more dangerous, expensive, and time consuming than the actual cleanup of the fire site.

Country Fire Authority (CFA) recognised this problem and called upon a team of Worcester Polytechnic Institute (WPI) students to investigate the effects of CFA's structural firefighting on water resources. Once the potential impact of structural fire-fighting on these resources was discovered, CFA desired to develop strategies and tools to enable minimisation of these impacts. The WPI project team, therefore, developed a risk assessment to enable others to identify and map areas or facilities with high risk of firewater run-off. This assessment also recommends the best ways to minimise pollution caused by water runoff from structural fire-fighting for each area of risk.

As the project team recruited to solve this problem, our group first researched the literature related to structure and ecosystem types, water quality standards, pollution caused by firewater runoff, case studies, and minimising water pollution. We investigated water quality standards in order to understand which toxicants affect the quality of water. We researched pollution caused by firewater runoff in order to comprehend the effect of structural fires on surrounding ecosystems. We examined

levels of risk according to several factors, including type of structure, type of water resources in proximity of the structure, and type of materials inside the structure. Case studies not only illustrated the environmental emergencies that have occurred in the past due to structural fire-fighting, but they also showed what has been done to prevent similar incidents from occurring.

We have reviewed current and suggested methods for minimising water pollution in order to provide CFA with an understanding of the best methods that are being used today. Reviewing the literature helped us to understand what others had already found on this topic, and it confirmed the importance of our project. We discovered that very little research has been conducted in regards to contamination of water resources due to structural fire-fighting.

Our methodology presents the steps our project team followed over the course of seven weeks in order to investigate and make recommendations for managing the potential problems related to firewater runoff from structural fire-fighting. We first created a list of information that we needed in order to complete this project and then illustrated the methods we used to find this information with as little bias as possible. In order to maintain a clear focus on the project, we conducted our research within the sample area of Frankston. Frankston was chosen for its close proximity to CFA Headquarters, its multiple land usages, and its variety of water resources.

We performed twenty informational interviews with key stakeholders who are directly related to the focus of this project. These interviews were performed with members of fire suppression authorities, environmental protection agencies, business insurance companies, and city planning councils. In addition, we conducted archival research to identify minimisation techniques performed internationally and examine past studies performed in verifying the effects of structural fire-fighting water runoff on water resources.

Through analysis of our data, it was verified that water runoff from structural fire-fighting poses a potential threat to water resources. We performed a risk assessment in order to determine areas at high risk for contamination. Our team identified the current best practices to minimise the effects of structural fire-fighting on the environment. We provided guidelines to assist CFA in the development of a Standard Operating Procedure in relation to planning for an emergency.

Industrial factories containing dangerous goods, operating within close proximity of sensitive ecosystems, and having prepared little pre-incident planning or contingency plans are high risk facilities for contamination from firewater runoff from structural fire-fighting. Facilities containing dangerous goods, however, are under regulation to provide containment for chemical spills, and they are advised to consider firewater runoff in their planning. For this reason, we recommend CFA extend its pre-incident planning procedures to include not just dangerous goods sites but commercial and small industrial facilities as well.

Pre-incident planning is a key component in the minimisation of contamination from structural fire-fighting water runoff. This planning procedure should consist of a representative from fire services investigating potential fire sites of medium to high-risk level. The representative examines safety, emergency, and contingency plans. These procedures must be conducted on a site-by-site basis, considering factors such as structure type, chemical type involved, and proximity to sensitive ecosystems.

A single organisation cannot successfully manage a major incident; emergency planning and response should be an integrated effort (Sherrington, 1995).

CFA should maintain a constant collaboration with Environment Protection Authority (EPA) of Victoria. Based upon a set of pre-defined trigger points, the fire brigades called to a scene will know the precise conditions under which EPA Victoria should be called to the scene. In addition, providing fire-fighters with a quick test for chemicals in runoff at the scene could greatly increase the efficiency in determining the amount of contamination in firewater during an emergency. In this way, the EPA will be able to arrive at a scene much faster. These methods will also enable the EPA to obtain as much information as possible prior to arrival on the scene. CFA and EPA Victoria have a common goal of protecting the environment, and cooperation in developing these trigger points is essential.

While pre-incident planning is very important for the prevention of contamination from structural fire-fighting water runoff, one can be certain that the inevitable incident will occur (Sherrington, 1995). For this reason, the fire brigades should have contingency plans prepared for an immediate response to an emergency. A practical method to reduce runoff during an emergency is the minimisation of water usage. There are many options for minimising water use, such as high-pressure hose nozzles, re-pressurizing sprinkler systems, and the use of foams. There is no general procedure for minimising the use of water; this procedure must be performed on a site-by-site basis. The reason for this is that each fire is different. There exists at different fire sites a variety of different chemicals involved. The decision for the use of these options in an emergency situation must be made during pre-incident planning.

Another practical method for reducing potential contamination as a result of firewater runoff is containment by fire brigades during the incident. There are several options for carrying out this procedure, and these methods can take place either outside or inside the facility. Containing runoff outside the facility through blocking drainage systems can be accomplished using a number of tools: soil shovelled over the drain, pre-manufactured plugs and barriers, inflatable bags, sandbags, or large diameter fire hoses. This technique can increase the health risk to fire-fighters. Containing runoff inside the facility may have a lower risk to fire-fighters, but the integrity of the structure must be considered. This containment would be accomplished by blocking all access into the building. Like minimising water usage, there is no general procedure for containment; it must be determined on a site-by-site basis during pre-incident planning.

Finally, we propose a program to educate members of CFA regarding potential environmental impacts of firewater run-off on water resources. Pre-incident planning will most likely not be carried out by volunteer fire-fighters; it needs to be done by professionals with experience in this field. One needs to know what to examine when inspecting potential fire sites. Since research pertaining to contamination from firewater runoff appears to be just beginning to emerge, there are not many individuals in CFA educated in this area. Therefore, some training will need to be completed by representatives who conduct pre-incident planning.

Fire-fighters should be educated in the potential dangers of firewater runoff contamination. Typically, a fire-fighter's only concern at a scene is putting out the fire, and they use as much water as they feel is necessary. Many times, environmental impacts are not considered until damage has occurred. For this reason, learning the potential effect of fire-fighting on water resources may be extremely beneficial for fire services. In addition, fire-fighters should be trained in possible containment methods, water minimisation techniques, and firewater runoff toxicity testing at an emergency scene.

Contamination from firewater runoff is an issue that has not been addressed until recently. By expanding pre-incident planning and establishing methods to minimise contamination, CFA has the opportunity to recognise and potentially control this problem. We believe the strategies and recommendations we provided will assist CFA in implementing an effective plan to minimise potential contamination from structural firewater runoff.

Authorship

Each member of our team contributed equally to each section of this report.

Acknowledgement

We would like to express our gratitude to the people that have assisted us during the course of our project.

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We wish to thank the entire CFA Community Safety Directorate for their warmth and hospitality, in addition to their assistance with our project.

Finally, we wish to acknowledge our advisors, Dr. Arthur Gerstenfeld and Dr. Susan Vernon-Gerstenfeld for helping and encouraging us every step of the way. It was a terrific experience

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Chapter 1: Introduction

Water runoff from fighting structural fires can cause contamination of local water resources. Country Fire Authority (CFA), one of the largest volunteer-based fire-fighting organisations in the world, has recognised this problem and seeks to develop a method to control this contamination. The goal of this project was to assist CFA in determining the potential environmental impacts on water resources as a result of firewater runoff from fighting structural fires and focus on strategies to minimise this risk. We developed methods to assist CFA brigades in controlling potentially harmful firewater runoff. We have provided CFA with a method to determine the environmental risk to water resources from structural firewater runoff and strategies to efficiently minimise that risk.

The bulk of our research was conducted in the Frankston area. Frankston is located approximately forty kilometres south of Melbourne on Port Phillip Bay. This area was selected because of the wide variety of water resources, assortment of land uses and building structures, as well as its proximity to Melbourne.

Contamination of local water sources in any country is a significant environmental issue, but in Australia's case it is a matter of particular urgency. Australia has an arid climate, and the water sources are not abundant to begin with (Environment Australia, 1999). When a source of water becomes contaminated, the amount of available useable water is further reduced. This contamination can cause problems for nearby human populations as well as for the surrounding ecosystems. Humans may not be able to make use of the source for drinking water, fishing, or any other everyday use. Sensitive ecosystems supporting plants, fish, birds, and other aquatic life perish when contamination reaches a dangerous level (Fowles, Person, & Noiton, 2001). When water is in limited supply, minimising the risks of contamination becomes an increasingly important concern. Identifying potential sources of pollution is the first step in reducing these risks. One of these potential sources of contamination may come from firewater runoff from structural fire-fighting.

Structural fires can pose a considerable threat to the environment. They can destroy many homes and pollute the air for long periods of time (Fowles et al., 2001). Due to the assortment of toxic materials present, structural fires create a greater risk to surrounding ecosystems than any other type of fire (Fowles et al., 2001). Fowles also states that the level of risk varies with different types of structural fires, and the largest contributing factors to environmental damage are the materials that are burning and the size of the fire. Some of these dangers are not as great in more recent structures, since many harmful compounds are no longer used in their construction (United States Environmental Protection Agency [USEPA], 2001; Environment Protection Authority of Victoria [EPA], 2001; Environment Australia, 1999). All of these factors determine what fire-fighting techniques are used and what is used as an extinguishing agent (Markert, 1998).

Water is the most frequently used tool in fighting fires and continues to be one of the best extinguishing agents today, according to Sargent, Beecher & Holding (1997). It is effective not only in quenching flames but also in reducing the heat fires radiate, which further reduces damage. While water has impressive heat transfer capacities, it also has drawbacks. Large fires require large amounts of water to extinguish, which, dependent upon the management in place, can cause massive amounts of water runoff.

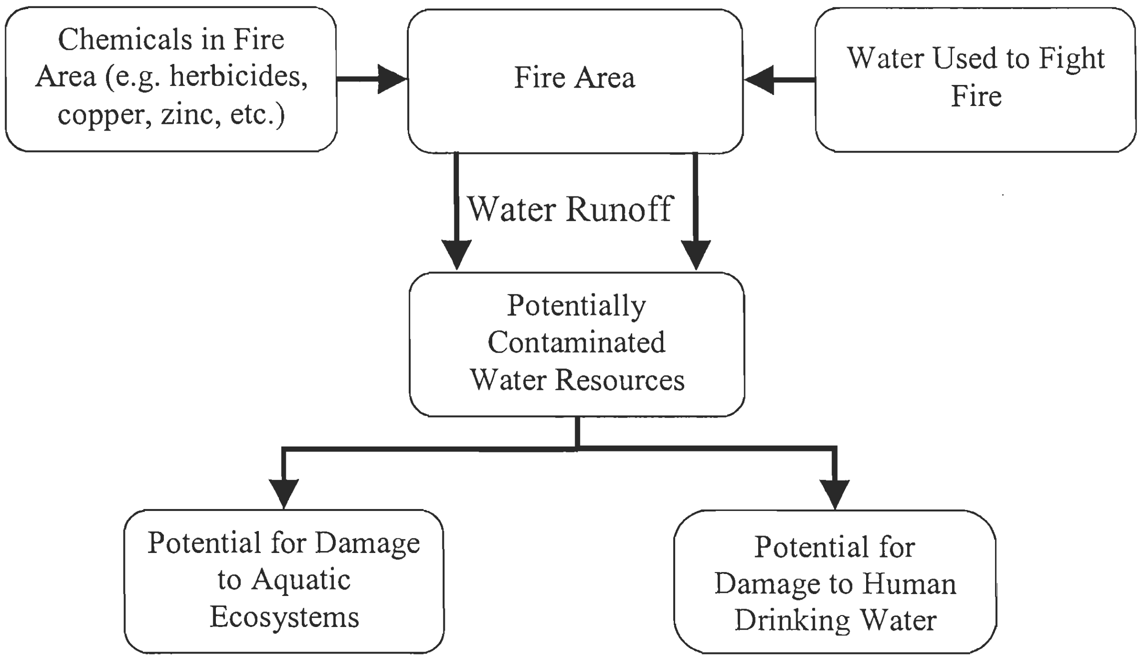


Figure 1.1. Flow Chart Displaying Implications of Water Runoff.

Water runoff can carry toxins from the fire site with it wherever it goes, according to Fowles et al. (2001). If not properly contained, runoff can contaminate nearby water bodies, ground water, and damage vegetation in the area, as shown in Figure 1.1. The proximity and sensitivity of human resources and ecological systems needs to be taken into account when determining the risk to the environment.

By formulating a method with which to contain firewater runoff from structural fire-fighting, damage to the environment can potentially be minimised (Fowles et al., 2001). Containment techniques may be used to prevent runoff from contaminating nearby ecosystems (Sargent et al., 1997). Some of these containment techniques involve structures or plans that may be able to be put into place long before the threat of a fire exists.

CFA is working to fully understand the potential environmental impacts of water runoff from structural fire-fighting and develop strategies to minimise the risks. CFA recognises an obligation to the residents of Victoria to consider the environment in all of their actions by doing everything in their power to prevent or minimise the contamination of local water sources. For example, in the Sandoz Chemical Factory fire discussed in Chapter 2: Literature Review, the impact of firewater runoff had a larger impact on the environment than did the actual fire (Fowles et al., 2001). Since structural fires are an emergency situation, the first concern for suppression forces would be putting out the fire. Knowing where the runoff will go before they start fighting the fire, however, has the potential to minimise water contamination.

Data was collected regarding the potential impact of firewater runoff on water resources through a number of methods. These methods included a literature review and interviews with various fire authorities, environmental agencies, and relevant stakeholders. Classification of structures and water resources assisted in determining how different types of structural fires may affect local water resources. Once these risks were identified, current procedures were examined, as well as advice and information from relevant stakeholders. The findings from our methods enabled the development of recommendations and identification of risk management strategies to reduce this risk.

This project has potential applications elsewhere because structural fires occur everywhere. Other fire authorities may be able to utilize the findings from this project to help minimise water pollution caused by firewater runoff from fighting structural fires.

Chapter 2: Literature Review

Water is the most widely used medium for fighting fires (Sargent et al., 1997), and it may not be thought of as a threat to the environment. When this water mixes with pesticides, fuels, or other hazardous materials, however, the result can be a harmful runoff. There have been cases in which water runoff from structural fires near water resources has caused contamination that takes years to erase, such as in the Sandoz Chemical Plant and the Allied Colloid Chemical Facility fires, as discussed in the case studies section on page 15 (Fowles, Person & Norton, 2001). This review investigates the relationship between structural fire-fighting water runoff and water pollution. Water quality standards, case studies, and current methods of minimising pollution are examined and discussed.

Classification of Structures

A portion of this project involves developing a risk assessment process for identifying the threat to water resources posed by firewater runoff from different types of structures. As a result, classifying the different types of structures is necessary. The Building Code of Australia (BCA) defines ten classes for buildings and structures (Australian Building Codes Board [ABCB], 1996), while the Frankston City Municipal Fire Prevention Plan identifies six environments for determining fire hazards, which they call "priority risks" (Municipal Fire Prevention Committee [MFPC], 1998).

The BCA provides a complete system of technical provisions for design and construction of buildings and other structures throughout Australia (ABCB, 1996). These provisions are applied to ten different classes of buildings and structures.

Class 1 consists of a single dwelling or a small (less than 300 sq. metres and holding not more than twelve residents) boarding house or guesthouse. Class 2 encompasses buildings containing at least two units with a single person dwelling. Class 3 includes long-term residential buildings for persons that are not related. These three classes correspond to the MFPC's priority risk one: residential environments. The MFPC defines a residential environment as a flat, mobile home, and permanent caravan in a caravan park, and we will refer to these types of buildings as residential environments.

The BCA defines a Class 4 structure as a dwelling in a non-residential building if it is the only dwelling in the building. Class 5 consists of an office building used for "professional or commercial purposes" (ABCB, 1996). Class 6 includes a building used to sell goods or services directly to the public. These three classes correspond to the MFPC's priority risk five: commercial environments. The MFPC defines a commercial environment as a shopping centre, restaurant, office building, and other commercial structures, and we will refer to these buildings as commercial environments.

Class 7 contains structures such as a garage or a storage or wholesale facility. Class 8 includes a laboratory or production facility. These two classes correspond to MFPC's priority risk four: industrial environments. The MFPC defines an industrial environment as a service station, factory, or warehouse, and we will refer to these buildings as industrial environments.

The BCA defines the Class 9 structures as a public building, either a health care facility or an assembly building, such as a school. This class corresponds to the MFPC's priority risk two: community care and public assembly environment. The MFPC defines this priority risk as hospitals, nursing homes, day care centres, schools and other assembly and care building, and we will refer to these buildings as community environments.

The BCA defines a Class 10 structure as a non-habitable building, such as a private garage, shed, fence, wall, or any other uninhabitable structure. The MFPC does not have a category that directly refers to this, so we will include it in a residential environment. The MFPC's priority risk three: urban bushland environment refers to wildfires and therefore will not be needed for this project. Priority risk six, special risk environment, refers to the transport of goods and outdoor events, which also does not relate to this project on structural fires. Thus, we have four types of structures that we will study in this project: residential, community, industrial, and commercial.

Classification of Water Resources

A portion of this project involves determining which types of water resources in the sample area of Frankston are at risk from firewater runoff due to structural fire-fighting. For this reason, the classification of water resources is necessary. The Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) published the Australian and New Zealand Guidelines for Fresh and Marine Water Quality in October of 2000. The Environment Protection Authority (EPA) of Victoria published the State Environmental Protection Policy (SEPP) for the waters of Victoria in 1988. The SEPP is a legislative tool that sets minimum standards for regulations (EPA Victoria, 2001). Each document provides a system for classifying water resources.

EPA Victoria's SEPP defines five classes of water resources referred to as segments. ANZECC's Water Quality Guidelines define ecosystem types and conditions for Australia and New Zealand.

The EPA Victoria SEPP defines the first ecosystem segment as an aquatic reserve. This segment includes surface waters within national parks and reserves, and it has the highest required EPA protection level for its beneficial uses to humans. The second segment defined by the SEPP is the parks and forests segment. The surface waters in this segment are located within high conservation areas and state forest boundaries as defined in Forests Act 1958. Aquatic reserves and parks and forests correspond to ANZECC's (2000) ecosystem condition number one: high conservation/ecological value system. We will refer to these ecosystems as aquatic reserves.

The third ecosystem segment, according to the EPA Victoria SEPP, is an estuarine segment. These surface waters consist of all flowing waters, such as rivers and streams. These waters correspond to ANZECC's classification of rivers and streams. ANZECC defines rivers and streams as "non-marine inland waters that for part of the time flow in one direction," (ANZECC, 2000) and we will refer to these ecosystems as estuarine systems.

The fourth SEPP ecosystem segment is the coastal waters segment. This segment includes all territorial coastal waters located in Victoria, including bays. This class corresponds to the ANZECC's classification of coastal and marine waters. The coastal and marine segment includes all waters located in Australia and New Zealand that are not freshwater and do not flow in one direction, and we will refer to these ecosystems as coastal systems.

The fifth and last SEPP ecosystem segment is the general surface waters segment. This segment includes all surface water not included in any other segment. This water consists of lakes and wetlands. This corresponds to the ANZECC's standing waters classification. Standing waters are all surface waters in Australia and

New Zealand that are freshwater and do not flow in one direction, and we will refer to these ecosystems as standing water.

Aquatic reserves, estuarine, coastal, and standing water are the four classifications of water resources and ecosystems that will be focused on throughout this project, since these resources are located within the city of Frankston.

Ecosystem Sensitivity

The ecological systems described above have varying levels of susceptibility to water pollution (ANZECC, 2000). The specific level of risk depends on several different factors. These factors include flow rate of estuarine systems, type of species within the ecosystem, and existing pollution problems within the ecosystem (Fowles, 2001).

Despite being the driest inhabited continent, Australia has many types of rivers and streams (ANZECC, 2000). Estuarine systems in temperate Australia average lower flow rates than systems in other parts of the world (ANZECC, 2000). Rivers and creeks with low flow rates are more susceptible to localised pollution than those estuarine systems with higher flow rates (Fowles, 2001). The slower the water moves, the slower the contaminated water can move. When contaminated water moves slowly, it can affect the quality of life at specific points in the stream for a long period of time (ANZECC, 2000).

The type of species living within the ecosystem is important when considering the ecological risk level of aquatic ecosystems (Fowles, 2001). An ecosystem containing an endangered species would be considered more sensitive than an ecosystem without endangered species (EPA, 1988). In addition, species living within Australian streams may be considered more sensitive to certain toxicants than species in other countries. This is because Australia's freshwater streams typically have softer water than streams in other countries. Soft water has a recognised effect of increasing the toxicity of certain chemicals (ANZECC, 2000).

When determining the sensitivity of ecosystems, it is important to consider whether the system has experienced problems with pollution in the past. A system that has been heavily impacted by contamination prior to an evaluation may be more susceptible to damage from a severe pollution incident in the future (Fowles, 2001).

Effect of Structural Fires on Water Quality

Water runoff from fire-fighting may decrease the quality of local water sources below acceptable water quality standards (United States Environmental Protection Agency [USEPA], 1999) (Department of Water Affairs and Forestry [DWAF], 1996). When considering water quality standards, one must first answer two important questions: First, who or what are these standards in place to protect? Second, what compounds may affect the water quality?

Water Quality Standards

To answer the first question, the standards discussed here are in place to protect two groups: human beings and aquatic plants and animals. Water quality standards are a legitimate concern as concentrations of certain chemicals above safe levels can cause acute or chronic health problems in populations of human and aquatic life (USEPA, 1999).

Compounds Affecting Water Quality

To answer to the second question, we must examine the two main groups of compounds that pose a threat to water quality with regard to human and aquatic life. These compounds are inorganics, especially heavy metals, and organic compounds (Pierce May and Suppes, 1996). One of the most important groups of chemicals that we will examine are chemicals used for fire-fighting. These are dangerous because of their organic components.

Metals.

Metals are found in nearly every structural fire, because they are contained in various building materials and paints. During the fire, these metals are not chemically changed and can be found in firewater runoff (Fowles et al., 2001). The toxicity of metals varies based on a number of factors. These factors include the types of metals and other pollutants in the water; the characteristics of the organism being affected, such as species, age, or life stage; and conditions of the water such as pH, salinity, and temperature (Avenant-Oldewage & Marx, 2000).

Different metals affect aquatic animals by accumulation in organs in different ways, as shown in Table 2.1. The table gives us the basic understanding that the liver and gills are the most highly affected organs in fish, in cases of heavy metal toxicity.

Table 2.1
Ranking of Metal Concentrations in the Different Organs and Tissues of the Fish Clarius Gariepinus

Metal	Ranking of Accumulation: The Highest to the Lowest Concentration			
	Organ	Organ	Organ	Organ
Chromium (Cr μg/g)	gills	> liver	> muscle	> skin
Copper (Cu μg/g)	liver	> gills	> muscle	> skin
Iron (Fe μg/g)	liver	> gills	> muscle	> skin

Source: Adapted from Avenant-Oldewage and Marx, 2000

The build-up of heavy metals in organs leads to toxicity to the organ and, in turn, the organism. By building up in different organs, different metals cause death by various means. One of the biggest toxicity problems lies in the rapidity with which metals accumulate in the gills, damaging gill function and thus inhibiting respiratory gas exchange (Avenant-Oldewage & Marx, 2000). Even though the Avenant-

Oldewage and Marx (2000) study focuses on fish not native to Australia, this data shows us the effects that heavy metals can have on any fish. Effects on such tissues as gill epithelium will not change greatly from species to species of fish (EPA, 2002).

Organic Compounds.

There are multiple types of organic compounds in firewater runoff that may pose a threat to water quality. A high-risk group of organic compounds is chemical biocides. This group encompasses pesticides, herbicides, fungicides, and similar chemicals. These chemicals are highly toxic to aquatic life forms and are found stored in most structures, but they are usually not found in excessive levels except in certain industrial and commercial structures.

Australia has been increasing the use of fire retardants and foams for a number of years (Adams & Simmons, 1999). Fire retardants and foams are usually divided into two categories: Class A, detergent based, and Class B, protein based. Protein based chemicals have been shown to be less toxic to aquatic ecosystems than detergent based chemicals. This is probably due to anti-corrosive additives, found in detergent based retardants, which are extremely toxic to aquatic life (Fowles et al., 2001). Foams have also been found to be more toxic to fish than non-foam fire retardant chemicals (Northern Prairie Wildlife Research Center [NPWRC], 1993). Foams contain surfactants, which are chemicals that decrease the surface tension of water. The presence of surfactants is believed to be the cause of many health problems in aquatic animals. Surfactants have been shown to cause inflammation and deterioration of gill epithelial cells in many fish species (EPA, 2002). Surfactants also cause alterations in the permeability of biological membranes. One example of this is an increase in gill permeability to cadmium (NPWRC, 1993). Cadmium is a heavy metal that is toxic to fish, as shown above. This shows that use of surfactants poses not only the threat of its own toxicity but also the increased susceptibility to metal toxicity.

Current Regulations.

The Dangerous Goods (Storage and Handling) Regulations Act 2000 states that spillages or leaks of dangerous goods should be contained within the facility that stores the chemical. They mention firewater runoff as a factor in determining the size of the containment system. They continue to state that a facility should consult with either the Metropolitan Fire and Emergency Services Board or the Country Fire Authority if the design of a containment system may affect emergency services' operating procedures.

Published Guidelines.

The ANZECC and ARMCANZ Water Quality Guidelines (2000), located in Appendix C, give trigger values for toxicants at which they contaminate water for Australia and New Zealand. The EPA Victoria SEPP for the waters of Victoria (1988) provides a similar list of toxicants for the state of Victoria. A comparison of these charts is provided in Table 2.2. The ANZECC values listed are the maximum amount of toxicant allowed for 99% of aquatic life preservation.

Table 2.2
Comparison of T values from ANZECC (2000) and the State Environment Protection Policy (Waters of Victoria)

Toxicants	**ANZECC (mg/L) (Trigger value for 99% protection)**	**SEPP (Waters of Victoria) (mg/L)**
Aluminium	0.027 if pH <6.5 ID if pH >6.5	0.05
Ammonia (unionised)	0.320	0.016
Arsenic	0.08	0.05
Beryllium	0.004	0.011
Cadmium	0.00006	0.0004
Chromium	0.01	0.01
Copper	0.001	0.01
Cyanide	0.004	0.005
Iron	1.000	1
Lead	0.001	0.025
Mercury	0.00006	0.00005
Methyl Mercury	ID	0.000004
Nickel	0.008	0.025
Selenium	0.005	0.05
Silver	0.00002	0.0001
Sulphide	0.0002	0.002
Zinc	0.0024	0.05

Source: EPA Victoria, *Yarra Catchment- Draft Policy Impact Assessment*, 2000.
NOTE: ID means there is insufficient data for a proper trigger value.

Charts from the USEPA *National Recommended Water Quality Criteria - Correction* in 1999 give values that can be used to help determine the risk level of a specific site. It is essential to keep concentration levels below values for concentrations needed to create a chronic problem, known as Criterion Continuous Concentrations (CCC) (DWAF, 1996; USEPA, 1999); however, the values for concentrations that create risk at an acute level (known as Criteria Maximum Concentrations [CMC]) are better suited to assessing risk on an episodic basis. CCC values are also helpful when one cannot find CMC values for a chemical (Fowles et al., 2001). Since there is concern over the safety of both humans and aquatic life, the lower, more conservative value should always be used when calculating risk so that the more susceptible species is protected.

Water is a precious resource, especially in a dry climate such as Australia (Environment Australia, 1999). This makes it even more important to protect the quality of the country's water. Steps need to be taken to prevent the firewater runoff from contaminating water sources (Environment Australia, 1999). As can be seen by the material presented here, unmanaged water runoff may kill animals living in local streams, lakes, and rivers. It will also harm or, possibly, kill humans who are using water from those sources or eating fish caught in them (USEPA 1999).

Case Studies

There have been several cases of water pollution caused by structural fire-fighting in the last twenty years. These incidents range from minimal pollution that lasted for a few hours to damage that cost millions of dollars and took years to clean up. The differences between these cases can be examined to help determine risk factors involved when examining potential fire sites and systems at risk from firewater runoff. The following examples show not only the levels of damage, but also what steps were taken to help prevent similar incidents or reduce their impact on the environment. While there is no ideal solution, the people involved in these incidents were forced to face the firewater runoff problem, and one can learn from their mistakes.

Sandoz Chemical Fire, Basel, Switzerland

The effects of firewater runoff were first given international attention when the Sandoz chemical storage plant in Basel, Switzerland caught fire on November 1, 1986. Sandoz Chemical Plant contained 840 tons of pesticides, fungicides, dyes, urea, and other toxic chemicals (Sargent, et al. 1997). The flames were too large to be battled with foams that are specifically made for structural fire-fighting. Because of this fact, water had to be taken directly from the Rhine River and sprayed at the rate of four hundred litres per second to combat the fire. For several hours, the chemicals mixed with the firewater and drained into the Rhine River (Fowles et al., 2001).
In total, thirty tons of highly toxic waste entered the waters of the Rhine in the span of a few hours and caused massive amounts of pollution. Thousands of fish were immediately killed. Dead eels were found up to two hundred kilometres from the site of the fire. Birds and ducks ate the poisoned animals and were found dead (Fowles et al., 2001).

During the next few weeks, numerous tests were done to determine which chemicals caused the most damage to the environment. Approximately eight hundred kilometres of the Rhine River were contaminated with thirty-four different chemicals (Earthbase Inc., 1996).

Endosulfan and the mercury compounds were determined to be the most hazardous chemicals to the fish. Endosulfan is a highly toxic chemical: if this chemical is found in water, it needs only a density of 1 μg/L in order to kill 100 percent of the fish that breathe in the water (Fowles, 2001). All mercury compounds are toxic to the environment, and they have been linked with cancer in lab experiments (http://www.webelements.com).

According to Fowles, the location of the Sandoz Chemical Company and the lack of safety planning were large factors in the amount of environmental damage in this accident. The storage facilities were located on the Rhine River and had no sprinkler systems or runoff control paths (Fowles, 2001). With nowhere else to go, the water being sprayed on the fire drained directly into the Rhine River. Inside the storage facilities, incompatible chemicals were kept next to one another. Some of these chemicals underwent chemical reactions during the fire, causing biologically active secondary substances to be released. These chemical compounds were also found to be harmful to aquatic life, according to Fowles et al. (2001).

The Sandoz chemical spill is an example of structural fire-fighting having a large effect on the environment. Water used to fight the fire mixed with chemicals, forming a runoff that led into the Rhine River, killing many fish and animals. The large amount of damage to the environment illustrates the importance of this project.

Allied Colloids Chemical Company, South Bradford, United Kingdom

According to Fowles, poor planning and plant location caused the damage to the environment from the Sandoz incident. An important aspect of our project is to be able to provide a system that minimises the effects from structural fires on the environment. The Allied Colloids Chemical Company Case is an example of a safety system failure resulting in an impact on local water resources. It also provides an example of attempts to redesign environmental procedures or prevent or reduce the risk of a similar incident happening again.

In South Bradford, United Kingdom, on July 21, 1992, a fire broke out in a raw materials warehouse owned by the Allied Colloids Chemical Company. Allied Colloids manufactures chemicals to be used in effluent and water treatment and in manufacturing paper, paints, and textiles. Firefighters provided thirty-six tenders—railroad cars designed to hold water—from which water was taken to fight the fire (Sargent, 1997). Over a span of three hours, an estimated sixteen million litres of water were used to put out the blaze.

Chemicals in the warehouse mixed with the water and formed viscous (sticky) polymers. The polymers and water flowed into the roadways and blocked drains and pumps. This caused the water and chemicals to flow into nearby rivers and streams, killing twenty thousand fish at distances of up to fifty kilometres away from the fire site (Fowles et al., 2001).

Tests performed after the disaster revealed that Allied Colloids did not have proper safety mechanisms, such as sprinkler systems. The company immediately took notice of their shortcomings and increased their safety methods on all levels. They built a new warehouse with a sprinkler system, fire hydrants, and a drainage and water retention system (Sargent, 1997). They reviewed other drainage systems in the geographical area and devised a list of standards for safety:

- Sewage system will flow directly to sewer.
- Wastewater will flow from industrial processes to the effluent (water flow) system.
- Uncontaminated rainwater from roads and roofs will flow directly to sewer or streams.

- Rainwater from areas where there is a low risk of pollution will flow to a containment system. There it will be tested for contamination, and be sent to either sewer or effluent system, depending on test results.
- Rainwater from areas where there is a high risk of pollution will flow directly to effluent system to be treated.
- Each water area is separated from the others so that water cannot flow from one area to another (Sargent et al., 1997)

Allied Colloids took many extra safety precautions as well. They created a bunding system that stretched around the low points of the facility to prevent leakage of contaminated water. They added thirty-nine drains to the site to divert water to the new system. They built a containment tank that can hold 4600 cubic meters of polluted water (Sargent et al., 1997). According to the new system, all contaminated water can flow to the sewer, effluent system, or be recycled.

Allied Colloids is an example of a company that invested much effort into changing its safety procedures with the hopes of preventing another incident (Sargent, 1997). It is an attempt to make a major improvement in safety measures and set a standard for other facilities to follow.

Plastimet, Inc., Hamilton, Ontario, Canada

The previous two examples illustrated large amounts of pollution from different chemicals. The next example displays a different level of risk to the environment. This case is presented in order to draw conclusions about different effects to the environment at potential fire sites.

The fire at Plastimet, Inc., in Hamilton, Ontario, Canada, lasted July 9-12, 1997 and consumed four hundred tons of polyvinyl chloride, which was being stored at this facility. Polyvinyl chloride (PVC) is a plastic used to make such things as pipes, vinyl siding on houses, and linoleum (Fenichell, 1996). When the PVC burned, high concentrations of hydrochloric acid were released into the environment, causing eye, skin, and throat irritation to nearby residents (Fowles et al., 2001).

The water runoff went to three different areas: into nearby Hamilton Harbour; into the sewer, where it was treated and released; into storage in containment systems and then treated (Socha, et al., 1997). Thirteen metals were initially found in levels that did not meet water quality standards, including copper and zinc. The contamination levels, however, experienced a 2-23 fold decline before the fire had even ended. Organic chemical concentrations were found, but had decreased by half in the span of a few days.

Although much damage was sustained in this fire, water contamination was much less significant than in the previous two cases. The facility already had safety procedures in place. They treated much of the water and safely released it to Windermere Basin (Fowles, 2001). In addition, the metal and chemical levels of the water dramatically decreased within a few days.

These case studies show different levels of risk for different levels of contamination. A house fire that is not located near other houses or water sources would not pose the same kind of threat as a large chemical plant located a few hundred feet from an environmental resource. In the first two cases, fungicides, pesticides, and other biocides caused the most damage when they contaminated the water sources. Also, hazardous chemical compounds such as phosphates and sulfates can be formed from combustion. All fires also produce toxic organic or halogenated (containing fluorine, chlorine, bromine, iodine, and astatine) organic compounds (Fowles et al., 2001). Metals from building structures are washed away by the water, and are unchanged by the fire. Many of these metals are toxic to aquatic life as well as humans. The third case shows the differences when the pollutants are metals instead of chemicals. According to the effects of the three cases, the contamination of the water was much less severe when metals were the pollutants instead of the fungicides (Fowles et al., 2001).

The closer a fire is to human settlements and sensitive ecosystems, the greater the risk becomes. Fires that create large amount of runoff, located near homes, can cause great risk to the area. Not only will toxins be released to the air, but firewater could run in the streets, such as it did in the Allied Colloid fire. The Sandoz fire case showed how dangerous a fire near a sensitive ecosystem could be. Chemicals can spill into the water and kill fish at a rapid rate. Fowles et al. (2001) identify three components in prioritising firewater runoff hazards: type and quantity of chemicals stored or in use at facility, proximity of human settlement, and proximity of sensitive ecosystems.

Minimising Water Pollution

Combustible products, along with different chemicals that may be stored at the fire site, may be carried away by firewater runoff. Many combustion products are predictable, allowing one to determine their nature and toxicity (Fowles et al., 2001), and thus allow for proper preventative measures to be put in place. Facilities that store as well as use chemicals are a much larger than usual risk to the environment in the event of a fire. Without proper preventative measures, a structural fire can cause an environmental catastrophe (Sargent, 1997).

Fowles et al. (2001) recommend that assessments be conducted of facilities that house large amounts of chemicals to determine the possible environmental impact of a fire. These assessments should take into account the type of chemicals and the species that will be exposed to the runoff. Facility assessments allow a containment system to be developed before a fire occurs.

There are many different structures that are currently constructed to contain runoff and drastically reduce the risk to the environment. Bunds, lagoons, and containment tanks are all examples of structures that are put in place to redirect and contain water runoff (Sargent et al., 1997). The quantity of runoff expected is very important in deciding what structure would be suitable (Fowles et al., 2001).

A bund is an embankment of land used to contain the contaminated water that results from runoff. There is a variety of types of bunds. These differences are found in the physical structure of the bund. One method of creating a bund is to lower the level of the facility's floor (Fowles, 2001). This creates a small wall inside the facility that can contain spills or water used to fight a fire. One other effective bunding method is to construct an exterior barrier or wall. This can be made out of steel, concrete, or even mounds of dirt. Bunds also act to redirect spills and water to containment vessels such as lagoons and containment tanks (Sargent et al., 1997).

Lagoons and containment tanks are usually used to control spills and water overflow. They also provide a site to test runoff before it drains into the sewer or drainage system (Fowles, 2001). These large vessels can be equipped with pump stations as well as treatment systems, allowing for the reuse of fire-water runoff while fighting a fire (Edwards, 1994). Lagoons and containment tanks also provide a site for the use of absorbents used for the removal of oil and tar.

Risk Assessment and Management

In order to assess our sample area for risk from firewater runoff, we need to use a systematic process of risk management to ensure accuracy. Risk management is a cyclical procedure consisting of specific steps which encourage improved decision-making by providing better insight into risks and their consequences. The Joint Standards Australia/Standards New Zealand Committee, 1999 prepared a generic framework for assessing and managing risk. This framework provides a process for organisations to make accurate decisions by providing consequences for these decisions at the outset of the assessment. There are seven main elements of the risk management process, as shown in Figure 2.1.

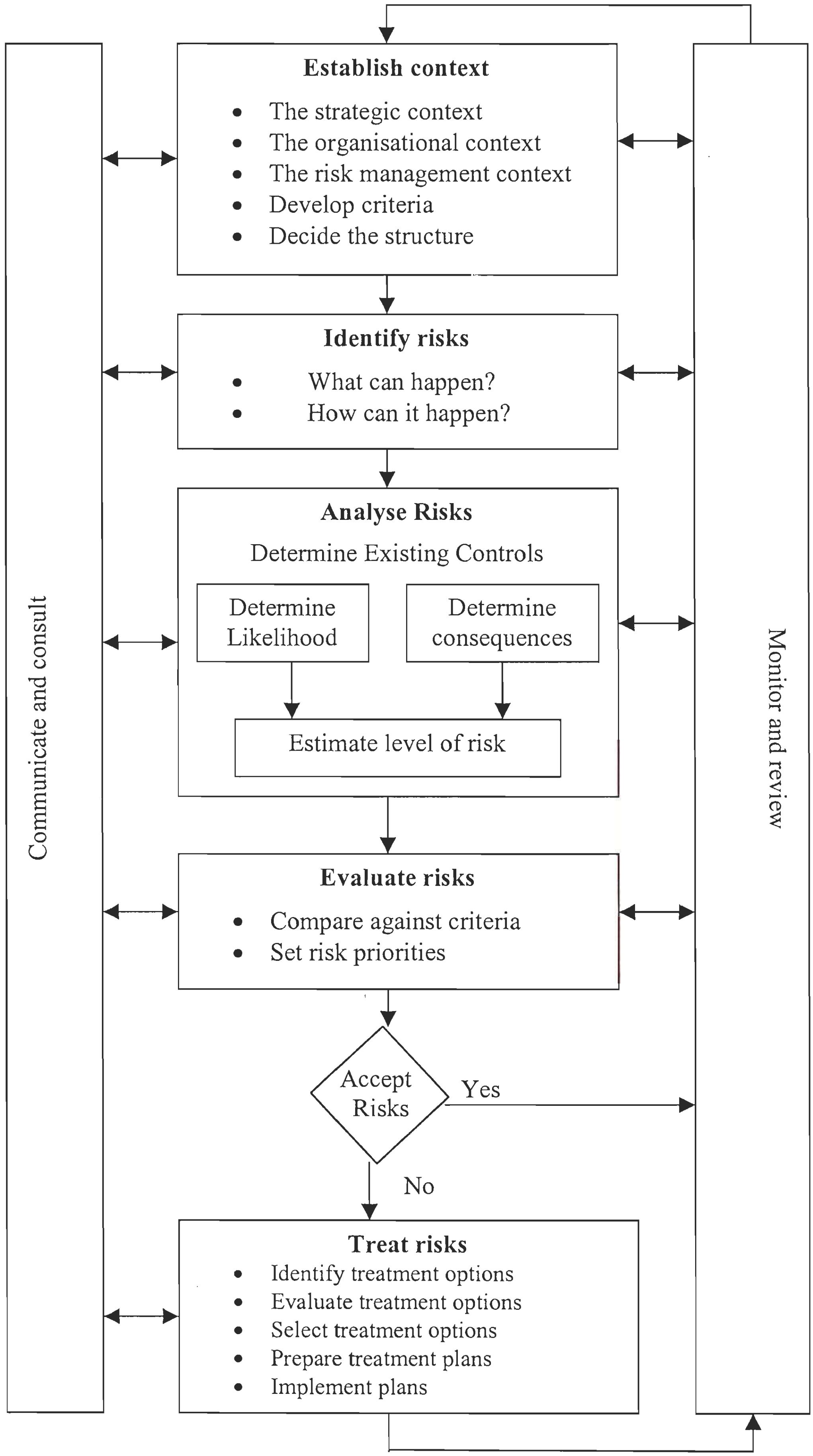


Figure 2.1. Risk Management Process
Source: Joint Standards Australia/Standards New Zealand, 1998

First, one must establish a strategic, organisational, and risk management context in which to perform the procedure. The strategic context should specify the relationship between the organisation and the environment and identify the strengths and weaknesses of the organisation. The organisational context creates an understanding of the organisation's capabilities, goals, and tools intended to meet those goals. The risk management context defines the goals, objectives, scope, and parameters of the procedure that is being assessed. Criteria in which the risks will be analysed against are then identified. Finally, one must separate the activity into a structure that will provide a framework for analysis.

The second step in the risk management process is risk identification. It is important to include a well-structured step-by-step procedure when identifying risks to ensure that all possible risks are considered. One must attempt to consider all possible scenarios that can occur and then determine the cause of that scenario. There are numerous tools to identify risks, such as flow charts, brainstorming, checklists, and many others.

The third step in risk management is risk analysis. This step uses either qualitative or quantitative techniques to determine the magnitude of the consequences of the risks identified in the last step and the likelihood of each risk occurring. These actions enable one to separate risks into two groups: minor and acceptable, and major and unacceptable.

The fourth step, risk evaluation, results in a list of prioritised risks and plans for further action. Each risk is compared against the criteria that are determined at the outside of the analysis. The minor risks are accepted with minimal treatment, but they must be monitored for further increase in likelihood or magnitude of consequence. If a risk is not accepted, one must move on to the last step, treating risks. During this step of the process, one identifies their options for treatment, evaluates each option, decides the best option, and implements the plan.

During the risk management process, two steps must be completed after each individual step: monitoring risk and communication and consult, as shown in Figure 2.1. One must continually monitor each risk and the effectiveness of the management system, as well as develop a communication plan so that executive decision-makers in the organisation are constantly aware of each risk. While this risk management plan is not directly related to firewater runoff, these risks can be adopted to environmental hazards resulting from a structural fire.

Pre-fire planning along with risk source identification is an important part of the risk management procedure (Särdqvist, 1996). Intervention possibilities and prevention techniques need to be determined prior to the occurrence of a fire. Once a fire starts, it is too late to consider such things.

Figure 2.2 is a flow chart depicting a pre-fire planning intervention procedure. The first step in this process is to brainstorm as many fire scenarios as one can. Next, the amount of damage with respect to people, property, and environment is estimated for each scenario. Based upon the amount of damage, goals need to be formulated on how to prevent this damage from occurring. After this, one must decide which strategy to take with regard to contamination. Is it more efficient to prevent the threat of contamination before a fire ever occurs, or is it more cost effective to deal with all contamination by intervening in the case of a fire? After a plan is developed and all these questions are answered, the plan must be evaluated to assess the safety level achieved through it (Särdqvist, 1996).

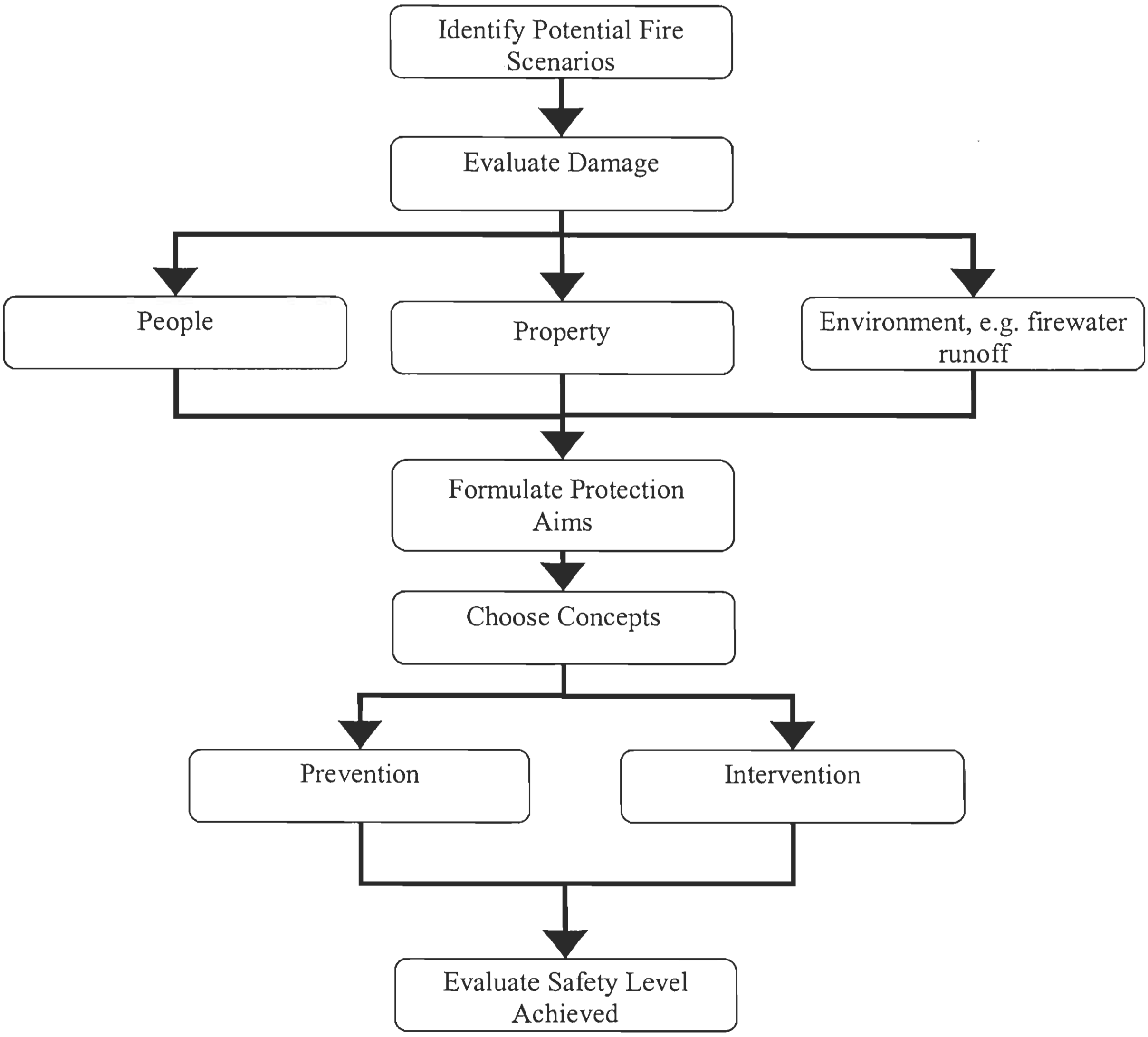


Figure 2.2. Pre-Fire Planning of Intervention.
Source: Adapted from Särdqvist, 1996

In recent years, risk analysis has become widely used to predict the odds of an accident, to assess the consequences of accidents, and to determine strategies to prevent accidents from occurring (Fowles, 2001). Complete risk assessment of a facility is costly. To help reduce the cost of risk assessments, rapid risk assessment (RRA) methods have been developed. Usually in the form of a software package, these offer the same recommendations as a full risk assessment, but with slightly less accuracy and precision (Khan & Abbasi, 1999).

There are many different software packages used for RRA. These include the TOXFIRE and RISKWIT systems developed by the Technical Research Centre of Finland (VTT), the MEMbrain system which links to Geographical Information System (GIS) technology, Tool for Rapid Risk Assessment in Petroleum Redinery and Petrochemical Industries (TORAP), VERIS, RISAM, and PROTEUS (Khan & Abbasi, 1999; Virtanen & Kakko, 1997; Stam, Bottelberghs, Post, & Bos, 2000; and Heino & Kakko, 1998). Each one of these software packages utilizes different methods and techniques to analyse probable fires before, during, and after the fact. Although these software packages use different analysis techniques, they all provide important and helpful information in the prevention and extinguishment of fires.

Fire Service Role

In some environmental emergencies, an organisation with resources available to carry out an immediate response is the fire authority (Sherrington, 1994). In many fire emergencies, however, fire brigades will not have the time or liberty to decide how a fire should be extinguished in such a way that would reduce environmental damage (Fowles, 2001). For this reason, Fowles (2001) suggests implementing methods to prevent or minimise contamination within facilities before it becomes a problem. The generalised risk assessment methods described earlier may be adopted to specify firewater runoff hazards. Fowles recommends evaluations of potential fire sites by fire services. These potential fire sites should be assessed for ecological hazards. These hazards may be broken down into two distinct categories: structure of facility and materials contained within facility.

When determining the ecological risk due the structure of the facility, many factors must be considered (Fowles, 2001). The type of facility is an important consideration because the facility type can provide an indication of the types of hazardous materials being stored or used within the facility. One must also consider the size of the facility being evaluated. A large facility commonly will require larger amounts of water to extinguish and therefore may produce more runoff. Fire services must also evaluate the facility's fire prevention methods such as sprinkler systems. Finally, the facility's contingency plans should be evaluated. The more prepared a facility is for the chance of an emergency, the less likely an environmental incident is to occur.

Accounting for these factors, Fowles (2001) ranks type of facilities in terms of hazards in the following manner:

1. Heavy Industrial Structures– Chemical storage areas, manufacturing, petroleum refineries, and similar facilities.
2. Light Industrial Structures – Large businesses and warehouses that store plastics and other solid materials.
3. Commercial Structures – Auto shops, dairies, fruit shops, sport stores, and similar facilities.
4. Residential Structures
5. Vehicular Fires

When evaluating the ecological risk of a facility in terms of the materials stored, one must consider the types and quantities of chemicals being stored or used within the facility (Fowles, 2001). Different chemicals pose different hazards to the environment. Pages 10-15 of this literature review describe the different chemicals that can affect water quality in hazardous ways. In addition, the more chemicals that are stored within a certain facility, the greater the risk involved with that facility. A facility with a greater turnover of chemicals will have a higher risk than a facility with a lower turnover.

Fowles also recommends determining the distance from each site to a water resource. The fire authority should determine criteria for high risk and low risk distances (Fowles, 2001). The distance from storm drains, sloping surfaces, and similar geographical features should also be considered. Fowles recommends using Geographical Information Systems (GIS) software to map potentially high risk fire sites to sensitive water resources in particular areas. Table 2.3 provides a summary of ecological risk level for different facilities and water resources.

Table 2.3. Considerations for Ranking Ecological Risks from Firewater Runoff.

Risk Level	General Condition	Specific considerations or examples
High	Large or medium-sized facilities with a lack of fire safety systems or contingency plans.	Includes chemical manufacturing or storage plants, metalworks, shipyards, industrial storage warehouses. Absence of sprinklers, alarms, proper storage plans. No pollution prevention plans.
	Facilities with high volumes of chemical storage or turnover.	e.g. over one tonne per week – risk varies with chemical type.
	Presence of high risk chemicals for any size facility or vehicle.	Agrichemicals, plastics, tyres, caustics, metals, cyanide, ammonia, petroleum products.
	Large or medium sized facilities in close proximity or that drain to waterways.	e.g. less than 100 metres from site or drain
	Any facilities near particularly sensitive waterways.	e.g. within 100 metres from a particularly sensitive waterway.
Medium	Small businesses with some fire safety systems and contingency plans.	Fruit shops, sports stores, auto shops, with old fire safety systems and no plans to contain runoff.
	Small to medium sized facilities with a low turnover of chemicals/materials.	e.g. less than 200 kg per week.
	Small facilities or businesses close to waterways.	Less than 100 metres from site or drain.
Low	Domestic houses close to waterways.	
	Large facilities beyond critical distance from sensitive areas.	e.g. over 100 metres from site or drain
	Large facilities with extensive contingency plans and fire safety systems.	Presence of containment systems, bunds, etc. Modern fire safety systems.
	Car fires	

Source: Fowles, *The Ecotoxicity of Fire-Water Runoff, Part III: Proposed Framework for Risk Management,* 2001.

Internationally

The Essex County Fire and Rescue Service in the United Kingdom is a fire authority that recognises the environmental consequences of fire emergencies (Sherrington, 1994). A result of this acknowledgement is the inclusion of environmental equipment being placed on all front-line fire-fighting tools. This equipment has been funded by the National Rivers Authority (NRA) of the U.K., a local water authority similar to the EPA. In addition, the brigade assisted in the development of the world's first purpose designed environmental response unit. The leader of the brigade stresses the importance of contact between the environmental agency and the fire authority in prevention of environmental disasters. This contact is most easily reached by on-site liaison with the particular environmental organisation involved. This procedure is known as integrated pollution control. Working as a team is an important part of emergency control; cooperation is a key to success in this and many other fields.

Chapter 3: Methodology

The goal of this project was to determine the potential effects of structural fire-fighting on water resources within a sample area of Victoria, Australia. This sample area of the Frankston CFA brigade area may then provide indications of what might be expected in similar areas. We developed a risk management strategy to identify, analyse, and evaluate the risks and strategies to assist in minimising the potential impact of firewater runoff on water resources.

Data Collected

In order to meet the goals described above, we needed to find many different pieces of information. We wished to discover how the problem of firewater runoff from structural fire-fighting was currently being controlled, so the current practices in minimising water pollution by fire services were determined. We examined other options to determine the best and most practical methods to minimise this contamination. We identified CFA's responsibility for cleaning up contamination from firewater runoff. We researched and interpreted current water quality standards. Our team created a list of risk parameters, which are structures and water bodies at risk from firewater run-off. Finally, we examined current regulations regarding firewater runoff control. The information was analysed and recommendations were provided to develop strategies for CFA to minimise potential water pollution during structural fire-fighting.

Water Quality

The Environment Protection Authority of Victoria (EPA) is one of the government associations that corresponds with CFA with respect to the potential environmental impacts of fire suppression. Interviews with members of the EPA were intended to gain an expert's opinion regarding the cause of water pollution in the immediate area. These interviews were also completed in order to provide links between local fires and local pollution. We interviewed one individual in the Environmental Education Department, one person in the Stormwater Action Program, and two people in the Operations Programs Department of the EPA in order to gain an understanding of water quality standards and contamination of water resources from structural fire-fighting.

If a fire caused pollution to a local water source, the individuals involved with local environmental protection programs in the area may be knowledgeable of this fact. They were able to indicate how this link was determined and suggested procedures to help minimise the impact. For these reasons, the interviews with the EPA were seen as potentially very valuable. In addition, these agencies can assist with interpretation and understanding of charts specifying Australian water quality standards. Semi-standardized interviews were used, as they could be tailored to the level of expertise of each participant. These types of interviews enabled more detailed information to be gathered if a respondent had specific expertise in an area that proved useful. The interview schedule included the following questions based on information requirements and current knowledge of the sample area. They were intended to obtain information about the EPA's procedures regarding water runoff from structural fire-fighting:

1. Is there a trigger for CFA having to call you?
2. What procedures do you perform when CFA calls you?
3. What are considered unsafe levels of dangerous goods?
4. What are the current water quality standards, and what do they mean?
5. How large is the impact on the environment that exists when firewater is soaked up by sand?
6. How are different water resources affected by firewater runoff?

7. How large is the impact on the environment that exists when firewater runoff drains into a creek and then into a large bay?

8. How does the type of structure (residential, community, commercial, industrial) affect the environmental impact of firewater runoff?

    a. Which structure presents the highest risk, and why?
    b. Which structure presents the lowest risk, and why?

9. According to the United States Environmental Protection Agency (USEPA), harmful compounds are not being used in construction of buildings anymore. Is this true for Australia as well?

10. Are there any Standard Operating Procedures in regards to cleaning up fire retardant foams?

11. How much, if any, firewater runoff drains into groundwater?

12. Are there any case studies you know of that we should look into?

13. Do you know of anyone else we should speak to?

We interviewed two of CFA's Dangerous Goods Officers and an officer of the Metropolitan Fire and Emergency Services Board's (MFESB) Dangerous Goods department. One of the roles they serve is to visit potentially hazardous sites and identify the sites' procedures regarding risk management. These respondents gave us information about the potential water-related impacts of structural fire-fighting and current methods of minimising that impact, as well as current regulations regarding firewater runoff control. These questions were intended to provide an understanding of the level to which the CFA, MFESB, EPA, and other relevant stakeholders consider firewater runoff a risk. In addition, this helped to identify the procedures the Dangerous Goods Departments of these organisations follow regarding cleanup and control of runoff.

In order to obtain this information, the following questions were asked:

1. How much of a problem, in your opinion, is firewater runoff?
2. What are the current Standard Operating Procedures/Standing Orders that the Fire Brigade/CFA is following?
    a. Are they good or bad?
    b. What changes are being looked into?
3. Are there major differences in runoff depending on the type of structure?
4. How do you classify the amount of water being used? (small vs. large amount)
5. Are there any case studies looking at firewater runoff containment that we should look into?
6. Are there any other people we should speak with?

Country Fire Authority

As the project was sponsored by CFA, we required a large amount of data regarding CFA and its procedures. This includes the chemicals CFA currently uses to fight or contain structural fires, when these chemicals were used and in what quantities, and precautions CFA takes during prevention planning and response phases to mitigate contamination.

This information was gathered via interviews with CFA Executive Team members. We used a semi-standardized interview instrument with the Executive Team members. We used reference sampling methods techniques to choose our interviewees.

The interview instrument contained the following questions:

1. What chemicals do you use to fight fires?
2. For what are each of those chemicals used?
3. In what situations do you use them?
4. In what quantities are they used?

5. What do you think about when you arrive at a fire?

6. What precautions do you take before hand?

7. What precautions do you take on the scene?

We investigated the regulatory and equipment information of the CFA in order to verify and validate the information given to us through the interviews.

The Study Site (Sample Area)

One of the reasons that Frankston was selected as the sample area was that it contains a variety of water sources. The City of Frankston is located on Port Philip Bay, and the Kananook and Sweetwater Creeks run through it. There are wetlands and a reservoir situated within the city limits as well. Different water sources may be affected by water pollution in different ways. How the specific water sources may be affected by water pollution, and more specifically, water runoff from structural fire-fighting, was determined. This data was gathered via interviews and interaction with CFA, Frankston City Water Management, and EPA Victoria.

In addition to interviews with members of the CFA Executive Management Team, we interviewed five fire-fighters and two captains from the Frankston Brigade. We discovered directly from the Frankston fire-fighters which structures present a risk of contamination. We asked questions in the following areas in order to provide us with a good idea of the possible contaminants and environmental effects from structural fires in the area:

- Construction characteristics of buildings in the area
- Chemicals that are stored in the area
- Current preventative measures, both required and additional
- Current regulations regarding firewater runoff control
- Locations with a high fire risk

The impact from a structural fire depends on what materials were used in the construction of the building, what safety precautions are taken, and what is located in the structure. All three of these factors can increase or decrease the level of risk to the environment during and after a fire. To determine the effect of these different factors, we examined the different structures in Frankston. This was done through observation and interviews with members of the Frankston Fire Brigade. We focused on four different types of structures: residential, commercial, industrial, and community (BCA, 1996; MFPC, 1998).

Insurance Polices

Insurance providers protect the investments of companies in the event of emergencies including fires. To provide protection, insurance providers require companies to follow certain safety guidelines. We interviewed an insurance representative to learn about the view of firewater runoff from the side of the potential fire sites. A semi-structured interview schedule was used to gather information regarding what policies and safety precautions insurance providers require companies to take.

The interview instrument contained the following questions:

1. What types of businesses does FM Global insure?
2. Why does FM Global concern itself with dangerous good storage?
3. What types of regulations are imposed on companies that store dangerous goods?
4. Do the containment systems that are in place allow for firewater runoff?
5. Why are companies required to contain dangerous goods spills but not firewater runoff?
6. Do you know of any case studies looking at firewater runoff containment that we should look into?
7. Do you know of any other people we should speak with?

GIS Feasibility Study

Geographical Information System (GIS) is a system of computer hardware, software, data, and personnel to help manipulate, analyse, and present information that is tied to a spatial location (www.gis.com). GIS has been proven to be a useful tool for the CFA in numerous applications, as evident by the need for a GIS IQP team. We performed a feasibility study to determine if GIS could be useful as a tool to graphically display risks due to firewater runoff from structural fire-fighting. We attended a CFA GIS informational meeting to become familiar with its use by the CFA, and we interviewed a GIS analyst at the CFA, along with the WPI Project Team: Application of GIS.

Chapter 4: Data Presentation and Analysis

The purpose of this project was the achievement of two distinct goals. Goal one was to determine the potential impact of structural fire-fighting water runoff on the environment. The second goal was to develop a set of tools and recommendations for CFA to minimise that impact. A listing of the persons interviewed is presented in Table 4.1.

Table 4.1. Summary of Interviews Performed

Name	Organisation	Department	Title	Number Interviewed
Geoff Conway	CFA	Operations	Project Officer	1
Neil Bibby	CFA	Community Safety	Director	1
Greg Allen	CFA	Community Safety	Administrative Officer	1
Chris Mason	CFA	Community Safety	Senior Dangerous Goods Consultant	1
Mark Potter	CFA	Westernport Area	Statutory Compliance Officer	1
Greg Allisey Phil Charles	CFA	Frankston Fire Brigade	Captains	2
Peter Merrick	CFA	Frankston Fire Brigade	Fire Officer	1
Greg Seing	CFA	Frankston Fire Brigade	Leading Firefighter	1
Thomas Hoppner Robert Groves Paul Edbrooke	CFA	Frankston Fire Brigade	Firefighters	3
Andrew Barrett	MFESB	Operations	Dangerous Goods Project Officer	1
Frank Mitchell	EPA Victoria	Knowledge Unit	Environmental Education Coordinator	1
Ian Innes-Wardell	EPA Victoria	Victorian Stormwater Action Program	Manager	1
Hamish Reid	EPA Victoria	Operations Directorate	Project Manager	1
Tania Brodie	EPA Victoria	Operations Programs	Emergency Response Coordinator	1
Andre Mierzwa	FM Global	Field Engineering	Chief Technical Engineering Specialist for Australasia	1
Noel Skehan	Frankston City Council	Infrastructure Planning	Infrastructure Planning Officer	1
Jonathan Barnett	Worcester Polytechnic Institute	Fire Protection Engineering	Professor	1

Members of EPA Victoria, MFESB, and the CFA Executive Management Team concur that firewater runoff has the potential to seriously damage the environment. CFA's Standard Operating Procedures (SOPs) are currently being changed by a team led by Geoff Conway, a CFA Operations Officer. Since the current SOPs do not mention firewater runoff, a need for the inclusion of firewater runoff control was recognised. It would be very useful to have a checklist that CFA could follow before, during, and after a fire to control potential damage from firewater runoff.

The potential damage to the environment depends on a range of different factors. These include the type of structure, the contents of the structure, the proximity to water resources, and the burn time.

From the data gathered, the type of structure seems to be the one of the best ways to qualify risk associated with different structures. Nineteen out of twenty respondents affirmed this statement. Residential properties have a much lower potential to cause environmental damage than commercial or industrial properties, although they cannot be ruled out as a potential hazard. Large chemical storage and processing facilities have the greatest potential for environmental damage due to the hazardous materials used and stored in them. These larger industrial facilities should sufficiently plan runoff containment during emergencies such as leaks and fires, according to current regulations. Safety measures such as suppression systems, isolated storage, and on site containment systems are often used. This leaves the middle ground between residential and large industrial sites. These smaller facilities often are not required to meet the same regulations that the large industrial facilities are. Without proper safety systems in place, smaller facilities may very well pose the largest immediate threat to the environment. The type of business taking place in different structures also needs to be considered. Businesses that do not use dangerous goods pose a much smaller threat to the environment than businesses that do.

The type of water resource near a facility also affects the amount of potential damage to the environment. This was stated by eight respondents, including members of CFA Executive Management Team, MFESB, EPA Victoria, and Frankston City Council. Water use, size of resource, and the sensitivity of ecosystems are all determining factors. According to members of the EPA, human drinking water has the highest level of protection and regulation. Larger bodies of water have the ability to dilute contaminants more than smaller water bodies. However, this dilution depends heavily on the rate of water flow. For instance, contamination in standing water is localised because the pollution is trapped and cannot move. Because of the contaminants continued contact with aquatic life, however, they can cause more damage to the environment than moving water.

Contaminants in a large slow moving body of water may stay localised to one section of the water body. Contamination in a swiftly moving body of water has the potential to harm a large area if not contained quickly. However, this contamination will not be as severe as in a slow moving body of water. Contaminants will move downstream, affecting everything that is passed along the way. The sensitivity of ecosystems also changes from waterway to waterway. Aquatic life in the creek is an important factor affecting the environmental impact from pollution. If the aquatic life is very sensitive, they may be more likely to die than if the life is insensitive, and the potential damage is increased. The creeks in Frankston do not have a large amount of aquatic life, but these numbers are improving.

Many different methods and precautions can be taken to minimise environmental damage. These include precautions before and during an incident. All of these methods focus on containing and treating firewater runoff.

Pre-incident planning has been proven to be a valuable method to reduce potential damage to the environment. Members of CFA Executive Management Team, MFESB, and FM Global view pre-incident planning as a critical method to reduce risk. This is evident in large chemical facilities, which require on-site containment systems and advanced suppression systems. A pre-incident plan can also assist emergency services in the event of an incident. Pre-incident plans can give fire brigades vital information about surrounding environmental and structural features, safety systems already in place, chemicals stored or used on site, and key contact information. Pre-incident plans also allow brigades to identify the best fire-fighting and containment techniques to use during an incident. Use of Geographic Information Systems (GIS) can assist the pre-incident planning process in identifying high-risk areas; however, CFA has not GIS for this purpose in the past. Determination of this information requires a survey of the area by an experienced professional. CFA and MFESB currently develop a limited number of pre-incident plans with facilities that use or house large amounts of dangerous goods.

Regulations can come from any number of different groups including local and state government, insurance companies, and Victorian WorkCover Authority. These regulations specify everything from storage specifications to on-site containment requirements. These requirements are put in place by different groups to protect investments, the public, and the environment. With proper safety precautions, a fire can be suppressed before there is serious damage to the facility and the environment.

Conducting tests to determine the contents of runoff would allow brigades to quickly determine the toxicity of the runoff. By determining the toxicity of the runoff, brigades will know whether the runoff needs to be contained and if human contact needs to be avoided. Currently, some brigade members are trained to test the air and smoke to determine the risk to the fire-fighters. According to Neil Bibby, director of Community Safety of CFA (17 April 2002, personal interview), the addition of water testing, as long as it is simple, would not be a significant problem. In addition, by knowing the contents of the runoff, brigades would be able to better inform the EPA of the situation.

The methods used to fight the fire can also help to minimise the environmental impact of firewater runoff. High-pressure fire hose nozzles use water more efficiently than traditional low-pressure nozzles, reducing the actual amount of water that needs to be applied to the fire. According to Andrew Barratt, Dangerous Goods Project Officer of the MFESB (18 March 2002, personal interview), using high-pressure nozzles and fog techniques can nearly eliminate runoff. He discussed a house fire where the conditions allowed the fire to be completely extinguished without any water damage to the structure or runoff being created. The fog technique makes use of the physical properties of water, particularly the high vaporization energy. By spraying a fine mist or fog of water onto the fire under the correct conditions, most of the water is vaporized removing energy from the fire. This causes the fire to cool and cause there to be little to no runoff. According to Andrew Barrett and Geoff Conway, Project Officer CFA Operations (20 March 2002, personal interview), however, the conditions need to perform this technique are very difficult to achieve.

Re-pressurising, or boosting, sprinkler and suppression systems is accomplished by connecting a fresh supply of water or foam to the system. Most systems have a supply of water or foam only large enough to run for approximately half an hour. Re-pressurising sprinkler and suppression systems applies water directly on the source of the fire. Suggested by Dr. Jonathan Barnett, Professor of Fire Protection Engineering, and supported by Andrew Barratt and members of the Frankston Fire Brigade, this method appears to be a suitable fire-fighting method. It is more efficient, safer for fire brigades, and uses less water than fighting the fire from the outside of the structure. According to Barratt, even after the structure to which the suppression system is mounted fails, it can still be utilised as long as at least one pipe is still intact.

Allowing the structure to burn is sometimes a very real consideration. Depending on the contents of the structure and the surrounding ecosystems, it is sometimes safer for the environment to let the structure burn. This strategy has been posed by members of EPA Victoria and CFA Executive Management Team. The surrounding exposures need to be taken into consideration as well when making this decision. The recommendation for this course of action would most likely have to come from the EPA, with the final decision coming from the fire officer in charge at the scene. However, this poses some problems for the brigades. To begin with, it is against a fire-fighter's training to just stand by and watch as a building burns to the ground. It would also be difficult to explain to the public why the fire was not being extinguished.

Runoff containment during the incident also has the ability to reduce potential environmental damage. Several containment options are available to brigades. These options include bunding (see Chapter 2: Literature Review for a definition) to physically contain or redirect the runoff.

Bunding all access points into the structure is one possibility to contain runoff, as suggested by Dr. Jonathan Barnett (17 March 2002, personal interview). This method would also help to keep the runoff from possibly coming in contact with brigade members and the public. The ability to perform this procedure would depend on the physical structure, burn time, the amount of water applied, and whether brigade members would have to enter the structure at any point. The structure would have to be stable enough to support any stresses applied to it. Some of these stresses could come from any water being applied to the structure from the outside, the pressure from the water being contained within the structure, and from collapsing sections of the structure. If the structure was to fail, additional containment would have to be put in place around the perimeter. Entry by brigade members may not be possible if runoff was being contained in the structure. Access over the bunding may be difficult. There could be significant health risks from being in contact with the runoff depending on the chemicals in the flow. The contained runoff may put the structure at risk of failure, which inturn would endanger anyone inside.

Runoff could also be contained in curbed streets or parking areas. This could involve blocking storm water drains and placing dams in sections without curbs. Soil, sandbags, pre-manufactured plugs and barriers, inflatable bags, or even large diameter fire hoses could be used to block drains and construct dams. The amount of water that can be contained using these methods is questionable. Because pool depth is relatively low, space is not efficiently used. If the containment area is inside of the brigade's operating area, it may pose an unacceptable risk to brigade members.

Containment in the drainage system is another possibility. This could be accomplished by using shutoff values if present, soil, sandbags, pre-manufactured plugs, or inflatable bags. By containing the runoff in the drainage system, runoff is removed from human contact. This would reduce risk to brigade members as well as the public. However, this is not a viable primary containment method in the Frankston area for a few reasons as stated by Noel Skehan of the Frankston City Council (10 April, 2002, personal interview). To begin with, much of the Frankston area drainage system is old. Pipes are deteriorating to the point where leakage could occur. In addition, the joint type used does not consider standing water. The joints are set up for flow in one direction and would leak if standing water or water flowing in the wrong direction was present. On top of these two issues, the system has no consistent path, many branches, and no control valves, which would make sealing sections off difficult.

Runoff could also be directed into portable tanks or nearby natural features, which would facilitate containment, as seen in the 1993 tyre fire at Deepcar, South Yorkshire, UK. This would allow for storage and treatment before release, as well as reuse of runoff. Reuse of runoff is a viable option as long as the contaminants in the water would not alter the operation of the pumps and other fire-fighting apparatus. According to Geoff Conway, Project Officer CFA operations (20 March 2002, personal interview), runoff sometimes can be reused at the beginning of the fire, but as the fire progresses it will become too contaminated. Isolated bodies of water are possible natural containment features, as the runoff would be contained in one place.

Depending on the types of contaminants, there are several methods available to reduce potential environmental damage. If the contaminants are less dense than water, they would float on the surface. This would allow containment of just the contaminants by skimming them off the surface of the runoff. This could be accomplished by suspending a large diameter hose or manufactured boom on the surface of the runoff. In the case that the contaminants are more dense than water, they could be "skimmed" off the bottom of the water. To accomplish this, a small dam in the flow could be used. The surface water would flow over the top of the dam, trapping the contaminants behind it.

Firewater runoff has been recognised as a problem; however, it is unclear who is responsible for containing it. The EPA currently advises brigades as to whether the runoff needs to be contained and treated. The company that owns the structure involved is required to have the runoff treated once it is contained. The Frankston brigade views contaminated firewater to be the EPA's responsibility.

One problem that may currently impede the containment of runoff is a lack of communication between brigades and the EPA. This has been recognised by both the EPA and the Frankston brigade. The EPA needs to be informed earlier with more information about the situation such as contents of the structure, burn time, the approximate amount of water applied, nearby water resources, and steps that have been taken to contain any runoff. The Frankston brigade is unclear about when they should actually contact the EPA and what information should be provided. This often leads to initial contact after some environmental damage has been done. Through preplanning, set trigger points could be established so that brigades know when the EPA needs to be called and the EPA receives the information that they require. Through collaboration with the EPA, a checklist for brigades regarding necessary information for the EPA is in the development stages.

In order to verify the problem of firewater runoff as well as determine the risk associated with various structures, Fowles (2001) conducted an experiment consisting of runoff sampling from various structural fires in New Zealand during 2000. The results of this study compared the results of the chemical testing of sampled runoff to published water quality guidelines. Runoff was sampled from the sites of the following structural fires: a fruit shop, a sports store, a house fire, an auto shop, and a vehicular fire. No fires at large industrial facilities were available for sampling during the course of the study. Table 4.2 displays the results of this study. The density of chemicals found in the runoff for each fire is compared with water quality guidelines the EPA Victoria SEPP (1986) as well as ANZECC guidelines (2001). The volume of water used for each fire is given, and the volume of water needed to dilute the runoff is shown.

Table 4.2. Analytical Results from runoff sampling from Fowles (2001) study compared to ANZECC 99% aquatic life protection (2000) and EPA Victoria's SEPP (Waters of Victoria) water quality guidelines. All densities are given in mg/L.

Material	**Car Fire**	**Fruit Shop**	**Sports Store**	**House Fire**	**Auto Shop**	**ANZECC guidelines**	**SEPP standards**
Arsenic	0.039	0.11	0.025	0.051	0.36	0.08	0.05
Cadmium	0.044	0.034	0.011	0.0012	0.008	0.00006	0.0004
Chromium	0.026	0.044	0.01	0.042	0.12	0.01	0.01
Copper	1.2	0.23	0.13	0.12	2.2	0.001	0.01
Cyanide	0.051	0.07	0.021	n.f.	n.f.	0.004	0.005
Lead	0.61	1.1	0.22	0.17	1.6	0.001	0.025
Mercury	n.f.	0.005	n.f.	n.f.	n.f.	0.00006	0.00005
Nickel	0.074	0.027	0.007	0.013	0.027	0.008	0.025
Zinc	11	15	1	1.6.	4.7	0.0024	0.05
Volume of Runoff (L)	200	3600	2000	n.r.	12,000		
Maximum Dilution(L)	72,000	446,400	18,000	34,440	34,440		

Source: Adapted from Fowles (2001): *The Ecotoxicity of Firewater Runoff, Part 2: Analytical Results* and EPA Victoria (2000) *Yarra Catchment – Draft Policy Impact Assessment.*

Note: n.f. means that the material was not found in the sampled runoff.
n.r. means not reported.

As shown in Table 4.2, the auto shop fire requires the greatest volume of unpolluted water for dilution in order to achieve a safe level of water quality. Copper and zinc were generally the most dangerous contaminants in the runoff sampled from these fires. In each structural fire, surface water was located from 20 to 50 metres away from the structure. This distance means that the runoff would very likely have a risk of entering these water resources.

From this study, Fowles (2001) concluded that runoff from each fire had a high level of toxicity in comparison with water quality guidelines. Fowles also concluded that the auto shop fire was the most toxic to the environment. This fact was due to the type of chemicals present in the structure. The house and vehicular fires presented the least amount of toxic runoff, as was expected.

Chapter 5: Conclusions and Recommendations

From the data collected, we have formed the following conclusions and developed corresponding recommendations to specifically address them. We believe that CFA should implement these recommendations in order to best address the problem of water contamination due to runoff from structural fire-fighting.

1) Conclusion: Written Standard Operating Procedures (SOP's) will raise awareness about firewater runoff and initiate a change in fire brigade activity.

Recommendation: We strongly recommend that CFA develop SOP's that specifically deal with firewater runoff from structural fires. There are currently no SOP's dealing with this important issue, and they are essential to provide a format for many of our recommendations. By implementing these recommendations through SOP's, we expect a wider acceptance of new techniques by fire brigades.

2) Conclusion: A stronger pre-incident planning procedure could significantly help CFA minimise the danger to water resources from firewater runoff.

Conclusion: The risk level of different structures depends on their contents and their proximity to water resources.

Recommendation: We recommend that CFA implements a pre-incident planning program to develop site-specific plans for businesses on a region-by-region basis. According to our data, pre-incident planning is the most effective way to minimise the environmental impact of fire-fighting as well as maximise the efficiency of fire-fighting. This could be done on the brigade or regional level and should involve individuals who travel to businesses at or above a predefined risk level and design emergency plans. These individuals should have knowledge of practical fire-fighting techniques, dangerous goods, and environmental impact management techniques. This may require training programs to be implemented for these individuals. The site-specific plans should include the following elements: strategies for fighting the fire, strategies for managing runoff, and information about any chemicals stored or used on site.

3) Conclusion: There is a lack of effective communication between CFA and the EPA regarding fire incidents.

Recommendation: It is our recommendation that CFA include in the firewater runoff SOP a checklist for use by fire-fighters in the field. This checklist will be used to determine whether the EPA should be called to the scene. This allows fire-fighters to determine whether or not to call the EPA almost immediately after reaching the scene. By minimising the time before the EPA is called, the time it takes the EPA to arrive on scene is minimised. This means that less damage will have occurred by the time the EPA arrives.

Recommendation: We recommend that CFA establish a deliberate and continuous line of communication with the EPA. This could be used to make suggestions for possible methods the EPA could use to improve response time as well as allowing a medium to discuss future issues. If the EPA can arrive sooner, then CFA brigades can focus strictly on the issue of fighting the fire and not on environmental protection. The lack of communication is a major issue since the Frankston brigade and many others do not have the human resources to control firewater runoff while fighting the fire.

Recommendation: We advise that the SOP dealing with firewater runoff include instructions for the officer in charge regarding informing the EPA about the incident. The brigade should make an effort to give the EPA as much information as possible including but not limited to the following: contents of the structure; water resources located nearby and where runoff is likely to go; what steps have been taken on scene; burn time; and, if possible, how much water has been put on the fire. A more complete checklist of information can be found in Appendix D under the Tania Brodie interview. It is recommended that a variation of this checklist be incorporated into the SOP.

4) Conclusion: Contaminated firewater runoff should not be allowed to enter waterways.

Recommendation: We recommend that CFA develop a quick and easy method for runoff containment to be implemented through pre-incident planning. In the event of dangerous runoff at a site that does not have permanent bunding, a containment method that is easy for fire brigades to construct and use, can be very useful. This is especially true in situations where the contaminants cannot be easily separated out of water.

5) Conclusion: Water conservation in fighting fires minimises runoff, thereby potentially minimising water resource contamination.

Recommendation: We believe it is essential for CFA to develop a continuing education and support program for fire-fighters. This program should be used to educate fire-fighters about techniques that are effective in fighting fires and effective at minimising environmental impact. These techniques should focus on water conservation. Many of our recommendations are based on the general principle of minimising water usage in fire-fighting. By minimising the water applied to the fire, one can minimise or even eliminate the runoff. This is the single most important aspect of any plan to minimise runoff contamination.

6) Conclusion: Pre-existing on-site fire suppression and fluid containment measures are useful tools for CFA fire brigades.

Recommendation: We further recommend that CFA include firewater runoff in its considerations for new planning permits. CFA can exercise a greater degree of regulatory control over new developments by imposing conditions to put various measures into place. For instance, on site drainage and isolation from external drains using valves should be given consideration. By requiring these measures to be in place, CFA can make pre-incident planning much easier to accomplish.

Directions for Future Research

1) We strongly recommend that CFA assign at least one person to stay in contact with other agencies that are beginning research dealing with firewater runoff. Through our research, we have discovered three projects similar to this one at the New South Wales EPA (contact David Taylor), in Western Australia, and in New Zealand (contact Hamish Reid at EPA Victoria). All of these projects are in the early stages of development. By keeping continuous communication among these other agencies, information can be shared. This allows research to progress faster and more efficiently, which benefits all involved parties. In order to keep procedures current and effective, continuous research will prove invaluable to CFA.

2) We recommend a project analysing the quantities of water used at different types of fires in Victoria. It is also recommended that this project determine the chemicals present in water runoff from these different types of fires. This project should result in average amounts of water used at various types of fires and contaminant levels in the runoff from those fires.

3) We recommend a project—possibly a joint project with the EPA—that develops a contingency plan in the event that runoff minimisation and containment techniques do not work. This research should include methods to remove contaminants from waterways.

4) We recommend a project exploring the option of fire-fighters testing water runoff in the field. There is a possibility that fire-fighters can use simple testing methods in the field to determine if firewater runoff is an environmental or health risk. This may allow fire-fighters to determine, without EPA advice, whether or not runoff needs to be contained. Further research into the feasibility of this option, and what tools are currently available, is necessary.

5) We recommend that CFA do more research into the pros and cons of various water containment methods. CFA should do a cost-benefit analysis of multiple options and determine which options are best in different situations.

6) We recommend that CFA initiate research to explore the possibility of using GIS in pre-incident planning. GIS could be used to model the progression of a fire as well as potential paths of water runoff. This information can be very useful in developing an approach for fighting a fire. One example of GIS use in pre-incident planning is a simple map of property use and waterways. This shows placement of industrial and commercial areas in relation to water resources. An example of this type of map can be found in Appendix E.

In summary, we propose these particular areas of research to build upon the results of this project. These projects will help CFA to further improve awareness of firewater runoff and techniques to manage it. With this research, CFA can become a leader in minimising the impact of firewater runoff.

Appendix A: CFA Overview

Overview

The Country Fire Authority (CFA) was established in April of 1945. Since then, it has grown to be one of the largest volunteer-based fire-fighting organizations in the world. CFA is responsible for fire prevention and suppression of over 150,000 square kilometres of land in Victoria, Australia. CFA's territory covers all of Victoria excluding Melbourne and its suburbs, State forests, and National parks. The organisation exists to provide a cost-effective fire and emergency service for the 2.5 million people living in Victoria. CFA also attempts to protect the environment from any damage that might come as a secondary result of fire-fighting practices (CFA Annual Plan, 2001/2002).

The following summary of CFA's duties was taken directly from the organisation's website (http://www.cfa.vic.gov.au):

Summary of Duties

CFA's duties and responsibilities can be classified broadly in the following categories:

- preventing or dealing with emergency situations;
- supervising the compliance of persons or property with codes or standards;
- determining and certifying standards and performance requirements;
- providing advice.

It is also clear that these duties and responsibilities (where appropriate) may be exercised by:

- the Authority as a Corporation;
- the Chief Officer;
- a delegate of the Chief Officer;
- any person authorised by the Authority for the purpose;
- any person authorised by the Chief Officer for the purpose;
- any person authorised by the CFA Act or other legislation or regulation for the purpose; and,

- any person acting under the direction of the Authority or the Chief Officer.

Finally, it should be noted that the discharge of the duties and responsibilities may involve matters, issues, actions, non-actions and contracts entered into by the Authority.

Organisation

The Chairman who oversees the Chief Executive Officer (CEO) heads the CFA (see Figure A.1). The CEO directly supervises the Executive Management Team (EMT) and the Area Management Team (AMT). The EMT is made up of seven department heads:

The Director of Community Safety is responsible for risk analysis, policies and strategies about risk identification, assessment, planning, and treatment, and risk communication. This position is also responsible for community fire and emergency safety programs as well as coordination of the brigade administration support program.

The Executive Manager of Public Affairs is in charge of strategic issues management, internal communications, media and external communications, publications and displays, special programs, advertising and sponsorships.

The Director of Human Resources is responsible for any human resource policies and making sure the workplace is safe for workers. The Human Resources Director is also in charge of training, volunteer support and employee/employer relations.

The Director of Support Services oversees building and property, commercial and contract management, communications, engineering, information technology, protective equipment, vehicle maintenance, and special project delivery.

The Director of Operations (Chief Officer) supervises operational leadership policy standards and strategy, operational service delivery and performance, preplanning of personnel, equipment and infrastructure, CFA operational command structure, major risk operational preplanning, and research and development.

The Director of Business Planning and Review is in charge of corporate and business planning, performance measurement, strategic and business analysis, strategic information management, business management, major project coordination and management, and internal audit.

The Director of Finance and Administration administers CFA funding and revenue, budget development and financial forecasting, financial management, implementation and reporting, treasury and debt management, and asset management.

The Area Management team is made up of eleven Area Managers. Each Area Manager is responsible for strategies and business planning in their respective areas. They are also responsible for delivery of all services within the area. They must manage resources to ensure effective and efficient service delivery, and local budget and expenditure. They are responsible for performance management and must contribute to organisation policy, standards, and strategy.

The eleven areas cover twenty regions that have 143 groups encompassing 1228 brigades. (http://www.cfa.vic.gov.au)

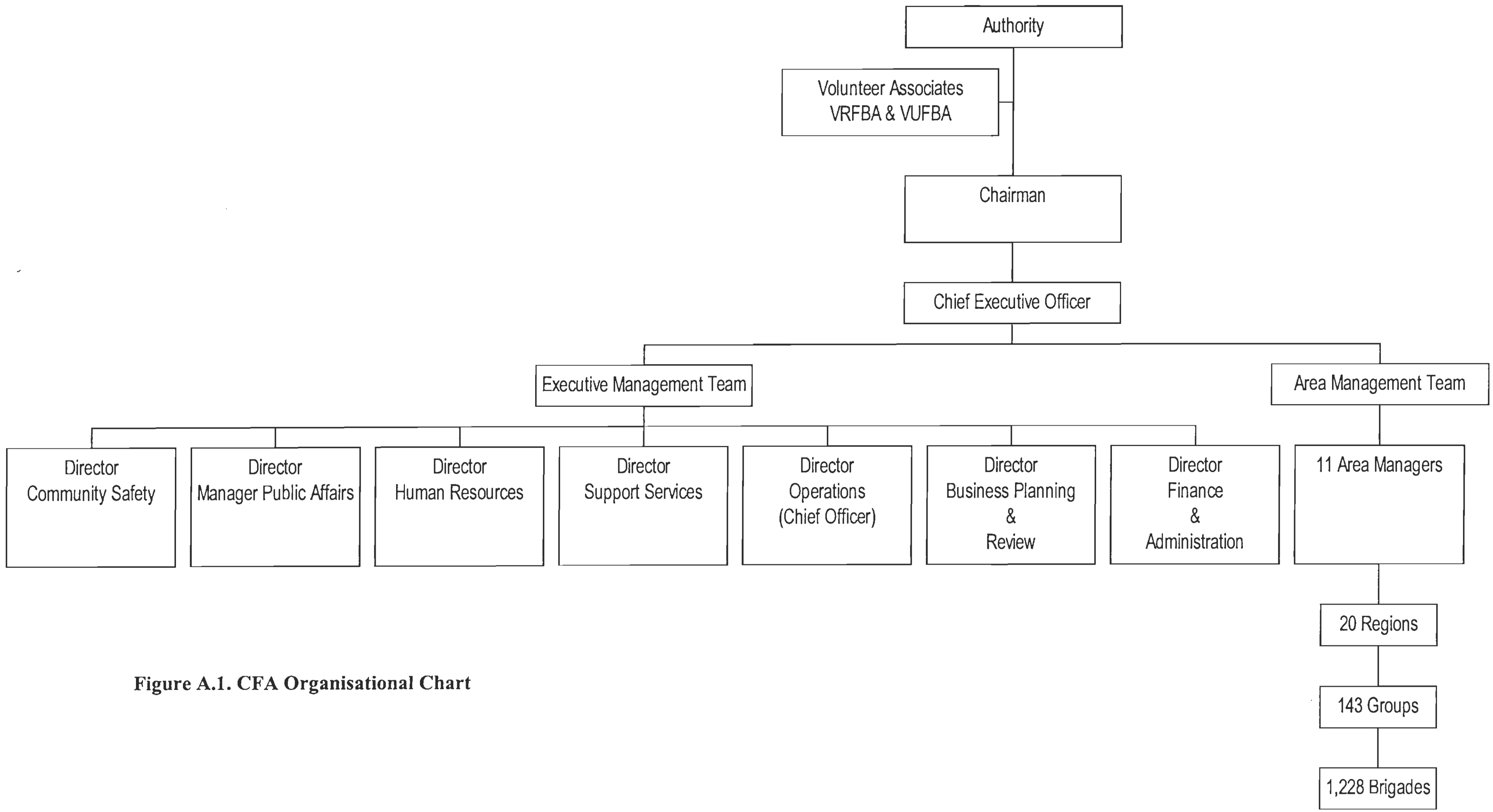


Figure A.1. CFA Organisational Chart

Appendix B: Methodology Definitions

In this section, we describe the theory behind our methods: why we chose them, what they mean, and the biases that can occur. We also give background on Geographical Information System (GIS).

We performed informational interviews at various organisations. These interviews were performed with professionals that have knowledge of the topic we studied. These were informational interviews because we knew the interviewee had information that is pertinent to our project. We did not ask the respondents for their personal opinion about firewater runoff. We were looking for hard data relating to this issue, so there is very little bias.

We used referenced sampling techniques for these interviews. Referenced sampling was used in order to obtain as many contacts as possible. We asked every respondent if they knew of anyone else we could talk to regarding runoff. In this way, we obtained as much information as possible through as many respondents as possible.

In order to decrease the amount of bias through interviews, we performed archival research relating to firewater runoff. This research was conducted relating to studies performed in collecting runoff data, international case studies, and other topics relating to runoff.

Geographical Information System (GIS)

Geographical Information System (GIS) is a method to visualize, manipulate, analyse, and display spatial data. They are also called "smartmaps," because they combine a database with a geographical map. While databases are useful, they are difficult to understand. GIS takes hard data and links it to a map to provide a visual understanding of the data. The official website for GIS explains it as a mapping software that links information about where things are with information about what things are like. A paper map displays data such as cities and rivers. A GIS map is similar, but contains different kinds of information that the user decides to include from databases. By mapping data relating to our goal onto a geographical map, we can find patterns in our data. We can also perform an analysis over a specific amount of time to observe change in our data.

Appendix C – Australian Water Quality Guidelines

Chemical		Trigger values for freshwater (μgL^{-1})				Trigger values for marine water (μgL^{-1})			
		Level of protection (% species)				Level of protection (% species)			
		99%	95%	90%	80%	99%	95%	90%	80%
METALS & METALLOIDS									
Aluminium	pH >6.5	27	55	80	150	ID	ID	ID	ID
Aluminium	pH <6.5	ID	ID	ID	ID	ID	ID	ID	ID
Antimony		ID	ID	ID	ID	ID	ID	ID	ID
Arsenic (As III)		1	24	94 [C]	360 [C]	ID	ID	ID	ID
Arsenic (AsV)		0.8	13	42	140 [C]	ID	ID	ID	ID
Beryllium		ID	ID	ID	ID	ID	ID	ID	ID
Bismuth		ID	ID	ID	ID	ID	ID	ID	ID
Boron		90	370 [C]	680 [C]	1300 [C]	ID	ID	ID	ID
Cadmium	H	0.06	0.2	0.4	0.8 [C]	0.7 [B]	5.5 [B,C]	14 [B,C]	36 [B,A]
Chromium (Cr III)	H	ID	ID	ID	ID	7.7	27.4	48.6	90.6
Chromium (CrVI)		0.01	1.0 [C]	6 [A]	40 [A]	0.14	4.4	20 [C]	85 [C]
Cobalt		ID	ID	ID	ID	0.005	1	14	150 [C]
Copper	H	1.0	1.4	1.8 [C]	2.5 [C]	0.3	1.3	3 [C]	8 [A]
Gallium		ID	ID	ID	ID	ID	ID	ID	ID
Iron		ID	ID	ID	ID	ID	ID	ID	ID
Lanthanum		ID	ID	ID	ID	ID	ID	ID	ID
Lead	H	1.0	3.4	5.6	9.4 [C]	2.2	4.4	6.6 [C]	12 [C]
Manganese		1200	1900 [C]	2500 [C]	3600 [C]	ID	ID	ID	ID
Mercury (inorganic)	B	0.06	0.6	1.9 [C]	5.4 [A]	0.1	0.4 [C]	0.7 [C]	1.4 [C]
Mercury (methyl)		ID	ID	ID	ID	ID	ID	ID	ID
Molybdenum		ID	ID	ID	ID	ID	ID	ID	ID
Nickel	H	8	11	13	17 [C]	7	70 [C]	200 [A]	560 [A]
Selenium (Total)	B	5	11	18	34	ID	ID	ID	ID
Selenium (SeIV)	B	ID	ID	ID	ID	ID	ID	ID	ID
Silver		0.02	0.05	0.1	0.2 [C]	0.8	1.4	1.8	2.6 [C]
Thallium		ID	ID	ID	ID	ID	ID	ID	ID
Tin (inorganic, SnIV)		ID	ID	ID	ID	ID	ID	ID	ID
Tributyltin (as µg/L Sn)		ID	ID	ID	ID	0.0004	0.006 [C]	0.02 [C]	0.05 [C]
Uranium		ID	ID	ID	ID	ID	ID	ID	ID
Vanadium		ID	ID	ID	ID	50	100	160	280
Zinc	H	2.4	8.0 [C]	15 [C]	31 [C]	7	15 [C]	23 [C]	43 [C]
NON-METALLIC INORGANICS									
Ammonia	D	320	900 [C]	1430 [C]	2300 [A]	500	910	1200	1700
Chlorine	E	0.4	3	6 [A]	13 [A]	ID	ID	ID	ID
Cyanide	F	4	7	11	18	2	4	7	14
Nitrate	J	17	700	3400 [C]	17000 [A]	ID	ID	ID	ID
Hydrogen sulfide	G	0.5	1.0	1.5	2.6	ID	ID	ID	ID
ORGANIC ALCOHOLS									
Ethanol		400	1400	2400 [C]	4000 [C]	ID	ID	ID	ID
Ethylene glycol		ID	ID	ID	ID	ID	ID	ID	ID
Isopropyl alcohol		ID	ID	ID	ID	ID	ID	ID	ID
CHLORINATED ALKANES									
Chloromethanes									
Dichloromethane		ID	ID	ID	ID	ID	ID	ID	ID
Chloroform		ID	ID	ID	ID	ID	ID	ID	ID
Carbon tetrachloride		ID	ID	ID	ID	ID	ID	ID	ID
Chloroethanes									
1,2-dichloroethane		ID	ID	ID	ID	ID	ID	ID	ID
1,1,1-trichloroethane		ID	ID	ID	ID	ID	ID	ID	ID

Chemical	Trigger values for freshwater ($\mu g L^{-1}$)				Trigger values for marine water ($\mu g L^{-1}$)			
	Level of protection (% species)				Level of protection (% species)			
	99%	95%	90%	80%	99%	95%	90%	80%
1,1,2-trichloroethane	5400	6500	7300	8400	140	1900	5800 [C]	18000 [C]
1,1,2,2-tetrachloroethane	ID	ID	ID	ID	ID	ID	ID	ID
Pentachloroethane	ID	ID	ID	ID	ID	ID	ID	ID
Hexachloroethane B	290	360	420	500	ID	ID	ID	ID
Chloropropanes								
1,1-dichloropropane	ID	ID	ID	ID	ID	ID	ID	ID
1,2-dichloropropane	ID	ID	ID	ID	ID	ID	ID	ID
1,3-dichloropropane	ID	ID	ID	ID	ID	ID	ID	ID
CHLORINATED ALKENES								
Chloroethylene	ID	ID	ID	ID	ID	ID	ID	ID
1,1-dichloroethylene	ID	ID	ID	ID	ID	ID	ID	ID
1,1,2-trichloroethylene	ID	ID	ID	ID	ID	ID	ID	ID
1,1,2,2-tetrachloroethylene	ID	ID	ID	ID	ID	ID	ID	ID
3-chloropropene	ID	ID	ID	ID	ID	ID	ID	ID
1,3-dichloropropene	ID	ID	ID	ID	ID	ID	ID	ID
ANILINES								
Aniline	8	250 [A]	1100 [A]	4800 [A]	ID	ID	ID	ID
2,4-dichloroaniline	0.6	7	20	60 [C]	ID	ID	ID	ID
2,5-dichloroaniline	ID	ID	ID	ID	ID	ID	ID	ID
3,4-dichloroaniline	1.3	3	6 [C]	13 [C]	85	150	190	260
3,5-dichloroaniline	ID	ID	ID	ID	ID	ID	ID	ID
Benzidine	ID	ID	ID	ID	ID	ID	ID	ID
Dichlorobenzidine	ID	ID	ID	ID	ID	ID	ID	ID
AROMATIC HYDROCARBONS								
Benzene	600	950	1300	2000	500 [C]	700 [C]	900 [C]	1300 [C]
Toluene	ID	ID	ID	ID	ID	ID	ID	ID
Ethylbenzene	ID	ID	ID	ID	ID	ID	ID	ID
o-xylene	200	350	470	640	ID	ID	ID	ID
m-xylene	ID	ID	ID	ID	ID	ID	ID	ID
p-xylene	140	200	250	340	ID	ID	ID	ID
m+*p*-xylene	ID	ID	ID	ID	ID	ID	ID	ID
Cumene	ID	ID	ID	ID	ID	ID	ID	ID
Polycyclic Aromatic Hydrocarbons								
Naphthalene	2.5	16	37	85	50 [C]	70 [C]	90 [C]	120 [C]
Anthracene B	ID	ID	ID	ID	ID	ID	ID	ID
Phenanthrene B	ID	ID	ID	ID	ID	ID	ID	ID
Fluoranthene B	ID	ID	ID	ID	ID	ID	ID	ID
Benzo(a)pyrene B	ID	ID	ID	ID	ID	ID	ID	ID
Nitrobenzenes								
Nitrobenzene	230	550	820	1300	ID	ID	ID	ID
1,2-dinitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,3-dinitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,4-dinitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,3,5-trinitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1-methoxy-2-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1-methoxy-4-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1-chloro-2-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1-chloro-3-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1-chloro-4-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1-chloro-2,4-dinitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,2-dichloro-3-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,3-dichloro-5-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,4-dichloro-2-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
2,4-dichloro-2-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID

Chemical		Trigger values for freshwater ($\mu g L^{-1}$)				Trigger values for marine water ($\mu g L^{-1}$)			
		Level of protection (% species)				Level of protection (% species)			
		99%	95%	90%	80%	99%	95%	90%	80%
1,2,4,5-tetrachloro-3-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1,5-dichloro-2,4-dinitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1,3,5-trichloro-2,4-dinitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1-fluoro-4-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
Nitrotoluenes									
2-nitrotoluene		ID	ID	ID	ID	ID	ID	ID	ID
3-nitrotoluene		ID	ID	ID	ID	ID	ID	ID	ID
4-nitrotoluene		ID	ID	ID	ID	ID	ID	ID	ID
2,3-dinitrotoluene		ID	ID	ID	ID	ID	ID	ID	ID
2,4-dinitrotoluene		16	65 [C]	130 [C]	250 [C]	ID	ID	ID	ID
2,4,6-trinitrotoluene		100	140	160	210	ID	ID	ID	ID
1,2-dimethyl-3-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1,2-dimethyl-4-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
4-chloro-3-nitrotoluene		ID	ID	ID	ID	ID	ID	ID	ID
Chlorobenzenes and Chloronaphthalenes									
Monochlorobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1,2-dichlorobenzene		120	160	200	270	ID	ID	ID	ID
1,3-dichlorobenzene		160	260	350	520 [C]	ID	ID	ID	ID
1,4-dichlorobenzene		40	60	75	100	ID	ID	ID	ID
1,2,3-trichlorobenzene	B	3	10	16	30 [C]	ID	ID	ID	ID
1,2,4-trichlorobenzene	B	85	170[C]	220[C]	300[C]	20	80	140	240
1,3,5-trichlorobenzene	B	ID	ID	ID	ID	ID	ID	ID	ID
1,2,3,4-tetrachlorobenzene	B	ID	ID	ID	ID	ID	ID	ID	ID
1,2,3,5-tetrachlorobenzene	B	ID	ID	ID	ID	ID	ID	ID	ID
1,2,4,5-tetrachlorobenzene	B	ID	ID	ID	ID	ID	ID	ID	ID
Pentachlorobenzene	B	ID	ID	ID	ID	ID	ID	ID	ID
Hexachlorobenzene	B	ID	ID	ID	ID	ID	ID	ID	ID
1-chloronaphthalene		ID	ID	ID	ID	ID	ID	ID	ID
Polychlorinated Biphenyls (PCBs) & Dioxins									
Capacitor 21	B	ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1016	B	ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1221	B	ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1232	B	ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1242	B	0.3	0.6	1.0	1.7	ID	ID	ID	ID
Aroclor 1248	B	ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1254	B	0.01	0.03	0.07	0.2	ID	ID	ID	ID
Aroclor 1260	B	ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1262	B	ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1268	B	ID	ID	ID	ID	ID	ID	ID	ID
2,3,4'-trichlorobiphenyl	B	ID	ID	ID	ID	ID	ID	ID	ID
4,4'-dichlorobiphenyl	B	ID	ID	ID	ID	ID	ID	ID	ID
2,2',4,5,5'-pentachloro-1,1'-biphenyl	B	ID	ID	ID	ID	ID	ID	ID	ID
2,4,6,2',4',6'-hexachlorobiphenyl	B	ID	ID	ID	ID	ID	ID	ID	ID
Total PCBs	B	ID	ID	ID	ID	ID	ID	ID	ID
2,3,7,8-TCDD	B	ID	ID	ID	ID	ID	ID	ID	ID
PHENOLS and XYLENOLS									
Phenol		85	320	600	1200 [C]	270	400	520	720
2,4-dimethylphenol		ID	ID	ID	ID	ID	ID	ID	ID
Nonylphenol		ID	ID	ID	ID	ID	ID	ID	ID
2-chlorophenol	T	340 [C]	490 [C]	630 [C]	870 [C]	ID	ID	ID	ID
3-chlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
4-chlorophenol	T	160	220	280 [C]	360 [C]	ID	ID	ID	ID
2,3-dichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,4-dichlorophenol	T	120	160 [C]	200 [C]	270 [C]	ID	ID	ID	ID

Chemical		Trigger values for freshwater (µgL-1)				Trigger values for marine water (µgL-1)			
		Level of protection (% species)				Level of protection (% species)			
		99%	95%	90%	80%	99%	95%	90%	80%
2,5-dichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,6-dichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
3,4-dichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
3,5-dichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,3,4-trichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,3,5-trichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,3,6-trichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,4,5-trichlorophenol	T,B	ID	ID	ID	ID	ID	ID	ID	ID
2,4,6-trichlorophenol	T,B	3	20	40	95	ID	ID	ID	ID
2,3,4,5-tetrachlorophenol	T,B	ID	ID	ID	ID	ID	ID	ID	ID
2,3,4,6- tetrachlorophenol	T,B	10	20	25	30	ID	ID	ID	ID
2,3,5,6- tetrachlorophenol	T,B	ID	ID	ID	ID	ID	ID	ID	ID
Pentachlorophenol	T,B	3.6	10	17	27 [A]	11	22	33	55 [A]
Nitrophenols									
2-nitrophenol		ID	ID	ID	ID	ID	ID	ID	ID
3-nitrophenol		ID	ID	ID	ID	ID	ID	ID	ID
4-nitrophenol		ID	ID	ID	ID	ID	ID	ID	ID
2,4-dinitrophenol		13	45	80	140	ID	ID	ID	ID
2,4,6-trinitrophenol		ID	ID	ID	ID	ID	ID	ID	ID
ORGANIC SULFUR COMPOUNDS									
Carbon disulfide		ID	ID	ID	ID	ID	ID	ID	ID
Isopropyl disulfide		ID	ID	ID	ID	ID	ID	ID	ID
n-propyl sulfide		ID	ID	ID	ID	ID	ID	ID	ID
Propyl disulfide		ID	ID	ID	ID	ID	ID	ID	ID
Tert-butyl sulfide		ID	ID	ID	ID	ID	ID	ID	ID
Phenyl disulfide		ID	ID	ID	ID	ID	ID	ID	ID
Bis(dimethylthiocarbamyl)sulfide		ID	ID	ID	ID	ID	ID	ID	ID
Bis(diethylthiocarbamyl)disulfide		ID	ID	ID	ID	ID	ID	ID	ID
2-methoxy-4H-1,3,2-benzodioxaphosphorium-2-sulfide		ID	ID	ID	ID	ID	ID	ID	ID
Xanthates									
Potassium amyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Potassium ethyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Potassium hexyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Potassium isopropyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Sodium ethyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Sodium isobutyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Sodium isopropyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Sodium sec-butyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
PHTHALATES									
Dimethylphthalate		3000	3700	4300	5100	ID	ID	ID	ID
Diethylphthalate		900	1000	1100	1300	ID	ID	ID	ID
Dibutylphthalate	B	9.9	26	40.2	64.6	ID	ID	ID	ID
Di(2-ethylhexyl)phthalate	B	ID	ID	ID	ID	ID	ID	ID	ID
MISCELLANEOUS INDUSTRIAL CHEMICALS									
Acetonitrile		ID	ID	ID	ID	ID	ID	ID	ID
Acrylonitrile		ID	ID	ID	ID	ID	ID	ID	ID
Poly(acrylonitrile-co-butadiene-co-styrene)		200	530	800 [C]	1200 [C]	200	250	280	340
Dimethylformamide		ID	ID	ID	ID	ID	ID	ID	ID
1,2-diphenylhydrazine		ID	ID	ID	ID	ID	ID	ID	ID
Diphenylnitrosamine		ID	ID	ID	ID	ID	ID	ID	ID
Hexachlorobutadiene		ID	ID	ID	ID	ID	ID	ID	ID
Hexachlorocyclopentadiene		ID	ID	ID	ID	ID	ID	ID	ID

Chemical		Trigger values for freshwater (µgL-1)				Trigger values for marine water (µgL-1)			
		Level of protection (% species)				Level of protection (% species)			
		99%	95%	90%	80%	99%	95%	90%	80%
Isophorone		ID	ID	ID	ID	ID	ID	ID	ID
ORGANOCHLORINE PESTICIDES									
Aldrin	B	ID	ID	ID	ID	ID	ID	ID	ID
Chlordane	B	0.03	0.08	0.14	0.27 C	ID	ID	ID	ID
DDE	B	ID	ID	ID	ID	ID	ID	ID	ID
DDT	B	0.006	0.01	0.02	0.04	ID	ID	ID	ID
Dicofol	B	ID	ID	ID	ID	ID	ID	ID	ID
Dieldrin	B	ID	ID	ID	ID	ID	ID	ID	ID
Endosulfan	B	0.03	0.2 A	0.6 A	1.8 A	0.005	0.01	0.02	0.05 A
Endosulfan alpha	B	ID	ID	ID	ID	ID	ID	ID	ID
Endosulfan beta	B	ID	ID	ID	ID	ID	ID	ID	ID
Endrin	B	0.01	0.02	0.04 C	0.06 A	0.004	0.008	0.01	0.02
Heptachlor	B	0.01	0.09	0.25	0.7 A	ID	ID	ID	ID
Lindane		0.07	0.2	0.4	1.0 A	ID	ID	ID	ID
Methoxychlor	B	ID	ID	ID	ID	ID	ID	ID	ID
Mirex	B	ID	ID	ID	ID	ID	ID	ID	ID
Toxaphene	B	0.1	0.2	0.3	0.5	ID	ID	ID	ID
ORGANOPHOSPHORUS PESTICIDES									
Azinphos methyl		0.01	0.02	0.05	0.11 A	ID	ID	ID	ID
Chlorpyrifos	B	0.00004	0.01	0.11 A	1.2 A	0.0005	0.009	0.04A	0.3 A
Demeton		ID	ID	ID	ID	ID	ID	ID	ID
Demeton-S-methyl		ID	ID	ID	ID	ID	ID	ID	ID
Diazinon		0.00003	0.01	0.2 A	2 A	ID	ID	ID	ID
Dimethoate		0.1	0.15	0.2	0.3	ID	ID	ID	ID
Fenitrothion		0.1	0.2	0.3	0.4	ID	ID	ID	ID
Malathion		0.002	0.05	0.2	1.1 A	ID	ID	ID	ID
Parathion		0.0007	0.004 C	0.01 C	0.04 A	ID	ID	ID	ID
Profenofos	B	ID	ID	ID	ID	ID	ID	ID	ID
Temephos	B	ID	ID	ID	ID	0.0004	0.05	0.4	3.6 A
CARBAMATE & OTHER PESTICIDES									
Carbofuran		0.06	1.2 A	4 A	15 A	ID	ID	ID	ID
Methomyl		0.5	3.5	9.5	23	ID	ID	ID	ID
S-methoprene		ID	ID	ID	ID	ID	ID	ID	ID
PYRETHROIDS									
Deltamethrin		ID	ID	ID	ID	ID	ID	ID	ID
Esfenvalerate		ID	0.001*	ID	ID	ID	ID	ID	ID
HERBICIDES & FUNGICIDES									
Bypyridilium herbicides									
Diquat		0.01	1.4	10	80 A	ID	ID	ID	ID
Paraquat		ID	ID	ID	ID	ID	ID	ID	ID
Phenoxyacetic acid herbicides									
MCPA		ID	ID	ID	ID	ID	ID	ID	ID
2,4-D		140	280	450	830	ID	ID	ID	ID
2,4,5-T		3	36	100	290 A	ID	ID	ID	ID
Sulfonylurea herbicides									
Bensulfuron		ID	ID	ID	ID	ID	ID	ID	ID
Metsulfuron		ID	ID	ID	ID	ID	ID	ID	ID
Thiocarbamate herbicides									
Molinate		0.1	3.4	14	57	ID	ID	ID	ID
Thiobencarb		1	2.8	4.6	8 C	ID	ID	ID	ID
Thiram		0.01	0.2	0.8 C	3 A	ID	ID	ID	ID
Triazine herbicides									
Amitrole		ID	ID	ID	ID	ID	ID	ID	ID
Atrazine		0.7	13	45 C	150 C	ID	ID	ID	ID

Chemical	Trigger values for freshwater ($\mu g L^{-1}$)				Trigger values for marine water ($\mu g L^{-1}$)			
	Level of protection (% species)				Level of protection (% species)			
	99%	95%	90%	80%	99%	95%	90%	80%
Hexazinone	ID	ID	ID	ID	ID	ID	ID	ID
Simazine	0.2	3.2	11	35	ID	ID	ID	ID
Urea herbicides								
Diuron	ID	ID	ID	ID	ID	ID	ID	ID
Tebuthiuron	0.02	2.2	20	160 [C]	ID	ID	ID	ID
Miscellaneous herbicides								
Acrolein	ID	ID	ID	ID	ID	ID	ID	ID
Bromacil	ID	ID	ID	ID	ID	ID	ID	ID
Glyphosate	370	1200	2000	3600 [A]	ID	ID	ID	ID
Imazethapyr	ID	ID	ID	ID	ID	ID	ID	ID
Ioxynil	ID	ID	ID	ID	ID	ID	ID	ID
Metolachlor	ID	ID	ID	ID	ID	ID	ID	ID
Sethoxydim	ID	ID	ID	ID	ID	ID	ID	ID
Trifluralin B	2.6	4.4	6	9 [A]	ID	ID	ID	ID
GENERIC GROUPS OF CHEMICALS								
Surfactants								
Linear alkylbenzene sulfonates (LAS)	65	280	520 [C]	1000 [C]	ID	ID	ID	ID
Alcohol ethoxyolated sulfate (AES)	340	650	850 [C]	1100 [C]	ID	ID	ID	ID
Alcohol ethoxylated surfactants (AE)	50	140	220	360 [C]	ID	ID	ID	ID
Oils & Petroleum Hydrocarbons	ID	ID	ID	ID	ID	ID	ID	ID
Oil Spill Dispersants								
BP 1100X	ID	ID	ID	ID	ID	ID	ID	ID
Corexit 7664	ID	ID	ID	ID	ID	ID	ID	ID
Corexit 8667		ID	ID	ID	ID	ID	ID	ID
Corexit 9527	ID	ID	ID	ID	230	1100	2200	4400 [A]
Corexit 9550	ID	ID	ID	ID	ID	ID	ID	ID

Notes: Where the final water quality guideline to be applied to a site is below current analytical practical quantitation limits, see Section 3.4.3.3 for guidance.

Most trigger values listed here for metals and metalloids are *High reliability* figures, derived from field or chronic NOEC data (see 3.4.2.3 for reference to Volume 2). The exceptions are *Moderate reliability* for freshwater aluminium (pH >6.5), manganese and marine chromium (III).

Most trigger values listed here for non-metallic inorganics and organic chemicals are *Moderate reliability* figures, derived from acute LC_{50} data (see 3.4.2.3 for reference to Volume 2). The exceptions are *High reliability* for freshwater ammonia, 3,4-DCA, endosulfan, chlorpyrifos, esfenvalerate, tebuthiuron, three surfactants and marine for 1,1,2-TCE and chlorpyrifos.

* = *High reliability* figure for esfenvalerate derived from mesocosm NOEC data (no alternative protection levels available).

A = Figure may not protect key test species from acute toxicity (and chronic) — check Section 8.3.7 for spread of data and its significance. 'A' indicates that trigger value > acute toxicity figure; note that trigger value should be <1/3 of acute figure (Section 8.3.4.4).

B = Chemicals for which possible bioaccumulation and secondary poisoning effects should be considered (see Sections 8.3.3.4 and 8.3.5.7).

C = Figure may not protect key test species from chronic toxicity (this refers to experimental chronic figures or geometric mean for species) — check Section 8.3.7 for spread of data and its significance. Where grey shading and 'C' coincide, refer to text in Section 8.3.7.

D = Ammonia as TOTAL ammonia as [NH_3-N] at pH 8. For changes in trigger value with pH refer to Section 8.3.7.2.

E = Chlorine as total chlorine, as [Cl]; see Section 8.3.7.2.

F = Cyanide as un-ionised HCN, measured as [CN]; see Section 8.3.7.2.

G = Sulfide as un-ionised H_2S, measured as [S]; see Section 8.3.7.2.

H = Chemicals for which algorithms have been provided in table 3.4.3 to account for the effects of hardness. The values have been calculated using a hardness of 30 mg/L $CaCO_3$. These should be adjusted to the site-specific hardness (see Section 3.4.3).

J = Figures protect against toxicity and do not relate to eutrophication issues. Refer to Section 3.3 if eutrophication is the issue of concern.

ID = Insufficient data to derive a reliable trigger value. Users advised to check if a low reliability value or an ECL is given in Section 8.3.7.

T = Tainting or flavour impairment of fish flesh may possibly occur at concentrations below the trigger value. See Sections 4.4.5.3/3 and 8.3.7.

Appendix D: Summary of Interviews

Geoff Conway, Project Officer, Operations Department, CFA
20 March 2002
3:30 p.m.

We interviewed Geoff Conway, a Project Officer in the Operations Department of CFA. Mr. Conway is the officer in charge of redeveloping the Standard Operating Procedures (SOPs) for CFA, so we wanted to talk to him to find out if CFA has any SOPs currently in place regarding firewater runoff. Mr. Conway informed us that currently there are no SOPs that even suggest what firewater runoff is. The team that is creating the SOPs sent out evaluation sheets to all CFA departments to see what CFA employees thought needed to be changed. One of the questions on the evaluation sheet asked what each employee thought the CFA should do to take better care of the environment. They received several answers regarding firewater runoff. This caused the team to realise a need for research in firewater runoff, thus a WPI team was asked to take on this project. This caused the interview to become more of a meeting about what we could do to help Mr. Conway out.

Mr. Conway asked us to create a set of recommendations for minimising the potential environmental impact of firewater runoff that he can use to write a checklist that the chief officer on duty could use at the scene of a fire. He was able to tell us that the biggest problem we have to consider in making recommendations is human resources. Often, fire brigades do not have the manpower or the practise to think about anything else but putting out the fire. It will be difficult for the fire-fighters to change the way they have been putting out fires all their lives.

Neil Bibby, Director, Community Safety, CFA
17 April 2002
4:00 p.m.

We interviewed Neil Bibby, the director of Community Safety at CFA. Mr. Bibby was once a fire-fighter as well, so we were able to get information from both the executive and the brigade side of fire services. Since Mr. Bibby was integral in setting up the WPI projects, he was already familiar with our project. We had many options for a possible solution to the runoff problem, and we wanted his experienced advice on these methods.

We gave detailed explanations of the possible firewater runoff minimisation methods to be taken by the fire-fighters on scene. These methods would occur either inside or outside the facility. For a detailed description of our possible methods, refer to the Data Presentation and Analysis section. We explained the benefits and drawbacks that we saw involved with these methods, such as a lack of personnel and fire-fighter safety. He told us that he agreed with the possible drawbacks, and he suggested these methods only be used as a contingency plan. He told us a story about a time during his fire-fighting days when drains had to be blocked with sandbags. Each method should be different for each individual site and should be decided upon in pre-incident planning.

We asked Mr. Bibby how much pre-incident planning was currently being performed by CFA. He responded, "Not enough." He stated that there was no consistent method for the CFA; the amount of pre-incident planning varies from region to region. He gave us a contact for more detailed information on the subject. He agreed with us on the importance of pre-incident planning in controlling firewater runoff.

We told him of our plan of developing a checklist for fire-fighters to use at a scene of an emergency. This checklist would help fire-fighters understand the conditions under which the EPA should be called. He told us this would be easy in a black-and-white situation where it is obvious that EPA should or should not be called. He suggested that fire-fighters actually go in and test the contained runoff for toxicity. That way, it will be easier to know when the EPA should be called, and when the EPA is called, the brigades will be able to offer more information. We asked him if fire brigades would have the proper mindset for that operation. He told us that they would need a culture change. We explained our idea for a training program for fire-fighters in the environmental impacts of their fire suppression activities. He told us that we have exceeded his expectations for this project.

Greg Allen, Administrative Officer, Community Safety, CFA
Chris Mason, Senior Dangerous Goods Consultant, CFA
12 March 2002

We interviewed Greg Allen, an Administrative Officer in the Community Safety division of CFA, and Chris Mason, the Senior Dangerous Goods Consultant in the Community Safety division of CFA, on the first day of our project in order to understand the scope of what we are dealing with. They both have expertise in dealing with Dangerous Goods. They informed us that many facilities that store or use hazardous chemicals have bunding in place that will hold the chemical if there is a spill, but they are not designed to hold firewater runoff. During a fire, containment is CFA's responsibility through the assistance of the EPA. The EPA generally reacts to accidents; they do not have any preventative measures or regulations in place.

Mr. Allen and Mr. Mason stated that it is important for chemicals to be classified. When fire-fighters on a scene do not understand what chemicals they are dealing with, they will not know what to do about the firewater runoff. In addition, regulations that are in place for potential fire sites are not enforced well enough by police officers. Mr. Allen and Mr. Mason estimated a five percent compliance rate with current chemical regulations by potential fire sites.

Mark Potter, Statutory Compliance Officer, Westernport Area, CFA
18 April 2002
10:30 a.m.

We interviewed Mark Potter, a Statutory Compliance Officer at CFA's Dandenong Headquarters. We explained the nature of our project to him and the risk assessment of different structures that we are performing. He told us that residential fires usually provide their own containment within their yard. He then informed us that fire-fighters do not usually think of firewater runoff. They think that the bigger the fire is, the more water is needed to put it out. They do not stop to think of different strategies they could use to extinguish the fire with as little damage to the environment as possible.

We asked Mr. Potter how much pre-incident planning was performed by CFA. He said it varies from brigade to brigade, but generally, there is not enough performed. There is a lack of personnel to ensure compliance with dangerous goods sites. Frankston does not have many dangerous goods sites in which pre-incident planning is required. The Dandenong office is responsible for checking seven dangerous goods sites. They visit them periodically to ensure that they are following regulations. We asked Mr. Potter if the compliance rate of dangerous goods sites is high, and he said no. He explained that dangerous goods regulations have recently changed. The past regulations described exactly what should be done when a specific amount of a specific chemical is stored at a site. The new regulations are performance-based; they describe a certain level of safety to be achieved. How to meet this safety standard is up to the owner of the property.

Mr. Potter told us that Dandenong has two levels of preplanning. The first level is very detailed, specifically for dangerous goods sites described above. The second level consists of information sheets for individual brigades. Fire-fighters bring these sheets to facilities that they have deemed to be potentially dangerous. In general, however, fire services have not addressed the problem of firewater beyond dangerous goods.

We asked Mr. Potter, a volunteer fire-fighter, his opinion on the practicality of fire-fighters at a scene testing firewater runoff for toxicity before calling the EPA. He thought it was a very good idea as long as the process is simple and easy to learn. He felt it could be very beneficial for CFA and the EPA. The fire-fighters have never been told when they should call the EPA. Mr. Potter told us that when industries want to build a facility in the Dandenong area, he has to review an application first. He thought it would be useful if containment systems were required right away.

Fire-fighter group interview
Phil Charles, Captain, Frankston Fire Brigade, CFA
Greg Allisey, Captain, Frankston Fire Brigafe, CFA
Firefighters, D Shift, Frankston Fire Brigade, CFA
2 April 2002
12:00 p.m.

We explained the purpose of our project to the CFA fire brigade in Frankston, and we told them we were trying to focus on how the fire service team can minimise any potential impact on the environment from structural firewater runoff. They informed us that in general, when they arrive at a fire, their minds are focusing on one thing: putting out the fire, they ca not do two jobs at once. In some cases, they will try to limit the amount of water that they spray on the fire, but in the majority of fires, they do not think about water runoff at all. In house and car fires, which are the most common for them, they generally have little to no firewater runoff.

A few different structures were mentioned that may potentially impact local water resources, such as a dry cleaners, an office building, or a paint store. Large factories could potentially pose a threat, but is a very small amount of large structural fires in the area. They do not check facilities beforehand for any containment systems, but they stated that many facilities do not have containment systems of any kind. Any water runoff from a structural fire in the area would flow into a creek such as Kanakook or Sweetwater and then into Port Phillip Bay. Once in the bay, they guessed it would be diluted.

The use of fire retardant foams has caused problems for the fire brigade in the past. While training volunteer fire-fighters using the foam, The Environment Protection Authority (EPA) Victoria has called to tell the brigade that they are polluting the creeks. Generally, the fire-fighters do not recognise that they are polluting the environment until it is too late. At that point, EPA Victoria will come, and it is out of the fire-fighters' hands; they do not think about it after that.

The fire-fighters asked us if we had any ideas for minimising the potential impact of structural firewater runoff on water resources. We informed them that in other areas such as the Metropolitan Fire Brigade (MFB) district, fire-fighters have been able to block drainage systems so that firewater runoff did not go into water resources. The Frankston brigade told us that they did not have the personnel nor the equipment for blocking drainage systems. They do not know how to control the water runoff. One fire-fighter stated it would almost be better if a representative from EPA Victoria came with the brigade to the scene because the EPA has expertise, and by the time the EPA gets to the scene now, copious amounts of water have already been sprayed on the fire, and it may be too late. The worst water runoff is most likely at the when the water is initially sprayed on the fire, before it becomes diluted, and EPA Victoria almost never gets there when that happens.

We also suggested the re-pressurising of sprinkler systems in facilities that are equipped with them. The fire brigade told us that facilities with sprinkler systems in place need a lot less water to put out by fire services, and that they are 99.9 percent protected from firewater runoff.

The fire brigade then began offering suggestions for how to minimise water runoff from structural fire-fighting. They questioned whether there was a device in existence that can suck the water back up once it becomes runoff, then treat it and reuse it They also suggested a tool that can skim the surface of water in the creek during a fire. These methods would probably cost a lot of money, and may or may not be practical. We then suggested that there could be foam or an inflatable device that can block drains. The fire team then determined there should be predefined trigger points in which the control centre can immediately know when the EPA should be notified. The set trigger points would define at which point the EPA should be called in. They could be when certain chemicals are involved, or when a certain amount of water is involved; however, it is difficult for fire-fighters to gauge the amount of water that is being used on a fire. We suggested the use of a flowmeter on the truck, and measuring the amount of time that has gone by; however, that again brings up the problem that there is not enough personnel or equipment to do this job. They concluded by stating if these trigger points could be defined and used, it could be helpful to them in knowing when EPA Victoria should become involved.

Andrew Barratt, Dangerous Goods Project Officer, MFESB
18 March 2002
2:00 p.m.

We interviewed Andrew Barratt, an Operations Officer in the Metropolitan Fire Brigade (MFB). Mr. Barrett has had experience with firewater runoff from structural fires. He visits potential fire sites and evaluates the systems that they have in place for the minimisation of environmental damage due to firewater runoff.

We first asked Mr. Barratt how large of a potential problem contamination from firewater runoff could be. He told us that it could be a "massive" problem, which could potentially cause more damage than the fire itself.

We then asked if there were current MFB SOPs or regulations regarding containment of runoff. He told us that there were "probably not enough," because people do not think about the problem of firewater runoff until it is too late. He gave us the name of two incidents in Melbourne, Butler's Transport and United Transport that had massive fires that caused much damage to the environment. He informed us of his job, which is to visit facilities and look at their emergency plans, and he asks them if they have any procedures in place to control firewater runoff. If they tell him they have bunding, he makes sure that the bunding is large enough to control chemicals plus water runoff, because the water has to go somewhere. In some cases, the facility gives the fire services a telephone number so they can call a counsel to come and block off drains and stop firewater runoff from entering waterways so it can be treated.

Mr. Barratt's job is to get people in fire services and potential fire sites to think about firewater runoff and its potential impacts. He focuses on the preplanning stage, because that is where you can accomplish the most. It is often too late once a fire starts, because obviously, the first thing on a fire-fighter's mind is to put out the fire, and they worry about the runoff afterwards. On occasion, fire-fighters have dug up a garden and shovelled the dirt onto drains in order to plug up the drainage system.

Next, we asked Mr. Barratt what kind of structures might present the biggest hazard to the environment in terms of firewater runoff. He told us that it depends the proximity to drainage systems and the types of chemicals involved. In general a house fire won't cause a large amount of runoff, but if there are harmful chemicals there, it could potentially cause damage. He then told us that there is no trigger for having to call the EPA during a fire; it is up to the officer in charge on the scene.

We asked Mr. Barratt how much water in considered a large amount of water when fighting a fire. He said that nobody has a standard for considering such things, but it might be a good idea to put a flow meter on a fire truck and then time the duration of the fire in order to determine how much water is used to put out a fire. Sprinkler systems that are in use also greatly reduce the amount of water that is needed to put out a fire.

Frank Mitchell, Environmental Education Coordinator, Knowledge Unit, EPA Victoria
Ian Innes-Wardell, Manager, Victorian Stormwater Action Program, EPA Victoria
27 March 2002
11:00 a.m.

We interviewed Frank Mitchell and Ian Innes-Wardell of EPA Victoria. Mr. Mitchell is the Environmental Education Coordinator, and Ian is the Manager of the Victorian Stormwater Action Program. They explained the documents called State Environmental Protection Policies (SEPPs) that outline Victoria's water quality standards. They explained that different water sources are used for different things. Depending on the resource's uses, the level of protection is different. For example, water used for drinking has a higher level of protection than water used for boating. All of this is outlined in the SEPPs.

They told us that although an isolated incident of firewater contamination in a water resource as large as Port Phillip Bay may seem miniscule, the effects of multiple incidents add, and eventually the effect is the same as one huge incident. The impact also depends on the types and quantities of chemicals present. Some chemicals pose a large threat even when very diluted. They informed us that for this reason it is extremely important for businesses to have Dangerous Goods signs on the outside of the building. These signs can tell the EPA whether they need to retain water. There are also other threats from water runoff not necessarily related to the building on fire. For instance, water runoff may wash animal faeces from the surrounding area into waterways and thereby contaminate water sources with E. Coli.

They also informed us that letting the runoff be absorbed by sand is not a safe solution. Although the soil may filter out some hazards, and soil may be easier to collect and treat, chemicals can still sink down through the soil into the groundwater tables below and contaminate water sources that way.

Tania Brodie, Emergency Response Coordinator, Operations Programs, EPA Victoria
Hamish Reid, Project Manager, Operations Directorate, EPA Victoria
28 March 2002
11:00 a.m.

We conducted an interview with Tania Brodie, the Emergency Response Coordinator in Operations Programs at EPA Victoria, and Hamish Reid, a project Manager in the Operations Directorate. They gave us much useful information about EPA's role in managing fire incidents as well as CFA/EPA inter-relations.

Ms. Brodie informed us that if less than sixty litres of hydrocarbons are burned in a fire then CFA does not have to call EPA but it is still up to the officer in charge whether and when EPA is called. They both agreed that in most cases, they feel the EPA is not called soon enough, and by the time they get to the site, a good deal of damage has already been done to the environment.

Ms. Brodie said that even in the case of some house fires she believes that firewater runoff is a more significant problem than most people think. She said that in some cases the EPA might even make the recommendation to let the fire burn rather than deal with the runoff from putting it out. Ultimately, though, it is up to the CFA officer in charge on the scene.

They told us that upon reaching a scene EPA concentrates on containing as much runoff as possible. They do this by stopping leaks and shutting off any valves or drains in place. Once the runoff is contained it is chemically tested. They informed us that if the water needs to be treated it is the responsibility of the property owner to treat it and the EPA will give them information about companies that will pickup and treat the water for them.

Ms. Brodie told us that these incidents must really be handled individually because any actions will depend on the types and quantities of chemicals present.

Different chemicals need different amounts of water to dilute them. EPA uses Material Safety Data Sheets (MSDS) and a SACS book to determine this information in the field. They also get information from the company. Both Ms. Brodie and Mr. Reid agreed that it helps quite a bit when these companies consider the toxicity and dilution needs of chemicals during pre-incident planning. They also told us that any information the fire brigade can give them about chemicals, quantities of water used, or any other factor involved in the incident can help the EPA deal with the situation.

Ms. Brodie informed us that the impact of letting runoff soak into the ground depends on the chemicals as well. If the chemicals will stick to the soil then, it may be easier to collect the soil and treat it than to contain runoff. If the chemicals will soak through to the ground water table then it is not helpful at all to let the water soak into the ground.

They told us that water runoff usually produces a localized impact, especially where the creek enters the bay. As it spreads, there is a great amount of dilution. This means that as it travels out further in the bay the potential impact is lower. Still, the localized impact near the mouth of the creek is potentially very large so it is important to stop it before it enters the bay as well as possible. When it goes into the bay, it can have a tendency to hug the coastline, which means there could be more localized impacts along the coast. We must also consider the localized impact in the creek.

According to Ms. Brodie and Mr. Reid, environmental impact depends a lot on the water resource being contaminated. Many factors affect the impact from the size of the resource to whether or not it is still or moving water to whether it is an isolated resource like a lake or a connected one like a river. Another important thing to consider is whether or not the resource is being used by humans.

They said that fire-fighting foams are a definite issue since they are quite toxic. Ms. Brodie said that she had heard of a foam that was less toxic than most but did not have any real information about it. They stressed that it is important for fire brigades to contain any foam they use since letting it flow away with runoff could be extremely damaging.

The following is a list of questions provided by Tania Brodie during a later correspondence on 17 April 2002, regarding information that the EPA would like to know when called by brigades.

Has EPA been notified?
Is EPA attendance required?
The location of the incident?
What time did the incident start?
What material is involved?
What are the characteristics of the material eg. volatile? Water soluble?
What volume/weight of material is involved?
Is there any section of the environment being effected, or under threat?
Are there storm water drains nearby?
Are there waterways nearby?
Has there been any containment or clean up already conducted by the fire services and/or company?
In the case of a leak, has the leak been stopped?
If the spill has entered the drain, has the drain been blocked to prevent the pollution spreading?
What are the responsible party details)ie. contact name and number of a representative of the company involved, or of the driver, etc.)
Have of other relevant agencies/authorities been contacted (eg. Local council, VicRoads) that can provide assistance in containment/clean up?
Are there media present?

Andre Mierzwa, Chief Technical Engineering Specialist for Australasia, Field Engineering, FM Global
4 April 2002
11:00 a.m.

We interviewed Andre Mierzwa, an Insurance Representative from FM Global Insurance Company. Mr. Mierzwa showed us specific data sheets that his company requires of clients, which house flammable chemicals. These data sheets explain in detail how to store and provide containment for these chemicals in the event of a fire. The goal of these sheets is to protect as much of the building as possible by storing these containers far enough away from each other so that if one tank sets on fire, the others will not. In this way, these data sheets only give specific information pertaining to the risk of a fire, not risk to the environment from a fire. There are no policies that cover the risk to the environment. Within FM Global's internal files not released for public use is a reference to environmental policies in other countries to offer a "heads up" to FM Global representatives that damage from firewater runoff can occur.

Mr. Mierzwa then offered us some of his personal experiences with environmental damage from structural fire-fighting, since he visits fire sites on a semi-regular basis. He stated that he could not remember any small facilities that caused a large environmental issue, but any fire sites create a sludge on the ground and water simply from the ash. He stated that the problem with firewater runoff is that the fire brigades do not perform any pre-incident planning. They should know exactly what sorts of chemicals are stored at the site and how to handle them. While his company recommends their clients meet with fire brigades to discuss preplanning, he stated that very few actually do. He also stated that the MFESB performs more preplanning than the CFA does, and that it should be the CFA's responsibility to perform evaluations and examine each site's emergency plans.

Noel Skehan, Infrastructure Planning Officer, Infrastructure Planning, Frankston City Council
10 April 2002
2:00 pm

We interviewed Noel Skehan, the Infrastructure Planning Officer of the Frankston City Council. Mr. Skehan informed us that the Frankston City Council is notified whenever there is an emergency in Frankston. The Council has created an emergency plan, and CFA has a copy of this plan. This plan explains the procedures the Council undertakes when an emergency occurs. There is no mention of firewater runoff in these plans.

Mr. Skehan showed us a map of the Frankston area and a map of the Frankston drainage system. He showed us water resources such as the Boggy Creek and where they emptied into Port Phillip Bay. We explained our idea of blocking of drainage systems in the event of a fire. Mr. Skehan told us that the drainage systems are too old, and they do not have that capability. It is difficult to manage this because the stormwater drains are managed by gravity. In the past, sandbags have been used to block drains during vehicular chemical spills, but Frankston has not seen a major pollution event.

He suggested that CFA perform a precinct-by-precinct pre-incident plan. He stated that there are priorities within Frankston in terms of structural risk. Frankston has GIS maps, and they recommend CFA use GIS to find high-risk cases for accidents. GIS would be used to map out industrial areas that are near water resources.

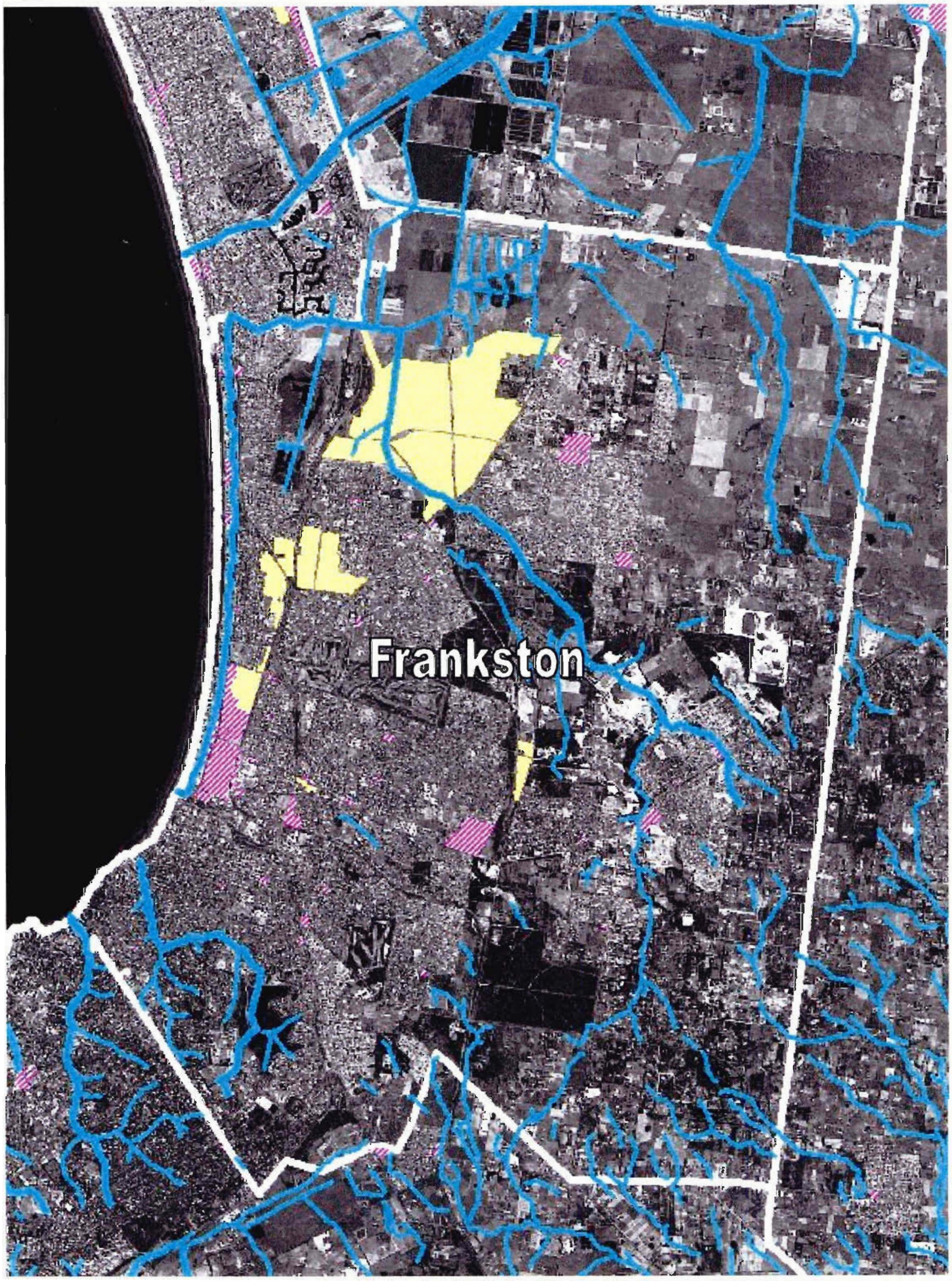
They suggested we talk to Melbourne Water, which is the main drainage authority in Frankston. They are the authorities that come to a scene with the EPA to discuss consequences of a fire incident.

Dr. Jonathan Barnett, Professor, Fire Protection Engineering, Worcester Polytechnic Institute
17 March 2002
10:00 am

We interviewed Dr. Jonathan Barnett of the WPI Fire Protection Engineering Department. Dr. Barnett is the co-director of the Melbourne Project Centre, and he is familiar with Country Fire Authority. We explained how the focus of our project has changed from the point of view of potential fire sites to CFA's abilities to reduce contamination from runoff. Dr. Barnett gave us several topics to think about, such as sprinkler systems, containment inside of structures, case studies, and a cost-benefit analysis. He explained that it is necessary to have a way to distinguish between large and small amounts of water if we want to distinguish between large and small fires. He encouraged us to quantify as many things as possible and to give benchmarks.

Dr. Barnett gave us several contacts from which we learned information about the problem of firewater runoff. He told us to contact a member of FM Global Insurance Company. The insurance representative explained what is required of potential fire sites for minimisation of runoff. He also obtained contacts for us at the EPA. Dr. Barnett told us that this could be an important project if we put in a large amount of work.

Appendix E: Map of Frankston Area



Legend

Figure E.1. Map of Frankston Area

Rivers	
Industrial Zone	
Commercial Zone	

Appendix F: Social Implications of this Project

This project has the potential to have a large impact upon society. There has not been an abundance of research conducted in the past regarding the potential environmental impacts of structural firewater runoff. Most of today's society is not even aware that this contamination can occur. However, contamination from firewater runoff can cause damage anywhere in the world (Fowles, 2001). Contaminated water sources can lead to damage to aquatic life, such as the fish that humans consume. Firewater runoff contamination may also lead to pollution of human drinking water, which will have a large impact upon society. Fires can occur in every community, and the more aware the public is concerning fire-fighting techniques and the environmental impact of fire suppression, the more protected one will be from the effects of fires. When a structural fire occurs, many individuals assume that the problem is over once the blaze is extinguished. As stated in this paper, it is important that society is knowledgeable of the risk associated with firewater runoff before a fire occurs so as to minimise contamination of aquatic ecosystems.

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