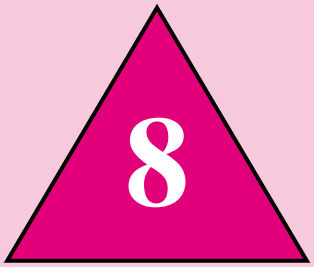



# SUPPRESSION TACTICS AND TECHNIQUES

# 8. SUPPRESSION TACTICS AND TECHNIQUES

## 8.1 General

Suppression means all the procedures which start on, or after the fire alarm. The main objective of the suppression activities is to extinguish the fire. Suppression procedures can be divided into two main parts, suppression tactics and suppression techniques. Sometimes it is difficult to separate these two main parts of the suppression procedures. In practice the tactics and the techniques must go 'hand in hand'.

### Definition of terms

**Tactics** - A method of skilful procedure according to plans, using manpower and equipment in the right place and at the right time. Tactical ideas involve large forces. It is necessary for tactics to be flexible within the fire situation. Quick and effective use of information from fire scouting is the basis of tactics.

**Technique** - The knowledge of the technical methods used in different fire situations. Knowledge and use of the different tools, equipment, and extinguishing techniques.

**Fireline** - The line around an actual fire that is cleared by men or machines. It does not include live barriers. The fireline, or the line, is usually built by removing all the vegetation and burnable material from the top of the ground so that the mineral soil is exposed. The line may also be made by using a water spray to wet the fuel in a strip of adequate width in those areas such as grass, crops, short brush, leaves, needles, and weeds.

The required clearing width of the line will depend on the kind of vegetation, the topography, the burning conditions, and the location in relation to the spread; that is, along the flanks or in front of the fire. The line may vary in width from an ordinary narrow cattle trail in light grass, to several bulldozer blades wide in a tall timber forest.

The fireline (in the soil), normally about half a metre wide, is usually made with hand tools, unless bulldozers, scrapper blades, ploughs, or other suitable earth moving equipment is available. Water spraying is most effective in light flashy fuels where the topography is such that the pumps can be driven along the burning edge. In all these cases the main objective is to keep the fire inside the fireline until control is certain.

The main meaning of the term 'fireline' is - an obstruction line built during a fire in order to encircle it.

Sometimes, the fuelbreaks which are prepared inside the protected forest before the fire danger season are also called 'firelines'.

**Natural barrier** - Any area within a forest where a lack of non-flammable material obstructs the spread of forest fires.

**Control line** - A comprehensive term for all fire barriers and treated fire edges used to control a fire. It includes natural barriers and hand or machine built lines that totally encircle the fire area.

**Fuelbreak** - Generally a 20 - 300 m wide strip of land on which the natural vegetation has been permanently modified so that fires burning into it can be more readily controlled. Some fuelbreaks contain other narrow firebreaks such as roads or hand-constructed lines. During a fire these firebreaks can quickly be widened, either with hand tools or by firing-out. Fuelbreaks have the advantage of preventing soil erosion, offering a safe place for the firefighters to work from and giving low maintenance costs and a pleasing appearance. Preparing fuelbreaks is part of the pre-suppression operations.

**Fire-break** - Any natural or constructed line which removes the fuelbase in order to separate and stop the spread of the fire, or to provide a control line from which to suppress the fire.

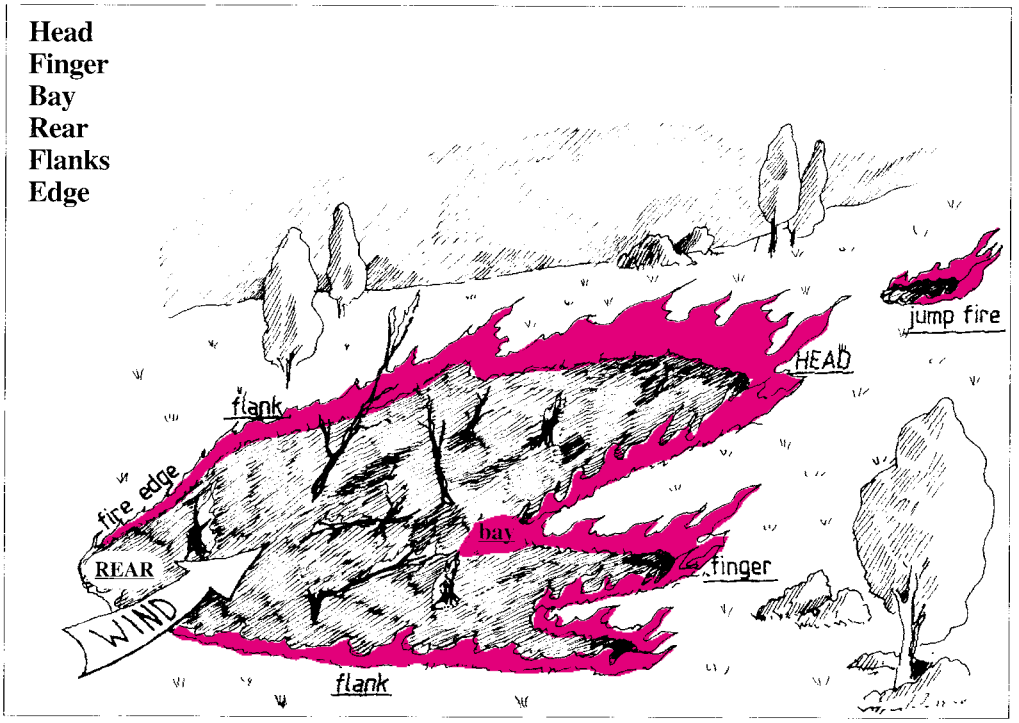
**Backfire** - A fire that is deliberately started along the inner edge of a control line in order to consume the fuels in the path of a forest fire, and/or to change the direction of the fire.

**Burning-out** - Also called firing-out, or clean burning. This means setting fire inside the control line to consume fuel between the edge of the fire and the control line.

**Backburn** - Any prescribed fire burning against the wind.

**Backing fire** - Generally a fire front spreading against the wind. A fire spreading on level or downward sloping ground with no wind is also called a backing fire. This process is called 'fighting fire with fire', and requires a control line around the intentionally burnt area so that the set fire can be controlled.

**Parts of a wildfire** - As illustrated in section 5.7 of this book the part of a wildfire are as follows:



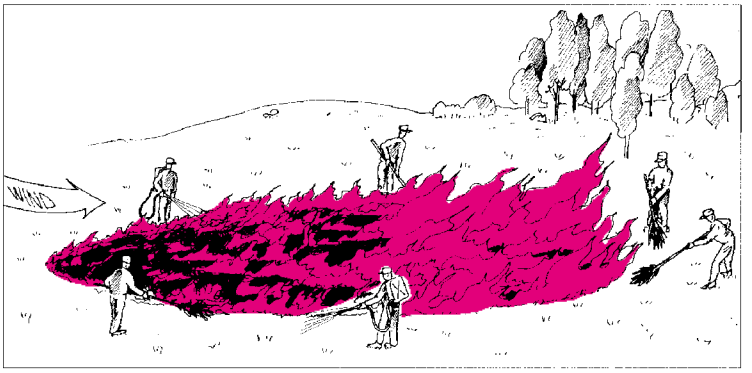
## 8.2 Phases of Wildfire Suppression

During every wildfire there are generally three phases of suppression action, especially in large fires. In small fires these three phases go on at the same time.

The three phases are:

**Phase (i) - Attack**

- Cut-off and / or restrict the fire.

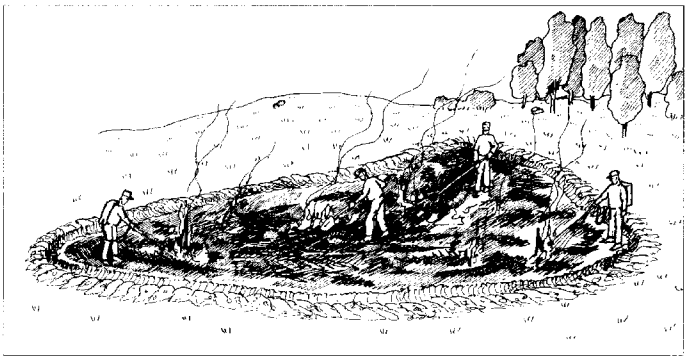



**Phase (ii) - Encircle**

- Surrounding the fire with the control line.

**Phase (iii) - Mopping-up**

- Mopping-up the fire.



In phase (i) a lot of knowledge is needed about fire suppression tactics.

In phases (ii) and (iii) a knowledge of fire suppression techniques is required.

In phase (iii) enough equipment and effective patrolling are required.

## 8.3 Tactics

### 8.3.1 Rule of thumb tactics

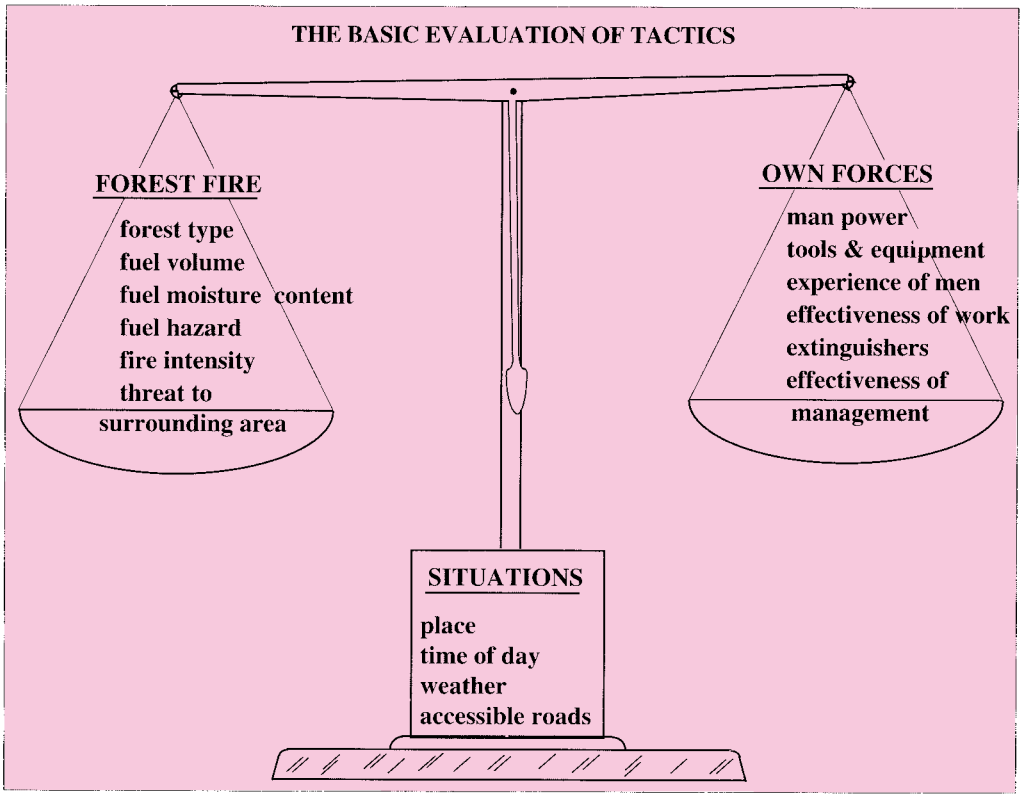
- Clear up all situations yourself.
- Use mainly simple methods.
- Try for the best results using the forces available at hand.
- The fire suppression forces should be concentrated on the most critical points.
- Continuous scouting and follow-up suppression work must be carried out.
- Prepare at all times for quick action on a critical area.
- Learn to use the weather and the terrain successfully.
- Management should continuously plan to prevent further outbreaks of fire.

### 8.3.2 Basic rules of fire suppression tactics

The basic rules for fire suppression tactics are:

(i) Ward off the greatest threats first.
(ii) Cut off the fire at the place where the threat of spreading is greatest.
(iii) Surround the fire area.
(iv) Take care to avoid accidents.

In the basic plan for starting fire suppression tactics the fire chief should continually think of the tactics as being a balancing act.



### 8.3.3 Sizing-up

**Size-up** is the evaluation and estimation of a fire by the officer in charge to determine a course of action for suppression of the fire. It is the first action upon arrival at the fire.

Actually, the sizing-up begins on the way to the fire, as soon as the smoke is seen and the location determined.

Size-up is the estimation of the conditions so as to arrive at an opinion. It is a continuous action through an ever-changing situation. It is a constant process which starts from the time the alarm is received to the time the fire is completely under control. Wildfire control is largely a process of problem solving and decision making.

First of all, the problems must be analysed by taking into consideration all the facts and conditions that can be seen or determined.

Secondly, on the basis of the analysis and the expected fire behaviour, a course of action must be formed to control the fire.

Thirdly, instructions must be given to those who will do the control work.

Fourthly, follow-up operations are necessary to make sure that the correct action has been taken.

Scouting of the fire and its immediate surroundings is necessary in order to gain an appreciation of the situation. If the fire is relatively small the appraisal can be done in a short time, on the way to the fire or while the fire crews are unloading. Later on, as more information is gained it may be necessary to change the plan. If the fire is larger than the initial attack-crew can handle work must start on those locations where most loss can be avoided, or where the spread can be checked. If reinforcements are necessary, make the request as soon as possible so that they will arrive in time to be the most effective.

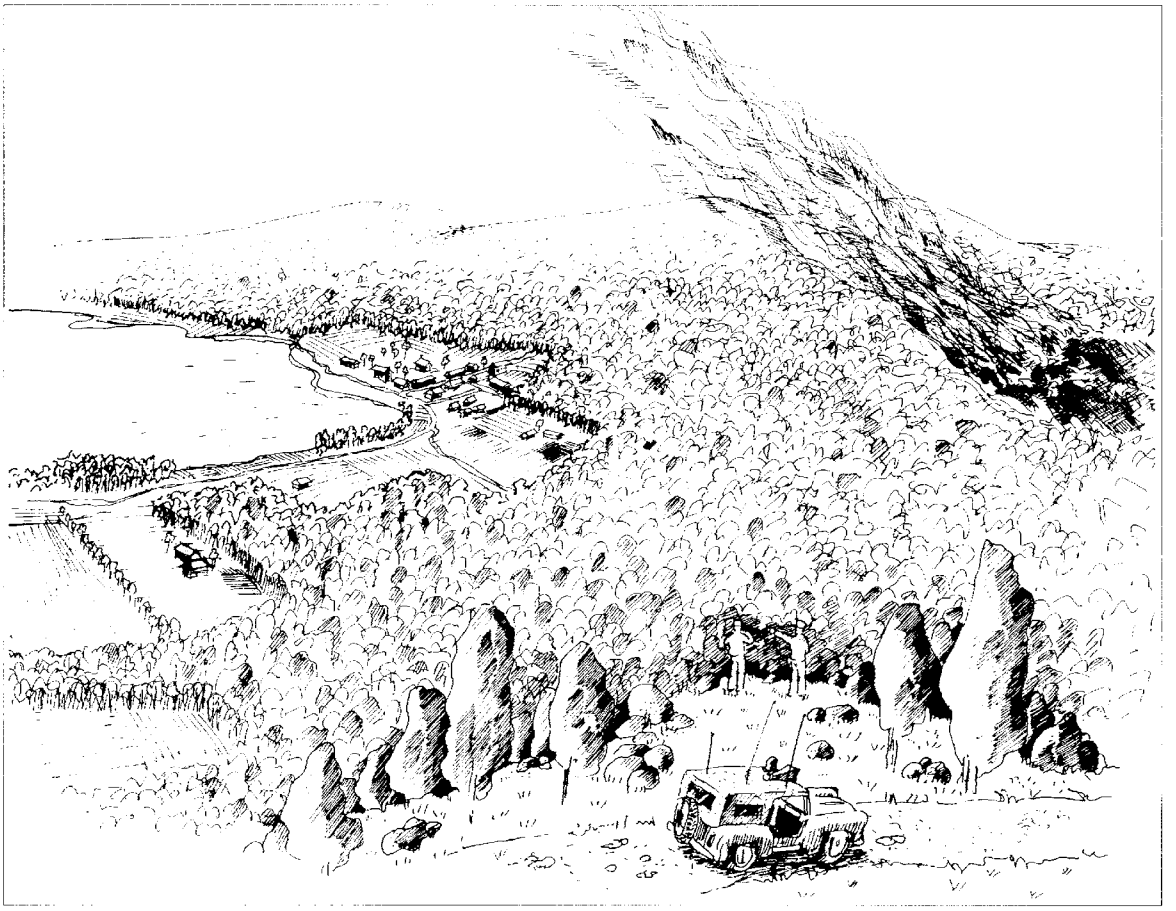
Sizing-up the situation is of great importance because it provides essential information and develops a definite plan of action for effective control. Without a reasonable size-up the attack may be completely ineffective.

Knowledge of fire behaviour is a basic requirement when sizing-up. If someone has a lot of experience of forest fires and fire behaviour they are able to make an accurate and prompt size-up. They must analyse the fuel, weather, and topography, and how they will affect the behaviour of the fire.

The following are important points when sizing-up the fire itself:

(i) Analysis of the fire.
(ii) Fire location.
(iii) Safety (hazards to life).
(iv) Resources available.
(v) Calculation of probabilities.
(vi) Plan and execution of control.

### 8.3.4 Analysis of the fire



The following questions on the behaviour of the fire should be answered:

- What is the direction of spread?
- Is the wind steady, or gusty and changeable?
- What is the shape of the fire area, its size, and its length?
- How intense is the burning and rate of spread?
- Are there fingers or danger spots that need immediate attention?
- Judging from the smoke, what is the direction and the speed of the wind?
- What is the fire weather forecast?
- Is the fire starting or slowing down? White or grey coloured smoke will indicate this.
- What kind of fuel is adjacent to the burning area, and ahead of it?
- Are sparks causing spot fires?
- Can anything be done to stop the spot fires?
- What is the main fuel and how does it burn?
- What is the topography?
- How will it affect the spread of the fire?
- Where is there access to the fire edge?
- How many natural barriers can be used?
- What length is the perimeter of the fire estimated to be?

### 8.3.5 Safety (hazards to life)

Hazards to life are the first priority in any fire. If buildings are threatened with fire, or if it can threaten to spread to buildings, they have to be evacuated. It must be checked whether there are any other areas where there could be a fire hazard, such as a camping site. Also, any hazards to the firemen, such as steep slopes, blind areas, rolling rocks, falling snags, and power lines must be checked for.

Furthermore, what additional information is needed? Where should scouting be carried out? What is the intensity and spreading speed of the fire?

### 8.3.6 Threatened property and some tactical advice

After the hazard to life has been determined, property, buildings, non-flammable storage, livestock, and so on have the next highest priority.

If the fire is beginning to start spot fires in the forest, extinguish them and then concentrate on the buildings. Keep a sharp look out for spot fires. If the wildfire is burning in a uniform fuel and at a constant speed towards the property, and if it is probable that it cannot be controlled before reaching the property, concentrate on saving the property.

Prepare a fireline around the buildings facing the fire. The distance will depend on the type of fuel and the effects of heat radiation. If possible, wet down the roof and walls of the buildings just before the first rush of heat reaches them. Consider burning back from the line towards the fire if circumstances are favourable and if the spot fires can be controlled.

### 8.3.6 Resources

The resources available to control the wildfire are an important factor in sizing-up the operation. Before a fire suppression tactical plan is made it must be known:

- How many firefighters are available for assignment?
- What kind and amount of equipment is in use, or can be assigned?
- Accessibility of the fire and the condition of the roads?
- How many and what type of reserves are available, and when can they be expected?
- What is the time of day and expected diurnal changes in relation to the size of the fire suppression work?
- What are the natural barriers and sources of water that can be used?
- What communications are available?
- Are maps or aerial photographs available on which to plot the fire and control strategy?
- What are the environmental considerations?

### 8.3.8 Situation evaluation (calculation of probability)

There are a variety of methods that can be employed to control a wildfire. To calculate which will be the most effective in a specific situation, the rate of spread must be determined, the type of the fuel must be classified, the size of the fire must be estimated, and the needs of the line control forces must be determined.

The weather, time of day, and time of year are also factors in control planning.

Water is of course the best and most effective control method if it is available and can be applied with reasonable efficiency. In the majority of locations, handtools are the most useful method of building the fireline. The use of handtools is best restricted to daytime use, while machines are best worked at night time. Earth-moving equipment, such as a bulldozer, is very productive, and usually efficient if available and possible to apply. However, earth-moving equipment still has to be followed-up by manual labour and may cause more damage than is justified. Normally, during the daytime, when the fire behaviour is difficult to assess and the fire is spreading rapidly, it is a risk to move any heavy machinery too near to the fire perimeter.

If possible, natural barriers should be used so that manpower and equipment can be applied to those sections where they can be most effective. Use all the forces available to get the situation under control quickly and efficiently.

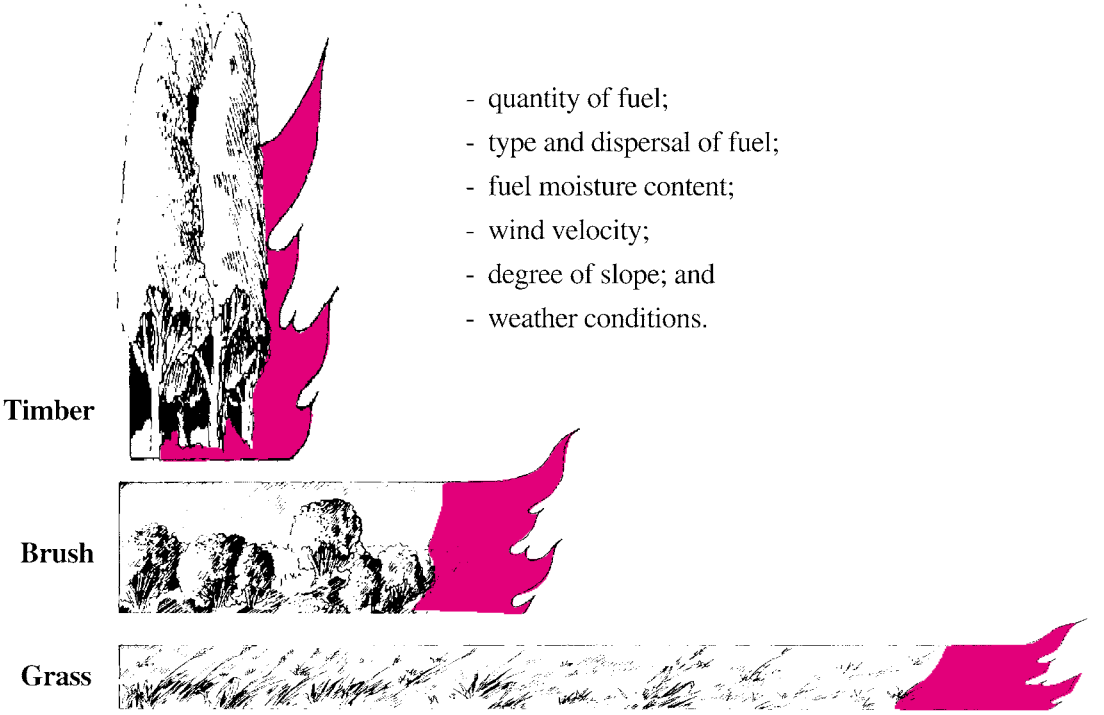
The best advice for any particular area can be obtained from a local forester who is working in the area daily.

One of the most important factors in the evaluation is the estimation of time. At all times, estimations and calculations must be carried out in order to assess the fire fighting progress and the spread of the fire.

### 8.3.9 Rate of spread and height of flame

In some countries, the general rates of spread for different fuel types are classified as low, medium, and high. The rate of spread depends on the:

- quantity of fuel;
- type and dispersal of fuel;
- fuel moisture content;
- wind velocity;
- degree of slope; and
- weather conditions.



### 8.3.10 Size of the fire

If the fire is small, the perimeter can be walked around and an accurate estimate of the area can be made. If the fire is large, the sizing-up should be done by scouting. After the size-up operation you must be able to estimate any increase in change per hour, and at the same time estimate the control time.

### 8.3.11 Priority of control action

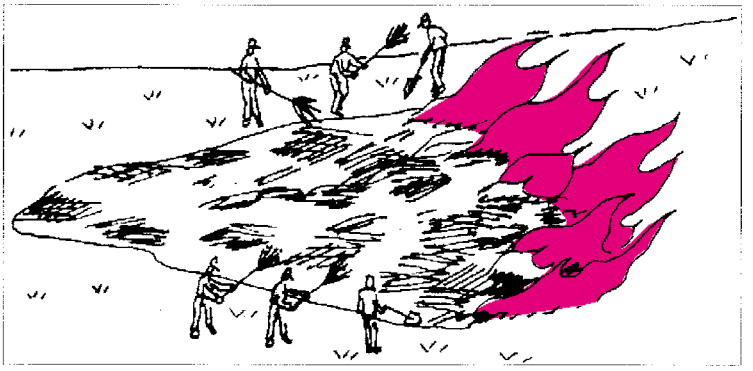
Some factors to be considered when deciding priority action are to:

- evaluate the hazard to life;
- estimate property values;
- estimate the relative value of the ground cover and / or resultant damage;
- cut off the fire from the most dangerous fuels;
- cut off the fire spreading on the head, or try to confine it by surrounding the fire with a fireline;
- make all the work contribute to the final control by becoming part of the final control line or by delaying the spread until the final line location can be built;
- use equipment in areas that are too hot for manpower, or where it can be used effectively;
- provide a line of retreat; and
- estimate the relative cost of control and evaluate any alternative action.

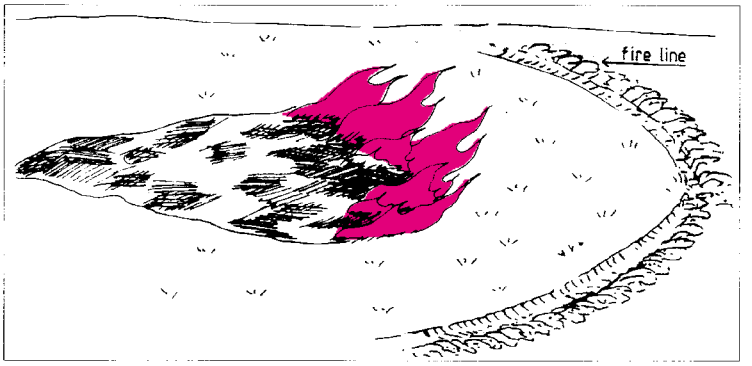
## 8.4 Methods of Attack

There are two basic methods of attack.

**Direct** - fighting the fire itself directly on the edge by using a water spray, throwing soil, using beaters, or building a line down to the mineral soil and throwing the burning edge into the fire, and then widening the line as necessary.

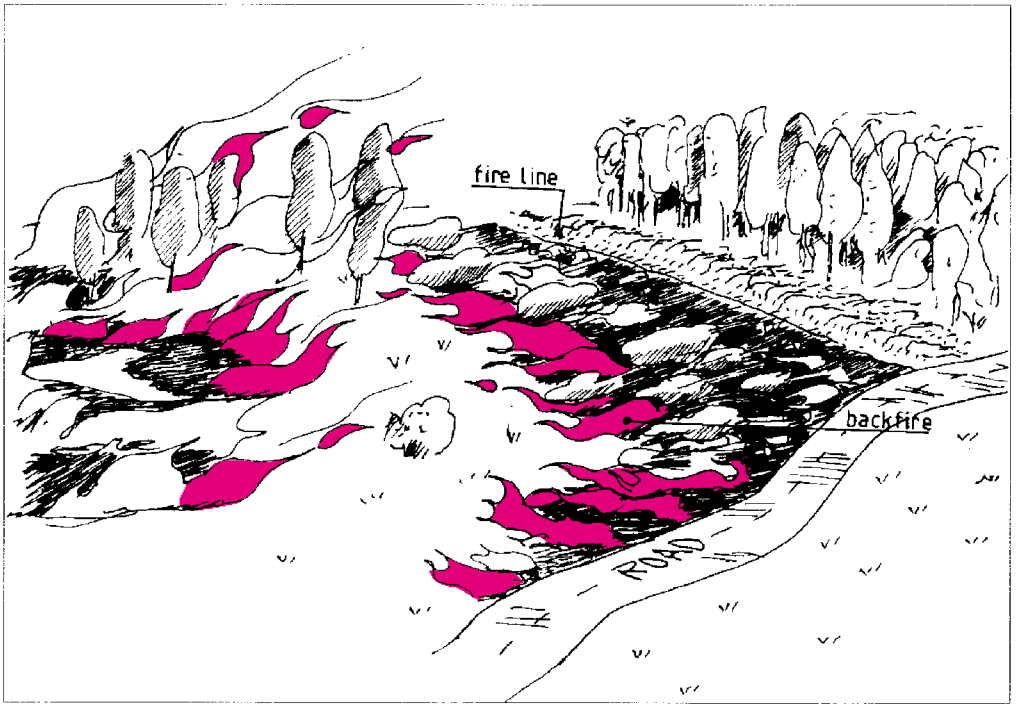


**Indirect** - building a line some distance from the edge of the fire, when the fire is too hot to fight directly.

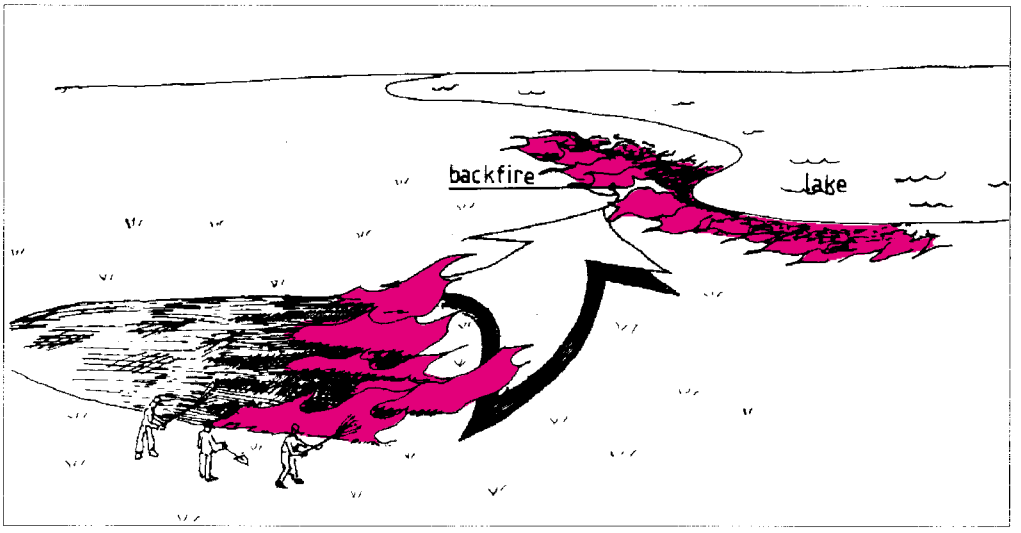


In addition, there are several variations and some combinations of these basic methods.

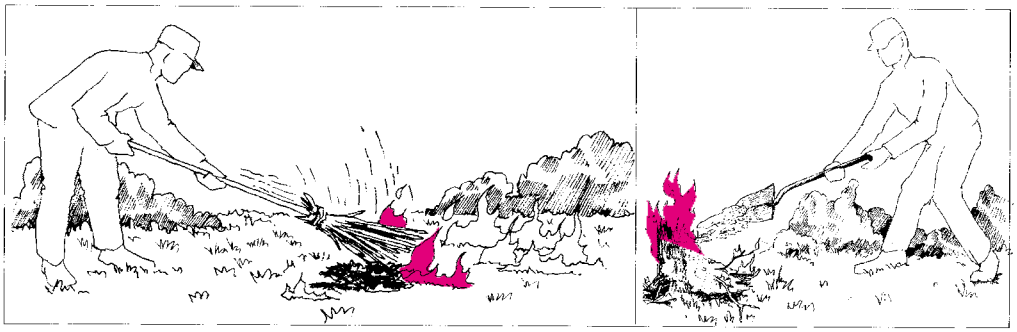
(i) **Fighting fire with fire.** Sometimes called backfiring. Fighting fire with fire is hazardous and complex. It should be used only by experienced fire fighters, and only as a last resort.




(ii) **Moving the direction of spread of the fire.** It is possible to stop the fire at a natural barrier some distance in front of the fire by altering its direction.




(iii) **Drowing the fire.** If the topography of the land permits, make the water source run down and cover the fire. This method is sometimes used on peatland fires.



(iv) **Initial attack.** The initial attack will be done as soon as possible - day or night. The first objective of the initial attack crew is to bring the fire to the state of "being held". With a few exceptions the "kill as you go" technique is not acceptable as the rate of line construction is often much slower than the rate of growth of the perimeter. Only sufficient work is done on the first pass to hold the fire's advance until the crew can return and affect the final control. A succession of passes is usually required before final control is attained.

The overall objective is to bring the fire under control, only mopping-up and patrolling work remaining during the first burning period (before 10 am on the next morning).

### 8.4.1 Direct attack

Direct attack is used mostly on ground or surface fuels, such as grass, brush, duff, underground fires, or on the flanks or rear of large fires. It is also used in the later stages of a large fire, and on any fire where the burning intensity, heat, and smoke are not too much for the fire fighters to work on the fire edge.

Direct attack is commonly used on the head of smaller fires, and on the flanks or rear of large fires where the heat intensity is such that the fire edge cannot be worked directly. It is also used on most grass fires, of any size, where pumps can be applied directly.

If the fire is small, and if the head can be attacked with safety, the control action is applied at the head first. After this both flanks can be attacked from head to rear. When the head is spreading fast and it is unsafe to get in front of it, the best method is to flank the fire on one or both sides. This method is used like a pincer movement, eventually cutting off the head.

The pincer action is normally done on both sides of the flank at the same time. However, sometimes topography, vegetation, or resources will determine that flanking can be carried out on only one side. After the head is cut off, and most of the spreading is stopped on the flanks a secure line must be prepared along the flanks. When this control line is established, mopping-up, spot fire control, and patrolling must be started in order to complete the operation.

### 8.4.2 Indirect attack

With the indirect method the line is located some distance from the fire's edge. How far it is located from the fire is of prime importance. All the factors of fire behaviour must be used in making the decision. Since the intervening material must be burnt out, the line must be located where it will be effective when the fire reaches it. The intervening area must be kept as small as possible so that no more is burnt than is necessary, otherwise the fire can build

up enough to jump the line. The right location can only be decided by experience and judgement.

The line must be wide enough so that the radiant heat developed by the type and amount of fuel inside will not ignite fuels outside the lines.

The primary factors of line locations are the:

- ability and efficiency of the line workers;
- time of day;
- intensity of the burning;
- speed and strength of the wind;
- topography and the degree of slope; and
- vegetation cover.

Since the indirect method is used where the fire edge is too hot to approach directly, it is the method that is most used on large fires and at the head of hot, fast running fires. It is also the method that is most used in the high fire danger classes.

The indirect method is often combined with the direct method in total line construction. The indirect method may be used during the time of day when the fire danger conditions are highest. When the conditions get easier, the attack may return to the direct method.

With the indirect method, the line is built some distance away from the fire's edge.

The main variations of the indirect methods are as follows.

(i) **Surrounding / parallel method**

With this version, the fire line is built about 0,5 - 10m from the fire edge. The distance away from the fire edge will depend on the fuel, the intensity of the fire, and the topography. In some cases the line can be built along one flank. The fire lines must be joined to a secure anchor point, such as a forest road, a stream, lake, or swamp. In any indirect line construction the intervening space between the line and the fire edge should usually be burnt-out to secure the line. This is called burning-out, in contrast to backfiring. Burning-out on the flanks is not nearly as hazardous as burning-out from a line in front of the head of the fire.

Because of the many combinations of conditions, a wide variety of methods are possible with the indirect method of attack.

(ii) **Hot spotting, or point and cut off technique**

This is a combination method that could be used in both the direct and indirect attack. In practice this method means that all the fingers of the fire are attacked first, and also the so called hot spots along the fire's edge by constructing part of the line across those edges that are burning faster.

**Rule of thumb**
The most effective place to stop a fire is at the advancing flame edge.
However this may not be practical or possible in many situations.

### 8.4.3 Burning methods

#### 8.4.3.1 Burning-out or clean burning

Burning-out is one part of line construction. It consists of starting a fire along the inside edge of the control line so that the fuel in the area between the fireline and the fire edge will be burnt.

Pockets and islands should be burnt-out after the line is built so that they do not pose a threat of spreading at a later time. This burning forms a wider barrier to the spreading main fire. The burn-out can be started with a torch, or by pulling burning material along with a rake. If the burn-out is patchy and not complete it may be more hazardous at a later time when burning conditions increase.

On hillsides, the burn-out should start from the top and work downwards.

The burning-out procedure must be determined by:

- The type of fuel, particularly in relation to several storied fuel.
- The ability to obtain a clean burn.

The hazards relevant to clean burning are such things as snags, piles of heavy ground fuels, live trees with branches extending to the ground, and trees covered with moss. These must be removed and broken up.

#### 8.4.3.2 Backfiring

Backfiring is one form of the indirect attack method. This method is normally used against a rapidly spreading fire. Backfiring is the process of intentionally starting a fire inside the fire edge or fire barrier in advance of a fire head, or along the forward flanks.

The person in charge of backfiring must have a lot of fire fighting experience.

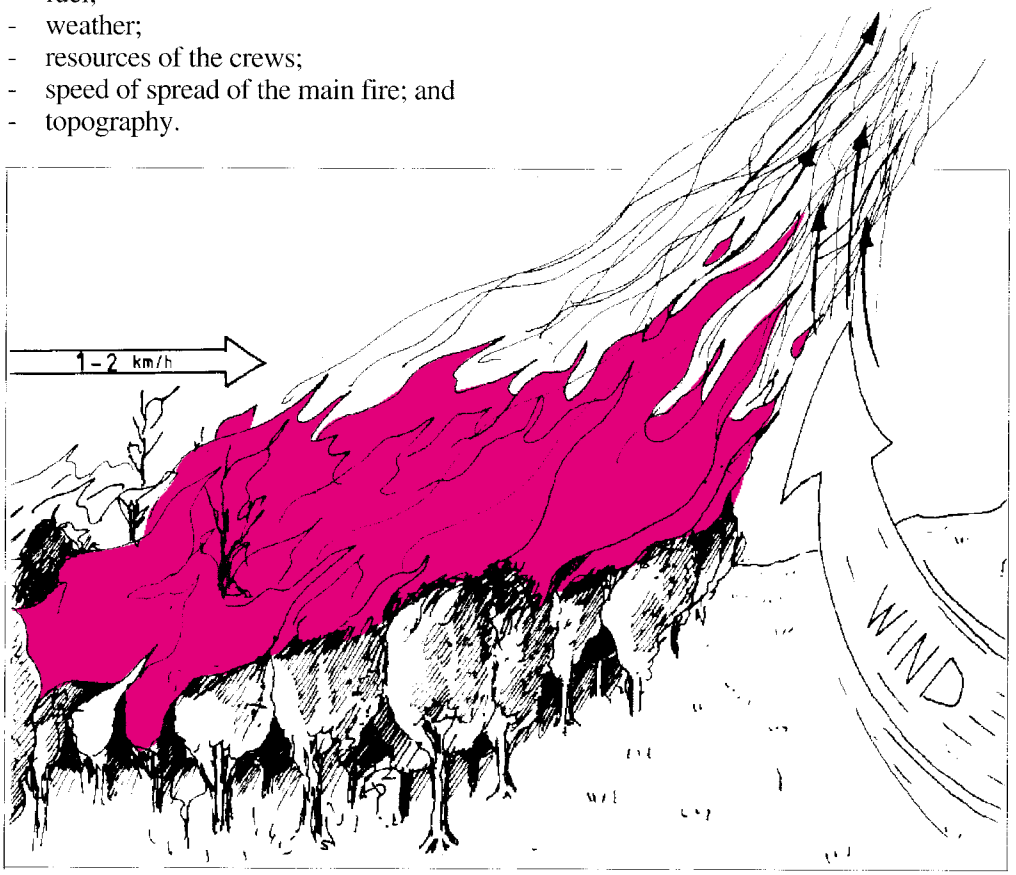
Backfiring means that the area between the control line and the fire head is burnt-out to eliminate all the fuel in front of the fire. This will widen the control line, change the direction of the fire, or slow the progress of the fire in order to gain time for line construction. The backfire is usually started a considerable way in front of the fire head. It is important that the fire that is started can be controlled, and that any spot fires from it can be extinguished quickly. There is no need to use backfire tactics on small or ordinary fires.

Organisation is of great importance. One qualified person must be responsible for controlling and directing the backfiring operation. On small fires the backfiring operation will be done under direct instructions from the fire chief. In large fires, the fire chief would delegate the operation to a qualified crew chief, or sector head of the sector involved. Constant communication between the person in charge and the fire crews is necessary.

In backfiring it is best not to use large crews as it is often difficult to control them.

Timing is another important factor in backfiring. The right time to start the backfire will depend on the:

- fuel;
- weather;
- resources of the crews;
- speed of spread of the main fire; and
- topography.




If backfiring is started too late it could result in an unsatisfactory burn. In large fires the best estimate and location of the backfire would be obtained from an aeroplane or helicopter flying over the area.

## 8.5 Factors Affecting Choice of Attack

Bringing a fire or part of the fire edge under control will depend on a number of factors, which can be determined after scouting the fire. These factors, which are also a check list for the fire chief before the start of planning the suppression tactic, are:

(i) fuel - volume, size, type, arrangement, condition pattern, moisture content;
(ii) topography - degree of slope, and aspect;
(iii) wind - direction, velocity, effect;
(iv) values to be protected - human life, property, natural and recreational, timber;
(v) soil type;

(vi) water sources;
(vii) access to the fire - paths, forest roads, etc;
(viii) available equipment;
(ix) available manpower; and
(x) fire behaviour at the fire site.

## 8.6 Suppression Techniques

Suppression technique means having a good knowledge of the methods of fire suppression together with the experience for selecting the right equipment.

### 8.6.1 The basic methods for extinguishing a fire

It should always be remembered that a fire cannot burn without HEAT, OXYGEN and FUEL in suitable combinations.

The extinguishing of a fire is therefore based on the removal of one or more of the three components represented in the fire triangle.

Extinguishing the fire can be done by:

(i) Cooling - a method of extinguishing where the temperature of the fire is reduced to below the point of ignition. After cooling, the fire will not start by itself. In forest fires, cooling can be done by the application of water, and is called 'cooling the fuel'.

(ii) Smothering - a method of extinguishing where the oxygen is removed from the fire. This can be accomplished in a forest fire by an application of sand or mineral soil, beating with the back of a shovel, or by swatting the fire with a firebeater. The fire is smothered by the sand or soil.

(iii) Starving - a method of extinguishing where inflammable fuel is removed. In a forest the fire can be starved by removing the supply of available fuel, or by allowing it to burn into a natural barrier or fireline.

In a forest just one main method is normally used for extinguishing a fire, although several methods can often be used on the fire at the same time.

### 8.6.2 Equipment and techniques in use

Special information about forest fire equipment is contained in chapter 6.

A short summary of the equipment in use, divided into main groups is:

(i) handtools and equipment for one person;
(ii) large machines and earth-moving equipment;
(iii) water suppression equipment; and
(iv) tools for controlled burning.

In general practice, several tools and pieces of equipment can be used to combat the same fire.

What the best tools, equipment, and techniques are will depend on, among other things:

(i) Type of fuel.
(ii) Topography and situation (water sources).
(iii) Fire intensity.
(iv) Method of attack.
(v) Manpower and experience.

### 8.6.3 Principal techniques for line construction

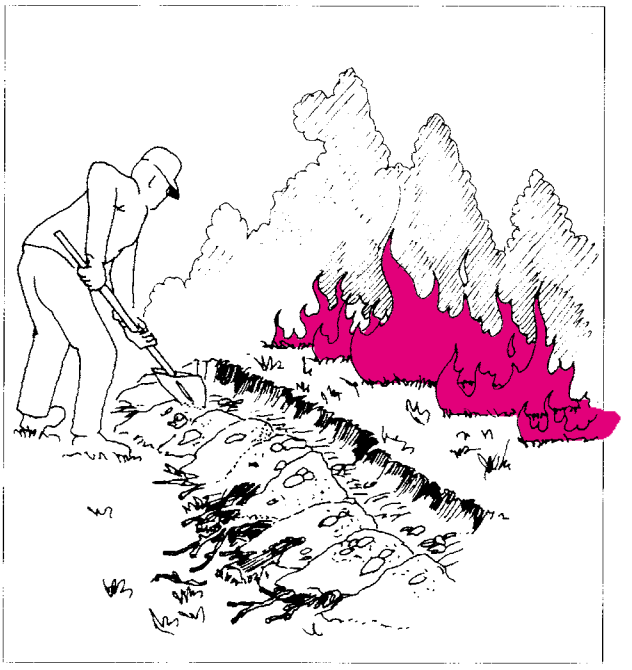
The fireline is constructed by a variety of methods, depending on the fuels involved, the available equipment and manpower, and the terrain.

The four principal techniques for fireline construction are as follows:

(i) By using hand tools only.
(ii) By using earth-moving equipment, which in this text includes bulldozers, trenchers, and ploughs. These must always be followed-up with hand tools, or water pumps where they can be used.
(iii) By applying water from ground tanks, directly from the vehicle (pump and roll), or by laying hose lines. This type of fireline also requires follow-up action with hand tools. Light grass fuels can be mopped-up with just a backpack pump and shovel.
(iv) By aerial application of retardants using helicopters or spray planes, followed up by ground forces using either hand tools, pumps, fire equipment, or any combination of these.

#### 8.6.3.1 Line construction with hand tools

In the majority of wild fire situations, hand tools are the only means of attacking the fire. In some situations, the use of hand tools must be combined with other methods of attack.



The best way of using hand tools has been developed from experience of all kinds of fires throughout the world.

Different organisations may have different kinds of tools and ways of distributing them to the various sections, but the basic methods are the same.

The main hand tools are: axes, shovels, rakehoes, rakes, beaters, saws, and burning-out torches.

The hand tool crews start the line by cutting, fuel dispersal, scraping, burning-out, and holding. Later on their job is mopping-up and patrolling. In some fuels, all these functions are performed by the same crew as it works along the line. In general, the sector head is responsible for pointing out or locating the line.

Some good practices for line location and line construction are as follows:

- Locate the line so as to speed up the work, with the minimum of effort to the crew. Choose the best route for easy and fast construction.
- Avoid heavy fuel areas, and if possible keep them outside the fire area.
- Pick the easiest way through without having too much land under firelines.
- Avoid undercut lines as much as possible. Locate where burning material cannot roll across.
- Generally, try to avoid steep slopes and locate the line just over the top of a ridge rather than across the slope, except under low fire weather conditions or for other suitable reasons.
- When the indirect method is used, locate the line a good distance from the fire edge so that the line can be constructed and burnt-out before the main fire reaches it.
- Always anchor the lines to the best natural barriers, or to any immediately available control point.
- Take advantage of diurnal and predicted fire weather.

Any fuel material that is on fire must be thrown as far inside the line as possible, and must not be scattered. Avoid building up fuel concentrations inside the line.

In general, all the fuel removed from the line must be thrown outside the line, so that when the fire burns on the line the radiant heat will not ignite it. In some cases, the removed fuels may be needed inside the burning-out. In this case, the fuel is thrown inside the line, but avoiding bunches.

**Rule of thumb**

The width of the clearing should be at least half the height of the fuel.
Under some circumstances it may have to be wider.

The width of the line made by hand tools should be from 20 m to 50 m, depending on the fuel material, wind speed, and fire intensity.

The basic phases in line construction are:

(i) line location;
(ii) line clearing - cutting the trees;
(iii) line digging - scraping down to the mineral soil;
(iv) stopping the fire;
(v) burning-out; and
(vi) mopping-up.

### 8.6.3.2 Some special advice for line construction

The clearing of the line, (cutting standing trees and bushes, removing branches and logs) can be done by axe, brush hooks, hand (bow) saws, or power saws.

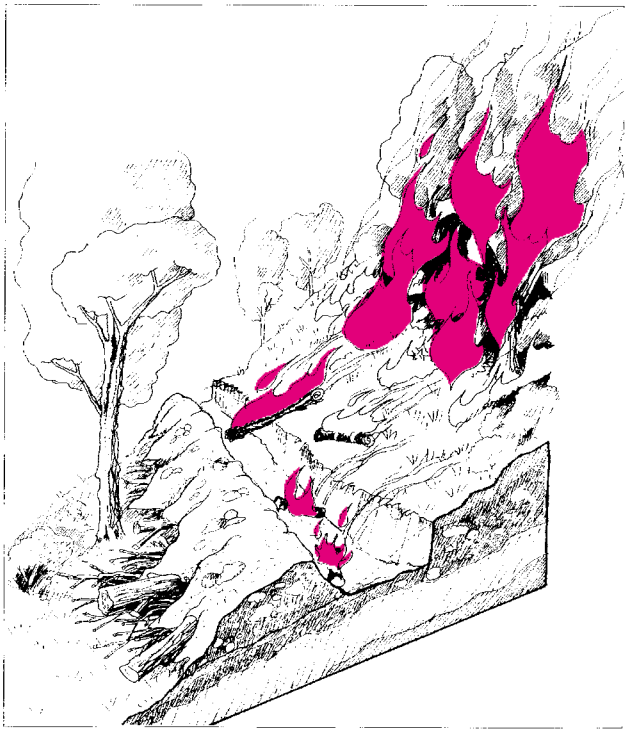
Line digging can be done by using an axe-hoe, hoe, rakehoe, shovel, or rake. The type of tools, or combination of tools, will depend on the type of fuel, amount of rock, and the type of soil. The line must be dug through the humus, right down to the bare mineral soil. All duff, litter, and humus from the digging must be removed to the outside of the line.

Burning-out can be one part of the operation in indirect attack. It is usually a critical operation that requires careful timing. The torchman follows the digging crew and must be ready to start the burning. He is usually assisted by men with shovels or backpack pumps, whose job it is to keep the fire inside the line. If the line is being built up a slope it should be fired downhill, against the line.

Full advantage should be taken of any winds blowing towards the main fire.

**Undercut lines** - where the fire-line must be built horizontally across a slope, and below the fire. It should be built as a trench or ditch to catch any rolling and burning fuel material from above. Pine cones and other pieces of burning material, even logs, often roll downhill as the fire burns around them, thus scattering burning material down the slope. An under cut line should be built as a deep trench that is well banked with earth on the berm and along its entire length.

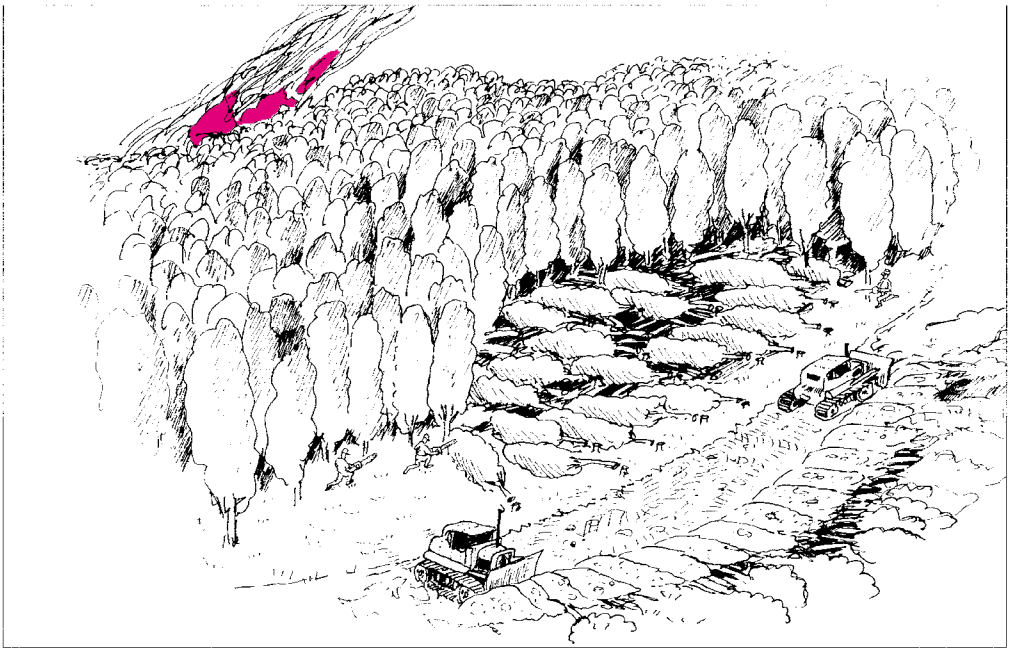
Logs, rocks, and any available material can be used to form the berm, but the surface should be of mineral soil. It should be deep enough to catch and hold any material that may roll into it.



Inflammable fuels outside the fireline which are not burning, such as rotting stumps, logs, and other material can be covered with mineral soil. Stumps and logs shoul be covered with enough soil so as to insulate them, or if possible, they should be wet down.

**Ringing a snag tree** - A snag tree is a standing dead tree, or part of a dead tree, from which the leaves and small branches have fallen. If the snag trees are inside and close to the line, but are not yet burning, and if there is insufficient time to fell them, the trees should be circled with a line and all burnable material removed from inside the ring. The circle should be at least 3 - 4 m in diameter, depending on the type and amount of ground fuel adjacent to it. This action prevents the snag tree from catching fire and throwing sparks across the line.

### 8.6.3.3 Line construction with earth-moving equipment



Bulldozers, fireline ploughs, and other heavy duty earth-moving equipment are extremely effective tools for building firelines, particularly in heavy fuels and brush. They must be followed by hand tools to finish the line, to burn-out where necessary, to hold the fire within the line, and to combat spill-overs and spot fires.

Once the fireline is built, it is necessary to begin the mopping-up from the fire edge towards the centre of the fire. This operation is done with hand tools. Often, if water is available, pumps and hose lines can be used to assist with the holding action and with the mopping-up. However, this will depend on the type and volume of the fuels.

Bulldozers can be used to a limited extent during the mopping-up operations. Very few fire services will have their own bulldozers or other heavy duty equipment. That is why in many countries the fire service has to make a contract with private owners or municipalities for use of the heavy duty equipment during the fire danger season. At the same time it must be checked that it is possible to obtain, when needed, good and experienced operators and mechanics for the equipment.

In addition, the heavy duty equipment requires special transport carriers, such as tilt-bed trucks or a truck and lowbody trailer for delivery of the unit to the fire site. Bulldozers and other heavy duty equipment can be used with success on heavy fuel areas, and where the humus layer is very thick.

A bulldozer line is normally needed in large and intense fires.

In general, experience has shown that it is not safe to use a bulldozer close to the fire edge during daytime hours. During this time the fire can spread so fast, or change direction, that the bulldozer cannot move away from it. The best working hours for heavy duty equipment are in the evening and in early morning when the wind is relatively calm.

Bulldozers - also called dozers, trail builders, and caterpillars - are effective fire fighting tools if they are correctly used. On the other hand, they are costly to operate and require good operators, good supervision, and adequate servicing facilities.

It is said that, in the same fuel type, one bulldozer will do the equivalent work of a crew of forty men. However, in excessively rocky areas and in dense timber stands where there are many large trees, their performance will be drastically reduced. In these areas the bulldozer will need a pioneer working ahead of it, such as a plough or fireline crew.

Locating a fireline across a slope with a bulldozer is not advisable either above or below the fire. Generally, on slopes of above 35% the production of the bulldozer drops off considerably.

A line locator should be assigned to the lead vehicle. He should be physically fit, have a good understanding of fire behaviour, and a good knowledge of the capability and limitations of the bulldozer. In many situations it pays to have a helper accompany the line locator, whose work is to blaze a trail on trees and bushes. The locator should know what is expected ahead and periodically check with the crew or sector head that the progress is on the right track.

Any location where the bulldozer cannot work effectively should be avoided and completed with hand tools. These locations would include areas of large rocks, rocky outcrops, excessively steep terrain, or any other obstacle that limits the use of the bulldozer.

As a general rule, in a bulldozer line all the material should be pushed outside the line, and not in a heavy pile. In all cases the amount and kind of fuel should be left in such a way that hot spots can safely burn-out inside the line without throwing fire over the line.

## Bulldozer line principles

The following points apply to bulldozer line operations:

(i) All unburnt fuels moved by the bulldozer should be pushed away from the fire line and scattered as extensively as possible.

(ii) The bulldozer should work as far away from the burning fire edge as possible, so that it does not pick up any burning material. It should shove any material that it does pick up to the outside of the line. Also, it should work in safety by observing the direction and spread of the fire.

(iii) In fuel types with large timber stands, wind thrown timber, or dry stands, it is best to use power saws ahead of the bulldozer; to cut the material, or break it, so that the bulldozer can easily and quickly move it aside. Usually one, or at the most, two saw cuts are all that are necessary. The route of the line to be built should be clearly marked.

(iv) As a rule of thumb, it is best to work the bulldozers in pairs, so that they can assist and reinforce each other. The width of the line, the fuel, and the topography will determine the suitability of the tandem operation. Typically, the lead bulldozer pioneers the line by doing the ground clearing, while the second machine cleans up the line down to the mineral soil, widens the line where necessary, and breaks down and scatters any piles of material.

(v) The width of the line will depend on many variables, such as the type and amount of fuel and the continuity, height, and steepness of the slope. The general rule for the width of the line is not less than one half of the height of the fuel. With the bulldozer, the minimum width would have to be one blade wide. The width of the line will mainly depend on the amount of heat that will be created when it is burnt. Where a wider line is required in tall timber the clearing should be made by felling the trees away from the line.

(vi) A clean-up crew is used behind the bulldozer both to speed up the line construction, and to make it secure. The main point here is that hand tools are needed to follow the bulldozers in any type of fuel to make sure the line is ready to be burnt-out.

(vii) The burn-out crew may be part of a combination crew that does both the cleaning-up and the burning-out. On large fires it will be separate crews supervised by, for instance, a section head. Usually, one to three torchmen are needed. The other men use shovels and backpack pumps. If the bulldozer line has been constructed in the evening or at night the burning-out can be done the next morning, when conditions for burning are more favourable.

(viii) Proper and professional supervision must be provided for a successful operation and if hired equipment is used. This equipment is normally very expensive and cannot be operated for long periods without servicing. Plans for servicing and repairs must be made before starting work.

(ix) Bulldozers are used in the suppression of wildfires by the direct and indirect (parallel) methods and to construct lines for backfiring and strip burning. They are also used to construct strategic secondary lines, assist hand crews with spill-overs, construct safe areas, open up alternative routes, clear out old firebreaks, and to construct roads and heli-pads.

### Ploughs

Fireline ploughs are pulled by four-wheel drive trucks or by crawler tractor. There are two principal types of plough - hard ground (soil) ploughs, and peat-land ploughs.

Soil ploughs are the best to use in fuel types that can be traversed without too much interference from standing timber, where the topography is more or less flat, and where the soil type is generally sandy, friable, and free of rocks. Rocky soils are impossible to plough. Also, as the slope increases, the efficiency of the plough decreases.

In suitable average fuels and soils, most tractors are able to pull at a maximum of 5 km / hour (or 80 m/min.), which is equal to the walking speed of a man. The speed of ploughing will vary considerably below 5 km per hour where there are boggy sections, trees, and other obstructions.

Line construction and line location principles are the same for the plough as for the bulldozer. The indirect (parallel) methods are almost always used with ploughs, since the direct method is rarely used for initial attack.

The depth of ploughing should be as shallow as possible, but must be down to the mineral soil. A shallow line is equally as efficient as a deep line, as long as it is clean and continuous. The shallow lines also put less drag on the tractor so that the ploughing is faster.

If burning-out is used with a ploughed line, the line construction should be as straight as possible. Deep pockets and turns provide a chance for build-up of fire intensity, and the consequence of spill-over.

Peat-land ploughs can be used on dry areas if the fire is on peat-land, or is going to spread to peat-land. This plough will plough quite deep and makes a wide ditch which functions as a fireline.

In real peat-land fires, where the fire is spreading underground, this ditch should be deep enough and wet at the bottom in order that the fire will not spill-over the ditch. If the peat-land fire is very intense, and the fire is deep into the ground, it is better to plough two ditches side by side to be sure of stopping the fire.

### Excavator

With an excavator a fireline can be prepared on hard ground or non peat-land by digging with its blade.

An excavator fireline always needs to be followed up with hand tools. An excavator can be used successfully in any type of fuel or ground, for instance in rocky areas.

In addition, by using an excavator holes can be dug in the ground to prepare a water source for the fire pumps, if of course there is water near the fire site.

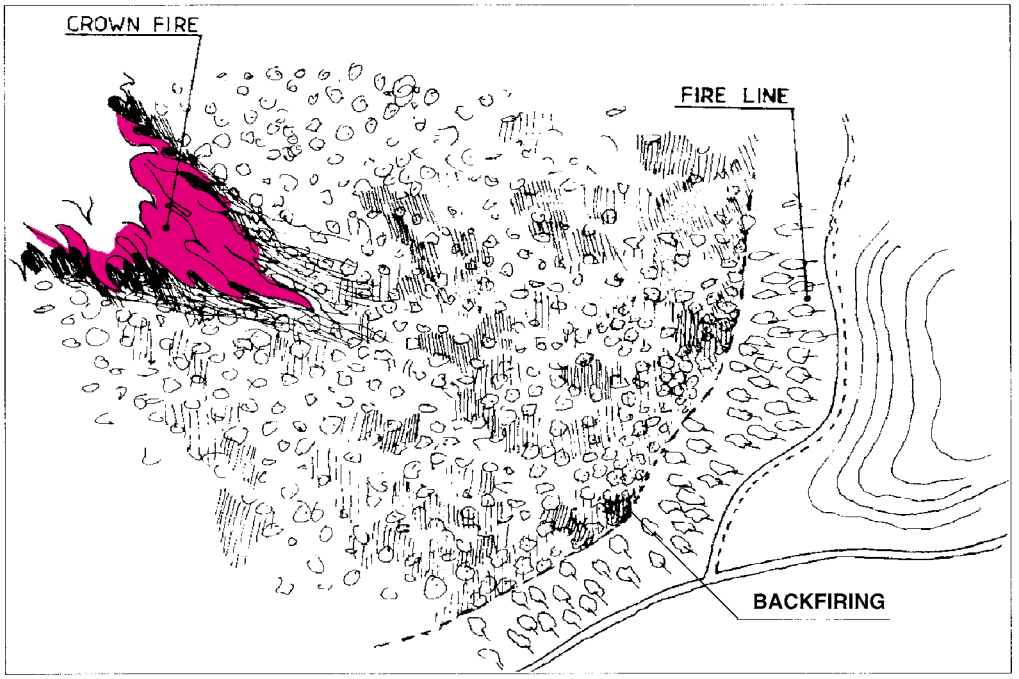
### Other heavy duty equipment.

There are many other special types of heavy duty equipment that can be used, such as the different types of forest tractors. Often these will be used in combination with other specialist heavy duty equipment.

It is very important that this type of equipment is under the control of experienced and professional supervisors. The drivers should have direct radio contact with the sector head or the fire chief.

## 8.6.4 Backfiring techniques

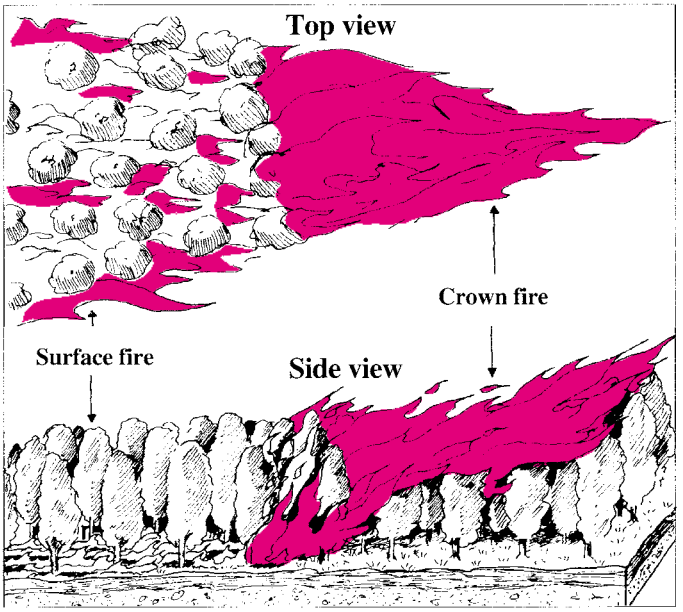
Normally, backfiring techniques are used in crown fires and in very fast spreading intense fires.



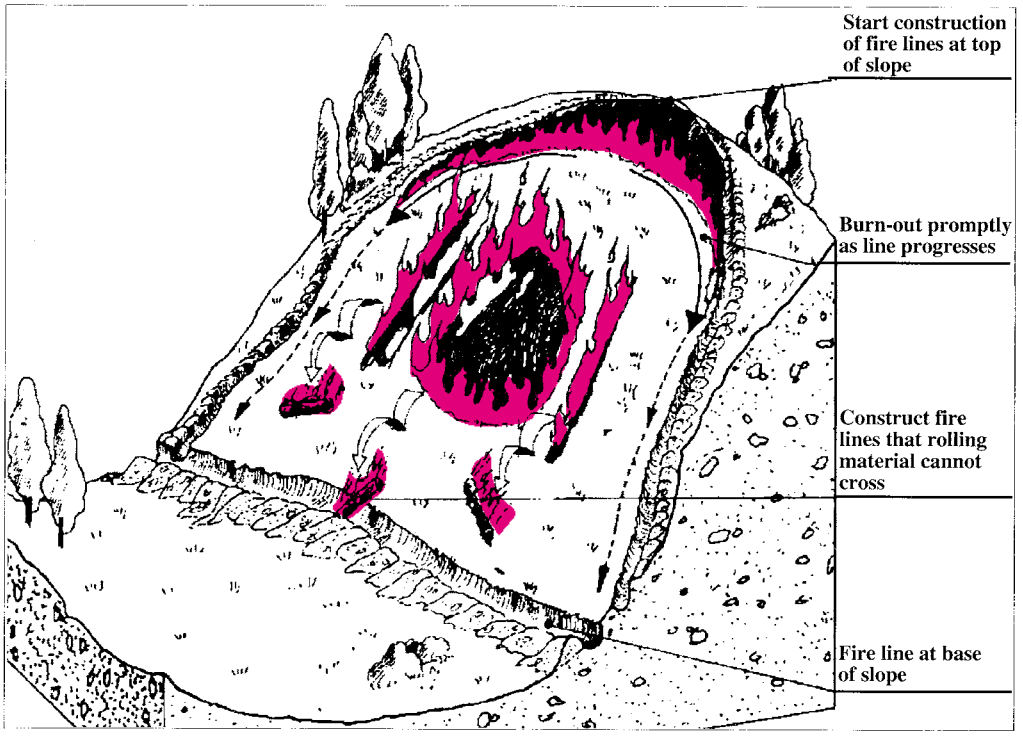

In these cases the only safe and accurate technique will be backfiring. If the fire is spreading very fast there will be no opportunity to send the crews and machines near the edge of the fire. In this situation it is best to prepare a fireline far in front of the head of the fire and start backfiring against the main fire at this line.

The use of backfiring techniques requires trained crews, sufficient manpower, and especially an experienced supervisor who can estimate the correct place to start the backfiring.

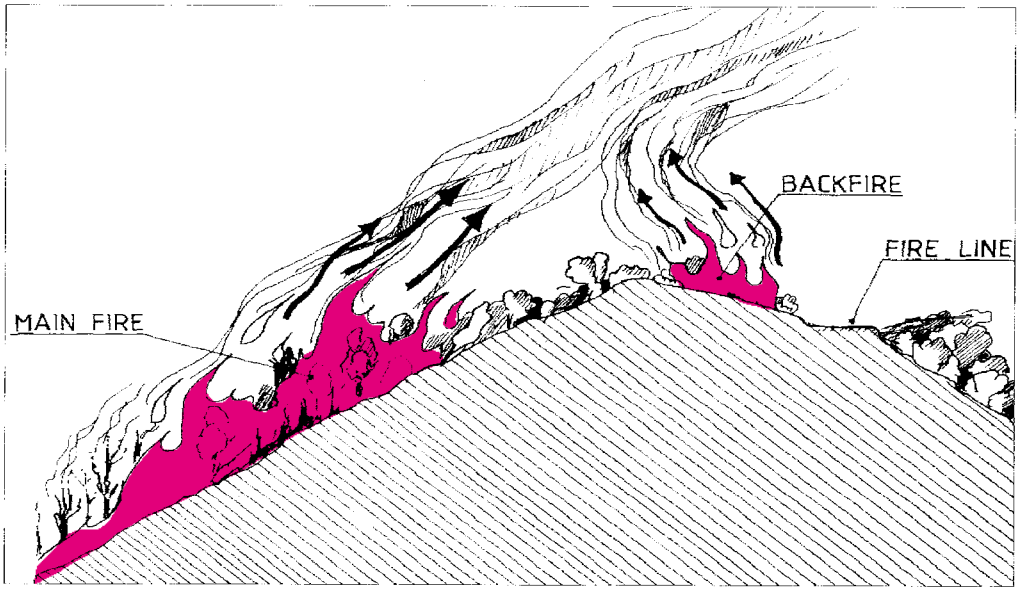
The principle of backfiring is based on the suction caused by the main fire, which produces a backwind.



The basic rules of backburning can be explained diagramatically.




In hilly or mountainous terrain the best place to start a backfire is just over the top of a hill, away from the slope where the main fire is located.




A fireline of sufficient width to hold the fire must be built in advance of the main fire, or use should be made of natural barriers such as a ridge top or a pre-planned and pre-built firebreak.

Anchor points must be in place prior to firing. Anchor points are the places where lines or barriers on both flanks of the main fire join the line across the front of the fire, examples of which are: a road, a cliff, or a man-made line. Lines along the flanks should be built so that the total area of the fire can be contained when the main fire reaches the backfire.

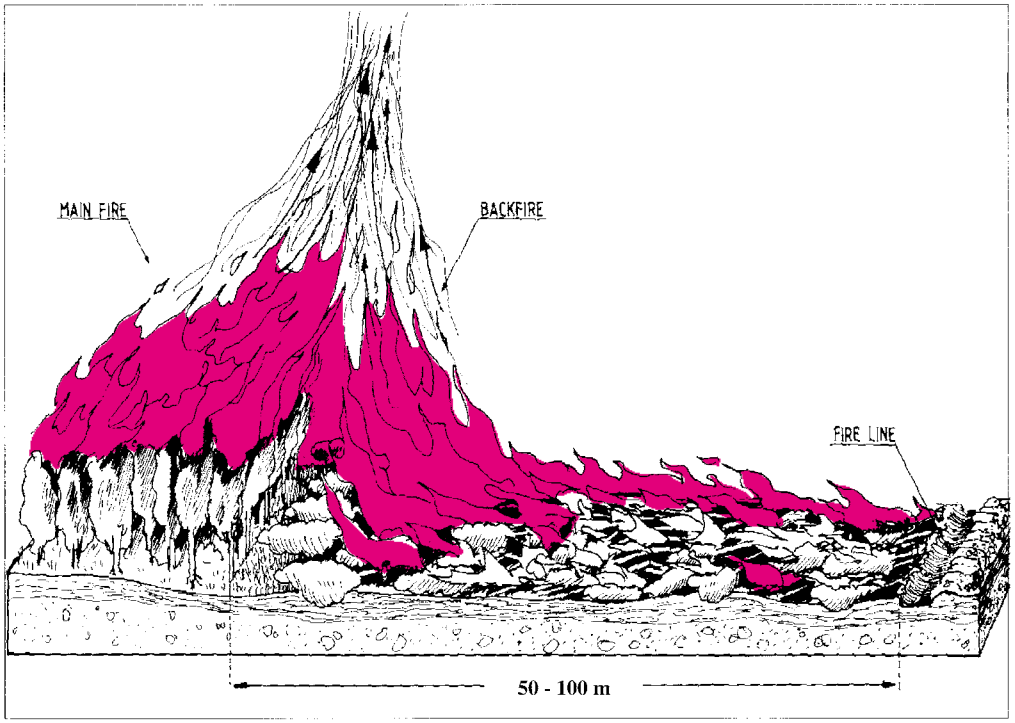
If the backfire is started too late, the impact of the main fire on the control line may become worse. The objective is to have the backfire drawn into the main fire at a safe distance from the control line.

Concentrations of fuel inside and adjacent to the control line should be scattered or removed, so that there will not be too much radiant heat and / or flames across the line for the resources to contain.

Before the start of the fire, all trees adjacent to the control line should be felled to fall inside and far enough from the line so that a surface fire will not jump outside the line.

The corners between the anchor points and the backfire line should be burnt-out first (these are the points that are the most difficult to hold). Then, the edge of the backfire line is established by burning from the anchor points towards the centre of the control line.

Next, burn from the anchor points downhill along the flanks. Where there is a choice, the backfire should always be started at the top of a slope and ignited towards the bottom, or downhill, to prevent the fire from building up and so that it can be held along the line.




A very slow rate of spread is not desirable with a backfire. On the other hand, a very hot backfire should also be guarded against because this may cause spot fires, jumping, and intense heat.

If the fire head is approaching in fingers, the backfire should be started at a place immediately at the head of each finger.

Burn only when you are sure that the wind direction and speed will remain steady.

Soil and / or water can be used along the backfire line to decrease the intensity of the backfire near the line until the backfire burns well away from the line and the intensity of the heat is diminished, or until the draught of the main fire pulls the backfire in.

It is a good practice to wet down an area outside and adjacent to the line in order to prevent ignition by sparks and embers. When using water, be careful not to extinguish the set fire.

### 8.6.5 Water suppression techniques

Water is the most widely used extinguishing agent for most fires because it has a high capacity to absorb heat.

It is usually readily available in most forest areas, but there are many areas where water is not available at all, especially in the dry season.

**Rule of thumb**

When water and adequate water equipment is available it should be used for fire suppression, as this is the most effective method in use. This method will also save manpower because one nozzle-man and his assistant are equal to 4 - 8 men with hand tools.

However, water alone will not do all the work in the control of wildfires and hand tools and patrolling will always be required.

The use of water equipment assumes a good knowledge of and practice with the equipment.

#### 8.6.5.1 Principles of water suppression techniques

In planning fire tactics it is worth considering water suppression techniques. Usually, the forest patrolling objective at the fire site is to check if there is an available source of water nearby. The water source could be a river, a lake, a dam, etc. The quantity and accessibility of the water is another important point to consider. If the water source is situated down a very deep ravine it may not be available to the equipment.

If the water source is far from the fire there must be enough hose and several pumps (booster pumps) to transfer the water. When water is taken from a natural water source a portable water pump is normally used. The other supply method is to carry the water to the fire in a fire truck or other type of tanker vehicle. This will mean that the trucks and vehicles should have easily accessible routes to the fire site.

#### 8.6.5.2 Procedure for attack and methods of nozzle use

In the case of a small fire, one or two nozzlemen are enough to keep down the flames, especially if the fuel type is light. If the fuel type is heavy, and the flames high and hot, several nozzlemen should be used, and they must work close to each other.

In crown fire attack there must be many nozzles in use at the same time. They should work very close to each other. The pressure in the nozzles must be high enough to produce a long straight stream of water because the nozzlemen cannot work close to the fire edge.

The first objective for the nozzleman is to stop the fire from spreading by knocking down the flames at the head of the fire. If this is not possible then the nozzleman should start to attack the flanks on both sides, or the surrounding fire edge. If the fire is small and fire weather conditions are moderate or low, the head of the fire is hit with a direct attack. This stops spreading. After that the flank attack is continued, and work procedes from the rear along the flanks, around the head, and then back to the point of start. The point of start on the flank will depend on the extent of the fire and the amount and type of manpower and equipment available. If a part of the flank appears to be dead, attack starts where the fire is burning intensely. The edge must be checked out to make certain it is secure. If the fire should start again behind the fire fighter it may not be too long before he is outflanked and caught in a pocket between two fires. Continue to work on around the head to pinch off the spread, and then tie in the entire perimeter. Check for spotfires and finish by mopping-up.

To break into a burning line, reach into it with a straight stream of water, aiming at the base of a hot spot. Bounce the straight stream off the ground to make more spray and to cool the fuel. As soon as a part of the edge has been knocked down, move into it fast. Then turn towards the head, change to a spray, cover only the burning fuel to stop the burning, and use the spray as a protective shield.

Hit the hottest edges first and then tie in the whole perimeter. If the fuel type changes, or there are dead and slow burning sections, hit the worst places first and then mop-up the other areas.

The volume of the water supply and the capacity of the pumps should be known.

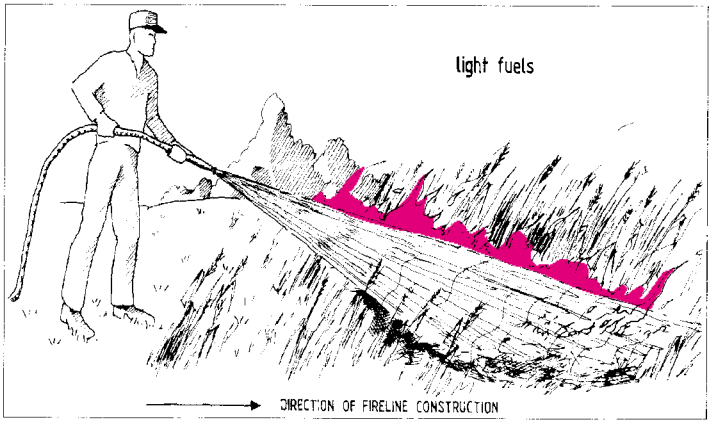
In the case of a surface fire or a crown fire, the fire is eliminated by the cooling and smothering effects of the water, and the condition of the fuel is changed by the addition of moisture.

The arrangement of the surface and sub-surface fuels can be altered by the force of the water from the nozzle. In the sub-surface layers this separation between the burning and unburnt fuels with water pressure is a most important action.

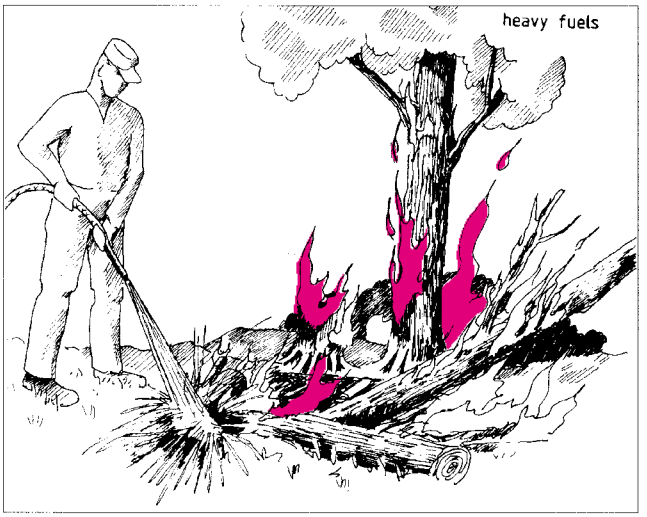
Skilled nozzlemen are required in order to obtain the best results from water under pressure.

In general, the angle at which the water stream is directed onto the fire edge will determine the effectiveness of the separation.

In light flash fuels the angle should be nearly parallel to the fire edge, and the stream should hit the fire edge about 5 - 8m from the nozzleman.



As the sub-surface fuel or the flame front increases in depth, the angle of delivery should increase accordingly, and the stream should hit the fire edge almost at right angles, approximately 1,5 - 3 m in front of the nozzleman. At all times the primary objective of an initial attack is to place the line in a condition of 'being held'.




Some good advice for the nozzleman on the type of nozzle used in different fire situations is as follows:

**Crown fire** - direct or scattered nozzle with sufficient pressure and waterflow, depending on the intensity of the fire.

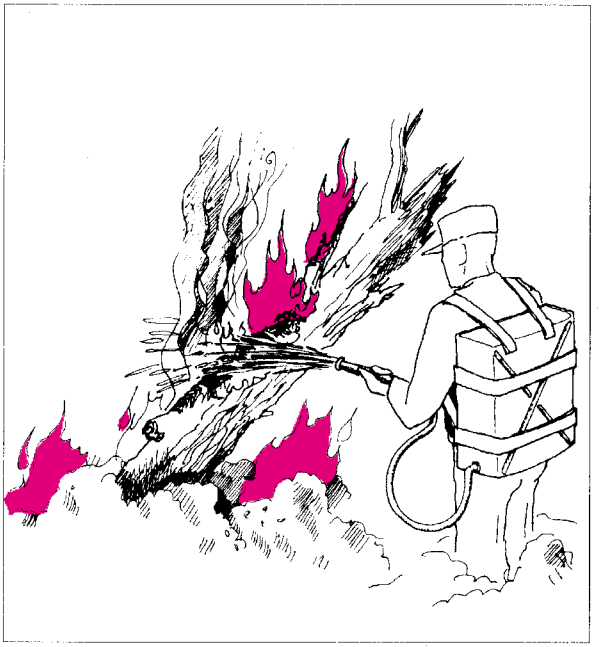
**Intensive surface fire** - scattered or direct nozzle pressure and water flow not so important.

**Low surface fire-** scattered nozzle, not very high pressure and waterflow.
Instead of nozzles, backpack pumps can be used.

**Mopping up** - direct nozzle which can be used like a drill into the hot spots.

### 8.6.5.3 Backpack pumps

Backpack pumps are not the most useful and effective of the wildfire tools. They are however the most efficient and economical means of delivering water onto a fire when they are skilfully operated. Backpacks are very useful in initial attack.



When the pump is used, one hand should be placed close to the forward end and held steady, aiming the pump to where the water is needed and as close to the base of the flame as possible. Pumping is done with other hand. By holding the forward hand steady, accurate direction is given to the stream. If a fan-shaped spray is needed, the stump is placed over the nozzle end.

Water carried in a backpack becomes very precious. The quantity of water carried is not very much and it must be therefore used as effectively as possible.

Backpacks are very useful in initial attack, especially to stop the fire spreading in lighter fuels, to cool down hot spots along the line, and to knock fire out of snags. They are especially effective if they can be readily filled.

Backpacks are almost indispensable on spot fires, as adjuncts to hand tools in the initial attack and especially in mop-up operations and patrols. If plenty of backpacks are available they may be scattered along the line by whatever transport is available, so that they are on hand when they are needed to combat flare-ups and to mop-up. Often the best use for a water tanker or fire truck is to supply the backpacks with water, especially if they themselves cannot reach the fire area.

Practice and training is necessary for the correct use of this equipment and the only way to achieve a satisfactory performance is to practice with the equipment available.

### 8.6.6 Aircraft used in suppression actions

In addition to detection and patrolling activities, aircraft can be used in several other aspects of fire suppression.

The use of aircraft at the beginning of the fire could be conclusive, if they are readily available. Aircraft will also save a lot of manpower, but they are very expensive to use. The main uses of aircraft can briefly be listed as follows below.

#### Agricultural aircraft

These can have limited use for spraying water or chemicals over the fire. The carrying capacity of an agricultural aircraft is normally very low.

#### Helicopter

The helicopter has a definite advantage for observation because it can move relatively slowly, can turn quickly, and needs a very small landing area.

The transportation of fire fighters is an important use for the helicopter, especially for the initial attack crew. Crews can often be transported quickly by helicopter to areas where most of their energy would have been used up in hard walking.

The helicopter is ideally suited for the transportation of men and equipment over short distances. Fitted with stretchers, it will make an excellent ambulance for transporting any persons injured in the fire area.

In addition, helicopters are used for fire suppression. In some countries special bags have been developed to hang below the helicopter to transport and release water on fires.

#### Water bombers

There is a special aircraft which has been developed to transport and release water on the fire. These special aircraft are called 'water bombers'. They have an average load capacity of between 1 000 - 5 000 litres of water. This type of aircraft requires special techniques and knowledge to operate.

### 8.6.7 Suppression techniques in peat-land fires

Peat-land fires (ground fires) can occur in peat-land or moss areas which have been dried out by the digging of trenches. These fires spread on a dry surface in the peat-land production areas, or they run under the ground inside the peat fuel. The underground fire can spread without any visible signs for many weeks and over many metres, making hot channels in the peat fuel, before surfacing in some other place.

These underground fires are very difficult to extinguish and produce a lot of heavy smoke, which is a danger to the firemen because it contains a lot of carbon-monoxide. In a strong wind, light burning particles of peat can easily fly many metres, spreading the fire very quickly and causing many spot fires. The fire can jump very easily over a 2 - 3 metre wide water ditch.

Surface peat-land fires can be extinguished with pumps and water sprays, and / or by flanking by using beaters.

Ground fires can be stopped by digging a very deep trench around the fire area. Another way to extinguish this type of fire is to use water. If a pump and nozzle is used it is best to use a high pressure and a straight stream, and to dig hot spots out of the ground.

If backpack pumps or buckets are used for water extinguishing a wetting agent must be used in the water, as untreated water has no effect against a ground fire. The wetting agent can be a liquid soap that breaks the surface tension of the water. This water sinks easily into the ground, through the peat fuel.

### 8.6.8 Mopping-up

Mopping-up is the process of putting out the whole fire, or putting out the fire in most of the area around the perimeter so that spot fires and breakaway fires cannot occur.

The size of the area to be mopped-up will depend on the fuel, the location of any smouldering fire in relation to the perimeter, and any possible changes in the weather. The burnt area should be mopped-up for at least 30 m from the perimeter towards the centre of the fire. In some fuels, and in small fires, it is necessary to mop-up all of the fire inside the line.

In heavy fuels the cost of a complete mop-up may be excessive. If all the fuel inside the line cannot be burnt completely, or if the fire cannot be completely extinguished, the area must be patrolled until there is no possibility of any ignition outside the line.

Mopping-up can mean the success or failure of the entire fire control operation. More fires have been lost because of poor or incomplete mopping-up than for any other reason. Mopping-up should begin as soon as the line is complete. In many situations the mopping-up may start during the line construction of the initial attack. Control is not achieved until enough mopping-up is accomplished to make sure the fire is permanently confined to a definite area.

Mopping-up is dirty, hard, and dangerous work. It is a real test of the effectiveness of the crew and its leaders. In many cases it is better to take a fresh crew to do the mopping-up work because the first crews will be tired after the initial control operations. Good leadership is required to obtain an effective job.

Snags inside the line and in places where sparks can be thrown across the line should be felled away from the line and extinguished.

Special snag safety precautions and notes for caution are as follows:

- Remove the roots from across the line.
- Fire can travel underground along the roots and can break out on the surface many metres away, and up to two weeks later.
- Fire in heavy duff may smoulder for a long time.
- A trench, dug down to the mineral soil, should be made around the outside of the area of burning duff. The area can then be allowed to burn-out, or be drenched with water.

In mopping-up, all the smoke must be out, all hot spots must be cooled and all burning material must be extinguished. Patrolling must be carried out after the mopping-up work in order to make sure that the underground fires are really out.

Where water is not available, or is in limited quantities, hand tools are very effective when they are used correctly. In fact, hand tools should be used with water for the best possible mopping-up results. The shovel, backpack pump, axe-hoe, pole axe, rake, and saw are the best tools for mopping-up.

Try to eliminate trouble spots before they flare-up and endanger the line. Keep the fire out of heavy fuels, concentrations of fuel, and unburnt islands. Break-up any concentrations of fuel that are burning. Improve the line and make sure it is secure and continuous. Turn logs over 180 degrees in their bed of ash, and cool the log and the bed. Do not cover burning stumps, logs, or large pieces of wood with soil and expect them to go out completely. Usually the soil drops away as it dries and the smouldering material underneath breaks into flame, sometimes allowing sparks to be carried by the wind. It is much better to completely extinguish all burning material by using water.

If water is available and can be applied it makes the mopping-up operation much faster and easier to accomplish. The best combination is water and hand tools.

Mopping-up with water may be carried out with backpacks or pumps and hose lines. It is not the amount of water that is used, but how effectively it is used.

A fine light spray is usually the best, and it saves water. Any burning material should be separated and exposed and a fine light spray applied until it is certain that all the fire is extinguished. In some instances a straight stream may be needed to penetrate or reach the burning material. If enough water is availble some areas can be drowned. In heavy fuel areas, or around stumps and roots, a high pressure and straight stream can be effective for digging out hot spots from under the ground.

**Fire Intensity**

The Fire Intensity indicates the amount of energy produced by the fire. The Intensity of fire expresses the amount energy or heat towards a surface-area and time unit, for example kacl/m2/s or kW/m2/s. The height of the flames described very well the Fire Intensity and can therefore easily be assessed in the field.

| Height of flames m | Intensity kW/m2/s | Description of fire |
|---|---|---|
| < 1, 2 | < 345 | Fire spreads slowly and is easily controlled |
| 1,2 - 2,4 | 345 - 1720 | Fire burns with steady flame and moves forward |
| 2,4 - 3.3 | 1720- 3450 | Fire spreads rapidly and continues to grow |
| > 3,3 | > 3450 | Fire burns fiercely, crown and spot fires occurring |