CHAPTER 6

PREPARATION OF A MAINTENANCE PROGRAMME

6.1 Introduction

A maintenance programme for an irrigation system consists of a schedule of maintenance operations to be undertaken on specific irrigation and drainage channels at specific times, using specified resources.

Figure 6.1 shows our recommended approach to the preparation of a maintenance programme for an irrigation and drainage system. It consists of five stages:

1. Establish a maintenance policy, including target levels of service
2. Identify maintenance strategy options to deliver the target levels of service. Each option will usually be a combination of desilting and weed control operations, each with a specified method and frequency.
3. Prepare a balanced programme and resource allocation for each option, to make efficient use of the resources while meeting the targets
4. Select the optimum maintenance strategy and programme from the options, to minimise the life cycle cost over the planning period
5. Prepare a detailed work programme for the optimum maintenance strategy.

Stage 1 has been described in Chapter 5, stages 2 and 3 are described in this chapter and stages 4 and 5 are considered in Chapter 7.

6.2 Maintenance strategy options

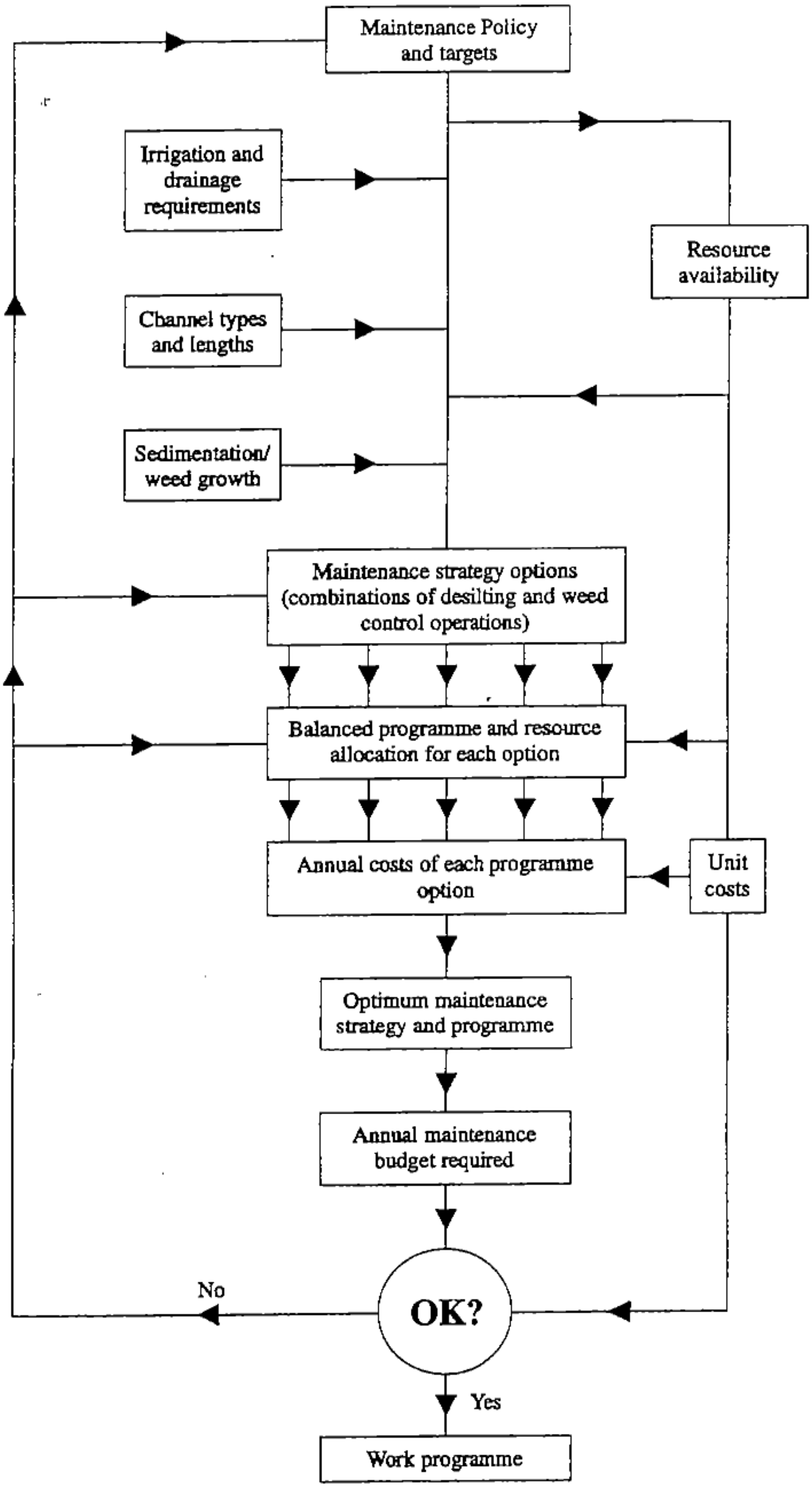
The time schedule of the maintenance programme is essentially governed by the cycle of activities in the agricultural year (e.g. Figure 2.4). For a particular crop, water requirements demand the timely and efficient supply and removal of water through different channel systems (canals and drains) requiring different timings and methods.

The differences in crop water demands through the year are also sometimes a constraint on maintenance activities but may also provide opportunities for maintenance. Effective managers are adept at exploiting these windows of opportunities (e.g. when channels are dry in Chisumbaiye Scheme, see Section 2.3.1.5).

Physical conditions which are frequently encountered in tropical or sub-tropical climates such as water turbidity and climate favouring rapid vegetative growth may dictate more frequent weed cutting and desilting than in similar systems in temperate climates. Failure to maintain the systems adequately may cause:

- more rapid deterioration of assets than in more temperate climates
- a reduction in the productivity of postponed maintenance which will be translated into higher costs per unit of clearance achieved - a machine will achieve less clearance per hour when assets are in an advanced state of deterioration.

Figure 6.1 Preparation of a maintenance programme for irrigation and drainage channels



Increasingly the nature of the maintenance activity is likely to be determined by ecological and health factors. The sensitivity of animal or human well-being may preclude some maintenance activities whilst promoting others.

In each situation there will be various possible options for a maintenance strategy which will deliver the target level of service. Each strategy option will be a combination of desilting and weed control operations, each with a specified method and frequency for each type of channel. The issues to be considered are shown in a flow chart in Figure 6.2, and explained below. (The terms maintenance policy, strategy, operations and programme are used as described in Chapter 5.)

The various feasible maintenance strategy options can be viewed as alternative investment projects, each characterised by different capital costs, operation and maintenance costs and environmental effects. An array of methods is available to control weeds in irrigation and drainage channels (see Chapter 4), and these can be combined in various ways as maintenance strategy options. These may include combinations of capital (e.g. hydraulic machinery) and labour (e.g. manual cutting). Alternatively, the input mix may be of machinery and herbicides, labour and herbicides, or include environmental or biological control. In many instances, technical and economic considerations constrain the practical application of the available control strategies.

6.2.1 Resource availability

It will be important to establish early in the programme planning which resources are available during each period of the year and whether there is any flexibility to buy in extra resources, e.g. casual labour and hire equipment, or to use resources elsewhere when not required for maintenance, e.g. mechanical equipment used for construction. These resources may include any or all of the following: a labour force, handtools, mechanical equipment, herbicides and biological agents. Any resource constraints will influence the feasibility of various desilting and weed control methods.

6.2.2 Setting channel capacity and condition targets over the annual cycle

Engineers are accustomed to specifying target discharges for each period in the annual cycle, varying with the irrigation and drainage requirements. For management purposes it will often be convenient to express these as percentages of the design discharge capacity of the channel, and an example is shown in Figure 6.3. These figures represent the minimum required Discharge Capacity Ratio (DCR) in each period, as described in Chapter 5.

The actual DCR of the channel in each period will depend on its silt-related and weed-related condition, and a judgement can then be made of the equivalent required condition for each period (for example, for each month). The weed-related condition could be expressed in terms of weed succession stages or percentage cover, as described in Chapter 3.

Figure 6.2 Development of maintenance strategy options

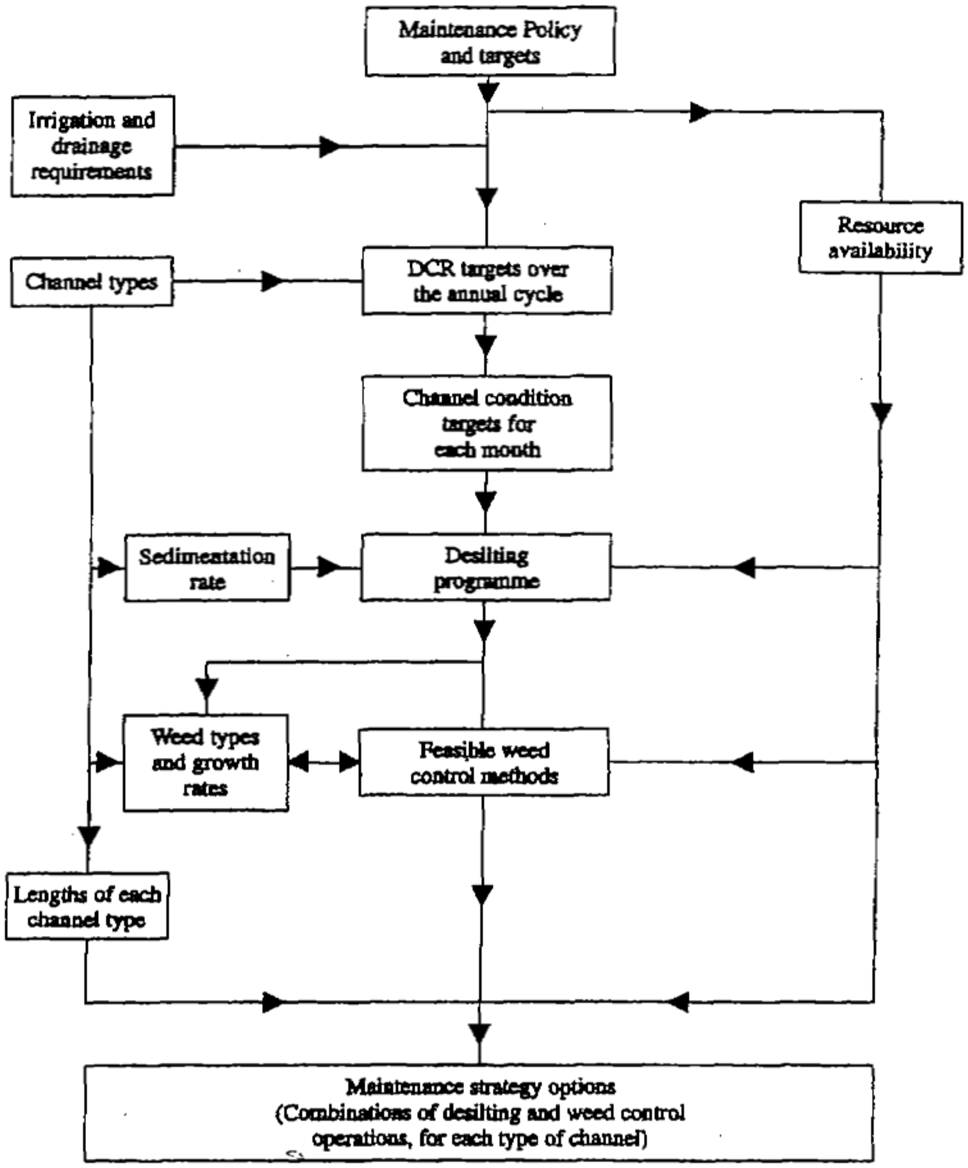
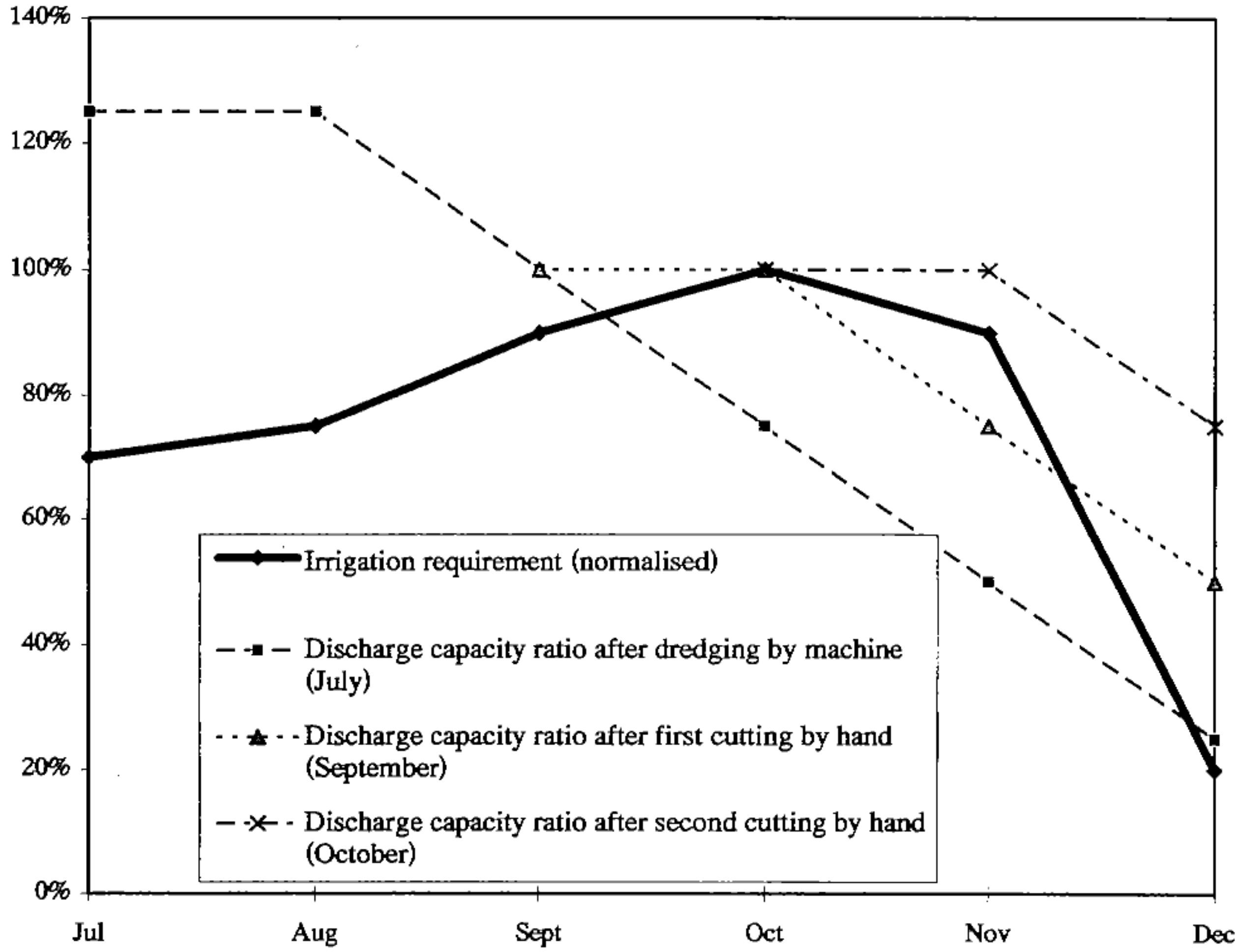


Figure 6.3 Variation in irrigation requirements and channel capacity over the season



6.2.3 Estimating the sedimentation rate and setting a desilting programme

The details of sediment rate estimation and desilting programmes are beyond the scope of this book. Sedimentation is usually slower than weed growth, so desilting operations are less frequent. These operations also have a major effect on weed growth, but generally use more resources than weed control. Therefore the desilting programme should generally be decided first, and then weed control can be scheduled to maintain the channel condition between desilting operations.

6.2.4 Identifying weed types, growth rates and feasible weed control methods

Weed types in each type of channel can be identified following Chapter 3. Data on growth rates can be collected by monitoring channel condition (e.g. monthly). Identification of feasible weed management methods was described in Chapter 4, and some of the more important considerations in developing countries are listed in Box 6.1.

Box 6.1 Criteria for selection of maintenance methods

1. Type of weeds to be controlled
- weed habit
- general control or targetted at certain species
2. Resources required
- labour
- equipment
- maintenance facilities
- fuel and spare parts
- operator skills
- herbicide
- biological agents
3. Access to channels
- service roads, on one/both banks, for foot/tracked/wheeled machine
4. Operational requirements
- draining of channel before maintenance
- time restrictions on maintenance activities
5. Environmental impacts
- water quality
- operators' health
- public health
- short/long term impacts
6. Period of effectiveness of control method
7. Estimated output/productivity of control method
8. Compatibility of control method with other maintenance activities
9. Costs
- capital/recurrent
- lifecycle/equivalent annual costs
- foreign/local currency
- finance available

6.2.5 Specifying maintenance strategy options

Once feasible control methods have been identified, a more detailed specification of each maintenance strategy can be made including methods and frequency of desilting and weed control operations on each channel type. Maintenance strategies should be programmed over extended planning periods (for example, a period of 15 years) since annual maintenance requirements are seldom constant. Planning maintenance over an extended period provides for the inclusion of more episodic components of maintenance programmes, such as desilting, which may be necessary only at three or four year intervals, and the purchase of equipment.

Specification of a maintenance programme facilitates the identification and quantification of inputs required to accomplish it. It also enables the breakdown of costs into fixed cost (capital cost) and variable cost (recurrent cost including operation and maintenance) categories and allows identification of their occurrence through time.

Once maintenance activities and inputs have been defined, the selection of the optimum maintenance strategy and programme from a list of options can be accomplished by viewing each maintenance strategy option as an investment project with expenditures occurring through time (see Chapter 7).

6.3 Programming and resource allocation for maintenance strategy options

The detailed planning and programming of a maintenance strategy option is shown in Figure 6.4.

One of the objects of producing a maintenance programme is to make effective use of the available resources (e.g. labour force, handtools, mechanical equipment, herbicides and biological agents). In most situations there will be little flexibility in the availability of resources, and the maintenance programme will therefore be resource driven rather than being demand-led. In other words, the programme must be planned around the resources availability and constraints, rather than the most convenient programme being drawn up and then the required resources procured. For example, financial constraints may preclude the purchase of hydraulic weed cutting equipment.

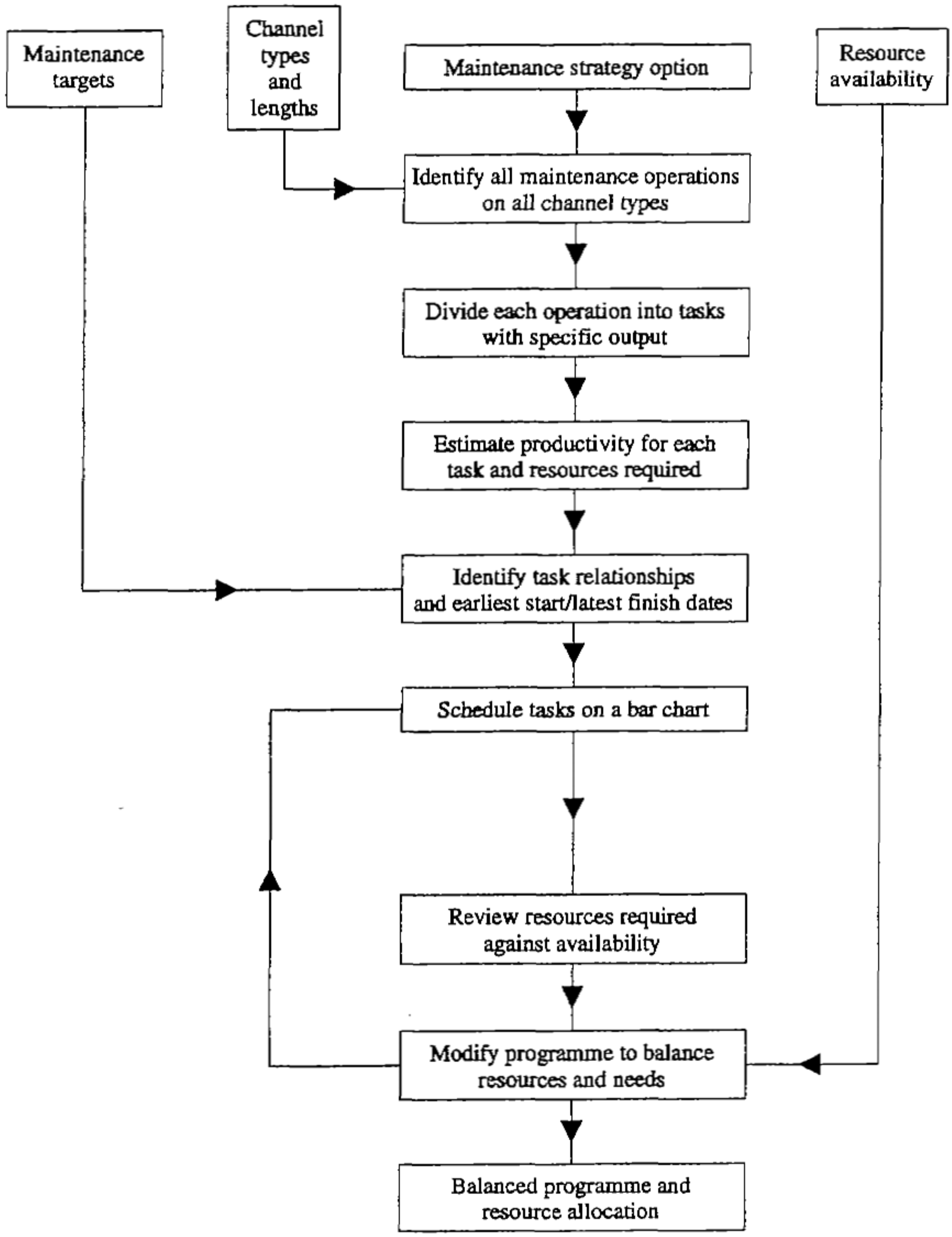
In order to obtain efficient utilisation of the scarce resources it is important that each resource is assigned to a task where it will have the greatest effect. Each irrigation or drainage channel performs a slightly different role to others, and has dimensions which may or may not be well matched to a particular maintenance method or resource (for example, the width of a channel compared to the reach of an excavator). The best maintenance method and resource will therefore vary between channels. This process provides the optimum choice of maintenance resource for each channel.

Efficient utilisation of scarce resources also requires that each resource is in use for the maximum length of time possible. This can be programmed by breaking down work into tasks, assigning the resources to the tasks, and creating a timetable for the work to be undertaken. A well planned timetable will result in maintenance work having a minimal effect on crop production and will minimise the periods of inactivity (down time) of the maintenance resources.

Note that this efficient use of resources will normally be reflected in their unit cost (by the spreading of fixed costs and reduction of surcharges at peak times). It is therefore important to consider efficient utilisation within the irrigation scheme as a whole, rather than individual channels. This may be done following the steps below which is based on work by Paul Larcher of WEDC, drawing on the Asian Development Bank (1988), Clifton (1985) and

Moder et al (1983); Microsoft Project was used in finalising the material. An example of the process is given in Section 6.4.

Figure 6.4 Preparation of balanced maintenance programme



6.3.1 Step 1: Identification of maintenance operations

The first step to take in the definition of a maintenance programme is to identify the maintenance requirements. These are intrinsically linked to the irrigation and drainage objectives for the scheme (see Chapter 5). Two issues are of particular importance in the identification of maintenance requirements:

- the total length of a particular channel or type of channel, (e.g. secondary canals) to be maintained; this should be available from the asset register;
- the timescale over which the maintenance activities must be carried out.

Time restrictions on maintenance activities impose a pressure on the available resources for weed control. In some cases they may constrain the selection of weed control strategies. For example, severe time restrictions may preclude the use of manual control because the productivity of the local labour force is insufficient to realise, in time, the desired maintenance objectives.

For each channel type, the required maintenance operations should be identified. These should include all planned maintenance activities which are necessary to maintain the hydraulic condition of the channel type over the designated planning period. These might be operations which must be carried out on an annual, or more frequent basis or they may be more episodic activities, such as desilting, that are necessary at less frequent intervals.

6.3.2 Step 2: Maintenance tasks

Each maintenance operation is broken down into its separate tasks, each with a specific output to be achieved using a specified method and major resource, for example, unskilled labour (ignoring for the present the tools and supervision needed) or excavator type XX. By dividing the maintenance operations up into individual tasks and maintaining more than one channel at a time, resource inactivity can be minimised. For example, an excavator may be dredging one channel, while the labour gang are working on another, thus preventing a labour gang standing idle while the machine is working or vice versa.

6.3.3 Step 3: Productivity and resources required

For each task derived in step 2, decide the productivity of the weed control method and estimate the major resource inputs required to complete the task under local conditions.

General estimates of the productivity of weed control methods can be obtained either from practitioners already employing the control methods or from manufacturers of equipment used for weed control. Tables 6.1 - 6.3 provide an illustration of the productivities of manual and mechanical methods of weed control. However, it should be noted that the productivity of weed control methods varies considerably according to local conditions. The factors which affect the rate at which weeds and silt may be cleared include:

- type of weed;
- rate of weed growth;
- density of weed growth;
- water levels in the channels at the time of maintenance;

- accessibility of the channels;
- quality of the maintenance work;
- skill of the labourers or operators;
- mechanism by which labourers or operators are reimbursed for their work.

Another factor to be considered at this stage is the impact a control method has on the vegetation in irrigation and drainage channels. Like productivity, this varies according to local conditions, and it also differs between control methods. Generally speaking, control methods which destroy the rooted parts of weeds as well as the aerial parts (e.g. desilting or a herbicide) are more effective than methods which eliminate only the aerial parts (e.g. cutting) (see Chapter 4).

If the impact of a control method is only of short duration, a particular channel type may require repeated treatments during the course of a year in order to meet hydraulic targets. In conjunction with any time constraints and the productivity of control methods, this factor has implications for the selection of weed control methods.

Table 6.1 Productivity of labour using different hand tools for the control of weeds in irrigation and drainage channels

Type	Use	Channel Dimensions	Productivity
Scythe [a]	Submerged, floating-leaved & emergent weeds & grass on banks	Small channels, 1 m bed width, & up to 2 m deep	15-25 m h^{-1}
Sickle, grasshook [a]	Submerged, floating-leaved & emergent weeds & grass on banks	Small channels up to 0.75-1.25 m deep	8-12 m^2 h^{-1}
Slasher	Emergent weeds & grass on banks	Up to 6 m width	500 m d^{-1}
Chain knives & chain scythes [a]	Submerged , floating-leaved & emergent weeds & grass on banks	Up to 6 m width	4-60 m^2 h^{-1} (two or three labourers)
Hoe	Submerged , floating-leaved & emergent weeds & grass on banks	Up to 6 m width	300-500 m d^{-1}
Dredging scoop	remove weeds and silt		2.8m^3

[a] Figures from Sagardoy (1982)

Table 6.2 Productivity of mechanical equipment for dredging irrigation and drainage channels.

Type	Attachment	Use	Operating Conditions	Productivity	Remarks
Dragline excavator	Small bucket ($0.3\ m^3$)	Submerged, floating-leaved & emergent weeds & silt	Operates from banks on dry or flowing channels. Reach: 9-10 m.	80 m d^{-1}[a] 120 m d^{-1}[b] 300 m d^{-1}[c]	Versatile machine adaptable to several jobs & working conditions. Spoil can be dumped clear of channel banks. Care required to avoid damage on compacted bed channels. Suitable for dredging tasks smaller than 3,000 m^{-3} km of channel.
	Large bucket ($1.0\ m^3$)	Submerged, floating-leaved & emergent weeds & silt	Operates from banks on dry or flowing channels. Reach: 18-20 m.	100 m d^{-1}[a] 160 m d^{-1}[b] 500 m d^{-1}[c]	Similar to small dragline excavator. Suitable for dredging tasks greater than 3000 m^{-3} km of channel.
Hydraulic excavator	Back-actor	Submerged, floating-leaved & emergent weeds & silt	Operates from banks on dry or flowing channels. Reach: 6-8 m; digging depth: 5-6.5 m.	800-1000 m d^{-1}[d]	Useful for dredging or weeding. Normally crawler mounted & all hydraulically operated. Those mounted on wheels require firm ground conditions. Wide variety of buckets may be fitted.
	Telescopic boom (Gradall type)	Submerged, floating-leaved & emergent weeds & silt	Reach: 9-11 m; digging depth: 6-7.5 m.	1000 m^3 d^{-1}[e]	Suitable for a variety of jobs, especially excavating new channels and heavy maintenance work. Compares favourably with small draglines.
Hydraulic backhoe	Tractor-mounted	Submerged, floating-leaved & emergent weeds & silt	Reach: 5.5-6.5 m; digging depth: 3.5-4.5 m.	300-600 m d^{-1}[b]	Suitable for construction & maintenance work; also effective for excavation, dredging & weeding tasks. Most common type is the side shift which can be mounted at each side of tractor. Normally associated with front-end loader attachment. Requires good footing. More powerful & robust than trailer type.
	Trailer-mounted	Submerged, floating-leaved & emergent weeds & silt	Reach: 4.5-6.0 m; digging depth: 2.8-4.0 m.	200-400 m d^{-1}[b]	Especially suitable & economic for maintenance work. Can operate in difficult positions while prime mover remains on level standing.
Dredger		Submerged, floating-leaved & emergent weeds & silt	Maximum depth: depends on model, but for small dredgers 2 m. Spoil deposited on nearest bank or collected in special pontoons.	100-200 m d^{-1}[f]	Highly specialised machine. Cable & winch system for locomotion requires strong anchorage points along banks. Good for use in marshy ground or along channels that cannot be cleaned from banks. Difficult to transport & move in & out of channels.
Flat bed ditcher (Briscoe type)		Submerged, floating-leaved & emergent weeds & silt	Operates within dry channels, towed by tractors from each side. Bed width: 1.2-4.2 m.	3000-5000 m d^{-1}[g] 12,000 m d^{-1}[h]	More suited for construction or reconstruction of channels. Most ditchers have own engine & hydraulic unit. Requires powerful crawler tractors for towing (D6, D7). Requires experienced operator.

[a] With standard bucket and heavy excavation.
[b] With light-weight bucket and for removal of silt and vegetation.
[c] With the weed bucket but does not include cleaning of the batters.
[d] For remodelling badly silted channels.
[e] Equipped with 2.4 m wide bucket.
[f] Desilting of 1.5 m wide channel; rates for soft weeds much higher.
[g] For normal cleaning operations towed by a D6 tractor.
[h] Light cleaning operation, with wheeled tractor.
Source: Sagardoy (1982)

Table 6.3 Productivity of mechanical equipment for cutting weeds in irrigation and drainage channels.

Type	Attachment	Use	Operating Conditions	Productivity	Remarks
Dragline excavator	Weed rake	Submerged, floating-leaved & emergent weeds	Operates from banks on dry or flowing channels. Reach: 9-21 m.	500 m d^{-1}	
	Mud bucket	Submerged, floating-leaved & emergent weeds	Operates from banks on dry or flowing channels. Reach: 9-21 m.	500 m d^{-1}	
Hydraulic excavator	Oscillating grass cutter bar	Emergent weeds & grass on banks	Reach: 6-12 m; digging depth: 3-5 m.	800-1,200 m d^{-1}	Wheeled machines have reduced reach.
	Rotary cutter	Emergent weeds & grass on banks	Reach: 6-12 m; digging depth: 3-5 m.	1000m^2 h^{-1}	Wheeled machines have reduced reach.
	Flail mower	Emergent weeds & grass on banks	Reach: 6-12 m; digging depth: 3-5 m.	1000 m^2 h^{-1}	Wheeled machines have reduced reach.
	Weed cutting bucket	Submerged, floating-leaved & emergent weeds & grass on banks	Reach: 6-12 m; digging depth: 3-5 m.	600-1,000 m d^{-1}	Wheeled machines have reduced reach.
	Mud bucket	Submerged, floating-leaved & emergent weeds & grass on banks	Reach: 6-12 m; digging depth: 3-5 m	400-600 m d^{-1}	Wheeled machines have reduced reach.
Tractor	Oscillating grass cutter bar	Emergent weeds & grass on banks	Reach: 3-6 m	1000-2,500 m h^{-1}	
	Rotary cutter	Emergent weeds & grass on banks	Reach: 3-6 m	1000-2,500 m h^{-1}	
	Flail mover	Emergent weeds & grass on banks	Reach: 3-6 m	1000-2,500 m h^{-1}	
	Chain, harrow	Submerged, floating-leaved & emergent weeds	Width: 2 m	500-3,000 m h^{-1}	
Large boats (10-15hp)	Oscillating knives	Submerged, floating-leaved & emergent weeds & grass on banks	Width: 6-10 m	1000-4,000 m h^{-1} 1.5-2.8 m wide cut	
	T-shaped cutter	Submerged, floating-leaved & emergent weeds	Width: 6-10 m	1000-4,000 m h^{-1} 1.5-2.8 m wide cut	
	D-shaped cutter	Submerged, floating-leaved & emergent weeds	Width: 6-10 m	1000-4,000 m h^{-1} 1.5-2.8 m wide cut	
Small boats (4-5 hp)	Oscillating knives	Submerged, floating-leaved & emergent weeds & grass on banks	Width: 5-6 m	1000-4,000 m h^{-1} 1.0-1.8 m wide cut	

6.3.4 Step 4: Task relationships

For each task derived in step 2, decide the earliest start and latest finish dates, including the recognition of the dependency of one task or another. These dates must allow the task to be compatible with the irrigation and drainage programme and the required discharge capacity of the channel. The duration required must be realistic to allow completion of the task.

6.3.5 Step 5: Scheduling maintenance tasks on a bar chart

The maintenance operations and tasks for all the channels can be shown as bars on a large chart, also known as a Gantt chart, with the x-axis divided into convenient periods such as months or weeks. (For an example, see Figure 6.6 later in the chapter). Initially there will be some flexibility in the start and finish dates, as in step 4, and this gives flexibility in scheduling the operations and tasks to even out the demand for resources. The chart may be prepared manually, by a trial and error process, or by using a computer programme.

It may be helpful to prepare a network diagram first, to show the relationships between the tasks, e.g., the order in which the tasks must be undertaken and tasks that may run consecutively.

6.3.6 Step 6: Reviewing the total resource requirements against availability

Resources should be allocated to each task in the diagram according to the requirements given in step 3. The allocation of resources will depend on the time available to complete the task and the resource used (see step 7 below). The start and finish dates can then be fixed for each task and the total resource requirements for each time period (e.g. month) are calculated and compared against those available.

6.3.7 Step 7: Modifying the programme to balance resources and needs

Unfortunately the first attempt to achieve a programme usually results in unacceptable or unavailable peaks in resource demand during certain times of the year and under utilisation of resources during others. In this case, the scheduling process should modified until a satisfactory result is obtained.

The alterations which may be made are:

a.) Extending the task start and finish dates, so long as this will have an acceptable or minimal effect on the crop production.

b.) Changing the resource allocated to the task for either a faster resource, if time constraints are a problem, or a resource in lower demand if peak demand is a problem. Changing the allocated resource may require a reappraisal of control methods or the resources in order to determine the most appropriate task for resource reallocation.

If a particular resource is available but not fully utilised following the balancing process, e.g. one excavator regularly idle, a global review of the maintenance programme may be carried out to determine if the overall preferred option would be to keep the resource idle or use it in another task, where it may not be the most suitable.

6.3.8 Step 8: Completion of the balanced programme and resource allocation

The result of working through steps 1 to 7 is the production of a balanced programme for the maintenance strategy option. This then needs to be compared with the programmes from other feasible strategy options, as described in Chapters 7 and 8. Following the selection of a maintenance programme, the approved programme Gantt or bar chart is then used to prepare work schedules for the different resources and their supervisors.

The maintenance manager should review the timetable at frequent intervals to check targets are being met and make alterations to the resources to allow for unexpected delays or emergency work. These reviews require a repetition of steps 3 to 6.

Box 6.2 Resource review

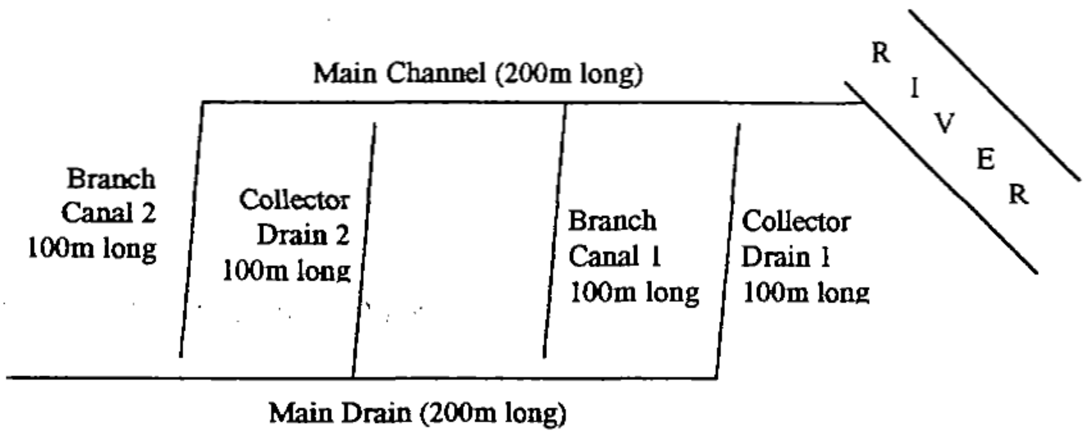
In order to choose the best resource for each task, its suitability should be assessed against four factors:

1. **Availability** Resource availability is the most important factor when choosing the maintenance method and should therefore be considered first and then reconsidered with the other three parameters before the final method is chosen. The availability of a particular resource may have seasonal variations (e.g. the strength of the labour force may be reduced during crop harvest). Support services must also be available; a mechanical excavator will be useless if fuel and maintenance facilities can not be obtained locally. Skilled workers would also be needed to apply herbicide, implement biological control, operate machinery and train others in the appropriate techniques.
2. **Cost** The costs of each method and resource are assessed and compared with each other. There may also be seasonal variations in the costs of some resources e.g. labour wages. The resource which is cheapest per unit of output will generally be the most desirable.
3. **Time** The time taken to complete the task depending on the method and resource used needs to be considered, e.g. the time taken to drain, maintain and refill a channel may be unacceptable. Some methods will be significantly faster than others, however, the time period between each maintenance session also needs to be considered.
4. **Quality** The quality of the work carried out by each resource should be assessed in order to decide if the use of the resource will be acceptable. This may be measured as the condition of the channel after maintenance and the regrowth rate.

6.4 Maintenance programming example

The maintenance programming technique may be demonstrated by the following simplified example. Consider an irrigation system consisting of a main channel with 2 branch canals and 2 collector drains outfalling to a main drain as shown in Figure 6.5. The maintenance timetable will be built up for one year.

Figure 6.5 Maintenance programming example- irrigation and drainage system



Step 1. Maintenance Operation

The maintenance operations during the year are identified for each channel (Table 6.4).

Table 6.4 Maintenance programming example - operations over a 12 month period

Main canal	Branch canal	Collector drain	Main drain
desilt	desilt	remove weeds (1)	desilt
remove weeds	remove weeds (1)	desilt (if required)	remove weeds (1)
-	remove weeds (2)	remove weeds (2)	remove weeds (2)
-	-	-	remove weeds (3)

Note: (1) indicates operation undertaken for the first time

(2) indicates operation undertaken for the second time etc.

Step 2. Maintenance tasks

For each channel the maintenance operations are broken down into their individual tasks.

Main channel: Broken down into 100 m task sections, with the top end maintained first to prevent silt and weeds from maintenance work being washed into a maintained section.

Branch Channels: Broken down into 50 m task sections, with the top end maintained first to prevent silt and weeds from maintenance work being washed into a maintained section.

Collector drains: Drains are broken down into 50 m task sections. Dredging is only occasionally required, but should be shown to indicate that resources may be required. The maintenance requirements of both collector drains are the same in this example.

Main Drain: The main drain is broken down into 100 m task sections.

Step 3: Productivity and resources required

For this example it will be assumed that there is one excavator and one labour gang available. The allocation of resources for a more complex problem would require the use of resource optimisation as described above.

The resources required for each task are identified, from which task data are specified. This includes the duration of the task and the resources to be used, as shown in the first four columns of Table 6.5.

Step 4: Task timing constraints and relationships

Where a task cannot be started until another has been finished (e.g., the task on an upstream section of channel) the link with the predecessor task is identified.

In addition, constraints on the start or finish dates are assigned to tasks as appropriate in order to be compatible with water demand and crop production. A "start no earlier than" constraint marks the earliest a task can start, and a "finish no later than" constraint fixes the latest a task can finish.

The right hand columns of Table 6.5 shows both timing constraints and any predecessor tasks, for each task. These data represent the requirements which have to be met by the maintenance programme.

Step 5: Scheduling maintenance tasks on a bar chart

The maintenance programme is shown as a bar chart in Figure 6.6. This is based on the resource requirements, constraints and predecessor links given in Table 6.5.

Step 6: Reviewing the total resource requirements against availability

After preparing the programme chart (Figure 6.6), it is necessary to check the utilisation of resources, to ensure that there are no periods when the amount of each resource scheduled for use exceeds that available. The result for this example is shown in Table 6.6. If there is a problem of excess allocation, the programme must then be adjusted to achieve an acceptable balance of resources. In some cases it may be impossible to meet all the constraints, and some may need to be relaxed, for example, operations allowed to finish late or scheduled in a different order, or additional resources used (perhaps at greater expense).

Table 6.5 Maintenance programming example

Task Number	Task Name	Resource	Duration (weeks)	Constraint	Constraint Date	Predecessor tasks
1	Desilt Main Canal		6	As Soon As Possible		
2	desilt MC 0-100m	excavator	3	Start No Earlier Than	01/01/96	
3	desilt MC 100-200m	excavator	3	Finish No Later Than	28/02/96	2
4	Weed Main Canal		4	As Soon As Possible		
5	weed MC 0-100m	labour gang	2	Start No Earlier Than	01/06/96	
6	weed MC 100-200m	labour gang	2	Finish No Later Than	30/09/96	5
7	Desilt Branch Canal 1		2	As Soon As Possible		
8	desilt BC1 0-50m	excavator	1	As Soon As Possible		2
9	desilt BC1 50-100m	excavator	1	Finish No Later Than	28/03/96	8
10	Weed (1) Branch Canal 1		2	As Soon As Possible		
11	weed (1) BC1 0-50m	labour gang	1	As Soon As Possible		5
12	weed (1) BC1 50-100m	labour gang	1	Finish No Later Than	31/07/96	11
13	Weed (2) Branch Canal 1		2	As Soon As Possible		
14	weed (2) BC1 0-50m	labour gang	1	Start No Earlier Than	01/09/96	
15	weed (2) BC1 50-100m	labour gang	1	Finish No Later Than	30/10/96	14
16	Desilt Branch Canal 2		2	As Soon As Possible		
17	desilt BC2 0-50m	excavator	1	As Soon As Possible		3
18	desilt BC2 50-100m	excavator	1	Finish No Later Than	30/04/96	17
19	Weed (1) Branch Canal 2		2	As Soon As Possible		
20	weed (1) BC2 0-50m	labour gang	1	As Soon As Possible		6
21	weed (1) BC2 50-100m	labour gang	1	Finish No Later Than	31/07/96	20
22	Weed (2) Branch Canal 2		2	As Soon As Possible		
23	weed (2) BC2 0-50m	labour gang	1	Start No Earlier Than	01/09/96	
24	weed (2) BC2 50-100m	labour gang	1	Finish No Later Than	31/10/96	23
25	Clear (1) Collector Drain 1		4	As Soon As Possible		
26	weed (1) CD1 100-50m	labour gang	1	Start No Earlier Than	01/04/96	
27	desilt CD1 100-50m	excavator	1	As Soon As Possible		26
28	weed (1) CD1 50-0m	labour gang	1	As Soon As Possible		27

29	desilt CD1 50-0m	excavator	1	Finish No Later Than	31/12/96	28
30	Weed (2) Collector Drain 1		2	As Soon As Possible		
31	weed (2) CD1 100-50m	labour gang	1	Start No Earlier Than	01/11/96	
32	weed (2) CD1 50-0m	labour gang	1	Finish No Later Than	31/12/96	31
33	Clear (1) Collector Drain 2		4	As Soon As Possible		
34	weed (1) CD2 100-50m	labour gang	1	Start No Earlier Than	01/04/96	
35	desilt CD2 100-50m	excavator	1	As Soon As Possible		34
36	weed (1) CD2 50-0m	labour gang	1	As Soon As Possible		35
37	desilt CD2 50-0m	excavator	1	As Soon As Possible		36
38	Weed (2) Collector Drain 2		2	As Soon As Possible		
39	weed (2) CD2 100-50m	labour gang	1	Start No Earlier Than	01/11/96	
40	weed (2) CD2 50-0m	labour gang	1	Finish No Later Than	31/12/96	39
41	Desilt Main Drain		6	As Soon As Possible		
42	desilt MD 200-100m	excavator	3	As Soon As Possible		37
43	desilt MD 100-0m	excavator	3	As Soon As Possible		42
44	Weed (1) Main Drain		4	As Soon As Possible		
45	weed (1) MD 200-100m	labour gang	2	Start No Earlier Than	01/03/96	
46	weed (1) MD 100-0m	labour gang	2	As Soon As Possible		45
47	Weed (2) Main Drain		4	As Soon As Possible		
48	weed (2) MD 200-100m	labour gang	2	Start No Earlier Than	01/08/96	
49	weed (2) MD 100-0m	labour gang	2	As Soon As Possible		48
50	Weed (3) Main Drain		4	As Soon As Possible		
51	weed (3) MD 200-100m	labour gang	2	Start No Earlier Than	01/10/96	
52	weed (3) MD 100-0m	labour gang	2	As Soon As Possible		51

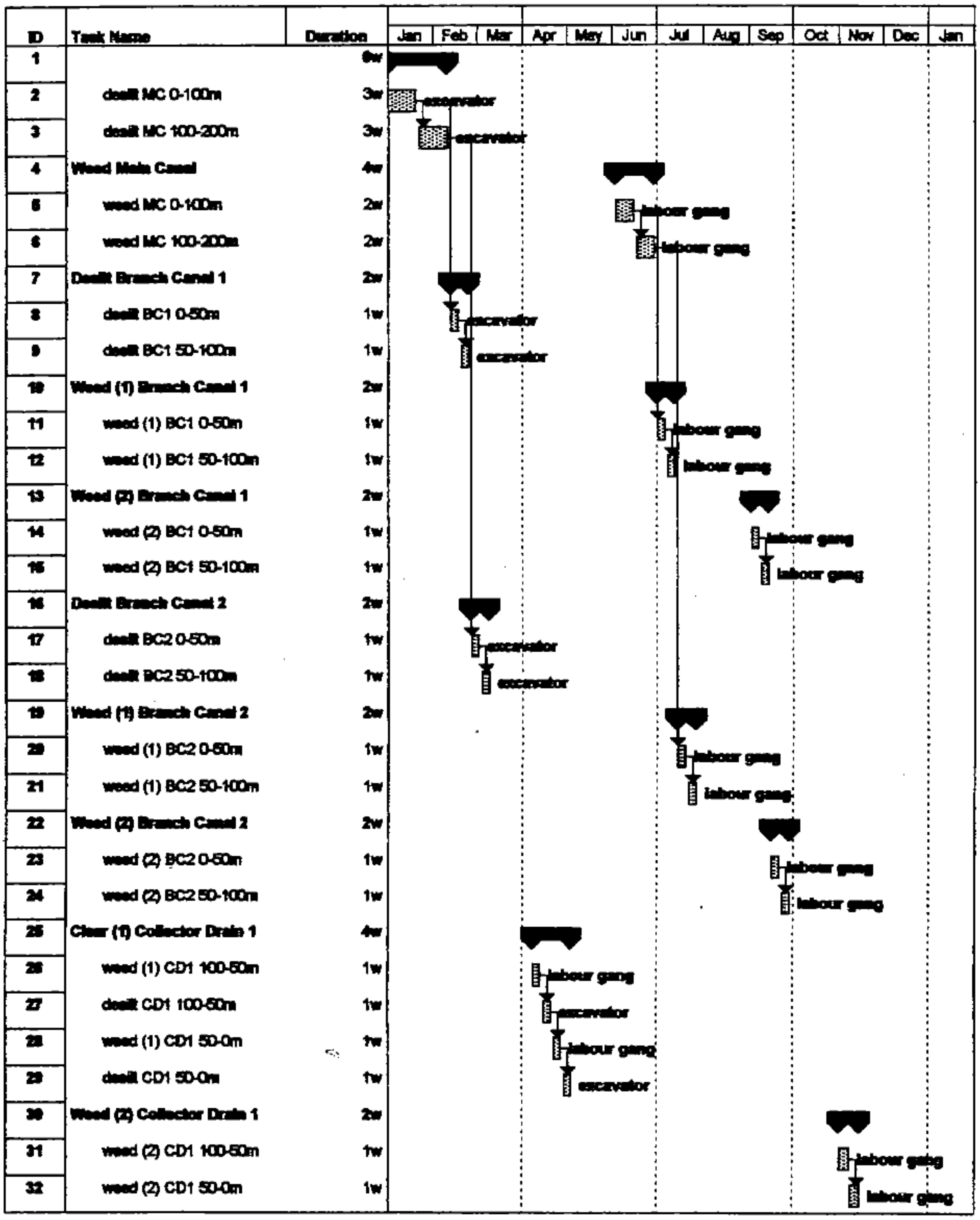
References

Asian Development Bank (1988), Handbook on the management of project implementation: A practical guide for the implementation of ADB-supported projects, Asian Development Bank

Clifton R. (1985), Principles of planned maintenance, Edward Arnold Ltd, UK

Moder J, Phillips C, and Davis E, (1983), Project management with CPM, PERT and precedence diagramming, Van Nostrand Reinhold, UK

Figure 6.6 Maintenance programming example - resource usage table



ID	Task Name	Duration
33	**Clear (1) Collector Drain 2**	4w
34	weed (1) CD2 100-50m	1w
35	desilt CD2 100-50m	1w
36	weed (1) CD2 50-0m	1w
37	desilt CD2 50-0m	1w
38	**Weed (2) Collector Drain 2**	2w
39	weed (2) CD2 100-50m	1w
40	weed (2) CD2 50-0m	1w
41	**Desilt Main Drain**	6w
42	desilt MD 200-100m	3w
43	desilt MD 100-0m	3w
44	**Weed (1) Main Drain**	4w
45	weed (1) MD 200-100m	2w
46	weed (1) MD 100-0m	2w
47	**Weed (2) Main Drain**	4w
48	weed (2) MD 200-100m	2w
49	weed (2) MD 100-0m	2w
50	**Weed (3) Main Drain**	4w
51	weed (3) MD 200-100m	2w
52	weed (3) MD 100-0m	2w