5.3 Action 2: To Implement the Physical Closure and Post Closure Management Including the Social Considerations

Based on the statement described in the safe closure guideline, procedure of landfill safe closure including physical closure and post closure management is shown in **Figure 5.3.1**.

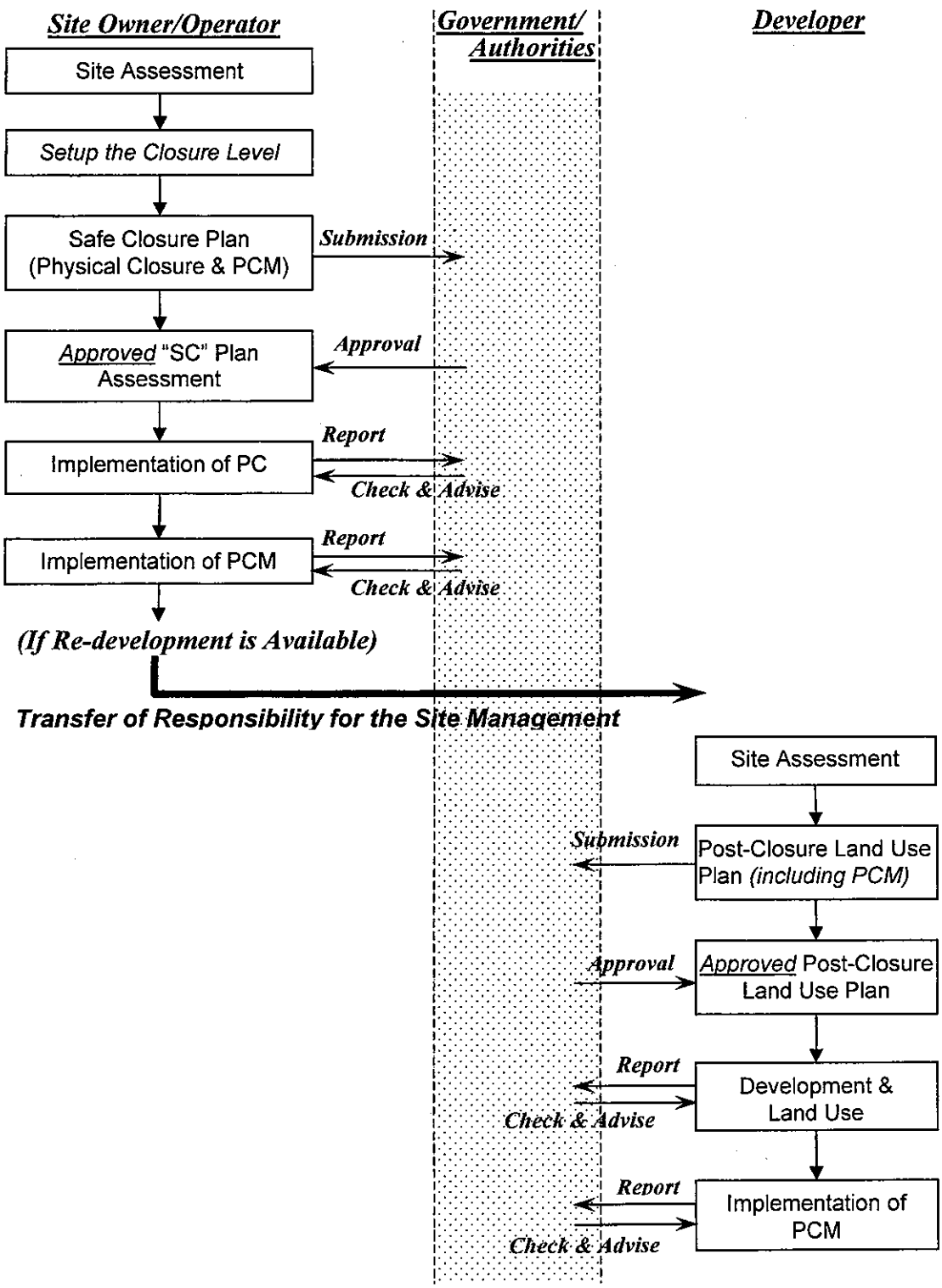


Figure 5.3.1 Process of Landfill Safe Closure

5.3.1 Physical Closure

(1) Physical closure plan

The Study has identified a total of 72 sites that require safe closure by the year 2010, and have been categorised into Groups A, B and C. The proposed implementation schedule should only commence from the year 2005, after the finalisation of the guideline and the necessary mechanisms.

The implementation schedule for the landfill safe closure is shown in **Table 5.3.1**. The table shows the annual breakdown of the number of sites, the closure levels and priority groups, which are to be closed from 2005 to 2010. The estimated CAPEX and OPEX have also been summarised in the table.

The required scope of works for physical closure should be determined on a case-to-case basis, including carrying out of the topographic surveys and soil investigations. The necessary steps for implementation are shown in the process for safe closure flowchart in **Figure 5.3.2**.

Table 5.3.1 Implementation Schedule for Landfill Safe Closure

(Unit of CAPEX & OPEX : RM)

1. CAPEX	2005					2006					2007					2008					2009					2010					Total
(Capital expenditure)	C1	C2	C3	C4	Total	C1	C2	C3	C4	Total	C1	C2	C3	C4	Total	C1	C2	C3	C4	Total	C1	C2	C3	C4	Total	C1	C2	C3	C4	Total	
A. Closed Sites																															
a) Group A			4	3	7																										
b) Group B							1	4	4	9																					
c) Group C											1	12	4		17																
A. Sub-total sites number					*7*					*9*					*17*					*0*					*0*					*0*	*33*
A. Sub-total CAPEX					*16,750,000*					*19,541,000*					*36,200,000*					*0*					*0*					*0*	*72,491,000*
A. Area of sites (ha)					*28.3*					*40.0*					*195.8*					*0*					*0*					*0*	*264.1*
B. Operating Sites																															
a) Group A			7	1	8				1	1			1		1			1		1			1	1	2					0	
b) Group B			4	1	5			3		3				3	3			1	1	2			2	1	3			1	1	2	
c) Group C			2		2			2		2		3			3					0			1		1					0	
B. Sub-total sites number					*15*					*6*					*7*					*3*					*6*					*2*	*39*
B. Sub-total CAPEX					*52,913,000*					*16,154,000*					*20,692,000*					*14,409,000*					*23,122,000*					*9,167,000*	*136,457,000*
B. Area of sites (ha)					*171.4*					*56.1*					*49.9*					*56.5*					*48.7*					*19.7*	*402.3*
Total Sites Number					*22*					*15*					*24*					*3*					*6*					*2*	*72*
Total CAPEX					*69,663,000*					*35,695,000*					*56,892,000*					*14,409,000*					*23,122,000*					*9,167,000*	*208,948,000*
Total Area (ha)					*199.7*					*96.1*					*245.7*					*56.5*					*48.7*					*19.7*	*666.4*

2. OPEX	2005					2006					2007					2008					2009					2010					Total
(Operational expenditure)	C1	C2	C3	C4	Total	C1	C2	C3	C4	Total	C1	C2	C3	C4	Total	C1	C2	C3	C4	Total	C1	C2	C3	C4	Total	C1	C2	C3	C4	Total	
A. Closed Sites																															
a) Group A						0	0	4	3	7	0	0	4	3	7	0	0	4	3	7	0	0	4	3	7	0	0	4	3	7	
b) Group B						0	0	0	0	0	0	1	4	4	9	0	1	4	4	9	0	1	4	4	9	0	1	4	4	9	
c) Group C						0	0	0	0	0	0	0	0	0	0	1	12	4	0	17	1	12	4	0	17	1	12	4	0	17	
A. Sub-total sites number										*7*					*16*					*33*					*33*					*33*	
A. Sub-total OPEX										*1,278,000*					*2,904,000*					*6,478,000*					*6,478,000*					*6,478,000*	*23,616,000*
A. Area of sites (ha)										*28.31*					*68.29*					*264.11*					*264.11*					*264.11*	*264.11*
B. Operating Sites															0					0					0					0	
a) Group A						0	0	7	1	8	0	0	7	2	9	0	0	8	2	10	0	0	9	2	11	0	0	10	3	13	
b) Group B						0	0	4	1	5	0	0	7	1	8	0	0	7	4	11	0	0	8	5	13	0	0	10	6	16	
c) Group C						0	0	2	0	2	0	0	4	0	4	0	3	4	0	7	0	3	4	0	7	0	3	5	0	8	
B. Sub-total sites number					*0*					*15*					*21*					*28*					*31*					*37*	
B. Sub-total OPEX					*-*					*5,277,000*					*7,044,000*					*8,671,000*					*10,059,000*					*11,868,000*	*42,919,000*
Total Sites Number					*0*					*22*					*37*					*61*					*64*					*70*	
Total OPEX					*-*					*6,555,000*					*9,948,000*					*15,149,000*					*16,537,000*					*18,346,000*	*66,535,000*

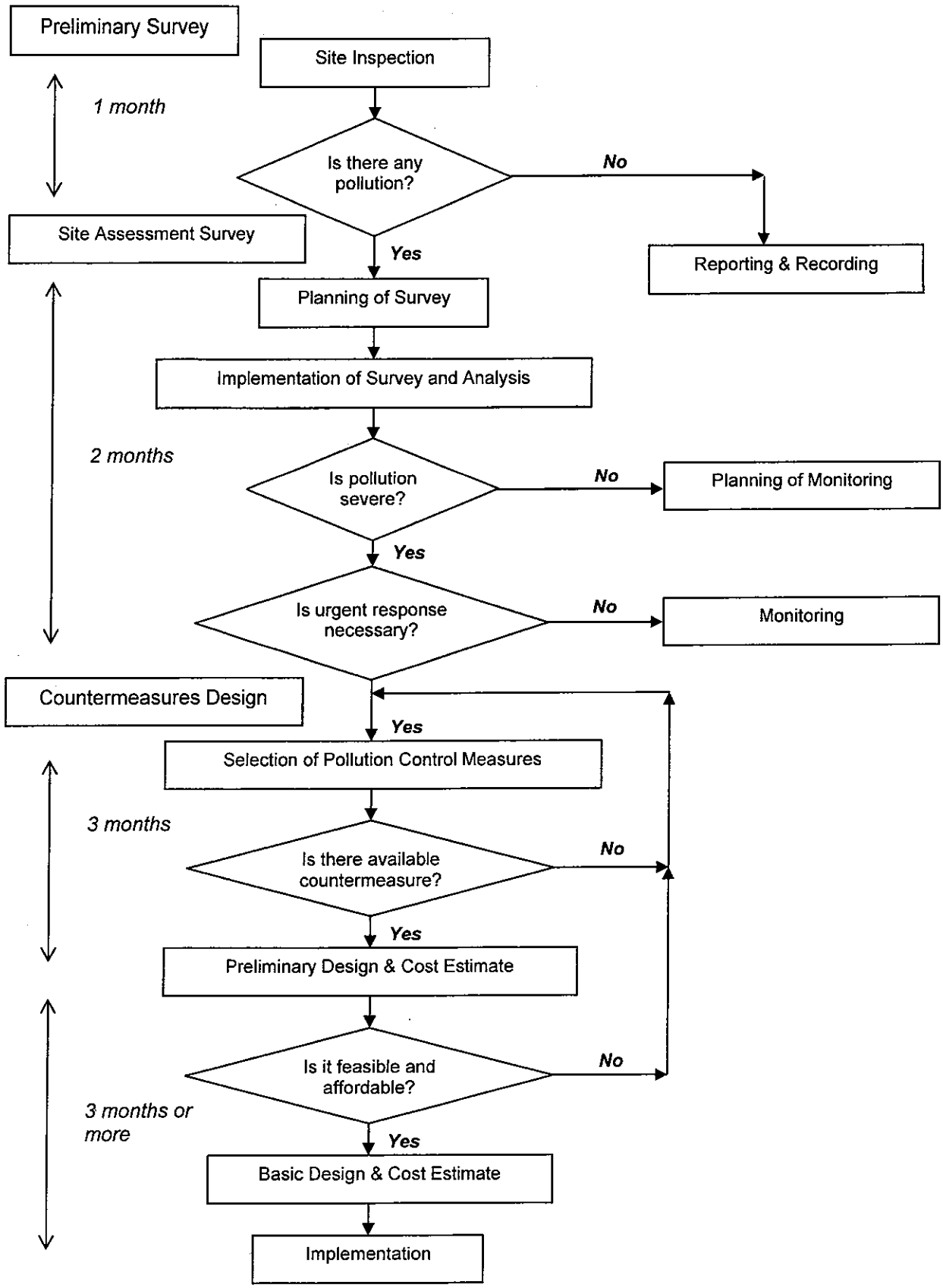


Figure 5.3.2 Process of Physical Closure

(2) Cost of Safe Closure up to the year 2010

The estimated total cost of safe closure up to the year 2010 is tabulated in **Table 5.3.2**. The total CAPEX is estimated to be about RM 209 million and OPEX is about RM66.5 million. The total estimated cost for the entire Action Plan period is estimated to be about RM 275.5 million.

Table 5.3.2 Cost of Safe Closure up to 2010

(Unit of CAPEX and OPEX: RM)

Item	2005	2006	2007	2008	2009	2010	Total
1. CAPEX							
A. Closed Sites							
a) Group A	16,750,000	-	-	-	-	-	16,750,000
b) Group B	-	19,541,000	-	-	-	-	19,541,000
c) Group C	-	-	36,200,000	-	-	-	36,200,000
Sub - Total	16,750,000	19,541,000	36,200,000	-	-	-	72,491,000
B. Operating Sites							
a) Group A	24,926,000	2,839,000	2,268,000	11,179,000	14,289,000	-	55,501,000
b) Group B	24,108,000	9,444,000	14,546,000	3,230,000	8,058,000	9,167,000	68,553,000
c) Group C	3,879,000	3,871,000	3,878,000	-	775,000	-	12,403,000
Sub - Total	52,913,000	16,154,000	20,692,000	14,409,000	23,122,000	9,167,000	136,457,000
Total CAPEX (Annual)	69,663,000	35,695,000	56,892,000	14,409,000	23,122,000	9,167,000	208,948,000
2. OPEX							
A. Closed Sites							
a) Group A	-	1,278,000	1,278,000	1,278,000	1,278,000	1,278,000	6,390,000
b) Group B	-	-	1,626,000	1,626,000	1,626,000	1,626,000	6,504,000
c) Group C	-	-	-	3,574,000	3,574,000	3,574,000	10,722,000
Sub - Total	-	1,278,000	2,904,000	6,478,000	6,478,000	6,478,000	23,616,000
B. Operating Sites							
a) Group A	-	2,409,000	2,596,000	2,837,000	3,917,000	4,958,000	16,717,000
b) Group B	-	2,421,000	3,580,000	4,575,000	4,883,000	5,544,000	21,003,000
c) Group C	-	447,000	868,000	1,259,000	1,259,000	1,366,000	5,199,000
Sub - Total	-	5,277,000	7,044,000	8,671,000	10,059,000	11,868,000	42,919,000
Total OPEX (Annual)	-	6,555,000	9,948,000	15,149,000	16,537,000	18,346,000	66,535,000
Total CAPEX + OPEX (Annual)	*69,663,000*	*42,250,000*	*66,840,000*	*29,558,000*	*39,659,000*	*27,513,000*	*275,483,000*

5.3.2 Post Closure Management

The facilities installed for safe storage of waste, prevention of environmental pollution and accelerating early stabilization should be operated and maintained properly, up until the closed landfill site has stabilised. The monitoring of the environmental pollution and stabilisation of waste should be carried out continuously.

The post closure management includes the operation and maintenance of installed landfill facilities such as the leachate treatment facility, gas ventilation system, maintenance of the top cover, surface drainage system, groundwater monitoring wells and the other supporting facilities (i.e. the access road and the vegetation growth)

The typical example of the maintenance items of the landfill facilities, method and scale/frequency are shown in **Table 5.3.3**.

Table 5.3.3 Summary of Maintenance Items

Facilities	Items	Methods	Scale/ Frequency
Top cover & dykes	Cracks, pools and soil erosion on the surface, State of plants	Periodical visual inspections	The entire site, weekly
Surface drainage on the top cover	Clogging by soil/leaves, Damage by sedimentation	Periodical visual inspections	The entire site, weekly (more frequent during the rain season)
Cut-off drainage around the site	Clogging by soil/leaves, Damage by traffic	Periodical visual inspections	The entire site, weekly (more frequent during the rain season)
Gas ventilation pipes	Clogging, damage to pipes, corrosion	Periodical visual inspections	all pipes, weekly
Leachate collection pipes	Clogging, damage to pipes, corrosion	Periodical inspections & comparison of the effluent quantity data	daily
Leachate treatment facility	Quality of treated effluent	Daily inspections (colour of effluent) Periodical effluent analysis	daily monitoring frequency
Monitoring facility	Conditions of the monitoring wells	Periodical inspections	all wells, weekly

Meanwhile, the post closure management also includes the monitoring of environmental pollution and stabilisation of water. The typical example of the monitoring items, parameters and frequency of monitoring are shown in **Table 5.3.4**.

Table 5.3.4 Summary of Monitoring Items

Monitoring media/parameters	Item and parameters	Frequency	Location
Preliminary site inspection	1) The surrounding environment 2) The condition of the facility 3) Nuisance condition	Once (before monitoring)	-
Leachate	• pH • BOD • COD • Nitrogen (Ammonia, Nitrate, Nitrite) • ORP • EC • TOC	4 times per year	1 point per leachate pond
Landfill gas	• Oxygen (O_2) • Nitrogen (N_2) • Methane (CH_4) • Carbonic anhydride (CO_2) • Hydrogen sulphide (H_2S) • Temperature	2 times per year	2 points per site
Soil subsidence	Topographic level at the top of the landfill	Once a year	1 point per landfill block
Groundwater	Groundwater benchmark parameters	Once a year	3 points per site
Surface water	Effluent standard parameters	Once a year	2 points per stream

5.3.3 Social Considerations

The social aspects/issues on scavengers and/or nearby households should be taken into consideration for each of the pre-closure, closing and post-closure stages of the landfill sites. The main issues are as follows:

(1) Scavengers

1) Pre-closure stage

a. Surveys

Site surveys on the situation of the scavenging activities at the landfills that are to be closed should be carried out as follows:

- Interviews with the scavengers at the sites
- Interview with recycling individuals/companies operating at the landfills in order to identify and to determine the number of scavengers engaged at the site and their activities

b. Clearing/eviction of scavengers

For the safety reasons, no unauthorised personnel should be working at the site, especially the scavengers. The Local Authorities or operators of the landfill sites should formulate plans to prevent or evict the scavengers from the site. The plan should take into consideration of the following:

- Any clearing/eviction plan should take into consideration of the social and financial plights of the scavengers and should be handled with care and understanding. In accordance with viewpoints of humanity, welfare of the socially disadvantaged groups and social context, safety and peaceful eviction plans shall be elaborated through democratic and consensual manner.
- The scavengers should be encouraged to leave the site voluntarily and should not be forcefully evicted.
- The clearing/eviction processes should take into consideration of the scavengers' opinions and reservations.

c. Notices for the closures

The preparations of relevant information for the notices of the closures should be carried out to include the following:

- The preparation of notice hoarding/signboards, and/or printed literature on the closures to be written in Bahasa Malaysia, English, Chinese and Tamil, and distributed. The notices should include information such as the closure date, the reasons for closure, the information on the new/alternative landfill, if any.
- To provide healthy and safety awareness briefings to the scavengers, to include information on possible diseases, infections, long term health risks, etc. The scavengers must be alerted to the possibilities of the transmission of communicable diseases and must be provided with hygiene and environmental health education.

d. Briefing the scavengers on the closures

- In addition to preparations of the printed notices, on-site briefings may be provided by the LAs. Such briefing should include the reasons for their eviction, the health and safety aspects, etc.

2) Closing/post closure stage

a. Warning Notices

In the closing/post closure stage there is the possibility that scavengers may try to gain entry to the landfill sites. Warning notices should be installed around the site informing of the closure, such notices should include the following:

- The putting up of "NO TRASSPASSING" and "DANGER" warning signs to prevent and discourage trespassing by the scavengers or other unauthorised personnel.
- In may also be necessary to put up "NO SMOKING" or "NO BURNING" signs to prevent any accidents that may result from the presence of methane and hydrogen gases.
- The information should include legal implications and regulatory warnings, and penalties imposed.

b. Construction of fences

In order to demarcate the physical boundary of the site and to deter trespassing, steel wire fences or hoardings should be constructed around the site. However, the fencing or hoardings should blend in with the surrounding and should not spoil the aesthetics of the area.

c. Inspections, monitoring and patrols

In order to ensure no further scavenging activities are being carried out at the site after the scavengers have been evicted, it is necessary for the LA or operator of the site to perform regular inspections and patrols to check on the activities at the site.

Verbal warnings may be given to the scavengers that are still trespassing the site. Stepwise warning systems against further scavengers should also be prepared. (For example. the 1st step is to warn the scavengers about illegal act verbally, 2nd step is to warn them about law enforcement measures and final stage is to enforce the action in cooperation with relevant law enforcement official or with the police).

(2) Nearby and Surrounding Households

1) Pre-closure stage

a. Surveys

The surveys on the number and types of properties, especially the households, nearby and surrounding the sites should be carried out and including interviews with the occupants of the premises, especially the nearby residents.

b. Notices for closures

The preparations of relevant information and notices for the closure are necessary, including the provision of notice signboards and printed literature materials on the closures, similar to those used for the scavengers.

Landfills as themselves may have a negative potential to the environment and the human health. Namely, landfills to be closed are the point of release of vectors (insects, small animals and scavengers) of communicable diseases, methane gas and other toxic chemical substances, and unexpected disasters like landslides. As well, the alternative landfills to be operated for closed ones will have the same negative potential.

c. Public briefings on the closures

Public briefings or education programmes should be provided to those working or staying around the landfill site. The briefing should include all relevant subject matters such as the environmental issues related to the site, the health and safety issues and also the proposed post-closure utilisation of the site.

d. Setting up of Public Complaints/Information desk at the LA

It may be necessary to set up the public complaints/information desk at the LA to deal with complaints or the request for more information by the public.

2) Closing/post closure stage

a. Warning Notices

Warning notices similar to those used for the scavengers should also be provided here.

In the closing/post closure stage (and even at the time of actual closure implementation), there is a possibility that children and others (for scavenging remaining waste or for constructing illegal houses) will try to enter the specific landfill sites.

- To prevent such acts, signboards, which prohibit entering specific landfill sites without permission issued by LA, shall be installed.
- To inform accidents may be caused by landslide, subsidence emerging of methane and hydrogen gases, related signboards should be installed.
- Such information shall include legal and regulatory compliance, and penalty measures.
- Preparation of the signboards shall be written in *Bahasa* Malaysia, English, Chinese and Tamil.
- Those languages to be used are determined with due consideration of present situation to each landfill site.

b. Construction of fences

Similar to the above, for the scavenger control, perimeter fencing should be provided to deter trespassing. However, the fencing or hoardings should blend in with the surrounding and should not spoil the aesthetics of the area.

c. Regular inspection, monitors and patrols

To make sure the prevention of further entering by children and others at specific landfill sites, LA and/or construction contractors are required to conduct regular inspection, monitors and patrols at the specific landfill sites.

- Regular inspection, monitor and patrol plans and systems shall be made in corporation with contractors at the initial stage of the closures.
- Stepwise warning systems against intruders and further scavengers shall be prepared. (For example. the 1st step is to warn the scavengers about illegal act verbally, 2nd step is to warn them about law enforcement measures and final stage is to enforce the action in cooperation with relevant law enforcement official or with the police).
- Briefings on the post-closure utilization of the landfills

d. Public briefing

Public briefings on the proposed post-closure utilisation should be carried out by LA and should also include the following:

- A survey and interview to ascertain the opinions of the residents on the potential land use for the site
- To carry out community participatory programmes, i.e. Post-Closure Management workshops and Public Awareness road shows.

5.4 Action 3: To Establish the Landfill Registration System

The landfill registration system is essential for the proper management and control of landfilling activities in the country. The registration provided up to date information on the landfill from the first day of operations through to the closure stage and continued over the post-closure period. The registration system should be carried out and the registration database should be maintained and updated regularly. Items need to be registered are shown in **Appendix 18, Volume 3**.

In addition, the registration system should be used to check and monitor the post-closure utilisation of the sites and to prevent any over exploitation of the site for purposes not suitable for the area.

The landfill registration system should be carried out by and managed by the State Government under the guidance of the Federal Government. The Local Authorities should be responsible for providing the updated information to the State, together with reporting of any infringements or irregularities that may occur. The introduction of the landfill registration system will be the first step towards preventing illegal waste dumping. The flowchart for the landfill registration and management system is shown in **Table 5.4.1**.

Table 5.4.1 Flowchart of Landfill Registration and Management System

Landfill classification \ Landfill stages			Plan/Const. Stage	Operating Stage	Post-closure stage
			Plan / Construction	Operation	Physical closure (PC) / Post-closure management (PCM) / (approx 10years) / Post-closure land use
New site	Management of Landfill site		Registration	Checking of landfill operation; Safe closure plan approval	Checking of PC works; Checking of PCM
New site	Management of post-closure land use				Post-closure land use plan (1 year) approval; Checking of land use works
Operating site	Management of landfill site			Checking of landfill operation; Registration; Safe closure plan approval	Checking of PC works; Checking of PCM
Operating site	Management of post-closure land use				Post-closure land use plan (1 year) approval; Checking of land use works
Closed site	Management of landfill site				Safe closure plan; Registration; Checking of PC works; approval; Checking of PCM
Closed site	Management of post-closure land use	Site not yet in use			Post-closure land use plan (1 year) approval; Checking of land use works
Closed site	Management of post-closure land use	Site already utilised			Review of post-closure land use

5.5 Action 4: To Arrange the Federal and State Organisations

5.5.1 Landfill Sites Management Committee (LSMC)

Since all land matters are under the control of the State Government, it is appropriate that the related authorities of the State Government should be responsible for implementing and maintaining the Landfill Registration System. It is understood that, even after the proposed privatisation of landfill sites, no specific agency will be responsible for the closed landfill sites or illegal dumping grounds, as the State Government should continue to be responsible for such sites.

It is proposed that the Landfill Sites Management Committee (LSMC) should be set up at the State Government level, as the main player in the management/monitoring of the safe closure of landfill sites. The main roles of the committee are:

i To carry out the registration of the landfill sites

ii. To provide approval for the "Safe Closure Plan", including physical closure and post-closure management plan

iii. To manage and monitor the activities of landfill operators/owners for the safe closure. The committee should also be responsible for the post-closure land-use of the closed landfill sites; i.e. approval and monitor the "Development Plan of Closed Site" which includes development plan, PCM and safety control plan.

The LSMC should comprise of members from the following departments or offices;

- The Local Government Unit, State
- The State Land Office
- The State Economic Planning Unit (UPEN)
- The State Department of Environment
- The State Health Department
- The State Land and Country Planning Department

As an alternative to the LSMC, the Landfill Site Management Division (LSMD) should be established and should be responsible for the landfill safe closure management activities in the State level. The proposed organisation structure of the LSMD is shown in **Figure 5.5.1**.

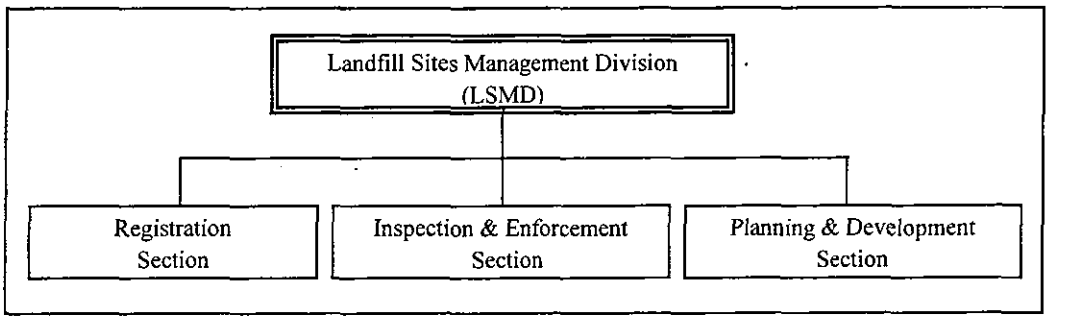


Figure 5.5.1 Organisation Structure of the LSMD

The State Local Government Unit should also assist the LSMD.

However, it is noted that many State Governments lack the technical expertise and human resources to administer these tasks. As such, MHLG is expected to develop human resources needs and provide technical advises to the State Government. It is also recommended that the Technical Committee for Management of Landfill Site (TCMLS) should be set up at the Federal level and to provide technical support to the State Government.

5.5.2 Technical Committee for Management of Landfill Site (TCMLS)

The proposed Technical Committee for Management of Landfill Site (TCMLS) should be set up at the Federal Government level. The main role of the committee is to give technical advice to the States, LAs, landfill operators/owners etc. The committee members should convene as and when necessary to discuss and evaluate the implementation of landfill management; including Post Closure (PC), Post Closure Management (PCM) and re-development of closed landfills.

The committee members should comprise of representatives from institutions related to landfill management and including academicians. The members should include the following:

- Representatives from the Local Government Department of MHLG (Chairperson)
- Representatives from the Ministry of Health
- Representatives from the Ministry of Natural Resources and Environment
- Representatives from the Economic Planning Unit, Prime Minister's Department
- Academic Scholars from local universities and institute of higher educations
- Representatives from private landfill sites

5.5.3 Role of Major Stakeholders for Landfill Safe Closure

The flowchart outlining the role of the major stakeholders for landfill safe closure; i.e. Federal government, State government, Local authority and site owner/operator, is shown in **Figure 5.5.2**.

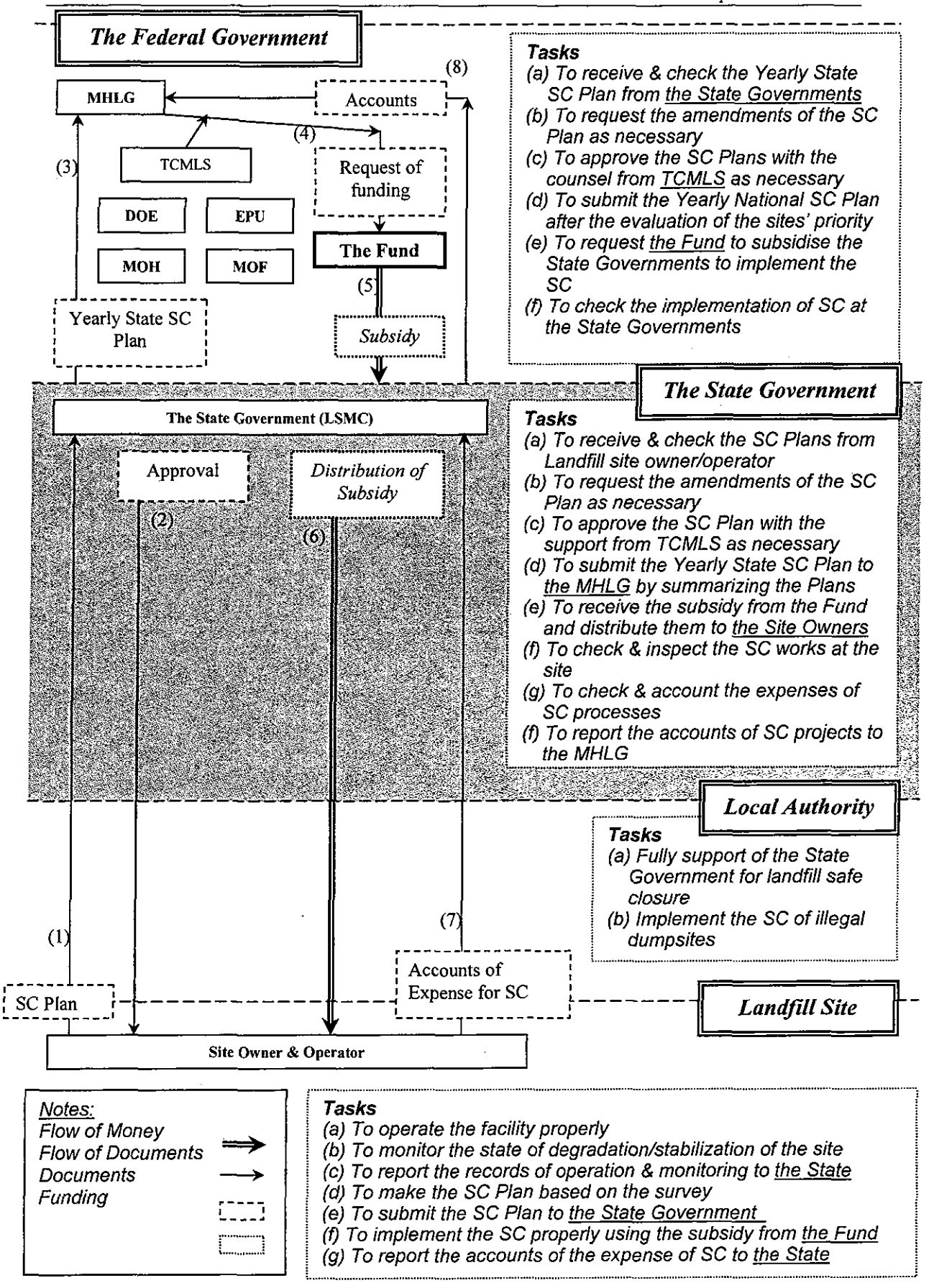


Figure 5.5.2 Roles of the Stakeholders for the Landfill Safe Closure Process

5.6 Action 5: To Establish a Funding System for Safe Closure

The Study made a preliminary financial analysis of the long-term plan on safe closure of landfill sites during 2005-2020. Taking into account this long-term perspective, the Study hereby recommends the funding system for implementation of the action plan with the target year of 2010.

(1) Basic Principle of Financing Safe Closure of Landfill Sites

Since the safe closure of landfill is an integral part of landfill operation, the cost for safe closure should also be included as a part of the cost for landfill operation.

The SWM collection services in Malaysia are in the midst of privatisation and some Local Authorities have contracted out their waste collection services to the concessionaire companies under an interim agreement. Similarly, some LA have also contracted out their disposal services to private companies to operate the transfer stations and some of the landfill sites.

The Federal Government, under BP 500, annually allocates budget for improvement of the existing landfills. Referring to the annual report by MHLG, the total budget allocations for SWM were approximately RM264 million for 2001, which accounts for about 10% of the total budget for MHLG. However, there has been virtually no budget allocation made for closure of waste landfills so far in Malaysia.

The draft NSP recommended that the cost of municipal solid waste management should be covered by those who generate wastes in accordance with the "Polluter Pays Principle" (PPP). The draft NSP also estimated the proposed fee for SWM services to be levied to the households and business premises to cater for the SWM costs. However, the cost for closure of landfills has not been fully identified in the draft NSP.

(2) Fund Raising Options for Safe Closure in Other Countries

The options for raising the fund for safe closure can be learned and adopted from examples of funding in some of the developed countries, e.g. Japan, USA, and the Netherlands. The examples were compared and the most suitable system for Malaysia was identified. The examples are as follows.

1) Japan

In 1997, the Government of Japan (GOJ) established the Reserve Fund for Maintenance of Closed Final Disposal Landfill under the amendment of the Waste Management and Cleansing Act. The outline of the reserve fund is as follows:

a. Purpose of the Fund

The purpose of the fund is to provide financial assistance for the proper operation and maintenance of closed final disposal landfills. The funds for each of the landfills are collected from the respective owners of the landfill during the landfill's period of operations.

b Basic Mechanism of the Fund

There are 3 major stakeholders responsible for the management of the reserve fund, they are;

- **Japan Environment Corporation (JEC),** this special government corporation was established in 1965 for providing technical and financial assistance for environmental pollution control, and is responsible for administration of the reserve fund,

- **Prefecture Governors,** who are responsible for determining the amount of fund collected from landfill owners for the reserve fund, and

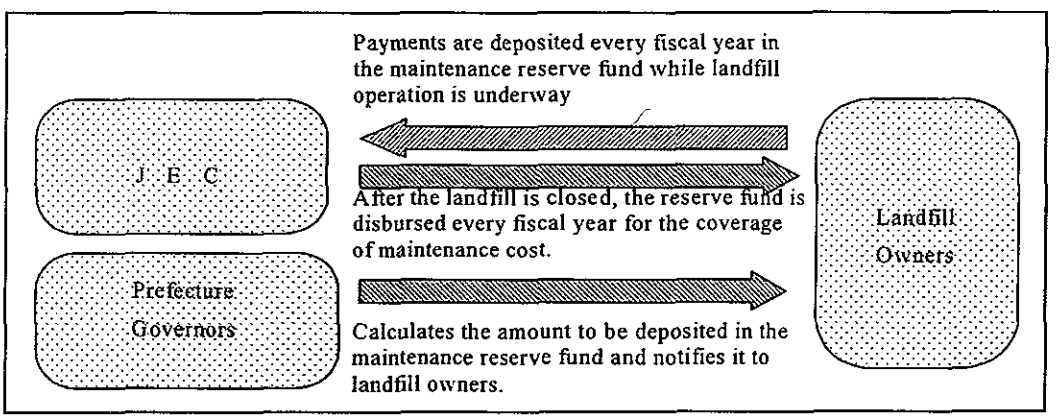
- **Landfill Owners,** who are responsible to deposit the fund with JEC, and eventually to withdraw from the fund for the closure of their site.

The duties of the above stakeholders are provided in the Waste Management and Cleansing Act. **Table 5.6.1** summarizes their duties and responsibilities in relation to the reserve fund.

Table 5.6.1 Duties and Responsibilities of Key Stakeholders

Stakeholder	Duties/Responsibilities
Japan Environment Corporation (JEC)	- Administer and manage the reserve fund collected from landfill owners. - Disburse the fund to landfill owners for maintenance of the closed landfills.
Prefecture Governors	- Determine the amount of reserved fund required for each landfill for proper maintenance after its closure. - Estimation of the amount of reserved fund is made in accordance with the methods provided by the administrative order by the Environment Minister, based on the cost of maintenance after closure of landfill and period of landfill operation up until its closure.
Landfill Owners	- Deposit the reserved fund at JEC annually during the period of landfill operation in accordance with the notification of the prefecture governors. - Landfill owners can recollect the reserve fund at the time of starting the maintenance of closed landfill.

The basic mechanism of the reserve fund is shown in **Figure 5.6.1**.



Source: http://www.jec.go.jp/eg/html/engl7.htm

Figure 5.6.1 Basic Mechanism of the Reserve Fund

2) United States of America (USA)

In the case of USA, every landfill owner and/or operator is required by law to reserve some funds for closure and post-closure management of the landfill. Approval of such fund reserve plan must be obtained from the relevant governmental authority before the license for landfill operation can be issued. Every site owner and/or operator is required to reserve and manage the fund by themselves prior to the commencement of the landfill operations. There is no external source of fund or subsidy allocated and all landfill owners/operators are solely responsible for closure and post-closure management of their landfills.

3) The Netherlands

In the Netherlands, the State Governments hold primary responsibility for operation of landfills as well as their closure and post-closure management. The funds for closure and post-closure management are also raised by the State Governments themselves. The sources of the fund may be from subsidy from the National Government and from the State Governments' own reserves from the revenue collected from tipping fees.

(3) Establishment of the National Fund for Landfill Closure

As illustrated in Figure 5.2.7 above, the primary sources of financing safe closure of landfill sites are allocation of national budget and collection of additional tipping fees for final disposal at landfills.

Above article (2) presents some developed countries' examples of raising the fund for closure and post-closure management of landfills. In the case of Japan and the Netherlands, establishment of the reserve fund is the solution to procurement of the fund for closure and post-closure management while USA obliges the landfill owners/operators to reserve the fund by themselves for their landfills. In the case of Malaysia, it is virtually impossible to let safe closure of landfills upon the shoulders of landfill owners or operators (state government or local authority in most of the cases) because they do not have enough budgets to properly conduct them without financial support from the Federal Government. It is also difficult to take over closure and post-closure of landfills to the state government such as the case in the Netherlands since their administration as well as financial capacity is still very limited in Malaysia. Therefore, the Study recommends applying the Japan's mechanism with modification adapted to local conditions in Malaysia. As the first step, the Study recommends establishment the federal reserve fund for closure and post-closure of landfills in Malaysia.

To secure availability of the fund, the Study recommends creation of the national fund for landfill closure in Malaysia. The fund mainly consists of:

- Additional allocation of national budget specifically used for landfill closure,
- Additional tipping fees collected from those who bring waste into the landfills including public and private SW haulers.

The percentage of each fund source will be determined based on the availability of national budget and also examination on the affordability of SW haulers. It is also

important to examine the possible increase of current SW collection fee rates levying to each household as well as other business establishments that generate solid waste.

In addition, the government should also make every possible effort of raising the fund from other sources including acquisition of CER under CDM of Kyoto Mechanism as mentioned earlier in Section 5.2.4 (3). If the safely closed landfill can be sold to the third party with strictly requirement of continuous environmental monitoring and specified land use, its income will also be added to the fund.

However, since the income from trading CER or selling of the closed landfill is not expected especially in the early years of the action plan period, allocation of national budget and collection of additional tipping fee will be the major sources of the fund.

(4) Recommended Fund Raising Plan

The Study here recommends the fund raising plan for safe closure of the landfill in accordance with the action plan. Primary sources of the fund are additional allocation of national budget and additional collection of tipping fees.

Considering the difficulty in obtaining the acceptance of citizens about the increase of the current rates of SWM services, additional tipping fee collection needs to be gradually applied to all the landfill sites, starting from metropolitan areas, subsequently to urbanized ones, and finally to other remaining areas. It means that governmental budget allocation is especially required in the early years of the action plan. Based on this recognition, the Study establishes the fund raising plan in accordance with the following preconditions.

- Fund raising from additional tipping fee collection will be carried out in accordance with the schedule shown in **Table 5.6.2**.

Table 5.6.2 Schedule of Additional Fee Collection

2005-2006	2007-2009	2010-
Additional fee collection will be carried out in KL	Additional fee collection will be gradually extended to other urbanized areas	Additional fee collection will be extended to the whole country.

- The shortage of the fund for implementing the action plan during 2005-2010 will be covered by additional allocation from the national budget.
- From 2010 onward, the fund for safe closure will be mostly covered by additional fee collection.

Table 5.6.3 below estimates the amount of the fund raised from additional fee collection and additional National budget allocation required for safe closure of the landfill sites in accordance with the action plan and the above preconditions.

Table 5.6.3 Estimated Amount of Fund with the Required Fund for Safe Closure of Landfill Sites during 2005 to 2010 (72 sites)

(Unit: RM thousand)

Item	2005	2006	2007	2008	2009	2010
National budget required	55,750	55,750	29,610	29,610	0	0
Collection of tipping fees	3,602	3,795	12,199	24,988	39,348	40,760
Required fund for closure	69,663	42,250	66,840	29,558	39,659	27,513
Balance	-10,311	17,295	-25,031	25,040	-311	13,247

Figure 5.6.2 shows the estimated trend of CAPEX and OPEX in accordance with the action plan for safe closure of landfill sites (72 numbers)

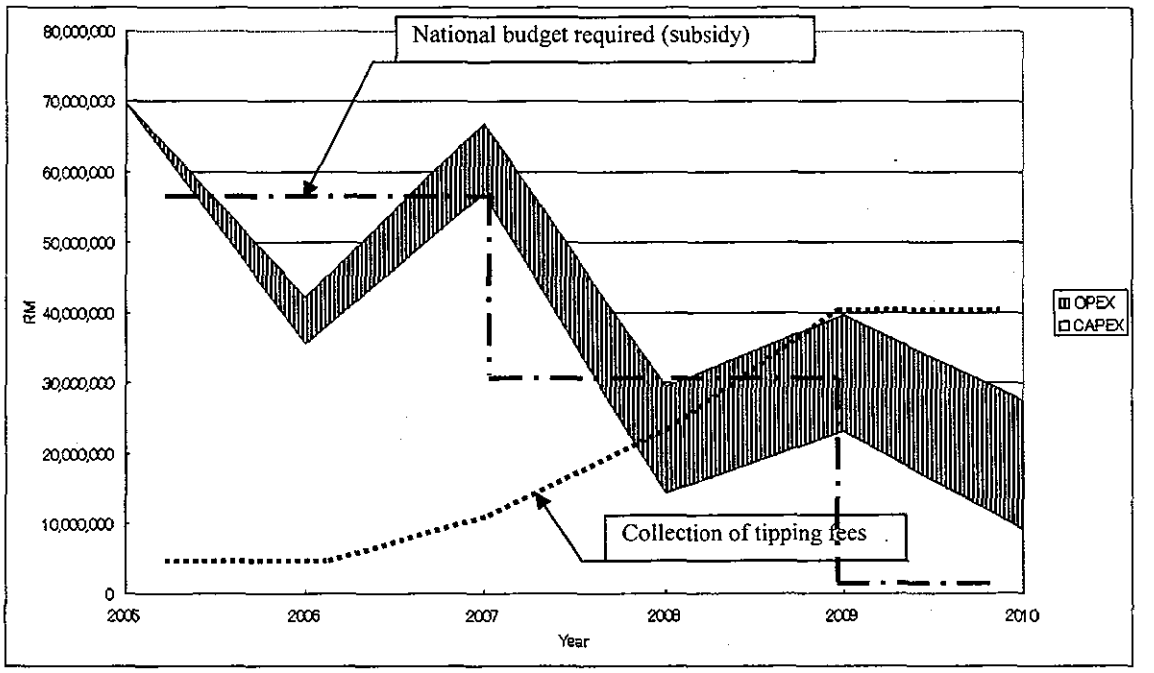


Figure 5.6.2 Trend of CAPEX and OPEX for Landfill Closure Action Plan (2005 - 2010)

The above fund raising plan may need to be adjusted to meet with the possible amount of the additional fee that can be collected and also the additional national budget that can be allocated by the Federal Government. Be that as it may, the percentage of the allocation of fund between the national budget and additional tipping fee collection will depend on availability of budget and affordability as well as willingness-to-pay of those who receive SWM services.

(5) Key Issues to be addressed for establishment of the National Fund

As to the budget allocation for the National Fund, it depends on the decision of the government while collection of additional tipping fee may entail several complex issues in relation to the SW collection fee rates, privatisation of SW collection and haulage services, and operation of the existing landfills. SW collection fee rates have to be carefully designed in consideration of equality among the peoples and their affordability and willingness to pay. With the collection of additional tipping fee for safe closure of landfills, the current contracts between private SW collection and haulage service

providers may need to be amended. The method of additional tipping fee collection will be another critical issue to be addressed. Taking into account the characteristics of the National Fund, the additional tipping fee should go to the fund and be managed by the government, in this case, MHLG, and provided to each landfill operating body at the time of landfill closure. The landfill owners and/or operators may be required to submit their landfill closure plan to the State authority while the state authority will submit these plans to MHLG for its approval of providing the fund.

As for the option for the allocation of the National Fund, it will be given to LAs taking into account the financial capability of targeted LAs. Range of subsidy from the fund might range between 50% to 100%.

As for the financial management of the reserve fund, the government financial institutes (GFIs) under the Ministry of Finance may take the main roles.

Initial seed money for the reserve fund may be required to be provided from the federal budget. In this regard, MHLG stated that it would consider some amount of budget to be earmarked for closure and post-closure of landfills in the Ninth Malaysia Plan.

5.7 Action 6: To Develop Human Resource for Capacity Building

In order for the proper implementation of safe closure of landfill sites, it is necessary to identify the responsible organisations, operators and managers who will handle the management and/or carry out the actual safe closure works. However, due to the lack of suitably trained managers or operators in this field in Malaysia at present, the Federal Government must ensure that proper training and technical assistance must be provided.

To develop the human resources in Malaysia, appropriate training programme should be prepared and carried out. It is recommended that bi-annual one-week training course be provided for this purpose for training of the personnel from the States, Local Authorities and also for the related private companies. The proposed contents of the training course are shown in **Table 5.7.1**.

Table 5.7.1 Proposed content of training courses for safe closure of landfill sites

	Training courses	State officials	LAs	Operator/ owner
1	Administration, management and finance	+++	+	+
2	Guideline	+++	+++	+++
3	Laws and enforcement	+++	++	+
4	Registration of landfill sites	+++	+	+
5	Inventory survey/priority and closure level set-up	+++	++	+
6	Physical closure and post-closure management	++	++	+++
7	Environmental risk and monitoring	++	+	+++
8	Re-development of closed landfill site	++	+	+++

Note: (+: Recommended, ++: Should Attend, +++: Compulsory)

5.8 Action Plan Schedule

5.8.1 Implementation Schedule

The implementation of landfill safe closure in accordance with the Action Plan has been determined by the consideration of the priority and closure schedule of operating sites. The implementation schedule for safe closure of landfill sites up to the year 2010 is shown in **Table 5.3.1** above.

(1) Outline

In order to implement the safe closure of landfills properly, the guideline for safe closure will have to be set up together with the "action plan for implementation of the guideline", and must be approved by the Government of Malaysia.

The Guideline and the Action Plan are supposed to be approved for implementation by the end of 2004. The Malaysian Counterparts are encouraged to expedite the approval process by making the necessary adjustments to the institutional set up and to obtain the Government's final approval for the Guideline and the Action Plan.

As for the approval of the guideline and the Action Plan, the setting up of the institutional mechanisms for landfill management and the special fund for safe closure are required, together with the collective approval by the Economic Planning Unit (EPU) and the Department of Environment (DOE).

(2) Implementation Schedule

In order to carry out the safe closure of landfill sites, the setting up and enactment of the safe closure guideline, the approval of the Action Plan, and budget allocation are urgently required to be completed. It is proposed that the Guideline and Action Plan should be set up in the year 2004. It is also desirable that the division for landfill management and fund for landfill safe closure should also be set up during this period.

The implementation schedule for the Action Plan is shown in **Table 5.8.1**. The main activities necessary to be carried out for the implementation of the Action Plan have been considered, they are;

1) Physical closure and post closure management
2) Enacting the safe closure guideline
3) Landfill registration system set-up
4) Completion of landfill sites list
5) Funding system set-up
6) Implementation of human resource development

Table 5.8.1 Implementation Schedule for Action Plan

	Activities	Agencies in charge	2003	2004	2005	2006	2007	2008	2009	2010
	JICA study for safe closure of Landfill sites									
	1. Preparation of guideline	JICA, MHLG, TWG								
	2. Preparation of action plan	JICA, MHLG, TWG								
	3. Pilot project and monitoring	JICA, MHLG, LAs								
	4. Human resources development	JICA, MHLG, TWG, States, LAs								
I.	**Physical closure and post closure management**									
	1. Instruction or public notice of landfill closure project	State								
	2. Preparation of safe closure plan	Operator/ owner or contractor								
	3. Approval of safe closure plan	State (and MHLG)								
	4. Physical closure	Operator/ owner or contractor								
	5. Post closure management (aftercare and monitoring)	Operator/ owner or contractor								
II	**Enacting the safe closure guideline**									
	1. Approval of the guideline	Federal gov. (MHLG and DOE)								
	2. Publicising/enacting the guideline	MHLG								
III	**Landfill registration system set-up**									
	1. Design of landfill registration system	MHLG								
	2. Publication of landfill registration system	MHLG								
	3. Set-up of landfill registration system	States								
	4. Registration of landfill sites	States and LAs (⇔ MHLG)								
IV	**Completion of landfill sites list (additional inventory)**									
	1. Data collection and survey of remaining landfill sites	LAs and States								
	2. Classification and closure level set-up	Sates and LAs								
	3. Compilation/ data base of additional landfill sites	States and MHLG								
V	**Funding system set-up for landfill safe closure**									
	1. Design of funding system	Federal gov. (EPU and MHLG)								
	2. Authorization of funding system	Federal gov. (EPU and MHLG)								
	3. National budget allocation for the fund	Federal gov. (EPU and MHLG)								
	4. Establishment of fund collection system from tipping fee	MHLG and States								
	5. Implementation of fund collection from tipping fee	LAs, States and MHLG								
	6. Budget allocation for physical closure/ aftercare of landfills	Federal gov. (EPU and MHLG)								
VI	**Implementation of human resource development**									
	1. Set-up training program	MHLG								
	2. Implementation of the program	MHLG								

5.9 Action Plan Evaluation

This section evaluates the financial and economic impacts of implementing the action plan on safe closure of landfills sites based on the analysis of cost and benefit arising from the action plan.

(1) The ratio of the cost for safe closure of landfills to the total SWM cost

According to the cost estimation made in this Study, the total cost required for implementing the action plan is as shown in the **Table 5.9.1** below.

Table 5.9.1 The Cost of Implementing the Action Plan

Description	Unit	Cost (RM)
1. Rehabilitation of Closed Landfills	Per tonne of waste generated	1.50
2. Safe Closure of Landfills in Operation	Per tonne of waste generated	4.10
Total Incremental Cost Required	Per tonne of waste generated	5.60
Total Incremental Cost Required (Urban household)	Per household per month	0.77
Total Incremental Cost Required (Rural household)	Per household per month	0.38

Notes:
- Amount of waste generation used in the table above is the total generation during the period of action plan from 2005 to 2010.
- The amount of household waste generation is estimated at 1.5 tons per urban household and 0.75 ton per rural household.

On the other hand, the draft NSP estimated the total cost of its implementation and currently levied assessment rate for SWM as shown in **Table 5.9.2**.

Table 5.9.2 The Cost of Implementing the Strategic Plan

Description	Unit	Cost (RM)
1. Current Cost of SWM Levied	Per tonne of waste generated	60 – 120
	Per household per month	7.5 – 15
2. Total Cost of Implementing the NSP	Per tonne of waste generated	227
	Per household per month	28

Source: MHLG, 2003

According to the cost estimations given above, the cost of implementing the safe closure of landfill sites up to 2020 only increases the rate of current levied cost of SWM by more or less 5.0%, or only 2.5% of the total cost required for implementing NSP. It implies that the impacts of the cost for safe closure of landfills would be small enough to be included in the total SWM cost.

(2) Willingness and Affordability to Pay of the household

Although there is no prior survey on willingness-to pay (WTP) of household in safe closure of landfills, there is a WTP survey on household in municipal solid waste management, which was carried out in 1998 by EPU-DANCED titled "A Contingent Valuation Study of Solid Waste Management in Kuala Lumpur & Petaling Jaya". Obviously the sampling households in this survey are dominated by the upper middle

class and may not represent average WTP of the average Malaysian public, the result can be referred as an example. It estimated that the sampling households are willing to pay on average about RM 15.17 per month or about 0.45% of their monthly household income.

According to this estimation, the cost for safe closure of landfill at the rate of RM0.77 per household is only about 5% of their WTP or around 0.02% of their monthly household income.

As to the affordability to pay of the household, the latest household income survey is conducted in 1999 is available in the 8th Malaysian Plan 2001-2005. The results of survey are shown in **Table 5.9.3**.

Table 5.9.3 Gross Monthly Household Income Distribution in 1999

Income Class	Gross Monthly Household Income (RM/month)		
	Overall	Urban	Rural
Average	2,472	3,103	2,589
Top 20%	6,268	7,580	4,214
Middle 40%	2,204	2,844	1,577
Bottom 40%	865	1,155	670

The percentage of the cost for safe closure of landfill to the gross monthly household income is therefore estimated and shown in the **Table 5.9.4** below.

Table 5.9.4 Percentage of the Cost for Safe Closure of Landfill to the Gross Monthly Household Income (RM0.70/month for household)

Income Class	Percentage (%)		
	Overall	Urban	Rural
Average	0.028	0.022	0.027
Top 20%	0.011	0.009	0.017
Middle 40%	0.032	0.025	0.044
Bottom 40%	0.081	0.061	0.104

As shown in the table above, the monthly cost per household for safe closure of landfills is mostly less than 0.1% of the gross monthly household income except for the lowest income category in rural area, which is just about 0.1%. It seems that the increase in the cost of less than 0.1% will be affordable to most of the households in Malaysia.

(3) Potential Economic Benefits Obtained from Implementation of the Action Plan

Although it is difficult to quantify the economic value of the benefits obtained from safe closure of landfills, there are many benefits of great importance that the Federal Government should pay attention to in terms of public health, environmental conservation, as well as sustainable development of the country. This section discusses and evaluates such benefits qualitatively as well as quantitatively as far as possible.

a. Prevention and minimization of the risks upon human health and environment through safe closure.

The primary objective of safe closure of landfills is to prevent and minimise the risks to human health and the environment that may otherwise be realised some time in the future. Such risks to the human health and the environment may include:

- Surface/ground water pollution due to leakage of leachate from landfills

  If proper closure is not undertaken in accordance with the action plan, the leachate may leak or wash out to contaminate the surface as well as the ground water. In the case of Malaysia, direct pollution to the potable water source may be minimised since most of the urban households are equipped with tap water from the potable water treatment plants and only a very small numbers of people directly use groundwater for their source of potable water. However, if there is agriculture land such as paddy field near the landfill sites, the leachate may contaminate the irrigation water and damages the agriculture crops. It should also be considered that there are some peoples who still use surface and groundwater from shallow wells directly, especially in rural areas. If the closed or operating landfills are located near such areas, peoples may suffer serious impacts from the pollution of their drinking water resources.

  Taking into account such conditions of surroundings, closure of landfills needs to be carefully examined so that potential risks can be eliminated or minimised.

- Washing out of waste from landfills

  The waste disposed at the landfills may be washed out due to heavy rains and contaminate the nearby area if proper closure including final soil cover have not been carried out at the landfills. It will damage the socio-economic activities of the nearby areas, especially to the agriculture and other human activities.

- Potential impacts of landfill gas on the nearby area

  There are some serious potential impacts of landfill gas on the nearby area if proper action has not been taken for safe closure of landfills. Such impacts include damages to agricultural crops due to exposure to landfill gas through the atmosphere as well as through the soil, incidental explosion and fire by landfill gas, damages to the buildings and infrastructure at nearby areas due to land subsidence through escape of landfill gas. These potential impacts can be eliminated or minimised by proper closure and monitoring of the landfills. Special attention needs to be paid to the landfills having some economic activities at the nearby areas.

Proper closure and post closure management of landfills will be able to prevent or minimise all the potential impacts above while the damages to human activities at the nearby area of landfill are sometimes large and irreversible. The economic loss arising from such damage is also sometimes very large, depending upon the type of land use and human activities at the nearby area. Therefore, the closure of landfill needs to be carefully determined in accordance with the criteria provided in the guidelines and action plan.

b. Maximisation of the development potential of the post closure landfill sites

Generally, the higher the closure level of the landfill site will result in the higher development and land use potential of the site. Properly closed landfills may also

permit the new land use and development earlier than those that were not properly closed. It is much more difficult to identify and estimate the potential risks of using and developing the landfills that are not closed in a proper manner. Such landfills can only be used for the purposes that do not involve many human activities.

The development potential of the land can be represented by its market value, which usually varies with types of land use and development potential. **Table 5.9.5** shows the examples of the difference in market value and prices of land for the types of potential land use.

Table 5.9.5 Variation of Market Land Price between Types of Land Use Potential

Unit: RM/m^2

State	Type of Land Use			
	Residential	Commercial	Industrial	Agricultural
Kuala Lumpur	679	2,422	NA	NA
Selangor	110	NA	118	14
Johor	44	NA	47	6
P.Pinang	145	609	508	30

NA: Data is not available.
Source: Property Market Report 2003, Valuation and Property Service Department, Ministry of Finance Malaysia.

Although the above figures are estimated from limited data currently available in Malaysia and also the market price of land depends upon not only the potential land use, but also the types and intensity of economic activities at nearby area, there still seems a big difference in the price of land among the types of potential land use, especially between the land for agricultural purposes and other development purposes. It implies that the value of land will be lower if it can be used only for the limited purposes due to existence of potential risks to human health and the environment resulting from improper closure and post closure management of landfills. Implementation of landfill safe closure and post closure management will have a significant influence upon the future land use and development potential of the closed landfills.

APPENDIX - Classification and Prioritisation of Landfill Sites

A.1 Findings on Landfill Safe Closure

A.1.1 State of Landfill Sites in Malaysia

An overview of the landfill sites in Malaysia is summarised as follows.

a. Landfilling is the most common method for waste disposal in Malaysia due to its relatively low operational costs. This disposal method is expected to be continuously adopted for the near future.

b. Most landfills are not properly managed.

c. Most landfills are located on State land.

d. In some landfills, waste tipping fees are being collected daily.

e. The waste tipping fees do not cover the costs for Post-Closure Management.

f. There is generally lack of experienced personnel to managing the site after the final waste filling.

g. Many landfills were closed without due care and may possess hazardous risks and environmental pollution.

h. Some of the landfills may require rehabilitation in order to prevent further hazards and environmental pollution.

i. Some of the closed landfills are being used for development purposes and may possess certain risks to the users.

j. Very little or no records were kept for the closed landfills.

A.1.2 General Facts/Issues Concerning Landfill Sites

For the purpose of the Study certain relevant facts and issues have been identified from observations reported in other similar studies from various parts of the world, they are highlighted here as follows:

(1) Technical aspects

Some of the more relevant technical issues to landfill closure are as follows:

a. The risks of environmental pollution and hazards will remain for a long time after waste filling work has been completed.

b. The quantity and quality of the leachate and gas will remain in high concentrations for a long period of time.

c. Major subsidence will usually occur in the first two years after final waste filling, and this may result in uneven soil settlement and erosion of the top soil cover.

d. A large number of disastrous and tragic accidents have been experienced in other parts of world due to landslide, slope collapse, gas explosion, etc.

e. There have been some successful cases of landfill rehabilitation and post-closure re-development where appropriate counter-measures, monitoring and maintenance were provided.

(2) Institutional Aspects

Some of the more significant institutional aspects related to landfill closure are as follows:

a. The Polluter Pays Principle, (PPP) should be adopted. However it may be difficult to identify the responsible parties or persons from amongst the stakeholders, i.e. the population, the waste generators, landfill operator/owners, the landowners, and the governmental bodies.

b. There is a limitation of the retrospective effects for imposing the regulations. It may be difficult to prosecute or take action against the responsible parties for their past activities.

c. A long period of time is required to manage the closed landfills. For example, in other parts of the world, the standard period for post-closure management as defined by the European Union Regulations is between 30 to50 years, and for the United States of America is about 30 years.

d. Specific funds or reserves for Post-closure management have been established in several countries such as;

- *Japan. Specific reserves for industrial waste landfill sites have been established and managed by a public agency*
- *USA: Each landfill should have their reserves deposited at a bank or trust, which will be monitored by the relevant authority*
- *The Netherlands: Every landfill sites should maintain their savings and be transferred to the State Governments when the site is closed.*

A.1.3 Past, Present and Future Key Issues on Safe closure in Malaysia

(1) Clarify existing issues

The problems associated with closure of landfills are not necessarily the results of "Past" operations or practices, i.e. from the closed sites, but they may also be from the operating sites. Landfills where disposal operation has stopped or is coming to an end should be closed safely. However, proper steps must also be considered for the operating sites so that they will not cause additional risks of hazard and environmental pollution. The activities for safe closure of landfills should be applied for both closed sites and operating sites.

(2) Public complaints against landfills

Proper physical closure and post-closure management will definitely improve the features and conditions of the closed landfill sites. With such visible improvements,

public complaints against the activities of landfilling may be lessened and the public will be more receptive to having the landfill around. The social benefits of properly implemented safe closure may contribute to the reduction of the "NIMBY" (Not In My Back Yard) attitude and reduces the opposition to future construction of sanitary landfills.

(3) Responsibility for landfill closure

The setting up of the PC & PCM systems will take some time to plan and establish the necessary procedures. Since the NSP is about to be authorised by the Government, it is necessary to start establishing the specific fund for safe closure of landfill sites and to decide upon the mechanism necessary to collect the funds, i.e wither from public funds, additional SWM charges or by the "PPP" (Polluter Pays Principle) policy.

A.2 Technical and Environmental Requirements

(1) Technical Requirement

1) Closure level

The closure level should be set by considering the *Environmental Risk Potential* and *Land Use Potential*, and in accordance with the Guideline for Safe Closure and Rehabilitation of Landfill Sites. (c.f. Volume 3). The number of sites are summarised in **Table A2.1**.

a. Closure Level 1 (C1) should be applied to the sites that have low *Environmental Risk Potential* and *Land Use Potential*.

b. Closure Level 2 (C2) should be applied to the sites that have lower *Environmental Risk Potential* that may be caused by leachate and for sites that are situated downstream of water intake points.

c. Closure Level 3 (C3) should be applied to the sites that have some *Environmental Risk Potential* caused by leachate and for sites that are situated up stream of water intake points.

d. Closure Level 4 (C4) should be applied to the sites that have greater *Environmental Risk Potential* on the surroundings and for sites that are situated near potable water sources or water intake points.

Table A2.1 Summary of Number of Sites for Each Closure Level

	C1	C2	C3	C4	**Total**
Closed site	1	13	12	7	**33**
Operating site	0	3	26	10	**39**
Total	**1**	**16**	**38**	**17**	**72**

2) Closure work

The estimated closure works for each the 4 closure levels are shown in **Table A2.2**. The estimated quantities are for "per hectare of landfill" basis.

Table A2.2 Estimated works for the Closure Levels (per hectare of landfill)

Item		Level C1	Level C2	Level C3	Level C4
(1) Final cover	a. Barrier layer thickness	600mm	600mm	600mm	600mm
	b. Top soil thickness	150mm	150mm	150mm	150mm
	c. Turfing	10,000 m^2	10,000 m^2	10,000 m^2	10,000 m^2
(2) Re-formation	a. Cut and fill		Where necessary	Where necessary	Where necessary
(3) Drainage	a. Earth drain		100 m	100 m	100 m
(4) Gas control	a. Horizontal gas pipe 50 m pitch		200 m	200 m	200 m
	a. Vertical gas vent		4 unit	4 unit	4 unit

(5) Leachate control	a. Leachate collection pipe			100 m	100 m
	b. Leachate pond and aerator			200m^2	200 m^2
	c. Re-circulation system			yes	yes
	d. Leachate treatment				yes
(6) Liner	a. Vertical liner				yes
(7) Monitoring		+	++	+++	+++

Note : + : Magnitude of monitoring necessity (+ : low, ++ : medium, +++ : high)

3) Leachate quality

The negative environmental impacts caused by the leachate are a major issue related to all landfill sites.

For example, the comparison of the leachate quality of the samples taken in Ampang Jajar and Taman Beringin landfill sites are shown in Table A2.3. The Ampang Jajar site was operated as a Level 3, Semi-aerobic landfill and leachate collection pipes were installed. The BOD level is almost half of the level as compared with the Taman Beringin landfill site.

Based on the examples, the effect on leachate on each closure level will be considered as follows:

a. The C1 and C2 closure will produce the similar leachate quality as in Taman Beringin landfill if no leachate recirculation system and collection pipes are provided. However, if the systems are installed and operating under semi-aerobic conditions, the BOD is expected to improve and be the similar to Ampang Jajar's results.

b. Under the C3 closure level, leachate collection pipes, retention pond and re-circulation system should be provided and the resultant average BOD will be expected to be less than 50 mg/l.

c. If further leachate treatment facility is provided such as in Ampang Jajar landfill, further improvement of the BOD may be expected.

It should be noted that the COD of leachate is quite complex and is very difficult to treat to meet the standard B without sophisticated leachate treatment system.

Table A2.3 Examples of Average Leachate Sample Quality

	Ampang Jajar			Taman Beringin	Standard B
	Leachate (C1, C2)	Re-circulation (C3)	After Treatment (near to C4)	Leachate (C1, C2)	
BOD	625	42	23	1,059	50
COD	1,878	580	321	3,718	100
SS	175	56	32	230	50
NH_4-N	501	102	175	544	

(2) Environmental requirements

Environmental monitoring should be planned and implemented at all the closed landfill sites as specified in the Guideline. The planning for the monitoring activities should be site specific and focused on the priority of potential risk to the site. The recommended monitoring activities have been carried out for the 3 Pilot Projects i.e, Ampang Jajar, Pekan Nenasi, and Ampang Jaya.

The main priority risk that should be considered and focused upon are the sites with downstream water intake points, groundwater wells nearby and sites with high post closure land use potential.

1) Landfill sites with downstream water intake points

Urgent priority must be given to the landfill sites with water intake point located downstream and the leachate are discharge to the water sources feeding to such intake points. From the landfill inventory, the landfill sites identified with downstream water intake points are tabulated **Table A2.4**.

Table A2.4 Environmental Risk Potential

State	No.	Name of LA	Name of site
Selangor	SL-03	MP Kajang	Sungai Kembong
N.Sembilan	NS-02	MP Nilai	Kuala Sawah
Melaka	ML-06	MD Jasin	Lipat Kajang
Melaka	ML-08	MD Jasin	Kesang Pajak
Johor	JH-01	MD Tangkak	Chohong
Johor	JH-07	MD Kota Tinggi	Batu Empat
Johor	JH-09	MD Kota Tinggi	Bandar Kota Tinggi
Kedah	KD-02	MD Baling	Pulai
Kedah	KD-06	MP Kota Setar	Bukit Tok Bertandok
Selangor	SL-05	MD Kuala Langat	Tapak Pelupusan Sampah
Pahang	PH-13	MD Jerantut	Tapak Pelupusan Sampah Kg.Mat Lilau
Pahang	PH-16	MD Maran	Tapak Sampah Jengka 10
Perak	PR-18	MD Tanjong Malim	Tapak Pelupusan Sampah Panderas
Johor	JH-21	MD Tangkak	Tapak Pelupusan Sampah Simpang Bekoh
Kedah	KD-08	MP Langkawi	Tapak Pelupusan Sisa-Sisa Pepejal Majlis

2) Landfill sites with groundwater well in the nearby areas

Similarly, the groundwater pollution is also a priority risk and should be monitored constantly. The identified landfill sites with groundwater well nearby have been tabulated in **Table A2.5**.

Table A2.5 Environmental Risk Potential

State	No.	Name of LA	Name of site
Perak	PR-06	MB Taiping	Jebong
Kedah	KD-02	MD Baling	Pulai

3) Landfill sites with high post closure land use potential

The site with high post closure land use potential and high land value could be used for high density development purpose. For such sites, the high level of risks should be taken into consideration and monitoring should be carried out regularly. The identified landfill sites are tabulated in **Table A2.6**.

Table A2.6 Landfill sites with high post closure land use potential

State	No.	Name of LA	Name of site
Selangor	SL-01	MP Petaling Jaya	Kelana Jaya
N.Sembilan	NS-01	MP Nilai	Pajam
Melaka	ML-04	MB Melaka	Krubong A
Melaka	ML-05	MB Melaka	Kota Laksamana
Terengganu	TR-06	MP K.Terengganu	Wakaf Tok Keh
Terengganu	TR-07	MP K.Terengganu	Kubang Ikan
Kelantan	KL-01	MP Kota Baru	Panji
Perak	PR-02	MD Kinta Selatan	Kg. Batu Putih (Kg. Tersusun)
Perak	PR-05	MB Ipoh	Buntong
Perak	PR-07	MB Taiping	Tekkah Jaya
Perak	PR-08	MD Tapah	Pekan Getah
Perlis	PL-01	MP Kangar	Kuala Perlis
Selangor	SL-07	MD Kuala Langat	Tapak Pelupusan Banting
Pahang	PH-14	MD Jerantut	Tapak Pelupusan Sampah Batu 57
Pahang	PH-18	MD Raub	Tapak Pelupusan Sampah Cheroh
Perak	PR-18	MD Tanjong Malim	Tapak Pelupusan Sampah Panderas
Selangor	SL-09	MP Subang Jaya	Worldwide Landfills Sdn Bhd
Perak	PR-19	MD Kerian	Tapak Pelupusan Sampah Jalan Dnnistown Parit Buntar
Perak	PR-20	MD Kerian	Tapak Pelupusan Sampah Pematang Pasir Alor Pongsu (Beriah) Bagan Serai.
Terengganu	TR-09	MD Hulu Terengganu	Tapak Pelupusan MDHT
Kelantan	KL-09	MD Bachok	Kg. Hujung Repek, Repek

A.3 Preliminary Analysis of Landfill Sites

The preliminary analysis of the landfill sites was based on the landfill information as provided by MHLG. In their list of landfill sites in Peninsular Malaysia, there are 171 landfill sites that are still in operations. However, there are a large number of landfill sites that have already been closed but were not registered. It was estimated that more than 100 landfill sites would require safe closure in the future.

During the site survey, it was noted that majority of the landfill sites have negative environmental impacts on the surroundings, such as the discharge of leachate to the surrounding waterways, odour problems and insect infestation. Such sites will require urgent attention for safe closure works to be carried out. However, the urgency should depend on the priority for each landfill site and subject to the findings and evaluation through the inventory survey. The level and scope of safe closure for each site will be different

A.3.1 Classification and Prioritisation of Landfill Sites

(1) Criteria for classification and prioritisation

The priority for safe closure should be determined based on the data acquired during the landfill inventory survey. The two main criteria for determining the classification are the *environmental risk potential* and the *land use potential.* There are a total of 14 keys parameters or items used to evaluate the environmental risk. The list of such items is shown in **Table A3.1**. There are 6 key items for evaluating the *land use potential*, such as "Existing Land Utilisation", "the Surrounding Area", and "Post Closure Land Use".

The relationship between the two criteria can be represented on a distribution graphical form by setting the *environmental risk potential* as the "X-axis" and the land use potential as the "Y-axis", refer to **Figure A3.1**. The "X-axis" represents the degree of environmental risk, such as occurrence of fires, insect infestations, leachate pollution etc. The "Y-axis" represents the current situation of the land utilisation, such as for housing and the future plans for development. The distribution chart can be subdivided into 4 groups, i.e. Groups A, B, C and D. Each Group represents the priority status of the landfill sites. The example of the group-priority distribution chart is shown in **Figure A3.1** and the relationship between the priority and the level of the safe closure is shown in **Table A3.1**.

Group A: Group A represents the highest priority whereby the landfill sites within this Group have the greatest environmental impact risk. It also represents the landfill sites that were either developed or have development nearby, for both the closed and the operating sites. Such sites are usually sites that are close to and downstream to water intake points. For Group A, the more advanced safe closure levels of C3 or C4 should be imposed.

Group B: Group B represents the medium priority whereby these sites have high environmental impact risks but lesser land use se potential. Landfills within this group should be safely closed to levels C2, C3 or C4 by taking into consideration the measures necessary to mitigate the environmental impacts.

Group C: Group C represents the landfills with low environmental impact risks but have high land use potentials. This group has a medium to low priority. The safe closure levels C2 and C3 should be imposed.

Group D: Group D represents the lowest priority whereby the landfills are considered to have both low environmental impact risks and low land use potentials. For such a group, closure levels C1 and C2 should be sufficient.

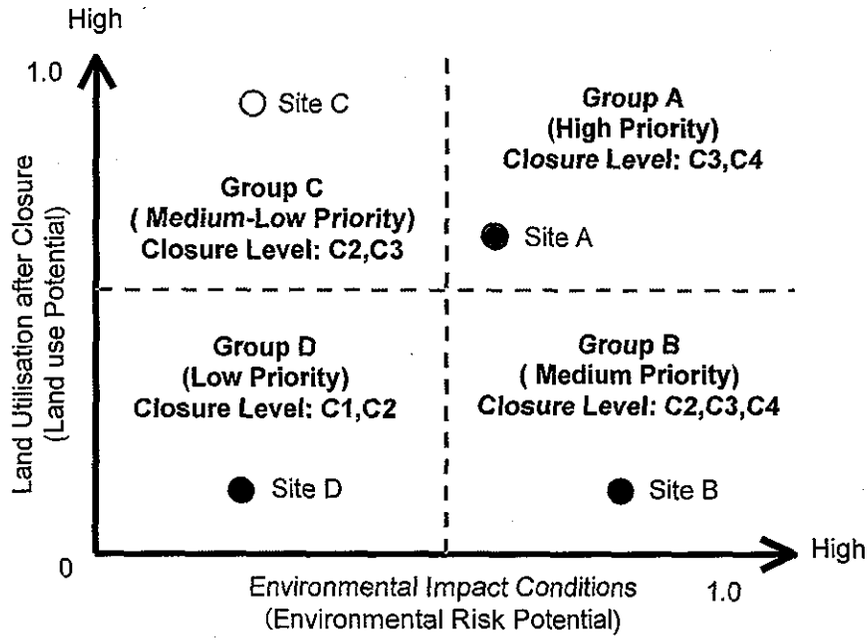


Figure A3.1 Example of the group - priority distribution chart

Table A3.1 Relationship between landfill closure priority and safe closure level

Group	Priority for closure	Safe closure Level			
		C1	C2	C3	C4
Group A	High			+++	++
Group B	Medium		+	+++	+
Group C	Medium - Low		+++	++	
Group D	Low	++	+++		

Notes: +, ++, +++: magnitude of the relation (+: low, ++: medium, +++: high)

(2) Determining the Priority

In order to determine the landfill sites priority and their classification into the 4 groups, it is necessary to calculate and establish the priority for the *environmental impact potentials* and the *land use potential* respectively.

There are a total of fourteen (14) keys parameters or items that were used to evaluate the *environmental risk potentials* and these are shown in **Table A3.9**. For every landfill site, an evaluation rating, or "Risk-Rate" is assigned for each of the 14 items. The rate is

either 0 or 1, where Risk-Rate 0 represents no environmental impact and Risk-Rate 1 represents potentially high environmental impact.

However, the relationship and importance of each of the 14 items varies and certain items that directly influence the human health, such as "Location of Water Intake" and "Location of Drinking Well", should have greater importance. As such, the JICA Study proposed and set up a "Weighting Factor" for each of the 14 items by taking into consideration of their importance and impact.

The Risk-Rate assigned to an item is multiplied by the Weighting Factor corresponding to that particular item. A score is then obtained and this is then repeated for all the other remaining items and their totals scores are summed and recorded. Similarly, the weighting factors for each of the items are also summed. Hence, the final assessment can be carried out by dividing the sum of the scores of all the items by the sum of the weighting factors, as shown below.

[Priority Score for *Environmental Risk (ER) potential*]
$= \Sigma_{(items)}\{[\text{Risk-Rate}]_{ER} \times [\text{Weighting Factor}]_{ER}\} / \Sigma_{(items)}[\text{Weighting Factor}]_{ER}$

With the similar procedures applied for the "*Land use potential*" items, the results are as follows.

[Priority Score for *Land Use (LU) potential*]
$= \Sigma_{(items)}\{[\text{Risk-Rate}]_{LU} \times [\text{Weighting Factor}]\} / \Sigma_{(items)}[\text{Weighting Factor}]$

(3) Risk-Rate for respective items of Environmental Risk

The Risk-Rate for each of the 14 key parameters that were used to evaluate the *environmental risk potential* has been defined as follows:

Table A3.2 Environmental Risk Potential

Item	Environmental Risk Potential
a) Landfill Facility Level	The Risk-Rate of "1" is assigned for the open dumping sites, which has the maximum *environmental risk potential.* The Risk-Rate of "0" is assigned for the level 4 landfills, with adequate measures for leachate treatment and has the least level of *environmental risk potential.* The Risk-Rates of 0.75, 0.5 and 0.25 have been assigned to the levels 1, 2 and 3 landfills, respectively.
b) Site Condition	The landfills on "hilly" terrain have been assigned the Risk-Rate of 1, the highest possible number because such sites have a high possibility of being located in the vicinity of water sources such as intake points and for irrigation purposes. For the landfill sites situated on "ex quarry, mines" and on "swampy area", the Risk-Rate is 0.5. The waste at such landfills tend to take a longer time to stabilise and toxic substances, such as heavy metals, tend to elute from the disposed waste in to the grounds, resulting in environmental damages. For the landfills on "flatlands", the Risk-Rate is set at 0.3, as it is comparatively easier to control the leachate, so the *environmental risk potential* is much smaller.

c) Waste Covered	For the landfills that have not been operated property and where no cover soil has been applied, the highest Risk-Rate of 1 is assigned. . For the landfills where daily cover soil has been applied and the site has been properly managed, the Risk-Rate of 0 is assigned. For the landfills where cover soil have been applied on "weekly", "monthly" or "annual" basis, the Risk-Rates of 0.25, 0.5 and 0.75 have been assigned respectively.
d) Vegetation Conditions	The condition of the plants and vegetation on the site are commonly used to determine the surface condition of the landfill site. Landfill sites with tall and healthy tree growth are considered as low risk and the Risk-Rate is set at 0. For the landfill sites where there is no plant life or vegetation growth, the Risk-Rate of 1 is assigned. For the landfill sites having some plant growth such as grass or bushes, the Risk-Rate is set at 0.5.
e) Landslide	Landfill sites with a high potential for landslides and thereby directly exposing human life to danger, are assigned the high Risk-Rate of 1. On the other hand, sites where there is no potential for landslide are given a Risk-Rate of 0. For the landfill site where landslide potential has been considered as "medium" risk, the Risk-Rate is set at 0.5.
f) Soil Subsidence	For the landfills where subsidence has been observed indicates that the biodegradation is still active and countermeasures for early stabilisation, such as gas venting, are required. The Risk-Rate for such sites is assigned at 1. The Risk-Rate for the landfill site where there is no soil subsidence is set at 0, and the Risk-Rate for the landfill site that showed minor soil subsidence is set to 0.5.
g) Vectors and wild animals	Vectors, rodents and wild animals are the major transmitters of diseases. The Risk-Rate for the landfill site with noticeable number of vectors, rodents and wild animals is set at 1, and the Risk-Rate for the landfill site where there are minor or no signs of vectors, rodents and wild animals is set at 0. For landfill sites with presence of vectors, rodents and wild animals, but not in large quantities, have been assigned the Risk-Rate of 0.5.
h) Odour, landfill gas and smoke	At the landfills where smoke or fire has been observed and bad odour from the waste and landfill gas emission has been detected, have been assigned the Risk-Rate of 1. For the landfill site where there is not much bad odour, or smoke, then the Risk-Rate is set at 0. For the landfill sites with some odour and traces of smoke, the Risk-Rate is set to 0.5.
i) Leachate Quantity	Leachate is the major factor that causes serious impact to the surrounding environment. However, in almost all landfills in Malaysia, the leachate quality has not been monitored and it is difficult to evaluate the leachate "quality" appropriately and hence the leachate "quantity" has been selected as the evaluation parameter. For the landfill site where the large quantity of leachate is observed, the Risk-Rate is set at 1. For the landfill sites where there is some leachate, the Risk-Rate is set at 0.5. For landfill sites where the leachate is not noticeable, the Risk-Rate is set at 0.
j) Location of water intake	For the landfill sites where the water intake points are located downstream of the site, the Risk-Rate is set to 1, otherwise the Risk-Rate is set to 0.

k) Location of Drinking Water Well	In Malaysia, the dependant on drinking water well as the main source of potable water is minimal and hence possesses no risk to the public. Nevertheless, for the purpose of this Study, the Risk-Rate of the landfill site where location of drinking water well is within 500m from the site is set at 1. For landfill site where location of drinking water well is over 500m, the Risk-Rate is set at 0.5. If there is no drinking water well around the site, then the Risk-Rate is set at 0.
l) Geological Condition	The geological conditions at the site are good indicators of the possibility of groundwater pollution that may be caused by the leachate. For the landfill site where "limestone" is present and there is the possibility of long-term migration through the cracks in the ground, then the highest Risk-Rate of 1 is assigned. For the landfills with "alluvial" soil, the flow velocity will be slow because of low water permeability, and the Risk-Rate is set to 0.2. Even if the flow velocity of groundwater is very slow, there is still some movement present, and hence the Risk-Rate of such landfill site is never set at 0. For the case whereby the geological conditions generate twice the risk of alluvial conditions, the Risk-Rate is set at 0.4.
m) Public Complaint	The number and the type of public complaints is a good indicator of the condition of the landfill site. For the landfill site where some public complaints have been received, the Risk-Rate is set at 1, and where there are no public complaints, the Risk-Rate is set at 0. However, due to the fact that the contents of the public complaints differs and are very subjective, the public complaint parameter can be regarded as one of a number of indices but cannot be regarded as an absolute index. Therefore, as shall be described later, the weighting factor is set at a comparatively low value.
n) Distance to the residential area	The buffer distance between the residential area and the landfill site is a main concern that may affect and influence the Risk-Rate. If the distance to the residential area is within 500m, then the Risk-Rate is set at 1, and when the distance is over 500m, and therefore minimum possibility of direct influence, the Risk-Rate is set at 0.2. When the distance apart is far, i.e. there is no residential area within 1 Km from the landfill site, and then the Risk-Rate is set at 0.

(4) Weighting Factor for each of the parameters of environmental risk potential

The weighting factor for each of the 14 parameters used in the determination of the *environmental risk potential* is tabulated in **Table A3.3**. Initially, the temporary weighting factors were established and discussed in the technical working group (TWG). Subsequently, a questionnaire survey was carried out amongst the participants at the Seminar on The Study on the Safe closure and Rehabilitation of Landfill Sites in Malaysia held in September 2003. The main purpose of the survey is to obtain the opinion of the participants with regards to the suitability and objectivity of the weighting factors. From the evaluation of the questionnaire replies, the final weighting factors were calculated and decided by taking the average of temporary weighting factors and proposed weighting factors. The general flow of the final determination procedures is shown in **Figure A3.2**.

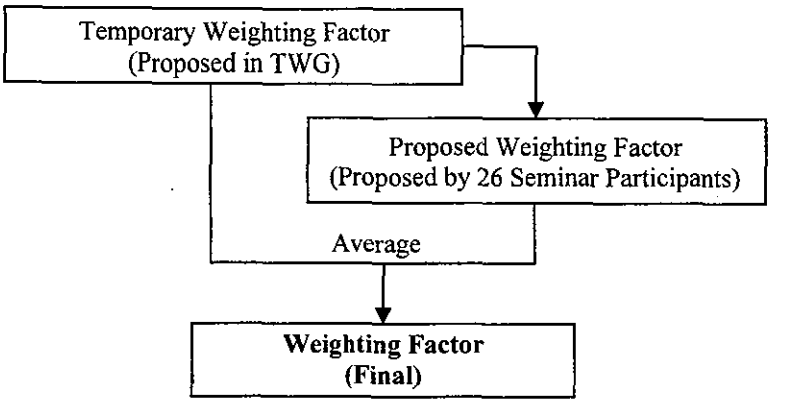


Figure A3.2 Procedure in Determining the Weighting Factors

In the temporary weighting factor as proposed in the TWG, the weighting factors for the "Location of Water Intake" and "Location of Drinking Water Well" parameters were set at 10, the highest possible value, due to their influence and effect to public health. The weighting factor for the "Landfill Facility Level" was also set at 10, as this is the key factor for environmental impact to the surrounding area.

The weighting factor for "Leachate Quantity" was set at 8 as it has the possibility, directly or indirectly, to extensively affect the public health and the environment over the long term.

For the "Landslide" which possesses risks to human life, and the "Geological Condition" which also possesses some environmental impact, both of these parameters were assigned the weighting factor of 5. The weighting factors for "Vector, rodents and wild animals" and "Odour, landfill gas and smoke" were set at 4.

However, from the results of the questionnaire, the proposed weighting factors by the seminar participants for "Site Condition", "Odour, landfill gas and smoke", Public Complaint", and "Distance to the residential area" were higher than the values initially proposed in the TWG.

The temporary weighting factor, the proposed weighting factor and the final average weighting factors are tabulated shown in **Table A3.3**.

Table A3.3 List of Weighting Factors on Environmental Risk Potential

Item		Temporary Weighting Factor (TWG)	Proposed Weighting Factor (seminar)	**Weighting Factor (Average)**
a)	Landfill facility level	10	9.1	**10**
b)	Site condition	2	4.0	**3**
c)	Waste covered	3	3.3	**3**
d)	Vegetation condition	2	1.9	**2**
e)	Landslide	5	4.7	**5**
f)	Soil subsidence	3	3.4	**3**
g)	Vector and wild animals	4	3.7	**4**
h)	Odour, landfill gas and smoke	4	5.1	**5**
i)	Leachate quantity	8	7.8	**8**

j)	Location of water intake	10	9.9	**10**
k)	Location of drinking water well	10	9.9	**10**
l)	Geological condition	5	4.9	**5**
m)	Public complaint	2	3.2	**3**
n)	Distance to the residential area	3	4.1	**4**

(5) Risk-Rate for Land Use Potential

The Risk-Rate for land use potential has been defined as follows:

Table A3.4 Risk Rate for Land Use Potential

Item	Risk Rate for Land Use Potential
o) Existing Land Utilisation	The degrees of the risks to public health and to the environment depend on the level and type of the land utilisation. The Risk-Rate for the landfill site that is being used for housing projects is set at 1, due to the high possibility of the constant risk of exposure from the closed landfill site. For the closed landfill site that has been used for industrial or commercial redevelopment, the Risk-Rate is set at 0.5, due to the fact that less people will be affected since their time spent at the site is lesser. For the closed landfill sites that are used for recreational purposes, the Risk-Rate is also set at 0.5. This is partly due to the fact that the visitors to the site may be in direct contact with the ground and with the covering soil. As for agriculture or low density utilisation use, fewer people will be affected and the Risk-Rate is set at 0.2. In case of the operating landfill sites, the likelihood that the large numbers of the general public will wander into the site will be minimal, and thus the Risk-Rate is set to 0.
p) Surrounding area	The type of land utilisation at the surrounding area of the landfill site will also be affected by the landfill and possesses certain risk to the public and the environment in the surrounding area. If the land of the surrounding area has been used for housing development, the risks associated with of exposure to the landfill will remain high and thus the Risk-Rate is set at 1. As for the surrounding area used for industrial or commercial purposes, the Risk-Rate is set at 0.5. Similarly, for the land of surrounding area used for recreation purposes, the Risk-Rate is also set to 0.5. For agricultural or other low density utilisation, the Risk-Rate is set to 0.2.
q) Post Closure Land Use	The category for the post closure land use is generally divided into "high use" indicating residential use, etc., "medium use" indicating recreational parks, etc., and "low use" such as for car parking, agriculture. For the "high use" category, the effects to the human health and to the buildings and structures must be taken into consideration; thus, the Risk-Rate is set at 1. For the "low use" category, the Risk-Rate is set at 0.3. The "medium use" category lies between the "high use" and "low use" categories and the Risk-Rate is set at 0.6. When there is no plan for land utilization in future, the Risk-Rate is set at 0.
r) Local Development Plan	When there is a local development plan in the area, which already contains a landfill site, with the high possibility to be affected from the landfill site directly or indirectly, such as the direct exposure to human being, the Risk-Rate is set at 1. When the local development plan is adjacent to the landfill site, the Risk-Rate is set to 0.5.

s) Development probability	For the landfill sites situated in strategic locations where the post closure re-development is high, the Risk-Rate is set at 1. On the other hand, when the social demand to the development is low, the possibility of future development is low, then the Risk-Rate is set to 0.
t) Distance from town centre	Generally, the distance from the built-up area or town centre relates to the social demand for development. Therefore, when the distance from town centre is less than 5km from the landfill site, the social demand to the development is thought to be very high, and the Risk-Rate is set at 1. When the distance from town centre is more than 10km, the social request to the development is thought to be low, and Risk-Rate is set at 0. In case that the distance from town centre is between 5 to10 km, the Risk-Rate is set at 0.5.

(6) Weighting Factors for Parameters for Land Utilisation

The weighting factors for the 6 parameters pertaining to the *land use potential* was determined in the similar way as that for the *environmental risk potential.* The procedure was based on the temporary weighting factors that were proposed in the technical working group (TWG), and the weighting factors that were proposed by the seminar participants. The average values were then calculated.

In the temporary weighting factor proposed in the TWG, the weighting factors for "Existing Land Utilization" and "Surrounding area" were both set at 10, the highest possible value. As for the "Post Closure Land Use", the Risk-Rate is set at 8. For the "Local Development Plan" and "Distance from town centre" which indicate potential rather than actual land use, the Risk-Rate is set at 3. For the "Be probably developed", which is the social demand for the re-development of closed landfill site, the Risk-Rate is set at 6.

From the replies of the questionnaire, the proposed weighting factors by seminar participants (26 persons) were generally similar to those proposed in the TWG. However, the weighting factor for "Local Development Plan" was slightly higher. The list of the weighting factors is shown in **Table A3.5**.

Table A3.5 List of weighting factors for land use potential

Item		Temporary Weighting Factor (TWG)	Proposed Weighting Factor (seminar)	**Weighting Factor (Average)**
o)	Existing Land utilization	10	9.5	**10**
p)	Surrounding area	10	9.6	**10**
q)	Post Closure Land Use	8	7.7	**8**
r)	Local Development plan	3	4.1	**4**
s)	Be probably developed	6	6.2	**6**
t)	Distance from town centre	3	3.4	**3**

<Example for calculation of the priority>

An example of the calculation to determine the priority of safe closure is shown in Table A3.6. For this example, the Taman Beringin landfill has been chosen. The description of the Risk-Rates are described in the "*Appendix to Volume 2, Chapter 5*", at the end of this chapter.

Firstly, the Risk-Rates for the Environmental Impact Conditions and the Land Utilisation after Closure parameters (items (a) to (t)) were filled in based on the information gathered during the site survey. The Risk-Rates were then multiplied by the respective Weighting Factor corresponding to the items and the resultant scores were obtained.

For the "*Environmental Risk (ER) potential*", the priority value was obtained by applying the equation as stated in 5.2.1(2), above, i.e. by dividing the sum of the scores of all the items by the sum of the weighting factors.

[Priority Score for *Environmental Risk (ER) potential*]
$= \Sigma_{(items)}\{[\text{Risk-Rate}]_{ER} \times [\text{Weighting Factor}]_{ER}\} / \Sigma_{(items)}[\text{Weighting Factor}]_{ER}$
$= 32.3 / 75 = 0.43$

Thus, the priority value of *Environmental Risk potential* was determined to be 0.43.

Table A3.6 The Example of Calculating the Priority (Taman Beringin Landfill Site)

		Risk Rates						Weighting Factor	Score
Environmental Impact Conditions (Environmental Risk)								(Total 75)	32.3
a)	Landfill Facility Level	Open dumping	Level 1	**Level 2**	Level 3	Level 4			
		1	0.75	**0.5**	0.25	0		10	5.0
b)	Site Condition	farland	hilly	**ex quarry, mines**	swampy area	others			
		0.8	1	**0.5**	0.3	0.5		3	1.5
c)	Waste Covered	no	daily	**weekly**	monthly	annually	others		
		1	0	**0.25**	0.5	0.75	0.75	3	0.8
d)	Vegetation Condition	trees	grasses, bushes	**no vegetation**					
		0	0.5	**1**				2	2.0
e)	Landslide	Noticeable	**Medium**	Not noticeable					
		1	**0.5**	0				5	2.5
f)	Soil Subsidence	Noticeable	Medium	**Not noticeable**					
		1	0.5	**0**				3	0.0
g)	Vector and wild animals	Noticeable	**Medium**	Not noticeable					
		1	**0.5**	0				4	2.0
h)	Odour, landfill gas and smoke	Noticeable	**Medium**	Not noticeable					
		1	**0.5**	0				5	2.5
i)	Leachate Quantity	**Noticeable**	Medium	Not noticeable					
		1	0.5	0				8	8.0
j)	Location of water intake	Upstream	Downstream	**No**					
		0	1	**0**				10	0.0
k)	Location of Drinking Water Well	<500m	>500m	**no**					
		1	0.5	**0**				10	0.0
l)	Geological Condition	limestones	**alluvial**	others					
		1	**0.2**	0.4				5	1.0
m)	Public Complaint	yes	**no**						
		1	**0**					3	3.0
n)	Distance to the residential area	**<500m**	>500m	no					
		1	0.2	0				4	4.0
Land Utilization after Closure (Value of Land Utilization)								(Total 41)	21.4
o)	Existing Land Utilization	**vacant**	agriculture	country/commerce	housing	recreation	others		
		0	0.2	0.5	1	0.5	0.2	10	0.0
p)	Surrounding area	vacant	agriculture	country/commerce	**housing**	recreation	others		
		0	0.2	0.5	**1**	0.5	0.2	10	10.0
q)	Ultimate land use	no	High Use	Medium Use	**Low Use**				
		0	1	0.6	**0.3**			8	2.4
r)	Local Development Plan	yes	**no**	without					
		1	**0**	0.5				4	0.0
s)	Site probably developed	**Most**	Less						
		1	0					6	6.0
t)	Distance from town centre	**<5km**	<10km	>10km					
		1	0.5	0				3	3.0

Priority Score for Environmental Impact Conditions] = 32.3 / 75 = 0.43
[Priority Score for Land Utilization after Closure] = 21.4 / 41 = 0.52

Similarly for the "*Land Use (LU) potential*", and the corresponding priority value was calculated to be 0.52.

Note: The information for each of the 69 landfill sites acquired during the inventory survey carried out by members of the Study Team were deemed to be accurate. As for some of the other sites that were not visited by the Study Team, the information was obtained from the analysis of questionnaires that were sent to the Local Authorities.

(7) Boundary of the priority

Once the priorities for all landfill sites have been calculated, the results can be plotted on the Group-Priority Distribution Chart as shown in **Figure A3.3**, one for the sites still in operations and the other for the closed sites.

The division of the chart into the 4 priority groups can be carried out visually and not subject to any fixed or calculated limits. Generally, from observation of the chart, the mean value for each of the X and Y-axis were selected as the division lines. The lines will eventually define the boundary of each of the priority groups.

Referring to **Figure A3.3**, for the operating landfill sites, the priority values are distributed between the approximate ranges from 0 to 0.8; therefore the approximate mean value was determined to be 0.4. The horizontal division line is then drawn and thus set the boundary for the priority grouping for the *Environmental Risk potential*. Similarly, for the *Land Use potential*, the distribution is between the ranges from 0 to 0.8; therefore the mean value was determined to be 0.4. The vertical division line is then drawn and set the boundary for the priority grouping for the land utilisation.

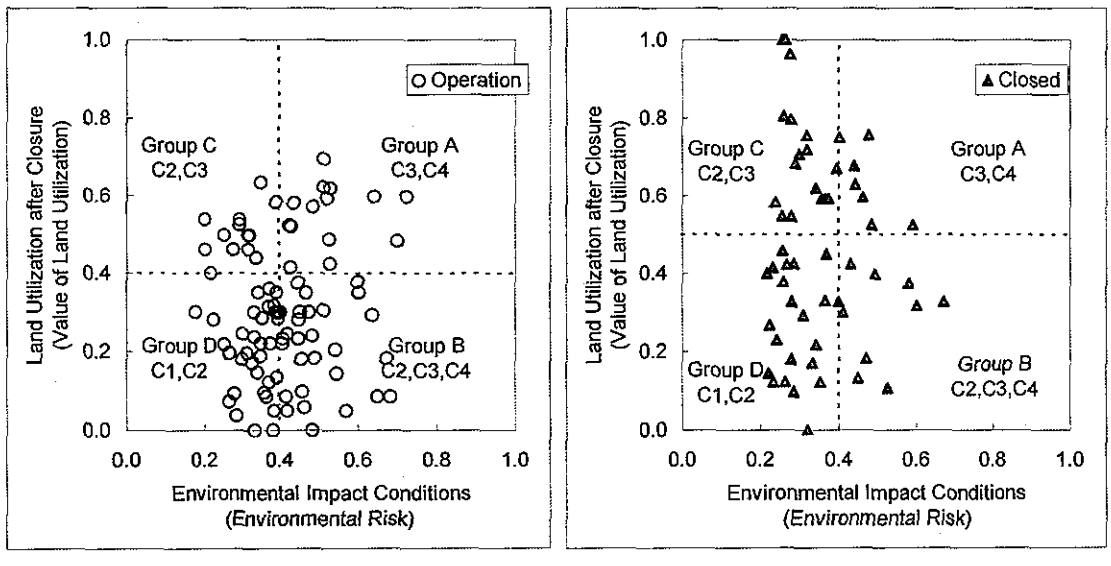


Figure A3.3 Distribution of the Priority of the Landfill Site for the Safe Closure

As for the closed landfill sites, the horizontal division line for the priority grouping for the land utilisation was determined at 0.5, slightly higher than for the operating sites. This is due to the fact that some landfill sites have already been utilised for redevelopment. The vertical division line for the *environmental risk potential* was determined to be 0.4, the same as that for the operating sites.

The actual priority of the 147 landfill sites have been determined and plotted on the distribution charts as shown in **Figure A3.3**. Of the 147 sites, 92 are still in operations and the remaining 55 are closed sites. There are a total of 22 sites in Group A, 38 in Group B, 29 in Group C and 58 in Group D. The breakdown of the number of sites is tabulated in **Table A3.7**.

Table A3.7 Number of landfill sites classified into the priority groups

	Operation	Closed	Total
Group A	15	7	22
Group B	29	9	38
Group C	12	17	29
Group D	36	22	58
Total	92	55	147

A.3.2 Landfill Closure Levels

(1) Closure Level Applied to the Landfill Sites

As described in the "Guideline for Safe Closure and Rehabilitation of Landfill Sites" in Volume 2, Chapter 4, the landfill closure levels are classified into 4 categories as follows.

Level C1: Minimal closure level (to provide final cover and drainage system around the site)

Level C2: Low closure level (similar to C1, but with the addition of dike, controlled slope and gas ventilation system)

Level C3: Middle closure level (similar to C2, but with the addition of semi-aerobic landfill system with leachate re-circulation)

Level C4: High closure level (similar to C3, but with the addition of groundwater pollution control measures with leachate treatment)

The necessary measures to be taken for each of the closure levels are tabulated in **Table A3.8**.

Table A3.8 Closure Levels and Required Measures/Facilities

Measures	Safe Closure Level			
	C1	C2	C3	C4
Final soil cover	++	+++	+++	+++
Storm-water drainage	+	++	+++	+++
Safe storage	+	++	+++	+++
Gas venting		++	+++	+++
Leachate collection / treatment facilities		+	+++	+++
Groundwater monitoring			++	+++
Early stabilisation		+	+++	+++
Post closure measures		+	+++	+++
Monitoring	+	++	+++	+++
Landfill system			Semi-aerobic System	

Note: +: minimum equipped/operated, ++: fair, +++: Fully equipped/operated

The schematic diagrams representing each of the landfill closure levels are shown in **Chapter 4, Figure 4.1.**

(2) Consideration for assigning the Safe Closure Level

The relationship between the landfill closure priority and the safe closure level is shown in Table A3.8 above. Basically the levels of the safe closure for each group have been determined but the actual closure level to be assigned to each landfill site must be carried out on a case-to-case basis.

The safe closure level is dependant on the environmental impact and influence at each landfill site. The closure level can be assigned based on the same items as per the *Environmental Risk potential that* were obtained from the inventory surveys. The *Environmental Risk potential* can be classified into 4 groups corresponding to he safe closure levels of C1 to C4The relationship between the safe closure level C1 toC4 and each item of the *Environmental Risk potential* is shown in **Table A3.9**.

For closure level C1, final cover should be provided with the aim of maintaining good sanitary conditions, and this relates to the environmental improvement of E3, waste cover, E4, vegetation condition, E7, vector and wild animals, and E8, odour, landfill gas and fire.

For closure level C2, provision of storage structures, re-formation and protection of slopes, storm water drainage facilities, gas vents, etc. must be considered with the aim of preventing overflow of waste and to achieve early stabilisation of the landfill. These will prevent landslides, subsidence etc, and thus relate to the environmental improvement of E5, landslide, E6, soil subsidence, E8, odour, landfill gas and fire, and E9, leachate quantity.

For closure level C3, leachate collection and leachate re-circulation systems should be provided with the aim of minimising the environmental impact caused by leachate. This relates to the environmental improvement of E9, leachate quantity, and E10, location of water intake.

For closure level C4, leachate treatment and seepage control work should be provided with the aim of groundwater protection. This relates to the environmental improvement of E11, location of drinking water well, and E12, geological condition.

As for "public complaint", this relates to all the 4 closure levels.

Table A3.9 Relationship between the Safe Closure Level and Each Item of the Environmental Risk Potential

Safe closure Level	Risk Evaluation Items	Safe Closure Countermeasures	Item of Environmental Risk Potential													
			E1) Landfill Facility Level	E2) Site Condition	E3) Waste Covered	E4) Vegetation Condition	E5) Landslide	E6) Soil Subsidence	E7) Vector and wild animals	E8) Odour, landfill gas and Fire	E9) Leachate Quantity	E10) Location of water intake	E11) Location of Drinking Water Well	E12) Geological Condition	E13) Public Complaint *	E14) Distance to the residential area
C1	Littering, Vectors, Odour, Fire	Final Cover			++	++			++	++					+	
C2	Flow of waste outside the site	Storage Structure														
	Landslide	Re-formation and protection of slopes, Storm water drainage facilities					++	++		++	++				+	
	Leachate generation	Final cover, Storm water drainage facilities														
	Landfill gas explosion	Gas Vents														
	Settlement	Gas Vents														
C3	Leachate pollution potential	Leachate collection system, Leachate re-circulation									++	++			+	
C4	Groundwater pollution	Leachate treatment, Seepage control work											++	++	+	

Note: * "Public Complaint" is equally divided to the 4 Closure Levels, C1 toC4.

(2) Calculating the Closure Level

In order to determine the necessity of the closure levels to be assigned to all the landfill sites, the closure levels, i.e. C1 to C4, will be evaluated and calculated as a numerical value.

That is, by every landfill sites, classifying each item of the *environmental risk potential* obtained by the inventory investigation into 4 groups, which relate to safe closure levels C1 - C4, and then, the total score of each closure level is calculated from the score of each item which was calculated in setting of the priority of the *environmental risk potential*. Simultaneously, the sum of the weighting factors for items, which relate to safe closure levels C1 - C4 is calculated. The final assessment is hence done by dividing the sum of the score of the items, which relate to safe closure levels C1 - C4 by the sum of the weighting factors, which relate to safe closure levels C1 - C4, and then the necessity index of closure levels C1 - C4 is calculated.

Moreover, the benchmark to judge the necessity to implement the closure measure is set, and in case that the necessity of closure level is less than the benchmark, it can be judged that it is not necessary to implement that level of safe closure at that site. Here, the benchmark is set to 0.2.

However, as for the landfill site, which is operating at present, even if its necessity closure levels C1 - C4 is less than the benchmark, the "final cover" is always necessary. Therefore, it is necessary for every operating landfill sites to implement the safe closure above level C1. In other words, for the operating landfill sites, it is impossible to judge that it is not necessary to implement the safe closure.

Moreover, as indicated earlier, there is a difference between the evaluation by the JICA experts at the on-site investigation and the evaluation by officers of the local authority. Hence, for landfill sites where the site visit investigation was not implemented by JICA Study Team, the necessity value is set at 20% increase (in case that the necessity is calculated over 1, the necessity is set at 1).

(4) An example of calculating the necessary closure level

The necessary closure level for Taman Beringin landfill site is calculated as shown in **Table A3.10**, as an example.

As for the closure level C1, the score of the related item which is "waste cover", "vegetation condition", "vector and wild animals", and "odour, landfill gas and smoke" is 0.75, 2.0, 2.0, and 2.0 respectively. Further, a quarter of score of "public complaint" is calculated as 0.5 (= 2.0 / 4) and added up to this score. Therefore, the total score is summed up to 7.25. Finally, by dividing the sum of the score of 7.25 by the sum of the related item's weighting factors of 13.5, the necessity value for closure level C1 is obtained as 0.55.

Also, similar calculation is done for closure levels C2 to C4, and the necessity values of closure levels obtained are 0.63, 0.47, and 0.11 respectively.

As mentioned previously, as a result of the calculation of the priority of the safe closure, this landfill site is classified into the highest group A, and the demanded closure level is

set to C3 or C4. Moreover, as a result of the calculation of the necessity of the closure level, the necessity of closure level C3 and C4 is 0.47 and 0.11 respectively. In this landfill, closure level C3 or C4 is demanded, but it is possible to judge that there is no necessity to implement the closure level C4, because the necessity of closure level (0.11) is less than the benchmark of 0.2 (refer to **Figure A3.4**).

As explained above, though this landfill site was classified as Group A with recommended closure levels of C3 or C4. Examination of closure level deemed that C4 was unnecessary. In other words, this landfill site is classified into Group A, with high urgency for implementation of safe closure at C3 level.

Table A3.10 Example of Calculating the Necessity of the Closure Level

Safety Closure Level	Score	C1	C2	C3	C4
E1) Landfill Facility Level	5.00 (max 10)				
E2) Site Condition	1.50 (max 3)				
E3) Waste Covered	0.80 (max 3)	0.80			
E4) Vegetation Condition	2.00 (max 2)	2.00			
E5) Landslide	2.50 (max 5)		2.50		
E6) Soil Subsidence	0.00 (max 3)		0.00		
E7) Vector and wild animals	2.00 (max 4)	2.00			
E8) Odour, landfill gas and smoke	2.50 (max 5)	2.50	2.50		
E9) Leachate Quantity	8.00 (max 8)		8.00	8.00	
E10) Location of water intake	0.00 (max 10)			0.00	
E11) Location of Drinking Water Well	0.00 (max 10)				0.00
E12) Geological Condition	1.00 (max 5)				1.00
E13) Public Complaint	3.00 (max 3)	0.75	0.75	0.75	0.75
E14) Distance to the residential area	4.00 (max 4)				
Total Score of the Site		8.05	13.75	8.75	1.75
Maximam Score		14.75	21.75	18.75	15.75
Necessity of Safty Closure Level		**0.55**	**0.63**	**0.47**	**0.11**

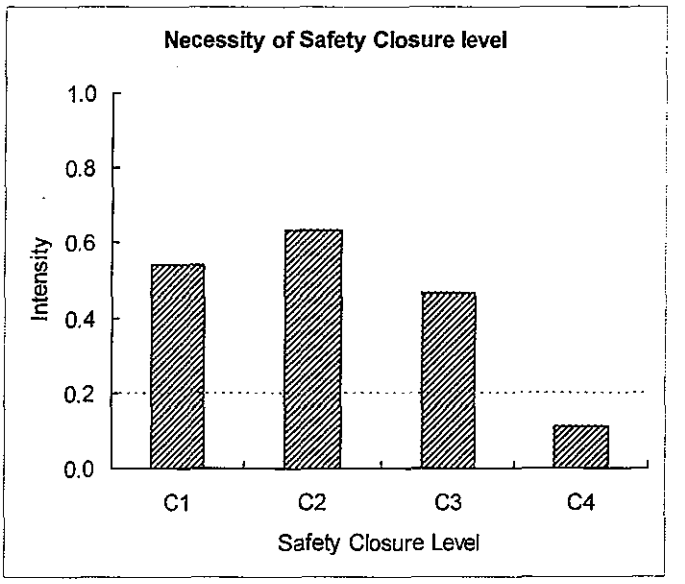


Figure A3.4 Example of the Necessity of the Closure Level (C1-C4)

(5) Target landfill site for safe closure

For the 147 landfill sites that were analyses by the Study, the priority and closure levels were determined and are tabulated in **Table A3.11** showing the number of landfill sites in their respective groups and corresponding closure levels, and together with the targeted operation end year, i.e. the year at which the sites have been schedules to be closed.

Table A3.11 Number of the Target Landfill Sites of the Safe Closure

	Operation End Year	Site	Safety Closure Level				
			not needed	C1	C2	C3	C4
Group A	Closed	7	-	-	-	4	3
	- 2005	9	-	-	-	8	1
	- 2010	4	-	-	-	2	2
	2010-	2	-	-	-	2	-
	Total	22	-	-	-	16	6
Group B	Closed	9	-	-	1	4	4
	- 2005	6	-	-	-	4	2
	- 2010	12	-	-	-	7	5
	2010-	11	-	-	-	10	1
	Total	38	-	-	1	25	12
Group C	Closed	17	1	-	12	4	-
	- 2005	2	-	-	-	2	-
	- 2010	6	-	-	3	3	-
	2010-	4	-	-	2	2	-
	Total	29	1	-	17	11	-
Group D	Closed	22	3	14	5	-	-
	- 2005	9	-	2	7	-	-
	- 2010	12	-	5	7	-	-
	2010-	15	-	6	9	-	-
	Total	58	3	27	28	-	-
Total	Closed	55	4	14	18	12	7
	- 2005	26	-	2	7	14	3
	- 2010	34	-	5	10	12	7
	2010-	32	-	6	11	14	1
	Total	**147**	**4**	**27**	**46**	**52**	**18**

Of the 147 landfill sites, 22 sites have been classified under Group A, i.e. the high priority sites, with 6 sites requiring safe closure to level C4, and 16 sites to level C3. For closure level, C4, 3 sites are already closed, 1 site is scheduled for closure by 2005, and 2 sites have been scheduled to close between 2005 and 2010. A total of 18 sites have been identified that required the closure level C4, 52 sites for closure level C3 are 52 sites, 46 sites for C2, and 27 sites for C1. 4 closed landfills sites have been identified and considered not necessary for safe closure.

Of the 147 landfill sites, 55 sites (37%) have been closed, and safe closure have been recommended for 51 of these sites. 26 sites that require safe closure are to be closed by 2005, 34 sites by 2010, and 32 sites after 2010.

The breakdown of the target landfill sites area is tabulated in **Table A3.12**. In terms of the area, 51% of the total area is occupied by landfill sites recommended for closure levels of C3 and C4, whilst just over 7% of the total area are for the sites recommended for safe closure of level C1.

Table A3.12 Total Area of the Target Landfill Site of the Safe Closure

(Unit ; Land area in hectares)

	Operation End Year	Site	Safety Closure Level				
			not needed	C1	C2	C3	C4
Group A	Closed	34	-	-	-	19	15
	- 2005	95	-	-	-	94	1
	- 2010	76	-	-	-	54	22
	2010-	7	-	-	-	7	-
	Total	211	-	-	-	174	38
Group B	Closed	45	-	-	1	26	18
	- 2005	65	-	-	-	54	11
	- 2010	99	-	-	-	72	26
	2010-	190	-	-	-	184	7
	Total	399	-	-	1	337	61
Group C	Closed	205	50	-	74	82	-
	- 2005	22	-	-	-	22	-
	- 2010	44	-	-	22	21	-
	2010-	84	-	-	32	52	-
	Total	356	50	-	128	178	-
Group D	Closed	76	33	30	13	-	-
	- 2005	175	-	8	168	-	-
	- 2010	167	-	24	144	-	-
	2010-	168	-	50	118	-	-
	Total	587	33	111	443	-	-
Total	Closed	360	83	30	88	127	32
	- 2005	357	-	8	168	170	11
	- 2010	386	-	24	166	148	49
	2010-	449	-	50	150	243	7
	Total	**1553**	**83**	**111**	**572**	**688**	**99**

A.3.3 Cost Estimations

(1) Basis for cost estimations

In order to estimate and determine the capital costs (CAPEX) and operating costs (OPEX) necessary for safe closure of the landfills, the following basis was considered;

1. The cost estimations have been carried for all 147 landfill sites that were identified in the Inventory Survey Of these sites, 55 sites are already closed and 92 sites are still in operations.
2. The capital costs estimation required for safe closure for each and every site has been carried out, based on the inventory survey data and the closure levels assigned to each site.
3. The proposed implementation schedule of safe closure is to commence from 2005 for Group A, Group B in 2006, Group C in 2007 and Group D in 2008. For the operating sites, the safe closure of each site should commence within a year after the targeted end-of-operation year of the landfill site. Of the total of 92 operating landfill sites, it is proposed to close 81 sites by 2020 and the remaining 11 sites after 2020. It was assumed that in accordance with Vision 2020 and the Draft NSP, that all sites would be safely closed by 2020. Hence for these sites end of operation year was assumed to be brought forward to 2019.
4. The estimated operation and maintenance (O&M) costs for each site were based on an annual basis beginning from the year immediately following the

implementation of the safe closure at that respective site. The O&M are expected to be continuous throughout the period for each site, up to 2020.

(2) Closure level and closure schedule

The cost estimations based on the proposed year of safe closure implementation for each of the groups and closure levels are tabulated in **Table A3.13**.

Table A3.13 Landfills targeted for safe closure implementation by year

Year[1]	Group A				Group B				Group C				Group D				Tot.
	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4	
2005			11[2]	4[3]			4	1			2		1	4			27
2006				1		1[4]	7[5]	4[6]			2			2			17
2007			1					3	1[7]	15[8]	4[9]		3	2			29
2008			1				1	1					17[10]	5[11]			25
2009			1	1			2	1			1		2	2			10
2010							1	1						2			4
2011			2				1						1				4
2013													1	1			2
2014							4				1		3	4			12
2016							1				1						2
2018														1			1
2019[12]								1				1	1				3
2020[13]							4			2			1	4			11
Total			16	6		1	25	12	1	17	11	1	30	27			147

Notes:
(1) The implementation year is one year after the end-of-operation year
(2) 4 of the sites are closed sites
(3) 3 of the sites are closed sites
(4) 1 of the site is a closed site
(5) 4 of the sites are closed sites
(6) 4 of the sites are closed sites
(7) 1 of the site is a closed site
(8) 12 of the sites are closed sites
(9) 4 of the sites are closed sites
(10) 17 of the sites are closed sites
(11) 5 of the sites are closed sites
(12) Sites to be closed in 2020 are not included
(13) All sites with end-of-operation year beyond 2020 are assumed to end operations in 2019 and safe closure implemented in 2020

(3) Cost of safe closure

The cost estimations for safe closure were based on the estimated cost required to provide the necessary facilities for each landfill site based on the respective closure level. The proposed facilities are outlined in **Table A3.14**.

Table A3.14 Facilities required for each closure level

Facility required	C1	C2	C3	C4
1. Final soil cover for top and slope	O	O	O	O
2. Waste storage and retention structures (embankments, planting and turfings)		O	O	O
3. Surface water / stormwater drainage system		O	O	O
4. Gas ventilation system (vertical and horizontal installations)		O	O	O
5. Leachate collection system (vertical and horizontal pipes)			O	O
6. Leachate re-circulation system (including aeration)			O	O
7. Leachate treatment/groundwater protection system				O
8. Monitoring wells	O	O	O	O

Note : O : recommended facilities to be provided

The cost estimations were carried out for each and every landfill site based on the site specific proposed scope of work and the present conditions of the site. The O&M costs were derived from the capital costs for the proposed facilities, such as provision of soil cover materials, leachate and gas piping, drainage systems, and pumps and aerators. An additional cost was added as a percentage of the total cost to include for engineering services, mobilisation costs and contingencies.

Details on the cost estimation exercise are given in article A4 of this chapter.

The estimated CAPEX for safe closure of the 147 landfill sites up to 2020 is approximately RM375.5 million, and the OPEX is estimated to be approximately RM342.9 million. The total estimated cost is RM 717.4 million. The summary of the financial allocations and cost breakdown for the period from 2005 to 2020 is shown in **Table A3.15**.

The above estimations were based on generic assumptions, however detailed investigations and should be carried out on case-to-case basis in order to determine the more accurate cost of implementation. Nevertheless, the present costs estimates provide the Government of Malaysia with some indication of the estimated budget allocations that will be required to implement and maintain the safe closure of the landfill sites for the next 20 years.

Table A3.15 Total cost for landfills safe closure

(Unit : RM thousand)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1. CAPEX																
A. Closed Sites																
a) Group A	16,750	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
b) Group B	-	19,541	-	-	-	-	-	-	-	-	-	-	-	-	-	-
c) Group C	-	-	36,200	-	-	-	-	-	-	-	-	-	-	-	-	-
d) Group D	-	-	-	12,670	-	-	-	-	-	-	-	-	-	-	-	-
B. Operating Sites	62,153	23,136	21,754	14,409	32,089	17,188	4,554	-	2,038	37,759	-	6,150	-	19,187	13,122	35,827
TOTAL A + B	78,904	42,677	57,954	27,080	32,089	17,188	4,554	-	2,038	37,759	-	6,150	-	19,187	13,122	35,827
Accumulated total CAPEX	78,904	121,582	179,536	206,617	238,706	255,894	260,449	260,449	262,487	300,246	300,246	306,397	306,397	325,585	338,707	374,534
2. OPEX																
A. Closed Sites																
a) Group A	-	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278
b) Group B	-	-	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626
c) Group C	-	-	-	3,574	3,574	3,574	3,574	3,574	3,574	3,574	3,574	3,574	3,574	3,574	3,574	3,574
d) Group D	-	-	-	-	1,557	1,557	1,557	1,557	1,557	1,557	1,557	1,557	1,557	1,557	1,557	1,557
B. Operating Sites	-	5,792	7,926	9,756	11,144	13,875	15,280	15,779	15,779	15,994	19,670	19,670	20,405	20,405	22,017	22,308
TOTAL A + B	-	7,070	10,830	16,236	19,181	21,913	23,318	23,817	23,817	24,032	27,707	27,707	28,442	28,442	30,054	30,346
Accumulated total OPEX	-	7,070	17,901	34,137	53,319	75,232	98,551	122,368	146,185	170,217	197,924	225,632	254,075	282,517	312,572	342,918
Accumulated total CAPEX + OPEX	78,904	128,652	197,438	240,754	292,025	331,127	359,000	382,817	408,672	470,464	498,171	532,030	560,472	608,103	651,280	717,453

(4) Costs of safe closure with relation to operation levels

The scope of work and the associated cost for safe closure is highly dependent on the type of landfill and how it was operated. For example, for the levels L3 and L4 landfills that have been operated properly, the cost of safe closure will be significantly lower than those for the landfills that were operated at Levels L2 or L1.

Table A3.16 shows the recommended facilities for each of the operation levels in relation to the proposed the closure levels.

Table A3.16 Facilities requirements by operation levels and closure levels

Safe Closure Levels	Sanitary Landfill Levels			
	L1	L2	L3	L4
C1				
Final soil cover (1)	Supplement	Supplement	Supplement	Supplement
C2				
Waste storage and retention structures	Provide			
Stormwater drainage	Provide			
Gas ventilation system	Provide			
C3				
Leachate collection	Provide	Provide		
Leachate re-circulation	Provide	Provide		
C4				
Leachate treatment	Provide	Provide	Provide	
Groundwater protection	Provide	Provide	Provide	

Notes: (1) Although all operation levels include applying the soil cover, at the time of safe closure it is assumed that additional soil cover will need to be provided.
(2) Monitoring wells are provided for all sanitary landfill levels and under each safe closure level.

The cost estimation for safe closure related to the landfill operation levels were based on the following assumptions.

- The typical landfill site shall have an area of 10 ha with the final waste height of 9m.
- The Typical landfill site receives 200 tonnes of waste per day.

The construction costs, or capital expenditure (CAPEX) for safe closure for such sites for each of the safe closure level and operation level were estimated and shown in **Table A3.17**.

Table A3.17 Costs of safe closure with relation to operation levels

Landfill Operation Levels	Safe Closure Levels - CAPEX (RM)			
	C1	C2	C3	C4
L1	793,000	1,102,000	1,917,000	5,189,000
L2	476,000	493,000	1,307,000	4,579,000
L3	238,000	255,000	255,000	3,526,000
L4	79,000	96,000	96,000	96,000

With this typical example, the total waste amount of waste disposed off is about 477,000 tonnes over a period of 7 years, i.e. from 2003 to 2010. From the table, for the L 4 site estimated cost for closure at level C4 is equivalent to RM0.2/tonne of waste (i.e. RM96,000/477,000). If the landfill was operated at L1, and closed to level C4, then the estimated cost is about RM10.9/tonne of waste (i.e. RM5,189,000/477,000).

A.3.4 Financial Analysis

This section discusses the financial aspects of landfill safe closure through estimation of the long-term average incremental cost per hectare of landfills that are to be closed during 2005-2020. It also estimates the average incremental cost per ton of waste collected during the above period and cost to be covered by each household.

(1) Review of CAPEX and OPEX for safe closure of landfill sites

Referring to the cost estimation carried out in the previous sections, the CAPEX and OPEX for safe closure of landfill sites were estimated separately for the closed landfills and the landfills currently in operation. The estimates identified 55 closed landfill sites with the total area of 340.47 hectare and the CAPEX and OPEX are shown in **Table A3.18** below.

Table A3.18 CAPEX and OPEX for safe closure of the 55 closed landfills from 2005 to 2020

Cost Item	Total Cost (RM)	Average Cost per hectare (RM)
Capital Expenditure (CAPEX)	85,163,000	250.13
Operational Expenditure (OPEX)	8,037,000	23.60

Remark: OPEX shown above is the average annual expenditure from the year 2009.

The trend of cost allocation for safe closure of the 55 closed landfills is as shown in the **Figure A3.5** below.

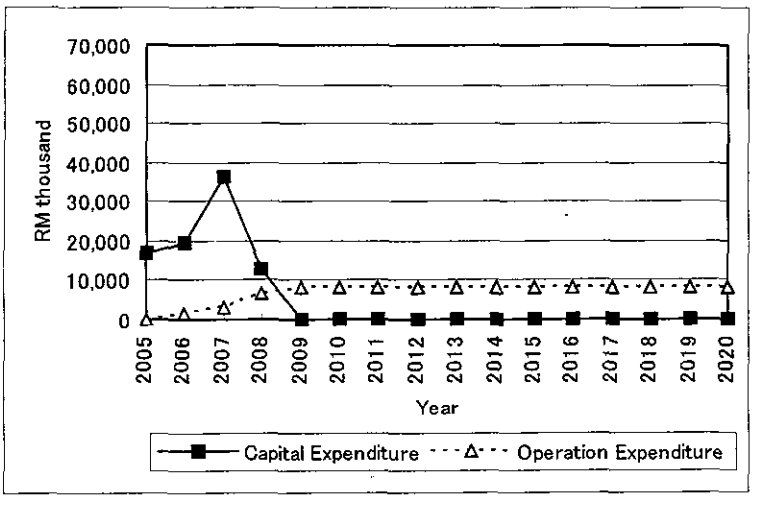


Figure A3.5 Trend of Cost Allocation for Safe Closure (Rehabilitation) of the 55 Closed Landfills

The capital expenditure for the 55 closed sites is at its peak between 2005 to 2008 since the action plan aims at completing the rehabilitation of the 55 closed landfills by the year 2008, followed by the monitoring activities.

For the remaining 92 landfills (i.e. a total area of about 1,200 ha) that are currently in operation and are subject for closure between 2005 and 2020, the estimated CAPEX and OPEX are shown in **Table A3.19**.

Table A3.19 CAPEX and OPEX for safe closure of the 92 operating landfill sites from 2005 to –2020.

Cost Item	Total Cost (RM)	Average Cost per hectare (RM)
Capital Expenditure (CAPEX)	289,372.000	241.11
Operational Expenditure (OPEX)*	22,309,000	18.6

Remark: * The total OPEX stated above is the estimated annual expenditure for the 81 landfill sites scheduled for closure 2020. The remaining 11 landfills will only be closed after 2020, and thus not included in the OPEX.

Figure A3.6 below shows the trend of estimated cost for safe closure for the 92 landfill sites that are currently in operation up to 2020.

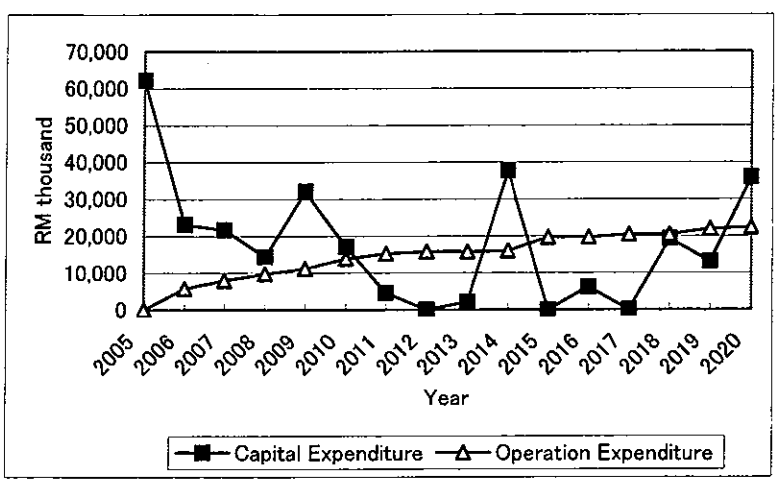


Figure A3.6 Trend of Estimated Cost for Safe Closure for the 92 Landfill Sites still in Operations

The capital expenditure will be the highest in the initial year of the action plan and should peak again approximately every other 5 years after 2005. On the other hand, the operation expenditure shows a gradual increase during the period of action plan mainly because of the ever increasing number of closed landfill sites to be monitored after closure.

Figure A3.7 shows the trend of the total cost for safe closure of landfills.

It shows that the total cost of the safe closure implementation is the highest in the initial year of 2005, followed by 2007, 2020, and 2014. The periodic increase in the total cost is mainly due to the increase in the number of landfill to be closed.

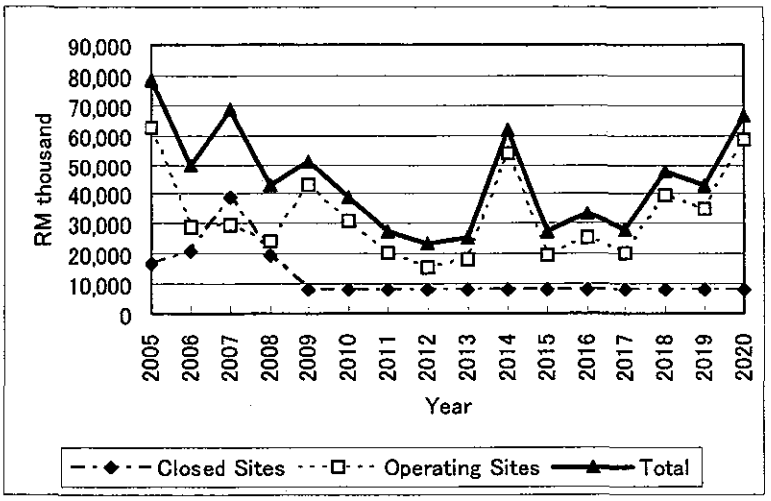


Figure A3.7 Trend of the Total Cost of Landfill Closure during the Period of Action Plan

(2) Estimation of incremental cost for safe closure of landfill sites

The cost required for safe closure of landfill sites should be an integral part of the total cost for solid waste management. For the landfills currently in operation, it may be practically possible to include the cost for safe closure by reflecting it to the tipping fee. However, for the landfills that had already been closed, the Government of Malaysia has to deicide who should cover the cost for its rehabilitation and improvement. Assuming that all the cost required for safe closure of landfills is covered as a part of the total cost of SWM, the Study estimated the unit cost of safe closure of landfills per ton of waste generated from 2005 to 2020. **Table A3.20** below shows the result of estimation.

Table A3.20 Average unit SWM cost required for safe closure of landfill sites during 2005-2020

Unit: RM/tonne of waste generated

Type of Landfill	Average Unit Cost Required
Closed landfill (55 sites, 340.47 ha)	1.50
Landfills in operation (92 sites, 1,200.15 ha)	4.10
Total incremental cost required	5.60

From the above "average unit cost required" value and the "average per household waste generation amount per month" value as provided by MHLG, the "incremental cost required" per household during 2005-2020 was estimated as shown in **Table A3.21**.

Table A3.21 Incremental cost required per household during 2005-2020

Unit:RM/household/month

Type of household	Incremental Cost Required
Urban Household	0.77
Rural Household	0.38

Note: For the purpose of this Study, the incremental cost estimation assumed 100% collection service efficiency and fee collection efficiency.

The result of estimation above revealed that additional cost of RM5.60 is required for every tonne of waste generated during 2005-2020 to implement safe closure of landfill sites. Taking into account the average municipal solid waste generation from rural and urban household during 2005-2020, an additional cost of RM0.38 is required monthly for disposal of the municipal waste generated from every rural household while RM0.77 for every urban household.

(3) Proposed sources of fund for safe closure and post-closure of landfills

Since the budget allocations for safe closure of landfills have not been fully realised, the funds must be collected from other sources. The proposed sources are as follows:

1. The allocation of an additional national budget for safe closure of landfills.
2. The collection of an additional fee to the existing tipping fee for waste disposal at landfills to cover the cost of safe closure.

Alternatively, the secondary sources of the fund for safe closure may be considered, such as;

i. Obtaining certified emission reduction (CER) through the use of Clean Development Mechanism (CDM) under Kyoto Mechanism of United Nations Framework Convention on Climate Change (UNFCCC)

ii. Increasing the value of land capitals of the Government through safe closure of landfill

<u>Clean Development Mechanism (CDM)</u>

The safe closure of landfills to Level 3 and Level 4 should considerably reduce the amount of methane emissions from the landfills. Similarly, by converting the anaerobic landfills to semi-aerobic landfills will also significantly reduce methane emissions. These types of activities may be eligible for CDM Project funding under the UNFCCC. If so, then the reduction in the amount of methane emission can be registered as the CER and be used for trading in the international market that is currently in the process of development under the Kyoto Mechanism. The revenue from the CER trade may be partially used for the safe closure of landfills.

For the preliminary estimation of the potential greenhouse gases (GHGs) emission reduction, the principles of semi-aerobic landfill was applied instead of anaerobic structure for the safe closure landfill sites, and the following assumptions were made.

1. The landfills that were closed from 1995-2003 or that will be closed from 2004-2020
2. The landfills to which the closure levels of C3 or C4 was applied.
3. Organic municipal solid wastes that are easily degradable
4. The period of GHGs emission estimation is from 2005 to 2020. It is also assumed that the emission of GHGs from the landfills will only be for 10 years after their closure. The emissions during the operations of landfills as well as the emissions

after the 10 years have not been included in the estimations. Also excluded are the landfills that were closed 10 years prior to 2005, i.e. those closed before 1995.

The results of the preliminary estimations, of potential GHGs emission reduction in the case of applying semi-aerobic landfill structure in accordance with the safe closure guideline, are presented in **Table A3.22** below. The details of the estimation methodology is described further in ***Volume 7, Book 5***.

Table A3.22 Preliminary estimations for GHGs

Description	Unit	Accumulated GHGs emission from 2005 to 2020
1. Methane emission		
(1) Anaerobic landfill structure	Tonne CO_2	28,732,000
(2) Semi-aerobic landfill structure	Tonne CO_2	9,490,000
(3) GHGs emission reduction (i.e. 1.(1) –1.(2))	Tonne CO_2	19,232,000
2. CO_2 emission		
(1) Anaerobic landfill structure	Tonne CO_2	2,456,000
(2) Semi-aerobic landfill structure	Tonne CO_2	4,982,000
(3) GHGs emission reduction (i.e. 2.(1) – 2.(2)	Tonne CO_2	-2,526,000
3. The net GHGs emission reduction (i.e. 1.(3) + 2.(3))	Tonne CO_2	16,706,000
4. The estimated unit value of CER in the expected carbon market	US$/tonne CO_2	5.00
5. Thus, the estimated total value of CER (i.e. item 3 x item 4)	US$	83,530,000
(Exchange rate : US$1.00 = RM3.770)	RM	314,908,100

Although the potential amount of GHGs emission reduction by applying the principle of semi-aerobic landfill is large enough, not all of them can obtain CER that can be traded in the expected carbon market. There are a number of strict requirements to comply with before a project can be officially recognised as a CDM project. However, the use of CDM is still an option of raising the fund for proper and safe closure of landfill sites in accordance with the guideline.

Increasing the value of land capitals of the government through safe closure of landfill

Once the landfills have been closed safely, the land may be used for other purposes. The possible use of the safely closed landfills site may be limited by the conditions of the soil, groundwater, and other environmental parameters, hence stricter and safer closure countermeasures may be required to increase the potential for their future land use. The increase of the future *land use potential* will be beneficial to the owners of the land, i.e. the Federal or State Governments, LAs or private owners. For the environmental value, the land can be developed into a park or for agricultural purposes. The park will have social benefits and beautifies the area. The farm or orchard can receive revenue from the sale of the produce. As for the monetary value, i.e as a

capital asset, the land could be leased or sold to obtain the revenue to cover for the safe closure works.

Thus, the options for the financing of the safe closure of landfills are summarised in **Figure A3.8** below.

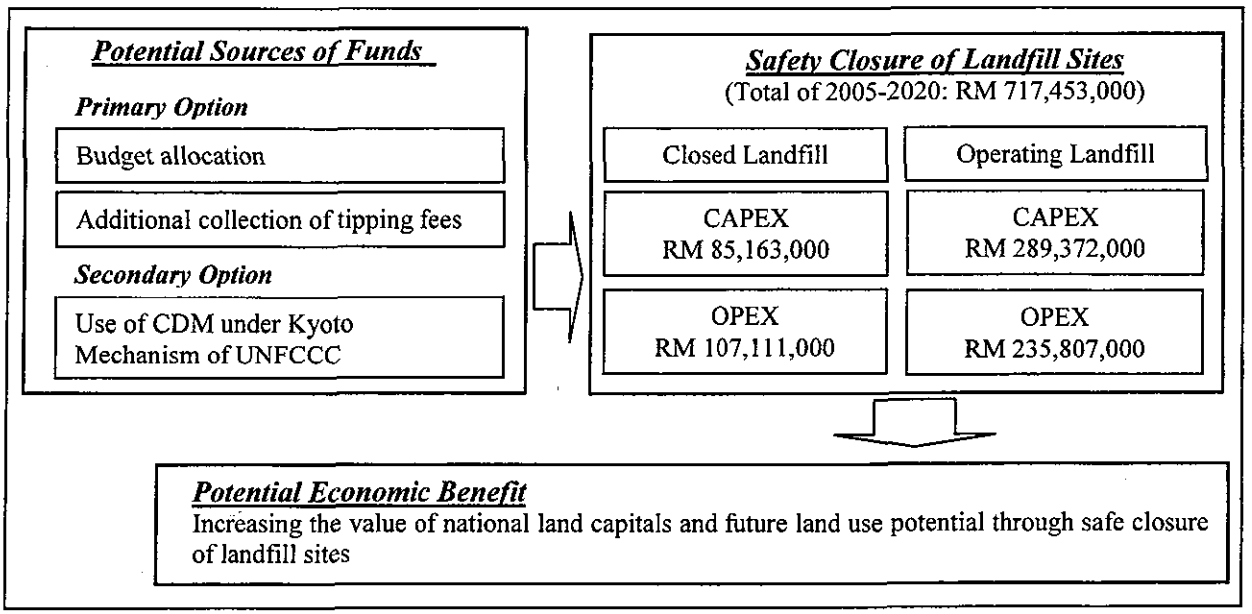


Figure A3.8 Summary of Options for financing of safe closure of landfills

A.3.5 Conclusion of Preliminary Analysis

As a result of the analysis of the safe closure of landfills (described in the Landfill Inventory) in Malaysia, priority, determination of closure level and total cost of implementation have been prepared. Issues related to funding sources have also been considered.

To carry out implementation of safe closure of landfills, it is important to strengthen the registration system for all the landfills including already-closed landfills, and to evaluate priority and closure level for each landfill systematically. The preliminary evaluation shows the following:

(1) In terms of landfill number, 13 % of landfill sites are in group A, and 26 %, 20 % and 39 % in groups B, C and D respectively.
(2) Closure levels are set based on environmental impact potential. 12% of landfill sites shall be closed with C4 level while 35 %, 31 % and 21 % with C3, C2 and C1 levels respectively.
(3) Total cost for safe closure up to 2020 is RM 717 million (equivalent to RM 45 million/year) including after care of closed landfill sites.
(4) Additional tipping fee/collection charge will be a major financial source. The cost for safe closure will be RM 5.6/ton of waste. Proper funding system shall be established.

(5) Allocation of Federal budget will also be required to facilitate safe closure of landfill site.
(6) CDM will be secondary option for the potential source of finance. However, more detail shall be examined.