ANNEXURE 17.1

ESTIMATION OF LANDFILL CAPACITY, LANDFILL HEIGHT, LANDFILL AREA

1. Current Waste generation per year = W (tons per year)
2. Estimated rate of increase (or decrease) of waste generation per year = x (percent) (use rate of population growth where waste generation growth rate estimates not available)
3. Proposed life of landfill (in years) = n (years)
4. Waste generation after n years = $W\left(1 + \frac{x}{100}\right)^n$ (tons per year)

5. Total waste generation in n years (T) in tons

$$T = \frac{1}{2}\left[W + W\left(1 + \frac{x}{100}\right)^n\right] n \quad \text{(tons)}$$

6. Total volume of waste in n years (V_w) (on the assumption of 0.85 t/cm.m density of waste)

$$V_w = T/0.85 \text{ (cu.m.)}$$

7. Total volume of daily cover in n years (V_{dc}) (on the basis of 15 cm soil cover on top and sides for lift height of 1.5 to 2 m)

$$V_{dc} = 0.1\ V_w \text{ (cu.m.)}$$

8. Total volume required for components of liner system and of cover system (on the assumption of 1.5m thick liner system (including leachate collection layer) and 1.0 m thick cover system (including gas collection layer)

$$V_c = k\ V_w \quad \text{(cu.m.)}$$

(k = 0.25 for 10 m high landfill, 0.125 for 20 m high landfill and 0.08 for 30 m high landfill. This is valid for landfills where width of landfill is significantly larger than the height)

9. Volume likely to become available within 10 years due to settlement / biodegradation of waste

$$V_s = m V_w$$

(m = 0.10 for biodegradable waste; m will for less than 0.05 for incinerated/inert waste)

10. First estimate of landfill capacity (C_i)

$$C_i = V_w + V_d + V_c - V_s \quad \text{(cu.m.)}$$

11. Likely shape of landfill in plan and section (To be based on topography of area, depth to ground water table and other factors) :
Area type, trench type, slope type, valley type, combination

12. First estimate of landfill height and area

(a) Restricted area available = A_r (sq.m.)
Area required for infrastructural facilities = 0.15 A_r
Area available for landfilling = 0.85 A_r
Average landfill height required (first estimate) above base level
$H_i = C_i / 0.9 A_r$ (m) (valid for area type landfill)

(b) No limitation on Area
Possible maximum average landfill height (first estimate) = H_i (typically between 10 to 20 m, rarely above 30 m)
Area required for landfilling seperations

$$A_i = C_I / H_i \quad \text{(sq.m.)} \quad \text{(valid for area type landfill)}$$

Total area required (including infrastructural facilities) (first estimate)

$$A_i = 1.15 A_i$$

13. Refinement in estimates of landfill capacities, landfill height and landfill area:

After obtaining the initial estimates, the volume of daily cover as well as volume of liner system and cover system can be revised keeping in view the shape of the landfill as well as on the basis of whether materials of daily cover, liner system and cover system will be excavated from within the landfill site.

Taking these revised values into account, refined estimates of landfill capacity, height and area can be made. The final and precise estimates will be arrived at after topographical survey results (0.30 m contour interval) become available.

It may be noted that landfill capacity values will undergo revision during operation of the landfill when waste quantities delivered at the site vary from the generation rates estimated prior to the start of landfill operations.

ANNEXURE 17.2

TYPICAL EXAMPLE (PRELIMINARY DESIGN)

The example given below is applicable for preliminary design of a landfill. Detailed design is not covered in this example. The word 'tentative' is used wherever adequate information was not available and when an adhoc estimate has been made.

17.A2.1 BASIC DATA

Location	:	Delhi
Waste Generation	:	1000 tons per day (current)
Design Life	:	Active Period = 16 years
		Closure and Post Closure Period=25 years
Topography	:	Flat ground
Subsoil	:	Sandy SILT upto 20m below ground surface, underlain by bedrock
Water-table	:	10m below ground surface
Average Total Precipitation:		750 mm per year
Base year	:	1998 prices

17.A2.2 LANDFILL CAPACITY, LANDFILL HEIGHT, LANDFILL AREA

(a) Current Waste Generation Per Year = 1000 t

(b) Estimated Waste Generation After 16 Years = 1700 t

(c) Total Waste Generation in 16 Years

$= 0.5 (1000 + 1700) \times 365 \times 16$

$= 7 \times 10^6$ tons

(d) Total Waste Volume (assumed density 0.85 t/cu.m.)

= $(7 \times 10^6)/0.85$

= 8.25×10^6 cu.m.

(e) Volume of Daily Cover

= $0.1 \times 8.25 \times 10^6$

= 0.825×10^6 cu.m.

(f) Volume of Liner and Cover Systems

= $0.125 \times 8.25 \times 10^6$

= 1.03×10^6 cu.m.

= 0.825×10^6 cu.m.

(g) First Estimate of Landfill Volume

Ci = $(8.25 + 0.825 + 1.03 – 0.825) \times 10^6$

= 9.28×10^6 cu.m.

(h) Likely Shape of Landfill

Rectangular in plan (length : width = 2:1)

Primarily above ground level, partly below ground level.

(i) Area Restrictions : Nil

(j) Possible Maximum Landfill Height = 20 m

(l) Area Required = $(9.28 \times 10^6)/20$

= 4.15×10^5 sq.m.

(m) Approximate Plan Dimensions = 450 m x 900 m

(n) Actual Landfill Section And Plan : Discussed in Section 17.A2.3.

17.A2.3 LANDFILL SECTION AND PLAN

(a) Landfill Section and Plan is evaluated on the basis of

(i) 4:1 side slope for the above-ground portion of the landfill.
(ii) 2:1 side slope for the below-ground portion of the landfill.
(iii) Material balance for daily cover, liner and final cover material through excavation at site.
(iv) Extra space around the waste filling area for infrastructural facilities.

(b) The final plan and section adopted is shown in Fig. 17.A2.1.
(c) Additional 30m land is acquired around the landfill to place infrastructure facilities. Final size of landfill = 572 m x 1172 m.

17.A2.4 LANDFILL PHASES

(a) Active life of landfill = 16 years
(b) Duration of one phase = one year
(c) Number of phases = 16. Each phase extends from base to final cover.
(d) Volume of one phase == landfill capacity/16
(e) Plan area of phase
= (Volume of one phase)/landfill height
= 240 m x 120 m (approx.)
(f) Number of daily cells = 365
(g) Plan area of one cell /on the basis of 2.0m lift of each cell
= (Volume of one cell)/2.0
= 22 x 42 m (approx.)
Landfill phases are shown in Fig. 17.A2.2.

17.A2.5 LANDFILL INFRASTRUCTURE & LAYOUT

(a) Site Fencing: All around the landfill

(b) Weighbridges: (computerised) Two weighbridges of 50T capacity (entry and exit) with office

(c) Administrative office: 30 m x 10 m building

(d) Site control office: 3m x 5m (portable cabin)

(e) Access Roads:

(i) Main Access Road : 7m wide; from main road to parking area

after weigh- bridge.

(ii) Arterial Road: 3.5 m wide all along the periphery.

(f) Waste Inspection And Sampling Facility: Nil; to be done at landfill area.

(g) Equipment Workshop & Garage: 30m x 20m building

(h) Vehicle Cleaning: Within the Workshop

(i) Other Facilities

(a) Temporary Holding Area: Excavated portion of half phase to be used
(b) Surface water drain: Adjacent to arterial road along periphery
(c) Leachate collection pipe: Adjacent to arterial road along periphery
(d) Leachate holding tank: 20x10x3m
(e) Leachate treatment facility: 40mx20m (in plan) (tentative)
(f) Gas Flaring facility: 20m x 10m (in plan) (tentative)
(g) Surface water sedimentation tank : 40 x 10 x 1.5m

All infrastructural facilities are shown in Fig. 17.A2.3.

17.A2.6 LINER AND LEACHATE COLLECTION SYSTEM

(a) Liner System

The liner system will comprise of the following layers below the waste:

(i) 0.30 m thick drainage layer comprising of Badarpur sand (coarse sand) or gravel (stone dust with no fines)
(ii) 0.2m thick protective layer of sandy silt (Delhi silt)
(iii) 1.50mm thick HDPE geomembrane
(iv) 1.0 m thick clay layer/amended soil layer (since clay is not easily available in Delhi, amended soil layer comprising of local soil + bentonite is to be designed)

(b) Amended Soil Layer Design Through Laboratory Testing

Sandy silt mixed with bentonite in proportions of 2, 4, 6, 8 and 10% in laboratory and permeability determined. Minimum bentonite content determined for achieving permeability of less than 10^{-9}m/sec. 5% Bentonite + sandy silt assumed in preliminary design.

(c) Leachate Evaluation

Average Total Precipitation in Delhi = 750mm/year
Only one phase is operative every year
Plan area of operating phase = 29000 sq.m.
Assuming 80% precipitation in 4 months (monsooon period), peak leachate quantity (thumbrule basis) = 200 cu.m. per day

(d) Leachate Collection Pipes

Dia of HDPE pipes (perforated) = 15 cm
Spacing of pipe required (hydraulic analysis) = 22m

(e) Leachate Holding Tank

Size of holding 3 days of leachate = 20 x 10 x 3 m

Liner system and leachate collection pipes shown in Figs. 17.A2.4 and 5.

17.A2.7 COVER SYSTEM DESIGN

(a) Cover System

The cover system will comprise of the following layer above the waste.

(i) 0.45 m thick gas collection layer comprising of gravel (stone dust with no fines)
(ii) 0.6 m thick barrier layer (sandy silt + 5% bentonite)
(iii) 0.3m thick surface layer of local top soil for vegetative growth

(b) Passive Gas Vents

Passive gas vents 1m high (above ground surface) will be provided at a spacing of 75mx75m.

17.A2.8 SURFACE WATER DRAINAGE SYSTEM

(a) Surface Water Runoff

Average Total Precipitation in Delhi = 750 mm/year

Peak discharge rate reaching drainage channel = 0.064 cu.m./sec.

Dimensions of drainage channel:
Depth = 0.6m, Base width = 0.6m, side slopes = 3:1

(b) Sedimentation Tank

To remove suspended particles of size 40 microns and above tank size required

= 40 x 15 x 1.5

Surface water drainage system depicted in Fig. 17.A2.6.

17.A2.9 ENVIRONMENTAL MONITORING SYSTEM

(a) Ground Water Monitoring Wells

Numbers = 6 (1 upgradient well; 5 wells along the sides in downgradient direction; all wells 30m away from landfill)

(b) Lysimeters

Numbers = 2 lysimeter under each phase. Total nos. = 32.

(c) Gas Monitors

Two portable gas monitors for landfill gas.

(d) Samplers

Stainless steel/HDPE samplers (25 nos.) for
(i) Groundwater samples
(ii) Leachate samples in vertical risers/wells

Grab samplers for landfill gas (25 nos.) at

(i) Passive vents
(ii) Gas wells

(e) Downhole Monitors

One multiparameter downhole groundwater monitoring system.

ANNEXURE 17.3

ESTIMATION OF LANDFILL COST BASED ON PRELIMINARY DESIGN

TABLE 1: SITE SELECTION AND SITE CHARACTERISATION COST

Sl. No.	**Item**	**Cost Rs x 10^5**
1.	Data Collection	0.50-0.75
2.	Environmental Impact Assessment	4.00-6.00
3.	Preliminary Bore Holes	1.50-2.25
4.	Geotechnical Investigation for Design , Borrow Material , Ground Water Investigation	7.50-11.25
5.	Topographical Investigation	1.50-2.25
6.	Hydrological Investigation	2.00-3.00
7.	Geological Investigation	2.00-3.00
8.	Traffic Investigation	0.50-0.75
9.	Water and Leachate Investigation	2.00-3.00
	Total	21.50-32.25
	Average	26.88

Note: This estimate is lumpsum and approximate. The values are indicative. However, actual costs will vary from site to site and should not be restricted by the range indicated in the table.

TABLE 2: DESIGN AND DETAILED ENGINEERING COST

Sl. No.	**Item**	**Cost Rs x 10^5**
1.	Design and Detailed Engineering	15.00-20.00
	Average	17.50

Note: This estimate is lumpsum and approximate. The values are indicative. However, actual costs will vary from site to site and should not be restricted by the range indicated in the table

TABLE 3: SITE DEVELOPMENT COST

Sl. No.	Item	Cost Rs x 10^5	Cost Rs x 10^5
1.	Land Acquisition*	830.00	
2.	Cost of Infrastructure		102.70
3.	Equipment for Landfill Construction/Operation **	359.00	
4.	Surface Water Drainage System		30.75
5.	Leachate Management Facility		23.85
6.	Environmental Monitoring Facility		8.00
7.	Gas Collection Facility***		
	Total	1189.00	160.30

** Land acquisition cost will vary drastically from location to location; market value indicated but not included in costing.*

*** Equipment cost indicated but not included in costing since all earthwork / waste placement work are computed on job basis.*

**** Not included in the example but to be taken into account whenever gas is collected for energy recovery / flaring.*

TABLE 4: PHASE DEVELOPMENT COST (YEARLY)

Sl. No.	Item	Cost Rs x 10^5
1.	Up-dated Design of Phase	2.00
2.	Preliminary Operation	112.10
3.	Temporary Surface Water Drains	0.80
4.	Monitoring Facility Below Liner	2.00
5.	Liner System	261.85
6.	Leachate Collection and Removal System	8.45
7.	Maintenance of Existing Facility	40.05
	Total	427.25

TABLE 5: PHASE OPERATION COST (YEARLY)

Sl. No.	Item	Cost Rs x 10^5
1.	Waste Filling , Spreading and Compaction	171.30
2.	Daily Cover Laying , Spreading and Compaction	19.45
3.	Pollution Prevention During Operation	4.00
	Total	164.75

TABLE 6: PHASE CLOSURE COST (YEARLY)

Sl. No.	Item	Cost Rs x 10^5
1.	Final Cover System	130.25
2.	Surface Water Drainage System on Cover	10.30
3.	Monitoring Facility on Cover	1.00
4.	Vegetation Growth on Cover	4.40
	Total	175.95

TABLE 7: POST CLOSURE CARE COST (YEARLY)

Sl. No.	Item	Cost Rs x 10^5
1.	Long Term Vegetative Stabilisation	16.00
2.	Operation of Leachate Management Facility	5.00
3.	Maintenance of Cover and Drainage System	12.50
4.	Environmental Monitoring	3.50
	Total	37.00

TABLE 8: INITIAL FIXED COST

Sl. No.	Item	Cost Rs x 10^5
1.	Site Selection and Site Characterisation Cost (Table 1) Average	21.50-32.25 26.88
2.	Design and Detailed Engineering Cost (Table 2) Average	15.00-20.00 17.50
3.	Site Development Cost (Table 3)	160.30
	Total	204.68

TABLE 9: YEARLY RUNNING COST (ACTIVE)

Sl. No.	Item	Cost Rs x 10^5
1.	Phase Development Cost (Table 4)	427.25
2.	Phase Operation Cost (Table 5)	164.75
3.	Phase Closure Cost (Table 6)	175.95
	Total	737.95

TABLE 10: YEARLY RUNNING COST (POST CLOSURE)

Sl. No.	Item	Cost Rsx10^5
1.	Post Closure Care Cost (Table 7)	37.00
	Total	37.00