A COMPUTER-GENERATED TABLE FOR THE DESIGN OF SEPTIC TANKS AND SOAKAWAY PITS

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ABSTRACT

Different methods of determining septic tank capacities are compared and it is suggested that soakaway pit capacities should be determined on the basis of water demand of the occupants of the building.

Subsequently, equations are formulated for determining dimensions of septic tanks and soakaway pits.

Finally, a computer program is developed for generating tables of septic tank and soakaway pit capacities and dimensions. These tables will enable quick selection of values and eliminate repetitive design calculations for different building projects.

1. INTRODUCTION

The septic tank and soakaway pit system constitutes the most common sewage disposal method employed in the urban areas of developing countries. This fact notwithstanding, the system happens to be one of the most overlooked aspects in building projects. Under-sized, over-sized and poorly dimensioned tanks and soakaway pits are built due to the ignorance of many of the designers of the systems. This results in poor functioning of the systems.

Furthermore, because the septic tank and soakaway pit are seen as an unimportant complementary aspect of building projects, proper supervision is usually not given during their construction.

Also during their use, a lot of indigestible matter is flushed into the septic tank and soakaway pit which eventually piles up and impairs the efficiency of the system. This situation is compounded by the irregular and non-frequent desludging of the tanks, prevalent in developing countries.

In this paper we highlight a way of facilitating the design of the septic tank and soakaway pit system by means of computer-generated tables of design parameters.

1.1 THE SEPTIC TANK

This is an underground covered tank, usually of concrete, with inlets from the building waste system and an outlet to a soakaway pit or drainage field.

Figure 1 shows a typical septic tank. Heavy solids settle at the bottom and form a sludge, a fraction of which is digested by anaerobic bacterial action. The lighter solids and grease (made up with some of the products of the bacterial action) float on the surface and form a scum. The liquid which occupies the region between the scum and the sludge constitutes the effluent which is piped to the soakaway pit or drainage field.

The tank is usually divided into two chambers by means of a divider partition, in order to encourage sludge settlement [1]. In order to reactivate it and ensure that the accumulated solids do not block inlet and outlet pipes, periodic cleaning of the tank is necessary.

1.2 THE SOAKAWAY PIT

This is a covered pit with porous (usually perforated) walls through which the effluent seeps or soaks into the surrounding subsoil.

A typical soakaway pit is shown in Figure 2 in which the walls of the pit are made of concrete blocks laid normal and on the sides in alternate layers. This arrangement provides enough perforations. In order

to ensure that the surrounding soil does not collapse through the perforations and enter the pit, the immediate surrounding of the pit is usually filled with hardcore or broken stones.

2. SEPTIC TANK DESIGN

The design of the septic tank involves determining its capacity and dimensions.

2.1 TANK CAPACITY:

The British Standard Code of Practice (CP) 302 [2] recommends for general use and with desludging of the tank undertaken at about six-monthly intervals, the formula.

$$C = 136.35N + 1818 \quad \text{.....(1)}$$

where C = tank capacity in litres

and N = number of persons in full-time residence

The rounded form of the formula, namely

$$C = 140N + 1820 \quad \text{.....(2)}$$

is more commonly used.

The Chartered Institution of Building Services Engineers (CIBSE) in their design guide (3) recommend for normal use the formula

$$C = 180N + 2000 \quad \text{.....(3)}$$

and in situations where domestic grinders are used they recommend the formula.

$$C = 250N + 2000 \quad \text{.....(4)}$$

Equations [3] and [4] both require a desludging interval of between 3 and 12 months, a 6-monthly interval being commonly acceptable.

In an earlier paper [4] the author had derived an expression for estimating the amount of settled but undigested sludge which remains in the septic tank in the interval between desludgings per head of population served, namely,

$$C = \frac{100 - d}{100}\left\{Q\eta_s\left(1 + \frac{p}{100 - P}\right)\right\} \quad \text{.....(5)}$$

where d = digested fraction of the settled sludge

Q = quantity of solid dry matter brought into the tank in the interval between desludgings per head

η_s = settlement efficiency, defined as quantity of solid matter settled in a given period divided by the total quantity brought into the tank within the same period

P = moisture content of the settled sludge

Simplifying equation 5 we obtain

$$C = \left(\frac{100 - d}{100 - P}\right) Q\eta_s \quad \text{.....(6)}$$

By substituting reasonable values of d, p, Q and η_s in the above expression, the author derived the equation [4]

$$C = 230N \quad \text{.....(7)}$$

for providing the minimum capacity of septic tanks.

Equation 7 has been derived on the sole consideration of the sludge holding, capacity of the tank. However, an additional consideration should be the fact that the contents of a small tank are liable to be stirred due to irregular discharges from the sanitary fixtures in the building, resulting in unsatisfactory settlement and the outflow of some undigested material with the digested effluent.

In order to minimise such turbulence, there is need to specify a minimum tank capacity which must be exceeded in design.

Another consideration in determining septic tank capacities should be the extent of neglect and abuse suffered by septic tanks (like other engineering systems) in developing countries.

Going by the foregoing considerations it is obvious that, for developing countries, the capacity provided by equation 7 should only be a minimum.

A comparison of equations 2, 3, 4, and 7 had been done graphically [4] (see Figure 3). Equation 2, gives higher capacities than (7) only up to N = 20 while equation 3 gives higher capacities than (7) up to N = 40. However, equation 4 gives higher capacities than (7) at all values of N. Equation 4 is therefore recommended in preference to equations 2, 3, and 7.

2.2 TANK DIMENSIONS:

In determining the different dimensions of the tank the following points are usually borne in mind, although other constructional constraints, such as available land space, may sometimes be more imposing.

a. the divider partition divides the tank into two sections of one-third and two-thirds of the tank volume [1]
b. the length of the tank is usually three times the width [5].
c. the depth of liquid is approximately half the length of the tank [1].
d. the pass-through opening is approximately one-third from the bottom of the tank [1].

3. SOAKAWAY PIT DESIGN

3.1 PIT CAPACITY: The rate at which water leaves sanitary fixtures in the building and enters the drainage system as effluent is the same as the rate at which water is supplied to these fixtures, expect for a small amount of water consumed by occupants. Thus the water demand of occupants as provided in CP 310 [6] and shown in Table 1 would provide the waste water volume. It has been recommended [4] that this water demand be equal to the soakaway pit capacity in soils having good seepage characteristics. Where the soil is not that good some other multiplying factor could be applied to the capacity recommended.

3.2 PIT DIMENSIONS: With the pit capacity determined its dimensions can easily be calculated by considering factors such as the shallowness of the natural level of subsoil water (which can impair construction work and also reduce the seepage rate), compactness of construction and the size of available land space. With the assumption that the natural level of subsoil water is reasonably deep and that available. Land space is adequate, a cubic form is recommended for providing a compact construction that can easily be built.

4. FORMULATION OF DESIGN EQUATIONS

From equation 4, $C = \frac{1}{1000}(250N + 2000)$, m^3 .....(8)

Also $C = L \times W \times D$.....(9)

where L = length of tank
W = Width of tank
D = Depth of liquid in the tank

From Section 2.2 $W = L/3$ .....(10)

$D = L/2$ .....(11)

$C = L \times \frac{L}{3} \times \frac{L}{2}$

$= \frac{L^3}{6}$

$L = \sqrt[3]{6C}$ .....(12)

Thus having obtained C from equation 8, the tank dimensions are calculated from equations 10, 11 and 12.

Also from section 2.2 the position of the divider partition from the inlet end.

$^{P}pat = \frac{2L}{3}$ .....(13)

and the depth of the pass-through opening below liquid level

$^{D}pat = \frac{2}{3}D = \frac{2}{3} \cdot \frac{L}{2} = \frac{L}{3}$

$= W$ .....(14)

These dimensions are illustrated in Figure 4. It should be noted from Figure 4 that the invert depth A of the inlet inspection chamber of the septic tank must be added to the depth D of the liquid in the tank, in order to obtain the total tank depth ^{D} Tot below ground.

i.e. ^{D} Tot = D + A .....(15)

Correspondingly, the total depth of the pass-through opening

^{D} pat, Tot = ^{D} pat + A

= W + A .....(16)

A is obtained from the underground drainage calculations as illustrated in available literature (5, 7)

The capacity of the soakaway pit, ^{C} pit, is determined by use of Table 1 with a multiplying factor (say 1.5). If the required water storage per person from Table 1 is WST, then

^{C} pit = N x WST x 1.5 .....(17)

The length of each side S of the pit is calculated from $S = \sqrt[3]{Cpit}$ .....(18)

This equation assumes the pit to be cubic in form.

However, to obtain the total pit depth ^{D} pit the depth below ground of the incoming effluent discharge pipe must be added to S (see Figure 5)

In Figure 5 which shows the general layout of the septic tank and soakaway pit, the fall in level from point 1 to 3 through 2 must be added to the invert depth of the septic tank inlet chamber, to obtain the depth below ground of the effluent discharge pipe at 3.

Let the general slope between points 1 and 3 to facilitate effluent flow = F

and the distance between septic tank and soakaway pit = X

Then depth of the soakaway pit below ground,

^{D}pit = S + A + F (L + X).....(19)

F is obtained from the underground drainage calculations as illustrated in available literature (7). X is chosen to be large enough to ensure that the walls of the septic tank do not impair the soaking process in the soil around the soakaway pit, but within the limits of available land space. A distance of 3 metres is usually considered adequate (7).

5. A COMPUTER PROGRAM FOR QUICK SELECTION OF SEPTIC TANK AND SOAKAWAY PIT DIMENSIONS

A computer program based on the equations presented in section 4 and written in Microsoft FoxPro has been developed by the author. By means of the program, tables of capacities and dimensions of septic tanks and soakaway pits for various values of A, F, X and WST (which depends on the use of the building) have been generated on an IBM 286 personal computer and are presently being used in design practice.

An example of such a table is shown in Appendix 1 which also shows a listing of the program. Thus by specifying values of A, F, X and WST the required capacities and dimensions can be obtained by entering the relevant table using the required number of occupants or users of the septic tank and soakaway pit system.

The program uses as input the water storage capacities, WST's listed in Table 1. The program can easily be written in other programming languages due to the simple form of the computational equations shown again as follows:

for the septic tank, $C = \frac{1}{1000}(250N + 2000)$.....(8)

$L = \sqrt[3]{6c}$.....(12)

$W = L/3$.....(10)

$^{P}pat = 2L/3$.....(13)

$^{D}pat, Tot = W + A$.....(16)

$D = L/2$.....(11)

$^{D}Tot = D + A = \frac{L}{2} + A$...(15)

and for the soakaway pit,

$^{C}pit = \frac{1}{1000}(N \times WST \times 1.5)m^3$ from (17)

$S = \sqrt[3]{Cpit}$.....(18)

$^{D}pit = S + A + F(L + X)$.....(19)

For better appreciation of the program a representation of the variables appearing therein is given in Appendix 2. The program flow chart is shown in Figure 6.

6. ILLUSTRATION OF THE USE OF THE COMPUTED RESULTS AND COMPARISON WITH CALCULATION PROCEDURE

To illustrate the use of such tables we consider a hotel project for which the depth, A, of the inlet inspection chamber of the septic tank is 0.6m, the general slope, F; of the sewage drainage pipework is 1 in 100 (0.01) and the soakaway pit is situated 3m away from the septic tank (i.e X = 3m). If we project a peak residency of 40 persons,

tank capacity, $C = \frac{1}{1000}(250 \times 40 + 2000) = 12.000m^3$

tank length $L = \sqrt[3]{6 \times 12} = 4.160m$

tank width, $W = \frac{4.160}{3} = 1.387m$

divider position,

$P_{pat} = 2/3 \times 4.160 = 2.773m$

depth of pass-through opening, ^{D}pat, Tot = 1.387 + 0.600 = 1.987m

tank total depth

$^{D}Tot = \frac{4.160}{2} + 0.600 = 2.680m$

required water storage, WST, for hotels = 135 ℓ per resident

$\therefore$ Soakaway pit capacity $^{C}pit = \frac{1}{1000}(40 \times 135 \times 1.5) = 8.100m^3$

length of side of pit, $S = \sqrt[3]{8.100} = 2.008m$

depth of soakaway pit below ground ^{D}pit = 2.008 + 0.600 + 0.01 (4.160 + 3.000)

= 2.680m

These calculated capacities and dimensions are the values appearing in the table of Appendix 1 when we simply enter the table at a number of users equal to 40.

7. CONCLUSION

Table of septic tank and soakaway pit capacities and dimensions have been generated by means of a computer program.

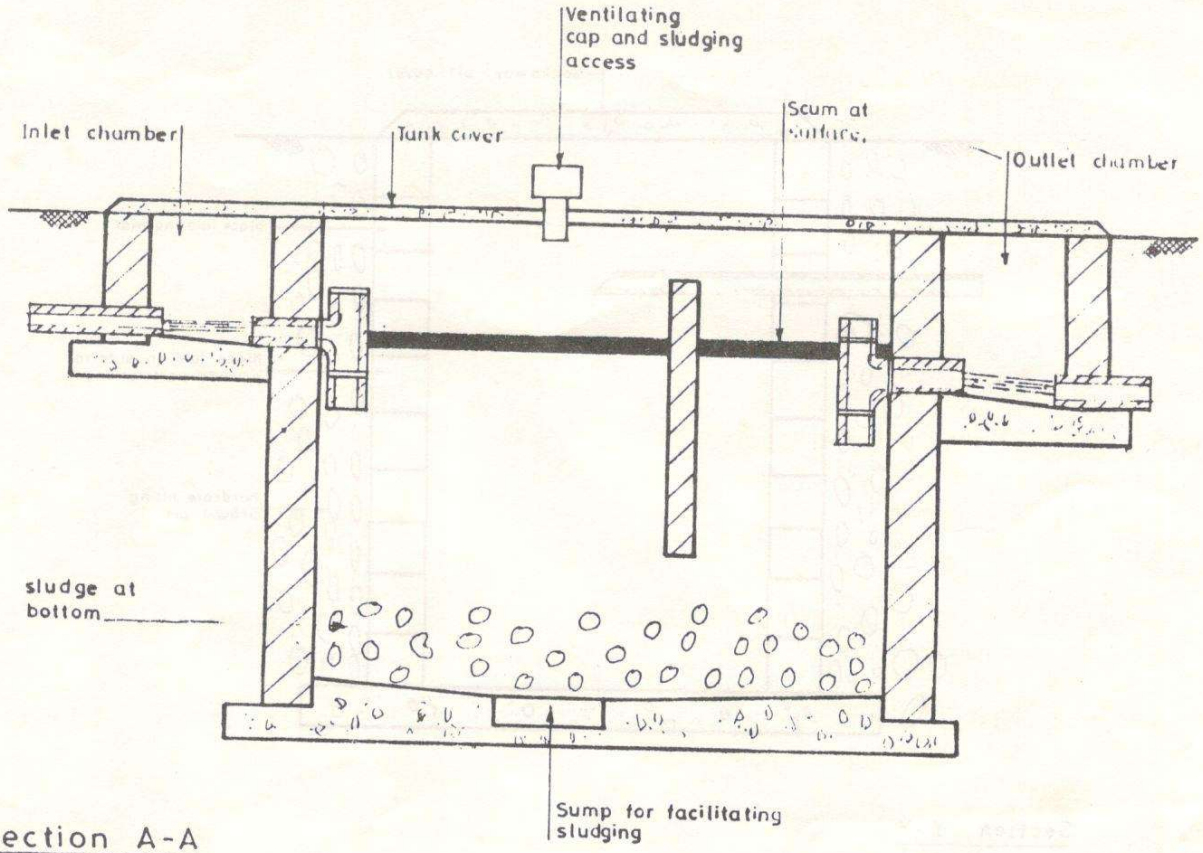
Such tables will enhance quick selection of capacities and dimensions, thereby eliminating repetitive design calculations for every building project.

REFERENCE

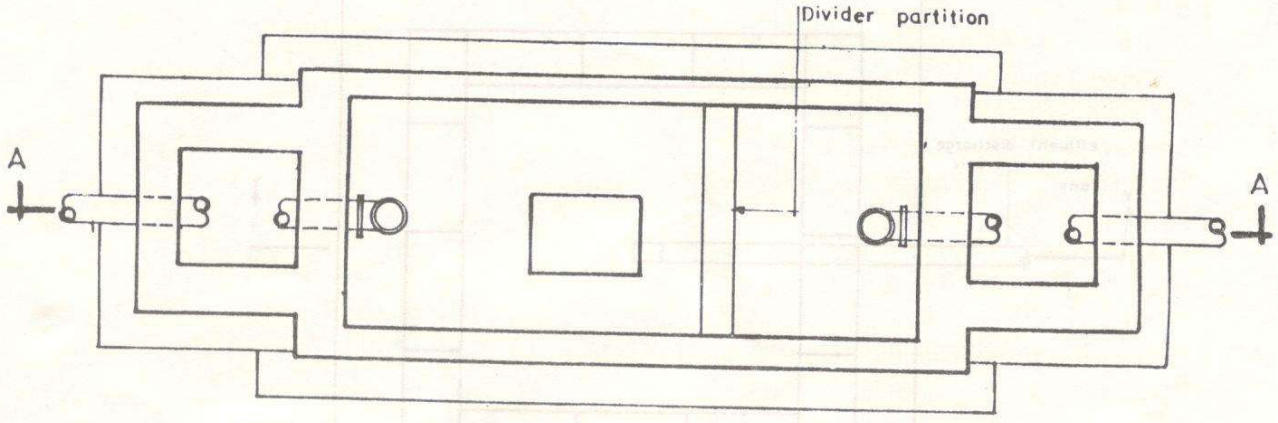
1. Mueller, J. P., Plumbing Design and Installation Details, Mcgraw - Hill, 1987.
2. British Standards Institution (BSI), Code of Practice 302: Small Sewage Treatment Works, BSI, London, 1972.
3. Chartered Institution of Building Services Engineers (CIBSE) Guide B8 Sanitation and Waste Disposal, CIBSE, London, 1977.
4. Sodiki, J. I., A suggested design Approach for Sewage Disposal in Isolated Buildings with particular Reference to the Septic Tank and Soakaway Pit System, N.S.E. Technical Transactions, Vol. 30 No. 4 1995, PP 29-37.
5. The Institute of Plumbing (I.O.P) Plumbling Design Guide, I.O.P, Essex, 1977
6. British Standards Institution (BSI), Code of Practice 310: Water Supply, BSI, London, 1965.
7. Barry, R., The Construction of Buildings Vol. 5; Supply and Discharge Services, Granada Publishing Ltd., London, 1984.

TABLE 1: WATER STORAGE CAPACITIES

Dwellings, Hostels, Boarding Schools	per resident	90 Litres
Hotels	per resident	135 Litres
Offices	per head	37 Litres
Offices with Canteens	per head	45 Litres
Restaurants	per head	
	per meal	7 Litres
Day Schools	per head	27 Litres
Nurses Homes and Medical Quarters	per resident	115 Litres

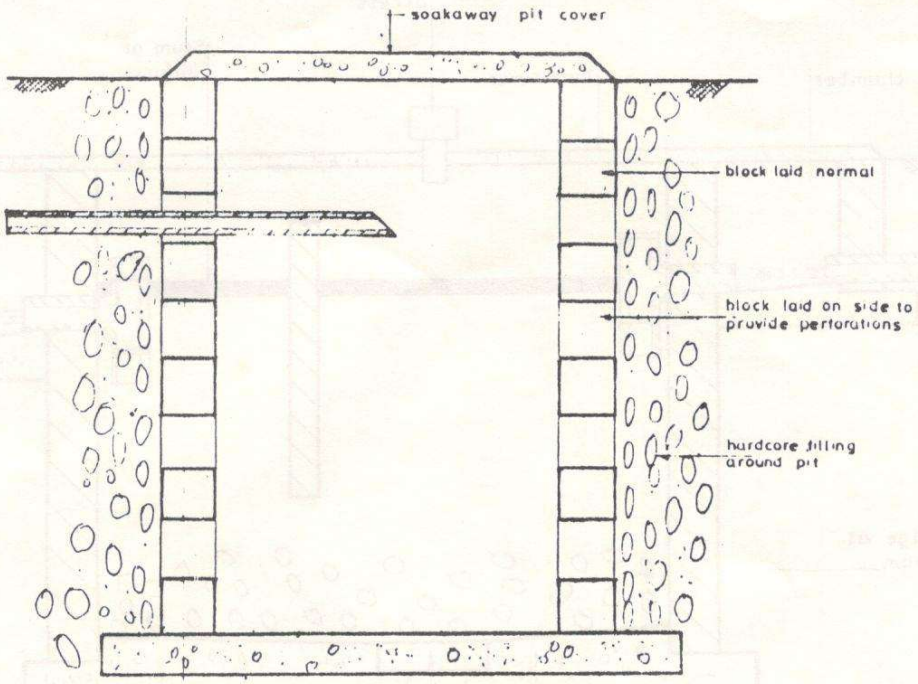


Section A-A

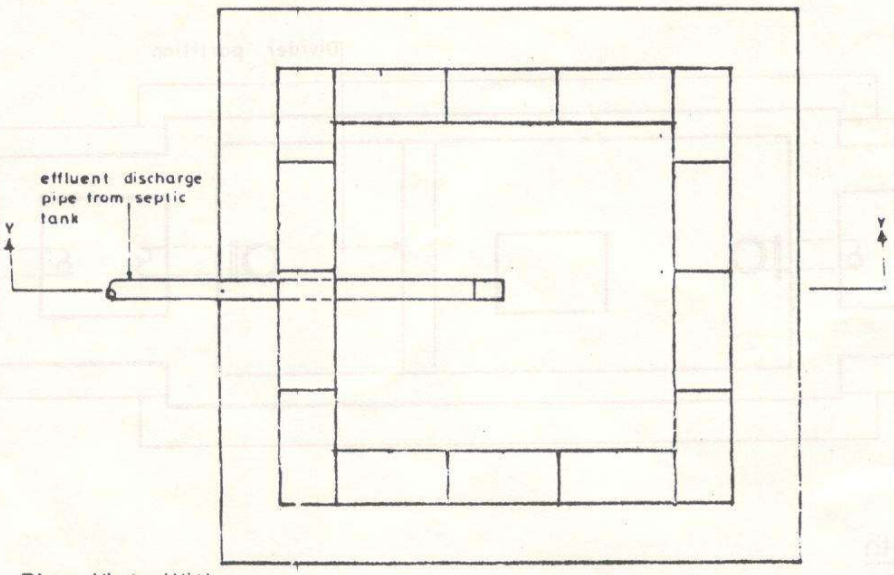


Plan View With Tank Cover Removed

Figure 1 : A typical septic tank



Section Y-Y



Plan View With Pit Cover Removed

Figure 2: A typical soakaway pit constructed in loose soil

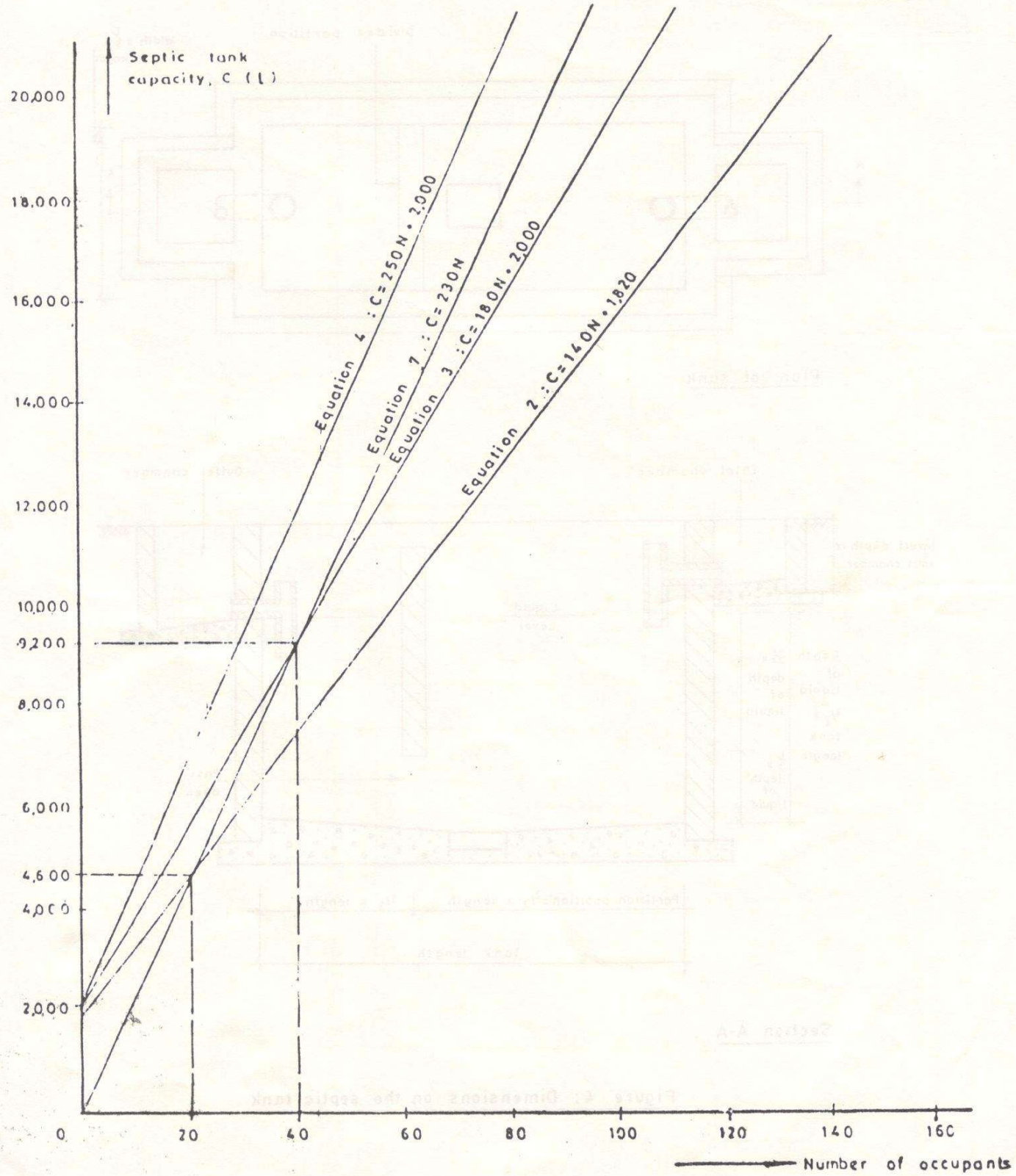
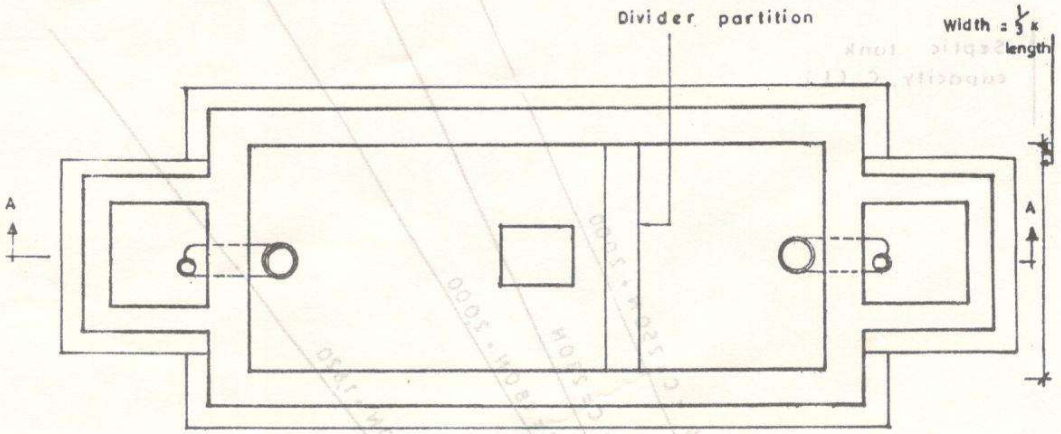
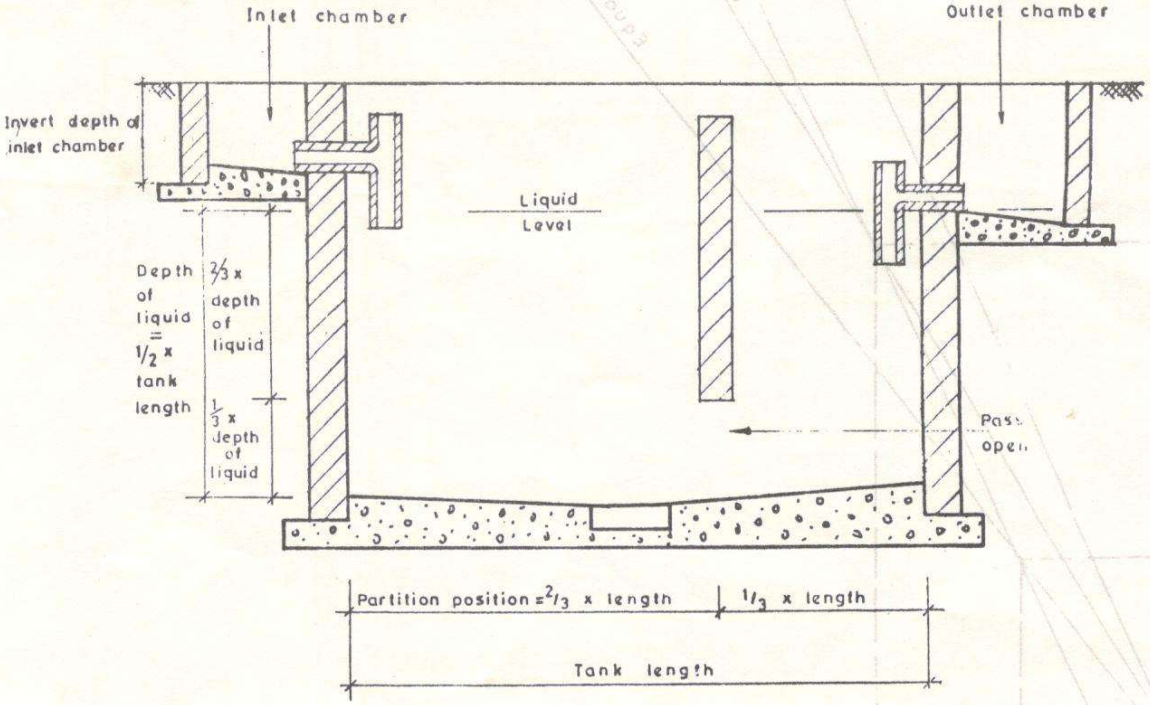


Figure 3: Comparison of septic tank capacity equations



Plan of tank



Section A-A

Figure 4: Dimensions on the septic tank

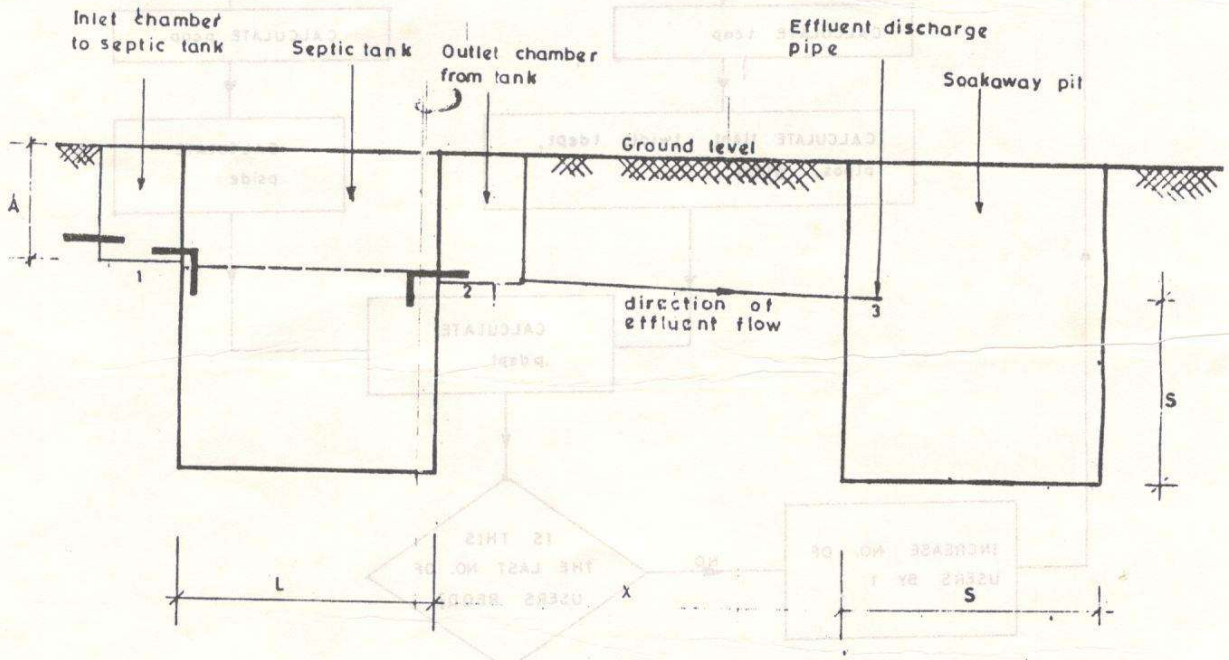


Figure 5: Layout of septic tank and soakaway pit

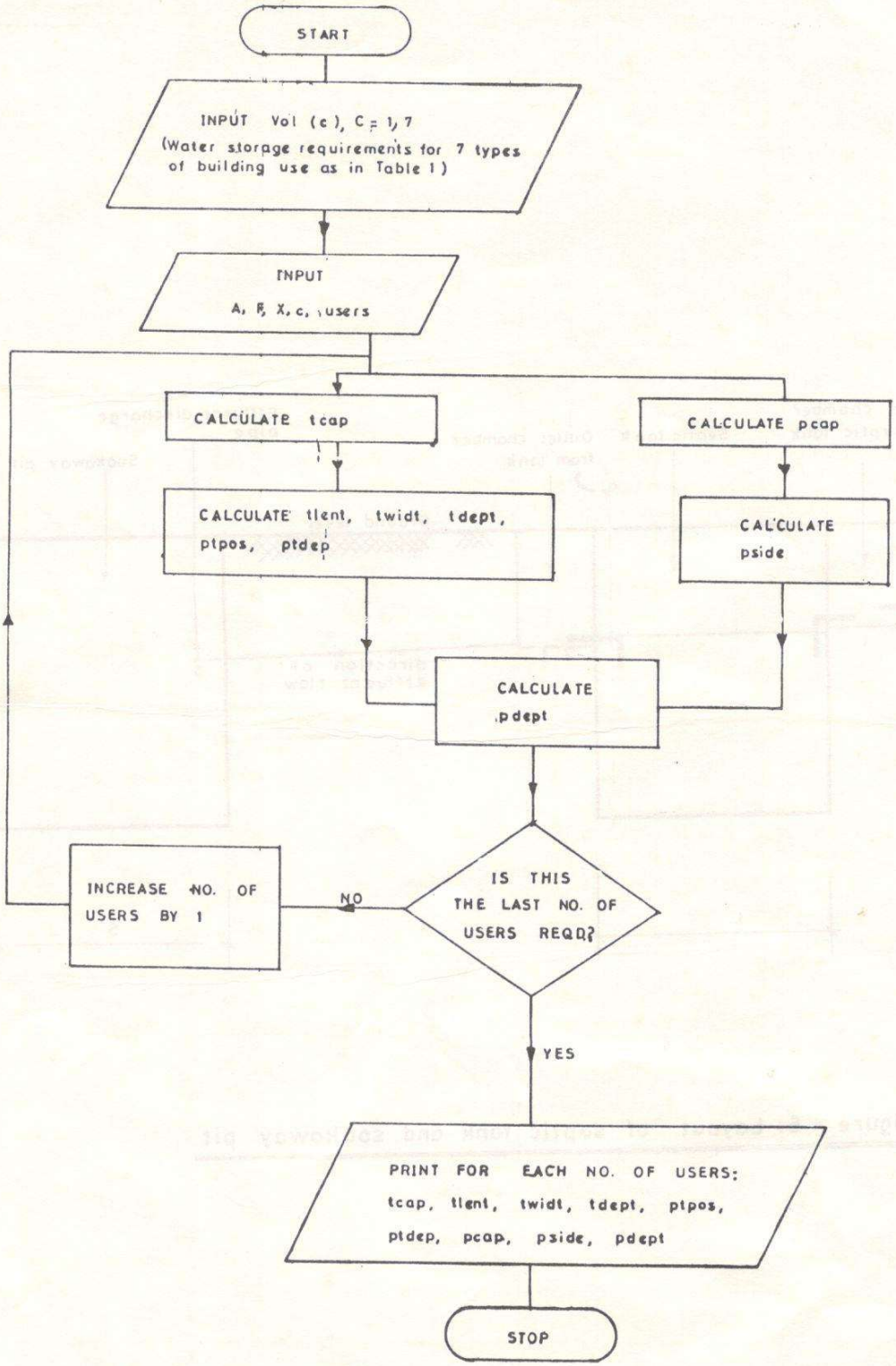


Figure 6: Flow chart for the design of septic tank and soakaway pit.

APPENDIX 1 : PROGRAM LISTING AND OUTPUT

```
* ************************************************************************************************
*                System:  Septic Tank & Soak –Away Pit Computation
*                Author:  John Sodiki
*     Prog. Language:  Microsoft FoxPro
*         Last Modified:  20–11–92
* ************************************************************************************************
*
CLEAR PROGRAM
CLEAR ALL
CLOSE DATABASES
SELECT A
USE tank          && Open TANK Database file
ZAP
SELECT B
USE storage
m.users = 0
STORE 0 TO m.tcap, m.tlent,m.twidt,m.tdept,m.ptpos
SOTRE 0 TO m.ptdep,m.pcap, m.pside,m.pdept
A =0.60
F = 0.01
X = 3.00
m.c. = 2
FOR m.users = 5 TO 50 STEP 1
      m.tcap  = (250 * m.users + 2000) / 1000
      m.tlent  = (6*m.tcap) ** (1/3)
      m.twidt  = m.tlent/3
      m.ptpos = 2* m.tlent/3
      m.ptdep = m.twidt + A
      m.tdept = (m.tlent/2 + A)
      DIMENSION mpcap (7)
      DIMENSION mpside (7)
      DIMENSION mpdept (7)
      SELECT storage
      GOTO m.c
      m.vol = vol
      mpcap (m.c)  =  m. users * m.vol / 1000 * 1.5
      mpside (m.c)  = mpcap (m.c) ** (1/3)
      mpdept (m.c.) = mpside (m.c) + A + F * (m.tlent + X)
      SELECT A
      APPEND BLANK
      REPLACE    users WITH m.users,;
                 tcap  WITH m.tcap,;
                 tlent  WITH m.tlent,;
                 twidt  WITH m.twidt,;
                 ptpos  WITH m.ptpos,;
                 ptdep  WITH m.ptdep,;
                 tdept  WITH m.tdept
      REPLACE    pcap2  WITH mpcap(2),;
                 pside2  WITH mpside(2),;
                 pdept2  WITH mpdept(2)
ENDFOR
CLOSE DATABASES
CLEAR MEMORY
RETURN
```

TABLE FOR SIZING SEPTIC TANK / SOAK–AWAY PIT
TYPE OF BUILDING: HOTELS 135 LITRES PER RESIDENT

USERS	TANK CAP (m3)	LENGTH (m)	WIDTH (m)	DEPTH (m)	--PARTITION-- POS. (m)	DPT(m)	PIT (m3)	PIT (m)	PIT (m)
5	3.250	2.692	0.897	1.946	1.794	1.497	1.013	1.004	1.661
6	3.500	2.759	0.920	1.979	1.839	1.520	1.215	1.067	1.725
7	3.750	2.823	0.941	2.012	1.882	1.541	1.418	1.123	1.782
8	4.000	2.884	0.962	2.042	1.923	1.562	1.620	1.174	1.833
9	4.250	2.943	0.981	2.072	1.962	1.581	1.823	1.221	1.881
10	4.500	3.000	1.000	2.100	2.000	1.600	2.025	1.265	1.925
11	4.750	3.055	1.018	2.127	2.036	1.618	2.228	1.306	1.967
12	5.000	3.107	1.036	2.154	2.071	1.636	2.430	1.344	2.005
13	5.250	3.158	1.053	2.179	2.105	1.636	2.633	1.381	2.042
14	5.500	3.208	1.069	2.204	2.138	1.653	2.835	1.415	2.077
15	5.750	3.255	1.085	2.228	2.170	1.669	3.038	1.448	2.111
16	6.000	3.302	1.101	2.251	2.201	1.685	3.240	1.480	2.143
17	6.250	3.347	1.116	2.274	2.231	1.701	3.443	1.510	2.173
18	6.500	3.391	1.130	2.296	2.261	1.716	3.645	1.539	2.203
19	6.750	3.434	1.145	2.317	2.289	1.730	3.848	1.567	2.231
20	7.000	3.476	1.159	2.338	2.317	1.745	4.050	1.594	2.259
21	7.250	3.517	1.172	2.358	2.345	1.759	4.253	1.620	2.285
22	7.500	3.557	1.186	2.378	2.371	1.772	4.455	1.645	2.311
23	7.750	3.596	1.199	2.398	2.397	1.786	4.658	1.670	2.336
24	8.000	3.634	1.211	2.417	2.423	1.799	4.860	1.694	2.360
25	8.250	3.672	1.224	2.436	2.448	1.811	5.063	1.717	2.384
26	8.500	3.708	1.236	2.454	2.472	1.824	5.265	1.740	2.407
27	8.750	3.744	1.248	2.427	2.496	1.836	5.468	1.762	2.429
28	9.000	3.780	1.260	2.490	2.520	1.848	5.670	1.783	2.451
29	9.250	3.814	1.271	2.507	2.543	1.860	5.873	1.804	2.472
30	9.500	3.849	1.283	2.524	2.566	1.871	6.075	1.825	2.493
31	9.750	3.882	1.294	2.541	2.588	1.883	6.278	1.845	2.514
32	10.000	3.915	1.305	2.557	2.610	1.894	6.480	1.864	2.533
33	10.250	3.947	1.316	2.574	2.631	1.905	6.683	1.884	2.553
34	10.500	3.979	1.326	2.590	2.653	1.916	6.885	1.920	2.572
35	10.750	4.010	1.337	2.605	2.674	1.926	7.088	1.921	2.591
36	11.000	4.041	1.347	2.621	2.694	1.937	7.290	1.939	2.609
37	11.250	4.072	1.357	2.636	2.714	1.947	7.493	1.957	2.627
38	11.500	4.102	1.367	2.651	2.734	1.957	7.695	1.974	2.645
39	11.750	4.131	1.377	2.666	2.754	1.977	7.898	1.991	2.663
40	12.000	4.160	1.387	2.680	2.773	1.987	8.100	2.008	2.680
41	12.250	4.189	1.396	2.694	2.793	1.996	8.303	2.025	2.697
42	12.500	4.217	1.406	2.709	2.811	2.006	8.505	2.041	2.713
43	12.750	4.245	1.415	2.723	2.830	2.015	8.708	2.057	2.730
44	13.000	4.273	1.424	2.736	2.848	2.024	8.910	2.073	2.746
45	13.250	4.300	1.433	2.750	2.867	2.033	9.113	2.089	2.762
46	13.500	4.327	1.442	2.763	2.884	2.042	9.315	2.104	2.777
47	13.750	4.353	1.451	2.777	2.902	2.051	9.518	2.119	2.793
48	14.000	4.380	1.460	2.790	2.920	2.060	9.720	2.134	2.808
49	14.250	4.405	1.468	2.803	2.937	2.068	9.923	2.149	2.823
50	14.500	4.431	1.477	2.816	2.954	2.077	10.125	2.163	2.838

APPENDIX 2: PROGRAM VARIABLES

Users	Number of users of septic tank and soakaway pit (building occupants)
tcap	Septic tank capacity
tlent	Septic tank length
twidt	Septic tank width
depth	Septic tank depth
ptpos	Position of divider partition measured from inlet end.
ptdep	Depth below ground of the pass-through opening in the divider partition.
pcap	Soakaway pit capacity
pside	Length of the sides of the soakaway pit
pdept	Depth below ground of the soakaway pit
A	Invert depth of the inlet inspection chamber to the septic tank
F	General slope of the sewer
X	Distance between septic tank and soakaway pit.
c	Counter for selecting the use of the building
vol.	Water storage requirements in terms of the use of building, as presented in Table 1.