New Wastewater Technologies For Pennsylvania

On-Lot Systems And Small Flows

Research And Development

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This research and demonstration project was funded from fees collected by the Department of Environmental Protection under Section 10 of Act 537 for the review of sewage facilities planning modules for new land development.

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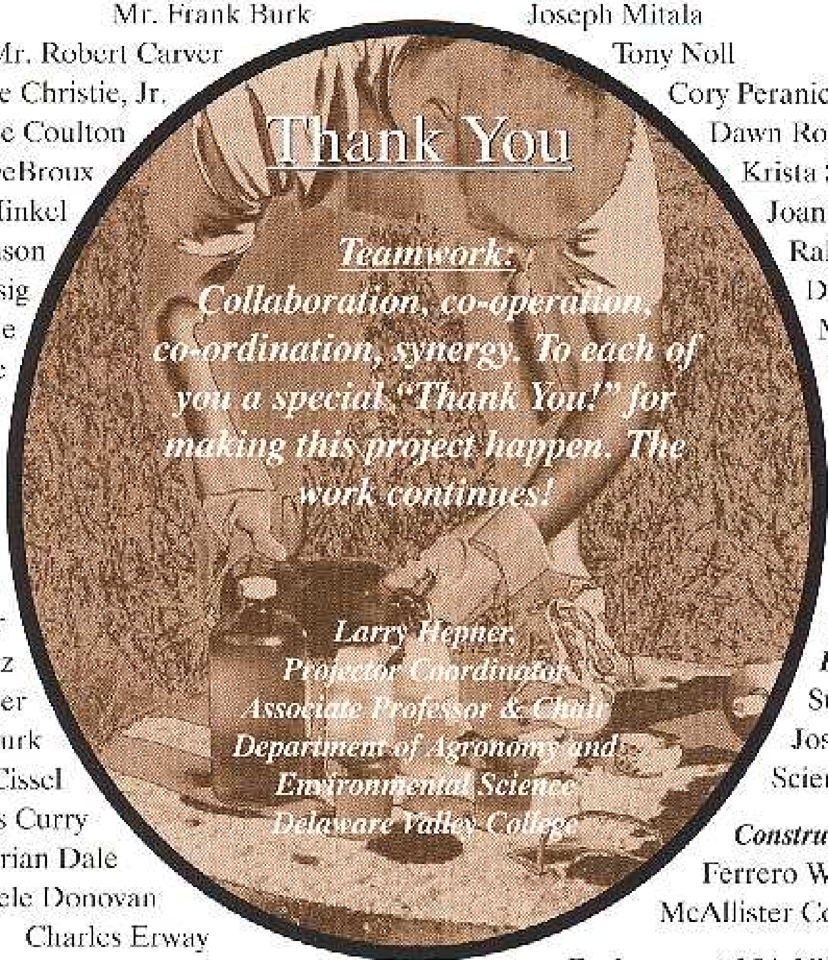

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IN 1994 the Department of Environmental Protection and the Agronomy and Environmental Science Department at Delaware Valley College formed the Research and Demonstration Center for On-Lot Systems and Small Flow Technology.

Funded by the DEP, the objectives of the Center were as follows:

- Consolidate data and information on systems used or under evaluation in other states and other countries.
- Establish technology priorities based on climate, geology, and soil conditions in PA where current alternatives are not available or are too costly.
- Construct six technologies and evaluate.
- Develop a final report with conclusions on systems' applicability to PA.

As a first step, on-lot systems technology components in use or under evaluation were reviewed nationally and internationally from published reports and direct contact with researchers, regulators, and industry people. A data base was developed to organize, store and access this information. Resource information for determining the technologies to be used at the center came from articles found through the Delaware Valley College Library's Dialogue Information Retrieval Service, direct contact with publishers, and through contact with the National Small Flows Clearing House at West Virginia University, surrounding states and the American Society of Agricultural Engineers. All information is held in the Agronomy and Environmental Science Department at Delaware Valley College.

Three nationwide trends emerged from the review of existing research information, discussions with regulatory people and discussions with industry people:

- Place systems in the Bio-Active soil zone. The bio-active soil zone is the soil horizons close to the surface, the A and B horizons. Traditionally, soil based systems (especially conventional type systems) are placed in the C horizons, beneath the bio-active zone. Most renovation occurs in the bio-active zone.
- Solids and BOD removal is needed to increase the effluent infiltration rates of soil, especially slowly permeable soil.
- There is a need to attempt to determine the thickness of the soil required to adequately renovate effluent. (Renovative Thickness)

Also, a Treatment Component Table was developed to organize information and aid in the selection process.

TREATMENT COMPONENT TABLE

PRIMARY	SECONDARY	SOIL BASED
Septic Tank	Intermittent Sand Filter	Wetland
Aerobic Tank	Recirculating Sand Filter	Spray Irrigation
	Peat Filters	Low Pressure Pipe
	Biological Filters	Drip Trickle
	N Removal	At Grade
	P Removal	Sand Mound
	Disinfection	

Selection criteria were established for choosing the combination of primary, secondary and soil based components. The goal was to test technologies that would be applicable to the climate, geologic, and soil conditions in Pennsylvania, or specific areas of Pennsylvania. The technologies selected had the potentials to provide an alternative for those areas where no current alternative is available, or provide additional cost effective alternatives for existing system types.

Six system technologies consisting of various primary treatment components, secondary treatment components, and soil based components were chosen for study as a result of the selection process. Full-scale models of these technologies were constructed for testing on the campus of Delaware Valley College. These technologies (A through F) are explained in this report. Site information, design information, and selected data are provided.

THE TECHNOLOGIES THEMSELVES WERE SELECTED TO FIT AS POSSIBLE ALTERNATIVES WITHIN THE CURRENT SYSTEM MATRIX

	<10"	10"	20"	24"	36"	48"	60"	72"
0-8%	(X) A,C	(SP) A,C,D	(EM) B,C,F	(EM) B,C,F	(EM) B,C,F	(EM) B,C,F	(CT) CT	(CB) CB
8-12%	(X) A,C	(SP) A,C,D	(EM) B,C,F	(EM) B,C,F	(EM) B,C,F	(EM) B,C,F	(CT) CT	(CT) CT
12-15%	(X) X	C,D	(EM) B,C,F	(EM) B,C,F	(EM) B,C,F	(EM) B,C,F	(EM) B,C,F	(CT) CT
15-20%	(X) X	(Sp1) C,E	(Sp1) C,E	(Sp1) C,E	(Sp1) C,E	(Sp1) C,E	(Sp1) C,E	(CT) CT
20-25%	(X) X	(Sp1) C,E	(Sp1) C,E	(Sp1) C,E	(Sp1) C,E	(Sp1) C,E	(Sp1) C,E	(CT) CT

1 mil* — 4 mil* — 8 mil* — 3 mil* — .06 mil* — 5 mil*

Acres calculated from USDA NRCS soil survey database.

CURRENT SYSTEM:

EM Elevated Mound
CT Conventional Trench
CB Conventional Bed

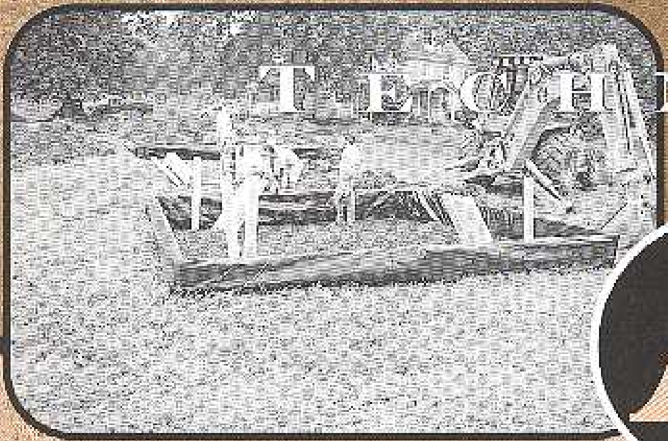
SP Spray Irrigation requiring 2 acre lot
Sp1 Spray Irrigation requiring wooded lot

NEW:

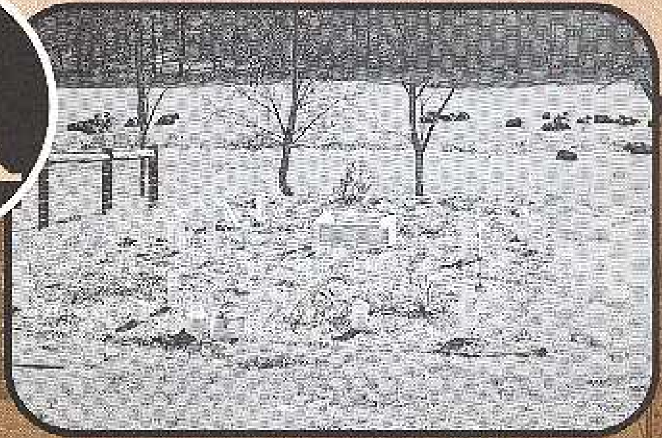
Technologies A through F are illustrated in the positions that they could potentially fill. These technologies could provide options for 21 million acres in Pennsylvania.

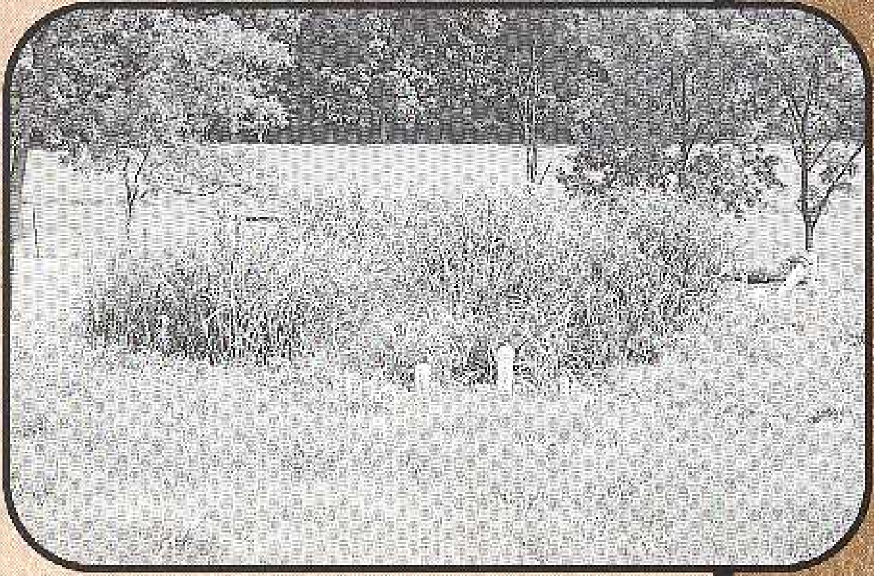
Technology A:	Constructed Wetlands
Technology B:	Recirculating Sand Filters
Technology C:	Sand Filter Bank
Technology D:	At-Grade Pressure Bed
Technology E:	Drip Trickle
Technology F:	Renovative Thickness

TECHNOLOGY



A

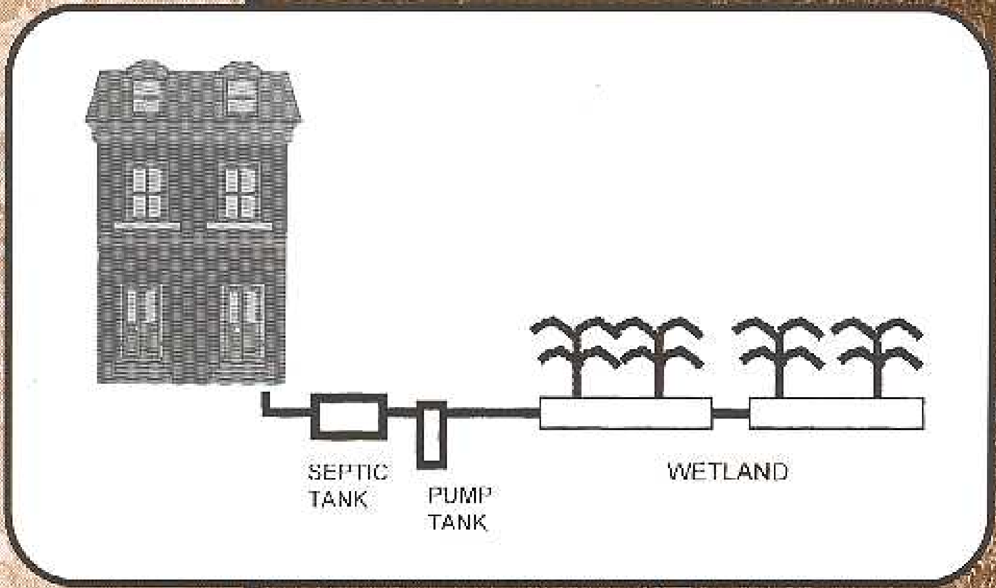




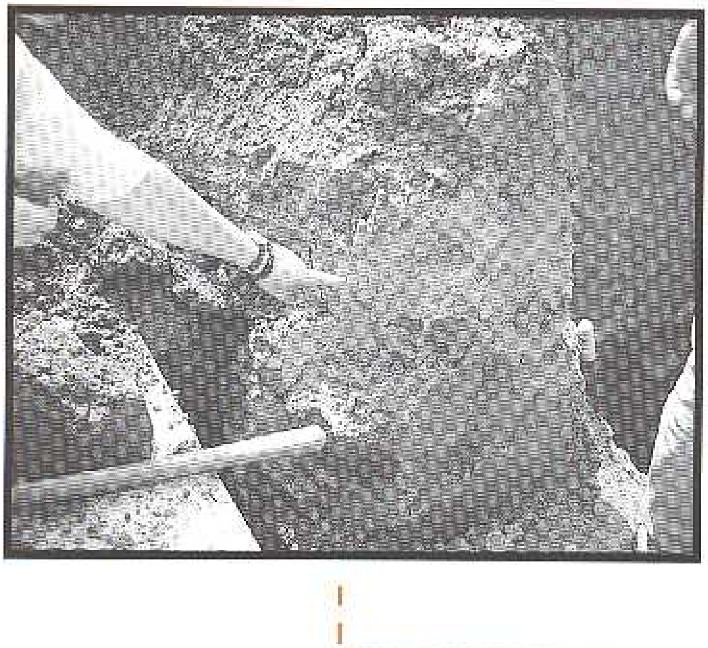
TECHNOLOGY

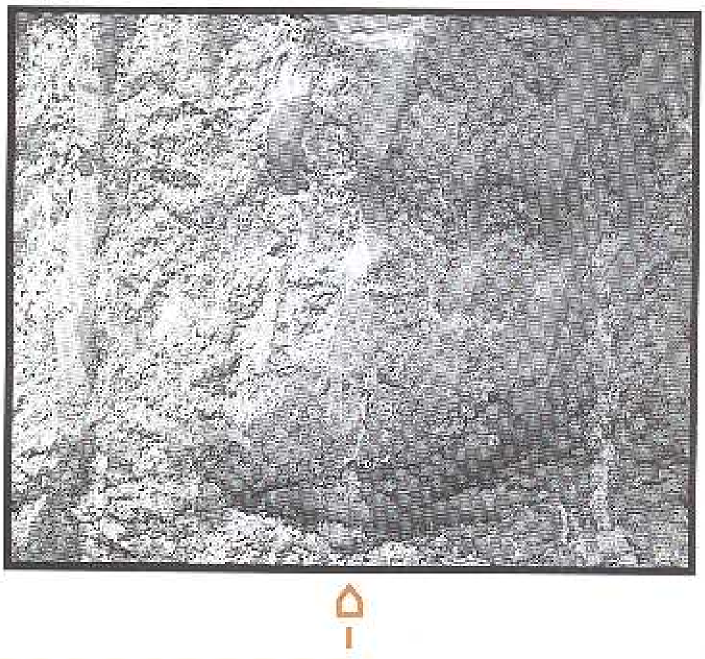
A

Constructed Wetlands



***Abbottstown**, somewhat poorly drained soil. Redox features (mottles) and polygonal structural cracks are common in this soil type. Seasonal high water table found at 10" beneath the surface.*





The Constructed Wetland is a natural method of treating water. The physical and chemical processes that nature provides can be adjusted by altering factors including depth, media, and vegetation in the wetland.

There are two major categories of constructed wetlands: the free-water surface and the subsurface flow. A free-water surface wetland has water exposed to the atmosphere, while the water in a subsurface flow wetland remains below the surface of the media. This project utilizes subsurface flow wetlands.

The subsurface wetlands can have horizontal flow through the wetland, or vertical flow through the system. The wetlands on this project were designed to function by either flow method depending on valve settings. The root zone in a typical horizontal flow bed remains saturated and must rely on the macrophyte plants to supply the oxygen required for the conversion of ammonia to nitrate. Nitrate can then be converted to gaseous nitrogen in the anaerobic areas and released to the atmosphere.

Sizing guidelines provided by Tennessee Valley Authority were utilized. Calculations were performed in order to predict the minimum cross sectional area and surface area required to handle the hydraulic load and to treat the biochemical oxygen demand. The wetlands for this project were sized at 16 feet by 16 feet and approximately 2.5 feet deep. The media used was ¾" clean stone. ***Scirpus sp.***, commonly known as bulrush, is a well-suited macrophyte due to its high ammonia tolerance and highly oxygenated rhizome. In addition, cattails and ***Juncus*** could be planted.

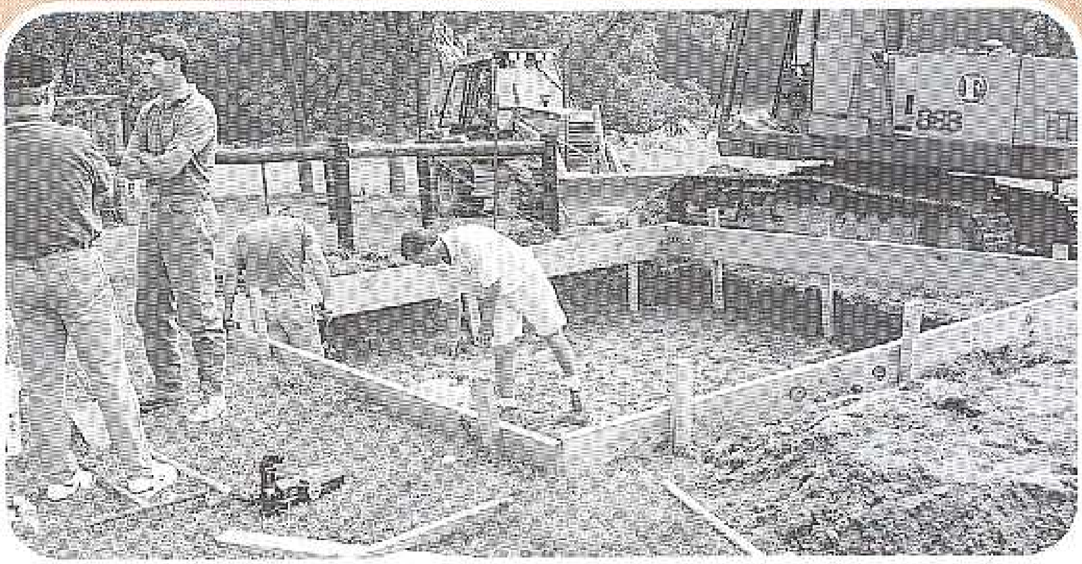
The system consists of two cells, each 16' by 16'. The first cell is lined with a 20 mil PVC liner. The second cell is open at the bottom, but lined around the sidewalls. Three wetlands were constructed. Each received septic tank quality effluent.

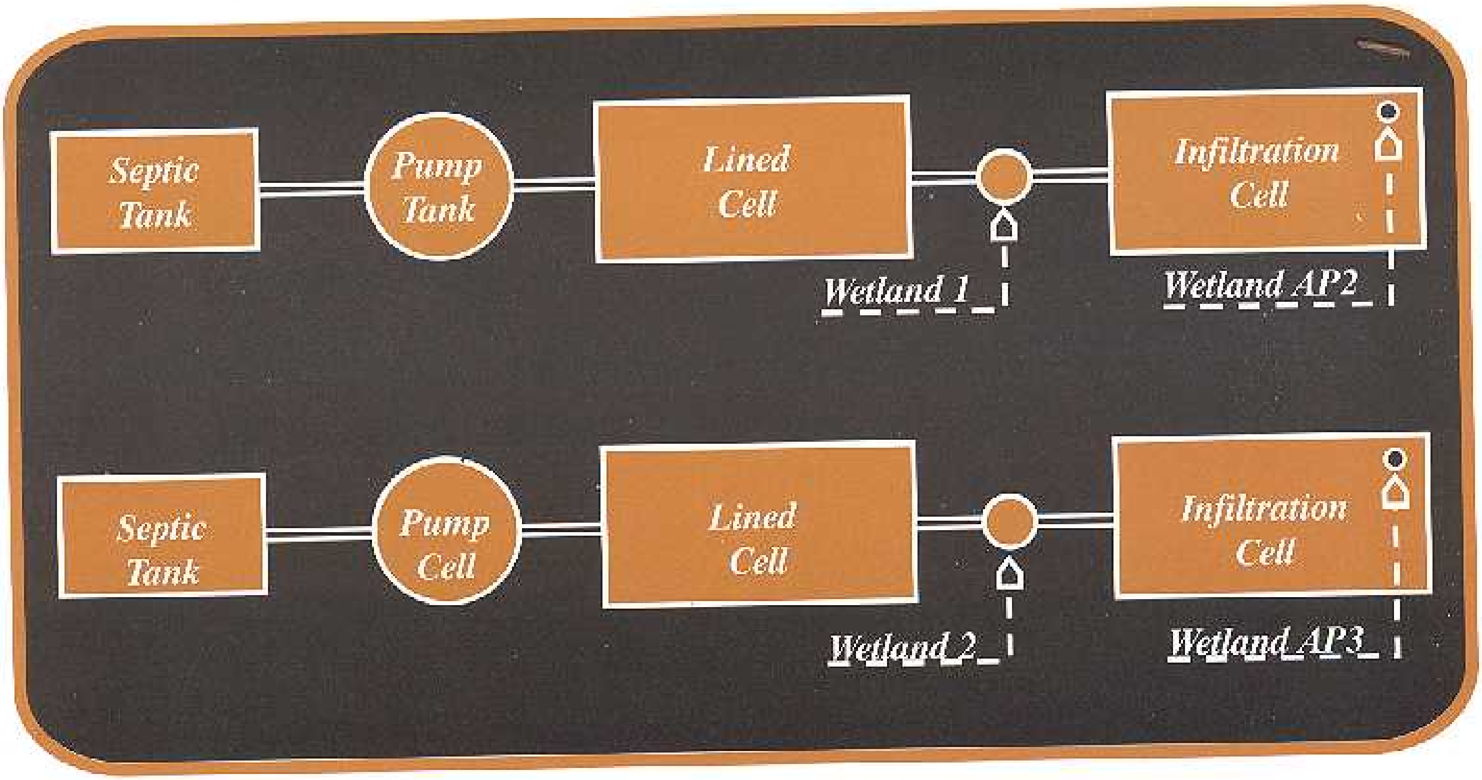
These systems produced an average reduction of 97% for fecal coliform bacteria, 55% for BOD, and 58% for ammonia. All values were statistically significant at the 95% level.

Construction Time and Materials

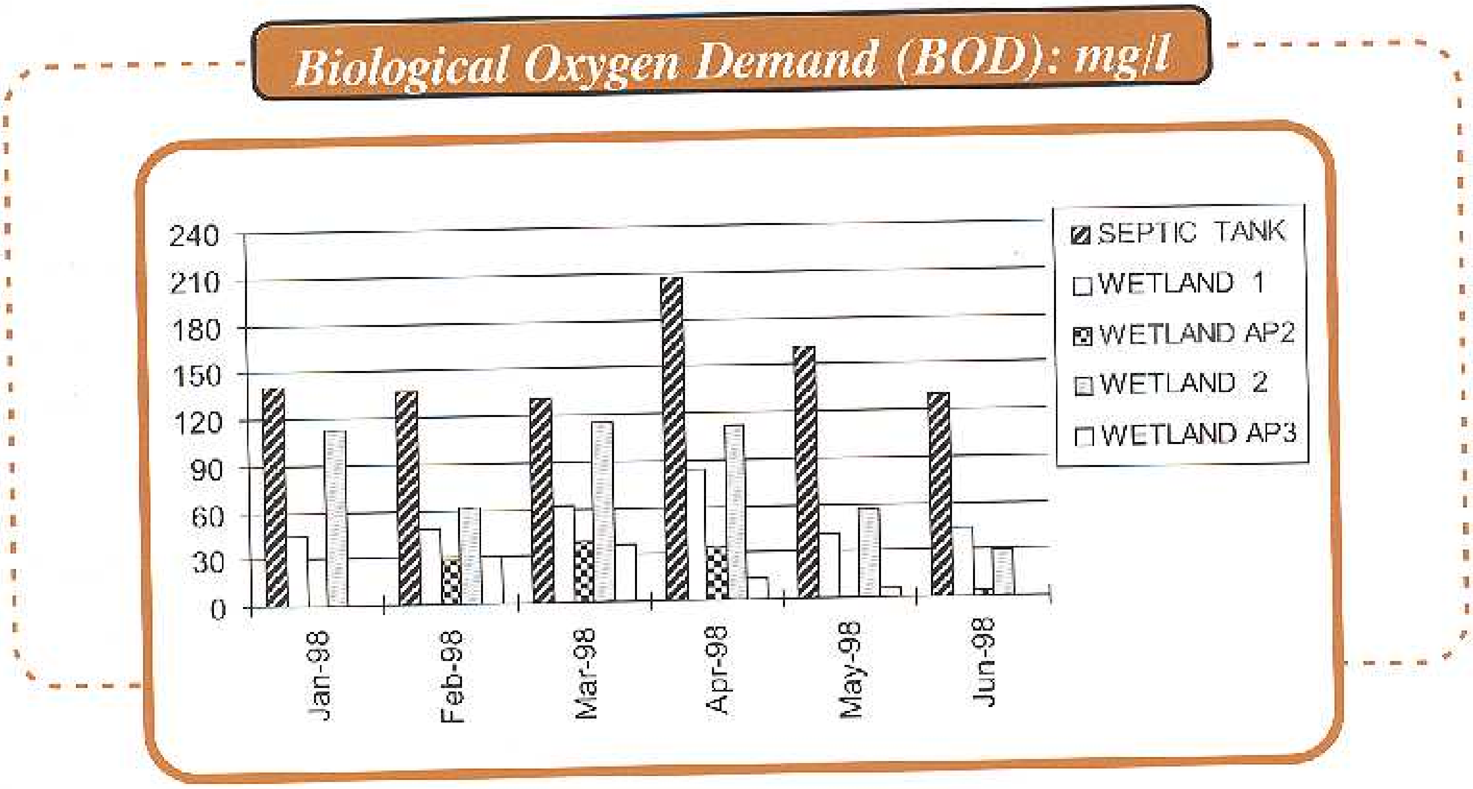
ITEM	*QUANTITY*
1000 gallon septic tank	1
500 gallon pump tank	1
Outlet control box	1
4" sch. 40 PVC	96 l.f.
4" perforated PVC	40 l.f.
2" sch. 40 PVC	50 l.f.
2" x 12" P. T. wood	128 l.f.
20 mil PVC cell liner	440 ft.^{2}
20 mil PVC wall liner	320 ft.^{2}
½ hp sewage pump	1
Pump controller and alarm	1
4" PVC ball valve	1
¾" clean crushed aggregate	96 tons
Pea gravel	3.5 tons
Hardwood mulch	4 yds.^{3}
Sand	3.2 tons
Wetland Plants	128
Miscellaneous fittings	varies

LABOR	*TIME*
Excavation (Backhoe, operator and laborer)	36 hrs.
Wetlands cell assembly (2 laborers)	24 hrs.
Electrical (Electrician and laborer)	8 hrs.
Piping (2 laborers)	10 hrs.

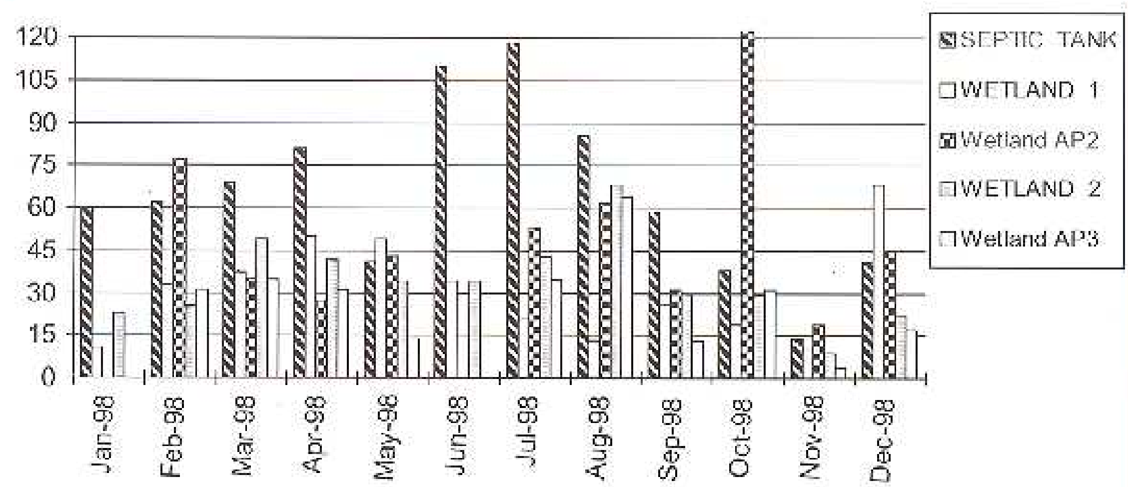




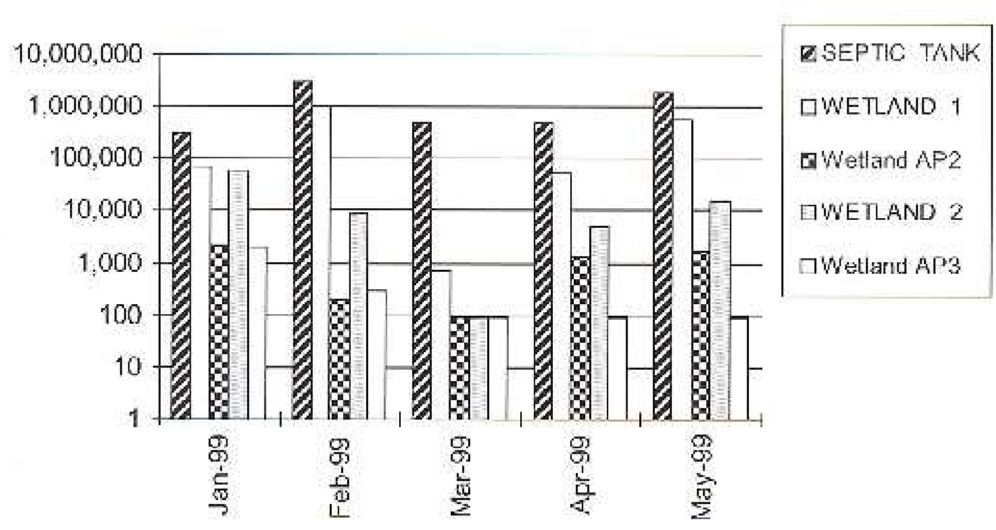
Selected Data:



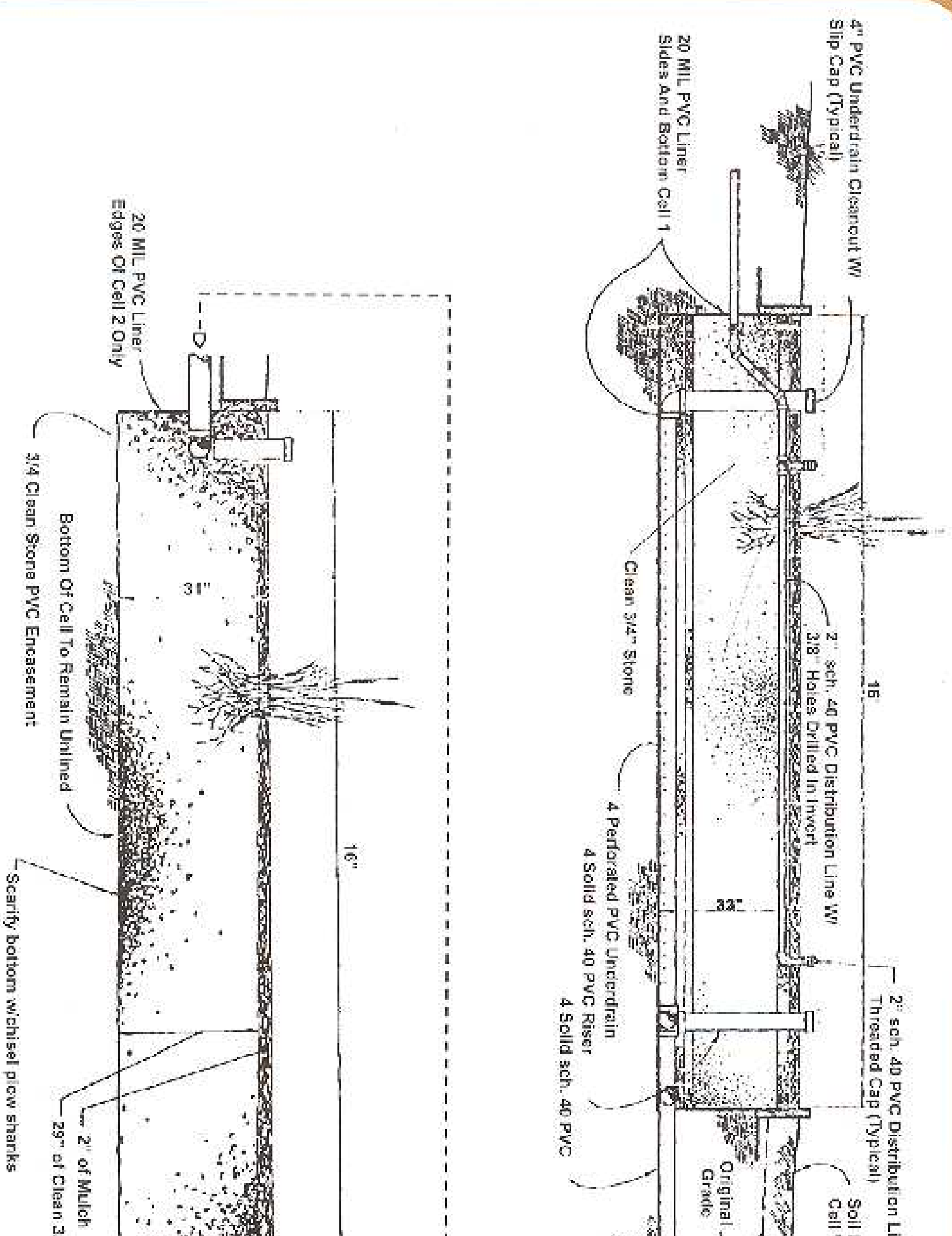
Total Suspended Solids (TSS): mg/l

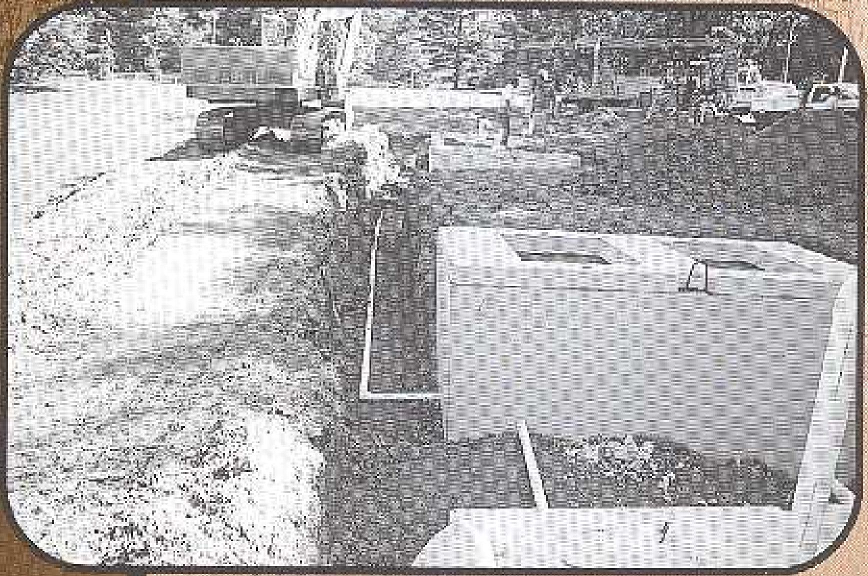


Fecal Coliform Bacterial (FC): mpn/100 ml



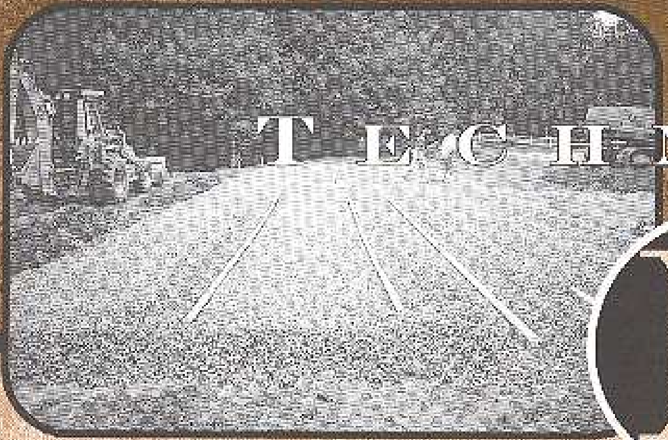
Bed Design Diagrams

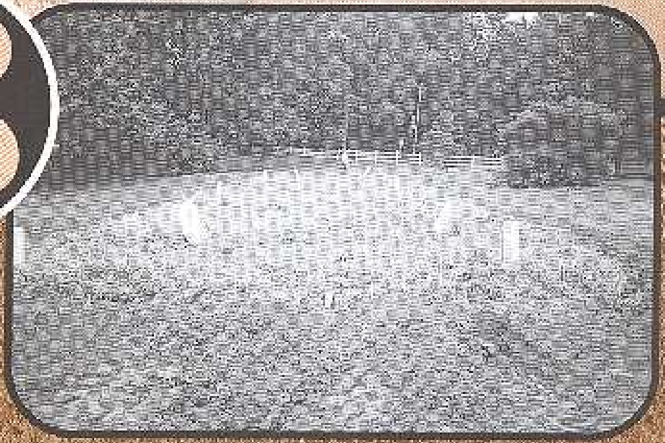


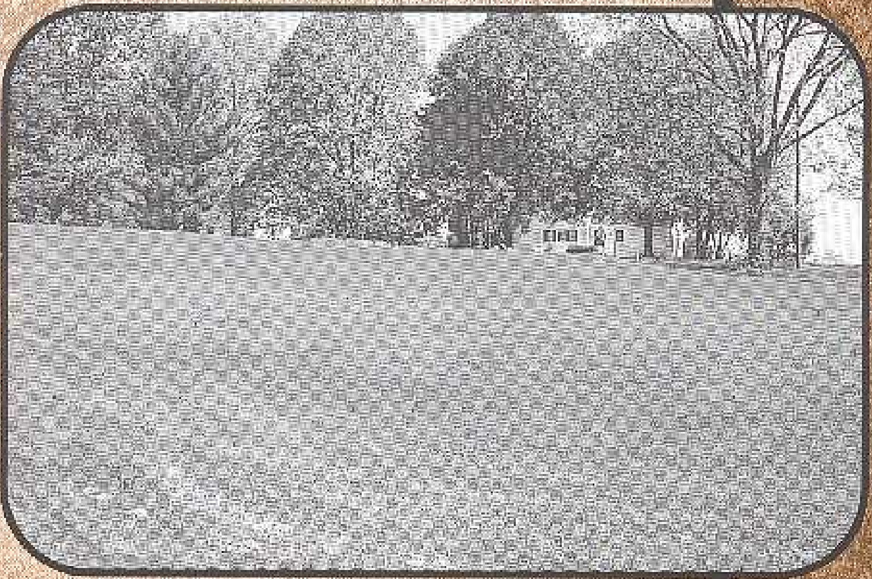


TECHNOLOGY

B

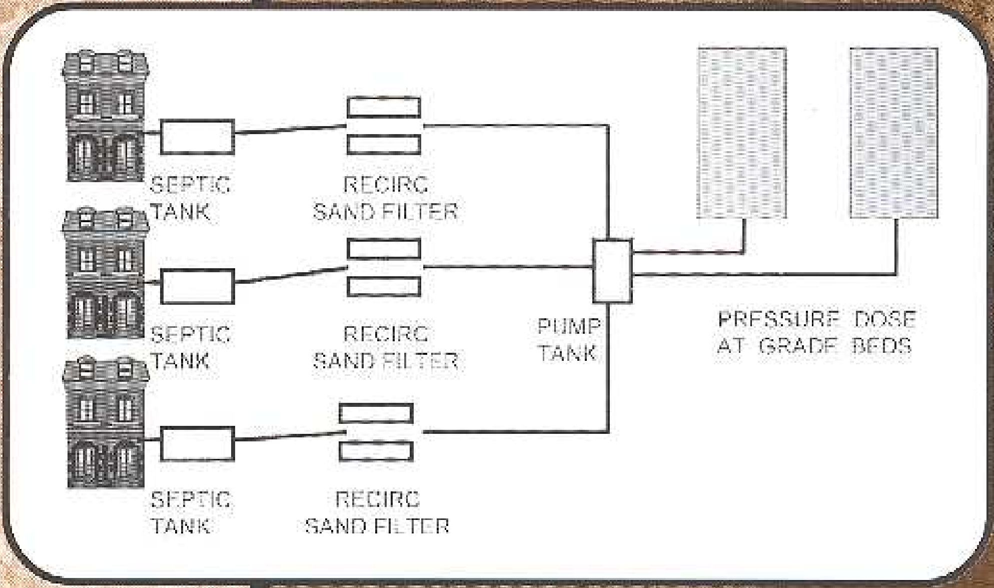






T E C H N O L O G Y

B



A COMMUNITY SYSTEM

Recirculation Sand Filters

Plus

At-Grade Pressure Distribution Beds

Recirculation Sand Filters

LAWRENCEVILLE Series

Ap 0-7" 10YR 4/3 brown silt loam; moderate medium granular structure; clear wavy boundary; 4% coarse fragments.

BA 7-16" 10YR 4/4 dark yellowish brown silt loam; moderate medium subangular blocky structure; abrupt irregular boundary; 3% coarse fragments.

Bt 16-24" 10YR 5/8 yellowish silt loam with few faint 10YR 5/3 brown mottles; moderate medium angular blocky structure; abrupt wavy boundary; 3% coarse fragments.

2Btx1 24-34" 7.5YR 5/4 brown loam with common to many 7.5YR 6/2 pinkish gray and 7.5YR 5/8 strong brown mottles; strong very coarse prismatic and strong medium to coarse angular blocky structure; clear wavy boundary; 10% coarse fragments.

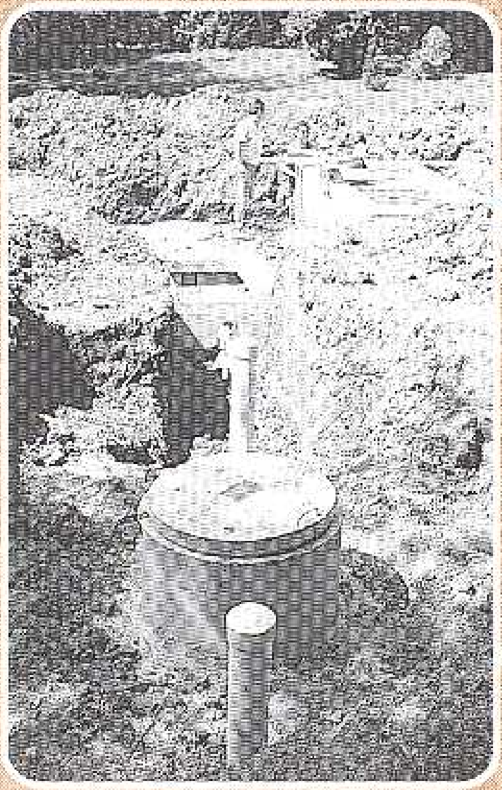
2Btx2 34-52" 7.5YR 5/4 brown channery loam with common prominent 5YR 6/2 pinkish gray and 7.5YR 5/8 strong brown mottles; strong very course prismatic and strong medium to course angular blocky structure; clear wavy boundary; 15% coarse fragments.

2C 52-70+" 10YR 7/2 loam; structureless massive; 10% coarse fragments.

This Technology **is a small community system handling three individual homes. The system consists of a septic tank and recirculating sand filter for each home. The effluent from each system then flows to a common pump chamber for distribution in a community at-grade pressure distribution bed. A summary of key components is as follows:**

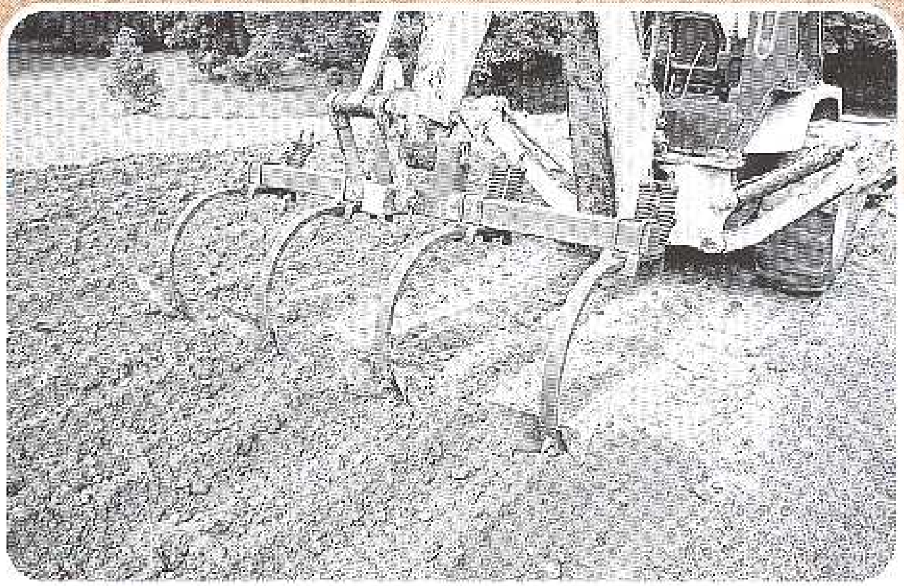
- 1,500 gallon concrete septic tank
- 1,500 gallon concrete two compartment anoxic tank with pump chamber and rock filled chamber
- 1,500 gallon sand filter with 1mm uniform sand (coefficient of uniformity <2)
- Raw effluent flows from house through septic tank, through rock filled chamber into pump chamber of second tank. Effluent is pumped into sand filter.
- Recirculation valve in sand filter determines amount of effluent sent through sand filter and amount sent to soil absorption field. Recirculation ratios of 3:1 and 15:1 were utilized. Effluent passing through sand filter for bacteria reduction, BOD reduction, and nitrification travels back to anoxic tank (rock filled) for nitrification.
- Soils: Lawrenceville series with faint mottles at 16 inches beneath the surface; prominent mottles at 24 inches beneath the surface and a fragipan at 24 inches beneath the surface.
- Limiting zone: Several pits examined over site with mottles ranging from 17" to 24" beneath the surface.
- Slope of site: 8.2 to 10.1 percent.
- Percolation rate: Average 10.4 to 36.5 minutes per inch. Range was 6.5 minutes per inch, to 120 minutes per inch.
- Hydraulic conductivity rates: 2.0 cm/day to 4.2 cm/day.
- Dosing cycle: Beds were demand dosed.

Typical Recirculating Sand Filter Construction
One Required for Each House



ITEM	QUANTITY
Denitrification Tank	1
Sand	5 tons
Nitrification Tank	1
½ hp sewage pump	1
Pump controller and alarm	1
2" sch. 40 PVC	20 l.f.
4" sch. 40 PVC	16 l.f.
4" perforated PVC	24 l.f.
2" ball valve	2
4" concrete blocks	12
Pipe hangers	3
Access covers (36" square, minimum)	3
¾" clean stone	1 ton
Pea gravel	¼ ton
Miscellaneous fittings	varies

LABOR	TIME
Excavation (backhoe, operator and laborer)	16 hrs.
Sand and rock filter construction (2 laborers)	24 hrs.
Electrician	4 hrs.



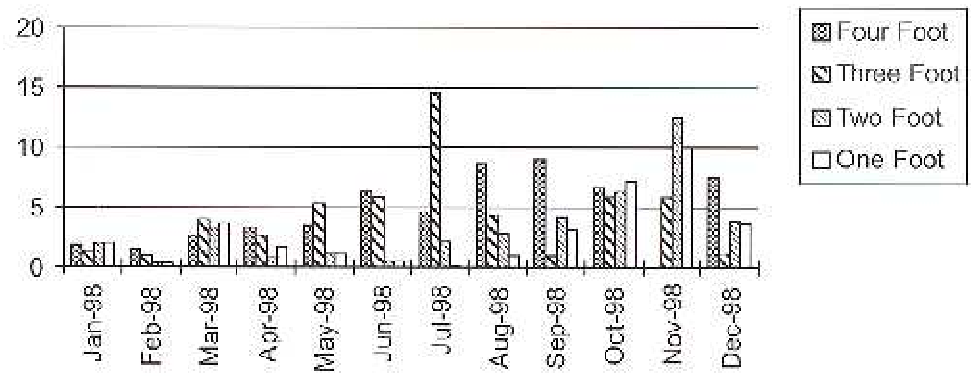
PERMEABILITY DATA
Soil Absorbtion Beds

Bed B1	Hole #	Perk MPI	cm/Day	Guelph Rate (cm/day)
Size: 15x60	1	10.4	351.9	3.72
Ave. Slope: 8.2%	2	14.1	259.6	1.04
	3	8.9	411.2	
	4	8.6	425.6	
	5	12.0	305.0	
	6	12.6	290.5	
	7	6.5	563.1	
	8	10.0	366.0	
	Average	10.4	352.3	2.4
	Geometric Mean	10.1	361.5	2.0

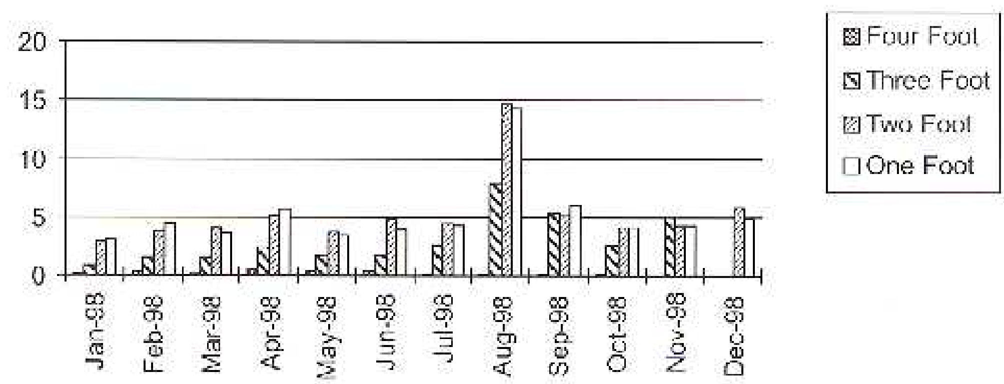
Bed B2	Hole #	Perk MPI	cm/Day	Guelph Rate (cm/day)
Size: 15x60	1	14.1	259.6	5.70
Ave. Slope: 10.1%	2	34.3	106.7	2.78
	3	40.0	91.5	
	4	20.0	183.0	
	5	48.0	76.3	
	6	120.0	30.5	
	7	7.7	475.3	
	8	7.5	488.0	
	Average	36.5	100.4	4.2
	Geometric Mean	24.5	149.5	4.0

GRAVITY LYSIMETERS BENEATH SOIL ABSORBTION BEDS

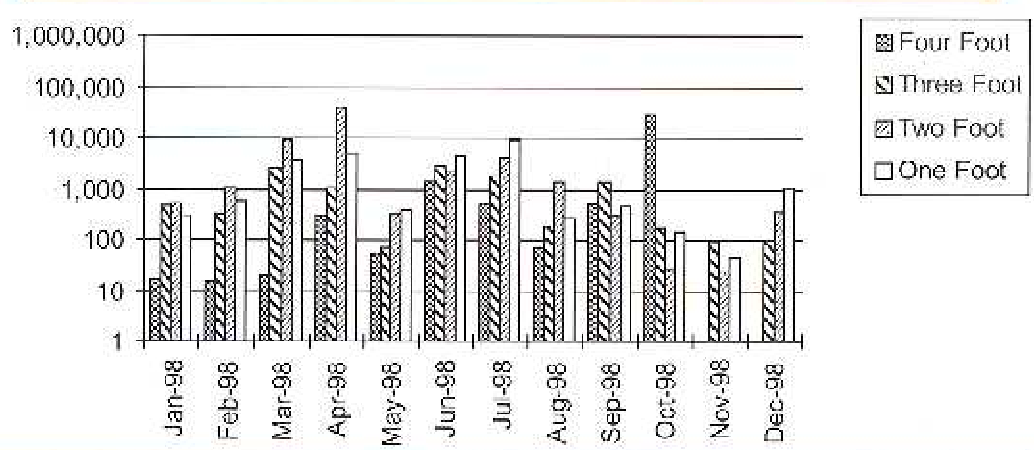
Average NO3-N: Tech. B-1998 (mg/l)



Average Total Phosphorous: Tech. B-1998 (mg/l)

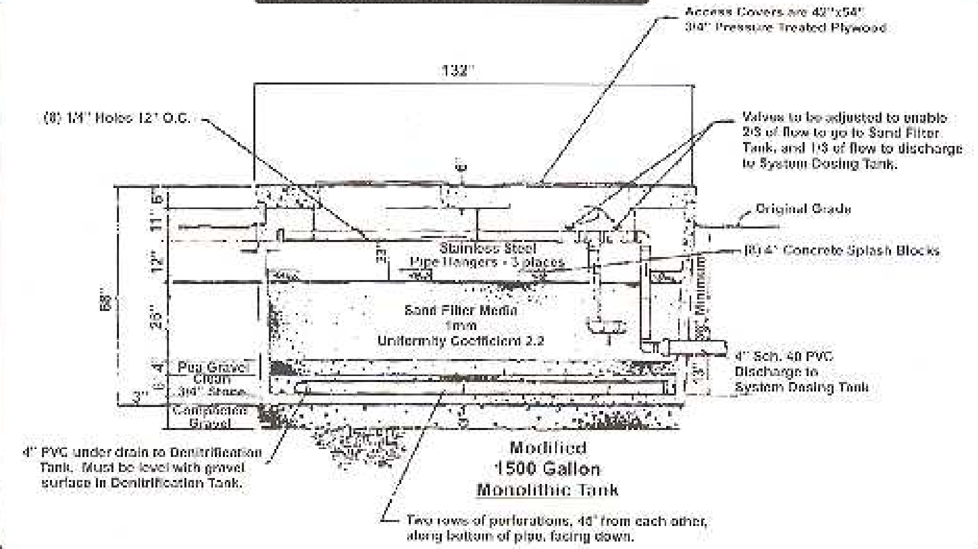


Geo Mean Fecal Coliform: Tech. B-1998 (MPN/100ml)

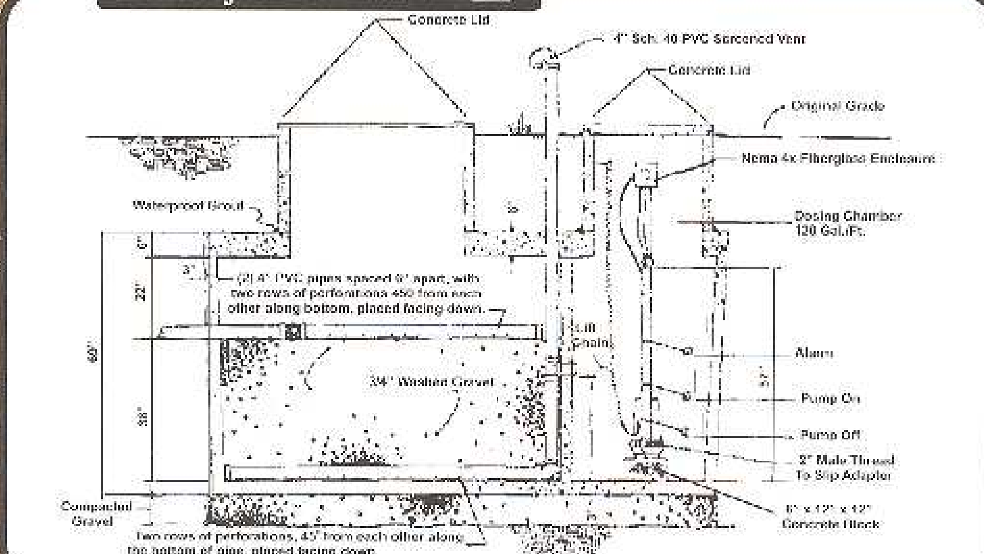


CONSTRUCTION DESIGN DETAILS

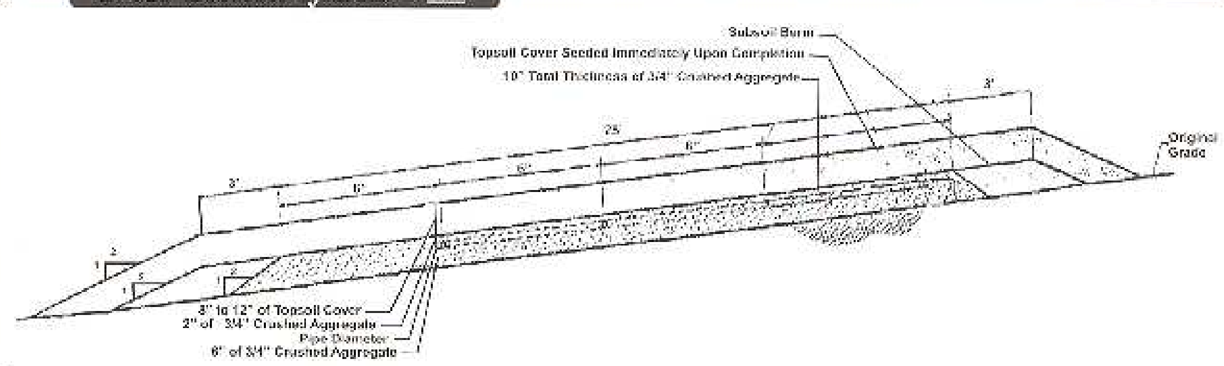
Nitrification Tank - NTS

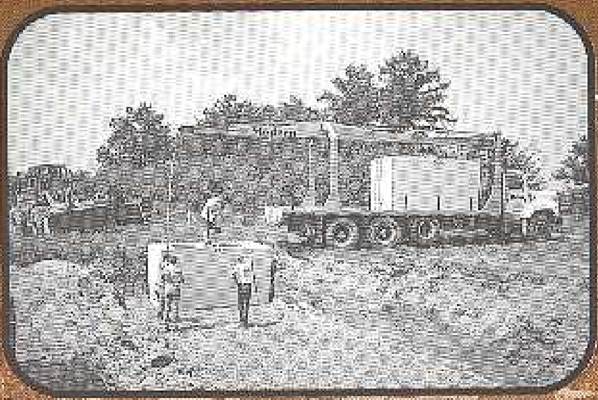


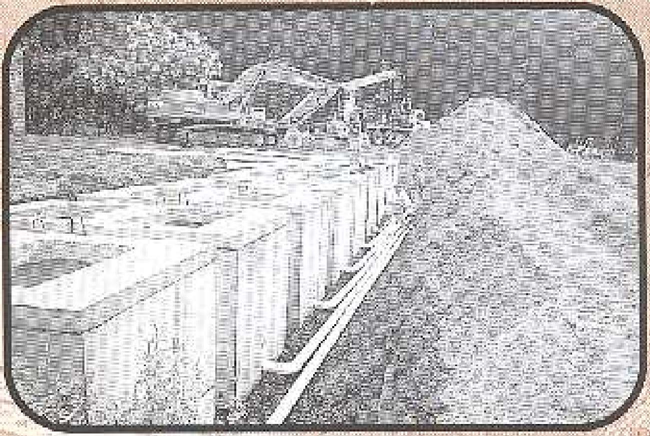
Denitrification Tank - NTS



Cross-Section of Bed - NTS







TECHNOLOGY

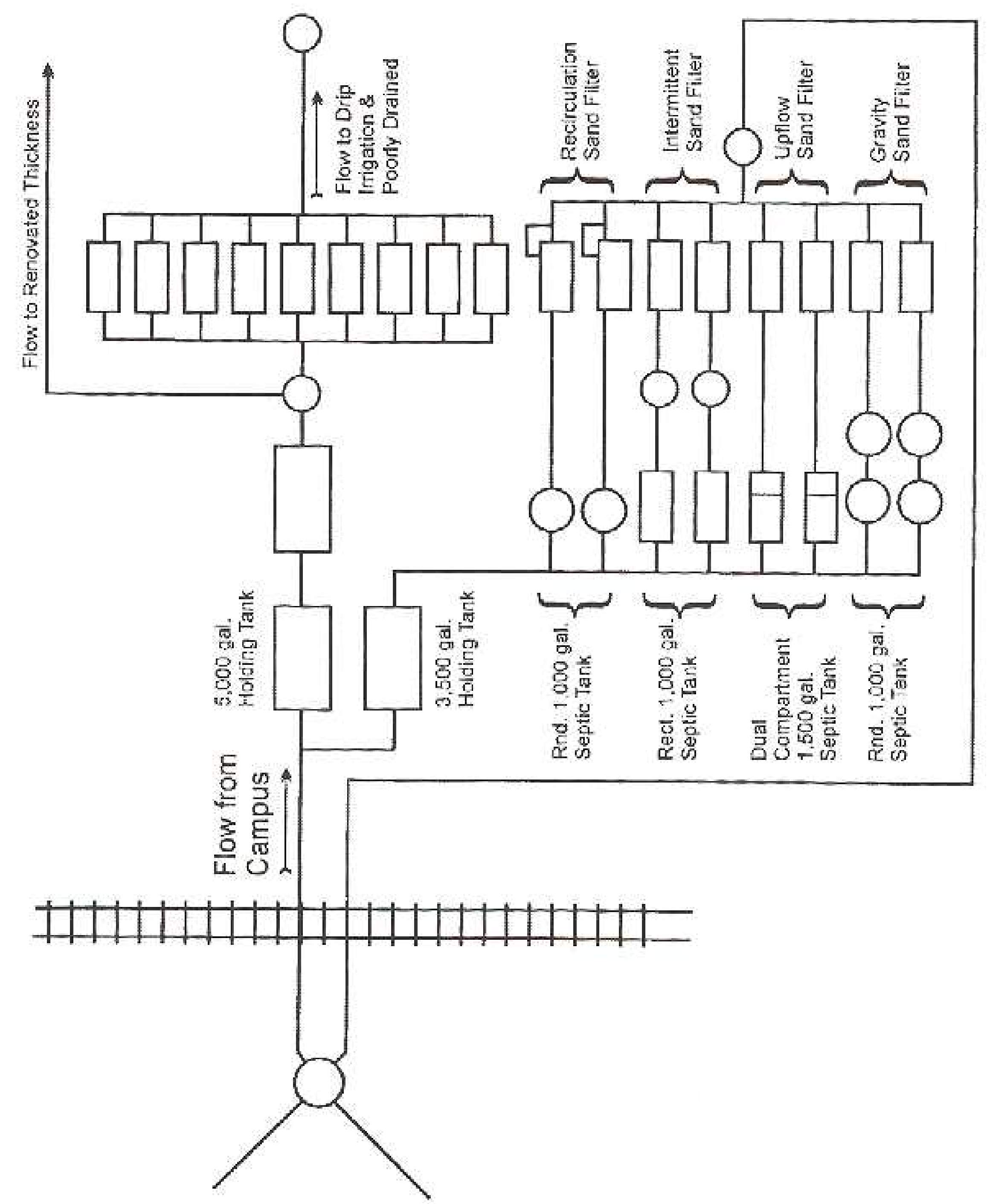
C

TECHNOLOGY

C

Sand Filter Bank

Schematic

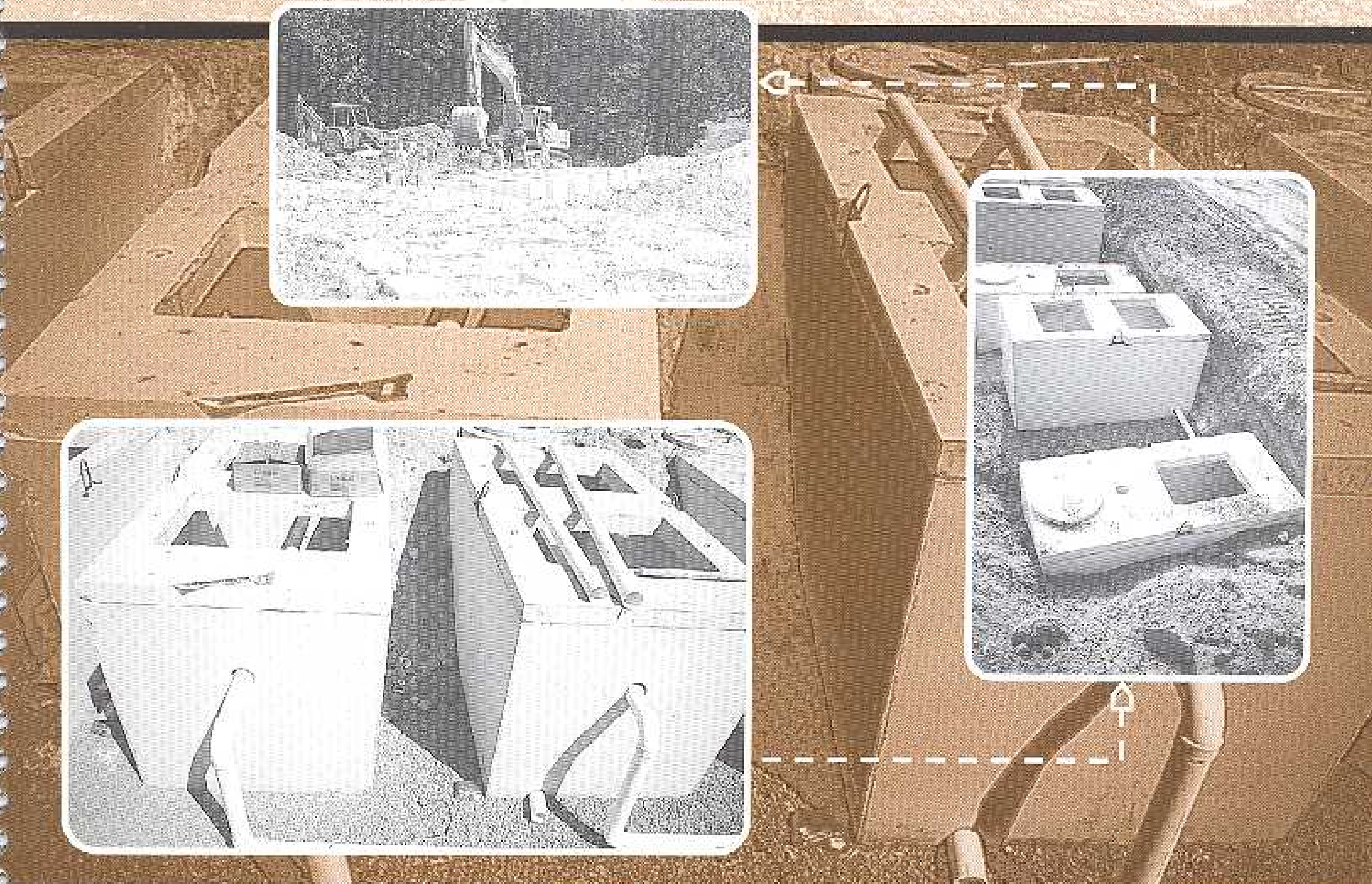

Flow to Renovated Thickness
Flow to Drip Irrigation & Poorly Drained
Recirculation Sand Filter
Intermittent Sand Filter
Upflow Sand Filter
Gravity Sand Filter
5,000 gal. Holding Tank
3,500 gal. Holding Tank
Rnd. 1,000 gal. Septic Tank
Rect. 1,000 gal. Septic Tank
Dual Compartment 1,500 gal. Septic Tank
Rnd. 1,000 gal. Septic Tank
Flow from Campus

TECHNOLOGY C: Sand Filter Bank

Various septic tanks and sand filters were evaluated. Effluent was drawn from the campus sewer line. The following sequences were used:

- Two 1,000 gallon round septic tanks in series to a gravity sand filter.
- One dual compartment 1,500 gallon rectangular tank to an up-flow sand filter.
- One single compartment rectangular tank to a pressure dosed single pass sand filter.
- One 1,000 gallon round septic tank to a recirculating sand filter.
- Loading rates: 8-gal./square foot/day; 5-gal./square foot/day; and 3-gal./square foot/day. Clogging occurred immediately at 8-gal./square foot/day. All sand filters functioned at 5-gal./square foot/day with the exception of the pressure dosed sand filter. Clogging occurred at the 5-gal./square foot/day-loading rate. The pressure dosed sand filter did not clog at the 3-gal./square foot/day rate.

Effluent was delivered to each septic tank from a common pump chamber. Flow pattern mimics the pattern of an individual single family home, peaking in the morning and again in the evening. Loading rates were 5-gallons/squarefoot per day for all systems except the intermittent filters, which were loaded at 3-gallons/square foot per day for a portion of the test period.



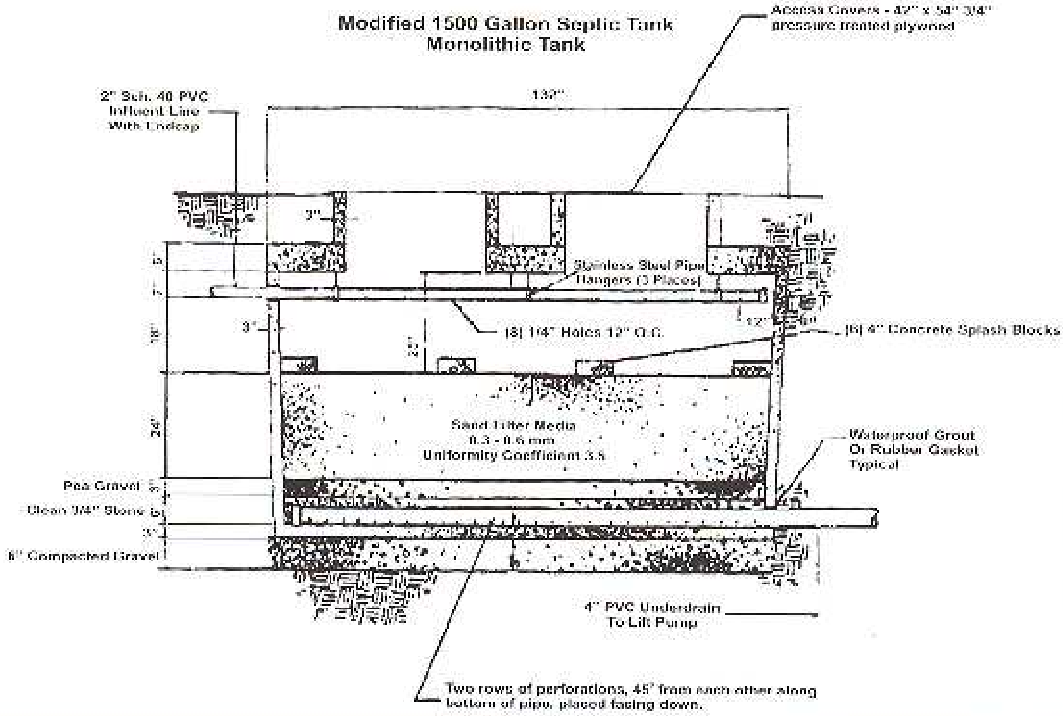
Percentage Reduction in Selected Parameters: Various Sand Filters

	Gravity	Upflow (Not Dosed)	Intermittent Sand Filter	Partial[1] Recirculating
BOD	82^{S}	83^{S}	71^{S}	77^{S}
COD	73^{S}	71^{S}	67^{S}	70^{S}
TSS	83^{S}	81^{S}	81^{S}	81^{S}
FS	98^{S}	98^{S}	98^{S}	93
FC	98^{S}	98^{S}	96^{S}	94^{S}
TOC	66^{S}	57^{S}	60^{S}	48^{S}
TN	40^{S}	48^{S}	37^{S}	46^{S}
NH3-N	63^{S}	62^{S}	61^{S}	53^{NS}

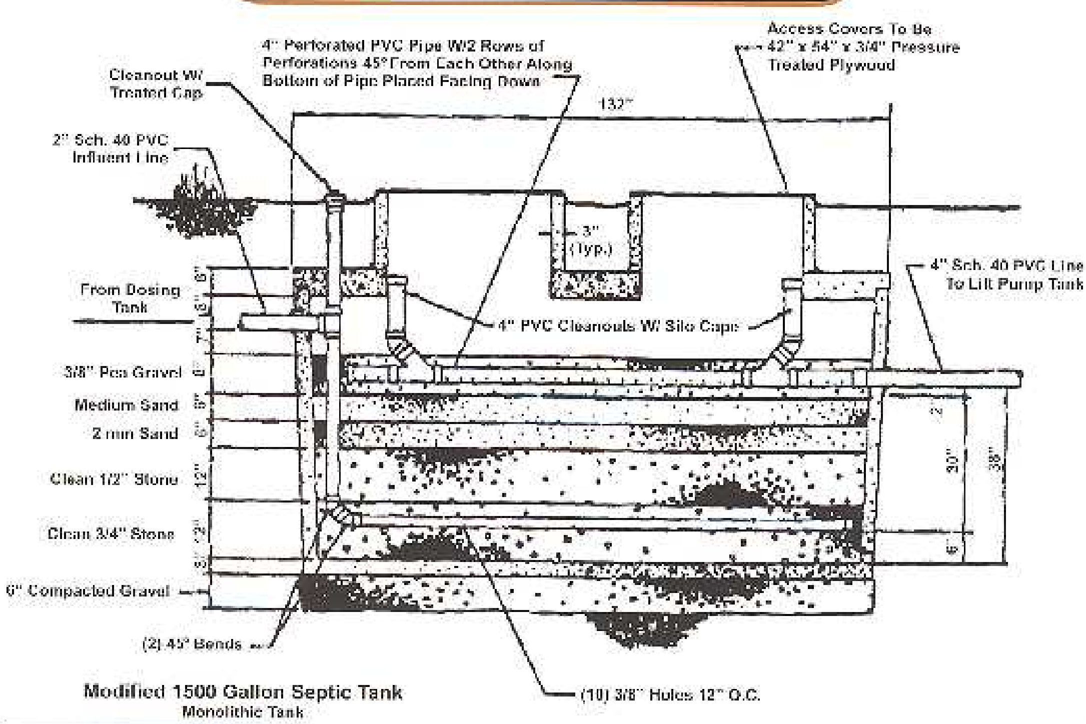
[1] - See design information in Technology B. Single pump recirculates and doses the system.

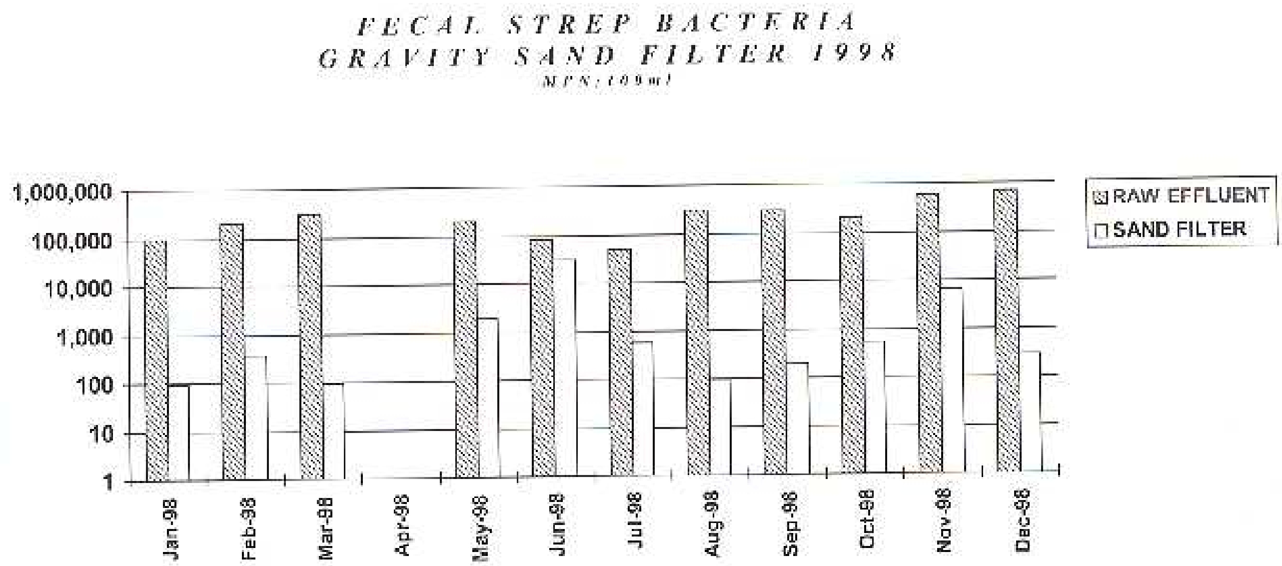
$\#^{S}$ - Significant reduction at 95% confidence level.

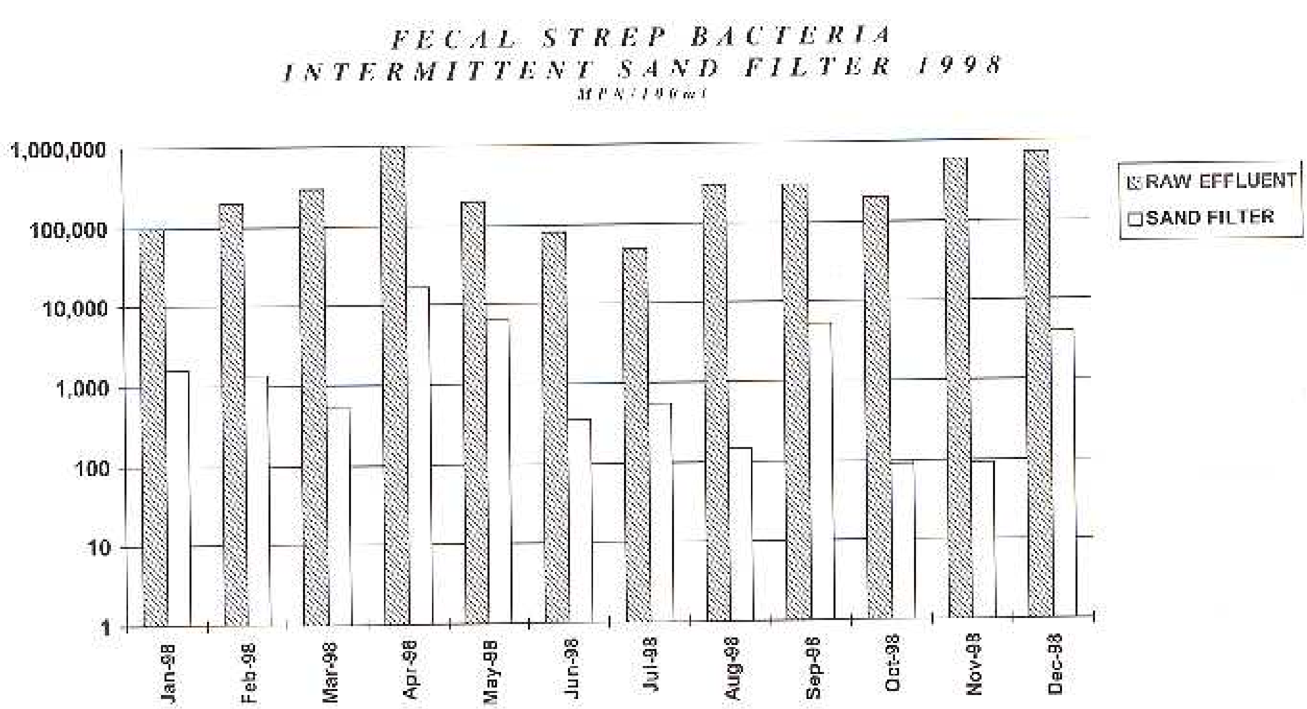
Intermittent Sand Filter



Upflow Sand Filter




FECAL STREP BACTERIA
GRAVITY SAND FILTER 1998
MPN:100ml
1,000,000
100,000
10,000
1,000
100
10
1
RAW EFFLUENT
SAND FILTER
Jan-98
Feb-98
Mar-98
Apr-98
May-98
Jun-98
Jul-98
Aug-98
Sep-98
Oct-98
Nov-98
Dec-98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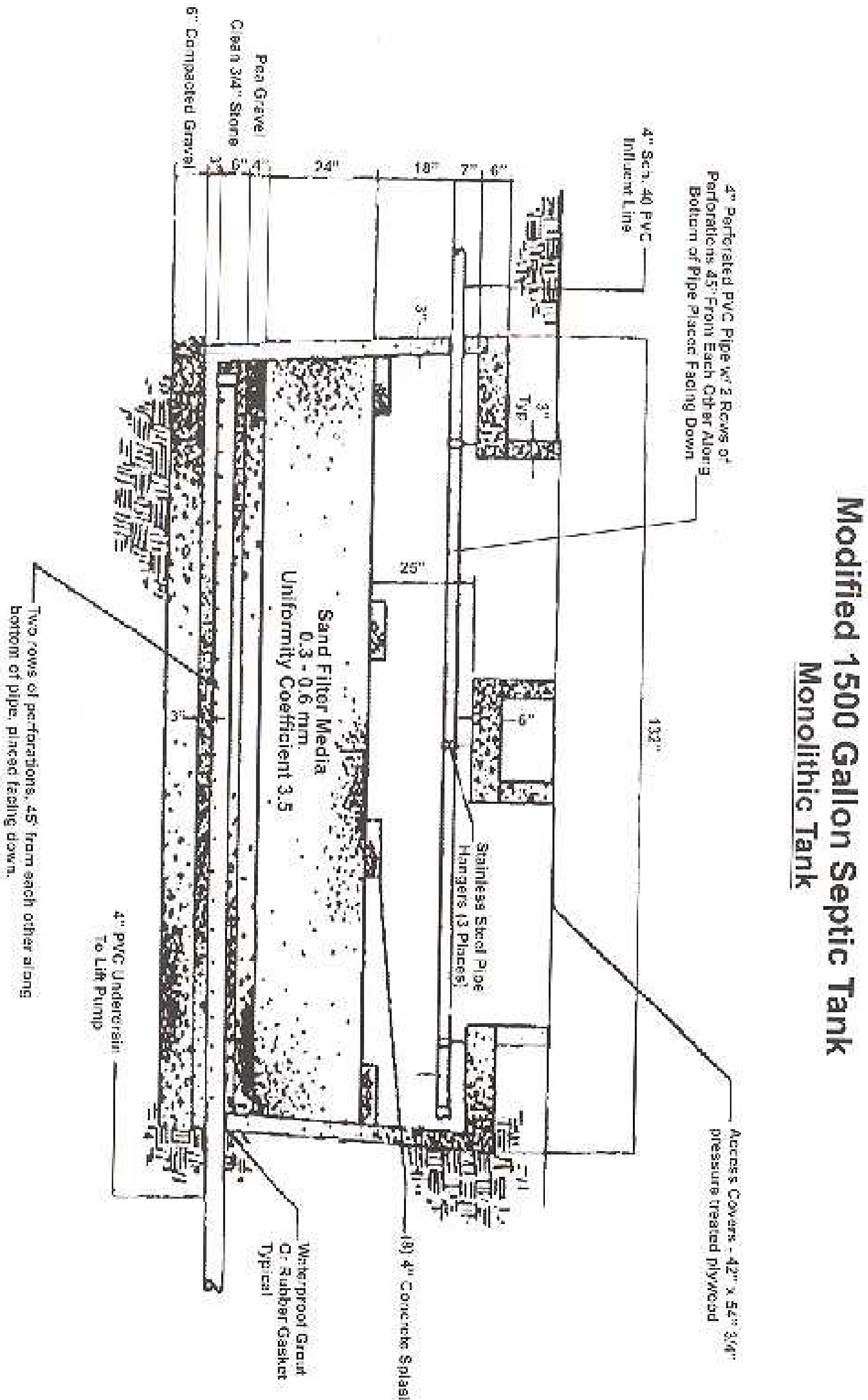
INTERMITTENT SAND FILTER 1998
MPN:100ml
1,000,000
100,000
10,000
1,000
100
10
1
RAW EFFLUENT
SAND FILTER
Jan-98
Feb-98
Mar-98
Apr-98
May-98
Jun-98
Jul-98
Aug-98
Sep-98
Oct-98
Nov-98
Dec-98

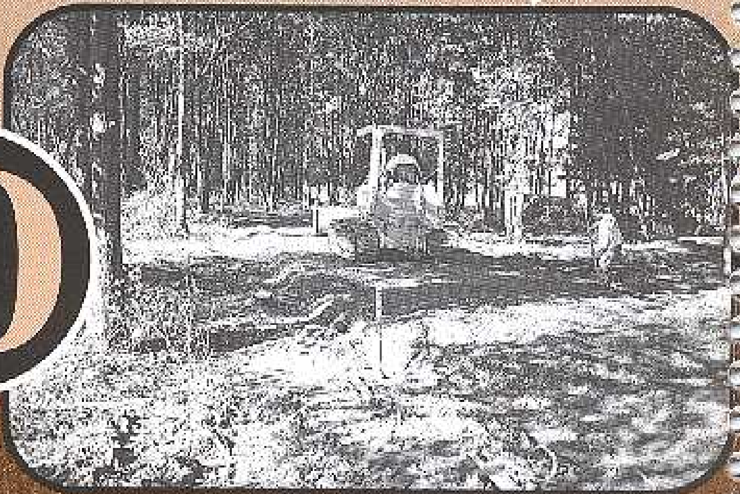
Gravity Sand Filter



Sand Filter Bank

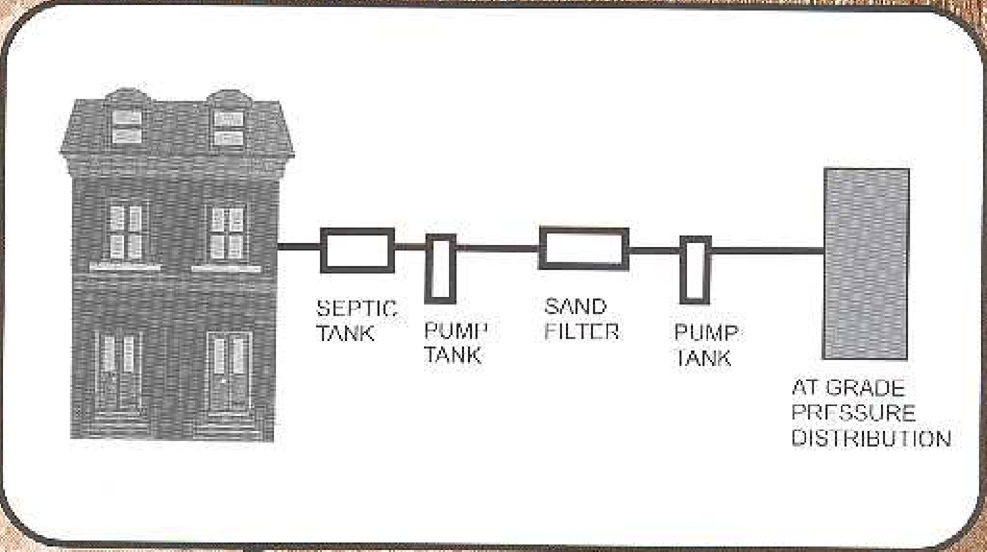
TECHNOLOGY

D



TECHNOLOGY

D



Sand Filter Plus At-Grade Bed

Typical At-Grade System

Item	*Quantity*
1,000 gallon septic tank	1
500 gallon septic tank	1
4" sch. 40 PVC	20 l.f.
2" sch. 40 PVC	80 l.f.
1 ½" sch. 40 PVC	216 l.f.
½ hp sewage pump	1
Pump controller & alarm	1
¾" crushed aggregate	7 tons
Topsoil cover	110 yds.^{3}
Miscellaneous fittings	varies

Labor	*Time*
Excavation (Backhoe, operator and laborer)	24 hrs.
At-grade bed construction	16 hrs.
Electrical (Electrician and laborer)	8 hrs.
Piping (2 laborers)	10 hrs.

Typical Sand Filter Construction
Intermittent

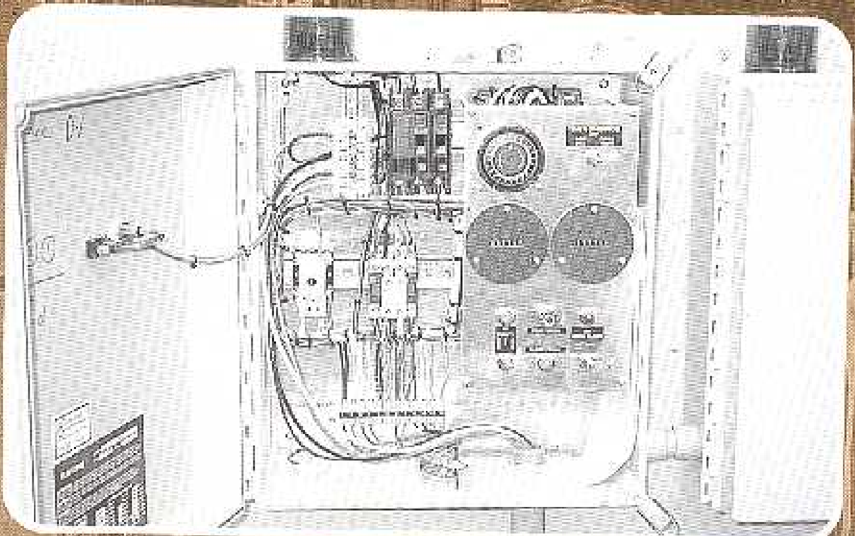
Item	*Quantity*
Sand filter tank	1
Sand	5 tons
Pump tank	1
½ hp sewage pump	1
Pump controller and alarm	1
2" sch. 40 PVC	20 l.f.
4" perforated PVC	12 l.f.
2" ball valve	1
4" concrete blocks	12
Pipe hangers	3
Access covers (36" square min.)	2
¾" clean stone	¼ ton
Pea gravel	¼ ton
Miscellaneous fittings	varies

Labor	*Time*
Excavation (BackHoe, operator and laborer)	8 hrs.
Sand filter construction (2 laborers)	8 hrs.
Electrician	4 hrs.

Effluent was drawn from the campus sewer system, passed through one of two 3,000 gallon single compartment septic tanks hooked in parallel and through one of 9 single pass intermittent sand filters with uniform (coefficient of uniformity <2) 2mm sand. Effluent was then sent to an at-grade pressure distribution soil absorption area. Each absorption area was dosed four times per day. Initial flow was 400 gpd but was quickly reduced to 250 gpd and eventually down to 75 gpd.

- Limiting zone depth: 13 inches beneath the surface.
  Slope: 3.7 to 3.9%
- Percolation rate: Average 70 to 197 minutes per inch. Range was 10.4 to 240 minutes per inch.
- Hydraulic conductivity: 0.4 to 5.8 cm per day.
- Dosing cycle: Dosed four times each day; flows 250 gpd down to 75 gallons per day
- Breakout of effluent from beds at flow rates greater than 75 gallons per day

***Chalfont series*, somewhat poorly drained; common faint mottles at 8" beneath the surface; common distinct mottles at 13 inches beneath the surface; fragipan at 21 inches beneath the surface.**



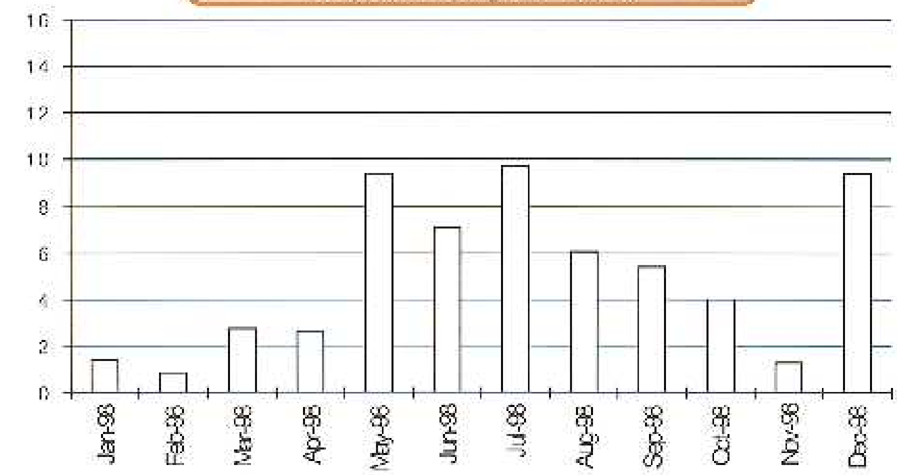
Technology D
At-Grade Bed Data

		Hole #	Perk Rate (MPI)	cm/day	Guelph Rate cm/day
Bed:	D1				
Bed Size:	15x60	1	60	61	4.96
Avg. Slope:	*3.8*	2	34.3	106.7	0.33
		3	60	61	
		4	34.3	106.7	
		5	120	30.5	
		6	40	91.5	
		7	240	15.3	
		8	80	45.8	
		Average:	83.6	64.8	2.6
		Geometric Mean:	66.7	64.9	1.3

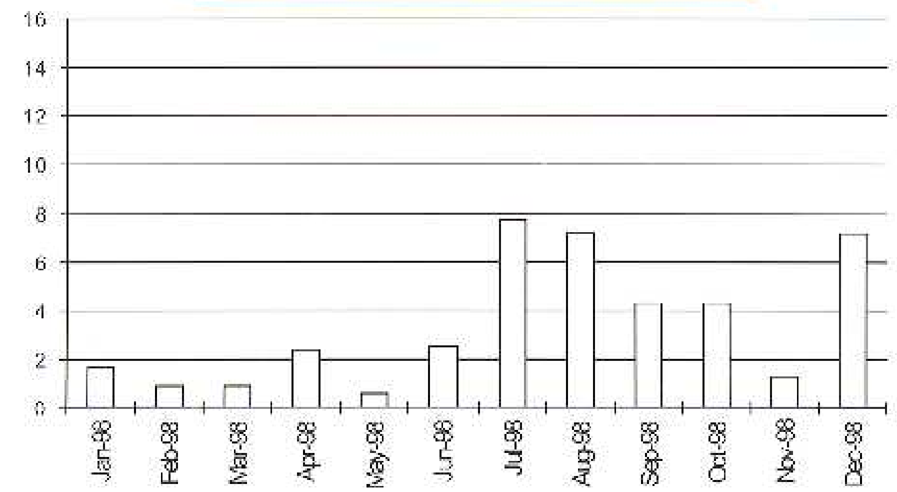
		Hole #	Perk Rate (MPI)	cm/day	Guelph Rate cm/day
Bed:	D2				
Bed Size:	15x60	1	240	15.3	0.75
Avg. Slope:	3.8	2	17.1	214	0.12
		3	120	30.5	
		4	240	15.3	
		5	240	15.3	
		6	240	15.3	
		7	240	15.3	
		8	240	15.3	
		Average:	197.1	42	0.4
		Geometric Mean:	158.2	23.1	0.3

		Hole #	Perk Rate (MPI)	cm/day	Guelph Rate cm/day
Bed:	D3				
Bed Size:	15x60	1	120	30.5	2.16
Avg. Slope:	3.9	2	60	61	9.42
		3	10.4	351.9	
		4	16	228.8	
		5	40	91.5	
		6	80	45.8	
		7	120	30.5	
		8	120	30.5	
		Average:	70.8	108.8	5.8
		Geometric Mean:	52.2	70.1	4.5

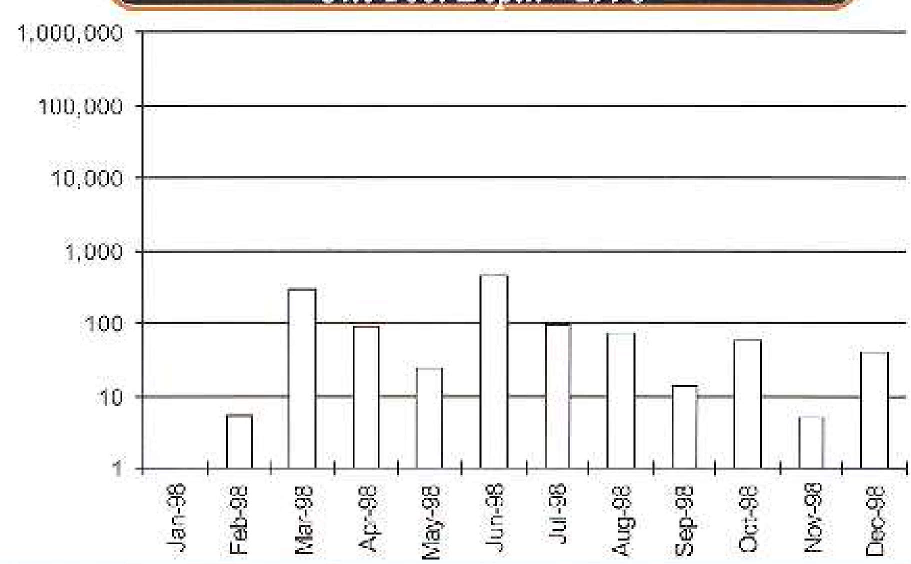
Average Nitrate Tech. D - mg/l
One Foot Depth - 1998



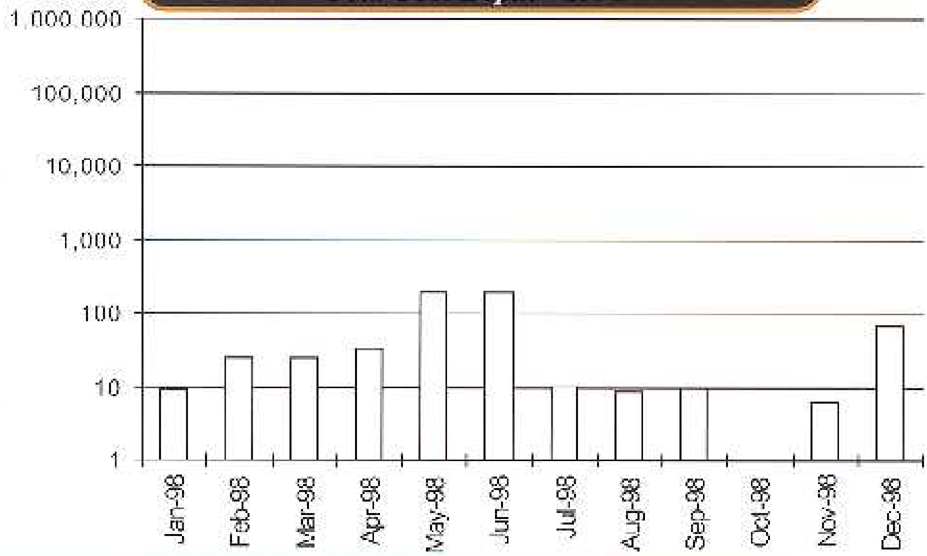
Average Nitrate Tech. D - mg/l
Four Foot Depth - 1998



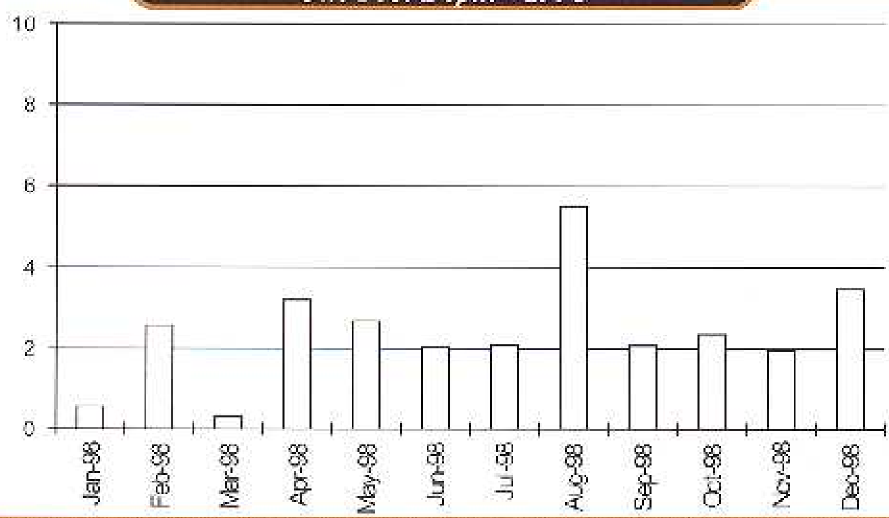
Geo Mean Fecal Coliform Tech. D - MPN/100ml
One Foot Depth - 1998



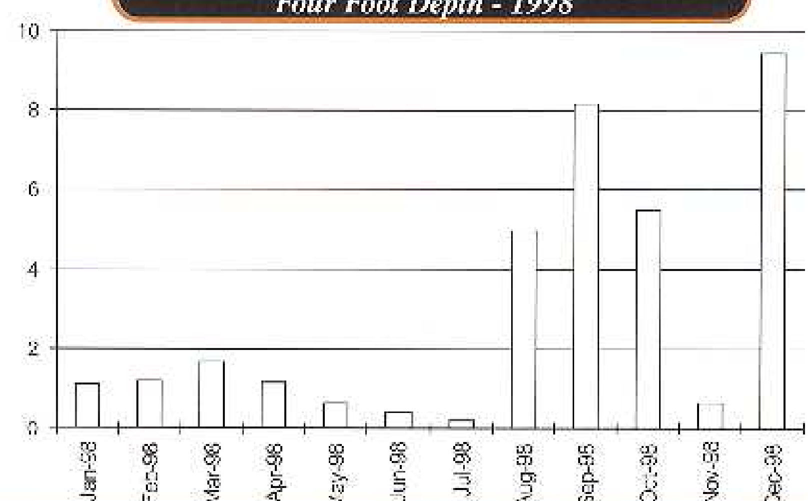
Geo Mean Fecal Coliform Tech. D - MPN/100ml
Four Foot Depth - 1998



Average Total Phosphorous Tech. D - mg/l
One Foot Depth - 1998

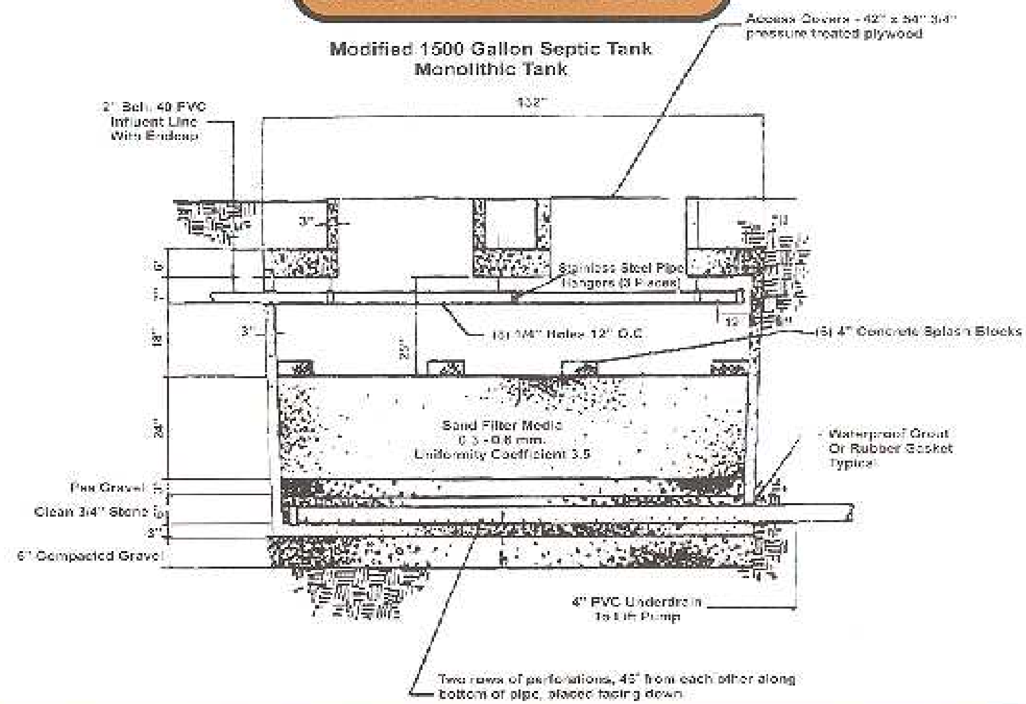


Average Total Phosphorous Tech. D - mg/l
Four Foot Depth - 1998

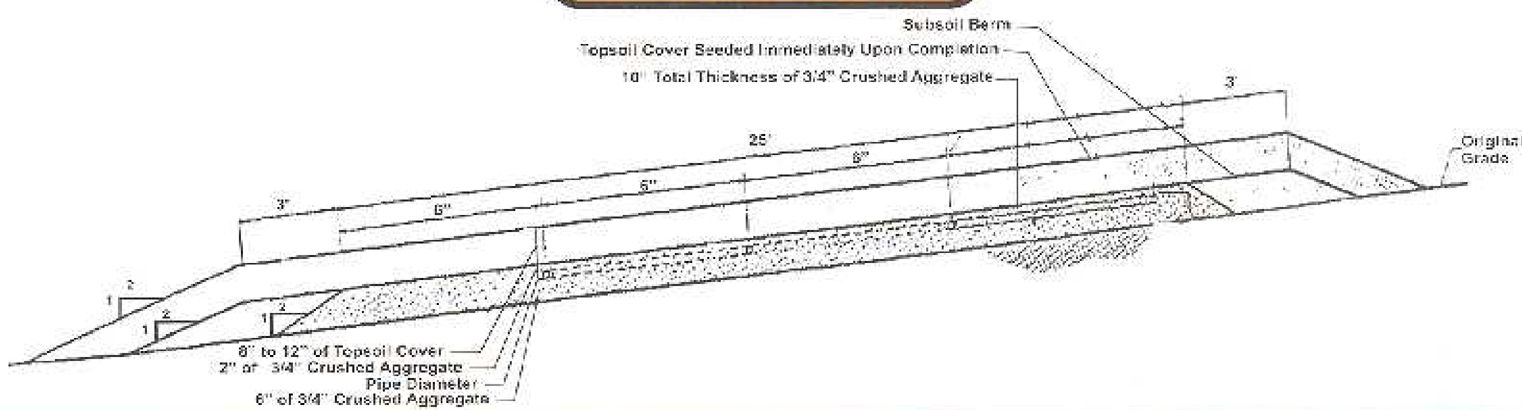


Sand Filter Plus At-Grade Bed

Intermittent Sand Filter

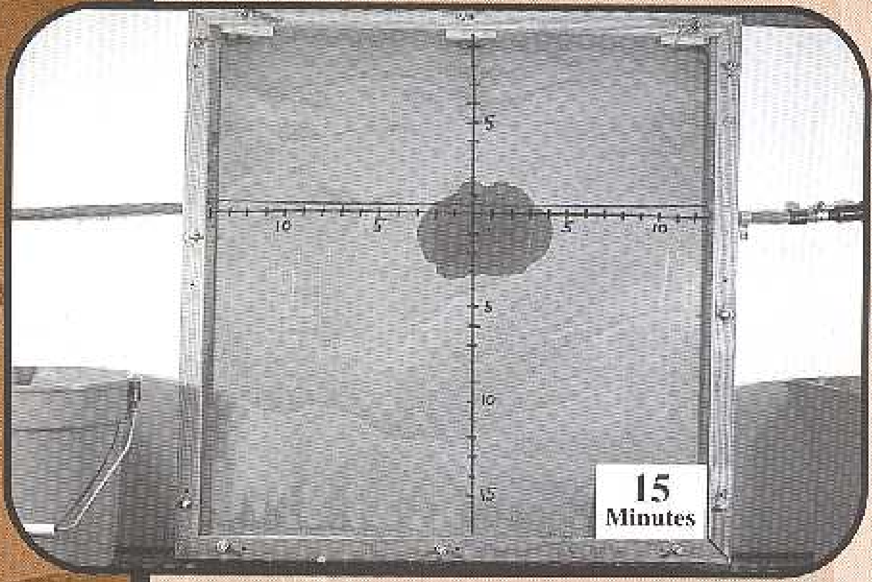


Cross-Section of Bed



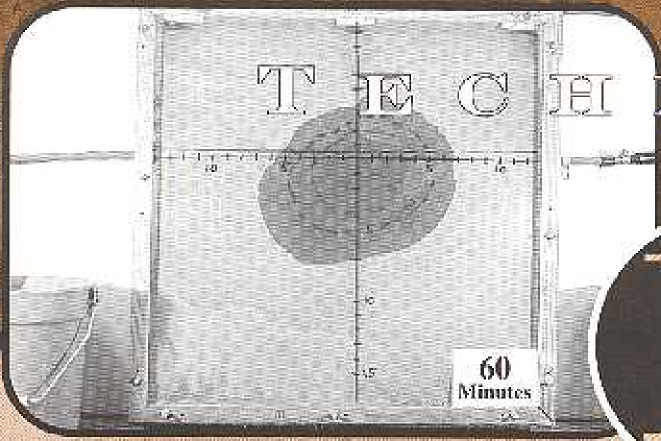
Wetting Front Movement

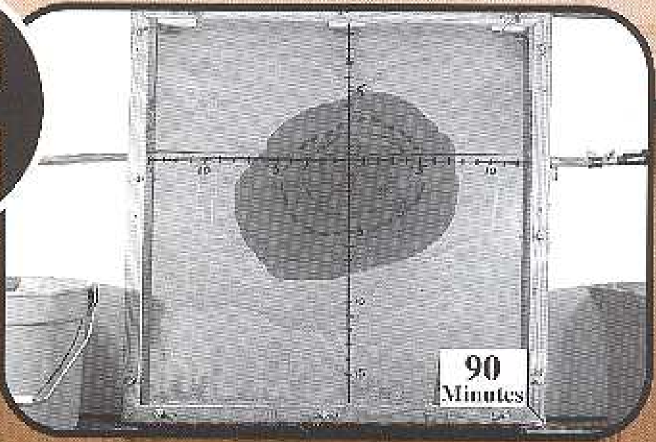
(Through Soil, Away From Emitter)

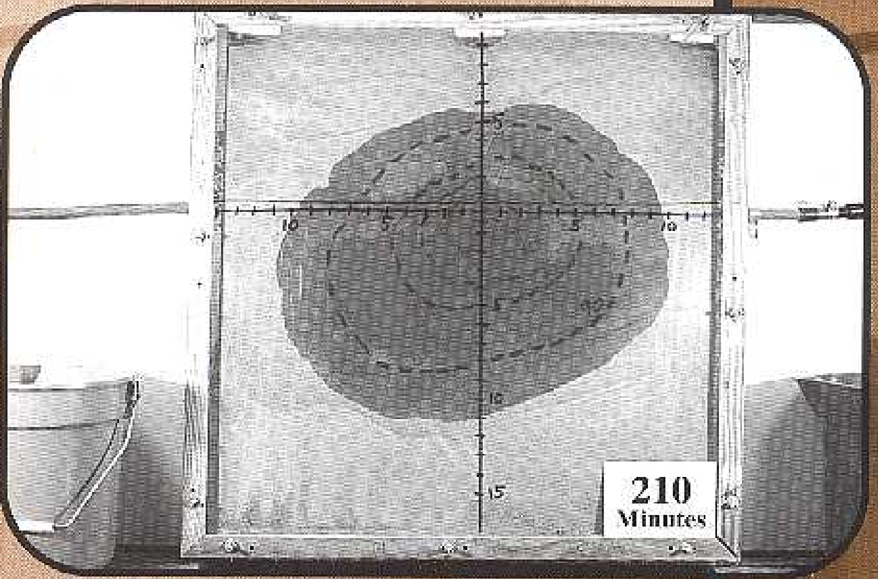


TECHNOLOGY

E

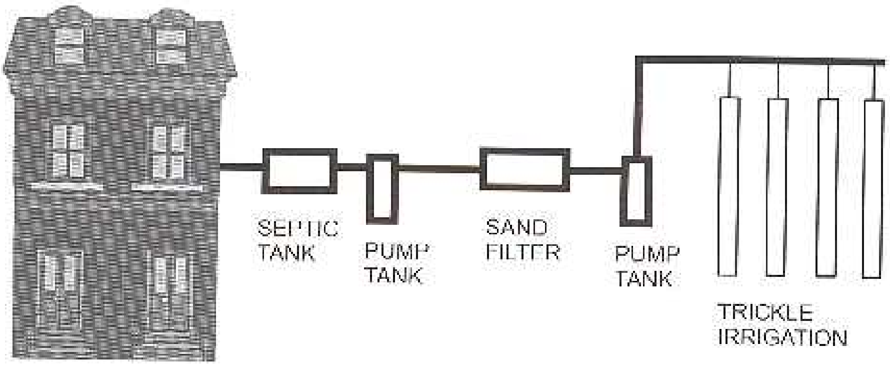






TECHNOLOGY

E



Drip/Trickle Irrigation

Single pass, sand filter treated effluent is sent to trickle irrigation systems. Each trickle irrigation system doses two 600 lineal foot zones 5 times per day with disc filtered effluent. After 20 doses the system automatically flushes the lines. Prior to each dose, the disc filters are backwashed.

- Limiting zone: 25 inches, mottles.
- Slope: 18.4 to 24.3%
- Percolation rate: Average 20.1 to 58.4 minutes per inch. Range was 2.8 minutes per inch to 120 minutes per inch.
- Hydraulic conductivity: 9.9 to 17.6 cm/day..
- Dosing cycle: Each zone is dosed five time per day; each system has two zones.
- Each system received approximately 400 gallons per day.

***Readington series**, moderately well drained; common distinct mottles at 25 inches, with fragipan.*

Bed:	E1	Hole #	Perk Rate (MPI)	cm/day	Guelph Rate cm/day
Bed Size:	15x60	3	48	76.3	5.94
Avg. Slope:	18.39	4	5	732	13.82
		5	24	152.5	
		6	10.4	351.9	
		7	3.8	963.2	
		8	26.7	137.1	
		9	34.3	106.7	
		10	2.8	1307.1	
		11	21.8	167.9	
		12	24	152.5	
		Average:	20.1	414.7	9.9
		Geometric Mean:	14.1	260	9.1

Bed:	E2	Hole #	Perk Rate (MPI)	cm/day	Guelph Rate cm/day
Bed Size:	15x60	28	120	30.5	17.63
Avg. Slope:	20.39	29	40	91.5	
		30	17.1	214	
		1	16	228.8	
		2	2.9	1262.1	
		13	120	30.5	
		14	120	30.5	
		15	20	183	
		16	48	76.3	
		17	80	45.8	
		Average:	58.4	219.3	17.63
		Geometric Mean:	36.5	100.2	

Bed:	E3	Hole #	Perk Rate (MPI)	cm/day	Guelph Rate cm/day
Bed Size:	15x60	23	48	76.3	
Avg. Slope:	24.25	24	4.4	831.8	13.82
		25	6.7	546	
		26	18.5	197.8	
		27	48	76.3	
		18	120	30.5	
		19	120	30.5	
		21	60	61	
		22	40	91.5	
		Average:	51.7	215.8	13.82
		Geometric Mean:	32.8	111.7	

Typical Drip Irrigation System Materials and Labor

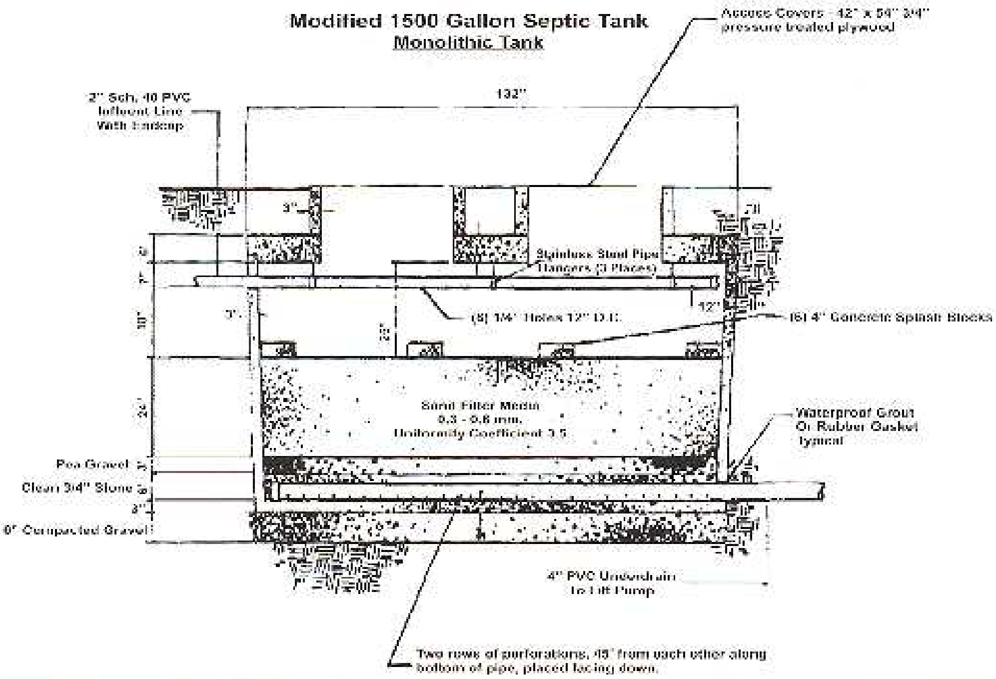
ITEM	QUANTITY
1,000 gallon septic tank	1
500 gallon pump tank	1
Sand filter tank	2
1,000 gallon pump tank	1
4" sch. 40 PVC	100 l.f.
2" sch. 40 PVC	30 l.f.
1 ½" sch. 40 PVC	150 l.f.
1" sch. 40 PVC	100 l.f.
6" sch. 40 PVC	12 l.f.
American On-Site 2 Zone Drip System	1 lot

Includes: Controller, hydraulic control unit, valve box, float tree, pump, 2,000 l.f. of tubing, black flexible PVC, specialty fittings.

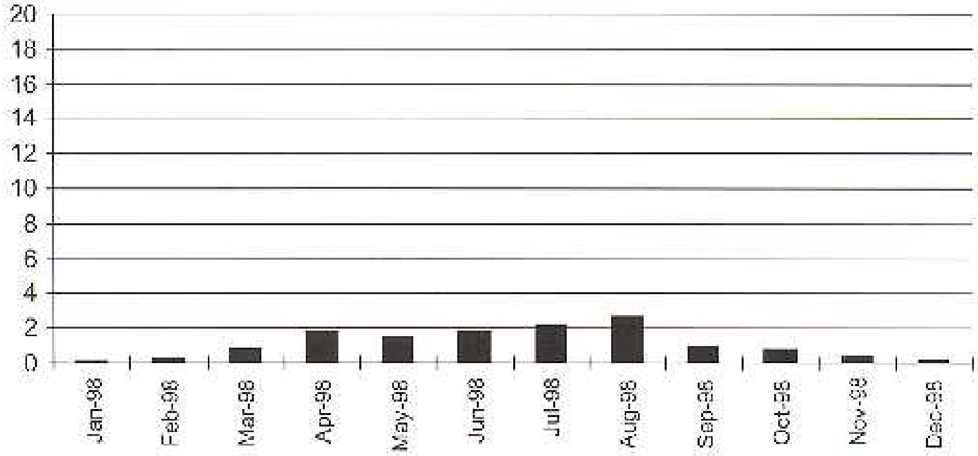
½ hp sewage pump	1
Sand filter media	10 tons
Miscellaneous fittings	varies

Note: Sand filters & 500 gallon pump tank can be replaced with peat filter in some instances.

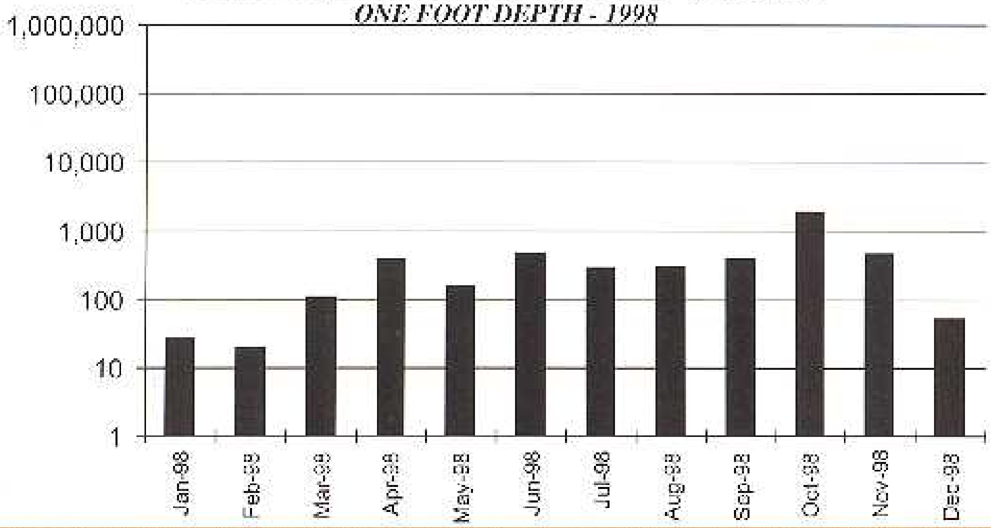
LABOR	TIME
Excavation (Backhoe, operator and laborer)	28 hrs.
Dripper line installation (2 laborers & cable plow)	32 hrs.
Electrical (Electrician and laborer)	16 hrs.
Piping (2 laborers)	32 hrs.



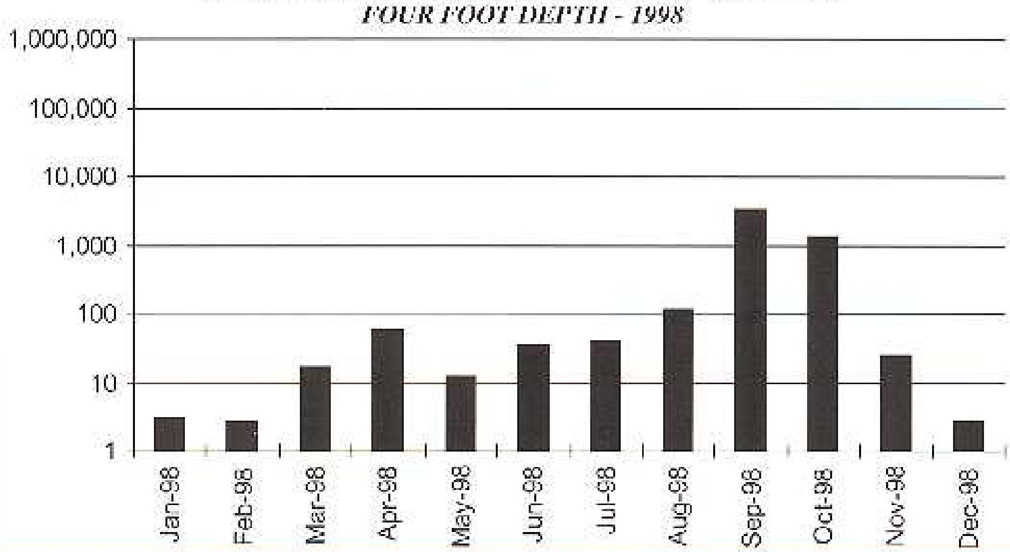
AVERAGE TOTAL PHOSPHOROUS TECH E -mg/l
FOUR FOOT DEPTH - 1998

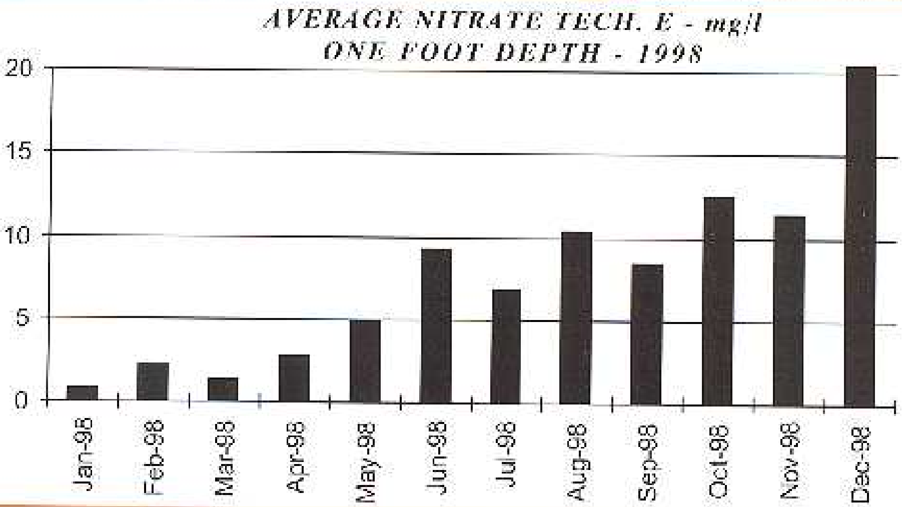


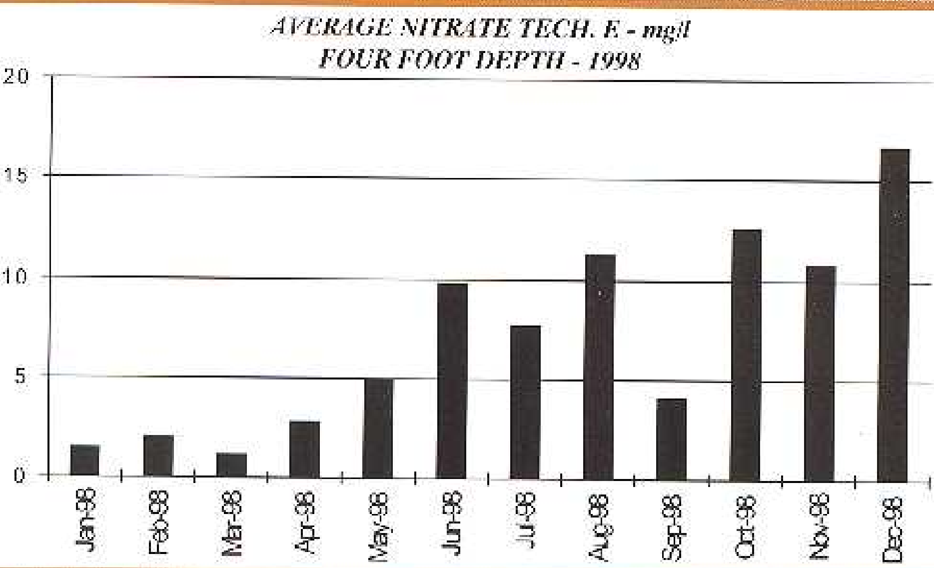
GEO MEAN FECAL COLIFORM TECH E - MPN/100ml
ONE FOOT DEPTH - 1998



GEO MEAN FECAL COLIFORM TECH E - MNP/100ml
FOUR FOOT DEPTH - 1998




AVERAGE NITRATE TECH. E - mg/l
ONE FOOT DEPTH - 1998
20
15
10
5
0
Jan-98
Feb-98
Mar-98
Apr-98
May-98
Jun-98
Jul-98
Aug-98
Sep-98
Oct-98
Nov-98
Dec-98


AVERAGE NITRATE TECH. E - mg/l
FOUR FOOT DEPTH - 1998
20
15
10
5
0
Jan-98
Feb-98
Mar-98
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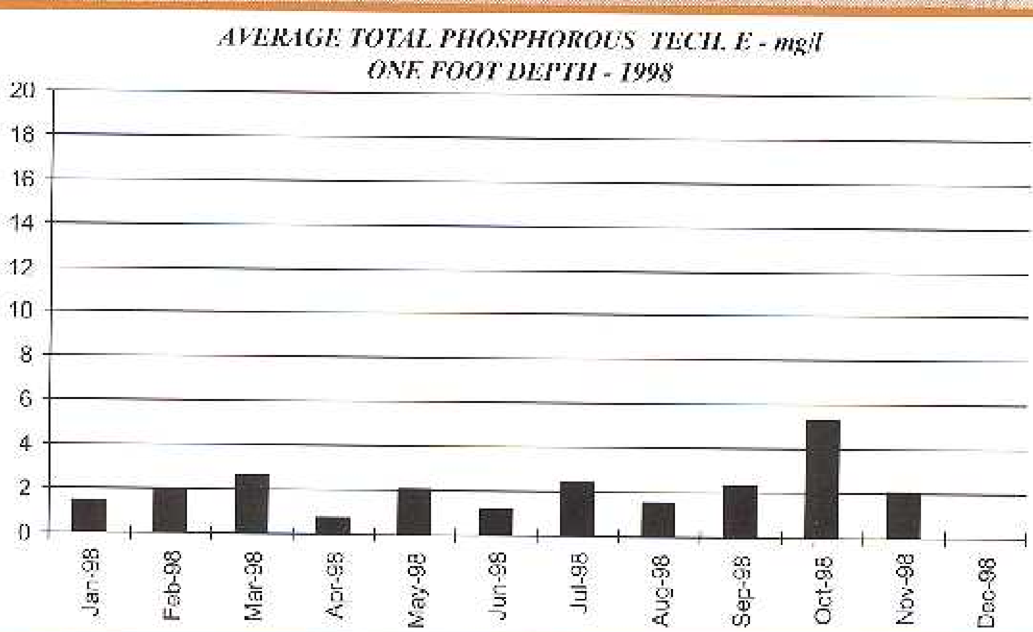
AVERAGE TOTAL PHOSPHOROUS TECH. E - mg/l
ONE FOOT DEPTH - 1998
20
18
16
14
12
10
8
6
4
2
0
Jan-98
Feb-98
Mar-98
Apr-98
May-98
Jun-98
Jul-98
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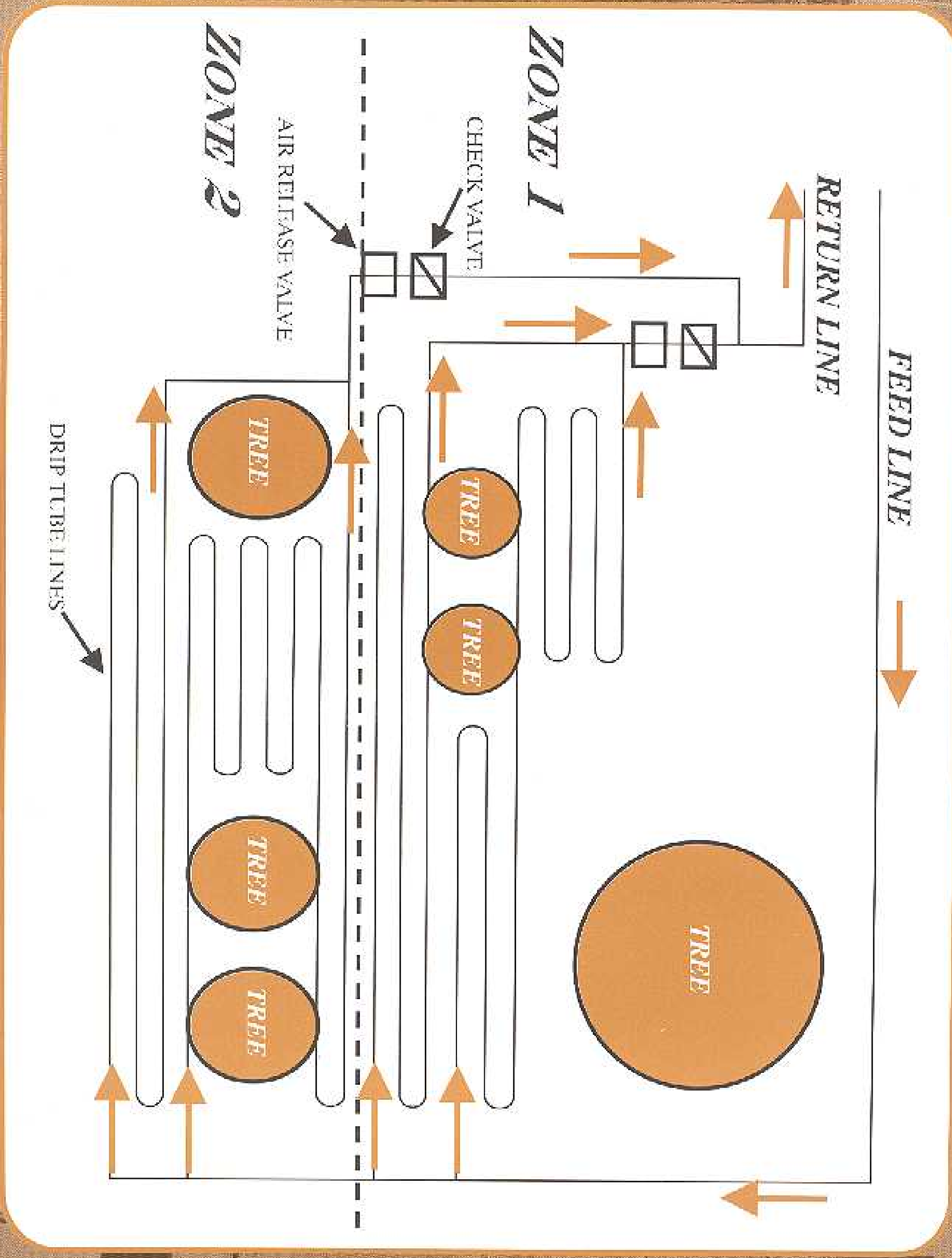
Oct-98
Nov-98
Dec-98

Drip/Trickle Irrigation



TECHNOLOGY

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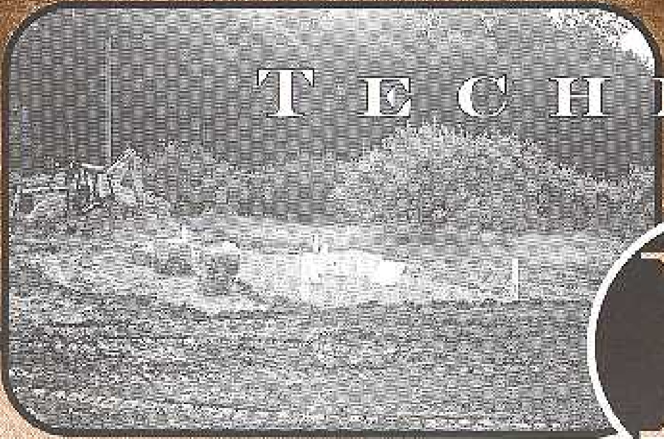
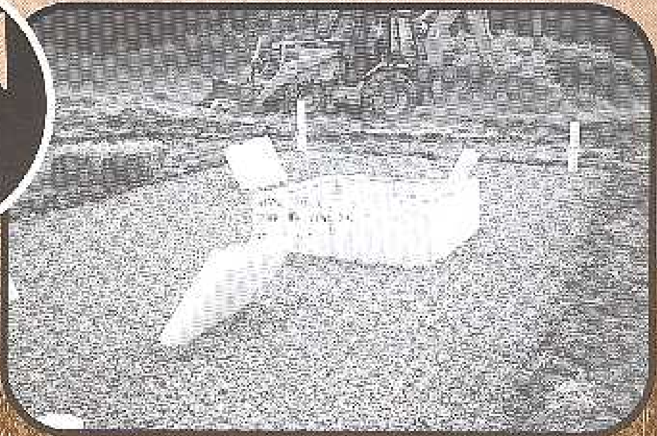
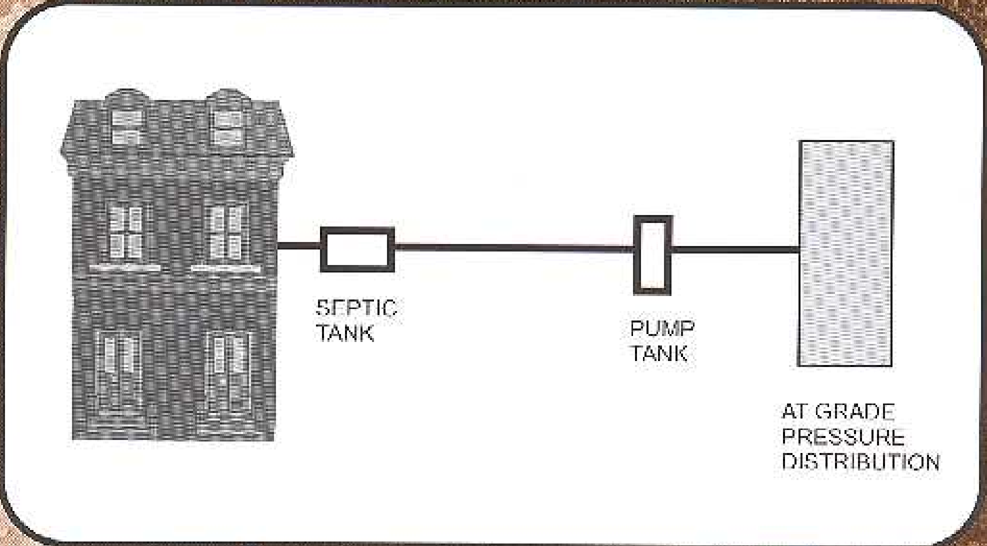
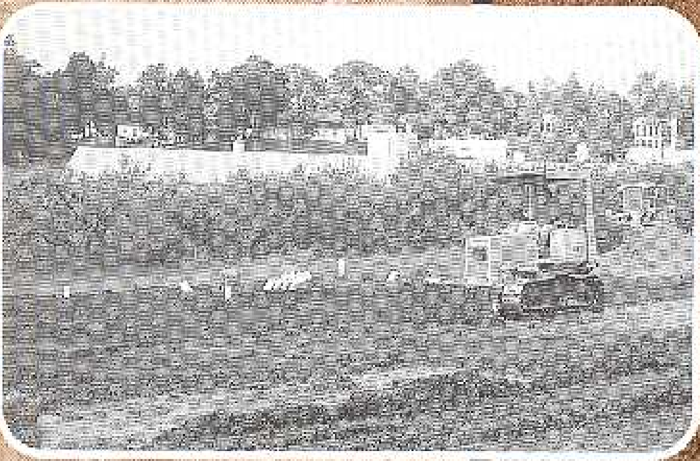




TECHNOLOGY

F





Renovative Thickness

Three at-grade pressure distribution systems received septic tank quality effluent. Effluent from the campus sewer system was sent through two parallel 3,000-gallon single compartment septic tanks. Effluent was then sent to a common pump chamber and dosed four times per day to each of three at-grade pressure absorption areas.

- Limiting zone: None to 72 inches.
- Slope: 1.6% to 8.5%
- Percolation rate: Average 11.5 to 18.3 minutes per inch. Range was 3.3 to 40 minutes per inch.
- Hydraulic conductivity: 26.4 to 103.3 cm/day.
- Dosing cycle: 4 doses per day per system; 300 gallons per day per system loading rate.

***Lansdale series**, deep, well drained soil; bedrock greater than 72 inches beneath the surface.*

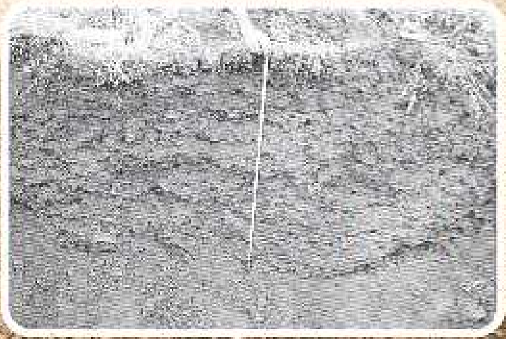
Bed I (cm/day)	Hole #	Perk MPI	cm/Day	Guelph Rate
Size: 15x40	1	8.0	450	3.76
Ave. Slope: 7.8%	2	7.3	493.15	48.98
	3	21.8	165.138	
	4	15	240	
	5	40	90	
	6	16	225	
	7	20	180	
	8	18.5	194.59	
Average		18.325	196.45	
Geometric Mean		16.1	233.56	

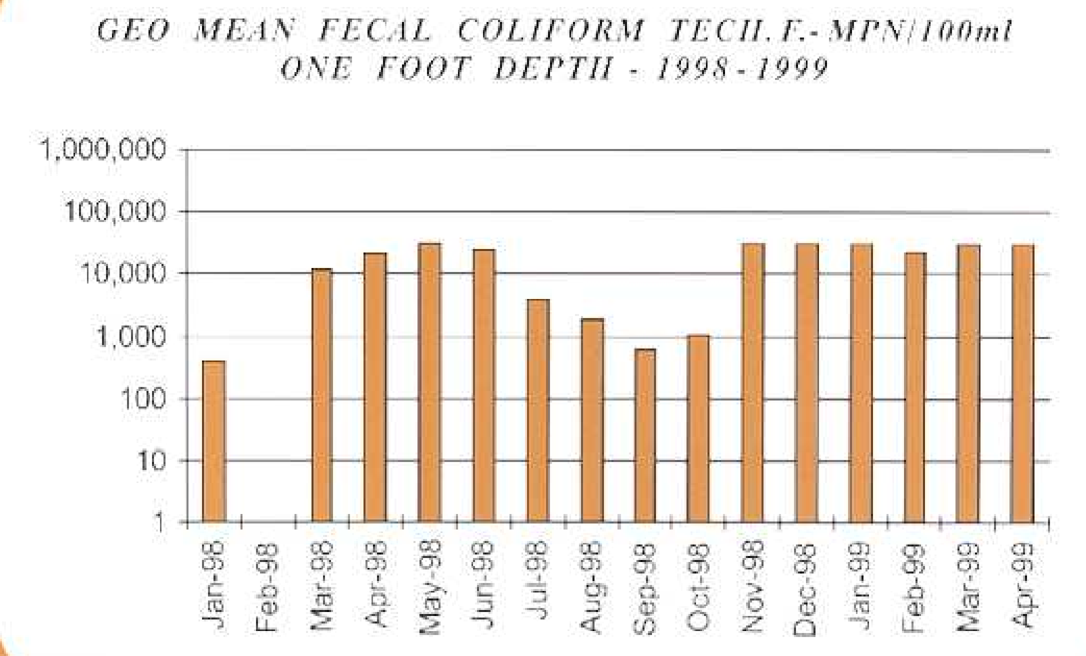
Bed II (cm/day)	Hole #	Perk MPI	cm/Day	Guelph Rate
Size: 15x40	1	12.6	285.71	43.02
Ave. Slope: 7.1%	2	9.6	375.0	35.42
	3	24.0	150.0	
	4	13.3	270.68	
	5	20.0	180.0	
	6	9.6	375.0	
	7	21.8	165.14	
	8	12.0	300.0	
Average		15.363	234.33	
Geometric Mean		14.49	248.51	

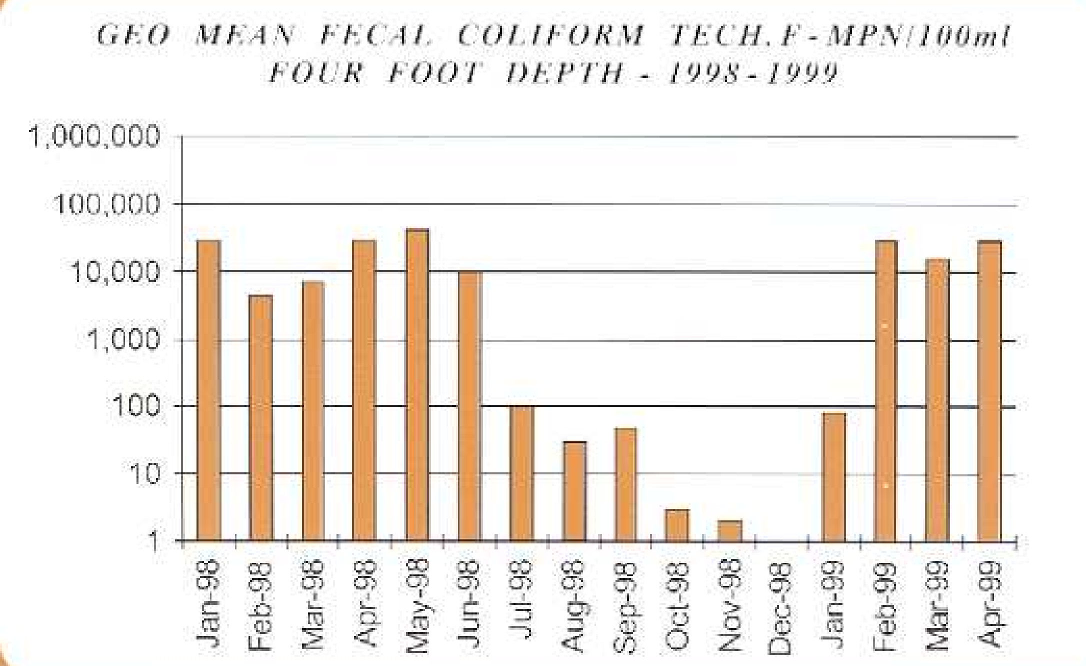
Bed III (cm/day)	Hole #	Perk MPI	cm/Day	Guelph Rate
Size: 15x40	1	9.2	391.3	28.68
Ave. Slope: 3.95%	2	8.9	404.49	177.98
	3	13.3	270.68	
	4	9.2	391.31	
	5	7.5	480.0	
	6	10.4	346.15	
	7	3.3	1090.91	
	8	30	120	
Average		8.1	444.44	
Geometric Mean		9.68	371.74	

Lansdale Series

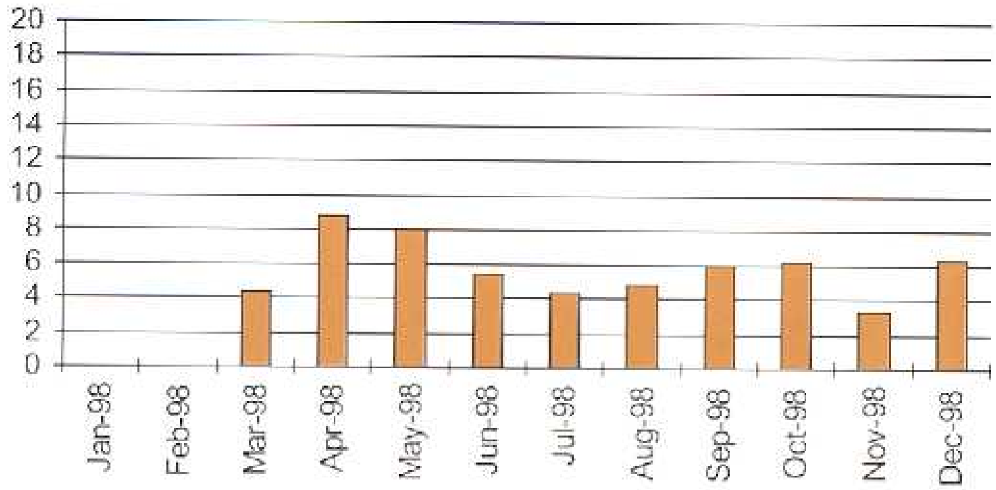
Ap1 0-6"	7.5YR 3/2 dark brown loam; moderate fine granular structure; 5% coarse fragments; clear wavy boundary.
Ap2 6-11"	7.5YR 3/2 dark brown loam; moderate fine to medium subangular blocky structure; 5% coarse fragments.
Bw 11-16"	10YR 4/3 brown and 10YR 4/2 dark grayish brown channery sandy loam; weak medium subangular blocky structure; 30% coarse fragments.
Bt1 16-22"	10YR 4/2 dark grayish brown channery loam; weak medium subangular blocky structure; 15% coarse fragments.
Bt2 22-30"	5YR 4/2 dark reddish gray and 7.5YR 5/4 brown channery loam with few fine 7.5YR 4/1 dark gray and 7.5YR 5/4 brown mottles; weak coarse subangular blocky structure; 20% coarse fragments. *(Discussion on mottles was that they were few and faint and probably caused by wet conditions without free water due to structural differences. Data on percolation and hydraulic conductivity testing done in this horizon shown in permeability section of this report. Rapid rates appear to validate this observation.)*
Bt3 30-47"	7.5YR 4/2 brown and 7.5YR 5/4 brown very channery loam with few fine 7.5YR 4/1 dark gray and 7.5YR 5/4 brown mottles; weak coarse subangular blocky structure; 40% coarse fragments. *(Discussion on mottles was that they were few and faint and probably caused by wet conditions without free water due to structural differences. Subsequent percolation testing in this horizon was 10 to 15 minutes per inch which appears to support this observation.)*
Bt4 47-60"	5YR 5/2 reddish gray and 7.5YR brown very channery loam structureless massive; 40% coarse fragments.



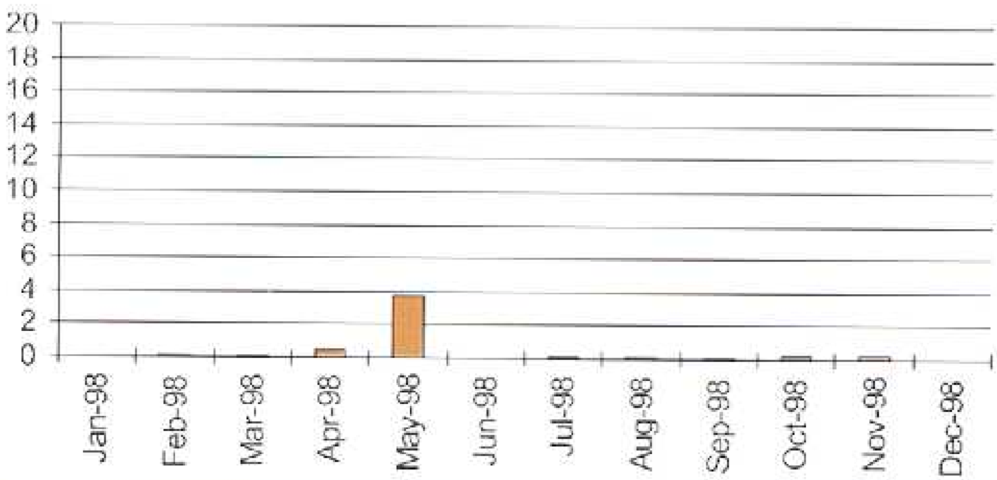

GEO MEAN FECAL COLIFORM TECH. F.- MPN/100ml
ONE FOOT DEPTH - 1998 - 1999
1,000,000
100,000
10,000
1,000
100
10
1
Jan-98
Feb-98
Mar-98
Apr-98
May-98
Jun-98
Jul-98
Aug-98
Sep-98
Oct-98
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99


GEO MEAN FECAL COLIFORM TECH. F - MPN/100ml
FOUR FOOT DEPTH - 1998 - 1999
1,000,000
100,000
10,000
1,000
100
10
1
Jan-98
Feb-98
Mar-98
Apr-98
May-98
Jun-98
Jul-98
Aug-98
Sep-98
Oct-98
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99

AVERAGE TOTAL PHOSPHOROUS TECH. F - mg/l
ONE FOOT DEPTH - 1998



AVERAGE TOTAL PHOSPHOROUS TECH. F - mg/l
FOUR FOOT DEPTH - 1998



Project Conclusions

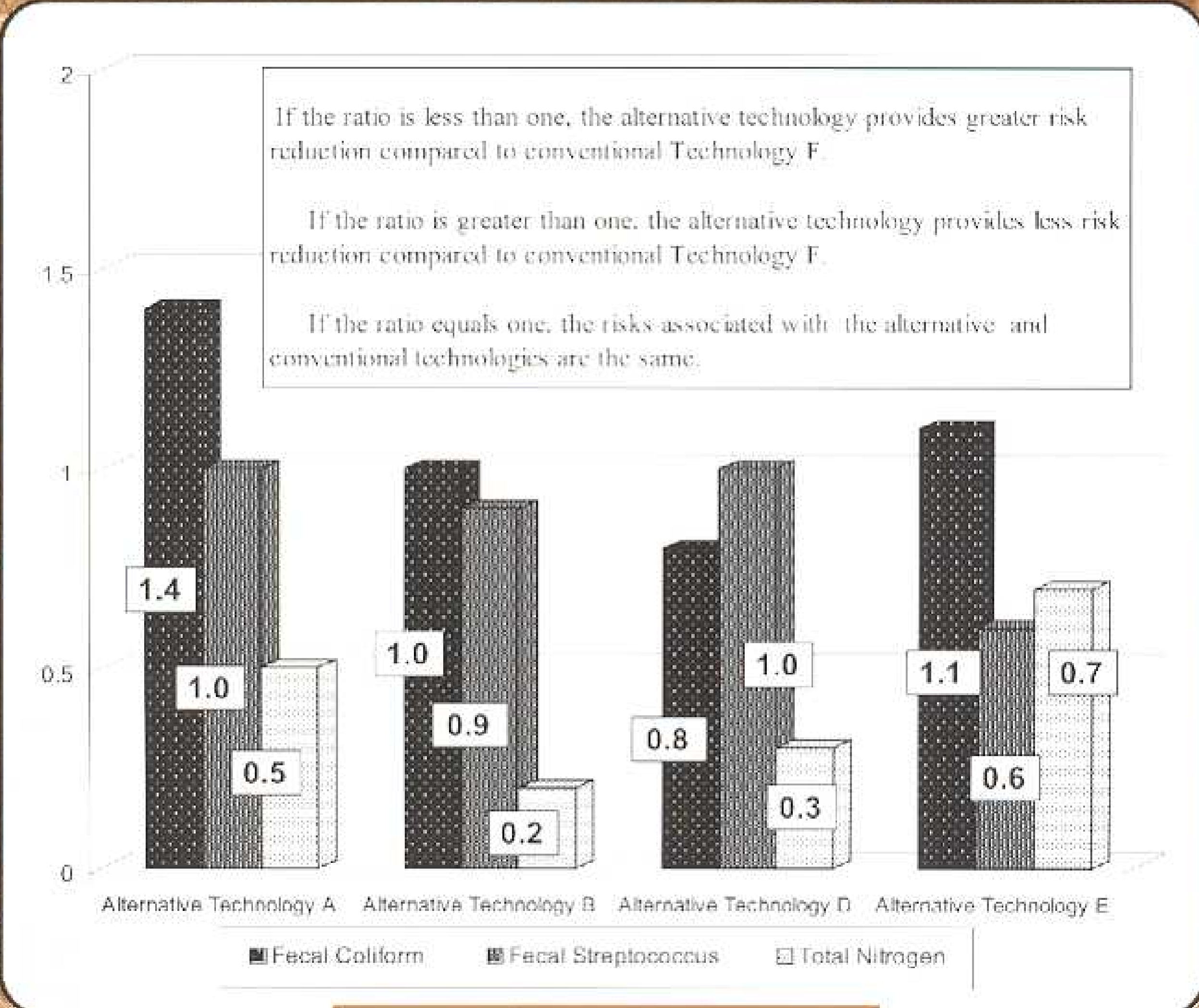
All systems tested showed statistically significant reduction in concentrations in most parameters tested.

The question becomes: *"Is a statistically significant reduction in a potential pollutant enough to protect public health?"* A comparative risk assessment evaluation (see graph on following page) supports a conclusion that the technologies tested pose no more additional risk than currently approved conventional type bed systems.

Neither the statistically significant reduction in potential pollutants nor the comparative risk assessment on their own should be used as a basis for approval. The testing does, however, provide some level of confidence in these systems and serves as a basis for comparison. Alternative technologies are not without risk, and approval should be based on sound judgement from regulators and the private sector.

It is clear that an increased level of supervision and management for alternative technologies will be required. In addition to normal maintenance such as pumping septic tanks and repair of pumps, such tasks as raking of sand filters, maintenance of hydraulic units on drip irrigation systems, managing of plants on wetland systems and visual observation of distribution areas for wetness will need to be performed. This additional level of management must be provided or systems will not function properly. As part of their guidance documents, DEP will be indicating maintenance requirements specific for the technology released.

Relative Hazard Ratios for Biological and Chemical Parameters
Technologies A, B, D, E, & F



Benchmarks
Fecal coliform > 200 mpn/100mL
Fecal streptococcus > 200 mpn/100mL
Total Nitrogen > 24mg/L
Total Phosphorous > 1 mg/L

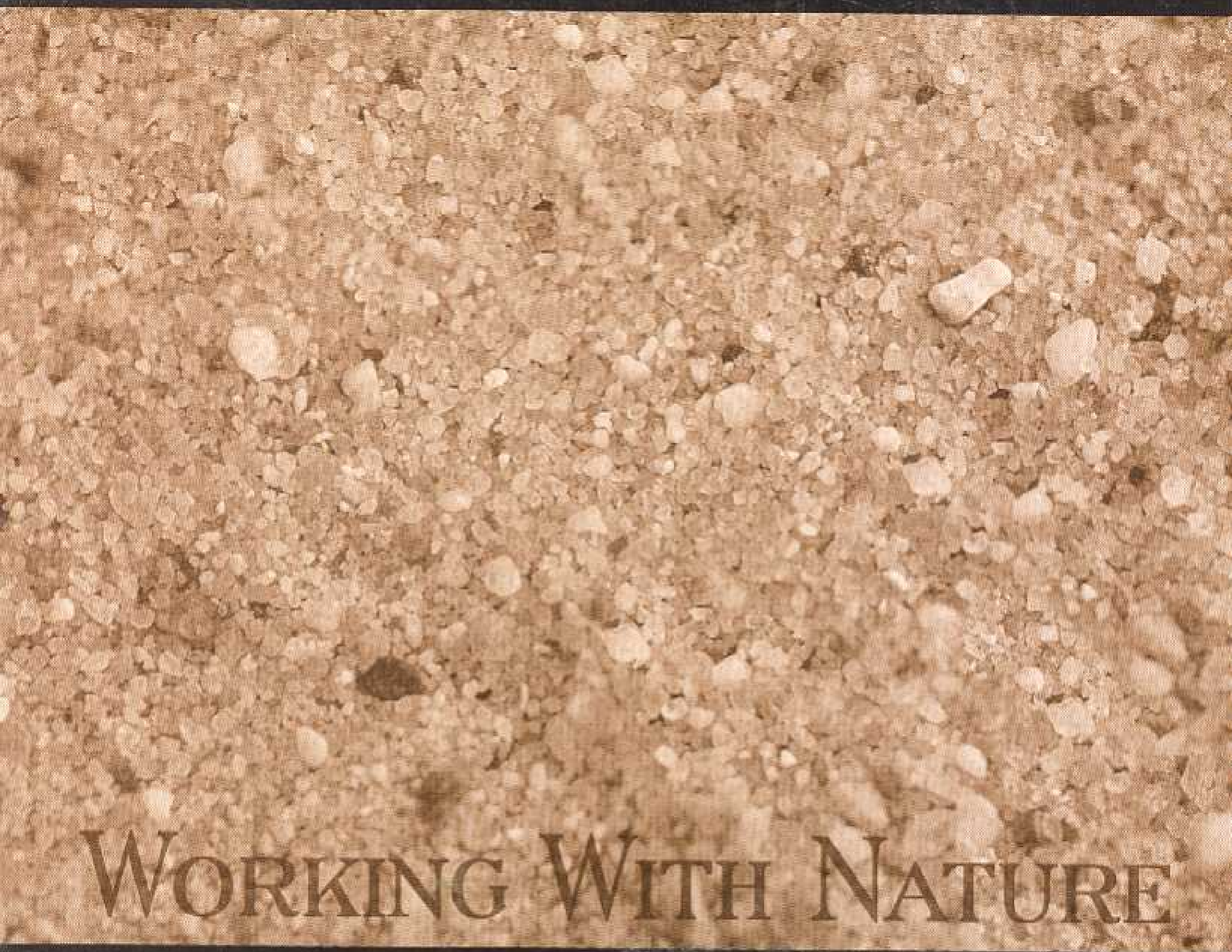
A relative hazard ratio for comparative risk evaluation of five of the on-lot systems was computed. Data from Technology A and from the four foot lysimeters installed in Technologies B, D, E, and F are used for comparison.

Excedence frequencies for fecal coliform and fecal strep bacteria, using 200 bacteria/100mL as the reference base, were computed for each system. Excedence frequencies for total nitrogen, using 24mg/l (level of Technology F), were computed for each system.

Excedence frequencies are calculated by computing the number of months the baseline (200 bacteria or 24mg/l TN) is exceeded, and dividing by the total number of months with available data. Excedence frequency of experimental technologies A, B, D, or E is then divided by the excedence frequency of the conventional technology (Technology F) to calculate a relative hazard ratio.

On-Lot Systems and Small Flows
Research and Development

***This CD-ROM** has been developed for use with the Project Final Report. The data represented by the graphs was collected from March, 1997 through August, 1999. To run: place disk in CD-ROM drive. If presentation does not automatically run, choose RUN from the START menu in Windows 95 or higher, and type: D\Autorun.exe. (Replace "D" with the drive letter of your CD-ROM.)*



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Graphic design: George E. Mendoza, PTGraphics, Inc.