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Forest Service Handbook 7409.11 – Sanitary Engineering and Public Health Handbook

Chapter 50 - Wastewater

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50.2 - Objective

The objective of this chapter is to provide the Engineer with the best available data for the design of wastewater systems based in large part on past Forest Service operational experience and system characteristics.

50.5 - Definitions

All technical terms used in this chapter shall be defined as found in Reference 3, Glossary - Water and Wastewater Control Engineering, and as noted below:

1. Recirculating Chemical Toilet. A chemical toilet with an electrically or manually activated pump that allows the liquid fraction to be reused as a flushing agent to prevent "dry bowl" soiling.

2. Oil Flush Toilet. A toilet fixture similar to a water closet where a clear, low viscosity oil is the flushing media instead of water. The oil may be filtered, cleaned and recycled. The waste may be conducted to an incinerator for disposal or transported to a central disposal area.

3. Low-Volume Flush Toilet. A hopper toilet without a trap that uses 1 to 2 quarts of water to clean the bowl after a mechanical seal is released.

50.8 - References

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50.9 - Process Substitution Diagram

There are a large number of wastewater collection modes, treatment processes, and disposal options that are related both to the characteristics of the waste and the degree of treatment required. Exhibit 1, Process Substitution Diagram, shows the full range of Forest Service experience in the management of wastewater from its generation to its disposal.

The selection of a wastewater management process or combination of processes will depend upon:

1. The characteristics of the wastewater.
2. The required effluent quality.
3. The availability of land for waste disposal.

4. The future upgrading of water-quality standards.

5. Hydraulic loading.
6. Future site development and expansion.

7. Operation and maintenance requirements.

The designer may choose one or more elements in each column to meet the above criteria. Each of the processes is discussed in subsequent sections of this chapter. Emphasis will be placed upon those processes most generally encountered in Forest Service wastewater management.

50.9 - EXHIBIT 1 IS A SEPARATE DOCUMENT

51 - Waste Characterization

The physical, chemical and biological characteristics of wastewater are essential information for the design and operation of collection, treatment, and disposal facilities. The principal parameters vary from precise wastewater chemical determinations to qualitative biological and physical descriptions. Many of the parameters are interrelated. The Forest Service facility wastewaters vary from strong vault waste to weak domestic sewage from administrative sites. This section will briefly outline the wastewater characteristics of Forest Service wastewaters.

An appraisal of the wastewater load should reflect the requirements of existing facilities, of planned expansions, and new facilities. The wastewater collection, treatment, and disposal system must have balanced and adequate capacities to function properly.

51.1 - Human Waste

The basis for characterization of Forest Service wastes is the daily contribution by each individual using connected facilities. An average adult will contribute approximately 100 grams of fecal matter and 1,200 grams of urine daily. This is approximately 3 pounds per day or 0.35 gallon/day, which is 7-8 percent total solids. Table 1 - Human Waste Generation, indicates typical strengths of human waste according to type of toilet facility.

The strength of waste being delivered to the treatment facility is affected by both the toilet facility and the transport system. Conventional flush toilets provide great dilution while vaults and chemical toilets provide minimal dilutions of chemical additives. Other wastes entering the system include kitchen, laundry, lavatory, treatment process and fish cleaning. See Table 2, Secondary Waste Sources; Table 3, Administrative Waste Sources; Table 4, Recreational Waste Sources; and Table 5, Special Waste Sources.

Sec. 51.1 - Table 1 Human Waste Generation Sources

Toilet Fixture	Volume/Use	Initial Charge	Chemical Additives Possibly Present	Deleterious Materials Possibly Present*	Strength at Discharge
Results	Human Waste	5-10 percent of available vault volume be initially filled with water after each pumping.	Odor Control: Bactericides Chlorobenzenes Chlorophenols Formaldehyde Quartarnary Ammonia Compounds Chlorinated Hydrocarbons	Rocks, cans, plastic bags, diapers, etc. Persistent chemicals	BOD – 15,000 mg/l TS 7-8 percent (before adding water) Dependent upon water tightness and evaporations.
Chemical Toilet / Recirc. Chem. Toilet	Human Waste	Approx. 5-10 gal. Varies dependents on unit. / Approx. 12 gal.	Formaldehyde, Perfumes, Surfactants, Anti-freeze.	Same as above	900-12—mg/l SO_4 or Formaldehyde. BOD - 20,000 – 30,000 Mg/l TS- 4-7 percent.
Toilet/Recirc. Chem. Toilet	Human Waste	Initial charge dependent on size of system installed. Make-up oil (Approx. 1%)	Oil-low viscosity, Low volatility, Low absorption, Capacity low, Freezing Temp.	Limited, to 3' spherical solid, flammables or other waste toxic materials. Portable or R-V toilet waster.	1 percent oil BOD – 20,000 - 30,000 mg/l TS 6-8 percent Ph 8
Volume Flush	1-2 qts. + Human Waste	Discharge to holding tank or sewer.	None	Same as above	BOD – 7,000 mg/l TS - 1.5-2.0 percent SS – 200-1100 mg/l
Conventional Flush	3-5 qts. + Human Waste	Discharge to sewer.	None	Same as above	BOD – 100-300 mg/l TS – 300-1200 mg/l SS – 100-350 mg/l

Anything can be present that will go through the opening.
If connected by pipe to the point of deposit, additional dosing may be required or clogging will result from solids deposited in the line.

51.1 –Table 2 – Typical Residential Waste Sources Rural Household

Type	Average Flow/Use (Gal.)	BOD Mg/ℓ	TS Mg/ℓ	SS Mg/ℓ	Primary Constituents
Sink Kitchen	1	1080	1330	209	Grease, Food, Detergent
Bathroom	2	260	480	230	Soap and Detergent
Bath/Shower	27	100	340	27	Soap and Detergent
Washing Machine	39	200	760	80	Detergent
Dishwasher	7	125	920	26	Detergent, Food
Garbage Disposal	2	4065	10750	6670	Food, Grease
Water Closet 1/	5	200	700	200	Fecal Matter, Urines

Note: These wastes are applicable to Guard Stations, Recreation Residences, Administrative Residences, and House Trailers.

1/ Tank Water Closet with no Water Saving Devices.

51.1 –Table 3 – Typical Administration Waste Sources

Type	Average Flow 1/ (gpcd.)	BOD mg/ℓ	SS mg/ℓ
Dwellings			
Single Family 2/	45-75	260-290	360-400
Barracks, Crew Quarters, Without Kitchens	30	290	200
Barracks, Crew Quarter, With Kitchens	40	250	920
House	60		
House Trailers			
Messhalls	15	6,500	9,200
Office	15	480	330
Guard Station	15	480	330
Camp Resident	40	350	520
Semi-Permanent	35	340	240
Non-Resident	10	480	330

1/ No water saving devices
2/ Includes garbage grinders
3/ Includes garbage grinders, institutional dishwashers, and food preparation sinks. Grease traps installed and operational.

51.1 –Table 4 – Typical Recreation Waste Sources

Use	Average Flow 1/ (gpcd.)	Use Unit	BOD (mg/f)	SS (mg/ℓ
Camping				
With Flush Toilets	25	PAGT	550	750
With Flush Toilets & Showers	35	PAGT	320	350
With Direct Trailer Connection	40	PAGT	1/	1/
Day Use				
With Flush Toilets	5	Person	280	500
With Flush Toilets & Showers	20	Person	85	120
Travel Trailer Station	720	Service point	3,600	3,900
Visitor Information Center	4	Person	120	650
Organization Camps	30	Person	400	280
With Central Plumbing	50	Person	600	400
With Individual Plumbing				
Recreation Residence	60	Person	330	450
(Summer Home)				

1/ Varies widely because of holding tanks which may or may not be discharged.

51.1 –Table 5 – Special Waste Sources

Use	Average Flow 1/ (gpcd.)	Use Unit	BOD (mg/f)	COD (mg/ℓ
Fish Cleansing Station	5	Fish	1370-3960	3430-9910
Travel Trailer Station	720	Service Point	3,600	6,600
Restaurant	8	Wash	750	2,200
Laundry 1/	40	Vehicle	200	550
Service Station	10		160	320

1/ Household type automatic washer.

51.2 - Other Wastes From Forest Service Activities

The waste generated at sites administered by the Forest Service can generally be characterized as "domestic" human and household waste products. There are some exceptions: The introduction of odor control chemicals into the waste stream when the pump out waste from chemical and vault toilets, when recreation vehicle dump stations are provided, water treatment process waste, and fish cleaning stations.

51.21 - Waste From Chemical and Chemical Recirculation Toilets

See Table 1, sec. 51.1.

51.22 - Recreational Vehicle Dump Stations

51.22a - Chemicals From Recreation Vehicle Holding Tanks

The type of chemicals encounter and their concentrations are quite variable because their use is controlled by individual recreational vehicle owners. Some generalizations can be made as shown in trends of mean concentrations of waste constituents sampled at trailer dump stations during 1971 and 1975 as follows:

Constituent	1971	1975	Maximum Water Quality Criteria	Trend
Zinc (Zn SO_4)	150	66	5	Down
Phenols	220	NIL	.001	
Eliminate				
Formaldehyde	10	37	----	Up
(All Values in mg/ℓ)				

The manufacturers of chemical toilets and odor control chemicals have voluntarily eliminated phenols because of their persistence in all waters.

Zinc Sulfate, once widely used, has been relied upon less by the industry because of the toxic effects of zinc in water bodies in concentrations of 5 mg/l or greater.

Therefore, the reliance of formaldehyde solution has increased. Formaldehyde is released in gaseous form or is combined with other organic material. Formaldehyde will more than likely not pose a treatment problem with passage of time in contact with waste material.

51.22b - Waste Generation Rates

Chemical toilet waste is a product of human waste plus the original charge of water and chemicals. See Table 1.

Trailer dump station waste is a product of R.V. holding tank contents, rinse water, and wash down water. The amount of waste is limited by the service time per vehicle with the following factors observed in USFS and COE waste characterization studies.

- Average Service Time - 12 minutes.
- Dumping occurs primarily on Sundays and Holidays.
- Average rinse volume - 25 gallons.
- 65 percent of camping vehicles had self-contained toilets equipped for using the dump station.
- 80 percent of vehicles equipped to use dump stations did use them.

Assume:

- Operation from 9:00 a.m. - 6:00 p.m. on "get-away" days.
- 100 percent campground capacity.
- 3.5 persons per R.V.

$$\text{Gallons/Peak Day} = \frac{0.5\,(\text{PAOT})}{3.5} \times (40 \text{ gallons})$$

$$= \underline{60\ (\text{PAOT})}$$

or based on maximum station occupancy:

$$= \frac{9 \times 60 \text{ min.}}{12 \text{ min.}} \times (40 \text{ gallons}) \times (\text{Number of Service points})$$

$$= \underline{1800\text{ N}}$$ whichever is larger.

Gallons/Average Days 1/

$$= 0.4\,(60)\text{ PAOT} = \underline{24\ (\text{PAOT})}$$

$$0.4\,(1800)\,(\text{N}) = \underline{72\text{ON}}$$ or whichever is larger.

This concentrated waste should be diluted 30:1 before introduction to a biological treatment to bring the BOD down to 1000 mg/l; Formaldehyde below 2mg/l; or zinc below 2 mg/l.

1/ The national average occupancy in season for developed sites is 40 percent.

51.23 - Fish Cleaning Stations

The possibility of providing central fish cleaning facilities at points of concentrated use on reservoirs and lakes in which fishing is a major activity should be considered. These wastes can be treated as solid waste and/or introduced through a grinder to the wastewater system. Unless collections are daily, it is not advisable to use the former method, and then only in cooler seasons.

51.23a - Fish Waste Characterization

The characterization of fish wastes is difficult because the body of information on these wastes deals with the commercial processing industry. The only available definitive reference on this subject is the unpublished report with bibliography, "Problems of Treating Wastes from the Fish Cleaning Station at Cedar Springs Marina, Flaming Gorge NRA, Dale Armstrong, Ashley National Forest." This report attempts to extrapolate sports fishing wastes from commercial fish processing data for the Salmonoid family. See Table 3. In general, sports fishermen discard a greater proportion of the fish, being interested only in the fillets, whereas commercial processors will extract most available protein. The degree of discard varies greatly, from heads and entrails for cold water species (less than 20 C), to the discard of 50 percent or more of the fish in warm water game fishing (i.e., bass). Fish wastes contain (1) highly unsaturated oils, (2) long chain, fatty acid molecules, (3) high COD's, and
(4) a large floatable fraction. These characteristics will be covered in a special section under wastewater treatment.

Table 3 - Synthesized Characteristics for Trout

	2 gal. flush per. lb. fish	4 gal. flush per lb. fish	6 gal. flush per lb. fish
BOD_5(mg/l)	3960	2040	1370
COD (mg/l)	9910	5100	3430

Total nitrogen levels can exceed 700 mg/l, so nitrification will contribute significantly to the oxygen demand. Therefore, BOD_{20} could be expected to be at least 3.5 times greater than BOD_5.

51.23b - Estimating Fish Waste Load

1. Contact the State Fish and Game Department to find the following data for lake or stream in question:

a. Stocking rate.

b. Natural stock.

c. Growth rate of fish.

d. The "success ratio" or catch rate per fisherman.

e. Fishery classification; warm water or cold water (Max. 20 C).

2. Use RIM (FSH 2309.11) figures to determine the number of visitors at developed site used for fishing.

3. Based upon the above, estimate the number of ponds of fish to be introduced (entrails and discarded portions) into the collection system. The cleaning loss per fish varies from 25 percent for trout to 60 percent total weight for bass.

4. Most fish cleaning stations employ commercial garbage grinders that require large volumes of water (5-15 gpm) for operation. Fishermen prefer to have water running throughout the cleaning process. The volume of water used per pound of fish waste will range from 2 gallons upward.

51.24 - Water Treatment Plant Wastes

The backwash and blow down water from a water treatment plant will contain solids removed by the treatment and possibly some chemicals. It should not impose a significant impact on a waste treatment facility. A possible use, if properly timed, is for the dilution of concentrated wastes which must be treated. Refer to Water Quality-Treatment, AWWA, for the expected constituents of water treatment plant backwash wastes.

52 - Self-Contained Systems

The pit privy, incinerating and composting toilets are three self-contained systems having applications to Forest Service requirements. See Table 6.

53 - Waste Water Collection

53.1 - Collection Pretreatment

Before waste is introduced into a collection system (sewer, tank trunk, etc.) it may be necessary to provide some pretreatment to protect the conveyance, prevent system failure, or dilute the waste so that it will flow easily. This pretreatment includes grinding, grease separation, and rough screening.

53.1 – Table 6 – Self Contained Systems

Toilet System	Capacity Limitations	Use Frequency	Method of Treatment/Disposal	Selection Criteria	Commercial Units
Pit Privy with or without shelter	Size of dug or crib reinforced pit.	No limitation	Backfill pit and move building or toilet. Scatter lime over excrement after use.	1. Pit Placed at least 4’ above seasonal high water table in “tight” soil. 2. At least 100’ down slope from any water source gradient. 3. Sited to eliminate surface runoff inflow. 4. Low volume of use. 5. Dispersed area. 6. Short use season. 7. Alternative pit locations. 8. Odor acceptable.	
Incinerating	None (mfgr. #1) 40 people/day (mfgr. #2)	Incinerating cycle usually 15-20 minutes. (mfgr. #1) No waiting, burning, occurs during off-use period (mfgr. #2)	Evaporation of liquids and complete combustion of solids.	1. Low use area (lookout) residence, guard, station, etc.) 2. Availability of commercial electric service. 3. Stack odors acceptable to residents. 4. Require oil or gas fuel.	1. Destroilet, LeMare Indus. 2. National Environmental Systems.
Composting	Capacity of composting tray.	16-20 uses/day	Aerobic composting over 1 2-4 year period. Spread compost around site.	1. Use by four or less people per day without rest period. 2. Seasonal use allowing interval for composting over four people per day. 3. Electric service (some units.)	1. Clivus Multrum 2. Ecolet, Recreation Ecology Conservation o U.S. 3. Toa Thorne. 4. Mull-toa.

53.11 - Grinding

Household or commercial grinders reduce solid sizes to permit free flow within the sewer system. Grinding reduces solid waste particle size, and its attendant problems, but significantly increases both water consumption and the load on the waste treatment system. See Table 2, Secondary Waste Sources. Grinders should not be used where either water or treatment capacity are limiting factors. It is more costly to remove solids from the treatment unit than to dispose of them in the garbage.

53.12 - Grease Separation

Grease traps are recommended for messhalls and automotive servicing facilities. The concentrated grease can be removed from the waste stream and disposed of with solid waste. Congealed grease can clog small diameter lines, and will certainly increase O&M problems in treatment facilities.

53.13 - Rough Screening

Separation is generally accomplished at the waste generation site manually to eliminate large foreign objects and deleterious material that will hinder the scavenger operation. Screening may also be a requirement for acceptance of the waste at a treatment facility operated by another entity, to prevent damage to comminutors, pumps, and other machinery in a sewage system. This is usually accomplished by a bar screen at the metering station to the treatment plant.

53.2 - Non-Water Carriage Collection

The Forest Service is responsible for the ultimate disposition of its vault toilet and septic tank pumping and waste sludge from treatment plant processes. Where suitable treatment sites are available, pumping and transportation by tank truck is often an attractive alternative to pipe transport. Scavenger service is provided in most cases by commercial haulers whose fee includes any treatment costs imposed by receiving agencies.

The availability of suitable treatment facilities or disposal sites is directly influenced by the type of waste being handled, its compatibility with the treatment processes and the willingness of the facility owner to receive such wastes. Any necessary pretreatment has been discussed in section 53.1. The Forest Service must provide adequate control, through contract administration, to prevent illegal and indiscriminate dumping and the attendant health problems, nuisances, and water quality degradation.

Most States have or are developing policies regarding the handling of these unstabilized wastes. Plans for water quality management mandated by PL 92-500 and recently instituted by the various States generally include policies which directly or indirectly control the treatment or disposal of sludges where surface or ground waters may be affected. (See chapter 20).

In general, State control of waste haulers is weak and regulation at the local level is the primary control. At the local level, the County Health Officer has the primary responsibility for the

regulation of sanitary waste haulers. The degree of control and specific requirements vary from county to county. If county and State regulations are inadequate in a given area, the Forest Service must implement control of contract haulers or provide its own pumping and transporting services. Annual contracts for regular service may upgrade the service and the equipment used. Contracts should stipulate that proof of satisfactory disposition of the wastes be a condition of payment.
Care must be exercised in the handling of untreated wastes since they contain pathogens and toxic materials. Because of their high strength, these wastes are capable of creating extreme nuisances if improperly handled. Many of the safety precautions noted for waste treatment plant operators in chapter 70 also apply to scavenger equipment operators.

53.21 - Dilution

Vault and holding tank wastes often contain 6 to 8 percent total solids, which is too viscous to pump out conveniently. A scavenger truck operator will add water to reduce the solids concentration to 3 or 4 percent. Municipalities and sanitary districts agreeing to accept unstabilized wastes from vaults and holding tanks often require dilution and metering to lessen the likelihood of organic shock loading to the treatment plant.

For this reason, it is important to know the strength of the wastes to be introduced at a treatment facility. The total amount of rinse water left in the vault when pumped, the amount of water introduced into vaults during normal use period, the amount of water introduced into vaults to facilitate pumping, and the amount of washdown water used at the waste receiving station need to be considered. Some campgrounds are signed directing campers to dispose of all wash water into the vaults. This type of dilution will greatly affect the strength of the waste.

The point at which vaults and holding tanks are serviced can also affect the strength of the waste. If a holding facility is pumped when less than full, the strength of the waste may vary considerably from that which would normally be expected. All of this type of information needs to be obtained and considered when determining a value for the strength of a particular wastewater.

53.3 - Operation and Servicing of Vault and Chemical Toilets

The Equipment Development Center at San Dimas has developed substantial information regarding the servicing of vault and chemical toilets. Recent publications include the following:

1. Vault Toilets Design and Maintenance. February 1976 topics include:

- Construction hints for vaults and toilet buildings.
- Pumping techniques.
- Pumping equipment.
- Use of odor control chemicals.

2. Mobile Servicing Equipment. Project, Record (2152), March 1976. An extensive work on the equipment and techniques available to Forest managers.

3. Vault Toilet Pumper Vacuum Interrupters. Project, Record (2151), March 1974. Most scavenger equipment relies on vacuum pumping. This publication discusses many of the problems associated with this type of equipment and possible solutions.

4. Vault Toilet Ventilation. A discussion of efficient odor control without the use of chemicals provides alternatives.

53.4 - Water Carriage Waste Collection Systems

Sewers perform the necessary functions of collecting waterborne wastes and conveying them to points of treatment and disposal. Their adequate design, proper construction and continued maintenance are essential to satisfactory performance.

The Forest Service has relatively few large scale sewage collection systems. Usually, piped collection constitutes a small quantity system which flows into a septic tank or small treatment plant. In some instances, lift stations are provided to pump wastewaters to a sanitary district or a Forest Service-operated treatment facility. Because Forest Service recreation facilities are widely dispersed, interceptor and trunk lines are seldom needed. Many developments rely on septic tanks and vault toilets with truck hauling of the pumping. As existing facilities expand, new ones are developed, and water quality requirements become more stringent, the number of central treatment systems is expected to increase.

The collection of sewage from dispersed points in adverse terrain offers many problems to the designer and planner. Sewer alignment should be designed to minimize soil disturbance, avoid obstructions, and blend with the landscape. These constraints, coupled with low average flow conditions, contribute to these problems.

Because of the high probability of rock or wet excavation, strict OSHA requirements for trenching safety, and the need for deep trenches or frequent drop structures or maintain grade in rough terrain, pressure sewers are often as economically feasible option. However, such an option also increases the dependence on an uninterrupted power supply.

53.41 - Design Period

Because wastewater collection systems are very costly and can be expected to last between 30 and 50 years, the designer must make the best possible estimate of the maximum probable population in the service area, the expected uses, and future tributary areas to the sewer under consideration.

Maximum use should be made of the area master plan. The land managers and their staff should first agree on a realistic project life before considering the relative economics of alternatives.

53.42 - System Flow Characteristics

The function of a collection system is to carry the average and peak discharges and to transport suspended solids without excessive deposition.

Wastewater flow rates will vary throughout any design period. The range of flows for which a sewer must be designed (peak flow to minimum) will vary from less than 3 to 1 for larger Forest Service sewers serving stable populations (administrative sites, Job Corps Centers, etc.) to more than 30 to 1 for small systems receiving recreation populations where domestic wastewater is most of the total flow.

There are various ways to predict daily average flows and estimates of peak wastewater flows for Forest Service facilities. Some of them are discussed in chapter 30. The designer must use the drainage fixture unit method (DFU) of determining flows in lateral sewer lines because the discharge rate from a tank type toilet is much greater than the filling rate. All other fixtures are accommodated in the curves development. Table 7 shows the relative load weight of various kinds of fixtures which can be used for estimated flow from a given number of fixtures.

53.43 - Trench and Pipe

53.43a - Preliminary Site Considerations

Considerable attention is required for areas contemplated for trenching to determine necessary working limits for the contractors to perform the required work and to ascertain the acceptable site disturbance.

Knowledge of soil and water table conditions along the route to the sewer should be obtained prior to design, and this, along with special bedding conditions, made part of the contract. Geologic information should be available to prospective bidders.

53.43b - Safety

Safety in trenching operations is a primary consideration in sewer design. The stability of the material encountered along the route must be considered in the design. The contractor has the responsibility to comply with all OSHA requirements, but normally has some options available for the method used. The width of clearing limits related to laying the trench back, sheeting, shoring and "sand boxes" (worker protection devices) are alternatives generally included in specifications. The angle of repose cohesive properties and moisture characteristics of the soil should be determined in connection with these construction methods.

53.43b – Table 7 - Load Weights of Fixture in Fixture Units

Fixture or Group 1/	Fixture-Unit Value as Load Factors	Min. Size of Trap-Inches
Bathroom Group		
Flush Tank for Closet	6	
Flush Valve for Closet	8	
Bathtub (with or without over-head shower)	2	1-½
Bathtub	3	2
Drinking Fountain	½	1
Dishwasher	2	1-½
Floor Drains	1	2
Kitchen Sink	2	1-½
Kitchen Sink, with food Waste grinder	3	1-½
Lavatory	1	1-¼
Lavatory	2	1-½
Shower Stall	2	2
Showers (group) per head	3	
Service Sink	2	2
Pedestal urinal, Syphon Jet, blowout	8	3
Wall Urinal	4	1-½
Urinal Stall, washout	4	2
Water Closet, flush tank	4	3
Water Closet, flush valve	8	3

1/ For fixtures no shown, weights may be assumed by comparing the fixture to one listed with a similar drainage flow loading.

53.43c - Sewer Pipe

There is a wide variety of pipe materials to choose from. The relative advantages and disadvantages of each is illustrated in Table 8. The designer may need to use a combination of pipe materials on a particular project to gain the advantages of each for the most serviceable system.

Main lines in conjunction with manholes should have a minimum diameter of 6 inches. Lines between manholes should be placed on a straight line, and grade should be checked for trueness by lamping.

Connection to the main line from other structures should not be less than 4-inches diameter; and then should be limited to about 200 feet distance and laid on at least 2 percent slope. Cleanouts must be provided for future maintenance.

Thermal plastic material will tolerate mild distortion of the pipe barrel and joint deflection up to 7° in seal-ring joints. The integrity of the pipe cross section can then only be checked with a "go-no-go" device which is pulled through the pipe at time of acceptance. A condition survey of the pipe can be made in the same manner.

53.43c – Table 8 – Sewer Pipe Material

ADVANTAGES	VC	CONC	PVC	ABS 1/	AC	DI	CI	ABS
Low roughness factor			X	X				X
Long laying lengths			X	X	X	X	X	X
Light weight			X	X				X
Tight Joints			X	X	X	X	X	X
Resistance to scour & Abrasion	X					X	X	
Chemical Resistance	X		X	X		X	X	X
Close Dimensional Tolerances			X	X	X	X	X	X
Dimensional Stability in Trench	X	X			X	X	X	
Available in both pressure & gravity		X	X		X	X	X	
Easy Installation		X	X			X	X	
Performs well in unstable soils						X	X	
Low cost/ft.	X		X	X	X			X
Stream crossing						X	X	
Long Service Life	X					X	X	
DISADVANTAGES								
Breakage during delivery & handling	X	X			X	X		
High No. of Joints per Miles	X	X						
Joint integrity poor	X	X						
High cost/ft.		X				X	X	
Deflects & deforms in trench			X	X				X
Not readily available (throughout Country)	X							
Sunlight damage (special storage)			X	X				X
Not available in small pipe diameter		X		X				

1/ Truss Pipe

53.43d - Structural Requirements

The trench must be designed to safely install the pipe and the required backfill. Care should be taken in the selection of the bedding and backfill material to provide adequate support of imposed loads and to prevent stress concentrations. Numerous references (see section 50.8) cite accepted criteria and methods for determining loads and supporting strength. Methods presented in those references are for estimating probable maximum live and dead loads and for both static and moving conditions. Note that the width of trench at the top of the pipe is the controlling factor in determining pipe loading.

53.43e - Backfilling

In general, a trench is excavated at least 6 inches below the grade line of the pipe bottom to remove rocks, roots, or nonuniform trench material. Bedding, selected for the required bedding conditions, is placed in the trench to the elevation of the bottom of the pipe for at least two lengths of pipe. This bedding material is compacted to a specific density approximating the natural ground conditions. After the pipe is installed, the trench is then backfilled with the required material to the pipe centerline and compacted according to the manufacturer's recommendations. The selected backfill is then placed in 6-inch lifts to at least 12 inches over the pipe. The remainder of the trench can then be backfilled with native material screened of oversized rock (generally 6 inches). This native material may be compacted to a specific limit to accommodate imposed loads. In nontraffic zones, a surcharge of material (approximately 1-inch per foot of trench depth) should be left to allow for settling.

53.43f - Wet Trenches

Where wet areas cannot be avoided, trenches must be permanently drained, or the pipe must be ballasted. In either case, the integrity of the joints must be assured. In either case, this is expensive and alternate routes should be selected if at all possible.

53.44 - Gravity Sewers

Gravity sewers ideally should be laid on a slope generally conforming to that of the ground surface, though excessively steep and very flat gradients are to be avoided. The maximum allowable gradient is usually governed by the wearing of the pipe invert by sands and grit at flow velocities in excess of 10-feet per second. The minimum allowable gradient is that required to prevent deposition of solids, usually taken as that required to maintain a velocity of 2-feet per second at full/half-full flow.

In the case of sanitary sewers where high velocity flow is continuous and grit erosion is expected to be a problem, the maximum acceptable design velocity (peak flow) is often 10 fps. For most Forest Service systems which carry little or no grit and intermittent flow is common, higher velocities may be used when necessary.

Steeper terrain may be accommodated by using drop manholes, flatter terrain by lift stations.

53.44a - Design Flows

Some designers work to attain maximum required flow with the sewer flowing full/half-full; others at two-thirds or three-fourths full to provide a margin of safety. In either case, the designer must provide for carrying velocities at average flow.

1. Maximum Flows. In lateral sewers the maximum flow is conservatively the fixture unit flow rate or instantaneous "peak." The flows in main lines collecting two or more laterals are dampened such that the maximum hour average demand would be an acceptable maximum design flow rate.
2. Average Flows. Are a function of both the number of site users and the period of use. There are various methods for estimating average flows; measure the flows in existing sewer systems and make the necessary adjustments to predict future requirements; estimate and total various compounds of flow; use some arbitrary value as the basis of design.

The various tables in section 51.1 have attempted to provide the most realistic method for Forest Service developments by relating daily average sewage generation rates to various category of use units. That is, some flow rates relate to site capacity, others to site users.

It must be recognized that the generation rate can vary significantly from development to development, depending upon the type of campsite, amenities supplied, remoteness of the site, climatic conditions and facility characteristics. The latter item is especially significant if water saving devices are used. Flow rates can be substantially reduced if water conservation systems are used.

Actual use figures for recreation sites should be carefully evaluated for those sites facilities are changed from nonwater carriage to waterborne systems. Use will change significantly when a water carriage system is introduced.

The period of use varies from 10 hours for an office or day use recreation site to 17 or 18 hours for a family campground or a residence compound. The average flow for a segment of sewer would be the tributary daily flow divided by the number of hours the tributary facilities are in use.

If the design velocities for average flows are adequate, solids deposited during the low flows will be resuspended when flows increase and no nuisance should result other than odors and possible vectors.

The system designer must consider the effects of infiltration, which often increases as the system ages. Pipe materials such as thermal plastic (ABS, PVC, etc.) with solvent welded joints or integral seal-ring systems greatly reduce infiltration. Manholes may be an infiltration problem because the field fabrication makes quality control more difficult. (See section 53.44c).

53.44b - Manning's Flow Formula and Friction Factors

The material of which a collection pipe is constructed and the frequency of fittings, manholes and alignment changes are basic to the selection of a friction factor for use in the design. For

these reasons, the designer may wish to select "n" values that are higher than those obtained in laboratory tests with clear water and new pipes usually displayed in manufacturer's literature. Table 9 illustrates the range of pipe slopes by the Manning formula for each type of pipe. The minimum slopes are shown for both one-quarter flow, one-half full, and full flow. A hydraulic element chart (figure 1), will have to be used for depths less than full. Systems design in limited by the energy available for cleansing velocities. The wider the variation rate of flow, the more difficult it becomes to meet this condition.

53.44b – TABLE 9 & FIGURE 1 ARE SEPARATE DOCUMENTS

53.44c - Manholes

Manholes should be durable, watertight structures providing convenient access to the sewer for observations and maintenance operations. They should cause a minimum of hydraulic interference in the sewer.

Manhole spacing should not exceed 400 feet for ease of rodding. Attention should be given to shaping the manhole bottom to minimize head loss and prevent deposition of solids. Care should be taken to ensure tight-joint connections where pipes enter and leave manholes.

Where different size pipes enter and leave the manhole, centerlines should be at the same elevation and at an angle which creates a minimum flow disturbance. U-shaped channels should be constructed in the manhole bottom for all lines, and should be at least the full depth of the line diameter. Floor areas outside the channels should be sloped to drain at a minimum of a 10 percent grade.

The minimum inside diameter of a manhole should be 4 feet for a vertical distance of 5 feet from flow line or to top of manhole, whichever is less. Shallow manholes should be provided with flat slab concrete tops deeper manholes should have eccentric cone tops.

The source of the greatest infiltration in modern sewer systems is often the manholes. They are usually field erected, either precast rings or cast-in-place, and particular care must be taken to seal all joints, whether tongue and groove or butt-joint construction. A number of water stop products are available for the construction joints between the base and the riser, and between precast rings. Manhole covers flush with the surface must be water tight, with blind lifting holes.

There are several considerations for manhole covers:

1. Diameter should not exceed 24 inches except under special conditions, so one man can lift it.

2. In traffic areas the cover should be so rated, non-rocking, and locking.

3. Use blind lifting holes.

4. Cover should have "SEWER" cast in.

Manhole rungs cast into the walls are required to comply with OSHA standards regarding configuration, size and protective coating. Use is discouraged because of the great potential for weakening due to corrosion. Portable ladders may be used as an alternative.

Drop manholes are useful to keep trench depth reduced and grades within acceptable limits. The increased cost of these manholes must be compared with increased trenching costs; therefore, drop manholes should not be used for drops of less than 2 feet, and drops should not be free falling.

53.44d - Cleanouts

Each service connection end of a lateral should be fitted with a cleanout. Clogging is most probable in the upper reaches of the system. A cleanout will enable maintenance crews to rod the line without having to work in confined space of a building and sharp angled plumbing. A cleanout is not a substitute for a manhole and should never be used where two or more laterals intersect.

53.45 - Pressure Systems

Many developed sites are located in upland or mountainous terrain with both favorable and adverse grade between points of sewage sources and treatment facilities. Many others are shoreline developments with inadequate grade for gravity sewers. Both situation may require pressure sewer systems to serve them. Although the Forest Service is not presently using them, vacuum systems may also provide a solution to this problem. There are three distinct types of positive pressure systems characterized by the nature of sewage they transport.

1. Grinder Pump. Solids are reduced by grinding and the resulting slurry is pumped through small diameter pipes to a collection sewer. These systems are generally low discharge and low to moderate head.

2. Force Main. Pumps and lines are sufficiently sized to pass at least a 3-inch spherical solid. These systems operate over the full range of volumes and heads, entirely dependent upon the pump selected.

3. Effluent Pumps. Used for handling septic tank effluents and secondary/tertiary wastewater treatment plant effluents. These pumps span the range between raw sewage pumps and conventional potable water pumps.

53.46 - System Selection

A pressure system should not be selected without an economic analysis simply because of adverse terrain. Economic considerations in situations where a gravity system is technically feasible may mitigate against its use because of deep trenches, solid rock, frequency of manhole placement, or extremely low flows. The advantage of placing small diameter pipes at relatively shallow depths may be more economical in spite of the cost of pump stations, wet walls, power requirements, and possible increased O&M costs over the life of the system.

Gravity lines should be used wherever economical, but a complete economic analysis must be made to determine this in many cases. A pressure sewer may often be advantageous as a portion of an otherwise gravity system.

53.47 - System Design

53.47a - Flows

Incoming gravity flows to wastewater system lift stations are determined in the same way as for a gravity system. As in a gravity collection system, a pressure system must be designed to effectively handle all wastewater flow generated in the service area during times of peak flow. The common force main should be sized to handle all of the wastewater from all contributing lift stations regardless of the pattern of generation.

53.47b - Line Sizing

In a pressure system having multiple contributing pumps, wastewater flows fluctuate during the course of the day. During periods of low or zero flow, sewage solids will deposit in the system lines, and the cleansing of these at average flows is very important to the operation of small diameter pressure lines.

It is important that system pressures during peak flow conditions are not too great to prevent design delivery from any pump intended to operate during such conditions.

Smaller pipe diameters produce higher velocities for the same flow and increased scouring capability. They also create greater energy losses. For long lines, an economical line sizing analysis should be made to achieve the optimum balance of line and power costs. Line size selection, therefore, must be an efficient compromise between economics, scouring requirements and system pressure limitations.

53.47c - Flow Velocities

Velocities are normally selected within a range of 3 to 5 fps. A velocity of 2 fps is considered to be sufficient to prevent settling of solids, but velocities of from 2.5 to 3 fps are usually required to resuspend those which already have accumulated in the force main. If flushing velocities are attained once or twice per day, excessive deposits are not likely to occur.

As previously mentioned, sewage flows may vary from zero to maximum over the course of a day. System conditions of pressure, velocity, deposition and scour must be considered for minimum, average, and maximum flows.

53.47d - Hydraulic and Energy Gradients

The designer of a pressure system must plot the hydraulic and energy gradients to ensure that both pressures and velocities are acceptable at points of entry to wet wells, manholes, or collecting sewers and is sufficient at points of conveying flows in other pressure lines to permit

delivery (such as a grinder pump discharging it to a force main). Both gradients must be plotted over the entire operating range of each segment of the system.

53.48 - Air-Release

High points in a pressure line must be equipped with automatically controlled valves or vertical riser pipes with allowance for surges and the release of accumulated air and relief of vacuum.

The designer must take care to specify an air release or vacuum relief valve especially designed for sewage application (the working mechanism isolated from sewage solids).

Large orifice valves are needed to release air quickly during the initial filling of the line. This valve can also be used as a vacuum relief valve during the emptying of the pipe for repairs.

53.49 - Pumping Stations

Location, arrangements, type of equipment and structure, and future needs, such as maintenance and external appearance, are all basic considerations in the design of any pumping or lift station. The possibility of flooding or overflow due to pump failures must also be considered in system layout.

53.49a - Pumping Equipment

Pumping equipment used in wastewater pumping stations may be classified into four general types; pneumatic ejectors, centrifugal pumps, air lifts, and positive displacement pumps (such as helical progressing cavity). Pneumatic ejectors are described in 53.45d2. The general description of other pumps, their characterization and their selection is found in chapter 60.

53.49b - Pneumatic Ejectors

Pneumatic ejectors are used largerly for lift stations (up to approximately 100 gpm) where their advantages outweigh their low efficiency (about 15 percent) and relatively high noise. Their advantages are: (1) Sewage is completely enclosed permitting no sewer gases to escape except through the vent; (2) The relatively few moving parts in contact with sewage require little attention or lubrication; and (3) Ejectors are not easily clogged.

The primary disadvantage is that their capacity must double the design inflow. A pneumatic ejector consists of a closed tank into which sewage flows by gravity until it reaches a certain depth. Then enough air under pressure is admitted into the tank to discharge the liquid. The inlet pipe check valve prevents sewage from leaving the tank except through the outlet pipe check valve, which prevents backflow into the tank. The following is an empirical formula for the approximate capacity of air required to operate an ejector:

$$V = \frac{Q(H+34)}{250}$$

In which V is the volume of free air required in cfm, H is the total head in feet, and Q is the rate of sewage discharge in gpm.

To allow for expansion of air is the storage tank, as the sewage is displaced, the volume of the air storage tank and the characteristics of the air compressors selected should be adequate to provide the proper volume of air at a pressure at least 40 percent higher than that required to raise all sewage the maximum computed lift.

The nature of the operation of an ejector is noisy; therefore, this must be considered in the selection.

Ejectors and compressors should always be installed in duplicate to assure that service will not be interrupted by mechanical failure or for regular maintenance.

53.49c - Wet Well Design

Storage capacity usually is required for all wastewater and storm water pumping stations where automatic controls and variable speed drives are not furnished to match pumping rates exactly with inflow rates. The selection of proper storage capacity is critical because it affects the retention time in the station and the frequency and time of operation of the pumping equipment.

From a mechanical standpoint it is desirable to operate a pump for long periods if not continuously, but to do this usually requires larger storage, long retention times and difficulty in the maintenance of aerobic conditions in the sewage. Aeration of the wet well may be considered.

Most design practices base detention on the average rate of flow, but the maximum and minimum rates are also determining factors in sizing the wet well. The desired results can be attained, except for large capacity stations, if the size of the wet well is such that with any combination of inflow and pumping, the cycle of operation for each pump will be not less than 3-5 minutes and the desirable retention time in the wet well will not average more than an hour during peak day operations. In many recreation areas, during midweek, the designer should strive for twice daily operation as a minimum.

It should be kept in mind that the longer the detention period, the greater the chance for the generation of dangerous gases from septic sewage and the accumulation of sludge in the bottom of the wet well. The latter will also increase nuisance odors and the frequency of pump stoppages. Explosion proof fixtures may be necessary where pump room ventilation depends on mechanical devices and there are no positive seals from the wet well. See section 62.91.

The shape of the wet well should be such that solids build-up is minimized. Accumulation of solids is less in wells with hopper bottoms. Hoppers in wet wells should be constructed with slopes not flatter than 1 horizontal to 1.75 vertical.

Provision should be made for adequate access to wet wells for inspection and cleaning. Proper lighting and ventilation facilities also should be available whenever the wet well is entered for any reason. Suitable access opening and facilities are needed for the removal of accumulated solid matter which cannot be pumped.

Where wet wells are totally enclosed, adequate vents are needed to allow for entrance and exit of air as the liquid level in the sump rises an falls.

53.49d - Screening Devices

Considerations should be given to protecting the pumps by some method of screening. The types generally used in Forest Service installations are (1) bar screens, (2) basket screens, (3) comminutors, and (4) combinations of (3) with (1) or (2).

53.49e - Wet Well, Only, Pump Stations

Many pump stations are simply wet wells containing submersible pumps which are either non-clog sewage pumps or grinder pump combinations. The designer must be especially concerned with liquid level control, clear access and room for pulling pumping equipment, and high hazard environment. The other disadvantages of these stations are (1) the pumping equipment is always in the waste, (2) the controls are usually panel mounted and some distance from but in sight of the station. The advantages are (1) lower cost in flow portions of the system, and where a deep lift station is necessary, (2) no priming equipment is necessary and (3) a less imposing impact on the site.

53.5 - Special Design Considerations

53.51 - Sulfide Generation

In wet wells, fore mains and long gravity runs where wastewater may stand for long periods of time, temperatures are elevated and ventilation is poor, sulfides may be developed through the anaerobic reduction of sulfates.

Under these conditions, hydrogen sulfide (H_2S) will be generated and may cause odors (rotten egg), structural damage (concrete and steel), explosion potential, or a lethal atmosphere. The system should be designed to minimize the effects of hydrogen sulfide production by maintaining steady flow to treatment by using dosing tanks with siphons to supplement low flows, and providing adequate pipeline ventilation or introducing diffused air in the stream if H_2S production becomes critical.

Anaerobic conditions can be expected in most recreation area systems because of low mid-week flows. It is suggested that neither concrete nor asbestos cement pipe be used where long retention times are expected. Type II cement should be specified for all structures in a sewage environment, and surfaces coated with coal tar epoxy to prevent the gas from deteriorating the inside.

53.52 - Burial Depth

In addition to attaining necessary grades for sewerlines, other factors influencing burial depth are: (1) water table elevation, (2) frost depth, (3) imposed live and dead loads, (4) selected pipe

materials, (5) potential erosion and (6) soil disturbance from other land management activities in the area.

53.53 - Siphons

Occasionally, sewers must be constructed with the sewer depressed below the hydraulic gradient for all conditions of flow (inverted siphons, inlets into lagoons). This is usually undesirable because of the difficulty of maintaining adequate cleansing or scouring velocities over the wide range of discharges encountered (the effective range is 3 to 5 fps.).

53.54 - Pipe Joints

Expansion joints in piping supported on bridges should match expansion joints in the bridge to which the pipe is attached. It may be necessary to provide insulation around suspended pipe. There are several very effective thermal protection systems on the market.

53.55 - Dosing Tanks

Minimum velocities should be sufficient to prevent solids deposition and retard sulfide formation. The sewer should be designed so that at the initial average flow a velocity of at least 2-feet per second will occur to prevent deposition of solids. When grades are extremely flat, or during the initial phases of development of the facility, it may be impossible to obtain scouring velocities without supplemental flows.

Where this is the case, a dosing tank with an automatic siphon discharging clear water or wastewater into the system at least once per day should be used. The average discharge of the dosing siphon should be sufficient to provide the needed velocity and the tank should be of sufficient size to provide several minutes flow. A velocity of 3-5 fps is needed to resuspend settled solids. This added hydraulic loading must be considered in the treatment facility design.

When properly installed, automatic dosing siphons will give satisfactory service. They contain no moving parts and are more dependable than devices that depend upon moving parts for their operation. For details and capacities, manufacturer's literature should be consulted.

53.56 - Multiple Utility Trenches

It is generally unadvisable to combine potable water and sewerlines in the same trench system, but this may be a last resort practice for reasons of economy and severe local environmental disturbance. Traditionally, codes and standards have mandated separate trenches for good reason:

10-foot horizontal separation between sewers and waterlines to prevent the contamination through cross-connection from the following:

Poor sewer pipe joint integrity in old pipe (lead and jute in C.I. and V.C. pipe and early ring seal joints); water system shutdown or negative pressure; and water pipe failure.

1. Cross-Connection Risk Reduction. The risk of cross connections occurring can be significantly lessened by using the following techniques: (See Figure 2, Multiple Utility Trench).

a. Placing the waterline a minimum of 18 inches clear distance above and horizontally away from the nearest sewer line (gravity or pressure).

b. Placing waterline on a natural ground bench.

c. Using pressure-rated plastic gravity sewer lines.

d. Casing pressure sewers with joints staggered to minimize simultaneous joint failure.

2. Other Considerations. The following are other considerations for multiple-use trenches.

a. Electrical and communication lines should be placed under a suitable colored concrete slurry under the sewerline. This will protect the cable during excavation and repair of the sewerlines.

b. Gravity and pressure sewers should be placed in horizontally separate positions with 18 inches clear distance between them for re-excavation protection.

c. Electrical or communication lines must be carefully inspected to ensure their integrity before and after backfilling and applying a slurry.

d. The use of magnetic pipe locator tape to permit these pipes to be conveniently located.

53.56 - FIGURE 2 IS A SEPARATE DOCUMENT

54 - Pretreatment

54.1 - Hydraulic Aspects: Managing Flow

The nature of the collection system is one factor which influences the characteristics of wastewater when it reaches the treatment plant. Unusually long collection lines, solids deposition in low gradient sewers, low flow depths, and extended retention times in lift stations and force mains can all contribute to the development of septic conditions within the system. Problems that are often encountered in the treatment process are brought on by abrupt changes in hydraulic loading, sewage strength, and composition of the influent. The detrimental effects of these problems can generally be minimized through judicious design, timely maintenance, and proper plant operation.

54.11 - Dilution

Under normal conditions, treatment plan influent is sufficiently diluted with water to enable the organic loading to be fairly well mixed when it reaches the plant. Although various treatment

methods are able to assimilate short-term shock organic loadings, a properly designed system can minimize their effects through different methods. The amount of dilution required to satisfactorily handle concentrated organic loadings depends on the plant size and type, present biological conditions, and loading rate. Excessive dilution of influent can be inhibiting to the stabilization process and is generally caused by inflitration of ground and surface water into the collection lines and manholes. Pipe joints, foundation bedding for sewers and manholes, and waterproofing of lift stations and manholes must all be tested during construction to assure that excessive infiltration is avoided.

54.12 - Concentration

Wastes from holding tanks, septic tanks, vault toilets, and chemical toilets are highly concentrated with organic and inorganic matter and often contain substances which can be toxic to micro-organisms. Many of these wastes, however, have proved amenable to treatment by aerobic biological methods. Formaldehyde based fluids used in recirculating type chemical toilets are one of the more commonly used chemicals found in portable units. The normal concentration of wastes from these units must generally be cut by a factor of at least 100, preferably using other wastewaters, to ensure continued adequate microbial action within the plant. This would result in influent BOD's of 200 to 300 mg/l. These and other organic concentrated wastes may be fed to the raw sewage influent in controlled doses to allow acclimatization or adaptation to be brought about by natural selection of the microorganisms. One method of applying concentrated waste to a small activated sludge treatment plant is to utilize an aerated holding tank as a side-line unit and equip the tank with a submersible type pump operated on an electric timer. Flow into the plant may be regulated by adjusting the amount of flow being diverted and recirculated back into the holding tank. Lagoon systems may not require dilution of concentrated wastes if they are designed for "slug" loadings.

54.13 - Flow Equalization (Surge Tanks)

The primary objective of flow equalization for wastewater plants is simply to dampen the diurnal flow variations, and thus achieve, as near as practicable, a constant flow rate into the treatment plant and through the downstream treatment processes. A desirable secondary objective is to dampen the variations in concentration and mass flow of wastewater constituents by blending the wastewater in the equalization tank. Where highly concentrated organic wastes must be treated, the equalization tank provides an additional buffer to lessen the adverse impact of shock organic loadings.

Flow equalization permits the sizing of new clarifiers based on equalized flow rates rather than peak rates. In the case of existing aeration plants, the addition of a surge tank decreases the surface overflow rate in the final clarifier, allowing the same effect as an increase in the clarifier size.

One procedure for computing equalization volume requirements is based on the characteristic diurnal flow pattern. In this case, the function of the surge tank is to store flows in excess of the average daily flow and to discharge them at times when the flow is less than average. The graphical determination of surge tank size is done using a hydrograph.

The hydrograph procedure starts out with establishing a diurnal flow pattern and should be based on actual plant flow data, if possible. Since flow patterns vary from day to day, the pattern selected for the design size must yield an effective volume to equalize any reasonable diurnal flow. Figure 1 depicts a typical flow pattern for an average flow of 43,000 GPD. The inflow-mass diagram is plotted first by converting flow data to equivalent hourly volumes, and an accumulation of the 24-hour day. A line is drawn from the origin to the end point of the inflow-mass diagram. The slope of this line actually represents the average daily flow. The vertical distance between the two parallel tangents A and B, drawn at the high and low points of the "curve," represents the required volume of the surge tank. In this example, the required volume for equalization is 7,400 gallons. The actual tank volume must be greater than that obtained with the hydrograph for several reasons, including:

1. Continuous operation of aeration and mixing equipment.
2. Built-in shutoff level of pumps will not allow complete drawdown.
3. Some contingency should be provided for unforeseen changes in diurnal flow.

Provisions for tank overflow into the plant should be allowed in the event of lift pump failure or excessive inflow. A sloped floor within the tank will help prevent solids deposition.

Single surge tank installations, which may be used for small plants, must allow for complete treatment during tank dewatering. This will require a bypass line around the basin, to allow the downstream portion of the plant facility to operate if the flow equalization facility is out of service; however, the surge tank should only be taken out of service during periods of low flows.

On larger plants it is often advantageous to provide the surge tank at a location other than at a single plant inlet. In some instances, the tank may be combined with the aeration compartment of an activated sludge treatment plant (inplant equalization). This configuration feeds effluent at a near constant rate to the final clarifier.

A side-line flow equalization basin may be installed which allows only an amount of flow above the average daily flow to be diverted through the equalization basin. This scheme minimizes pumping requirements at the expense of less effective concentration damping.

SEE PAPER COPY FOR FIGURE 1

54.2 - Physical-Mechanical Aspects: Managing Suspended and Settleable Solids

Components providing pretreatment of wastewater in the plant headworks enhance the performance of the biological treatment process and protect pumping and other mechanical equipment.

Typical headworks components usually perform physical or mechanical processes rather than chemical or biological processes.

In wastewater treatment facilities of the sizes common to many Forest Service installations, pretreatment may be adequately accomplished by racks or bar screens, comminutors or grinders, and possibly grit chambers.

54.21 - Screening

Screening is used to remove suspended or floating material which could interfere or cause damage to subsequent equipment or processes. Basically, it involves placing a device in the wastewater flow that has fixed openings.

The installation of bar screens or racks is common to most treatment plan headworks for screening out larger solids. Rectangular bars approximately 3/8 inch by 2 inches and welded in parallel with openings about 1-1/2 inches wide are common. This rectangular screen is normally sloped back at an angle to the flow line so that debris is caught and is easily removed by periodic manual raking or, in some instances, by mechanical devices Screens are generally categorized as course or fine. Coarse screens are often referred to as racks or bar screens and have nominal openings 1/8 inch or larger. Fine screens (1/8 inch or smaller) retain smaller solids and usually consist of a rotating cloth media that is cleaned by high pressure water sprays.

54.22 - Comminution

Comminutors are essentially electric grinders which usually follow bar screens to cut up solids in the raw wastewater to prevent adverse effects on later pumping or treatment processes. Where grinder type pumps are used at the plant headworks, the need for a cominutor is eliminated. Because comminutors require periodic maintenance and often temporary removal, a permanent bar screen upstream of the comminutor should be installed to prevent downstream problems.

54.23 - Grit Removal

Grit removal equipment is utilized for the same general purpose as screening equipment; to protect downstream equipment from premature breakdown and repair caused by grit. By locating grit removal equipment immediately after the bar screen and ahead of all other treatment units, much of the mechanical equipment can be protected from excessive abrasion and wear.

Grit removal equipment includes grit chambers and centrifugal separators. Grit chambers are designed to remove grit consisting of sand, gravel, cinders or other heavy solid material which is substantially denser than most organic solids in the wastewater. Grit chambers provide a basin or channel in which the velocity of flow is reduced, allowing the inert higher specific gravity particles to settle out and the organic material to pass through. Aerated grit chambers are used to enhance the separation of the grit from the organic material and they often provide the dissolved oxygen required to maintain aerobic conditions prior to actual physical or biological removal of organic material. Settled grit can be removed by hand (duplex channels required), inclined screw, reciprocating rake, or air lift pump. Some grit removal devices include a grit washing cycle to further rid the grit of remaining organics.

Centrifugal separators or liquid cyclones remove grit by centrifugal force. Wastewater is pumped through the separator causing the water to circulate such that the heavier particles are

forced (centrifugally) to the outside and collected. The smaller and lighter particles pass through the device along with the wastewater.

The need for a grit removal device at a Forest Service facility should be carefully analyzed before a decision is made to include it in a treatment process. Grit removal equipment is generally most effective when used in municipal type wastewater treatment plants.

54.24 - Oil, Grease Scum Removal

Oil, grease, and floating solids may interfere with some treatment processes and should be removed if large quantities are present in the raw wastewater. Aerated skimming tanks with detention times of about 3 minutes are commonly used for oil, grease, and floating solids removal. Air requirements are approximately 0.03 ft 3/gal. of wastewater for these units.

54.3 - Biochemical Aspects: Managing Dissolved Solids

A large portion of the BOD found in raw domestic wastewater is dissolved and cannot be removed in the pretreatment process through physical or mechanical means. When the wastes arrive at the plant in a septic condition, the facultative and anaerobic bacteria have begun utilizing the available oxygen, nitrates and sulfates, in the wastewater as their energy source.

The pretreatment process may be employed at the headworks of the treatment plant, or within the collection system itself, in order to mitigate any adverse impacts of septic wastes on the treatment process.

Methods commonly employed for this purpose follow.

54.31 - H_2S and Odor Control

Fresh domestic sewage has only a slightly musty odor, and as long as aerobic conditions are maintained odors are minimal. Under anaerobic conditions, biological activity with sulfates produces hydrogen sulfide, which is one of the most common toxic by-products of septic domestic raw wastewater. Hydrogen sulfide, with its characteristic rotten egg odor, is not only extremely toxic to humans, but is a highly flammable gas. These odors should be controlled upstream of the plant through the use of aeration or chemical treatment.

54.31a - Prechlorination

Chlorination is probably the most widely used of the chemical treatment methods available to control odors because of its effectiveness and because it is usually available at the treatment plant. The application of chlorine acts on the odor producers by reacting chemically with odorous sulfur compounds, oxidizing them to innocuous forms and by retarding biological action.

The prime consideration here is that the chlorine dosage should not produce a high residual chlorine level which may in turn be detrimental to secondary biological units.

54.31b – Pre-aeration

The prevention of odor problems through pre-aeration is effective with relatively short aeration periods, in the order of 15 minutes. Additional improvements to the treatability of raw wastewater by longer aeration periods include the benefits of grease separation and improve flocculation of solids. The main considerations in the design of pre-aeration facilities are air application rate and retention time. Detailed design data is available in references.

54.31c - Hydrogen Peroxide

Hydrogen peroxide is used to control hydrogen sulfide in wastewater. Hydrogen peroxide reacts with hydrogen sulfide to form water and sulfur. Theoretically, this reaction requires a 1:1 ratio; however, in practice a higher ratio is used. The result is a contribution of dissolved oxygen which inhibits the regeneration of hydrogen sulfide.

54.32 - Heavy Metals Control

Forest Service wastewater plants will normally not be involved with the treatment of wastewaters that contain a high concentration of heavy metals. However, the type and source and control of these wastes is briefly discussed.

54.32a - Types and Sources

Most wastewaters that contain heavy metals are associated with discharges from industrial processes or manufacturing plants. Metal finishing wastes contain oil, cyanide, chromium, and other toxic metal ions. Textile wastes have relatively high BOD and total solids concentrations. Food processing wastes have high grease content and may also contain large amounts of nitrogen and phosphorus. Many manufacturing wastes contain refractory compounds such as dissolved salts. The strengths and toxicity of these wastes varies greatly with the process or product involved.

54.32b - Effects on Treatment Processes

Most industrial wastewaters containing heavy metals or other toxic materials or having other high strength substances will have an adverse effect on biological treatment processes. The degree of problem can range from total destruction of the biological organisms due to toxic metal ions to a temporary upset of the plant efficiency because of un-equalized flows. BOD concentrations can be much greater than those for domestic wastes. Total solids are greater and vary in character from colloidal and dissolved organics, to predominantly inorganic salts. The suspended solids concentration relative to BOD must be considered when using conventional sedimentation and secondary biological treatment. The high strength, settleability, nutrient content, and toxicity of these wastes must be controlled to alleviate the impact on the treatment processes and to provide an acceptable final effluent.

54.32c - Control

The majority of industrial type wastes are more amenable to biological treatment after dilution, generally with domestic wastewater flows. However, regulations now require pretreatment at the source for wastes having strengths or characteristics significantly different from sanitary wastewater.

The method or type of pretreatment includes waste strength reduction, flow equalization, by-product recovery, implant wastewater reuse, and segregation of waste streams for individual pretreatment or controlled mixing and separate disposal. Pretreatment of these wastes prior to discharge into conventional biological treatment systems will reduce or eliminate the adverse effects experienced in the past.