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CASCADE WATER REUSE.(U)

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Cascade Water Reuse.

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CIVIL AND ENVIRONMENTAL ENGINEERING DEVELOPMENT OFFICE

(AIR FORCE SYSTEMS COMMAND)
TYNDALL AIR FORCE BASE
FLORIDA 32403

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The water reuse model described in this report was developed to assist Air Force personnel in reusing wastewater on Air Force bases. The model aids in selecting the most cost effective networks for wastewater collection, treatment and reuse in base activities.

The model is comprised of two separate phases. Phase I provides a basic activities summary to simplify and clarify reasonable cascade couplings between activities. With this as a foundation, feasible activity cascade

networks can be developed for input into Phase II of the model. Phase II provides the following data for each of these networks:

1. Requirements for piping and storage.

2. Required treatment efficiencies and treatment chains.

3. Estimated total reuse system costs (water purchase, discharge fees, piping, pumping, storage, and treatment.

In developing this model, the contractor gathered pertinent information relating to water quality and quantity demands of various base activities and the extent of degradation through use. This information, along with specific data gathered at individual bases, was used to test the cascade reuse model at Davis-Monthan and March Air Force Bases to evaluate reuse potential at Andrews Air Force Base and to aid in the conception and actual design of treatment and reuse facilities at Peterson Air Force Base. The users manual for use of the computer software for this model is published as CEEDO TR-77-26; a description of the software is published as CEEDO TR-77-28.

FOREWORD

This report documents work performed during the period 1 October 1974 through 1 December 1976 by SCS Engineers of Long Beach CA. The contract number was F2960175C0019, through the AFCMD/PMR office at Kirtland AFB NM. The effort was controlled inhouse under job order number 21036W45 by AFWL/DEE, Kirtland AFB NM (1 October 74 through 1 April 75), AFCEC/OL-AA/EVW, Kirtland AFB NM (1 April 75 through 1 March 76), and AFCEC/EVW, Tyndall AFB FL (1 March 76 through 1 December 76). The final report was edited and published under AFCEC/ EVW, Tyndall AFB FL (1 December 76 through 15 April 77) and Det 1 (CEEDO) ADTC/ECW, Tyndall AFB FL (after 15 April 77). The Air Force project officer was Captain Fredrick Inyard from 1 October 74 through 1 March 74, Captain Stephen P. Shelton from 1 March 74 through 1 June 77, and Captain Gary R. McNutt from 1 June 77 through 1 August 78.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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INTRODUCTION

SCOPE

Wastewater reuse has become an important tool in solving a number of stressing problems. It offers a means of extending water supplies and alleviating fresh water demand. Where stringent discharge requirements or high surcharge fees are a problem, reuse can reduce discharge volumes and costs. As the demands on our fresh water resources grow steadily and environmental protection becomes increasingly critical, wastewater reuse has been shown to be an effective, important method of resource conservation.

Across the United States, over 300 full scale wastewater reuse programs are in operation. The majority of these utilize the water for irrigation, although a growing number are supplying industrial plants and recreational facilities. These programs have shown the economic and environmental benefits of reuse under properly controlled conditions.

Many Air Force facilities could benefit from efficient reuse of wastewater. A large percentage of these bases are located in areas of potential water shortage or in areas with stringent effluent discharge and/or sewer surcharge requirements. One method of alleviating the severity of these problems is to maximize wastewater reuse.

It is the purpose of this study to develop, test, and apply a computer program that will aid in selecting cost effective cascade reuse networks for Air Force bases.

In essence, a cascade reuse network is a system in which wastewater discharged from activities (i.e., base housing, vehicle washing, laundry, etc.) is collected, blended, treated, transported and reused in the same or other activities on the base. In this way, fresh water normally required for these operations is conserved, and volumes of wastewater ultimately discharged to streams or municipal sewage systems are minimized. In practice, the computer program aids in determining the networks that provide water reuse at the lowest cost.

The cascade reuse model was tested at two case study sites: March Air Force Base and Davis-Monthan Air Force Base. In addition, evaluation of limited reuse potential for Andrews Air Force Base was performed. The model was then utilized at Peterson AFB in Colorado Springs to aid in the basic design of a treatment/reuse facility at that installation.

OBJECTIVES

In order to develop a successful reuse program, it is necessary to have knowledge of the tolerable water supply limits and discharge water characteristics for base activities. In addition, one must be able to provide adequate blending, treatment, and storage of wastewater streams throughout the system so that sufficient water quality and quantity is ensured at all activities at all times. A further criterion is to minimize total system cost.

The objectives of this report are:

1. To summarize existing data on Air Force base activities in regards to necessary water supply quality and quantity, and wastewater characteristics.

2. To develop a cascade water reuse model (and associated computer software) to aid in selection of the most cost effective reuse networks.

The first objective will render reuse more effective by succinctly delineating the quality and quantity of water required for use by activities and discharged by activities. If this information is not available, it is very difficult to determine appropriate treatment requirements.

The second objective will allow base engineers to quickly evaluate many different reuse schemes that would require months to do manually. The computerized model provides a concise summary of total project costs and a solid means of alternative comparison.

APPROACH

The basic approach taken in developing an effective wastewater reuse model can be divided into four avenues: data acquisition, model development, case study trials, and application.

Data acquisition consisted of reviewing all pertinent literature to obtain data on tolerable input water quality concentrations and degradation effects of Air Force activities. This information serves to substantiate specific base data and to fill in gaps where actual results are not available. In addition, information was gathered relating to the water distribution, wastewater collection, and treatment systems of the three bases which were used for case studies.

Model development consisted of six months of intensive work by the contractor's programming staff in conjunction with environmental engineering personnel. Initial trial runs and debugging procedures were conducted at the Air Force computer center at Kirtland AFB, New Mexico. The final model is a sophisticated tool that can be used for a variety of wastewater reuse systems. Although primarily designed for use at Air Force installations, the program can be similarly applied to other military facilities, municipalities, and large private industries.

Three Air Force bases (Andrews, Davis-Monthan, and March) were selected as case studies to test the performance of the computer oriented model. These trial runs were necessary for debugging the model to highlight shortcomings that could be corrected. In this way, it was possible to modify the computer software to provide the most practicable tool under actual operating conditions. The field investigation at Andrews Air Force Base, however, showed that only minor reuse potential existed there, and it was not cost effective to perform the computer analysis for Andrews. A manual analysis was performed for Andrews Air Force Base and serves as an example of a base where preliminary investigation shows that the situation does not warrant proceeding into the computer simulation phase.

Peterson AFB was then selected as the first "real world" application of the model. Although not a large base, Peterson is anticipating problems of water shortage and rising procurement costs. Located in semi-arid central Colorado, initial investigation showed a strong potential for irrigational reuse on golf course and base landscaping. Output from the cascade program was instrumental in the early selection and design phase of a reuse system highlighted by aerated lagoon and slow sand filter treatment prior to irrigation.

SECTION II

BASE ACTIVITY DESCRIPTIONS

GENERAL

This section summarizes typical Air Force base activities in their relation to cascade wastewater reuse. Literature data pertaining to activity water volume usage, tolerable source water quality, wastewater volume generation, and wastewater pollutant concentrations (degradation by the activity) was obtained from the Industrial Waste and Water Pollution Surveys. These surveys were conducted at various Air Force bases by the Environmental Health Laboratory at Kelly Air Force Base, Texas, unless otherwise noted.

Very little work has been done to date in determining acceptable water quality levels for Air Force base activities, excluding strictly domestic uses. The Air Force literature is void of such information, and future effort should be made to identify these limits. Wherever feasible, other non-Air Force literature sources were utilized to estimate tolerable quality limits for various activites. For example, the necessary quality of irrigation water for golf courses, athletic fields, etc., is well documented in the technical literature and entirely applicable to similar activities at Air Force bases.

ACTIVITIES

Air Force bases are, in essence, small cities with all the services and activities one would expect in a small metropolitan area including residential, commerical, industrial, and recreational components. Table 1 lists the typical activites found at Air Force bases. Not all bases will contain the activities listed in Table 1, and some bases will contain water using and wastewater generating activities not listed, e.g., laundries. As the reader will see in later sections of this report, however, activities can be added or deleted from the water reuse model as desired.

A major difference between Air Force bases is the extent of industrial activity. Those bases designated Air Logistics Centers (ALC's) contain extensive industrial operations which strongly influence the character of the overall base wastewater generation. Major ALC's include Tinker, Kelly, Hill, McClellan, and Robbins Air Force Bases. Other bases may have industrial discharges, but in general, the industrial component will be minimal in flow and pollutant loadings compared to the domestic portion.

A second major difference between Air Force bases is the quantity of water required for irrigation. Bases located in geographical areas

TABLE 1. TYPICAL WATER CONSUMING/GENERATION ACTIVITIES AT AIR FORCE BASES

Domestic

Base Housing
BOQ
VOQ
Barracks
Unclassified Office Space
Hospital/Clinic
Commercial Services (BX, Recreational Activities, Filling Station, Guest Hall, Cafeteria, Clubs, Retail Facilities)

Industrial

Aircraft Wash Rack
Vehicle Wash Rack
Plating and Metal Finishing
Photo Processing
Paint Shop
NDI Shop
Degreasing
Heating/Cooling/Power Generation Plant
Jet Engine Test Cells

Total Sinks

Golf Course
Landscaping
Athletic Fields
Parade Grounds
Fire Protection/Spill
Washdown Reservoir
Recreational Lakes

enjoying regular rainfall, e.g., Andrews Air Force Base, use very little irrigation water, whereas, bases located in semi-arid areas, e.g., Davis-Monthan Air Force Base, use large quantities of irrigation water. Since irrigation is usually the most significant potential use for reclaimed wastewater, those bases having plentiful rainfall are less likely candidates for wastewater reuse.

The following subsections provide a brief summary of the water usage and wastewater generation characteristics of various base activities listed in Table 1.

BASE HOUSING

The Air Force typically uses a design figure of 100 gallons per capita per day as the anticipated average domestic sewage flow from base housing residential areas. The average per capita figure is multiplied by the number of dwelling units times the estimated average persons per dwelling unit (an average of 3.5 persons per dwelling is used) to arrive at the total average daily domestic sewage flow. Typically, these design assumptions are conservative, i.e., they result in an estimated average flow volume which is more than the actual average flow volume, thus providing a built-in safety factor for sewer capacity design purposes. For reuse system design, however, the base may wish to carefully measure its actual average domestic sewage flow volume since this volume will often be the major portion of the wastewater available for potential reuse purposes.

TOLERABLE WATER QUALITY

The water supply quality for base housing should meet the US Public Health Service drinking water standards. Table 2 summarizes some of these limits.

TYPICAL FINAL EFFLUENT

Effluent from residential base housing is normally typical domestic waste, as summarized in Table 3. Significant differences can occur between bases, however, as a result of groundwater infiltration, window cooler contributions, garbage grinders, and other reasons. If a major wastewater reuse system is planned, an evaluation of the specific wastes generated at the base being considered should be performed.

The reader will note in Table 3 that some of the inorganic constituent concentrations in the wastewater are dependent upon the concentrations of those constituents in the source water supply. For example, if the source water TDS concentration is designated "X", then the wastewater TDS concentration is equal to X plus the additional TDS increment added by domestic household use of the freshwater.

TABLE 2. RECOMMENDED UPHS DRINKING WATER STANDARDS

Constituent	Max. Limit mg/l
Phenol	0.001
Cyanide	0.2
Cadmium	0.01
TDS	500
Chlorides	250
Sulphates	250
Chromium (total)	0.05
Copper	1.0
Iron	0.3
Lead	0.05
Manganese	0.05
Nitrates	45
Zinc	5.0

TABLE 3. TYPICAL BASE HOUSING SEWAGE CHARACTERISTICS

Constituent	Concentration, mg/l	
BOD	200	
COD	300	
SS	300	
O&G	0.5	
NH_4	30	
PO_4	10	
CN	0.01	
Phnl	0.15	
TDS	300	plus source water concentration
Cl	100	plus source water concentration
Na	50	plus source water concentration
$CaCO_3$	80	plus source water concentration
Fe	1.0	plus source water concentration
B	1.0	plus source water concentration

Cascade Potential

Currently, potable wastewater reuse is not economically feasible in the United States. Therefore, base housing and other domestic activities on Air Force bases will not be considered as potential users of reclaimed water. The normally large volume of wastewater generated by base housing has, however, excellent subpotable reuse potential after secondary or tertiary treatment.

OFFICERS QUARTERS, BOQ AND VOQ

Description

Each base provides apartment-type quarters for bachelor officers (BOQ) and visiting officers (VOQ).

Flow

Wastewater generated by BOQ and VOQ quarters averages approximately 45 gallons per person per day.

Tolerable Water Quality

These quarters require water meeting the Drinking Water Standards as delineated under the "Base Housing" activity.

Typical Final Effluent Quality

These quarters generate domestic wastewater with constituents as summarized under base housing.

Cascade Potential

Cascaded water is not currently acceptable for use in the BOQ and VOQ. However, the wastewater from these activities has excellent subpotable reuse potential after treatment.

BARRACKS and TRANSIENT AIRMEN'S QUARTERS (TAQ)

Description

Each base provides barracks for enlisted men and transient airmen's quarters that are similar to the barracks accommodations.

Flow

Wastewater generated by the barracks and TAQ facilities averages approximately 25 gallons per day per person.

Tolerable Water Quality

See base housing.

Typical Final Effluent Quality

See base housing.

Cascade Potential

See base housing.

UNCLASSIFIED OFFICE SPACE

Description

Unclassified office space is limited to office facilities only (i.e., not buildings with labs) and includes: headquarters, base operations and various tenants.

Flow

Wastewater generated by office facilities averages from 10 to 25 gallons per person per day.

Tolerable Water Quality

See base housing.

Typical Effluent Quality

See base housing.

Cascade Potential

See base housing.

HOSPITAL/CLINIC

Description

Current Air Force policy requires a base to have 2,700 active-duty personnel to be eligible for a hospital. Smaller bases provide clinics primarily for out-patient service.

Flow

Wastewater generated by hospitals and clinics averages roughly 200 gallons per day per bed.

Tolerable Water Quality

See base housing.

Typical Effluent Quality

See base housing.

Cascade Potential

See base housing.

COMMERCIAL SERVICES (BX, FILLING STATION, CLUBS, CAFETERIAS, RECREATION FACILITIES, THEATERS)

General

Air Force bases are essentially small cities and as such, require the commercial services listed above.

Flow

Wastewater generated by commercial services is domestic in quality and usually of negligible volume. It can be assumed that the domestic volumes previously discussed adequately include the volume generated by commercial activities.

Tolerable Water Quality

See base housing.

Typical Effluent Quality

See base housing.

Cascade Potential

See base housing.

AIRCRAFT/AGE WASH RACK

Description

All bases have facilities for washing aircraft. However, the magnitude of the operation varies greatly from base to base. The major wastewater generation is from water used to rinse off solvents (i.e., PS 661) and detergents applied to the aircraft.

Flow

Wastewater generation depends on the number and type of aircraft washed. Average volumes generated are reported to be 2,000 gallons per plane for small craft up to 7,500 gallons for large aircraft. Total generation at bases ranges from approximately 5,000 to 50,000 gpd.

Tolerable Water Quality

Table 4 summarizes tolerable water quality concentrations for aircraft wash rack operations. As shown, aircraft washing apparently could be accomplished using water of a quality produced by good secondary level sewage treatment. There is, however, no experience record or data to confirm this speculation.

Typical Effluent Quality

Table 5 summarizes typical effluent quality for aircraft washing operations. As shown, the waste is very high in BOD, COD, O&G, and PO_4.

Cascade Potential

High quality secondary effluent can potentially be used for aircraft washing. Contaminants of most concern in this regard are: BOD, SS, Cl, $CaCO_3$, and bacteria. Highgrade secondary treatment of domestic waste generally provides an effluent that will satisfy the tolerable requirements.

The extremely high BOD and COD of aircraft washwater effluent generally prevents its reuse in other activities without significant dilution and treatment. If future reuse is contemplated, usually the most feasible method of handling this effluent is pretreatment for O&G, BOD, and COD removal prior to dilution and further treatment.

VEHICLE WASH RACK

Description

All bases provide vehicle washing facilities at one or more motor pools. The operation is similar to a commercial car wash with more emphasis on manual rather than automatic operations. The magnitude of the operation varies from base to base, depending upon number of vehicles, road conditions, weather, and other factors.

Flow

Wastewater generation ranges from 500 to 45,000 gpd at an Air Force base. Generation per vehicle is reported at approximately 50-100 gallons.

TABLE 4. TOLERABLE WATER QUALITY AIRCRAFT WASH RACK

Constituent	Concentration (mg/l)[a]
BOD	20
COD	50
Phnl	3.0
SS	20
TDS	2000
O&G	10
Cl	600
NO_3	--
NH_4	15
PO_4	--
Na	600
$CaCO_3$	500
B[(b)]	--
CN	0.5
Fe	40

a All tolerable levels estimated by the contractor as no literature or base data was available.

b Concentration not significant for this operation.

TABLE 5. TYPICAL EFFLUENT QUALITY AIRCRAFT WASH RACK

Constituent	Concentration (mg/l)[a]
BOD	5700
COD	8400
Phnl	8.5
SS	470
TDS[b]	--
O&G	280
Cl[b]	--
NO_3	0.8
NH_4	(0.1)
PO_4	80
Na[b]	--
$CaCO_3$[b]	--
B	(0.1)
CN	(0.005)
Fe[b]	1.1

a Concentration in parenthesis estimated by the contractor.

b Concentration dependent on source water quality.

Tolerable Water Quality

Tolerable water quality concentrations are listed in Table 6. In general, it appears that that good secondary level sewage treatment effluent would be acceptable for vehicle washing operations. There is, however, no experience record or data to confirm this speculation.

Typical Effluent Quality

Table 7 summarizes typical effluent quality from vehicle washing operations. As shown, the waste is high in COD and O&G.

Cascade Potential

Vehicle washing appears to have good cascade potential as a recipient of high grade secondary effluent.

PLATING AND METAL FINISHING

Description

Although a few bases other than ALC's have some type of plating and metal finishing facilities, it is a significant activity only at the five ALC's. Plating materials include nickel, zinc, copper, Cd, Cr, Ag, Au, and others.

Flow

Wastewater generated by plating operations at the ALC's ranges in volume from 200,000 to 500,000 gpd. The larger flows may represent significant percentages of the entire base effluent.

Tolerable Water Quality

Water quality limits for plating depend on the type of plating being performed and the particular operation receiving the water. Potable water or deionized water is required for rinse tanks and scrubbers which together represent approximately 80 percent of the activity water demand. Washdown water is the only subpotable quality water use activity in the plating operation, and it comprises approximately 20 percent of the total water demand.

Typical Effluent Quality

Effluent generated by plating and metal finishing operations is totally dependent on the types of processes involved. For this reason, no typical values are presented here.

TABLE 6. TOLERABLE WATER QUALITY VEHICLE WASH RACK

Constituent	Concentration (mg/l)[a]
BOD	20
COD	50
Phnl	3.0
SS	20
TDS	2000
O&G	10
Cl	600
NO_3[b]	--
NH_4	15
PO_4[b]	--
Na	600
$CaCO_3$	500
B[b]	--
CN	0.5
Fe	40

a All concentrations estimated by the contractor.

b Concentration not significant for this activity.

TABLE 7. TYPICAL EFFLUENT QUALITY VEHICLE WASH RACK

Constituent	Concentration (mg/l)[a]
BOD	450
COD	1100
Phnl	0.01
SS	(500)
TDS[b]	--
O&G	110
Cl[b]	--
NO_3	3.3
NH_4	(0.1)
PO_4	12
Na[b]	--
$CaCO_3$[b]	--
B	(0.1)
CN	(0.005)
Fe[b]	2.6

a Concentrations in parenthesis are contractor estimates.

b Concentrations are strongly dependent on source water quality.

In general, if reuse is not practiced internally, the waste can be expected to contain high concentrations of metal ions and cyanides but will otherwise be of fairly high quality. It will be necessary for each of the ALC's to monitor their own plating activities.

Cascade Potential

Plating operations may offer limited cascade potential. High quality secondary or tertiary effluent is a possible source for washdown water. It is doubtful, however, that a separate system providing reclaimed water only for washdown would be economically and practically feasible. Other water uses demand very high quality water that would not be economically available in a cascade system.

Due to the high metals and/or cyanide content of the effluent from the plating shop, direct cascade to another activity is not generally practicable without pretreatment for metal removal and/or cyanide destruction prior to blending and further treatment. For ALC's with high plating flows, inshop reuse should be pursued to its greatest potential.

PHOTO PROCESSING

Description

All bases provide some type of photo processing facilities. Most are small, 8-hour per day shops. A few bases, however, have large photo processing capability and operate on a 24-hour basis.

Flow

Volumes of wastewater generated range from a few hundred to 20,000 gpd depending on the type of facility.

Tolerable Water Quality

Table 8 summarizes typical quality limits for photo processing source water. As can be seen, the limits are quite stringent and virtually demand the use of fresh water.

Typical Effluent Quality

Table 9 provides typical effluent quality for discharges from photo processing operations. As shown, a high cyanide concentration in the discharge is of principal concern.

Cascade Potential

Photo processing does not appear to be a feasible recipient of cascaded water. The effluent, however, can be reused for some purposes following cyanide destruction and high grade secondary treatment.

TABLE 8. TOLERABLE WATER QUALITY PHOTOGRAPHIC PROCESSING

Constituent	Concentration (mg/l)
BOD	0.1
COD	1.0
Phnl	0.001
SS	1.0
TDS	700
O&G	0.2
Cl	200
NO_3	20
NH_4	0.1
PO_4	3.0
Na	100
$CaCO_3$	400
B	0.1
CN	0.01
Fe	0.3

TABLE 9. TYPICAL EFFLUENT QUALITY PHOTOGRAPHIC PROCESSING

Constituent	Concentration (mg/l)
BOD	100
COD	320
Phnl[a]	(0.001)
SS	30
TDS[b]	--
O&G	3.9
Cl[b]	--
NO_3	8.8
NH_4	16
PO_4	9.3
Na[b]	--
$CaCO_3$[b]	--
B	2.8
CN	4.8
Fe	3.8

a Contractor estimate.

b Concentrations strongly dependent on source water quality.

PAINT SHOP

Description

All bases provide facilities for painting. However, this activity is only significant at the ALC's as water generated by routine air base paint shops is negligible.

Flow

Large painting facilities at ALC's generate significant volumes of wastewater as blowdown from wet wall scrubbers (approximately 10,000-50,000 gpd). The wet wall scrubber is used to filter the exhaust air and entrain any paint particles not adhering to the part being processed.

Tolerable Water Quality

Water for the wet wall need not be of high quality. Table 10 summarizes tolerable concentration limits for water used in paint shop wet walls. Similar quality water can be used for washdown purposes.

Typical Effluent Quality

Table 11 delineates typical effluent quality for discharges from paint shop facilities. As can be seen, the waste is very high in BOD, COD, O&G, MBAS, and chromium.

Cascade Potential

Large painting facilities at ALC's appear to be good potential users of cascaded water as their wet walls and washdown activities do not demand high quality water. Secondary effluent could be used for these purposes.

Effluent from paint shops is highly contaminated and of no potential reuse value, unless significantly diluted prior to further treatment.

HEATING/COOLING/POWER GENERATION PLANT

Description

These activities are combined in this report because they are often concentrated in one or more centralized facilities. In addition, they have similar water supply quality requirements and generate a combined discharge.

TABLE 10. TOLERABLE WATER QUALITY PAINT SHOP WET WALL SCRUBBER

Constituent	Concentration (mg/l)[a]
BOD	30
COD	60
Phnl[b]	--
SS	60
TDS[b]	--
O&G	30
Cl[b]	--
NO_3[b]	--
NH_4	15
PO_4[b]	--
Na	--
$CaCO_3$	--
B[b]	--
CN	0.5
Fe	--

a All concentrations estimated by contractor engineers.

b Concentrations not significant for this activity.

TABLE 11. TYPICAL EFFLUENT QUALITY PAINT SHOP WET WALL SCRUBBER

Constituent	Concentration (mg/l)[a]
BOD	8,100
COD	13,600
Phnl	1.2
SS	2,000
TDS	--
O&G	280
Cl[b]	--
NO_3	(28)
NH_4	(0.1)
PO_4	(3.0)
Na[b]	--
$CaCO_3$	--
B	(0.1)
CN	(0.005)
Fe	3.2
Cr (total)	13
MBAS	4,900

a Concentrations in parenthesis are estimates by contractor engineers.

b. Concentrations dependent on source water quality.

Flow

Wastewater generated consists of continuous or intermittent blowdown from the system that will vary in quality depending on the size of the boiler facility, the mode of operation, and the quality of the source water (TDS, hardness, etc.). An average blowdown volume at a moderately sized boiler plant ranges from approximately 2,000 gpd to 10,000 gpd. If air conditioning and/or power generation is also done at the plant, the blowdown may increase to 50,000 to 100,000 gpd, or more.

TOLERABLE WATER QUALITY

The technology of boiler feedwater makeup and cooling tower makeup waters is complex, as evidenced by the large number of major US corporation which specialize in providing consulting and chemical supply services for treatment of this water. For the purposes of this report, we have assumed that low pressure boilers (200-400 psia) are being used for heating and/or power generation and that feedwater of adequate quality for steam generation is also adequate for air conditioning equipment purposes.

Water quality requirements for boilers vary depending on the operating pressure. Even low pressure boilers (200-400 psia) require water of low hardness to reduce scaling of pipes and heat exchange units. Table 12 summarizes water quality requirements for low pressure boilers.

Final Effluent Quality

Closed loop boiler systems concentrate contaminants in the source water roughly 5 to 10 times before discharge due to evaporative loss. Table 13 shows typical discharge concentrations. As shown, the effluent will tend to be high in TDS, hardness, dissolved salts, and perhaps nutrients, depending on the source water concentrations for these constituents.

CASCADE POTENTIAL

High quality demands for boiler feedwater makeup systems normally preclude the feasible use of cascaded water for this purpose, however, there are three known locations, all in west Texas, where reclaimed municipal effluent is subjected to extensive additional treatment and used for boiler feedwater makeup. In all three cases, the existing freshwater alternate supplies are in very short supply.

There are approximately ten locations in the US where reclaimed municipal sewage effluent is further treated and used for cooling water makeup at large power generation facilities. Because of economies of scale, it is doubtful that an Air Force base could justify the cost of

TABLE 12. TOLERABLE WATER QUALITY
BOILER PLANT/COOLING TOWER SYSTEM

Constituent	Concentration (mg/l)[a]
BOD	(1.0)
COD	(3.0)
Phnl	(0.1)
SS	10
TDS	700
O&G	(1.0)
Cl	(200)
NO_3[b]	(30)
NH_4	(0.5)
PO_4	(4.0)
Na	(200)
$CaCO_3$	20
B	(2.0)
CN	(0.5)
Fe	(0.5)

a Concentrations in parenthesis are contractor estimates, other values were taken from US Department of the Interior, Waste Quality Criteria: Report of the National Technical Advisory Committee to the Secretary of the Interior, Washington, US Government Printing Office, 1968, p. 194.

b Concentrations not significant for this activity.

TABLE 13. TYPICAL EFFLUENT QUALITY
BOILER PLANT/COOLING TOWER SYSTEM

Constituent	Concentration (mg/l)[a]
BOD	5.0
COD	15
Phnl	0.005
SS	50
TDS	3,500
O&G	5.0
Cl	1,000
NO_3	150
NH_4	2.0
PO_4	20
Na	1,000
$CaCO_3$	100
B	10
CN	2.5
Fe	2.5

a All concentrations generated at 5 times tolerable source water quality limits.

the additional relatively small scale treatment facilities and chemicals to further treat reclaimed effluent to a level commensurate with alternate fresh water supplies.

Blowdown from the boiler facility is usually high in TDS but is one of the few activity effluents which may be suitable for direct reuse without further treatment in activities for which salts are not a problem.

POWER/BOILER PLANT SCRUBBER

Description

Bases burning coal or high sulfur oils for power or steam generation are often faced with the problem of particulate and SO_2 removal. Particulate materials are usually removed mechanically or by electrostatic precipitators, but the present air pollution regulations require either SO_2 removal or limiting the fuel supply to low sulfur fuels. Combined removal of both particulates and SO_2 can be achieved with wet scrubbing techniques. These wet scrubbing systems require significant amounts of input water and may be operated in an open or closed loop mode, depending upon the design selected. The amount of water required depends upon the mode of operation and the size of the fuel burning system.

In the closed loop mode of operation, all input water leaves the system by evaporation or with the sludge (primarily composed of particulate material and/or insoluable SO_2 and SO_3 compounds - calcium sulfites and sulfates).

Flow

Flows from scrubbers on small power plants will range from virtually 0 for a closed loop system (all water being discharged in the sludge) to a 40,000 gpd discharge for an open system.

Tolerable Water Quality

The water quality acceptable for use in a wet scrubber depends upon the specific design of the unit. Generally, they will accept very poor quality except for pump seal lubrication and demister rinse operations (a secondary water usage). Many SO_2 scrubbers have been successfully operated with internal recirculating slurries containing 15 percent SS and 15 percent DS. They have also been operated using soda/lime clarifier sludge as an input water and chemical supply.

In general, well designed wet scrubbers can accept almost any quality of water if provisions are made to use non-scaling, non-corrosive water for pump seals and demisters. Assuming that two separate water supplies to the scrubber are not desirable, the tolerable water quality would be similar to that shown in Table 14.

TABLE 14. TOLERABLE WATER QUALITY POWER PLANT SCRUBBER

Constituent	Concentration (mg/l)[a]
BOD	100
COD	200
Phnl	2.0
SS	100
TDS	2,000
O&G	50
Cl	600
NO_3	50
NH_4	20
PO_4[b]	--
Na	600
$CaCO_3$	300
B[b]	--
CN	0.5
Fe	20
Mg	200

a All concentrations are contractor estimates.

b Concentrations not significant for this activity.

Typical Effluent Quality

Naturally, effluent quality will vary depending on the amount of recycle. Typical concentrations for open loop operation from Air Force bases are summarized in Table 15.

Cascade Potential

The power plant scrubber is an excellent recipient for treated or untreated cascade water. The scrubber is tolerant to most other constituents, and its performance is enhanced to some extent by dissolved solids.

Effluents from scrubbers, particularly some types of semi-closed loop systems, are concentrated and usually not suitable for cascade to other activities.

NDI Shop

Wastewater generated by the Non-Destructive Testing Shop is so low in volume and high in contamination that it has virtually no potential for cascade reuse.

Degreasing

Wastewater generated by degreasing activites is so low in volume and high in contamination that it has virtually no potential for cascade reuse.

IRRIGATION

Description

Many bases provide significant irrigation of golf courses, athletic fields, landscaping, parade grounds, and housing areas. In semi-arid locations, irrigation is usually the major water user. Irrigation with treated municipal sewage effluent can be considered an established technology with approximately 300 such applications in operation in the US, including over 40 at golf courses.

Flow

It is assumed that no water is discharged from irrigated grounds and that irrigation demand will vary tremendously depending on climatic conditions. Potential irrigation reuse applications in semi-arid areas are typically greater than the total wastewater production of the base.

TABLE 15. TYPICAL EFFLUENT QUALITY POWER PLANT SCRUBBER

Constituent	Concentration (mg/l)[a]
BOD	10
COD	724
Phnl	(0.001)
SS	3,267
TDS	(5,000)
O&G	0.3
Cl	(400)
NO_3	(28)
NH_4	(0.1)
PO_4	5.4
Na	(72)
$CaCO_3$	(200)
B	(0.1)
CN	(0.005)
Fe	5.3

a Concentrations in parenthesis are contractor estimates.

Tolerable Water Quality

Table 16 lists tolerable quality limits for irrigation water applied to golf courses. Of particular importance are Boron, Chlorides, and TDS. Note that some vegetation is much less tolerant to various constituents than the concentrations shown in Table 16.

Typical Effluent Quality

No discharge.

Cascade Potential

Golf courses and other irrigation areas are excellent recipients (sinks) for cascaded wastewater if satisfactorily treated. Nutrients in the wastewater are an advantage as fertilizer. Where concentrations of certain constituents are intolerable or borderline, intelligent irrigation management and/or blending with freshwater supplies will provide satisfactory solutions.

FIRE PROTECTION/SPILL WASHDOWN RESERVOIR

Description

All ALC's must provide storage of large volumes of water for fire protection and for washdown of oil and fuel spills.

Flow

It is assumed that the reservoir is kept full and refilled as needed to make up for evaporative losses. It could also be used as an irrigation water buffer.

Tolerable Water Quality

Table 17 lists tolerable water quality limits for fire protection/spill washdown reservoirs.

Typical Effluent Quality

No discharge.

Cascade Potential

These reservoirs would be excellent recipients for secondary effluent on a sporadic basis.

TABLE 16. TOLERABLE WATER QUALITY IRRIGATION

Constituent	Concentration (mg/1)[a]
BOD	30
COD	60
Phnl	0.5
SS	50
TDS	2,000
O&G	30
Cl	350
NO_3[b]	--
NH_4	20
PO_4[b]	--
Na	350
$CaCO_3$	--
B	3.0
CN	0.01
Fe	10

a All concentrations are contractor estimates, and generally constitute maximums for hardy turf applications. Many plants may have a lower tolerance to certain constituents (e.g., boron) than listed here.

b Concentrations not significant for this activity.

TABLE 17. TOLERABLE WATER QUALITY
FIRE PROTECTION/SPILL WASHDOWN RESERVOIRS

Constituent	Concentration (mg/l)[a]
BOD	20
COD	60
Phnl	0.01
SS	20
TDS[b]	--
O&G	1.0
Cl	--
NO_3	5.0
NH_4	25
PO_4	20
Na[b]	--
$CaCO_3$	--
B	0.1
CN	0.1
Fe	5.0

a All concentrations are contractor estimates.

b Concentrations not significant for this activity.

RECREATIONAL LAKES

Description

Recreational lakes for picnicing, fishing, and boating are potential cascade activities although bases do not currently use wastewater for this purpose.

Flow

The lakes would be filled as needed or when suitable water was available that would otherwise be discharged.

Tolerable Water Quality

Table 18 summarizes tolerable water quality limits for limited body contact, recreational lakes. As shown, tertiary effluent with nutrient removal would be necessary to provide satisfactory quality.

Typical Effluent Quality

No discharge.

Cascade Potential

These lakes would be possible recipients of tertiary effluent.

TABLE 18. TOLERABLE WATER QUALITY RECREATIONAL LAKES (LIMITED BODY CONTACT)

Constituent	Concentration (mg/l)[a]
BOD	10
COD	60
Phnl	(0.01)
SS	10
TDS	575
O&G	(5.0)
Cl	300
NO_3	2.5
NH_4	0.1
PO_4	0.3
Na	250
$CaCO_3$	--
B	0.1
CN	(0.1)
Fe	(5.0)

a Concentrations in parenthesis are contractor estimates. Other values come from contractor engineers, "Demonstrated Technology and Research Needs for Reuse of Municipal Wastewater," Office of Research and Monitoring, US EPA, Washington, DC 20460, 1974.

SECTION III

TREATMENT OPTIONS

GENERAL

This section describes the treatment alternatives used to provide input data to the cascade reuse model. This treatment input data included estimated removals of various pollutants and costs of treatment as a function of flow. The model is designed so that the engineer may select to use different process efficiencies and costs than are described in this section.

CASCADE REUSE TREATMENT MODULES

The cascade water reuse model is constructed so that all treatment data, including costs, are included in the input data. In this way, AF civil engineers are free to modify current treatment data or add new chains and costs. Methods for amending and inputting these parameters are delineated in the user manual.

A total of five regular treatment chains and four special pretreatment options were selected for use in testing the cascade water reuse computer program, as listed in Table 19. Treatment efficiencies and total costs have been evaluated for these regular treatment chains and pretreatment units.

The following subsections briefly summarize the important cost derivation information for each of the treatment chains and pretreatment options shown in Table 19.

COSTS

All treatment capital costs have been approximated by equations of the form:

$$\text{Total Capital Cost (\$)} = (A + BQ^{C}) \frac{CCI}{CCI'}, \text{ where:}$$

A = fixed capital cost ($)
B = unit capital cost ($/gallon)
C = economy of scale factor
Q = flow (gpd)
CCI = current Engineering News Record (ENR) Construction Cost Index
CCI′ = January 1975 ENR Construction Cost Index

TABLE 19. TREATMENT OPTIONS SELECTED AND COSTED

Regular Treatment

1. Primary Only
2. Conventional Secondary (with chlorination)
3. Conventional Secondary plus multi-media filtration
4. Conventional Secondary plus filtration, plus carbon adsorption
5. Conventional Secondary plus filtration, plus carbon adsorption, plus reverse osmosis
6. Aerated Lagoons
7. Aerated Lagoons plus multi-media filtration
8. Aerated Lagoons plus slow sand filtration

Special Treatment

1. Metal Removal[a]
2. Oil and Grease Removal[b]
3. Softening
4. Chemical Coagulation

a Assigned the same cost function as chemical coagulation for purposes of case study trial runs of the computer program.

b Assigned the same cost function as primary treatment for purposes of case study trial runs of the computer program.

All treatment O&M costs have been approximated by equations of the form:

$$\text{Annual O\&M Cost (\$/yr)} = (A + BQ^{C}) \frac{LCI}{LCI'}, \text{ where:}$$

A	= fixed O&M cost ($/yr)
B	= unit O&M cost ($/yr/gallon)
C	= economy of scale factor
Q	= flow (gpd)
LCI	= current ENR Labor Cost Index
LCI´	= January 1975 ENR Labor Cost Index

This uniform representation of costs facilitates modification or extension of the treatment cost data, if desired. Note that all cost coefficients must be updated to January 1975 dollars. The program will automatically update treatment costs for following years using the ratio of $\frac{\text{the current ENR index}}{\text{1975 ENR index}}$.

In each case, a capital recovery factor (CRF) of the form:

$$CRF = \frac{(\text{Capital Cost})\ i\ (1 + i)^{n}}{(1 + i)^{n} - 1}$$

where:

i = interest (actual value supplied as input data)
n = years (actual value supplied as input data)

The CRF was applied to the capital cost figure to obtain a yearly capital cost which was then added to the annual O&M cost to obtain a total yearly cost for treatment.

Note that the cost functions used are good approximations for facilities with treatment capacity only up to approximately 5 mgd. In addition, treatment costs are based on normal concentration ranges. Caution must be used in applying these costs to unusually strong wastes. Land costs are not included.

REGULAR TREATMENT CHAINS

Primary Treatment

Primary treatment consists of bar screening, comminution and clarification in a circular concrete tank, anaerobic sludge digestion, and sludge drying beds. Costs include all concrete, mechanical apparatus, electrical, and installation.

Costs for primary treatment are represented by the following equations[1]:

$$\text{Capital Cost (\$)} = (36.28\ Q^{0.713})\ \frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (0.315\ Q^{0.824})\ \frac{LCI}{4.71}$$

Conventional Secondary Treatment

Conventional secondary treatment consists of primary clarification, activated sludge secondary treatment, final clarification, chlorination, anaerobic digestion, and sludge drying beds. Costs include all concrete, mechanical apparatus, electrical and installation.

Capital and O&M costs for conventional secondary treatment (including primary) are represented by the following equations[2]:

$$\text{Capital Cost (\$)} = (1159.00\ Q^{0.508})\ \frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (362.90\ Q^{0.40})\ \frac{LCI}{4.71}$$

Conventional Secondary Treatment Plus Filtration

This treatment chain consists of the addition of multi-media filtration to the conventional secondary treatment described above. The Capital Cost Curves for these treatment chains are shown by Figure 1, Operation and Maintenance costs are shown by Figure 2.

---

1 Costs taken from: Smith, R., "Cost of Conventional and Advanced Treatment of Wastewater," JWPCF, 40, September 1968.

2 Costs taken from "Wastewater Treatment Plan Cost Estimating Program," Advanced Waste Treatment Research Laboratory, Water Quality Office, Environmental Protection Agency, Cincinnati, OH, April 1971.

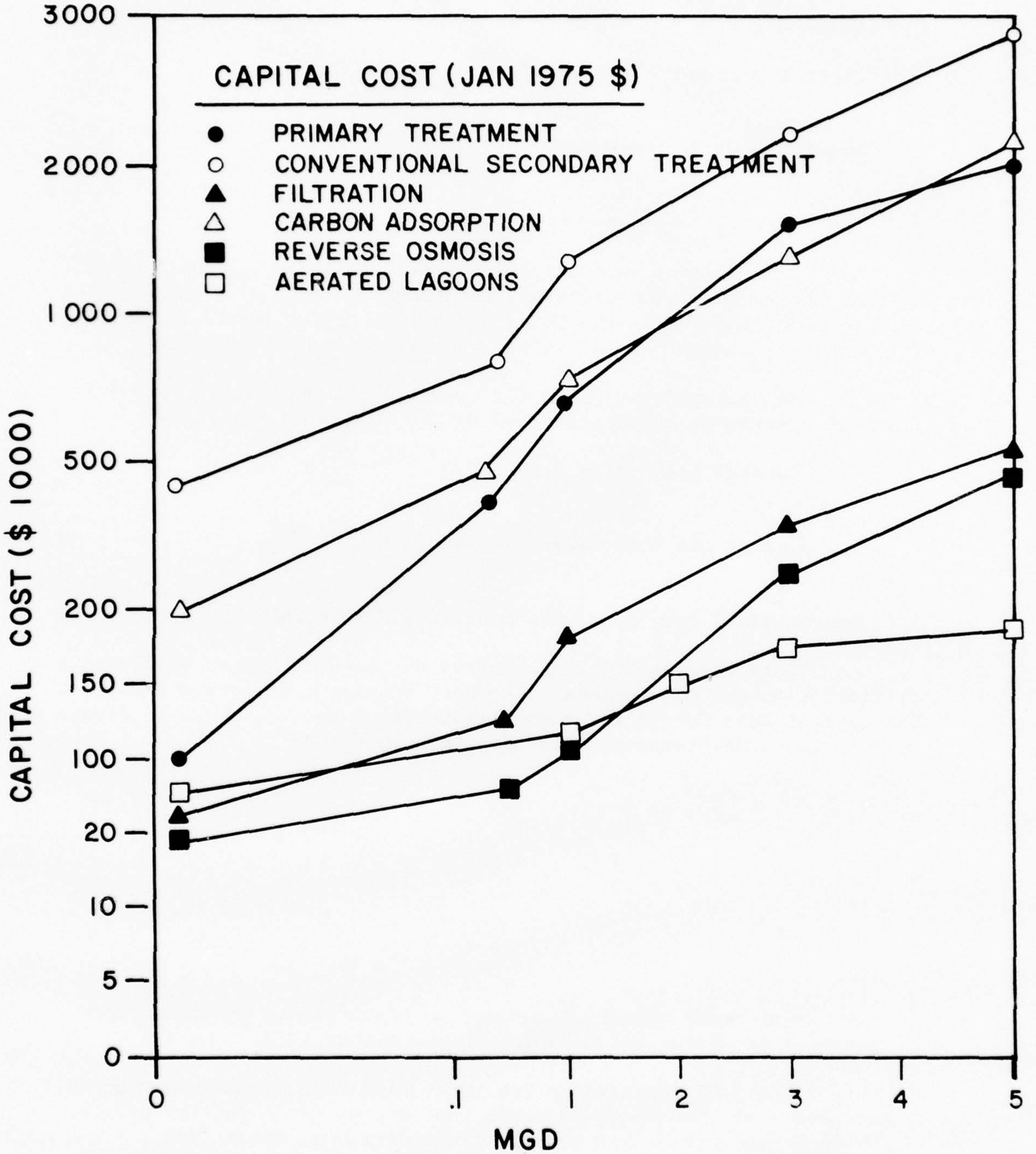

Figure 1. Capital Costs, Regular Treatment Chains

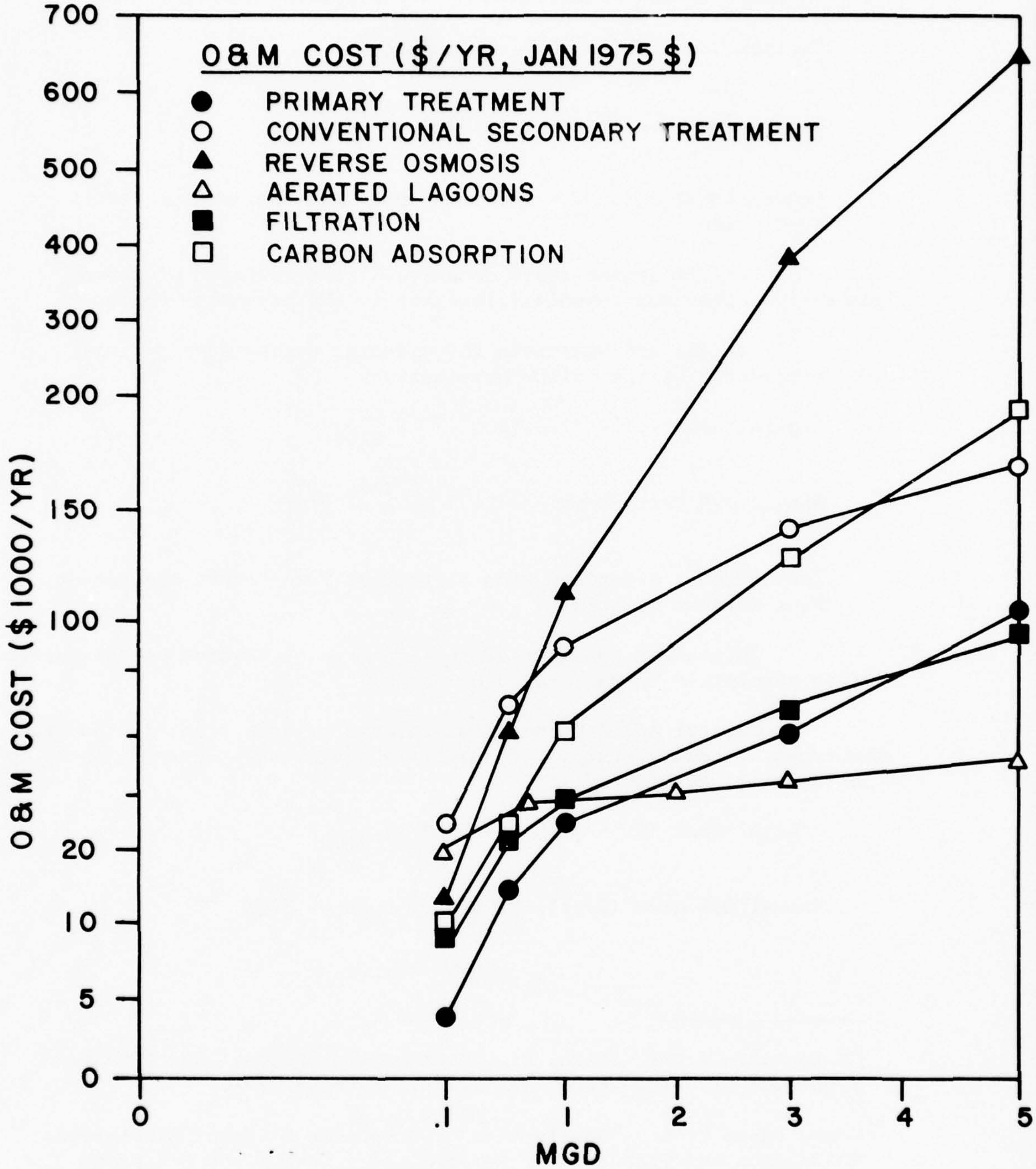

Figure 2. O&M Costs, Regular Treatment Chains

Capital and O&M costs for the multi-media filtration unit alone (at 4 gpm/sq ft) are represented by the following equations[3]:

$$\text{Capital Cost (\$)} = (29.97\ Q^{0.631})\ \frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (5.95\ Q^{0.633})\ \frac{LCI}{4.71}$$

Conventional Secondary Treatment Plus Filtration Plus Carbon Adsorption

This treatment chain consists of the addition of carbon adsorption after multi-media filtration in the preceding chain.

Capital and O&M costs for granular carbon adsorption alone are represented by the following equations[3]:

$$\text{Capital Cost (\$)} = (128.10\ Q^{0.627})\ \frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (2.73\ Q^{0.724})\ \frac{LCI}{4.71}$$

Conventional Secondary Plus Filtration Plus Carbon Adsorption Plus Reverse Osmosis

This chain consists of the addition of reverse osmosis after carbon adsorption in the preceding chain.

Capital and O&M costs for reverse osmosis alone (including membranes, feedwater pump, and auxiliary equipment) are represented by the following equations[4]:

$$\text{Capital Cost (\$)} = (13550 + 0.10\ Q)\ \frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (75.78 + 0.13\ Q)\ \frac{LCI}{4.71}$$

---

[3] Costs taken from: Smith, R., "Cost of Conventional and Advanced Treatment of Wastewater," JWPCF, 40, September 1968.

[4] Costs taken from: "Development Document for Effluent Limitations Guidelines and Standards of Performance - Canned and Preserved Fruits and Vegetables Industry, SCS Engineers, Effluent Guidelines Division, Environmental Protection Agency, Washington, DC, December 1974.

Aerated Lagoons

This treatment alternative consists of biological treatment in a series of two aerated lagoons. Costs include all earthwork, impermeable lining installation, mechanical aeration, internal piping, electrical work, and chlorination.

Capital and O&M costs for this treatment chain are represented by the following equations[5]:

$$\text{Capital Cost (\$)} = (1352.00\ Q^{0.32})\ \frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (1767.00\ Q^{0.21})\ \frac{LCI}{4.71}$$

Aerated Lagoon Plus Multi-Media Filtration

This treatment alternative consists of the addition of tertiary multi-media filtration to the aerated lagoon system just discussed.

Costs for the filtration facility alone are identical to those previous delineated in Chain No. 2.

Aerated Lagoon Plus Slow Sand Filtration

This alternative consists of the addition of slow sand filter beds to the basic aerated lagoon system.

Costs for slow sand filtration alone (0-1 mgd) including earth work, drainage tile, media preparation, and piping are represented by the following equations[6]:

$$\text{Capital Cost (\$)} = (0.15\ Q)\ \frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (0.0043\ Q)\ \frac{LCI}{4.71}$$

---

[5] Costs taken from: "Development Document for the Effluent Limitations Guidelines and Performance Standards - Canned and Preserved Fruits and Vegetables Industry, SCS Engineer for Effluent Guidelines Division, Environmental Protection Agency, Washington DC, December 1974.

[6] Costs developed by contractor engineers.

SPECIAL TREATMENT UNITS

Metal Removal

Metal removal basically consists of chemical addition and mixing in a clarifier for precipitation or oxidation.

This unit is intended to be employed as a pretreatment at heavy industrial operations generating significant waste metals that might interfere with successful biological treatment and reuse.

Capital and O&M costs for special metal removal are represented by the following equations[7]:

$$\text{Capital Cost (\$)} = (435.00\ Q^{0.41})\ \frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (16.24 + 57.93\ Q^{0.41})\ \frac{LCI}{4.71}$$

Oil and Grease Removal

The oil and grease removal unit is assumed to be an API type separator. Costs include concrete, mechanical scrappers and rakes, electrical, and installation.

Capital O&M costs for oil and grease removal are represented by the following equations[8]:

$$\text{Capital Cost (\$)} = (36.28\ Q^{0.713})\ \frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (0.31\ Q^{0.824})\ \frac{LCI}{4.71}$$

---

[7] Costs taken from: "Development Document for the Effluent Limitations Guidelines and Performance Standards - Canned and Preserved Fruits and Vegetables Industry, SCS Engineers for Effluent Guidelines Division, Environmental Protection Agency, Washington DC, December 1974.

[8] Costs taken from: Smith, R., "Cost of Conventional and Advanced Treatment of Wastewater," JWPCF, 40, September 1968.

Softening

Softening is pretreatment to reduce calcium carbonate hardness and thereby enhance cascade potential between activities in which hardness is the primary concern. Softening is assumed to be the conventional ion exchange process used for smaller flows.

Capital and O&M costs for softening are represented by the following equations[9]:

$$\text{Capital Cost (\$)} = (5000 + 0.02\ Q)\ \frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (0.36\ Q)\ \frac{LCI}{4.71}$$

Chemical Coagulation

Chemical coagulation is a special pretreatment process intended to be used for BOD, COD, and SS removal at industrial sites discharging very strong wastes. The process is basically one of dissolved air flotation with chemical addition to enhance flocculation.

Capital and O&M costs for chemical coagulation are represented by the following equations[10]:

$$\text{Capital Cost (\$)} = (435.00\ Q^{0.41})\ \frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (16.24 + 57.93\ Q^{0.41})\ \frac{LCI}{4.71}$$

---

[9] Cost functions calculated by contractor engineers.

[10] Costs taken from: "Development Document for the Effluent Limitations Guidelines and Performance Standards - Canned and Preserved Fruits and Vegetables Industry, SCS Engineers for Effluent Guidelines Division, Environmental Protection Agency, Washington DC, December 1974.

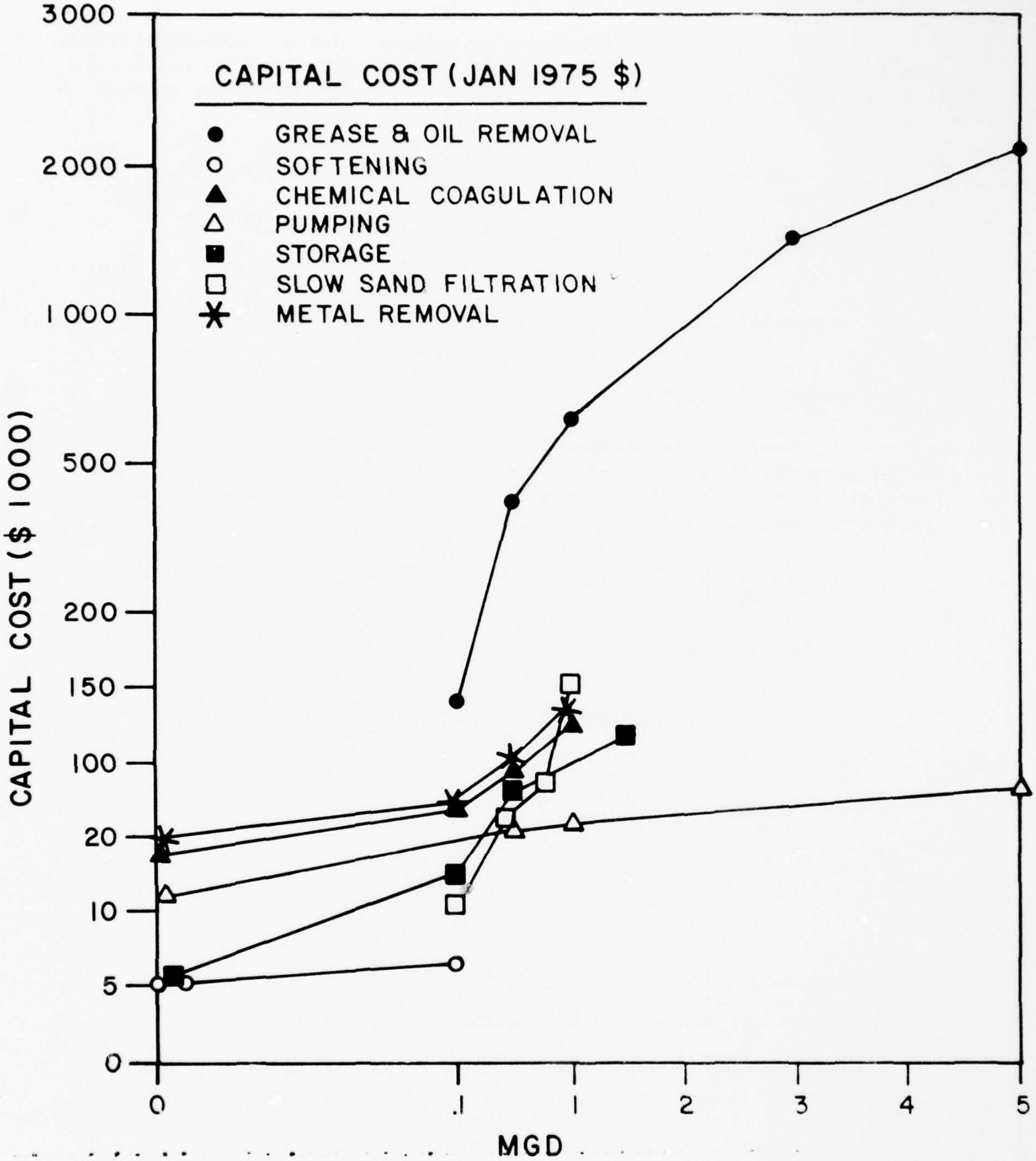

Figure 3. Capital Costs, Special Treatment Units

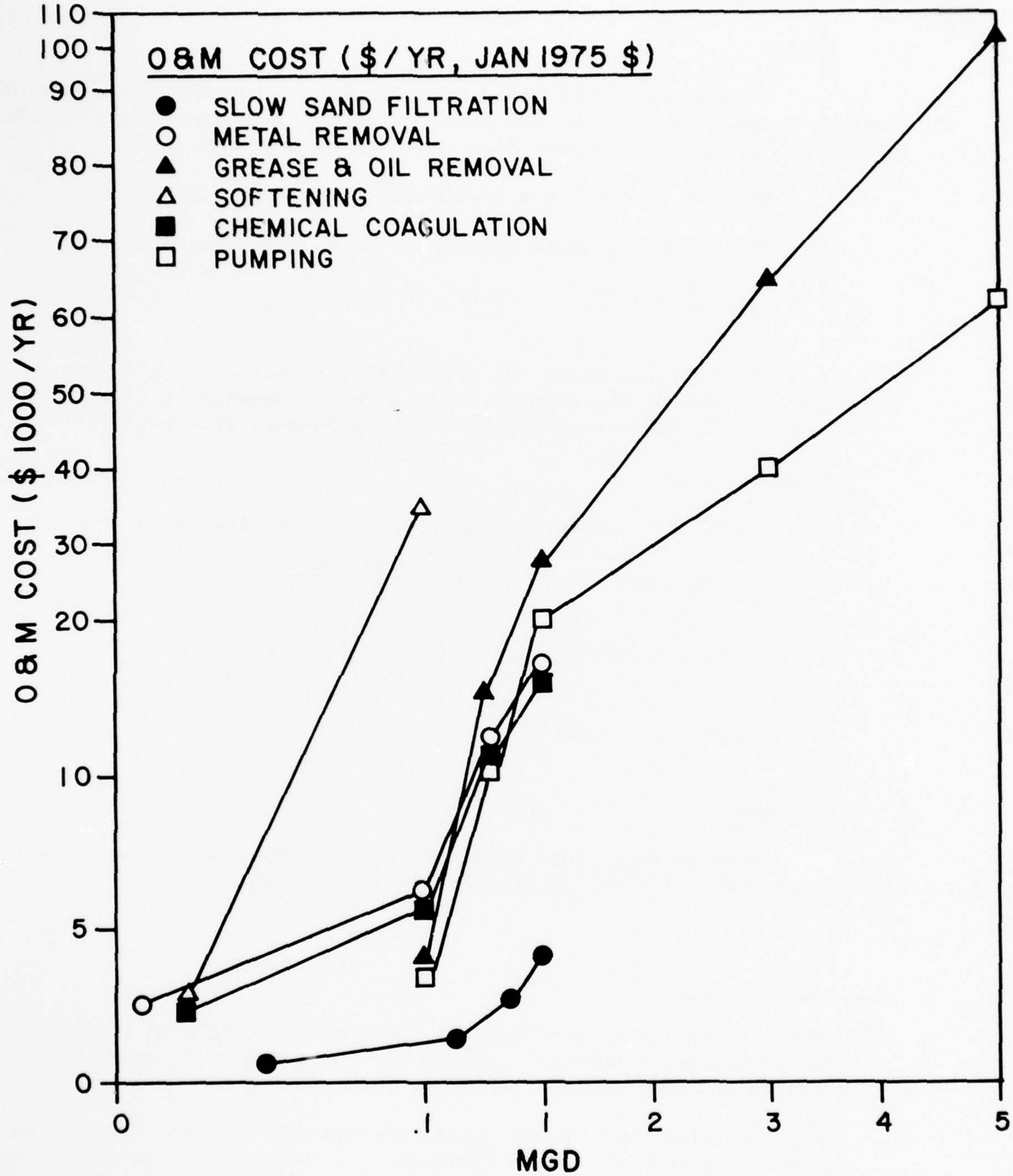

Figure 4. O&M Costs, Special Treatment Units

MISCELLANEOUS COSTS

Piping

Piping costs were based on \$/day per ft length. Two equations were used for this purpose; the first to calculate minimum diameter when given flow in gph and maximum flow velocity in the pipe:

$$D(in) = (gph \times 144 \times 4/velocity \times \pi \times 7.48 \times 3600)^{\frac{1}{2}}$$

The second equation calculates cost, given the diameter:

$$\text{Capital } \$ = (2.00 \times D(in) \times L\ (ft))\ \frac{CCI}{2103}$$

The only allowance for potential bulk solids in water to be piped is provided by the program in setting a minimum pipe diameter of 4 inches for all lines carrying material wastewater from activities.

Pumping

Costs for pumping are represented by the following equations[11]:

$$\text{Capital Cost } (\$) = (204.43\ Q^{0.48})\ \frac{CCI}{2103}$$

$$\text{Annual O\&M Cost } (\$/yr) = (5.23\ Q^{0.766})\ \frac{LCI}{4.71}$$

(Note: Q in gph)

Storage

Storage costs were based on calculations assuming a circular steel tank, with 12 foot depth, and 1/4 inch walls.

---

11 Capital costs taken from "Capital and Operating Costs of Pollution Control Equipment Modules - Volume II - Data Manual," Office of Research and Development, EPA-R5-73-023b, July 1973.

O&M costs taken from "Development Document for Effluent Limitations Guidelines and Standards of Performance - Canned and Preserved Fruits and Vegetables Industry," SCS Engineers for Environmental Protection Agency, December 1974.

The cost calculation involved two equations; the first to compute tank diameters[12]:

$$D = ((gal. \times 4/(7.48 \times 12 \times \pi))^{\frac{1}{2}}$$

where:

D is the tank diameter in ft, and gal = tank capacity in gallons:

and the second to calculate capital cost:

$$\text{Cost } (\$) = (292.02\ D + 6.08\ D^2)\ \frac{CCI}{2103}$$

In addition, a safety factor was applied to each actual storage volume according to the following equation:

$$\text{Additional Storage (gal) } 50.0 \times (\text{Actual Max Storage (gal)})^{0.7}$$

Thus for small tanks (10,000 gallons) the required volume was basically quadrupled for safety while a 1 mg tank was increased 79 percent.

Performance

Treatment performance efficiency data must be estimated and included in the input base information. Table 20 shows the treatment removal efficiencies assumed for this report for both regular treatment at BTS's and for special pretreatment at activities. In each case, removals are specified for the entire chain not just the component (i.e., the carbon adsorption chain removals are for the complete tertiary chain including filtration and secondary treatment). Base personnel are free to use these values or substitute others.

Part of the Phase I program evaluates the effects of pretreatment at activities. In order to determine which pretreatments are most applicable, the program requires threshold concentrations over which it assumes a certain pretreatment is warranted. Table 21 shows the values assumed for the four special treatments: metal removal, softening, and chemical coagulation. Minus ones (-1's) indicate essentially that the threshold is infinity for that constituent.

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[12] Costs taken from communication with prominent national manufacturer.

TABLE 20. TREATMENT REMOVAL EFFICIENCIES

	PRIMARY	SECONDARY	FILTRATION	CARBON ADS	REV. OSMOS
BOD	30.%	85.%	94.%	99.%	100.%
COD	30.%	80.%	88.%	96.%	99.%
PHNL	30.%	75.%	75.%	92.%	92.%
SS	70.%	85.%	98.%	100.%	100.%
TDS	0.%	0.%	20.%	20.%	91.%
O&G	50.%	75.%	85.%	96.%	97.%
CL	0.%	0.%	0.%	0.%	80.%
NO_3	0.%	0.%	0.%	20.%	70.%
NH_4	0.%	95.%	95.%	100.%	100.%
PO_4	0.%	20.%	85.%	85.%	98.%
NA	0.%	0.%	0.%	0.%	75.%
$CACO_3$	0.%	0.%	0.%	0.%	90.%
B	10.%	10.%	10.%	10.%	75.%
CN	10.%	80.%	80.%	80.%	96.%
FE	10.%	50.%	60.%	60.%	96.%

SPECIAL TREATMENT REMOVAL EFFICIENCIES

	METAL REM	OIL+GREASE	SOFTENING	CHEM COAG
BOD	20.%	25.%	0.%	50.%
COD	20.%	30.%	0.%	50.%
PHNL	20.%	20.%	0.%	30.%
SS	20.%	50.%	0.%	70.%
TDS	0.%	0.%	0.%	0.%
O&G	20.%	75.%	0.%	20.%
CL	0.%	0.%	0.%	0.%
NO_3	0.%	0.%	0.%	0.%
NH_4	0.%	0.%	0.%	0.%
PO_4	0.%	0.%	0.%	85.%
NA	0.%	0.%	0.%	0.%
$CACO_3$	0.%	0.%	98.%	0.%
B	85.%	10.%	0.%	0.%
CN	85.%	10.%	0.%	0.%
FE	85.%	10.%	0.%	0.%

TABLE 21. SPECIAL TREATMENT CONCENTRATION LEVELS (MG/L)

	METAL REM	OIL+GREASE	SOFTENING	CHEM COAG
BOD	-1.0	-1.0	-1.0	1000.0
COD	-1.0	-1.0	-1.0	2000.0
PHNL	-1.0	-1.0	-1.0	-1.0
SS	-1.0	-1.0	-1.0	1000.0
TDS	-1.0	-1.0	-1.0	-1.0
O&G	-1.0	200.0	-1.0	-1.0
CL	-1.0	-1.0	-1.0	-1.0
NO_3	-1.0	-1.0	-1.0	-1.0
NH_4	-1.0	-1.0	-1.0	-1.0
PO_4	-1.0	-1.0	-1.0	100.0
NA	-1.0	-1.0	-1.0	-1.0
$CACO_3$	-1.0	-1.0	500.0	-1.0
B	100.0	-1.0	-1.0	-1.0
CN	.5	-1.0	-1.0	-1.0
FE	100.0	-1.0	-1.0	-1.0

SECTION IV

COMPUTER SOFTWARE SYNOPSIS

INTRODUCTION

The primary objective of this project was the design of a cascade water reuse computer program to aid in designing wastewater reuse systems. The program requires various input data and human decision-making to be effective. The purpose of this section is to explain briefly:

1. How the program works.

2. What quantitative input data is required from base personnel.

3. What output can be anticipated.

4. What decisions will have to be made by the base engineer.

Comprehensive cookbook type instructions for completing all required input forms and data are supplied in CEEDO-TR-77-26, "User Manual."

The reader is cautioned that he should not expect to thoroughly understand the computer program by a one-time reading of this section. Several thousand man-hours of effort was expended to develop this software, and the average engineer will have to thoroughly review the appendices and case studies before undertaking to work with the computer. The rewards are great, however, because the computer can comparatively analyze many potential alternate reuse systems in a few minutes. Results which would take an engineer working manually many months to accomplish.

THE COMPUTER SOFTWARE IN GENERAL

The cascade water reuse computer software was written in American Standard Fortran IV and has been tested on the CDC 6600 computer and the compiler at Kirtland Air Force Base, New Mexico.

Figure 5 shows the structure diagram for the entire program. The figure delineates the interconnections between the main program and all subroutines. A thorough study of CEEDO-TR-77-26 is required to fully appreciate Figure 5.

The software is divided into two separate phases. Phase I (Activity Description) assimilates activity data supplied by the base and prints out several forms for each activity showing flow patterns, effluent quality characteristics after various levels of treatment, the effects of recommended pretreatment units, and cascade potential. Output from Phase I is intended to assist the engineer in selecting feasible activity cascade networks.

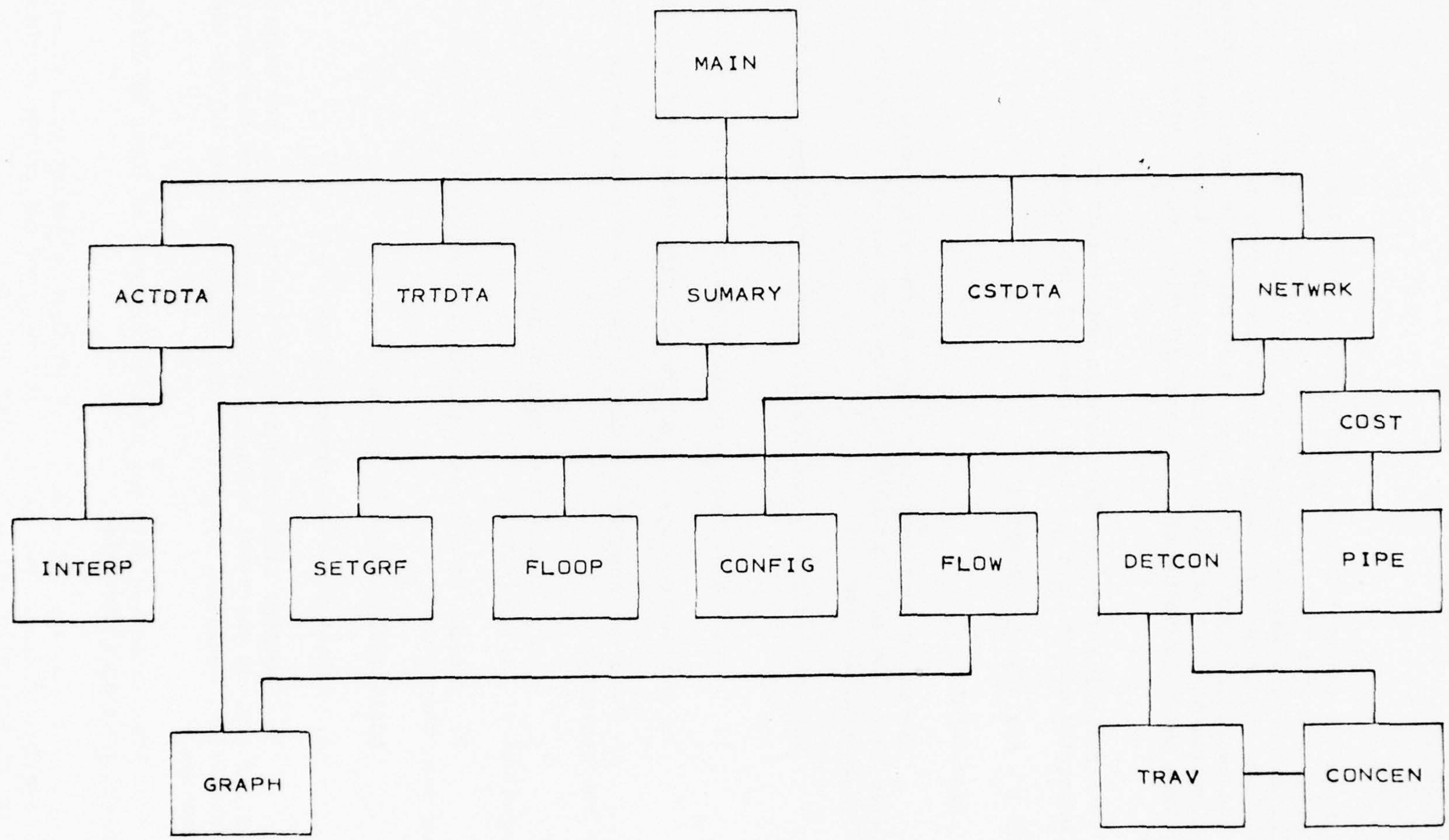

Figure 5. Program Structure Diagram

Phase II (Network Feasibility) quickly evaluates any number of potential networks selected. Output provides a comprehensive network description including the requirements for piping, pumping, and storage facilities, the required removal efficiencies, type of treatment chains, and the estimated total cost of the entire cascade system. Continued modification of the most cost effective cascade networks should lead to selecting the most comprehensive, cost effective reuse system for the base.

The following sections delineate in more detail the required input and generated output data for both phases of the cascade reuse model.

PHASE I - ACTIVITY DESCRIPTION

Base Input

The major portion of the input to the first phase of the model involves gathering and presenting in proper format all necessary information on base activities:

For each activity, and for all water constituents of interest; the

1. Source water flow into the activity (hourly if available).

2. Wastewater flow out of the activity (hourly if available).

3. Average constituent concentrations for the source water into the activity.

4. Average constituent concentrations for the wastewater flowing out of the activity.

5. Maximum acceptable contaminate concentrations for source water into the activity.

Additional data required include:

1. Base fresh water source(s) quality.

2. Required final discharge(s) quality, i.e., the restrictions, if any, on the final discharge or discharges from the base to a surface water, municipal system, or other final receiver of the waste discharge.

The following data may also be included as input if different from the preprogrammed data:

1. Removal efficiencies of various pollutant constituents by the treatment chains. For example, the engineer may choose to show a 90 percent removal of BOD by secondary treatment.

2. Removal efficiencies of various pollutant constituents by pretreatment units. For example, the engineer may stipulate chemical coagulation pretreatment on some unit process that will achieve 50 percent BOD removal, 70 percent SS removal, etc.

3. Threshold concentrations over which the model will assign special pretreatment units at activities.

Computer Model Output

Output from the Phase I program fully describes the activities and possible cascade flows from activity to activity with varying degrees of intervening treatment. A thorough discussion of this output is presented in the User Manual.

For each activity the following information is provided (see following pages for sample printout):

1. Cumulative and hourly flows including graphs. (Table 22).

2. Constituents in and out and degradation through use as average concentrations in mg/l and loadings in lbs/day, and tolerable source water concentrations. (Table 23).

3. Wastewater contaminant concentrations after treatment by each regular treatment chain. (Table 24).

4. Wastewater contaminant concentrations after appropriate pretreatment followed by each regular treatment chain. (Table 25).

5. A summary of the suitability of the activity wastewater for reuse in other activities after various levels of special and regular treatment. (Tables 26 and 27).

At the end of Phase I, previous data is summarized in one table showing acceptable cascades between activities at various levels of treatment. This is shown in Table 28, where X's denote totally acceptable quality for the cascade, and 1's and 2's denote that one or two constituents, respectively, are not acceptable whereas all the other parameters are permissible.

PHASE II - NETWORK FEASIBILITY

Base Input

Phase II input involves appropriate cost data and representation of cascade networks to be analyzed.

TABLE 22. ACTIVITY WATER DEMAND AND WASTEWATER GENERATION

Base: March Air Force Base
Activity: Aircraft/Age Wash Rack
Activity Code: A/AWR

HOUR	WATER IN (GPH)	WASTEWATER OUT (GPH)	CUMULATIVE IN (GAL)	CUMULATIVE OUT (GAL)
1	0.	0.	0.	0.
2	0.	0.	0.	0.
3	0.	0.	0.	0.
4	0.	0.	0.	0.
5	0.	0.	0.	0.
6	0.	0.	0.	0.
7	0.	0.	0.	0.
8	0.	0.	0.	0.
9	1000.	800.	1000.	800.
10	1000.	800.	2000.	1600.
11	1000.	800.	3000.	2400.
12	0.	0.	3000.	2400.
13	0.	0.	3000.	2400.
14	0.	0.	3000.	2400.
15	0.	0.	3000.	2400.
16	0.	0.	3000.	2400.
17	0.	0.	3000.	2400.
18	0.	0.	3000.	2400.
19	0.	0.	3000.	2400.
20	0.	0.	3000.	2400.
21	0.	0.	3000.	2400.
22	0.	0.	3000.	2400.
23	0.	0.	3000.	2400.
24	0.	0.	3000.	2400.

```
 10.  GPH                            100. GAL

100         ***                       40
 95                                   38
 90                                   36
 85                                   34
 80         +++                       32
 75                                   30          **************
 70                                   28
 65                                   26
 60                                   24          ++++++++++++++
 55                                   22
 50                                   20         *
 45                                   18
 40                                   16         +
 35                                   14
 30                                   12
 25                                   10        *
 20                                    8        +
 15                                    6
 10                                    4
  5 ++++++++   +++++++++++++           2 ++++++++
    000000000111111111122222             000000000111111111122222
    123456789012345678901234             123456789012345678901234
```

TABLE 23. WATER QUALITY SUMMARY

Base: March Air Force Base
Activity: Aircraft/Age Wash Rack
Activity Code: A/AWR

	TOL(MG/L)	IN(MG/L)	OUT(MG/L)	DEGR(MG/L)	IN(LBS/DAY)	OUT(LBS/DAY)	DEGR(LBS/DAY)
BOD	20.0	0.0	5711.0	5711.0	0.0	114.3	114.3
COD	50.0	0.0	8434.0	8434.0	0.0	158.9	168.9
PHNL	3.0	0.0	8.5	8.5	0.0	.17	.17
SS	20.0	0.0	470.0	470.0	0.0	9.4	9.4
TOS	2000.0	568.0	600.0	32.0	14.2	12.0	-2.2
O&G	10.0	.2	285.0	284.8	.005	5.7	5.7
CL	600.0	185.0	185.0	0.0	4.6	3.7	-.9
NO_3	-1.0	20.0	25.0	5.0	.5	.5	0.0
NH_4	15.0	.1	.1	0.0	.003	.002	-.001
PO_4	-1.0	2.0	81.0	79.0	.05	1.6	1.5
NA	600.0	72.0	72.0	0.0	1.8	1.4	-.3
$CACO_3$	500.0	308.0	308.0	0.0	7.7	6.1	-1.5
B	-1.0	.1	.1	0.0	.003	.002	-.001
CN	.5	0.0	0.0	0.0	0.0	0.01	0.01
FE	40.0	.010	1.1	1.0	.002	.02	.02

TABLE 24. ACTIVITY WASTEWATER CONCENTRATIONS AFTER TREATMENT (MG/L)

Base: March Air Force Base
Activity: Aircraft/Age Wash Rack
Activity Code: A/AWR
Special Treatment: None

	NONE	PRIMARY	SECONDARY	FILTRATION	CARBON ADS	REV. OSMOS
BOD	5711.0	3997.7	856.6	342.6	57.1	0.0
COD	8434.0	5903.8	1686.8	1012.0	337.3	84.3
PHNL	8.5	5.9	2.1	2.1	.58	.6
SS	470.0	141.0	70.5	9.4	0.0	0.0
TDS	600.0	600.0	600.0	480.0	480.0	54.0
O&G	285.0	142.5	71.2	42.7	11.4	8.5
CL	185.0	185.0	185.0	185.0	185.0	37.0
NO_3	25.0	25.0	25.0	25.0	20.0	7.5
NH_4	.1	.1	.005	.005	0.0	0.0
PO_4	81.0	81.0	64.8	12.1	12.1	1.6
NA	72.0	72.0	72.0	72.0	72.0	18.0
$CACO_3$	308.0	308.0	308.0	308.0	308.0	30.8
B	.1	0.1	.09	.09	.09	.02
CN	0.0	0.0	0.0	0.0	0.0	0.0
FE	1.1	1.0	.4	.4	.4	.04

TABLE 25. ACTIVITY WASTEWATER CONCENTRATIONS AFTER TREATMENT (MG/L)

Base: March Air Force Base
Activity: Aircraft/Age Wash Rack
Activity Code: A/AWR
Special Treatment: Chem Coag

	NONE	PRIMARY	SECONDARY	FILTRATION	CARBON ADS	REV. OSMOS
BOD	2855.5	1998.8	428.3	171.3	28.5	0.0
COD	4217.0	2951.9	843.4	506.0	158.5	42.1
PHNL	5.9	4.1	1.4	1.4	.57	.54
SS	141.0	42.3	21.1	2.8	0.0	0.0
TDS	500.0	600.0	600.0	480.0	480.0	54.0
O&G	228.0	114.0	57.0	34.2	9.1	6.8
CL	185.0	185.0	185.0	185.0	185.0	37.0
NO_3	25.0	25.0	25.0	25.0	20.0	7.5
NH_4	.1	.1	.005	.005	0.0	0.0
PO_4	12.1	12.1	9.7	1.8	1.8	.2
NA	72.0	72.0	72.0	72.0	72.0	18.0
$CACO_3$	308.0	308.0	308.0	308.0	308.0	30.8
B	.1	.1	.09	.09	.09	.03
CN	0.0	0.0	0.0	0.0	0.0	0.0
FE	1.1	1.0	.4	.4	.4	.04

TABLE 26. SUITABILITY OF ACTIVITY EFFLUENT FOR REUSE

Base: March Air Force Base
Activity: Aircraft/Age Wash Rack
Activity Code: A/AWR
Special Treatment: None

	NONE	PRIMARY	SECONDARY	FILTRATION	CARBON ADS	REV. OSMOS
	AHBOPAGVOGAH	AHBOPAGVOGAH	AHBOPAGVOGAH	AHBOPAGVOGAH	AHBOPAGVOGAH	AHBOPAGVOGAH
	/OOFHHEWFOHO	/OOFHHEWFOHO	/OOFHHEWFOHO	/OOFHHEWFOHO	/OOFHHEWFOHO	/OOFHHEWFOHO
	AJQFOHNRFLIS	AJQFOHNRFLIS	AUQFOHNRFLIS	AJQFOHNRFLIS	AUQFOHNRFLIS	AUQFOHNRFLIS
	WS T I IFRP	WS T I IFRP	WS T I IFRP	WS T I IFRP	WS T I IFRP	WS T I IFRP
	RE O R R R	RE O R R R	RE O R R R	RE O R R R	RE O R R R	RE O R R R
BOD						XXXXXXXXXXXX
COD						
PHNL			X X	X X	X X	X X
SS				X XXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
TDS	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
O&G					X XXX	X XXXX
CL	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
NO_3	XXXX XXXXXXX	XXXX XXXXXXX	XXXX XXXXXXX	XXXX XXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
NH_4	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
PO_4	X XXXXX	X XXXXX	X XXXXX	X XXXXX	X XXXXX	XXXXXXXXXXXX
NA	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
$CACO_3$	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
B	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
CN	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
FE	X XXXXX	X XXXXX	X XXXXX	X XXXXX	X XXXXXX	XXXXXXXXXXXX

TABLE 27. SUITABILITY OF ACTIVITY EFFLUENT FOR REUSE

Base: March Air Force Base
Activity: Aircraft/Age Wash Rack
Activity Code: A/AWR
Special Treatment: Chem Coag

	NONE	PRIMARY	SECONDARY	FILTRATION	CARBON ADS	REV. OSMOS
	AHBOPAGVOGAH	AHBOPAGVOGAH	AHBOPAGVOGAH	AHBOPAGVOGAH	AHBOPAGVOGAH	AHBOPAGVOGAH
	/OOFHHEWFOHO	/OOFHHEWFOHO	/OOFHHEWFOHO	/OOFHHEWFOHO	/OOFHHEWFOHO	/OOFHHEWFOHO
	AUQFOHNRFLIS	AJQFOHNRFLIS	AUQFOHNRFLIS	AUQFOHNRFLIS	AUQFOHNRFLIS	AUQFOHNRFLIS
	WS T I IFRP	WS T I IFRP	WS T I IFRP	WS T I IFRP	WS T I IFRP	WS T I IFRP
	RE O R R R	RE O R R R	RE O R R R	RE O R R R	RE O R R R	RE O R R R
BOD					X XXX	XXXXXXXXXXXX
COD						X XXXXX
PHNL			X X	X X	X XXXXX	X XXXXX
SS		X XXX	X XXX	X XXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
TDS	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
O&G					X XXXXX	X XXXXX
CL	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
NO_3	XXXX XXXXXXX	XXXX XXXXXXX	XXXX XXXXXXX	XXXX XXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
NH_4	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
PO_4	X XXXXX	X XXXXX	X XXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
NA	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
$CACO_3$	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
B	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
CN	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
FE	X XXXXX	X XXXXX	X XXXXX	X XXXXX	X XXXXX	XXXXXXXXXXXX

TABLE 28. ACCEPTABLE CASCADES AT VARIOUS LEVELS OF TREATMENT

Base: March Air Force Base

	NONE	PRIMARY	SECONDARY	FILTRATION	CARBON ADS	REV. OSMOS
	AHBOPAGVOGAH /OOFHHEWFOHO AUQFOHNRFLIS WS T I IFRP RE O R R R	AHBOPAGVOGAH /OOFHHEWFOHO AJQFOHNRFLIS WS T I IFRP RE O R R R	AHBOPAGVOGAH /OOFHHEWFOHO AUQFOHNRFLIS WS T I IFRP RE O R R R	AHBOPAGVOGAH /OOFHHEWFOHO AUQFOHNRFLIS WS T I IFRP RE O R R R	AHBOPAGVOGAH /OOFHHEWFOHO AUQFOHNRFLIS WS T I IFRP RE O R R R	AHBOPAGVOGAH /OOFHHEWFOHO AUQFOHNRFLIS WS T I IFRP RE O R R R
A/AWR						1 21222
...OIL+GREASE					2 2	1 11111
...CHEM COAG					2 12111	X XXXXX
HOUSE			X XXX	X XXXXX	X XXXXX	X222 2XXXXX2
BOQ			X XXX	X XXXXX	X XXXXX	X222 2XXXXX2
OFF			X XXX	X XXXXX	X XXXXX	X222 2XXXXX2
PHOTO			2 22222	X 1X111	X 1X111	X222 21X1112
...METAL REM			2 22222	X 1X111	X 1X111	X11111XXXXX1
AHH			X XXX	X XXXXX	X XXXXX	X222 2XXXXX2
VWR				1 111	X XXXXX	X22222XXXXX2
HOSP			X XXX	X XXXXX	X XXXXX	X222 2XXXXX2

Cost data that must be provided includes the following:

1. Annual rate of interest.

2. Engineering News Record Construction Cost Index.

3. Engineering News Record Labor Cost Index.

4. Estimated life of the system.

5. Costs of regular or special treatment units or chains.

6. Cost per 1,000 gallons for each source water supply and each final waste discharge to disposal.

With the aid of the Phase I output, the engineer should be able to develop several feasible cascade networks. These networks must be presented in proper format along with all estimated lengths of pipe between activities and treatment facilities which are included in the cascade network.

Figure 6 shows a typical schematic diagram of a network for March AFB CA.

Model Output

For each network provided, this cascade program summarizes flows and concentrations throughout the system, and finally lists all related costs. Again, a detailed discussion of all Phase II printout is presented in the User Manual.

At each BTS (Blending-Treatment-Storage) unit in a network the program summarizes and graphs: flows through the BTS, storage required, and make-up or discharge needed. In addition, required constituent removals are listed as well as all concentrations into and out of the BTS. Tables 29, 30, and 31 on the following pages display these typical printouts.

Costs for each network are then summarized including:

1. Size, length, and cost of all pipes in the network.

2. Cost of storage and pumping for each BTS.

3. Costs and description of special treatment at activities and regular treatment at each BTS.

4. Total yearly cost for the cascade system including fresh water purchase and final wastewater discharge costs.

(See Tables 32 through 36 for sample printouts.)

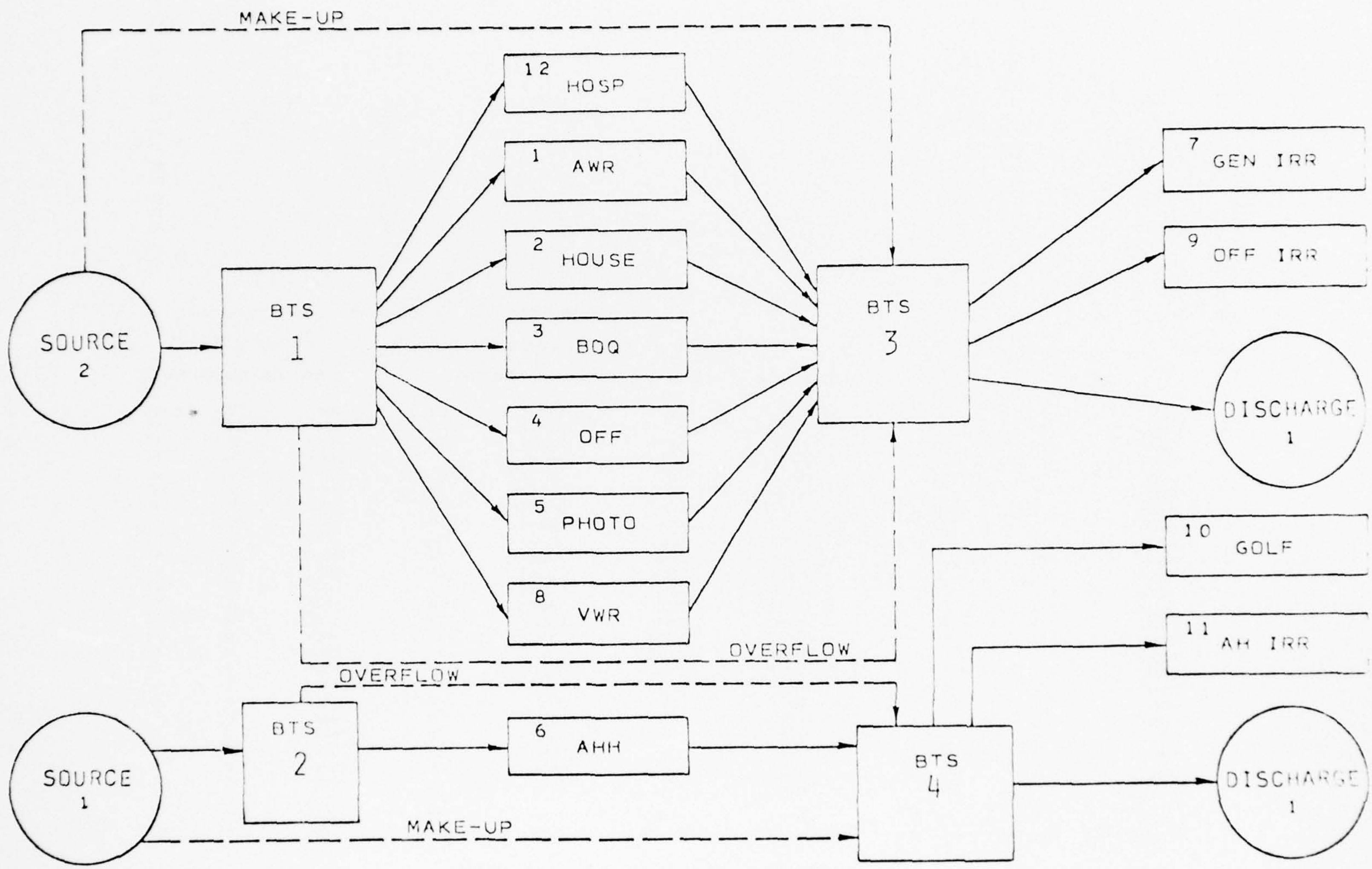

Figure 6. Sample Cascade Reuse Network Diagram

TABLE 29. FLOW SUMMARY FOR BTS 1

HOUR	IN (GPH)	OUT (GPH)	CUM IN (GAL)	CUM OUT (GAL)	MOD IN (GPH)	MOD CUM IN (GAL)	MIN STOR (GAL)	REQ STOR (GAL)	MAKE-UP (GPH)
1	0.	800.	0.	900.	800.	800.	0.	0.	800.
2	0.	800.	0.	1600.	800.	1600.	0.	0.	800.
3	0.	800.	0.	2400.	800.	2400.	0.	0.	800.
4	0.	800.	0.	3200.	800.	3200.	0.	0.	800.
5	0.	800.	0.	4000.	800.	4000.	0.	0.	800.
6	0.	1300.	0.	5300.	1300.	5300.	0.	0.	1300.
7	0.	3200.	0.	8500.	3200.	8500.	0.	0.	3200.
8	0.	8000.	0.	16500.	8000.	16500.	0.	0.	8000.
9	0.	26000.	0.	42500.	26000.	42500.	0.	0.	26000.
10	0.	24400.	0.	66900.	24400.	66900.	0.	0.	24400.
11	0.	22800.	0.	89700.	22800.	89700.	0.	0.	22800.
12	0.	20200.	0.	109900.	20200.	109900.	0.	0.	20200.
13	0.	20200.	0.	130100.	20200.	130100.	0.	0.	20200.
14	0.	20200.	0.	150300.	20200.	150300.	0.	0.	20200.
15	0.	20200.	0.	170500.	20200.	170500.	0.	0.	20200.
16	0.	20200.	0.	190700.	20200.	190700.	0.	0.	20200.
17	0.	3200.	0.	193900.	3200.	193900.	0.	0.	3200.
18	0.	4800.	0.	198700.	4800.	198700.	0.	0.	4800.
19	0.	6400.	0.	205100.	6400.	205100.	0.	0.	6400.
20	0.	6400.	0.	211500	6400.	211500.	0.	0.	6400.
21	0.	6400.	0.	217900.	6400.	217900.	0.	0.	6400.
22	0.	4800.	0.	222700.	4800.	222700.	0.	0.	4800.
23	0.	3700.	0.	226400.	3700.	226400.	0.	0.	3700.
24	0.	800.	0.	227200.	800.	227200.	0.	0.	800.

EXCESS STORAGE REQUIRED 0. GALLONS REQUIRED STORAGE CAPACITY 0. GALLONS

HOURLY FLOWS 1000. GPH

CUMULATIVE FLOWS 10000. GAL

STORAGE 1. GAL

MAKE-UP 1000. GPH

TABLE 30. CONCENTRATION SUMMARY FOR BTS 1

	SPEC. REMOVAL	REMOVAL	TOLERABLE (MG/L)
BOD	0.%	0.%	.100
COD	0.%	0.%	1.000
PHNL	0.%	0.%	.001
SS	0.%	0.%	1.000
TDS	0.%	0.%	700.000
O&G	0.%	0.%	.200
CL	0.%	0.%	185.000
NO_3	0.%	0.%	20.000
NH_4	0.%	0.%	.100
PO_4	0.%	0.%	3.000
NA	0.%	0.%	100.000
$CACO_3$	0.%	0.%	400.000
B	0.%	0.%	.100
CN	0.%	0.%	.010
FE	0.%	0.%	.300

TABLE 31. CONCENTRATION THROUGH BTS 1 (MG/L)

	TDS			O&G		
	INTO TREATMENT	OUT OF TREATMENT	OUT OF STORAGE	INTO TREATMENT	OUT OF TREATMENT	OUT OF STORAGE
1	0.0	568.0	568.0	0.0	.20	.200
2	0.0	568.0	568.0	0.0	.20	.200
3	0.0	568.0	568.0	0.0	.20	.200
4	0.0	568.0	568.0	0.0	.20	.200
5	0.0	568.0	568.0	0.0	.20	.200
6	0.0	568.0	568.0	0.0	.20	.200
7	0.0	568.0	568.0	0.0	.20	.200
8	0.0	568.0	568.0	0.0	.20	.200
9	0.0	568.0	568.0	0.0	.20	.200
10	0.0	568.0	568.0	0.0	.20	.200
11	0.0	568.0	568.0	0.0	.20	.200
12	0.0	568.0	568.0	0.0	.20	.200
13	0.0	568.0	568.0	0.0	.20	.200
14	0.0	568.0	568.0	0.0	.20	.200
15	0.0	568.0	568.0	0.0	.20	.200
16	0.0	568.0	568.0	0.0	.20	.200
17	0.0	568.0	568.0	0.0	.20	.200
18	0.0	568.0	568.0	0.0	.20	.200
19	0.0	568.0	568.0	0.0	.20	.200
20	0.0	568.0	568.0	0.0	.20	.200
21	0.0	568.0	568.0	0.0	.20	.200
22	0.0	568.0	568.0	0.0	.20	.200
23	0.0	568.0	568.0	0.0	.20	.200
24	0.0	568.0	568.0	0.0	.20	.200

	CL			NO_3		
	INTO TREATMENT	OUT OF TREATMENT	OUT OF STORAGE	INTO TREATMENT	OUT OF TREATMENT	OUT OF STORAGE
1	0.000	185.000	185.000	0.000	20.000	20.000
2	0.000	185.000	185.000	0.000	20.000	20.000
3	0.000	185.000	185.000	0.000	20.000	20.000
4	0.000	185.000	185.000	0.000	20.000	20.000
5	0.000	185.000	185.000	0.000	20.000	20.000
6	0.000	185.000	185.000	0.000	20.000	20.000
7	0.000	185.000	185.000	0.000	20.000	20.000
8	0.000	185.000	185.000	0.000	20.000	20.000
9	0.000	185.000	185.000	0.000	20.000	20.000
10	0.000	185.000	185.000	0.000	20.000	20.000
11	0.000	185.000	185.000	0.000	20.000	20.000
12	0.000	185.000	185.000	0.000	20.000	20.000
13	0.000	185.000	185.000	0.000	20.000	20.000
14	0.000	185.000	185.000	0.000	20.000	20.000
15	0.000	185.000	185.000	0.000	20.000	20.000
16	0.000	185.000	185.000	0.000	20.000	20.000
17	0.000	185.000	185.000	0.000	20.000	20.000
18	0.000	185.000	185.000	0.000	20.000	20.000
19	0.000	185.000	185.000	0.000	20.000	20.000
20	0.000	185.000	185.000	0.000	20.000	20.000
21	0.000	185.000	185.000	0.000	20.000	20.000
22	0.000	185.000	185.000	0.000	20.000	20.000
23	0.000	185.000	185.000	0.000	20.000	20.000
24	0.000	185.000	185.000	0.000	20.000	20.000

TABLE 32. COST OF PIPE

	IN					OUT				
	SIZE (IN.)	LENGTH (FT.)	MAX FLOW (GPH)	COST/FT ($)	COST ($)	SIZE (IN.)	LENGTH (FT.)	MAX FLOW (GPH)	COST/FT ($)	COST ($)
A/AWR	2.	0.	1000.	4.00	0.	4.	0.	800.	8.00	0.
HOUSE	3.	0.	5000.	6.00	0.	4.	0.	5000.	8.00	0.
BOQ	1.	0.	500.	2.00	0.	4.	0.	500.	8.00	0.
OFF	6.	0.	15000.	12.00	0.	6.	0.	15000.	12.00	0.
PHOTO	2.	0.	2000.	4.00	0.	4.	0.	2000.	8.00	0.
AHH	6.	0.	18000.	12.00	0.	6.	0.	18000.	12.00	0.
GENIR	6.	3200.	14600.	12.00	38400.	0.	0.	0.	0.00	0.
VWR	1.	7500.	250.	2.00	15000.	4.	0.	225.	8.00	0.
OFFIR	4.	4000.	10500.	8.00	32000.	0.	0.	0.	0.00	0.
GOLF	10.	3600.	60000.	20.00	72000.	0.	0.	0.	0.00	0.
AHIRR	8.	7000.	28000.	16.00	112000.	0.	0.	0.	0.00	0.
HOSP	2.	0.	2500.	4.00	0.	4.	0.	2500.	8.00	0.

BTS	SIZE (IN.)	LENGTH (FT.)	MAX FLOW (GPH)	COST/FT ($)	COST ($)
1	6.	0.	26000.	12.00	0.
2	6.	0.	18000.	12.00	0.
3	6.	0.	24300.	12.00	0.
4	10.	0.	59000.	20.00	0.

TABLE 33. COST OF PUMPING AND STORAGE

BTS	STORAGE (GAL)	DIAMETER (FT)	STO. COST ($)	MAX. FLOW (GPH)	PUMP CAP COST ($)	PUMP O&M COST ($/YR)
1	0.	0.	0.	26000.	26899.	1096.
2	0.	0.	0.	18000.	22547.	843.
3	1282.	4.	1356.	25350.	26574.	1075.
4	78398.	33.	16500.	65000.	41759.	2329.

TABLE 34. SPECIAL TREATMENT COSTS

ACT	TREATMENT	FLOW (GPD)	CAP. COST ($)	O&M COST ($/YR)

TREATMENT COSTS

BTS	TREATMENT	FLOW (GPD)	CAP. COST ($)	O&M COST ($/YR)
3	CARBON ADS	228400.	1003213.	84887.
4	SECONDARY	281000.	696504.	54862.

TABLE 35. COST OF SOURCE WATER

		GPD	$/1000 GAL	$/YEAR
1	COLO	739000.	.50	134868.
2	WELLS	603200.	.49	107882.

COST OF DISCHARGE

		GPD	$/1000 GAL	$/YEAR
1	DISCH	0.	.30	0.

TABLE 36. COST SUMMARY

	COST SUMMARY ($)	EXISTING FACILITIES COST ($)	NET COST ($)
Capital Cost of Pipe	269400.		
Capital Cost of Pumping	117779.		
Capital Cost of Storage	17856.		
Capital Cost of Regular Treatment	1699717.		
Capital Cost of Special Treatment	0.		
Total Capital Cost	2104752.		
Yearly Cost for Pipe	29679.		
Yearly Capital Cost for Pumping	12975.		
Yearly O&M Cost for Pumping	5344.		
Yearly Capital Cost for Storage	1967.		
Yearly Capital Cost for Regular Treatment	187255.		
Yearly O&M Cost for Regular Treatment	139748.		
Yearly Capital Cost for Special Treatment	0.		
Yearly O&M Cost for Special Treatment	0.		
Yearly Cost of Source Water	242750.		
Yearly Cost of Discharge	0.		
Total Yearly Cost	619718.		

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

1. The cascade water reuse computer model, developed during this investigation is a useful planning tool for comparative analysis of potential reuse systems at Air Force installations. The model provides a systematic methodology for organizing the basic information required to evaluate the wastewater reuse potential at any base by analyzing the tabulated data quickly to determine what potential reuse systems might be feasible. The program requires input and interaction with an engineer experienced in water and wastewater management. The model also requires the service of an adequate computer facility. The model input-output is designed, however, so the engineer and the computer can be geographically separated and work effectively.

Important outputs of the computer model are the quantity and quality of supply water required by each activity, quantity and quality of waste-water genrated by each activity, treatment level required for reuse, storage requirements, results of blending of various wastewaters and/or freshwater, pumping, pipeline transport, and estimated system costs.

2. The computer model requires substantial data input describing the individual base activities which are potential suppliers and/or users of reclaimed water. The accumulation of this data input and processing of the data into the computer program is estimated to require a minimum of two to four man-weeks of effort. The program is most cost effective to use, therefore, when it is anticipated that a significant number of potential reuse systems will have to be compared during the planning process in order to select the most cost effective system or systems.

3. Air Force bases which use large amounts of water for irrigation and/or industrial type activities are prime candidates for comprehensive cascade water reuse analysis. These include bases located in areas of below average rainfall and bases which are Air Logistic Centers.

4. The technology of wastewater reuse requires knowledge in three areas, i.e., (1) the pollutant constituents contained in the wastewater generated by the contributing Air Force base activity or activities, (2) the capability of available kinds of waste treatment processes to remove the various pollutants contained in the wastewater generated, and (3) limits of various pollutant concentrations which can be tolerated by the base activities being considered as recipients (users) of the treated wastewater to be reused. In reviewing the state-of-the-art in these three areas of knowledge, it was found that the first two, i.e., wastewater characteristics and treatment capabilities, are reasonably well documented (or can be determined by sampling, technology transfer techniques, etc.).

The third area, maximum acceptable pollutant limits for supply water to various base activities, was found, however, to be virtually devoid of information. This is understandable because only isolated in-process industrial reuse systems are being utilized. As a result of this data shortage, it was necessary for the purposes of this report to estimate the acceptable water supply quality criteria for various base activities from limited data.

5. This report itself, exclusive of the cascade reuse model, can be helpful to base personnel by providing background data on wastewater reuse. Summarized herein is the best information available on the wastewater characteristics of Air Force base activities and estimates of maximum acceptable contaminant levels for supply water to activities.

6. It is recommended that research be initiated to better determine maximum contaminant concentrations for various Air Force activities which are significant water users. As previously indicated (conclusion 4), this is an area that severely handicaps analysis of wastewater reuse potential at Air Force bases. Without comprehensive data on the maximum acceptable contaminant levels for water supplied to major activities, cascade reuse programs must either ignore these activities or estimate maximum contaminant levels acceptable to those activities.

The required research would likely follow two main avenues: (1) a comprehensive literature search would be conducted to gather all pertinent existing information on private sector activities similar to Air Force operations; and (2) several key pilot reuse operations would be developed for prime activities (aircraft washing, metal plating, power plant cooling, etc.). Once major activity maximum acceptable water contaminant levels are better defined, reuse operations could be more effectively implemented.

7. The cascade reuse model was utilized effectively in actual application at Peterson AFB CO. A full-scale wastewater treatment/reuse facility has been designed with the initial aid of the model output. Aerated lagoons and slow sand filtration was the treatment system selected to prepare the water for golf course irrigation.

8. Preliminary results from this report show that wastewater reuse can provide cost savings over freshwater usage at bases with extensive irrigation or industrial water demands, potential water supply problems, and/or high discharge fees.

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