

PN-RAU-738
ISN=46742

ARID WATER DISTRIBUTION,
SEWERAGE, STORM DRAINAGE AND
SOLID WASTE DISPOSAL PROJECT

WASTEWATER TREATMENT ALTERNATIVES

SUBMITTED TO:

MINISTRY OF MUNICIPAL AND RURAL
AFFAIRS AND THE ENVIRONMENT
OF
THE HASHEMITE KINGDOM OF JORDAN

JANUARY 29, 1981



WESTON INTERNATIONAL, INC.



DESIGNERS-CONSULTANTS

WESTON WAY • WEST CHESTER, PA 19380 • PHONE: (215) 692-3030 • TELEX: 83-5348 • FROM OFFICE OF THE PRESIDENT, JAMES P. MILLER, P.E.

January 29, 1981

Ministry of Municipal and Rural
Affairs and The Environment
The Hashemite Kingdom of Jordan
Amman, Jordan

Attention: Mr. Lutfi Tadrous

Re: IRBID WATER DISTRIBUTION, SEWERAGE, STORM DRAINAGE AND SOLID WASTE
DISPOSAL PROJECT - WASTEWATER TREATMENT ALTERNATIVES.

Gentlemen:

WESTON International, Inc. has reevaluated the wastewater treatment alternatives considered in the previously submitted feasibility report and its addenda as you requested during the meetings on 6-9 December 1980. These alternatives were compared with new alternatives developed from criteria discussed in these meetings in Amman. This evaluation is presented in detail in the attached report.

We have also attached a decision matrix comparing pertinent criteria, both economic and noneconomic criteria, for each of the alternatives developed in this report. In this matrix lower scores indicate better alternatives.

Inspection of this matrix leads to the following conclusions:

1. Based on equally weighted factors as described herein, Alternative 1, extended aeration activated sludge (the alternative recommended in the feasibility study) is the most desirable alternative.
2. If rating factors for effluent quality are ignored Alternative 4, activated sludge with reduced effluent quality, is the best apparent alternative.
3. If rating factors for effluent quality are ignored and emphasis on power costs is doubled Alternative 3, two stage trickling filter, is the best alternative.
4. If effluent quality is considered and emphasis on power costs is doubled Alternative 2, trickling filter/activated sludge, is slightly more desirable than Alternative 1.

January 29, 1981

WESTON International, Inc. feels that a decision to lower the recommended wastewater treatment effluent standards is not in the best interests of management of the scarce water resources in Jordan. High effluent standards should be strongly considered in comparison of alternatives. Also, excessive emphasis on one evaluation criteria such as power costs, is misleading unless the costs and impacts of lower water quality are also considered.

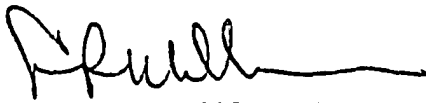
On the basis of these factors Weston International, Inc. recommends Alternative 1 as the best wastewater treatment alternative for the City of Irbid.

We await your authority to proceed with the design of Irbid wastewater treatment facilities. If a decision is made to proceed with an alternative other than Alternative 1, the Stage II engineering costs will have to be increased in addition to the Stage II costs requested in our 6 December 1980 letter. This cost is insignificant, however, when compared to total project costs and should not influence the alternative selection.

A revised time schedule for completion of wastewater treatment plant design will be prepared after a treatment alternative has been selected and you give us a notice to proceed with the design.

Very truly yours,

WESTON INTERNATIONAL, INC.



James P. Miller, P.E.
President

cc: National Planning Council
U.S.A.I.D. Jordan
U.S.A.I.D. Washington, D.C. ✓

Attachments

JPM:mmk



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R A T I N G F A C T O R S

CRITERIA \ ALTERNATIVES	Weighting Factor	Extended Air Original Recommendation	Trickling Filter w/ Activated Sludge	Two Stage Trickling Filter	Activated Sludge Red. Effl. Quality	Same as 4 & Anaerobic Digestors	Same as Alt. 2 w/ Power Generation	Same as Alt. 3 w/ Power Generation	Same as Alt. 5 w/ Power Generation
	1	2	3	4	5	6	7	8	
EFFLUENT QUALITY	a/	1	1	10	10	5	1	10	5
CAPITAL COSTS		3	7	8	1	6	7	8	6
POWER COSTS	b/ c/	10	6	2	9	10	5	1	8
OTHER OPERATING COSTS		3	4	1	3	3	6	4	5
OPERABILITY/MAINTAINABILITY		1	3	3	1	3	5	5	5
FLEXIBILITY/EASE OF UPGRADING		1	1	5	2	2	1	5	2
ALL FACTORS EQUALLY WEIGHTED		<u>19</u>	22	29	26	29	25	33	31
a/ RATING W/O EFFLUENT QUALITY		18	21	19	<u>16</u>	24	24	23	26
b/ RATING W/DOUBLE EMPHASIS ON POWER AND W/O EFFLUENT QUALITY		28	28	<u>21</u>	25	34	29	24	34
c/ W/DOUBLE EMPHASIS ON POWER & W/ EFFLUENT QUALITY		29	<u>28</u>	31	35	39	38	34	39

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RATING FACTORS

5. OTHER OPERATING COSTS (PRESENT VALUE 1979)

1	2,400,000	-	2,450,000
2	2,450,000	-	2,500,000
3	2,500,000	-	2,550,000
4	2,550,000	-	2,600,000
5	2,600,000	-	2,650,000
6	2,650,000	-	2,700,000

6. OPERABILITY / MAINTAINABILITY

- 1 ALTERNATIVES WITH AEROBIC SLUDGE HOLDING
- 3 ALTERNATIVES WITH ANAEROBIC SLUDGE DIGESTION
- 5 ALTERNATIVES WITH ANAEROBIC SLUDGE DIGESTION AND POWER GENERATION USING DIGESTER GAS

7. FLEXIBILITY / EASE OF UPGRADING

- 1 ALTERNATIVES THAT MEET 30 mg/l BOD & 30 mg/l ss EFFLUENT QUALITY STANDARDS WITHOUT UPGRADING.
- 2 ALTERNATIVES THAT CAN MEET 30 mg/l BOD & 30 mg/l ss EFFLUENT QUALITY STANDARDS WITH EXPANSION OF EXISTING OR ADDITION OF NEW SECONDARY TREATMENT PROCESSES.
- 5 ALTERNATIVES THAT REQUIRE ADDITION OF ADVANCED TREATMENT PROCESSES TO MEET 30 mg/l BOD AND 30 mg/l ss EFFLUENT QUALITY STANDARDS.

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RATING FACTORS

1. EFFLUENT QUALITY

1	30 mg/l BOD & 30 mg/l ss	entire 20 year period	
5	90 mg/l BOD & 90 mg/l ss	first 10 years and 30 mg/l BOD & 30 mg/l ss	last 10 years
10	90 mg/l BOD & 90 mg/l ss	entire 20 year period	

2. CAPITAL COSTS

1	CAPITAL COST	JD 2,500,000	-	JD 2,700,000
2		2,700,000	-	2,900,000
3		2,900,000	-	3,100,000
4		3,100,000	-	3,300,000
5		3,300,000	-	3,500,000
6		3,500,000	-	3,700,000
7		3,700,000	-	3,900,000
8		3,900,000	-	4,100,000
9		4,100,000	-	4,300,000
10		4,300,000	-	4,500,000

3. ANNUAL COSTS (PRESENT VALUE 1979)

1	4,600,000	-	5,000,000
2	5,000,000	-	5,400,000
3	5,400,000	-	5,800,000
4	5,800,000	-	6,200,000
5	6,200,000	-	6,600,000
6	6,600,000	-	7,000,000
7	7,000,000	-	7,400,000
8	7,400,000	-	7,800,000
9	7,800,000	-	8,200,000
10	8,200,000	-	8,600,000

4. POWER COSTS (PRESENT VALUE 1979)

1	0	-	500,000
2	500,000	-	1,000,000
3	1,000,000	-	1,500,000
4	1,500,000	-	2,000,000
5	2,000,000	-	2,500,000
6	2,500,000	-	3,000,000
7	3,000,000	-	3,500,000
8	3,500,000	-	4,000,000
9	4,000,000	-	4,500,000
10	4,500,000	-	5,000,000

IRBID WATER DISTRIBUTION, SEWERAGE, STORM DRAINAGE AND SOLID
WASTE DISPOSAL PROJECT

REEVALUATION OF WASTEWATER TREATMENT ALTERNATIVES

I. INTRODUCTION

Several wastewater treatment alternatives considered in the feasibility study as well as new alternatives developed in this analysis have been evaluated at the request of the National Planning Council based upon several criteria discussed in meetings in Amman between Weston and National Planning Council and Ministry of Municipal and Rural Affairs and the Environment representatives during December 1980. Special criteria examined were as follows:

1. Cost Escalation applied to Alternatives

Capital and operating costs were escalated ten percent per year through the study period. Power costs were escalated from 1980 rates and other operating and capital costs were based upon 1979 prices.

2. Reduced Effluent Standards

The impact of reduced effluent standards on the selection of treatment alternatives was examined. Reduced treatment levels of 90 mg/L BOD₅ and suspended solids were evaluated against the 30 mg/L BOD₅ and suspended solids effluent standards proposed in the feasibility report. Weston regards reductions in the effluent standards recommended in the feasibility report as being undesirable and should be considered only as very short-term measures.

3. Gas Power Generation

The effect on operating costs of power generated using gas produced from anaerobic sludge digestion was examined.

2. DESCRIPTION OF ALTERNATIVES

The features of the alternatives considered in this analysis are described below:

Alternative 1: Extended Aeration Process (Feasibility Report Recommended Process, Figure 1) Feasibility Report Alternative MT-4 Extended Aeration Activated Sludge; this alternative is designed to produce good quality effluent (30mg/L BOD₅ and suspended solids) features include aerated sludge holding tanks and sludge drying beds. Process consumes power at a significant rate.

Alternative 2: Trickling Filter/Activated Sludge Process (Figure 2)

Feasibility Report Alternative MT-2 Trickling Filter and Activated Sludge; this alternative is also designed to produce good quality effluent (30 mg/L BOD₅ & suspended solids) features include primary treatment and anaerobic sludge digestion with sludge drying beds. Some decrease in annual power costs. Harder to operate and maintain than Alternative 1.

Alternative 3: Two Stage Trickling Filter (Figure 3)

This alternative was not developed in the Feasibility Report. It produces moderate effluent quality (90 mg/L BOD₅ and suspended solids) features includes primary treatment, anaerobic sludge digestion and sludge drying beds. Energy efficient process. Difficult to operate and maintain. Expensive to upgrade treatment levels.

Alternative 4: Modified Feasibility Report Alternative MT-4 (Figure 4)

Modifies the activated sludge process to produce moderate effluent quality (90 mg/L BOD₅ and suspended solids). This alternative requires less aeration capacity (aerators and aeration tank volume than Alternative 1. Power requirements are reduced. Simple to upgrade to produce higher quality effluent.

Alternative 5: Activated Sludge Process/Anaerobic Digesters (Figure 5)

This is a combination of Alternative 1 and 4. In Phase I of this alternative facilities necessary to meet the moderate effluent quality standards are constructed as per Alternate 4. In Phase II the facilities are upgraded to provide good effluent quality as in Alternate 1. In addition, anaerobic digesters are constructed in Phase II. The aerobic sludge holding tanks are converted to gravity thickeners.

Alternative 6: Trickling Filter/Activated Sludge Process + Gas Power Generation (Figure 6).

This is alternative 2 with the addition of gas recovery equipment in Phase II to allow for power generation with methane gas reuse. Significantly decreases power costs in the long term. Very difficult to operate and maintain.

Alternative 7: Two stage Trickling Filter + Gas Power Generation (Figure 7).

This is alternative 3 with the addition of gas recovery equipment in Phase II. Comments regarding power costs and O & M in Alternative 6 apply.

Alternative 8: Activated Sludge Process + Gas Power Generation (Figure 8).

This is alternative 5 with the addition of gas recovery equipment in Phase II. Comments regarding power costs and O & M in Alternative 6 apply.

Capital costs for these alternatives are listed in Table 1.

TABLE I

COMPARISON OF ALTERNATIVES

CAPITAL COSTS BASED ON 1979 PRICES

COSTS IN THOUSANDS OF JD

PARAMETER	ALT.	1	2 & 6	3 & 7	4	5 & 8
CAPITAL COSTS		STAGE				
1. Land Costs - trmnt area	I	90	90	90	90	90
	II	-	-	-	-	-
2. Site Prep/Grading/Fencing	I	40	40	40	40	40
	II	-	-	-	-	-
3. Preliminary Trtmt Works	I	100	100	100	100	100
	II	50	50	50	50	50
4. Primary Trmt Works	I	-	150	150	-	-
	II	-	75	75	-	-
5. Biological Trmt inc. Clarification	I	1131	1360	1628	967	967
	II	673	388	365	499	837
6. Dininfection/Reaeration	I	15	15	15	15	15
	II	5	5	5	5	5
7. Gravity Thickeners/sludge holding	I	109	92	92	109	109
	II	64	46	46	64	30
8. Two Stage Anaerobic Digesters	I	-	561	561	-	-
	II	-	-	-	-	561
9. Ancillary Bldgs. & structures	I	71	71	71	71	71
	II	20	20	20	20	20
10. Emergency Generators	I	54	41	33	50	50
	II	23	17	14	21	27
11. Site Piping	I	181	282	310	181	181
	II	119	93	100	119	119
12. Sludge Drying Beds	I	251	251	251	251	251
	II	36	36	36	36	36
TOTALS:						
Stage I - Phase I		1263	2160	2202	1177	1177
Stage I - Phase II		779	893	1139	697	697
Total Stage I		2042	3053	3341	1874	1874
Stage II		990	730	711	814	1685
TOTAL CAPITAL COST		3032	3783	4052	2688	3559

FIGURE 1 - EXTENDED AERATION ACTIVATED SLUDGE

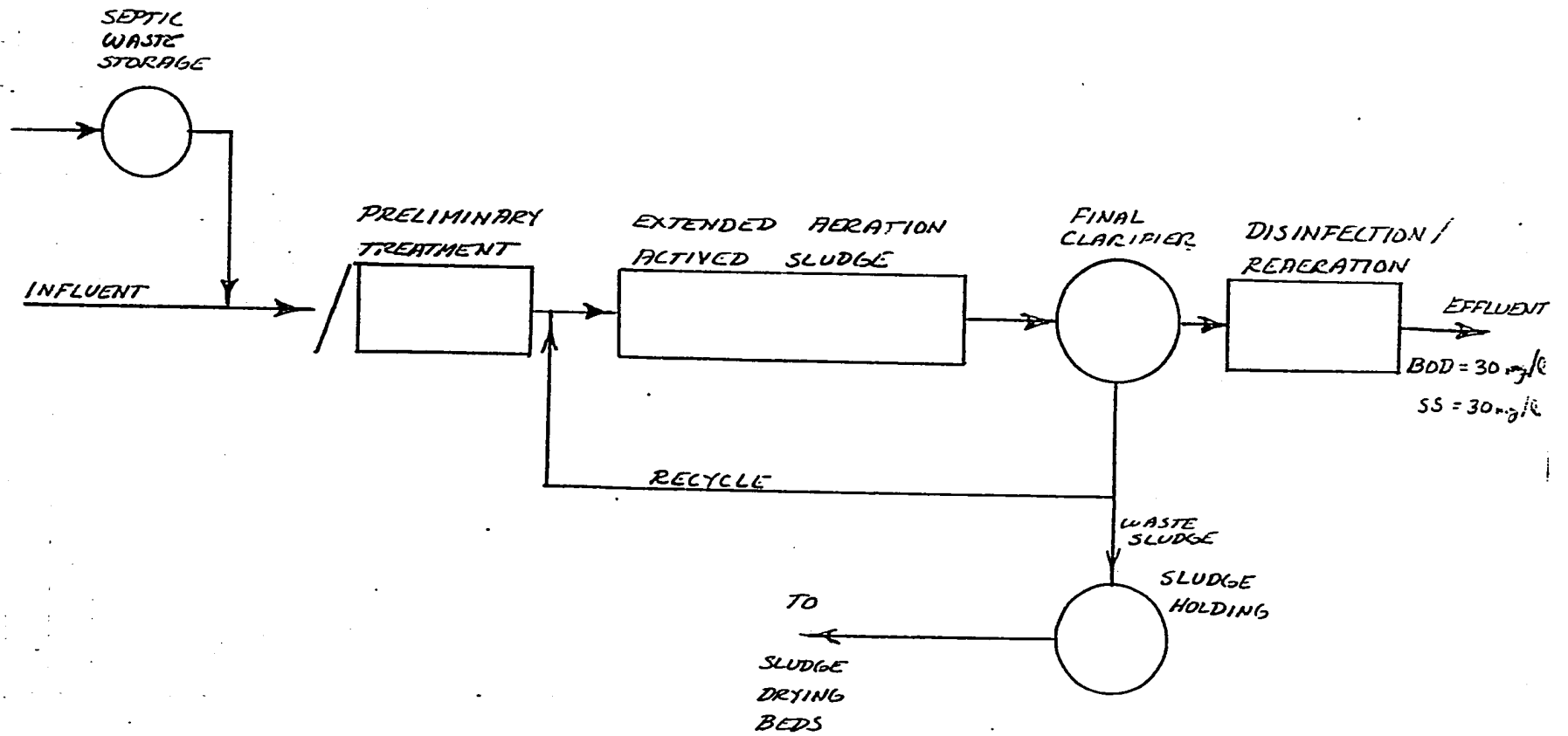


FIGURE 2 - TRICKLING FILTER - ACTIVATED SLUDGE

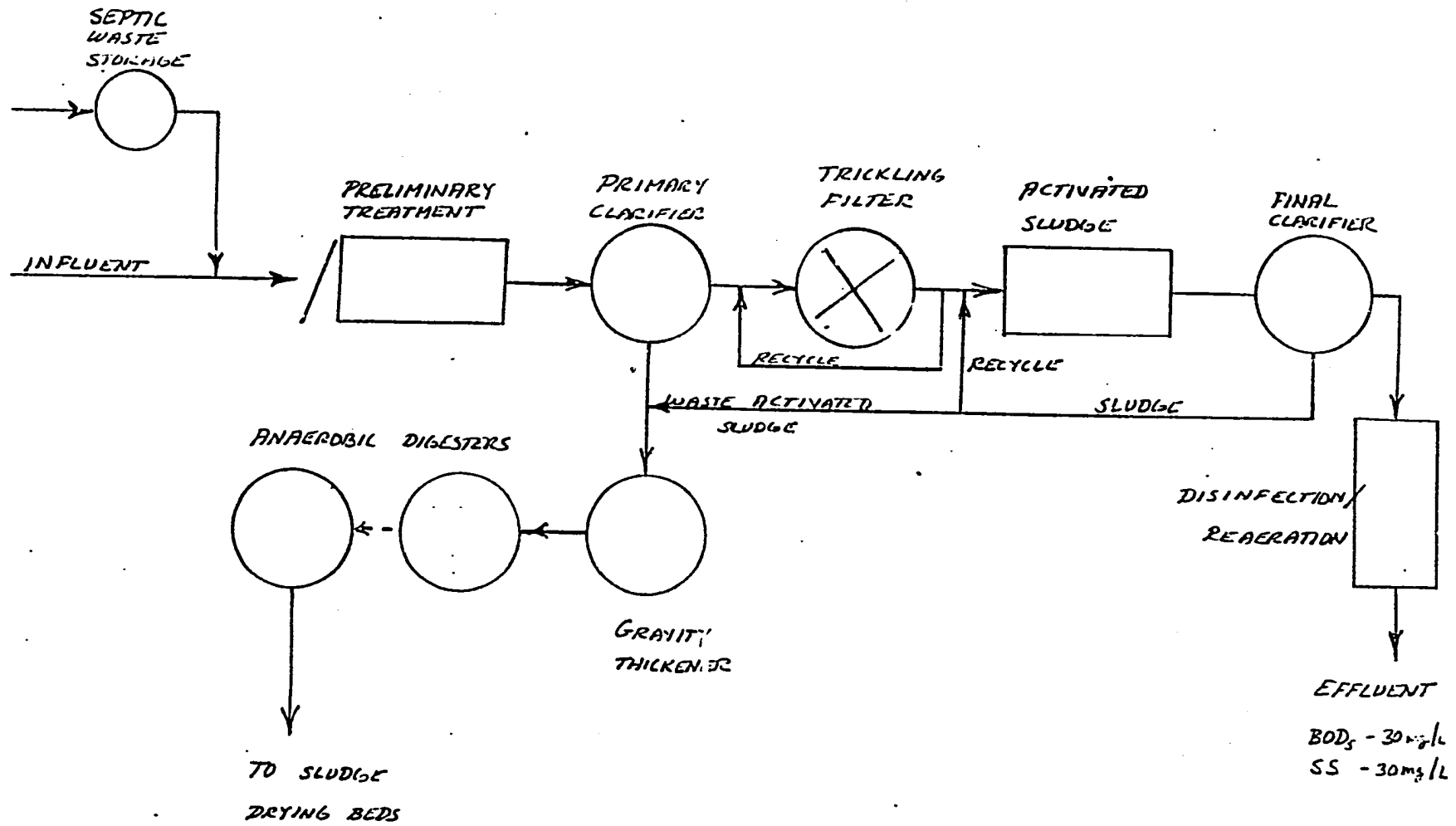


FIGURE 3 - TWO STAGE TRICKLING FILTER

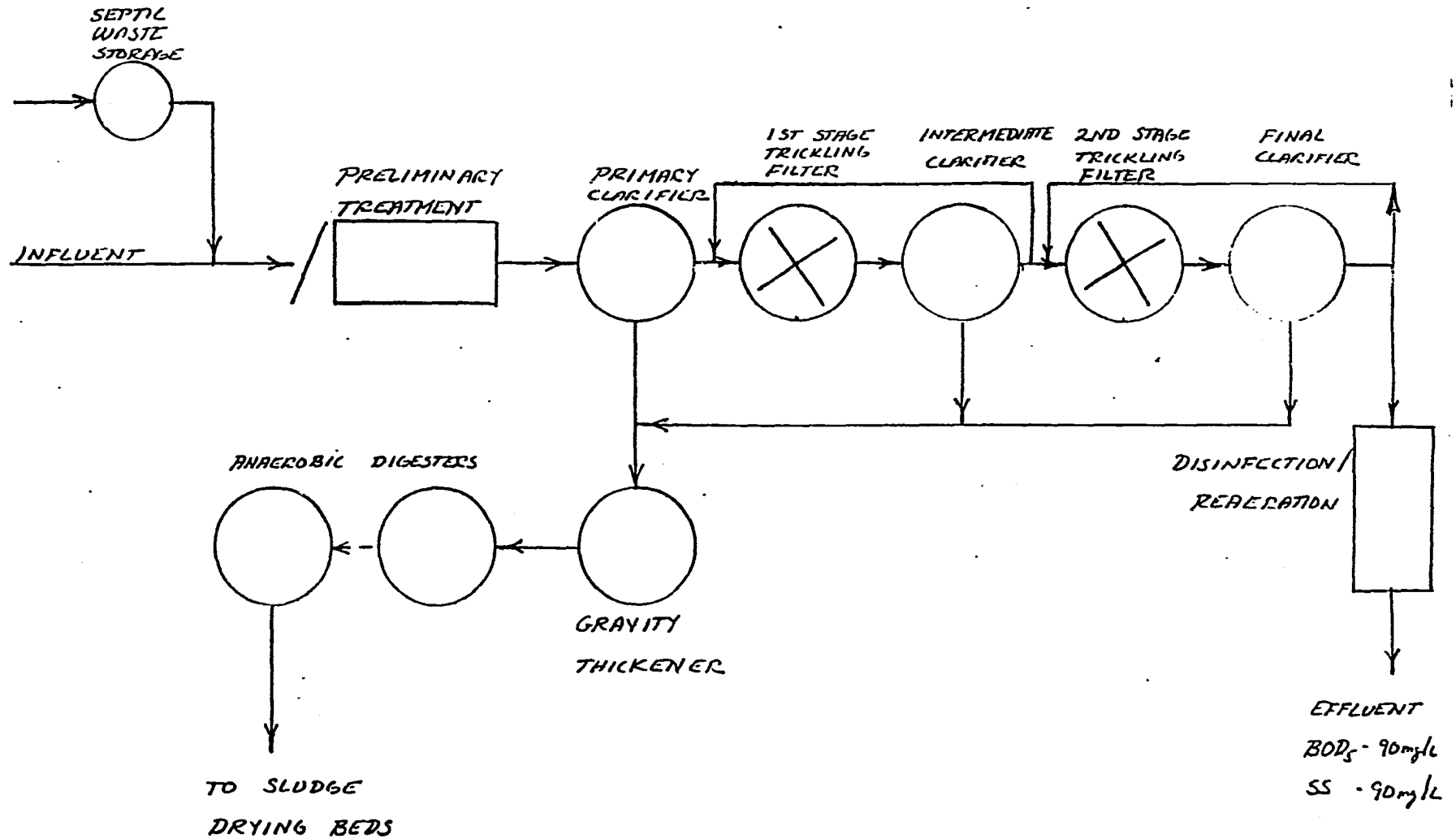


FIGURE 4 - MODIFIED ACTIVATED SLUDGE

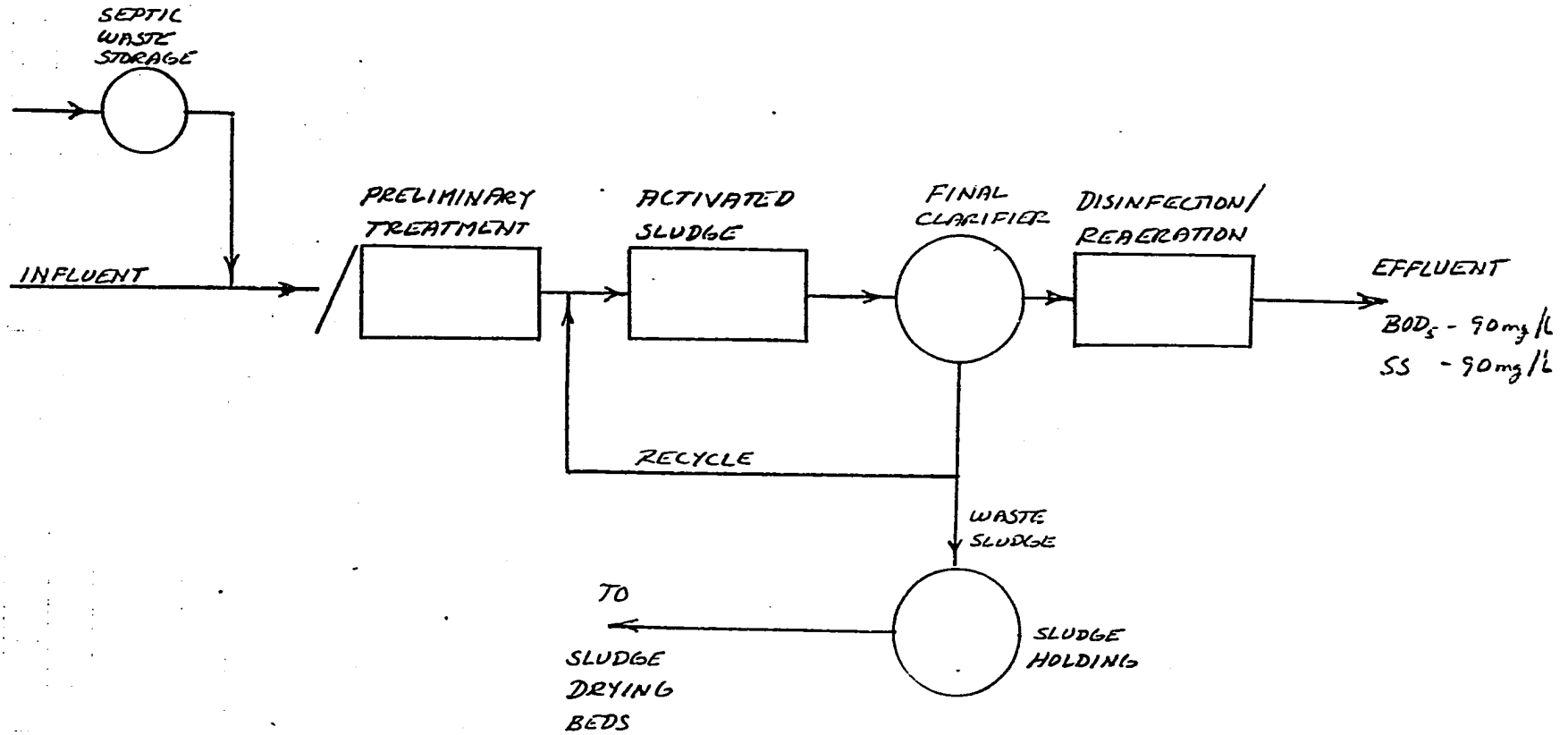


FIGURE 5 - .. ACTIVATED SLUDGE

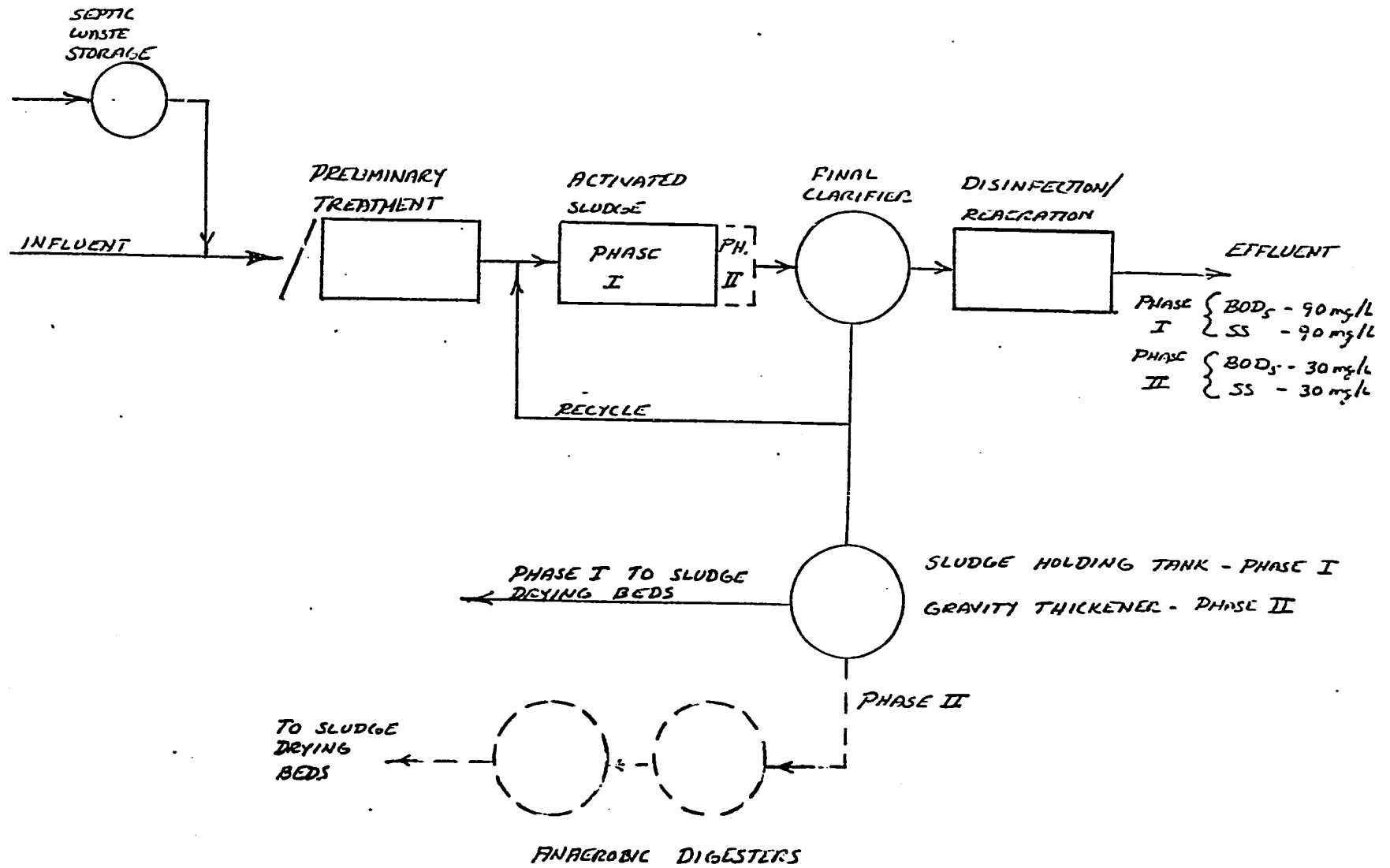


FIGURE 6 - TRICKLING FILTER - ACTIVATED SLUDGE

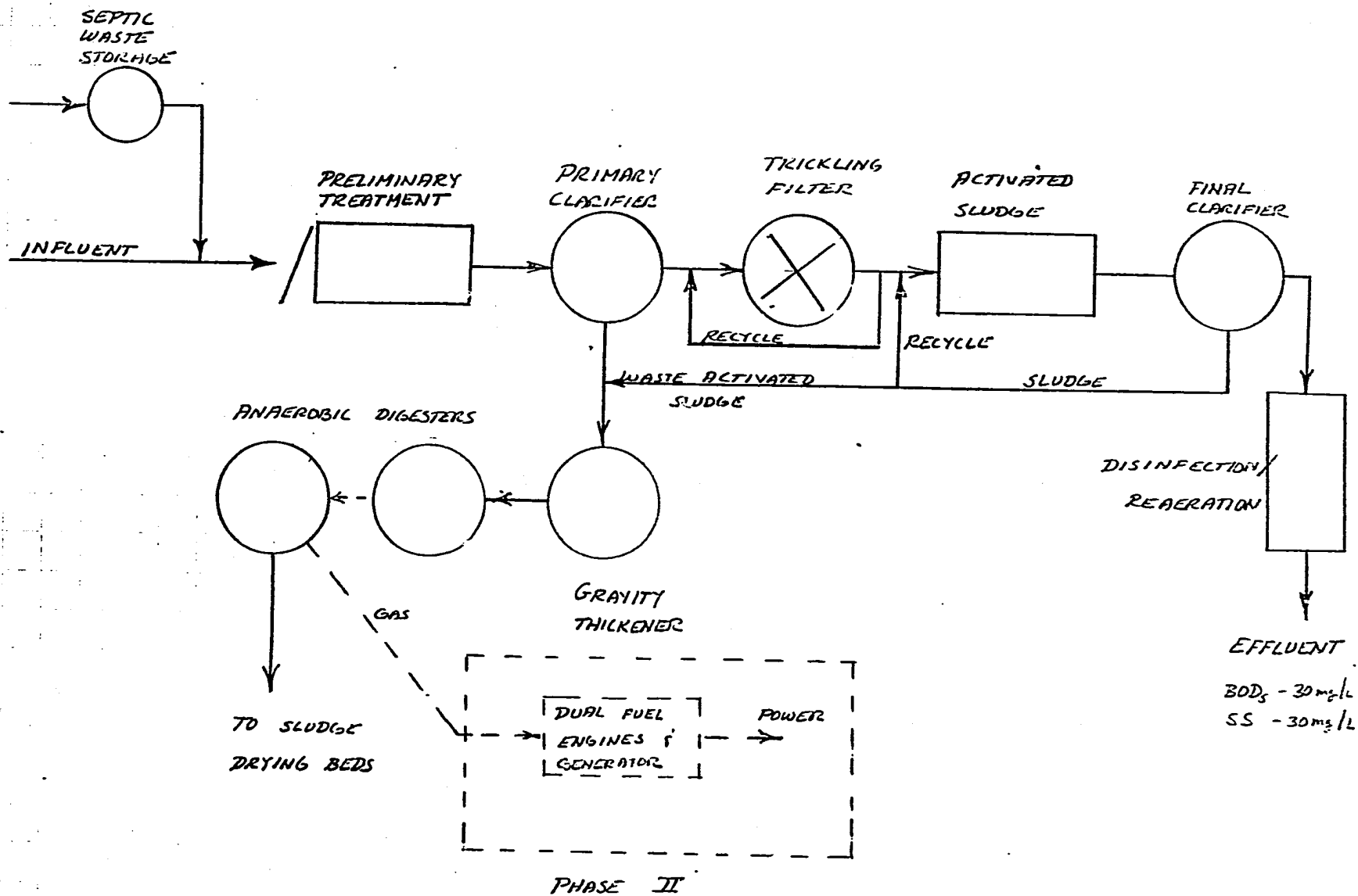
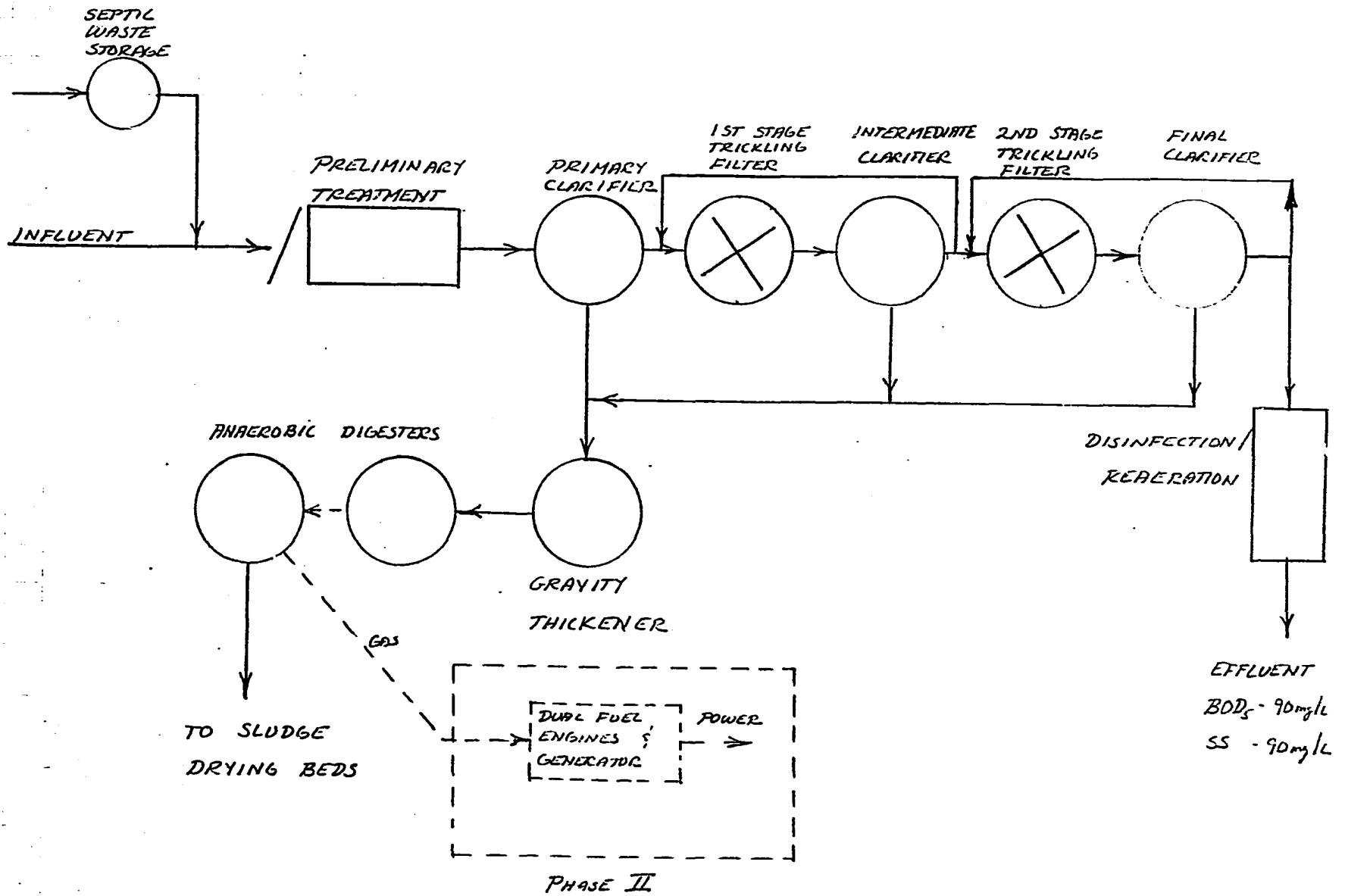
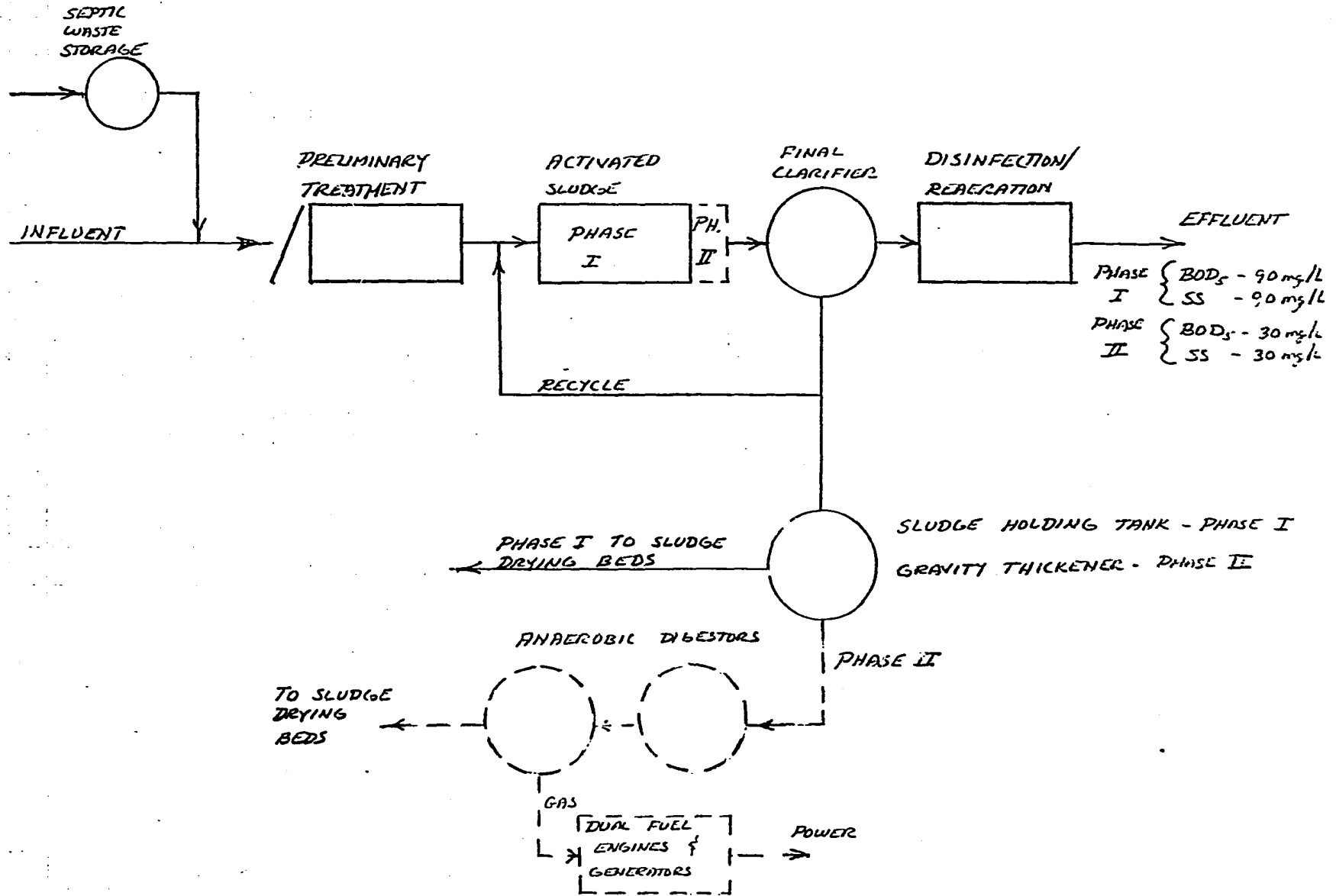


FIGURE 7 - TWO STAGE TRICKLING FILTER



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FIGURE 8 - ACTIVATED SLUDGE



Based upon the new criteria, the least cost alternatives are as follows:

<u>EVALUATION CRITERIA</u>	<u>LEAST COST ALTERNATIVE</u>
1. Effluent requirements - 30 mg/L BOD ₅ and suspended solids - through entire study period - without power generation	Alternative 2 - Trickling Filter with Activated Sludge (Feasibility Report Alternative MT-2)
2. Effluent requirements - 90 mg/L BOD ₅ and suspended solids through entire study period without power generation.	Alternative 3 - Two stage trickling filter (new alternative).
3. Effluent requirements - Phase I 90 mg/L BOD ₅ and suspended solids without power generation.	Alternative 2 - Trickling Filter with Activated Sludge. Note: Phase I costs are less for Alternative 5 (modified activated sludge) but overall costs for Alternative 5 are more than for Alternative 2.
4. Power Generation using Digester Gas.	Power Generation from anaerobic sludge digester gas reduces the overall costs for the Alternatives but does not change the relative ranking of alternatives.

On the basis of these analyses the first phase of Alternative 5 is the most flexible Phase I treatment choice. This alternative has the lowest overall Phase I cost and it can be upgraded by addition of activated sludge capacity, addition of primary clarifiers and trickling filters and/or anaerobic sludge digesters with or without gas recovery and reuse for power generation.

On site power generation from methane gas produced in anaerobic sludge digesters should be deferred until Phase II when there are sufficient connections to the Irbid Sewer System to produce sufficient quantities of sludge to ensure satisfactory gas production and efficient utilization of power generation facilities.

ECONOMIC EVALUATION OF ALTERNATIVES

Alternatives 1 through 8 have been evaluated in accordance with the following procedure:

1. A phased capital investment schedule was developed based on the schedule listed in the analyses of the funded project performed for U.S. A.I.D. in June and July 1980. The capital investments are escalated at a rate of 10 percent per year from the base year, 1979. Annual capital costs are computed based upon repaying the capital investment over a 20 year period at an annual interest rate of 6 percent except for the initial construction which will have no repayment the first three years and then the entire amount, including accumulated interest is repaid in 17 years at an annual interest rate of 6 percent.

2. Annual power costs are estimated using the electric power tariffs in effect in Jordan in 1980. The power costs are escalated at a rate of 10 percent per year from 1980.
3. Other annual costs are estimated on the basis of 1979 costs and they are escalated at a rate of ten percent per year.
4. Annual costs are accumulated over the twenty year study period and brought back to the 1979 base year using present worth analysis at an annual interest rate of 10 percent. The salvage value of the facilities is considered equal to the outstanding capital costs due after the year 2000. This has the effect of reducing the present worth cost of deferred capital expenditures.

The analyses of these costs together with estimated annual operating costs are developed in Tables 2-1 through 2-8. These computations are summarized and compared in Table 3.

The cost effectiveness analysis developed in the Irbid Feasibility Study evaluated alternatives capable of achieving good effluent standards (30 mg/L, BOD₅ and suspended solids). These alternatives were evaluated on the basis of environmental effects, energy requirements, compatibility with other plans, reliability and comparison of unescalated costs, including 1979 power rates in effect at the time the study was made. This evaluation was performed in accordance with U.S. Environmental Protection Agency guidelines for cost effectiveness evaluations. On the basis of these evaluations the extended aeration activated sludge alternative was recommended. This alternative has the least capital cost but greater power cost, especially in future years, than the other alternatives evaluated in the Feasibility Study.

Selection of the recommended wastewater treatment alternative depends upon the emphasis placed upon the various evaluation criteria. Subsequent to completion of the feasibility study greater emphasis has been focused on power costs to the extent that lesser degrees of treatment may be tolerated. In 1980 electric power rates in Irbid were doubled. The alternatives selected in this study have been designed to determine cost effective treatment schemes based on the following criteria.

- Cost Escalation
- Effluent Standards
- Power Generation from Digester Gas

The effects of these criteria on evaluation of the wastewater treatment alternatives are discussed below:

COST ESCALATION - In the feasibility study alternatives were evaluated based on 1979 prices without escalation due to inflation. On this basis Alternative 1, Extended Aeration Activated Sludge, was determined to be the least cost alternative.

IRBID WASTEWATER TREATMENT FACILITIES

(ALTERNATE MT 4 - EXTENDED AERATION ACTIVATED SLUDGE)
ALTERNATIVE 1

ALL COSTS IN JD X 1000

TABLE 2-1

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
PHASE I - STAGE 1																				
Capital Cost - 1979 base	338	665	260																	
Capital Cost - Escalated	409	885	381																	
Amortized Interest	25	79	107																	
Cumulative Total (to be financed)	434	1398	1886																	
Annual Payment	-	-	-	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180
PHASE I - STAGE 2																				
Capital Cost - 1979 base																				
Capital Cost - Escalated							259	260	260											
Cumulative Total							555	613	674											
Annual Payment							48	102	161	161	161	161	161	161	161	161	161	161	161	161
PHASE 2																				
Capital Cost - 1979 base																				
Capital Cost - Escalated											330	330	330							
Cumulative Total											1036	1139	1253							
Annual Payment											90	190	299	299	299	299	299	299	299	299
TOTAL ANNUAL CAPITAL COSTS				180	180	180	228	282	341	341	431	531	640	640	640	640	640	640	640	640
OPERATING COSTS																				
Power Costs - 1980 base	-	-	-	46	76	100	128	212	274	314	332	352	370	388	403	426	444	462	482	500
Power Costs - Escalated	-	-	-	67	122	177	249	454	646	814	947	1105	1277	1473	1704	1957	2244	2567	2948	3364
Other Costs - 1979 base				112	115	116	119	122	123	142	143	146	148	169	171	173	175	177	178	180
Other Costs - Escalated				180	204	226	255	288	319	405	449	504	562	706	786	874	973	1083	1197	1332
Total Operating Costs - Escalated				247	326	403	504	742	965	1220	1396	1609	1839	2179	2490	2831	3217	3650	4145	4696
TOTAL ANNUAL CAPITAL & OPERATING COSTS - ESCALATED				427	506	583	732	1024	1306	1561	1827	2140	2479	2819	3130	3471	3857	4290	4785	5336
Present Worth - 1979 base i= 10%				265	286	299	341	434	503	547	582	620	653	675	681	687	694	701	711	721
Present Worth				551	850	1191	1625	2128	2675	3257	3877	4530	5205	5886	6573	7267	7968	8679	9400	

9400 - 793 (salvage) = 8607

IRBID WASTEWATER TREATMENT FACILITIES
(ALTERNATIVE HT 2)
ALTERNATIVE 2

TABLE 2-2

ALL COSTS IN JD X 1000

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
PHASE 1 - STAGE 1																				
Capital Cost - 1979 base	580	1140	440																	
Capital Cost - Escalated	702	1517	644																	
Amortized Interest	42	136	182																	
Cumulative Total (to be financed)	744	2397	3223																	
Annual Payment	-	-	-	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308
PHASE 1 - STAGE 2																				
Capital Cost - 1979 base																				
Capital Cost - Escalated							300	300	293											
Cumulative Total							643	707	760											
Annual Payment							643	1350	2110											
							56	118	184	184	184	184	184	184	184	184	184	184	184	184
PHASE 2																				
Capital Cost - 1979 base																				
Capital Cost - Escalated																				
Cumulative Total												243	243	244						
Annual Payment												763	839	927						
												763	1602	2529						
												67	140	220	220	220	220	220	220	220
TOTAL ANNUAL CAPITAL COSTS																				
				308	308	308	364	421	492	492	559	632	712	712	712	712	712	712	712	712
OPERATING COSTS																				
Power Costs - 1980 base				28	44	60	76	126	162	186	196	208	218	228	240	252	262	272	284	296
Power Costs - Escalated				41	71	106	148	270	382	482	559	653	753	866	1003	1158	1324	1512	1737	1991
Other Costs - 1979 base				118	122	125	125	128	129	147	148	151	153	168	170	172	174	176	177	179
Other Costs - Escalated				190	216	244	268	302	335	419	464	521	581	702	781	869	967	1076	1191	1325
Total Operating Costs - Escalated				231	287	350	416	572	717	901	1023	1174	1334	1568	1784	2027	2291	2588	2928	3316
TOTAL ANNUAL CAPITAL & OPERATING COSTS - ESCALATED																				
				539	595	658	780	998	1209	1393	1582	1806	2046	2280	2496	2739	3003	3300	3640	4028
Present Worth - 1979 base i= 10%	335	336	337	364	423	466	488	504	523	539	546	543	542	540	540	540	541	541	544	
Present Worth				671	1008	1372	1795	2261	2749	3253	3776	4315	4861	5404	5946	6486	7026	7567	8111	

8111 - 675 (salvage) = 7436

IRBID WASTEWATER TREATMENT FACILITIES

ALTERNATIVE 3 - Two Stage Trickling Filter

ALL COSTS IN JD X 1000

TABLE 2 - 3

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
PHASE 1 - STAGE 1																				
Capital Cost - 1979 base	590	1162	450																	
Capital Cost - Escalated	714	1547	659																	
Amortized Interest	43	138	186																	
Cumulative Total (to be financed)	757	2442	3287																	
Annual Payment	-	-	-	314	314	314	314	314	314	314	314	314	314	314	314	314	314	314	314	314
PHASE 1 - STAGE 2																				
Capital Cost - 1979 base							370	380	389											
Capital Cost - Escalated							793	896	1009											
Cumulative Total							793	1689	2698											
Annual Payment							69	147	235	235	235	235	235	235	235	235	235	235	235	235
PHASE 2																				
Capital Cost - 1979 base											237	237	237							
Capital Cost - Escalated											744	818	900							
Cumulative Total											744	1562	2462							
Annual Payment											65	136	215	215	215	215	215	215	215	215
TOTAL ANNUAL CAPITAL COSTS				314	314	314	383	461	549	549	614	685	764	764	764	764	764	764	764	764
OPERATING COSTS																				
Power Costs - 1980 base				8	13	18	23	38	49	57	60	63	66	70	73	77	80	83	87	90
Power Costs - Escalated				12	21	32	45	81	116	148	171	198	228	266	335	354	404	461	532	605
Other Costs - 1979 base				114	117	118	121	124	125	140	141	144	146	159	161	163	165	167	168	170
Other Costs - Escalated				184	207	230	259	292	324	399	443	497	554	664	740	824	917	1021	1130	1258
Total Operating Costs - Escalated				196	228	262	304	373	440	547	614	695	782	930	1075	1178	1321	1482	1662	1863
TOTAL ANNUAL CAPITAL & OPERATING COSTS - ESCALATED				510	542	576	687	834	989	1096	1228	1380	1546	1694	1839	1942	2085	2246	2426	2627
Present Worth - 1979 base i = 10%				317	306	296	320	354	381	384	391	400	407	406	400	384	375	367	361	355
≤ Present Worth				623	919	1239	1593	1974	2358	2749	3149	3556	3962	4362	4746	5121	5488	5849	6204	

6204-798 (salvage) = 5406

IRBID WASTEWATER TREATMENT FACILITIES

ALTERNATE 4

ALL COSTS IN JD X 1000

TABLE 2 - 4

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
PHASE I - STAGE 1																				
Capital Cost - 1979 base	294	588	295																	
Capital Cost - Escalated	356	783	432																	
Amortized Interest	21	70	100																	
Cumulative Total (to be financed)	377	1230	1762																	
Annual Payment	-	-	-	168	168	168	168	168	168	168	168	168	168	168	168	168	168	168	168	168
PHASE I - STAGE 2																				
Capital Cost - 1979 base							232	233	232											
Capital Cost - Escalated							497	549	602											
Cumulative Total							497	1046	1648											
Annual Payment							43	91	144	144	144	144	144	144	144	144	144	144	144	144
PHASE 2																				
Capital Cost - 1979 base											271	272	271							
Capital Cost - Escalated											851	939	1029							
Cumulative Total											851	1790	2819							
Annual Payment											74	156	246	246	246	246	246	246	246	246
TOTAL ANNUAL CAPITAL COSTS				168	168	168	211	259	312	312	386	486	558	558	558	558	558	558	558	558
OPERATING COSTS																				
Power Costs - 1980 base				41	68	90	115	191	247	283	299	317	333	349	367	386	400	416	434	450
Power Costs - Escalated				61	110	159	224	409	581	733	853	994	1150	1325	1534	1774	2022	2313	2854	3027
Other Costs - 1979 base				112	115	116	119	122	123	142	143	146	148	169	171	173	175	177	178	180
Other Costs - Escalated				180	204	226	255	288	319	405	449	504	562	706	786	874	973	1083	1197	1332
Total Operating Costs - Escalated				241	314	385	479	697	900	1138	1302	1498	1712	2031	2320	2648	2995	3396	3851	4359
TOTAL ANNUAL CAPITAL & OPERATING COSTS - ESCALATED				409	482	553	690	956	1212	1450	1688	1966	2270	2589	2878	3206	3553	3954	4409	4917
Present Worth - 1979 base i= 10%				254	272	284	322	405	467	508	538	570	598	620	626	634	639	646	655	664
Present Worth				526	810	1132	1537	2004	2512	3050	3620	4218	4838	5464	6098	6737	7383	8038	8702	

8702 - 669 (salvage) = 8033

IRBID WASTEWATER TREATMENT FACILITIES

ALTERNATE 5

ALL COSTS IN JD X 1000

TABLE 2 - 5

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
PHASE 1 - STAGE 1																				
Capital Cost - 1979 base	294	588	295																	
Capital Cost - Escalated	356	783	432																	
Amortized Interest	21	70	100																	
Cumulative Total (to be financed)	377	1230	1762																	
Annual Payment				168	168	168	168	168	168	168	168	168	168	168	168	168	168	168	168	168
PHASE 1 - STAGE 2																				
Capital Cost - 1979 base							232	233	232											
Capital Cost - Escalated							497	549	602											
Cumulative Total							497	1046	1648											
Annual Payment							43	91	144	144	144	144	144	144	144	144	144	144	144	144
PHASE 2																				
Capital Cost - 1979 base										561	562	562								
Capital Cost - Escalated										1761	1940	2134								
Cumulative Total										1761	3701	5835								
Annual Payment										153	323	509	509	509	509	509	509	509	509	509
TOTAL ANNUAL CAPITAL COSTS				168	168	168	211	259	312	312	465	635	821	821	821	821	821	821	821	821
OPERATING COSTS																				
Power Costs - 1980 base				41	68	90	115	191	247	283	299	317	333	388	408	426	444	462	482	500
Power Costs - Escalated				61	110	159	224	409	581	733	853	904	1150	1473	1704	1957	2244	2567	2948	3364
Other Costs - 1979 base				112	115	116	119	122	123	142	143	146	148	169	171	173	175	177	178	180
Other Costs - Escalated				180	204	226	255	288	319	405	449	504	562	706	786	874	973	1083	1197	1332
Total Operating Costs - Escalated				241	314	385	479	697	900	1138	1302	1498	1712	2179	2490	2831	3217	3650	4145	4696
TOTAL ANNUAL CAPITAL & OPERATING COSTS - ESCALATED				409	482	553	690	956	1212	1450	1767	2133	2533	3000	3311	3652	4038	4471	4966	5517
Present Worth - 1979 base i= 10%				254	272	284	322	405	467	508	563	618	667	718	720	722	726	731	738	745
Σ Present Worth				526	810	1132	1537	2004	2512	3075	3693	4360	5078	5798	6520	7246	7977	8715	9460	

9460 - 1161 (salvage) = 8299

IRBID WASTEWATER TREATMENT FACILITIES
 (ALTERNATIVE MT - 2 WITH POWER GENERATION FROM DIGESTER GAS)
 ALTERNATIVE 6

ALL COSTS IN JD X 1000

TABLE 2 - 6

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
PHASE I - STAGE 1																				
Capital Cost - 1979 base	580	1140	440																	
Capital Cost - Escalated	702	1517	644																	
Amortized Interest	42	136	182																	
Cumulative Total (to be financed)	744	2397	3223																	
Annual Payment	-	-	-	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308
PHASE I - STAGE 2																				
Capital Cost - 1979 base																				
Capital Cost - Escalated							300	300	293											
Cumulative Total							643	707	760											
Annual Payment							643	1350	2110											
							56	118	184	184	184	184	184	184	184	184	184	184	184	184
PHASE 2																				
Capital Cost - 1979 base																				
Capital Cost - Escalated											243	243	244							
Cumulative Total											763	839	927							
Annual Payment											763	1602	2529							
											67	140	220	220	220	220	220	220	220	220
TOTAL ANNUAL CAPITAL COSTS				308	308	308	364	426	492	492	559	632	712	712	712	712	712	712	712	712
OPERATING COSTS																				
Power Costs - 1980 base				28	44	60	75	126	162	186	196	208	218	134	142	150	155	161	169	177
Power Costs - Escalated				41	71	106	148	270	382	482	559	653	753	509	593	689	783	895	1034	1191
Other Costs - 1979 base				118	122	125	125	128	129	147	148	151	153	187	189	191	193	195	197	199
Other Costs - Escalated				190	216	244	268	302	335	419	464	521	581	781	868	965	1073	1193	1325	1473
Total Operating Costs - Escalated				231	287	350	416	572	717	901	1023	1174	1334	1290	1461	1654	1856	2088	2359	2664
TOTAL ANNUAL CAPITAL & OPERATING COSTS - ESCALATED				539	595	658	780	998	1209	1393	1582	1806	2046	2002	2173	2366	2568	2800	3071	3376
Present Worth - 1979 base $i = 10\%$				335	336	337	364	423	466	488	504	523	539	479	473	468	462	458	456	456
Present Worth				671	1008	1372	1795	2261	2749	3253	3776	4315	4794	5267	5735	6197	6655	7111	7567	

7567-675 (salvage) = 6892

IRBID WASTEWATER TREATMENT FACILITIES

ALTERNATIVE 7 - TWO STAGE TRICKLING FILTER WITH POWER GENERATION FROM DIGESTER GAS

ALL COSTS IN JD X 1000

TABLE 2 - 7

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
PHASE I - STAGE 1																				
Capital Cost - 1979 base	590	1162	450																	
Capital Cost - Escalated	714	1547	659																	
Amortized Interest	43	138	186																	
Cumulative Total (to be financed)	757	2442	3287																	
Annual Payment	-	-	-	314	314	314	314	314	314	314	314	314	314	314	314	314	314	314	314	314
PHASE I - STAGE 2																				
Capital Cost - 1979 base							370	380	389											
Capital Cost - Escalated							793	896	1009											
Cumulative Total							793	1689	2698											
Annual Payment							69	147	235	235	235	235	235	235	235	235	235	235	235	235
PHASE 2																				
Capital Cost - 1979 base											237	237	237							
Capital Cost - Escalated											744	818	900							
Cumulative Total											744	1562	2462							
Annual Payment											65	136	215	215	215	215	215	215	215	215
TOTAL ANNUAL CAPITAL COSTS				314	314	314	383	461	549	549	614	685	764	764	764	764	764	764	764	764
OPERATING COSTS																				
Power Costs - 1980 base				8	13	18	23	38	49	57	60	63	66	4	4	4	4	4	4	4
Power Costs - Escalated				12	21	32	45	81	116	148	171	198	228	14	15	18	20	22	24	27
Other Costs - 1979 base				114	117	118	121	124	125	140	141	144	146	178	180	182	184	186	188	190
Other Costs - Escalated				184	207	230	259	292	324	399	443	497	554	744	827	920	1023	1138	1265	1406
Total Operating Costs - Escalated						262	304	373	440	547	614	695	782	758	842	938	1043	1160	1289	1433
TOTAL ANNUAL CAPITAL & OPERATING COSTS - ESCALATED				510	542	576	687	834	989	1096	1228	1380	1546	1522	1606	1702	1807	1924	2053	2197
Present Worth - 1979 base i= 10%				317	306	296	320	354	381	384	391	400	407	364	349	337	325	315	305	297
≤ Present Worth				623	919	1239	1593	1974	2358	2749	3149	3556	3920	4269	4606	4931	5246	5551	5848	

5848 - 798(Salvage) = 5050

IRBID WASTEWATER TREATMENT FACILITIES

ALTERNATIVE 8 - (ALTERNATIVE 5 WITH POWER GENERATION FROM DIGESTER GAS)

ALL COSTS IN JD X 1000

TABLE 2 - 8

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
PHASE I - STAGE 1																				
Capital Cost - 1979 base	294	588	295																	
Capital Cost - Escalated	356	783	432																	
Amortized Interest	21	70	100																	
Cumulative Total (to be financed)	377	1230	1762																	
Annual Payment				168	168	168	168	168	168	168	168	168	168	168	168	168	168	168	168	168
PHASE I - STAGE 2																				
Capital Cost - 1979 base							232	233	232											
Capital Cost - Escalated							497	549	602											
Cumulative Total							497	1046	1648											
Annual Payment							43	91	144	144	144	144	144	144	144	144	144	144	144	144
PHASE 2																				
Capital Cost - 1979 base										561	562	562								
Capital Cost - Escalated										1761	1940	2134								
Cumulative Total										1761	3701	5835								
Annual Payment										153	323	509	509	509	509	509	509	509	509	509
TOTAL ANNUAL CAPITAL COSTS				168	168	168	211	259	312	312	465	635	821	821	821	821	821	821	821	821
OPERATING COSTS																				
Power Costs - 1980 base				41	68	90	115	191	247	283	299	317	333	294	310	324	337	351	367	381
Power Costs - Escalated				61	110	159	224	409	581	733	853	994	1150	1116	1295	1489	1703	1951	2244	2563
Other Costs - 1979 base				112	115	116	119	122	123	142	143	146	148	186	189	191	193	195	196	199
Other Costs - Escalated				180	204	226	255	288	319	405	449	504	562	777	868	965	1073	1193	1319	1473
Total Operating Costs - Escalated				241	314	385	479	697	900	1138	1302	1498	1712	1893	2163	2454	2776	3144	3563	4036
TOTAL ANNUAL CAPITAL & OPERATING COSTS - ESCALATED				409	482	553	690	956	1212	1450	1767	2133	2533	2714	2984	3275	3597	3965	4384	4857
Present Worth - 1979 base, i=10%				254	272	284	322	405	467	508	563	618	667	650	649	648	647	648	651	656
Present Worth				526	810	1132	1537	2004	2512	3075	3693	4360	5010	5659	6307	6954	7602	8253	8909	

8909 - 1162 (salvage) = 7747

T A B L E 3

COMPARISON OF ALTERNATIVES

ANNUAL COSTS BASED ON ESCALATED PRICES

P A R A M E T E R	ALT.	Cost in Thousands of JD							
		1	2	3	4	5	6	7	8
1. Annual Capital Requirement	1985	180	308	314	168	168	308	314	168
	1990	341	492	549	312	312	492	549	312
	1995	640	712	764	558	821	712	764	821
	2000	640	712	764	558	821	712	764	821
	Present Worth		1270	2022	2088	1175	1163	2022	2088
2. Power Cost	1985	122	71	21	110	110	71	21	110
	1990	814	482	148	733	733	482	148	733
	1995	1704	1003	335	1534	1704	593	15	1295
	2000	3364	1991	605	3027	3364	1191	27	2563
	Present Worth		4829	2878	875	4380	4629	2174	384
3. Other Operating Costs	1985	204	216	207	204	204	216	207	204
	1990	405	419	399	405	405	419	399	405
	1995	786	781	740	786	786	868	827	868
	2000	1332	1325	1258	1332	1332	1473	1406	1473
	Present Worth		2509	2562	2442	2509	2509	2697	2578
4. Total Annual Costs	1985	506	595	542	482	482	595	542	482
	1990	1561	1393	1096	1450	1450	1393	1096	1450
	1995	3130	2496	1839	2878	3311	2173	1606	2984
	2000	5336	4028	2627	4917	5517	3376	2197	4857
5. Total present worth of cumulative costs through 2000 less salvage. Salvage assumed equal to capital costs due after 2000		8607	7436	5406	8033	8291	7712	5050	7747

If a ten percent inflation rate with increased power rates is considered, Alternative 2, Trickling Filter with Activated Sludge, becomes the least cost alternative.

The difference in overall costs between alternatives is sensitive to the inflation rate selected as well as relative differences in inflation rates between operating costs, especially power costs, and construction costs.

EFFLUENT STANDARDS - The effluent requirements have a significant effect on selection of the wastewater treatment alternative.

Alternatives 1, 2 and 6 are selected to produce good effluent quality (30 mg/L BOD₅ and suspended solids) while Alternatives 5 and 8 produce moderate effluent quality through Phase I of the study period and the effluent quality is then upgraded during Phase II. The effects of these standards on the alternatives are summarized below:

- A. Reduced Standards - Alternative 3, two stage trickling filter, meets the reduced effluent standards with an overall cost approximately 30 percent less than an activated sludge alternative (No. 4) designed to meet equivalent standards.
- B. Good Standards - If effluent standards of 30 mg/L BOD₅ and suspended solids are required throughout the project, Alternative 2 is the least cost choice.
- C. Varying Standards - If reduced effluent standards are accepted initially it is likely that better standards will be required during the 20 year study period. Alternative 3 is not easily upgraded to provide higher treatment levels. Another treatment step such as filtration may be required to achieve good effluent standards. The additional treatment step will require increased construction costs and increased power consumption.

If increased (good) effluent standards are known to be required during the study period Alternative 2 constructed initially is the least cost alternative.

If future treatment requirements are uncertain the first phase of Alternatives 4 and 5 will meet the initially reduced standard, at less cost than Alternative 2 and this alternative can be upgraded either by addition of activated sludge capacity (Alternatives 4 or 5) or addition of primary clarifiers and trickling filters (to provide the same facilities as Alternative 2 but at an increased overall cost).

ON-SITE POWER GENERATION - Alternatives 6, 7, and 8 have been developed to examine the effect of power generation from digester gas on annual operating costs and total present worth costs. Alternatives 6, 7 and 8 correspond directly to Alternatives 2, 3 and 5. Alternatives 1 and 4 do not include anaerobic digestion.

The number of customers connected to the Irbid sewer system is projected to range from 3,600 in 1984 to 26,000 in 1990. The system will not produce sufficient quantities of digester gas during the initial years to operate equipment sized to work efficiently on quantities of gas expected to be available in 1990 and later years. Because of this we assumed the capital expenditure for gas collection equipment will be deferred until Phase II and credits for on-site power generation will accrue after Phase II construction is completed.

RECOMMENDED PLAN

WESTON regards the application of gas gathering/power generation technology to the Irbid Treatment Plant to be premature for several reasons:

- A. Sufficient quantities of gas will not be generated in the near future.
- B. Operation and maintenance of such facilities are very difficult.
- C. Hardware for such installations has not demonstrated a high degree of reliability in U.S. applications.

WESTON recommends that high effluent quality standards be maintained. Water quality protection and management must be given emphasis in a water-short environment such as Jordan. Adoption of interim, lower quality effluent standards creates an uncertainty as to when upgrading is to be accomplished. If the upgrading is delayed, significant water quality degradation of both surface and groundwater resources downstream from the point of discharge will occur.

WESTON regards maintenance of high effluent quality standards to be of greater importance than the related power costs to achieve them. We also believe that all of the factors or criteria used should be considered on more or less of an equal basis.

For these reasons, WESTON recommends that your office decide to proceed with the design of Alternative No. 1, the extended aeration plant. Further, WESTON recommends that NPC/MMRAE apply to the Government for a subsidized, reduced power rate based on the benefit to the Kingdom of the high quality effluent that would be produced thereby.