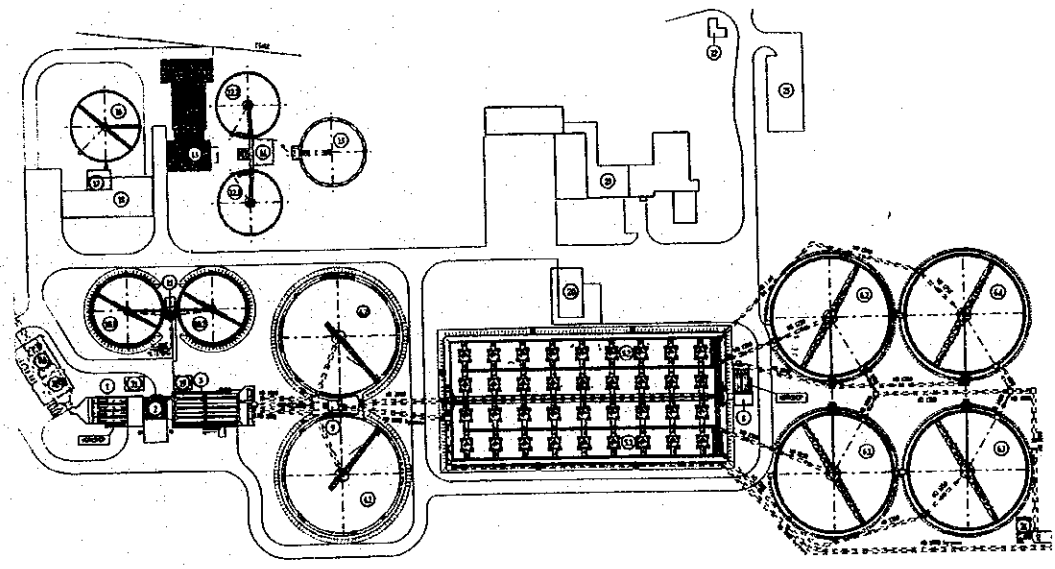
O. PROCESS CALCULATIONS



APPENDIX O. PROCESS CALCULATIONS

SARAJEVO WASTE WATER TREATMENT PLANT
PROCESS DESIGN CALCULATIONS
FOR PRETREATEMENT WORKS

Design year 2000 and 2015

I – Design data:

Peak flowrate (PWWF) available to pretreatment stage: 4,320 l.p.s. = 15,552 m^3 / h

II – Lower Grit Chambers:

Number of channels:	3	units
Number of channels in duty:	2	units
Width of each channel:	1.50	m
Depth of storage area:	1.50	m
Bottom width of each channel (for grab location):	0.80	m
Slope of trapezoidal storage section:	65	°
Transversal surface area for storage area:	1.99	m^2
Length of each channel:	10	m
Net volume for grit storage:	20	m^3 / channel
Water height above storage area at PWWF:	1.75	m
Transversal flow rate (if storage area is empty):	0.5	m / s (for 2 channels in operation at PWWF)
Transversal flow rate (if storage area is full):	0.82	m / s (for 2 channels in operation at PWWF)

Falling velocity of a 1.50 mm diameter sand particle at transversal flow rate of 0.8 m/s	15	cm / sec	
Required time for a 1.50 mm diameter particle to reach the storage area:	11.7	sec	
Required channel length to capture the particle:	9.6	m →	10 m

III – Coarse and medium rack and pinion bar screens:

Coarse screens:

Number of screens installed:	3	units
Number of screens in duty:	2	units
Maximum flowrate per screen:	2.16	m^3 / s
Mesh:	50	mm
Channel width:	2	m
Water height upstream screen:	1.92	m
Water velocity upstream screen:	0.58	m / s
Head loss at PWWF:	150	mm WG

Medium screen:

Number of screens installed:	3	units
Number of screens in duty:	2	units
Maximum flowrate per screen:	2.16	m^3 / s
Mesh:	25	mm
Channel width:	2	m
Water height upstream screen:	1.76	m
Water velocity upstream screen:	0.63	m / s
Head loss at PWWF:	250	mm WG

IV – Raw water lifting station:

Number of Arohimedean screws installed:	4	units		
Number of Archimedean screws in stand-by:	1	unit		
ΔH:		m		
Unit capacity:	1,080	l.p.s.		
Maximum flow to be treated in pretreatment stage	4,320	l.p.s. for	4	units in operation

V – Fine screens (Stepscreen type) :

Number of screens installed:	4	units
Number of screens in duty:	3	units
Maximum flowrates per screen:	1.44	m^3 / s
Mesh:	6	mm
Channel width	1.50	m
Water height upstream screen:	1.71	m
Water velocity upstream screen:	0.57	m / s
Head loss at PWWF	220	mm WG

VI – Aerated grit chamber:

Number of chambers:	3	units
Length of each chamber:	29	m
Width of each chamber:	4	m
Total surface for the chambers:	348	m^2
Maximum water depth in each chamber:	4.40	m
Total net volume for the chambers:	1,200	m^3

		year 2000	year 2015
Hydraulic loads at ADWF:	m / h	14	23
Hydraulic loads at PWWF of 4,400 l.p.s.:	m / h	46	46
Hydraulic retention time at ADWF:	m / h	14.4	8.8
Hydraulic retention time at PWWF of 4,400 l.p.s.:	m / h	4.5	4.5

Design temperature: 10 ℃

I – Design data:

Flowrates: PDWF or PWWF: 1,982 l.p.s. = 7,136 m^3 / h
ADWF: 1,389 l.p.s. = 5,000 m^3 / h = 120,000 m^3 / day

Raw water quality parameter:

Temperature (T) =	10 ℃ (minimum)		
COD =	350 mg / l =	42,000 kg / day	
BOD_5 =	200 mg / l =	24,000 kg / day	COD / BOD_5 = 1.75
TSS =	270 mg / l =	32,400 kg / day	TSS / BOD_5 = 1.35
VSS =	189 mg / l =	22,680 kg / day	VSS / TSS = 70 %

Treated water quality parameters (as a 24 hrs composite sample)

COD =	90 mg / l =	10,800 kg / day
BOD_5 =	20 mg / l =	2,400 kg / day
TSS =	30 mg / l =	3,600 kg / day
Total Coliforms=	200 MPN / 100 ml	

Total removal efficiencies (minimum):

COD removal =	74 %
BOD_5 removal =	90 %
TSS removal =	89 %

II – Primary settling tanks:

Existing PST diameter:	52	m
Number of PST installed:	2	units
Total settling surface area:	4,245	m^2
Overflow rate at ADWF:	1.18	m^3 / m^2 h
Overflow rate at PDWF:	1.68	m^3 / m^2 h
Settleable solids in raw water:	180	mg / l (2/3 of TSS in raw water)
Settleable solids removal in primary sedimentation:	90%	
TSS removal in primary sedimentation:	60%	
Inorganic SS removal in primary sedimentation:	65%	
VSS removal in primary sedimentation:	58%	
TSS removed in PST:	19,440	kg / day
VSS removed in PST:	13,122	kg / day
VSS/TSS in primary sludges:	67.5%	
BOD_5 removal in primary sedimentation:	0.63	g BOD_5 / g VSS removed
BOD_5 removal in primary sedimentation:	8,201	kg / day
BOD_5 in PST effluent:	132	mg / l
TSS in PST's effluent:	106	mg / l
VSS in PST effluent:	80	mg / l
TSS / BOD_5 in PST's effluent:	0.82	

Design temperature: 10 ℃

II – Aeration basin (activated sludge) design:

Existing aeration basin capacity:	23,900	m^3
Hydraulic Residence Time (HRT) at ADWF	4.78	hours
HRT at PDWF	3.35	hours
Mixed liquor Suspended Solids (MLSS):	2.5	kg / m^3
BOD_5 loading:	0.66	kg BOD_5 / m^3 day
F/M ratio (calculated on TSS concentration):	0.27	kg BOD_5 / kg TSS day
% VSS in mixed liquor:	74.7%	
F/M' ratio (calculated on TSS concentration):	0.35	kg BOD_5 / kg VSS day

Effluent temperature for activated sludge process calculation: 10 ℃

1 – Treated water BOD_5 calculation:

1.1 – Soluble BOD_5 – Lf:		10.55	mg / l	(Eckenfelder formula)
with	BOD_5 primary effluent =	132	mg / l	
	MLSS =	2.5	kg / m^3	
	% VSS in mixed liquor =	74.70%		
	HRT at ADWF =	4.78	hours	
	k =	1.29		
1.2 – Particulate BOD_5 – L'f:		8.77	mg / l	
with	TSS in treated water	20	mg / l	
	F/M' =	0.355	kg / kg day	
	Estimated DBO/TSS ratio	0.439	in treated water	

1.3 –Total BOD_5 in treated water – Ls = Lf + L'f: 19.32 mg / l

1.4 –Total BOD_5 removed: 13,522 kg / day or 113 mg / l

2 – Biological sludge production calculation:

The following parameters have to be taken into account in the calculations:

F/M ratio calculated on volatile matter:	F/M' =	0.355	kg BOD / kg VSS / day
Temperature calculation:	T =	10	℃
Endogenous decay factor at 10 ℃:	b at T = 10 ℃ =	0.059	day

2.1 – Inorganic sludge production calculation: 3,402 kg SS / day

2.2 – Organic sludge production calculation:

1)	0.35 × $VSS_{PST\ effluent}$:	3,345	kg VSS / day
2)	0.64 × $BOD_{5\ removed\ in\ sedimentation\ tank}$ =	8,654	kg VSS / day
3)	- (0.75 × b / (F/M')) × $BOD_{5\ PST\ effluent}$ =	-1,965	kg VSS / day
1 + 2 + 3)	Total organic sludge production =	10,034	kg VSS / day

The total sludge production will be: 13,436 kg VSS / day
with: 74.7 % of volatile matter

Average SRT = 4.45 days

Design temperature: 10 ℃

III – Net biological sludge production (to be treated in sludge treatment line):

TSS in treated water (secondary effluent) =	20	mg / l
Sludge losses in treated water (secondary effluent) =	2,400	kg MS / day
Total biological sludge net production:	13,436	kg TSS / day
Net biological sludge net production:	11,036	kg TSS / day
Net biological organic sludge net production:	8,241	kg VSS / day
Net biological sludge net production:	2,794	kg ISS / day

IV – Total sludge production calculation (primary + biological sludge):

Primary sludge:	19,440	kg TSS / day		
	13,122	kg VSS / day	% VSS / TSS =	67.5%
Biological sludge:	11,035	kg MS / day		
	8,241	kg MV / day	% VSS / TSS =	74.7%
Total	30,476	kg MS / day	% PS / BS =	63.8%
	21,363	kg MV / day	% VSS / TSS =	70.1%

V – Oxygen requirements calculation:

5.1 – Oxygen requirement for BOD_5 removal: **a' × BOD_5 removed**

These requirements are proportional to the BOD_5 mass removed in the biological treatment.
For high rate activated sludge process (HRAS) as well as for medium rate activated sludge (MRAS), which is the case for Sarajevo W. W. T. P. the proportionally factor "a'" depends on the F/M' ratio calculated taking into the global MVSS weight present in the aeration basins as well as in secondary clarifiers,

F/M' ratio =	0.355	kg BOD_5 / kg VSS day (calculated on aeration tanks only)
F/M" ratio =	0.189	kg BOD_5 / kg VSS day (calculated on aeration tanks and secondary clarifiers)
a' =	0.658	kg O_2 / kg BOD_5 day
$BOD_{5\ removed}$ =	13,522	kg BOD_5 day
a' × $BOD_{5\ removed}$ =	8,903	kg O_2 / day

It has been assumed that the peak factor for oxygen requirement for BOD removal is the same as the hydraulic peak factor.

Peak factor = PDWF / ADWF = 1.43
Hourly peak oxygen requirement for BOD_5 removal = 529 kg O_2 / hour

5.2 – Oxygen requirements for VSS endogenous respiration: **b' * MVSS**

These requirements are proportional to the global VSS weight present in the system (aeration tanks + secondary clarifiers). The proportionality factor 'b' "depends on the F/M" ratio, calculated taking into account the global VSS weight in the system as well as on mixed liquor temperature.

Mixed liquor temp. =	10	℃
F/M" ratio =	0.189	kg BOD_5 / kg VSS day (calculated on aeration tanks and secondary clarifiers)
b' at 10 ℃	0.073	kg O_2 / kg VSS day

Design temperature: 10 °C

Aeration basins:

MLSS:	2.5	g / l
MLVSS:	1.87	g / l
MLVSS in aeration basin:	44,621	kg

Secondary clarifiers:

Estimated diluted sludge volume index (DSVI):	120	ml / g	
Average TSS concentration in sludge blanket:	5.0	g / l	(500 / SVI × % SSV)
Average VSS concentration in sludge blanket:	3.7	g / l	(600 / SVI × % SSV)
Number of secondary clarifiers:	4	units (4 for year 2000 + 2 for year 2015)	
Diameter:	52	m	
Unit clarification surface area:	2,124	m^2	
Total clarification surface area:	8,495	m^2	
Cylindrical height:	3	m	
Estimated sludge blanket height:	0.75	m	
Total volume (cylindrical section):	25,485	m^3	
Total volume (as per Degremont design):	29,560	m^3	
Total volume of cone shaped section:	4,075	m^3	
Total VSS weight in secondary clarifiers:	39,007	kg MVS	

Aeration basins + Secondary clarifiers:

Total VSS weight in aeration basins + secondary clarifiers:	83,628	kg

So, the total oxygen requirements for endogenous respiration is:

b' × VSS present aeration basins + Secondary Clarifiers =	6,130	kg O_2 / day
Hourly requirements (Daily requirements / 24) =	255	kg O_2 / day

5.3 – Global Oxygen Requirements:

Hourly peak conditions			Daily average conditions		
a' × $BOD_{5\ removed}$ =	529	kg O_2 / h	a' × $BOD_{5\ removed}$ =	8,903	kg O_2 / day
b' × $VSS_{(aeration\ basins\ +\ SC)}$ =	255	kg O_2 / h	b' × $VSS_{(aeration\ basins\ +\ SC)}$ =	6,130	kg O_2 / day
Total =	785	kg O_2 / h	Total =	15,032	kg O_2 / day
			or:	626	kg O_2 / h

VI – Secondary clarification:

Number of treatment lines:	2	line(s)
Number of secondary clarifiers per line:	2	unit(s)
Secondary clarifiers' diameter:	52	m
Total surface area for clarification:	8,495	m^2
Unit volume:	7,390	m^3
Total volume:	29,560	m^3
Surface flow rate	0.59	m / h at ADWF
	0.84	m / h at PWWF
Hydraulic retention time:	5.91	hours at ADWF
	4.14	hours at PWWF

Design temperature: 10 ℃

Test on surface flow rate using ATV standards:

DSVI:	120	ml / g
MLSS:	2.5	g / l
Qsv defined by ATV rules:	450	l / m^2 h at PWWF – for mainly horizontally flowed-through secondary clarifiers, to obtain 20 mg / l TSS in treated water
Maximum allowed surface flow rate:	1.50	m / h

Test on surface flow rate: Surface flow rate OKI

VII – Effluent disinfection (chlorine disinfection):

Quality standard:	200	FC / 100 ml	
Contact chamber total volume:	3,960	m^3	
Number of channels:	8	units	
Channel width:	3	m	
Water depth:	3	m	
Channel length:	55	m	
Contact time at ADWF:	48	min.	
Contact time at ADWF:	33	min.	
Average chlorine dosage to achieve quality standard:	8	mg / l	
Daily average consumption:	960	kg / day	
Number of 2000 lbs. chlorine cylinders to be installed:	15	units, equivalent to	15 days autonomy

Design temperature: 10 ℃

I – Design data:

Flowrates:	PDWF or PWWF:	3,241 l.p.s. =	11,667 m^3 / h	
	ADWF:	2,271 l.p.s. =	8,175 m^3 / h =	196,200 m^3 / day

Raw water quality parameter:

Temperature (T) =	10 ℃ (minimum)		
COD =	350 mg / l =	68,670 kg / day	
BOD_5 =	200 mg / l =	39,240 kg / day	COD / BOD_5 = 1.75
TSS =	270 mg / l =	52,974 kg / day	TSS / BOD_5 = 1.35
VSS =	189 mg / l =	37,082 kg / day	VSS / TSS = 70 %

Treated water quality parameters (as a 24 hrs composite sample)

COD =	90 mg / l =	17,658 kg / day
BOD_5 =	20 mg / l =	3,924 kg / day
TSS =	30 mg / l =	5,886 kg / day
Total Coliforms=	200 MPN / 100 ml	

Total removal efficiencies (minimum):

COD removal =	74 %
BOD_5 removal =	90 %
TSS removal =	89 %

II – Primary settling tanks:

Existing PST diameter:	52	m
Number of PST installed:	2	units
Total settling surface area:	4,245	m^2
Overflow rate at ADWF:	1.93	m^3 / m^2 h
Overflow rate at PDWF:	2.75	m^3 / m^2 h
Settleable solids in raw water:	180	mg / l (2/3 of TSS in raw water)
Settleable solids removal in primary sedimentation:	87%	
TSS removal in primary sedimentation:	58%	
Inorganic SS removal in primary sedimentation:	63%	
VSS removal in primary sedimentation:	56%	
TSS removed in PST:	30,725	kg / day
VSS removed in PST:	20,713	kg / day
VSS/TSS in primary sludges:	67.4%	
BOD_5 removal in primary sedimentation:	0.63	g BOD_5 / g VSS removed
BOD_5 removal in primary sedimentation:	12,946	kg / day
BOD_5 in PST effluent:	134	mg / l
TSS in PST's effluent:	113.4	mg / l
VSS in PST effluent:	83	mg / l
TSS / BOD5 in PST's effluent:	0.85	

Design temperature: 10 ℃

II – Aeration basin (activated sludge) design:

Existing aeration basin capacity:	23,900	m^3
Hydraulic Residence Time (HRT) at ADWF	2.92	hours
HRT at PDWF	2.05	hours
Mixed liquor Suspended Solids (MLSS):	4.0	kg / m^3
BOD_5 loading:	1.10	kg BOD_5 / m^3.day
F/M ratio (calculated on TSS concentration):	0.28	kg BOD_5 / kg TSS day
% VSS in mixed liquor:	74.2%	
F/M' ratio (calculated on TSS concentration):	0.37	kg BOD_5 / kg VSS day

Effluent temperature for activated sludge process calculation: 10 ℃

1 – Treated water BOD_5 calculation:

1.1 – Soluble BOD_5 – Lf:		10.99	mg / l	(Eckenfelder formula)
with	BOD_5 primary effluent =	134	mg / l	
	MLSS =	4	kg / m^3	
	% VSS in mixed liquor =	74.20%		
	HRT at ADWF =	2.92	hours	
	k =	1.29		
1.2 – Particulate BOD_5 – L'f:		8.90	mg / l	
with	TSS in treated water	20	mg / l	
	F/M' =	0.371	kg / kg day	
	Estimated DBO/TSS ratio	0.445	in treated water	

1.3 –Total BOD_5 in treated water – Ls = Lf + L'f: 19.89 mg / l

1.4 –Total BOD_5 removed: 22,388 kg / day or 114 mg / l

2 – Biological sludge production calculation:

The following parameters have to be taken into account in the calculations:

F/M ratio calculated on volatile matter:	F/M' =	0.371	kg BOD / kg VSS / day
Temperature calculation:	T =	10	℃
Endogenous decay factor at 10 ℃:	b at T = 10 ℃ =	0.060	day

2.1 – Inorganic sludge production calculation: 5,880 kg SS / day

2.2 – Organic sludge production calculation:

1)	0.35 × $VSS_{PST\ effluent}$:	5,729	kg VSS / day
2)	0.64 × $BOD_{5\ removed\ in\ sedimentation\ tank}$ =	14,328	kg VSS / day
3)	- (0.75 × b / (F/M')) × $BOD_{5\ PST\ effluent}$ =	-3,171	kg VSS / day
1 + 2 + 3)	Total organic sludge production =	16,886	kg VSS / day

The total sludge production will be: 22,766 kg VSS / day
with: 74.2 % of volatile matter

Average SRT = 4.20 days

Design temperature: 10 ℃

III – Net biological sludge production (to be treated in sludge treatment line):

TSS in treated water (secondary effluent) =	20	mg / l
Sludge losses in treated water (secondary effluent) =	3,924	kg MS / day
Total biological sludge net production:	22,766	kg TSS / day
Net biological sludge net production:	18,842	kg TSS / day
Net biological organic sludge net production:	13,975	kg VSS / day
Net biological sludge net production:	4,867	kg ISS / day

IV – Total sludge production calculation (primary + biological sludge):

Primary sludge:	30,725	kg TSS / day		
	20,713	kg VSS / day	% VSS / TSS =	67.4%
Biological sludge:	18,842	kg MS / day		
	13,976	kg MV / day	% VSS / TSS =	74.2%
Total	49,667	kg MS / day	% PS / BS =	62.0%
	34,689	kg MV / day	% VSS / TSS =	70.0%

V – Oxygen requirements calculation:

5.1 – Oxygen requirement for BOD_5 removal: **a' × BOD_5 removed**

These requirements are proportional to the BOD_5 mass removed in the biological treatment.
For high rate activated sludge process (HRAS) as well as for medium rate activated sludge (MRAS), which is the case for Sarajevo W. W. T. P. the proportionally factor "a'" depends on the F/M' ratio calculated taking into the global MVSS weight present in the aeration basins as well as in secondary clarifiers,

F/M' ratio =	0.371	kg BOD_5 / kg VSS day (calculated on aeration tanks only)
F/M" ratio =	0.204	kg BOD_5 / kg VSS day (calculated on aeration tanks and secondary clarifiers)
a' =	0.666	kg O_2 / kg BOD_5 day
$BOD_{5\ removed}$ =	22,388	kg BOD_5 day
a' × $BOD_{5\ removed}$ =	14,653	kg O_2 / day

It has been assumed that the peak factor for oxygen requirement for BOD removal is the same as the hydraulic peak factor.

Peak factor = PDWF / ADWF = 1.43
Hourly peak oxygen requirement for BOD_5 removal = 871 kg O_2 / hour

5.2 – Oxygen requirements for VSS endogenous respiration: **b' * MVSS**

These requirements are proportional to the global VSS weight present in the system (aeration tanks + secondary clarifiers). The proportionality factor 'b' "depends on the F/M" ratio, calculated taking into account the global VSS weight in the system as well as on mixed liquor temperature.

Mixed liquor temp. =	10	℃
F/M" ratio =	0.204	kg BOD_5 / kg VSS day (calculated on aeration tanks and secondary clarifiers)
b' at 10 ℃	0.076	kg O_2 / kg VSS day

Design temperature: 10 ℃

Aeration basins:

MLSS:	4.0	g / l
MLVSS:	2.97	g / l
MLVSS in aeration basin:	70,908	kg

Secondary clarifiers:

Estimated diluted sludge volume index (DSVI):	120	ml / g	
Average TSS concentration in sludge blanket:	5.0	g / l	(500 / SVI × % SSV)
Average VSS concentration in sludge blanket:	3.71	g / l	(600 / SVI × % SSV)
Number of secondary clarifiers:	6	units (4 for year 2000 + 2 for year 2015)	
Diameter:	52	m	
Unit clarification surface area:	2,124	m^2	
Total clarification surface area:	12,742	m^2	
Cylindrical height:	3	m	
Estimated sludge blanket height:	0.75	m	
Total volume (cylindrical section):	38,227	m^3	
Total volume (as per Degremont design):	44,340	m^3	
Total volume of cone shaped section:	6,113	m^3	
Total VSS weight in secondary clarifiers:	58,113	kg MVS	

Aeration basins + Secondary clarifiers:

Total VSS weight in aeration basins + secondary clarifiers:	129,021	kg

So, the total oxygen requirements for endogenous respiration is:

b' × VSS present aeration basins + Secondary Clarifiers =	9,764	kg O_2 / day
Hourly requirements (Daily requirements / 24) =	407	kg O_2 / day

5.3 – Global Oxygen Requirements:

Hourly peak conditions			Daily average conditions		
a' × $BOD_{5\ removed}$ =	871	kg O_2 / h	a' × $BOD_{5\ removed}$ =	14,653	kg O_2 / day
b' × $VSS_{(aeration\ basins\ +\ SC)}$ =	407	kg O_2 / h	b' × $VSS_{(aeration\ basins\ +\ SC)}$ =	9,764	kg O_2 / day
Total =	1,278	kg O_2 / h	Total =	24,417	kg O_2 / day
			or:	1,017	kg O_2 / h

VI – Secondary clarification:

Number of treatment lines:	2	line(s)
Number of secondary clarifiers per line:	3	unit(s)
Secondary clarifiers' diameter:	52	m
Total surface area for clarification:	12,742	m^2
Unit volume:	7,390	m^3
Total volume:	44,340	m^3
Surface flow rate	0.64	m / h at ADWF
	0.92	m / h at PWWF
Hydraulic retention time:	5.42	hours at ADWF
	3.80	hours at PWWF

Design temperature: 10 ℃

Test on surface flow rate using ATV standards:

DSVI:	120	ml / g
MLSS:	4.0	g / l
Qsv defined by ATV rules:	450	l / m^2 h at PWWF – for mainly horizontally flowed-through secondary clarifiers, to obtain 20 mg / l TSS in treated water
Maximum allowed surface flow rate:	0.94	m / h

Test on surface flow rate: Surface flow rate OKI

VII – Effluent disinfection (chlorine disinfection):

Quality standard:	200	FC / 100 ml
Contact chamber total volume:	3,960	m^3
Number of channels:	8	units
Channel width:	3	m
Water depth:	3	m
Channel length:	55	m
Contact time at ADWF:	29	min.
Contact time at ADWF:	20	min.

Average chlorine dosage to achieve quality standard:	8	mg / l	
Daily average consumption:	1,570	kg / day	
Number of 2000 lbs. chlorine cylinders to be installed:	24	units, equivalent to	14 days autonomy

SARAJEVO WASTE WATER TREATMENT PLANT
PROCESS DESIGN CALCULATIONS
Wastewater Treatment Line

Design year 2000

Design temperature: 10°C

I – Design data:

13-juli-99

Flowrates: PDWF or PWWF: 1,982 l.p.g = 7,135 m^3/h
ADWF: 1,389 l.p.g = 5,000 m^3/h = 120,000 m^3/day

Raw water quality parameters:

Temperature (T) =	10	°C (minimum)						
COD =	220	mg/l	=	26,400 kg/day				
BOD_5 =	130	mg/l	=	15,600 kg/day	COD/BOD_5	=	1.69	
TSS =	80	mg/l	=	9,600 kg/day	TSS/BOD_5	=	0.62	
VSS =	60.6	mg/l	=	7,295 kg/day	VSS/TSS	=	76%	

Treated water quality parameters (as a 24 hrs composite sample)

COD =	90	mg/l	=	10,800	kg/day
BOD_5 =	20	mg/l	=	2,400	kg/day
TSS =	30	mg/l	=	3,600	kg/day
Total Coliforms =	200 MPN/100ml				

Total removal efficiencies (minimum)

COD	removal = 59%
BOD_5	removal = 85%
TSS	removal = 63%

II – Primary settling tanks:

Existing PST diameter:	52	m
Number of PST installed:	2	units
Total settling surface area:	4,245	m^2
Overflow rate at ADWF:	1.18	$m^3/m^2.h$
Overflow rate at PDWF:	1.68	$m^3/m^2.h$
Settleable solids in raw water	53.3	mg/l (2/3 of TSS in raw water)
Settleable solids removal in primary sedimentation:	60	%
TSS removal in primary sedimentation:	40	%
Inorganic SS removal in primary sedimentation:	43	%
VSS removal in primary sedimentation:	39	%
BOD_5 removal in primary sedimentation:	0.63	g BOD_5/ g VSS removed
BOD_5 removed in primary sedimentation:	1781	kg/day
BOD_5 in PST effluent:	115.7	mg/l
TSS in PST's effluent:	48	mg/l
VSS in PST effluent:	37	mg/l
TSS/BOD5 in PST's effluent:	0.41	

Design temperature: 10°C

II – Aeration basin (activated sludge)design:

Existing aeration basin capacity:	23,900	m^3
Hydraulic Residence Time (HRT) at ADWF:	4.78	hours
HRT at PDWF:	3.35	hours
Mixed liquor Suspended Solids (MLSS):	2.0	kg/m^3
BOD_5 loading:	0.58	kg BOD_5/m^3.day
F/M ratio (calculated on TSS concentration):	0.29	kg BOD_5/ kg TSS.day
% VSS in Mixed liquor:	84.6	%
F/M ratio (calculated on MLVSS concentration):	0.34	kg BOD_5 / kg VSS.day

Effluent temperature for activated sludge process calculations: 10°C

1-Treated water BOD_5 calculation:

1.1-Scluble BOD_5-Lf: **10.12** **mg/l** (Eckenfelder formula)

with:	BOD_5 primary effluent =	115.7	mg/l
	MLSS =	2	kg / m^3
	% VSS in mixed liquor =	84.63	%
	HRT at ADWF =	4.78	hours
	K =	1.29	

1.2-Particulate BOD_5-L'f: **8.67** **mg/l**

with:	TSS in treated water	20	mg/l
	F / M' =	0.343	kg/kg.day
	Estimated DBO/TSS ratio =	0.434	in treated water

1.3-Total BOD_5 in treated water-Ls = Lf + L'f: **18.79** **mg/l**

1.4-Total BOD_5 removed: 11,629 kg / day or 97 mg / l

2-Biological sludge production calculation:

The following parameters have to be taken into account in the calculations:

F / M ratio calculated on volatile matter:	F / M' =	0.343	kg BOD / kg VSS /day
Temperature calculation:	T =	10	°C
Endogenous decay factor at 10°C:	b at T = 10 °C =	0.058	day^{-1}

2.1-Inorganic sludge production calculation: 131 kg SS / day

2.2-Organic sludge production calculation:

1)	0.35 x VSS PST effluent:	1,566	kg VSS / day
2)	0.64 x BOD5 removed in aeration tank =	7,443	kg VSS /day
3)	- (0.75 x b/(F/M')) * BOD5 PST effluent =	-1,760	kg VSS / day
1+2+3)	Total organic sludge production =	7,239	kg VSS / day

The total sludge production will be: **8,552** **kg TSS / day**
with: **84.6%** **of volatile matter**

Average SRT = 5.59 days

Design temperature: 10°C

III – Net biological sludge production (to be treated in sludge treatment line):

TSS in treated water (secondary effluent) =	15	mg / l
Sludge losses in treated water (secondary effluent) =	1,800	kg MS / day
Total biological sludge net production:	5,715	kg VSS / day
Net biological sludge net production:	6,752	kg VSS / day
Net biological organic sludge net production:	5,715	kg VSS / day
Net biological sludge net production:	1,037	kg VSS / day

IV –Total sludge production calculation (primary + biological sludge)]

Primary sludge:	3,840	kg TTS / day		
	2,849	kg VSS / day	% VSS / TSS =	74.2 %
Biological slud	6,752	kg MS / day		
	5,715	kg MV / day	% VSS / TSS =	84.6%
Total	10,592	kg MS / day	% PS / BS =	36.3 %
	8,564	kg MV / day	% VSS / TSS =	80.9%

V –Oxygen requirements calculation

5.1.-Oxygen requirements for BOD_5 removal: **a' x BOD_5 removed**

These requirements are proportional to the BOD_5 mass removed in the biological treatment.
For high rate activated sludge process (HRAS) as well as for medium rate activated sludge (MRAS), which is the case for Sarajevo W.W.T.P., the proportionality factor "a'" depends on the F / M' ratio calculated taking into the global MVSS weight present in the aeration basins as well as in secondary clarifiers.

F / M' ratio =	0.343	kg BOD_5 / kg VSS.day (calculated on aeration tanks only)
F / M" ratio =	0.164	kg BOD_5 / kg VSS.day (calculated on aeration tanks and secondary clarifier)
a' =	0.665	kg O_2 / kg BOD_5.day
$BOD_{5\ removed}$ =	11,629	kg BOD_5. day
a' x $BOD_{5removed}$ =	7,737	kg O_2 / day

It has been assumed that the peak factor for oxygen requirements for BOD removal is the same as the hydraulic peak factor.

Peak factor = PDWF / ADWF = 1.43
Hourly peak oxygen requirements for BOD_5 removal = 460 kg O_2 / hour

5.2-Oxygen requirements for VSS endogenous respiration: **b' * MVSS**

These requirements are proportional to the global VSS weight present in the system (aeration tanks + secondary clarifier). The proportionally factor "b'" depends on the F / M" ratio, calculated taking into account the global VSS weight in the system as well as on mixed liquor temperature.

Mixed liquor temp. =	10	°C
F / M" ratio =	0.64	kg BOD_5 / kg VSS.day (calculated on aeration tanks and secondary clarifier)
b' at 10°C	0.069	kg O_2 / kg VSS.day

Design temperature: 10°C

Aeration basins:

MLSS:	2.0	g / l
MLVSS:	1.69	g / l
MLVSS in aeration basin:	40,460	kg

Secondary clarifiers:

Estimated diluted sludge volume index (DSVI):	120	mg / l	
Average TSS concentration in sludge blanket:	5.0	g / l	(500 / SVI x % SSV)
Average VSS concentration in sludge blanket	4.2	g / l	(600 / SVI x % SSV)
Number of secondary clarifiers:	4	units	(4 for year 2000 + 2 for year 2015)
Diameter:	52	m	
Unit clarification surface area:	2,124	m^2	
Total clarification surface area	8,495	m^2	
Cylindrical height:	3	m	
Estimated sludge blanket height:	0.75	m	
Total volume (cylindrical section):	25,485	m^3	
Total volume (as per Degremont design):	29,560	m^3	
Total volume of cone shaped section:	4,075	m^3	
Total VSS weight in secondary clarifiers:	44,211	kg MVS	

Aeration basins + Secondary clarifiers:

Total VSS weight in aeration basins + secondary clarifiers:	84,671	kg

So, the total oxygen requirements for endogenous respiration is:

b' x VSS present in aeration basins + Secondary Clarifiers =	5,809	kg O_2 / day
Hourly requirements (daily requirements / 24) =	242	kg O_2 / h

5.3.-Global Oxygen Requirements:

Hourly peak conditions	**Daily average conditions**
a' x $BOD_{5removed}$ = 480 kg O_2 / h	a' x $BOD_{5removed}$ = 7, 737 kg O_2 / day
b' x VSS(aeration basins + SC) = 242 kg O_2 / h	b' x VSS(aeration basins + SC) = 5, 809 kg O_2 / day
Total = 702 kg O_2 / h	Total = 13, 546 kg O_2 / day or: 564 kg O_2 / h

VI-Secondary clarification

Number of treatment lines:	2	line(s)
Number of secondary clarifier per line:	2	unit(s)
Secondary clarifier diameter:	52	m
Total surface area for clarification:	8,495	m^2
Unit Volume:	7,390	m^3 / clarifier
Total volume:	29,560	m^3
Total volume:	0.59	m/h at ADWF
Surface flow rate:	0.84	m / h at PWWF

Design temperature: 10°C

Hydraulic retention time:	5.91	h at ADWF
	4.14	h at PWWF

Test on surface flow rate using ATV standards:

DSVI:	120	mg / l
MLSS:	2.0	g / l
Qsv defined by ATV rules:	450	l / m^2.h at PWWF- for mainly horizontally Flowed-through secondary clarifiers, to Obtain 20 mg / l TSS in treated water
Maximum allowed surface flow rate:	1.88	m / h

Test on surface flow rate: **Surface flow rate OK!**

VII-Effluent disinfection (chlorine disinfection):

Quality standard:	200	FC / 100 ml
Contact chamber total volume:	3,960	m^3
Number of channels:	8	units
Channel Width:	3	m
Water depth:	3	m
Channel length:	55	m
Contact time at ADWF:	48	min
Contact time at ADWF:	33	min

Average chlorine dosage to achieve quality standard:	8	mg / l
Daily average consumption:	960	kg / day
Number of 2000 lbs chlorine cylinders to be installed:	16	units, equivalent to 15 days autonomy

Design temperature: 10°C

I – Design data:

15-juli-99

Flowrates: PDWF or PWWF: 3,241 l.p.g = 11,667 m^3/h
ADWF: 2,271 l.p.g = 8175 m^3/h = 196,200 m^3/day

Raw water quality parameters:

Temperature (T) =	10	°C (minimum)						
COD =	220	mg/l =	43,164	kg/day				
BOD_5 =	130	mg/l =	25,506	kg/day	COD/BOD_5 =		1.69	
TSS =	80	mg/l =	15,695	kg/day	TSS/BOD_5 =		0.62	
VSS =	60.8	mg/l =	11,929	kg/day	VSS/TSS =		76%	

Treated water quality parameters (as a 24 hrs composite sample)

COD =	90	mg/l =	17,658	kg/day
BOD_5 =	20	mg/l =	3,924	kg/day
TSS =	30	mg/l =	5,886	kg/day
Total Coliforms =	200 MPN/100ml			

Total removal efficiencies (minimum)

COD	removal = 59%
BOD_5	removal = 85%
TSS	removal = 63%

II – Primary settling tanks:

Existing PST diameter:	52	m
Number of PST installed:	2	units
Total settling surface area:	4,245	m^2
Overflow rate at ADWF:	1.93	$m^3/m^2.h$
Overflow rate at PDWF:	2.75	$m^3/m^2.h$
Settleable solids in raw water	53.3	mg/l (2/3 of TSS in raw water)
Settleable solids removal in primary sedimentation:	60	%
TSS removal in primary sedimentation:	40	%
Inorganic SS removal in primary sedimentation:	43	%
VSS removal in primary sedimentation:	39	%
BOD_5 removal in primary sedimentation:	0.63	g BOD_5/ g VSS removed
BOD_5 removed in primary sedimentation:	2,912	kg/day
BOD_5 in PST effluent:	115.7	mg/l
TSS in PST's effluent:	48	mg/l
VSS in PST effluent:	37	mg/l
TSS/BOD5 in PST's effluent:	0.41	

Design temperature: 10°C

II – Aeration basin (activated sludge)design:

Existing aeration basin capacity:	23,900	m^3
Hydraulic Residence Time (HRT) at ADWF:	2.92	hours
HRT at PDWF:	2.05	hours
Mixed liquor Suspended Solids (MLSS):	3.0	kg/m^3
BOD_5 loading:	0.95	kg BOD_5/m^3.day
F/M ratio (calculated on TSS concentration):	0.32	kg BOD_5/ kg TSS.day
% VSS in Mixed liquor:	84.7	%
F/M ratio (calculated on MLVSS concentration):	0.37	kg BOD_5 / kg VSS.day

Effluent temperature for activated sludge process calculations: 0°C

1-Treated water BOD_5 calculation:

1.1-Scluble BOD_5-Lf: **10.94** **mg/l** (Eckenfelder formula)

with:	BOD_5 primary effluent =	115.7	mg/l
	MLSS =	3	kg / m^3
	% VSS in mixed liquor =	84.57	%
	HRT at ADWF =	2.92	hours
	K =	1.29	

1.2-Particulate BOD_5-L'f: **8.93** **mg/l**

with:	TSS in treated water	20	mg/l
	F / M' =	0.374	kg/kg.day
	Estimated DBO/TSS ratio =	0.447	in treated water

1.3-Total BOD_5 in treated water-Ls = Lf + L'f: **19.87** **mg/l**

1.4-Total BOD_5 removed: 18,803 kg / day or 96 mg / l

2-Biological sludge production calculation:

The following parameters have to be taken into account in the calculations:

F / M ratio calculated on volatile matter:	F / M' =	0.374	kg BOD / kg VSS /day
Temperature calculation:	T =	10	°C
Endogenous decay factor at 10°C:	b at T = 10 °C =	0.060	day^{-1}

2.1-Inorganic sludge production calculation: 2,147 kg SS / day

2.2-Organic sludge production calculation:

1)	0.35 x VSS PST effluent:	2,545	kg VSS / day
2)	0.64 x BOD5 removed in aeration tank =	12,034	kg VSS / day
3)	- (0.75 x b/(F/M')) * BOD5 PST effluent =	-2,722	kg VSS / day
1+2+3)	Total organic sludge production =	11,856	kg VSS / day
The total sludge production will be:		**14,003**	**kg TSS / day**
	with:	**84.7%**	**of volatile matter**

Average SRT = 5.12 days

Design temperature: 10°C

III – Net biological sludge production (to be treated in sludge treatment line):

TSS in treated water (secondary effluent) =	15	mg / l
Sludge losses in treated water (secondary effluent) =	2943	kg MS / day
Total biological sludge net production:	14,003	kg VSS / day
Net biological sludge net production:	11,060	kg VSS / day
Net biological organic sludge net production:	9,364	kg VSS / day
Net biological sludge net production:	1,695	kg VSS / day

IV –Total sludge production calculation (primary + biological sludge)]

Primary sludge:	6,278	kg TTS / day		
	4,659	kg VSS / day	% VSS / TSS =	74.2 %
Biological slud	11,060	kg MS / day		
	9,364	kg MV / day	% VSS / TSS =	84.7%
Total	17,339	kg MS / day	% PS / BS =	36.2 %
	14,023	kg MV / day	% VSS / TSS =	80.9%

V –Oxygen requirements calculation

5.1.-Oxygen requirements for BOD_5 removal: **a' x BOD_5 removed**

These requirements are proportional to the BOD_5 mass removed in the biological treatment.
For high rate activated sludge process (HRAS) as well as for medium rate activated sludge (MRAS), which is the case for Sarajevo W.W.T.P., the proportionality factor "a'" depends on the F / M' ratio calculated taking into the global MVSS weight present in the aeration basins as well as in secondary clarifiers.

F / M' ratio =	0.374	kg BOD_5 / kg VSS.day (calculated on aeration tanks only)
F / M'' ratio =	0.179	kg BOD_5 / kg VSS.day (calculated on aeration tanks and secondary clarifier)
a' =	0.661	kg O_2 / kg BOD_5.day
$BOD_{5\ removed}$ =	18,803	kg BOD_5. day
a' x $BOD_{5removed}$ =	12,434	kg O_2 / day

It has been assumed that the peak factor for oxygen requirements for BOD removal is the same as the hydraulic peak factor.

Peak factor = PDWF / ADWF = 1.43
Hourly peak oxygen requirements for BOD_5 removal = 739 kg O_2 / hour

5.2-Oxygen requirements for VSS endogenous respiration: b' * MVSS

These requirements are proportional to the global VSS weight present in the system (aeration tanks + secondary clarifier). The proportionally factor "b'" depends on the F / M" ratio, calculated taking into account the global VSS weight in the system as well as on mixed liquor temperature.

Mixed liquor temp. =	10	°C
F / M'' ratio =	0.179	kg BOD_5 / kg VSS.day (calculated on aeration tanks and secondary clarifier)
b' at 10°C	0.071	kg O_2 / kg VSS.day

Design temperature: 10°C

Aeration basins:

MLSS:	3.0	g / l
MLVSS:	2.54	g / l
MLVSS in aeration basin:	60,706	kg

Secondary clarifiers:

Estimated diluted sludge volume index (DSVI):	120	mg / l	
Average TSS concentration in sludge blanket:	5.0	g / l	(500 / SVI x % SSV)
Average VSS concentration in sludge blanket	4.2	g / l	(600 / SVI x % SSV)
Number of secondary clarifiers:	6	units	(4 for year 2000 + 2 for year 2015)
Diameter:	52	m	
Unit clarification surface area:	2,124	m^2	
Total clarification surface area	12,742	m^2	
Cylindrical height:	3	m	
Estimated sludge blanket height:	0.75	m	
Total volume (cylindrical section):	38,227	m^3	
Total volume (as per Degremont design):	44,340	m^3	
Total volume of cone shaped section:	6,113	m^3	
Total VSS weight in secondary clarifiers:	66,335	kg MVS	

Aeration basins + Secondary clarifiers:

Total VSS weight in aeration basins + secondary clarifiers: 127,041 kg

So, the total oxygen requirements for endogenous respiration is:

b' x VSS present in aeration basins + Secondary Clarifiers =	9,071	kg O_2 / day
Hourly requirements (daily requirements / 24) =	378	kg O_2 / h

5.3.-Global Oxygen Requirements:

Hourly peak conditions		Daily average conditions	
a' x $BOD_{5removed}$ =	739 kg O_2 / h	a' x $BOD_{5removed}$ =	12 , 434 kg O_2 / day
b' x VSS(aeration basins + SC) =	378 kg O_2 / h	b' x VSS(aeration basins + SC) =	9, 071 kg O_2 / day
Total =	1,117kg O_2 / h	Total =	21, 505 kg O_2 / day or: 896 kg O_2 / h

VI-Secondary clarification

Number of treatment lines:	2	line(s)
Number of secondary clarifier per line:	3	unit(s)
Secondary clarifier diameter:	52	m
Total surface area for clarification:	12,742	m^2
Unit Volume:	7,390	m^3 / clarifier
Total volume:	44,340	m^3
Total volume:	0.64	m/h at ADWF
Surface flow rate:	0.92	m / h at PWWF

Design temperature: 10°C

Hydraulic retention time:	6.42	h at ADWF
	3.80	h at PWWF

Test on surface flow rate using ATV standards:

DSVI:	120	mg / l
MLSS:	3.0	g / l
Qsv defined by ATV rules:	450	l / m^2.h at PWWF- for mainly horizontally Flowed-through secondary clarifiers, to Obtain 20 mg / l TSS in treated water
Maximum allowed surface flow rate:	1.25	m / h

Test on surface flow rate: **Surface flow rate OKI**

VII-Effluent disinfection (chlorine disinfection):

Quality standard:	200	FC / 100 ml
Contact chamber total volume:	3,960	m^3
Number of channels:	8	units
Channel Width:	3	m
Water depth:	3	m
Channel length:	55	m
Contact time at ADWF:	29	min
Contact time at ADWF:	20	min
Average chlorine dosage to achieve quality standard:	8	mg / l
Daily average consumption:	1,570	kg / day
Number of 2000 lbs chlorine cylinders to be installed:	24	units, equivalent to 15 days autonomy

SARAJEVO WASTE WATER TREATMENT PLANT
PROCESS DESIGN CALCULATIONS FOR SLUDGE TREATMENT LINE ACCORDING TO RAW WATER AS PER INTERIM REPORT (BOD = 200 mg/l and TSS = 270 mg/l)

Design year 2000 and 2015

Design temperature: 10℃

	Units	Row Water according to JICA Interim Report	
		Year 2000 Q=120,000 m³/day	Year 2015 Q=196,200 m³/day
RECORD OF PRIMARY AND BIOLOGICAL SLUDGE PRODUCTIONS			
PRIMARY SLUDGES			
Net primary sludge production	kg / day	19,440	30,725
organic	kg / day	13,122	20,713
inorganic	kg / day	6,318	10,012
SS percentage recovery on thickener	%	96%	96%
Primary sludges to be extracted from primary clarifiers	kg / day	20,250	32,005
Sludge concentration at extraction poin	g/l	10	10
Net primary sludge volume to be extracted	m³/hour	2,025	3,201
Time of extraction (primary sludges)		13.50	21.34
Withdrawal flowrate (primary sludges)		150	150
BIOLOGICAL SLUDGES			
Net biological sludge production	kg / day	11,023	18,843
organic	kg / day	8,229	13,976
inorganic	kg / day	2,794	4,867
SS percentage recovery on thickener	%	96%	96%
Biological sludges to be extracted form recirculation	kg / day	11,482	19,528
ML.SS	g/l	2.5	4.0
Expected sludge volume index (SVI)	ml/g	120	120
Maximum theorical sludge withdrawal concentration	g/l	8.3	8.3
Operation sludge withdrawal concentration	g/l	6.5	8.0
Corresponding recycling rate	% of Q av.	63%	100%
Net volume of extracted biological sludge	m³/day	1,378	2,355
Time of extraction (biological sludge)	hour/day	11.48	18.53
Withdrawal flowrate (biological sludge)	m³/hour	120	120
% of primary sludge or mixed sludge	%	64%	62%
1-MIXED SLUDGE CYCLONING			
Maximum mixed sludge flowrate to be cycloned	m³/hour	150	150
2-MIXED SLUDGES GRAVITY THICKENING			
Net mixed sludge weight to be thickened	kg / day	30,463	49,567
SS concentration in thickened sludge	g/l	50	50
Net volume of thickened sludge	m³/day	609	991
Time of extraction (thickened sludge)	hour/day	10.15	16.52
Withdrawal flowrate (thickened sludge)	m³/hour	60	60
Return liquors generated by thickeners	m³/day	2,794	4,564
SS load	kg / day	1,260	2,065
SS concentration	mg/l	454	452
Theorical massic load on gravity thickeners	kgSS/m²/day	50	50
Running time of gravity thickeners	hour/day	24	24
Theorical minimum required surface area	m²	609	991
Number of thickener in operation	-	1	2
Theorical minimum required unit surface area	m²	609	496

SARAJEVO WASTE WATER TREATMENT PLANT
PROCESS DESIGN CALCULATIONS FOR SLUDGE TREATMENT LINE ACCORDING TO RAW WATER AS PER INTERIM REPORT (BOD = 200 mg/l and TSS = 270 mg/l)

Design year 2000 and 2015

Design temperature: 10℃

	Units	Row Water according to JICA Interim Report	
		Year 2000 Q=120,000 m³/day	Year 2015 Q=196,200 m³/day
Theorical thickener diamater	M	27.88	25.13
Existing thickener diameter	M	30.00	30.00
Operating massic load on gravity thickeners	kgSS/m²/day	43.12	35.08
4.MIXED THICKENED SLUDGE ANAEROBIC DIGESTION			
Mixed sludge weight to be digested	kg / day	30,463	49,567
Mixed sludge volume to be digested	m³/day	609	991
Required net volume to obtain 20 days digestion retention time	M³	12,185	19,827
Existing net digesters volume	M³	18,000	18,000
Net sludge retention time on anaerobic digestion	Days	29.54	18.16
Type of digestion		Mesophilic (1stage)	
Net digester volume	M³	9,000	9,000
Type of digesters		Primary	Primary
Digester diameter	M	27.80	27.80
Sludge straight height in digesters	M	14.83	14.83
Mixed sludge weight to be digested	kg / day	30,463	49,567
Mixed organic sludge weight to be digested	kg / day	21,351	34,689
Mixed inorganic sludge weight to be digested	kg / day	9,112	14,879
% VSS in mixed sludge to be digested	%	70.09%	69.98%
Sludge loading	kgSS/ m³.d	1.69	2.75
Organic sludge loading	kgVSS/ m³.d	1.19	1.93
Reduction in volatile solids	%	48%	45%
	KgVSS/ day	10,248	15,610
VSS destroyed by digestion			
VSS weight after digestion	KgVSS/ day	11,102	19,079
SS weight after digestion	kg SS/ jour	20.214	33,958
% of volatile solids in digested sludges	%	55%	56%
Digested sludge concentration	g/l	33.18	34.25
Biogas net production rate	Nm³/kgSSV destroyed	1	1
Biogas net production	Nm³/day	10248	15610
	Nm³/hour	427	850
% of methane contained in biogas	%	65	65
Methane heating value at 0℃ and 760 mm Hg	kCal/ m³	8,570	8,570
Corresponding biogas apecific heating value	kCal/ Nm³	5571	5571
Biogas net heating value	Th./day	57089	86955
	Th./hour	2379	3623
Extreme conditions:			
Lower operating air temperature	℃	-15	-15
Digester temperature	℃	+35	+35
Sludge temperature:			
summer period:	℃	18	18
winter period:	℃	8	8
Air temperature:			
summer period:	℃	25	25

SARAJEVO WASTE WATER TREATMENT PLANT
PROCESS DESIGN CALCULATIONS FOR SLUDGE TREATMENT LINE ACCORDING TO RAW WATER AS PER INTERIM REPORT (BOD = 200 mg/l and TSS = 270 mg/l)

Design year 2000 and 2015

Design temperature: 10℃

	Units	Row Water according to JICA Interim Report	
		Year 2000 Q=120,000 m^3/day	Year 2015 Q=196,200 m^3/day
winter period:	℃	-15	-15
Minimal sludge temperature in digesters	℃	35	35
Estimated heat losses from digesters			
summer period:	kCal./m^3.day	32.5	32.5
winter period:	kCal./m^3.day	163	163
Net heat losses from digesters			
summer period:	kCal./day	585,000	585,000
summer period:	Th./day	585	585
summer period:	kW	28.3	28.3
summer period:	kW / digester	14.2	14.2
winter period:	kCal./day	2,934,000	2,934,000
winter period:	Th./ hour	2,934	2,934
winter period:	KW	142.2	142.2
winter period:	kW / digester	71.1	71.1
Hourly net heat losses from digesters			
summer period:	kCal./hour	24,375	24,375
summer period:	Th./hour	24	24
winter period:	kCal./hour	122,250	122,250
winter period:	Th./hour	122	122
Corresponding digester heat loss coefficient:			
summer period:	kCal./m^3.h.℃	0.14	0.14
winter period:	kCal./m^3.h.℃	0.14	0.14
Sludge temperature in digesters	℃	35	35
Required heat to raise incoming sludge temperature			
summer period:	kCal./day	10,357,263	16,852,946
summer period:	Th./day	10,357	16,853
summer period:	kCal./hour	431,553	702,206
summer period:	Th./hour	432	702
summer period:	KW	502	817
summer period:	kW / digester	251	408
winter period:	kCal./day	16,449,771	26,766,443
winter period:	Th./day	16,450	26,766
winter period:	kCal./hour	685,407	1,115,268
winter period:	Th./hour	685	1,115
winter period:	KW	797	1,297
winter period:	kW / digester	399	649
Total heat requirement for digestion process			
Daily in summer period:	kCal./day	10,942,263	17,437,946
Daily in summer period:	Th./day	10,942	17,438
Daily in winter period:	kCal./day	19,383,771	29,700,443
Daily in winter period:	Th./day	19,384	27,700
	kW	939	1,439
Hourly peak in summer period:	kCal./hour	455,928	726,581
Hourly peak in summer period:	Th./hour	456	727
Hourly peak in summer period:	KW	530	845
Hourly peak in summer period:	kW / digester	265	423
Hourly peak in winter period:	Kcal./hour	807,657	1,237,518
Hourly peak in winter period:	Th./hour	808	1,238
Hourly peak in winter period:	KW	939	1,439
Hourly peak in winter period:	kW / digester	470	720

SARAJEVO WASTE WATER TREATMENT PLANT
PROCESS DESIGN CALCULATIONS FOR SLUDGE TREATMENT LINE ACCORDING TO RAW WATER AS PER INTERIM REPORT (BOD = 200 mg/l and TSS = 270 mg/l)

Design year 2000 and 2015

Design temperature: 10℃

	Units	Row Water according to JICA Interim Report	
		Year 2000 Q=120,000 m^3/day	Year 2015 Q=196,200 m^3/day
Number of boilere in operation		2	2
Unit bioler heat power		750 kW	750 kW
Biogas consumption for sludge heating requirements			
summer period:	Nm^3/day	1,859	3,025
winter period:	Nm^3/day	2,953	4,805
Biogas consumption to balance digester heat losses			
summer period:	Nm^3/day	105	105
winter period:	Nm^3/day	527	527
Total biogas production:			
summer period:	Nm^3/day	1,964	3,130
winter period:	Nm^3/day	3,480	5,332
Excess biogas production:			
Daily average in summer period:	Nm^3/day	8,284	12,480
Daily average in winter period:	Nm^3/day	6,769	10,278
Hourly average in summer period:	Nm^3/hour	345	520
Hourly average in winter period:	Nm^3/hour	282	428
Equivalent calorific power contained in excess biogas for electricity generation and building's heating			
summer period:	kW	2,236	3,369
winter period:	kW	1,827	2,775
5-EXISTING GAS HOLDER			
Daily net biogas production	Nm^3/day	10,248	15,610
Gas holder capacity	m^3	5,000	5,000
Biogas retention time	hour	11.71	7.69
6-DIGESTED SLUDGE HOLDING TANK			
Existing tank capacity	m^3	3,675	3,675
Digested sludge retention time	days	6.03	3.71
7- SLUDGE DEWATERING BY BELT FILTER PRESSES			
Dewatering process working days	day / week	5	5
Sludge weight to be dewater / calender day	kg SS / day	20,214	33,958
Sludge volume to be dewater / calender day	m^3/day	609	991
Digested sludge concentration	g / l	33.18	34.25
Weekly digested sludge weight	kg SS / week	141,499	237,703
Digested sludge to be dewatered /working day	kg SS / day	28,300	47,541
Number of belt filter presses to be installed:	Units	5	7
in duty	Units	4	6
in stand-by	Units	1	1
Belt width	M	3	3
Massic load per machine	kg DS / hour	697	719
	kg DS / m.hour	232	240

SARAJEVO WASTE WATER TREATMENT PLANT
PROCESS DESIGN CALCULATIONS FOR SLUDGE TREATMENT LINE ACCORDING TO RAW WATER AS PER INTERIM REPORT (BOD = 200 mg/l and TSS = 270 mg/l)

Design year 2000 and 2015

Design temperature: 10℃

	Units	Row Water according to JICA Interim Report	
		Year 2000 Q=120,000 m^3/day	Year 2015 Q=196,200 m^3/day
Effective volumic load	m^3/hour	21.00	21.00
	m^3/h.m of belt	7.00	7.00
Daily working time	h / jour	7.25	7.87
Dewatered sludge (cake) concentration	%	24	24
Estimated cake density	-	1.1	1.1
Cake volume to be disposed	m^3 / hour	14.78	22.89
	m^3 / day	107	180
Cake weight to be disposed	Ton.wet sludge/day	118	198
SS percentage recovery on belt filter presses	%	97%	97%
SS concentration in return liquors	g / l	1.16	1.20
Net volume of return liquors (except polymer)	m^3 / day	735	1,190
SS load in return liquors	kg / day	849	1,426
Polymer dosage for sludge floculation	kg / Ton DS	4	4
Daily average polymer consumption	kg / day	113	190
Hourly average polymer consumption	kg / hour	15.6	24.2
8- RETURN LIQUORS			
From thickeners	Flow-m^3/d	2,794	4,564
	% inlet flow	2.33%	2.33%
	SS – kg / d	1,269	2,065
	% inlet SS load	3.83%	3.81%
From Belt filter presses	Flow-m^3/d	735	1,190
	% inlet SS load	0.61%	0.61%
	SS – kg / d	849	1,426
	% inlet SS load	2.56%	2.63%
Total	Flow-m^3/d	3,529	5,754
	% inlet SS load	2.94%	2.93%
	SS – kg / d	2 118	3,492
	% inlet SS load	6.40%	6.45%

SARAJEVO WASTE WATER TREATMENT PLANT
PROCESS DESIGN CALCULATIONS FOR SLUDGE TREATMENT LINE ACCORDING TO RAW WATER AS PER INTERIM REPORT (BOD = 130 mg/l and TSS = 80mg/l)

Design year 2000 and 2015

Design temperature: 10℃

	Units	Row Water according to JICA Interim Report	
		Year 2000 Q=120,000 m³/day	Year 2015 Q=196,200 m³/day
RECORD OF PRIMARY AND BIOLOGICAL SLUDGE PRODUCTIONS			
PRIMARY SLUDGES			
Net primary sludge production	kg / day	3,840	6,278
organic	kg / day	2,849	4,659
inorganic	kg / day	991	1,620
SS percentage recovery on thickener	%	94%	94%
Primary sludges to be extracted from primary clarifiers	kg / day	4,085	6,679
Sludge concentration at extraction poin	g/l	10	10
Net primary sludge volume to be extracted	m³/hour	409	668
Time of extraction (primary sludges)	hour / day	2.72	4.45
Withdrawal flowrate (primary sludges)	m³ / hour	150	150
BIOLOGICAL SLUDGES			
Net biological sludge production	kg / day	6,752	11,060
organic	kg / day	5,715	9,364
inorganic	kg / day	1,037	1,696
SS percentage recovery on thickener	%	94%	94%
Biological sludges to be extracted form recirculation	kg / day	7,183	11,766
ML.SS	g/l	2.0	3.0
Expected sludge volume index (SVI)	ml/g	120	120
Maximum theorical sludge withdrawal concentration	g/l	8.3	8.3
Operation sludge withdrawal concentration	g/l	5.5	6.0
Corresponding recycling rate	% of Q av.	57%	100%
Net volume of extracted biological sludge	m³/day	862	1,412
Time of extraction (biological sludge)	hour/day	7.18	11.77
Withdrawal flowrate (biological sludge)	m³/hour	120	120
% of primary sludge or mixed sludge	%	36%	
1-MIXED SLUDGE CYCLONING			
Maximum mixed sludge flowrate to be cycloned	m³/hour	150	150
2-MIXED SLUDGES GRAVITY THICKENING			
Net mixed sludge weight to be thickened	kg / day	10,592	17339
SS concentration in thickened sludge	g/l	35	35
Net volume of thickened sludge	m³/day	303	495
Time of extraction (thickened sludge)	hour/day	5.04	8.26
Withdrawal flowrate (thickened sludge)	m³/hour	60	60
Return liquors generated by thickeners	m³/day	968	1,584
SS load	kg / day	676	1,107
SS concentration	mg/l	699	698
Theorical massic load on gravity thickeners	kgSS/m²/day	40	40
Running time of gravity thickeners	hour/day	24	24
Theorical minimum required surface area	m²	265	433
Number of thickener in operation	-	1	1

SARAJEVO WASTE WATER TREATMENT PLANT
PROCESS DESIGN CALCULATIONS FOR SLUDGE TREATMENT LINE ACCORDING TO RAW WATER AS PER INTERIM REPORT (BOD = 130 mg/l and TSS = 80mg/l)

Design year 2000 and 2015

Design temperature: 10℃

	Units	Row Water according to JICA Interim Report	
		Year 2000 Q=120,000 m^3/day	Year 2015 Q=196,200 m^3/day
Theorical minimum required unit surface area	m^2	265	433
Theorical thickener diamater	m	18.37	23.50
Existing thickener diameter	m	30.00	30.00
Operating massic load on gravity thickeners	kgSS/m^2/day	14.99	24.54
4.MIXED THICKENED SLUDGE ANAEROBIC DIGESTION			
Mixed sludge weight to be digested	kg / day	10,592	17,339
Mixed sludge volume to be digested	m^3/day	303	495
Required net volume to obtain 20 days digestion retention time	m^3	6,053	9,908
Existing net digesters volume	m^3	9,000	9,000
Net sludge retention time on anaerobic digestion	days	29.74	18.17
Type of digestion		Mesophilic (1stage)	
Net digester volume	m^3	9,000	9,000
Type of digesters		Primary	Primary
Digester diameter	m	27.80	27.80
Sludge straight height in digesters	m	14.83	14.83
Mixed sludge weight to be digested	kg / day	10,592	17,339
Mixed organic sludge weight to be digested	kg / day	8,564	14,023
Mixed inorganic sludge weight to be digested	kg / day	2,028	3,316
% VSS in mixed sludge to be digested	%	80.86%	80.88%
Sludge loading	kgSS/ m^3.d	1.18	1.93
Organic sludge loading	kgVSS/ m^3.d	0.95	1.56
Reduction in volatile solids	%	45%	43%
	kgVSS/ day	3,854	6,030
VSS destroyed by digestion			
VSS weight after digestion	kgVSS/ day	4,710	7,993
SS weight after digestion	kg SS/ jour	6,738	11,309
% of volatile solids in digested sludges	%	70%	71%
Digested sludge concentration	g/l	22.26	22.83
Biogas net production rate	Nm^3/kgSSV destroyed	1	1
Biogas net production	Nm^3/day	3,854	6,030
	Nm^3/hour	161	251
% of methane contained in biogas	%	65	65
Methane heating value at 0℃ and 760 mm Hg	kCal/ m^3	8,570	8,570
Corresponding biogas apecific heating value	kCal/ Nm^3	5,571	5,571
Biogas net heating value	Th./day	21.469	33,589
	Th./hour	895	1,400
Extreme conditions:			
Lower operating air temperature	℃	-15	-15
Digester temperature	℃	+35	+35
Sludge temperature:			
summer period:	℃	18	18
winter period:	℃	8	8
Air temperature:			
summer period:	℃	25	25

SARAJEVO WASTE WATER TREATMENT PLANT
PROCESS DESIGN CALCULATIONS FOR SLUDGE TREATMENT LINE ACCORDING TO RAW WATER AS PER INTERIM REPORT (BOD = 130 mg/l and TSS = 80mg/l)

Design year 2000 and 2015

Design temperature: 10℃

	Units	Row Water according to JICA Interim Report	
		Year 2000 Q=120,000 m³/day	Year 2015 Q=196,200 m³/day
winter period:	℃	-15	-15
Minimal sludge temperature in digesters	℃	35	35
Estimated heat losses from digesters			
summer period:	kCal./m³.day	32.5	32.5
winter period:	kCal./m³.day	163	163
Net heat losses from digesters			
summer period:	kCal./day	292,500	292,500
summer period:	Th./day	293	293
summer period:	KW	14.2	14.2
summer period:	kW / digester	14.2	14.2
winter period:	kCal./day	1,467,000	1,467,000
winter period:	Th./ hour	1,467	1,467
winter period:	KW	71.1	71.1
winter period:	kW / digester	71.1	71.1
Hourly net heat losses from digesters			
summer period:	kCal./hour	12,188	12,188
summer period:	Th./hour	12	12
winter period:	kCal./hour	61,125	61,125
winter period:	Th./hour	61	61
Corresponding digester heat loss coefficient:			
summer period:	kCal./m³.h.℃	0.14	0.14
winter period:	kCal./m³.h.℃	0.14	0.14
Sludge temperature in digesters	℃	35	35
Required heat to raise incoming sludge temperature			
summer period:	kCal./day	5,144,682	8,421,678
summer period:	Th./day	5,145	8,422
summer period:	kCal./hour	214,362	350,903
summer period:	Th./hour	214	351
summer period:	KW	249	408
summer period:	kW / digester	249	408
winter period:	kCal./day	8,170,965	13,375,606
winter period:	Th./day	8,171	13,376
winter period:	kCal./hour	340,457	557,317
winter period:	Th./hour	340	557
winter period:	KW	396	648
winter period:	kW / digester	396	648
Total heat requirement for digestion process			
Daily in summer period:	kCal./day	5,437,182	8,714,178
Daily in summer period:	Th./day	5,437	8,714
Daily in winter period:	kCal./day	9,637,965	14,842,606
Daily in winter period:	Th./day	9,638	14,843
		467	719
Hourly peak in summer period:	kCal./hour	226,549	363,091
Hourly peak in summer period:	Th./hour	227	363
Hourly peak in summer period:	KW	263	422
Hourly peak in summer period:	kW / digester	263	422
Hourly peak in winter period:	Kcal./hour	401,582	618,442
Hourly peak in winter period:	Th./hour	402	618
Hourly peak in winter period:	KW	467	719
Hourly peak in winter period:	kW / digester	467	719

SARAJEVO WASTE WATER TREATMENT PLANT
PROCESS DESIGN CALCULATIONS FOR SLUDGE TREATMENT LINE ACCORDING TO RAW WATER AS PER INTERIM REPORT (BOD = 130 mg/l and TSS = 80mg/l)

Design year 2000 and 2015

Design temperature: 10℃

	Units	Row Water according to JICA Interim Report	
		Year 2000 Q=120,000 m³/day	Year 2015 Q=196,200 m³/day
Number of boilere in operation		1	1
Unit bioler heat power		750 kW	750 kW
Biogas consumption for sludge heating requirements			
summer period:	Nm³/day	924	1,512
winter period:	Nm³/day	1,467	2,401
Biogas consumption to balance digester heat losses			
summer period:	Nm³/day	53	53
winter period:	Nm³/day	263	263
Total biogas production:			
summer period:	Nm³/day	976	1,564
winter period:	Nm³/day	1,730	2,665
Excess biogas production:			
Daily average in summer period:	Nm³/day	2,878	4,466
Daily average in winter period:	Nm³/day	2,124	3,365
Hourly average in summer period:	Nm³/hour	120	186
Hourly average in winter period:	Nm³/hour	88	140
Equivalent calorific power contained in excess biogas for electricity generation and building's heating			
summer period:	kW	777	1,205
winter period:	kW	573	908
5-EXISTING GAS HOLDER			
Daily net biogas production	Nm³/day	3,854	6.030
Gas holder capacity	m³	5,000	5,000
Biogas retention time	hour	31.14	19.90
6-DIGESTED SLUDGE HOLDING TANK			
Existing tank capacity	m³	3,675	3,675
Digested sludge retention time	days	12.14	7.42
7- SLUDGE DEWATERING BY BELT FILTER PRESSES			
Dewatering process working days	day / week	5	5
Sludge weight to be dewater / calender day	kg SS / day	6,738	11,309
Sludge volume to be dewater / calender day	m³/day	303	495
Digested sludge concentration	g / l	22.26	22.83
Weekly digested sludge weight	kg SS / week	47,166	79,162
Digested sludge to be dewatered /working day	kg SS / day	9,433	15,832
Number of belt filter presses to be installed:	Units	5	7
in duty	Units	2	3
in stand-by	Units	3	4
Belt width	M	3	3
Massic load per machine	kg DS / hour	468	479
	kg DS / m.hour	156	160

SARAJEVO WASTE WATER TREATMENT PLANT
PROCESS DESIGN CALCULATIONS FOR SLUDGE TREATMENT LINE ACCORDING TO RAW WATER AS PER INTERIM REPORT (BOD = 130 mg/l and TSS = 80mg/l)

Design year 2000 and 2015

Design temperature: 10℃

	Units	Row Water according to JICA Interim Report	
		Year 2000 Q=120,000 m^3/day	Year 2015 Q=196,200 m^3/day
Effective volumic load	m^3/hour	21.00	21.00
	m^3/h.m of belt	7.00	7.00
Daily working time	h / jour	7.21	7.86
Dewatered sludge (cake) concentration	%	19	19
Estimated cake density	-	1.06	1.06
Cake volume to be disposed	m^3 / hour	6.50	10.00
	m^3 / day	47	79
Cake weight to be disposed	Ton.wet sludge/day	50	83
SS percentage recovery on belt filter presses	%	97%	97%
SS concentration in return liquors	g / l	0.76	0.78
Net volume of return liquors (except polymer)	m^3 / day	374	610
SS load in return liquors	kg / day	283	475
Polymer dosage for sludge floculation	kg / Ton DS	6	6
Daily average polymer consumption	kg / day	57	95
Hourly average polymer consumption	kg / hour	7.9	12.1
8- RETURN LIQUORS			
From thickeners	Flow-m^3/d	968	1,584
	% inlet flow	0.81%	0.81%
	SS – kg / d	676	1,107
	% inlet SS load	2.04%	2.04%
From Belt filter presses	Flow-m^3/d	374	610
	% inlet SS load	0.31%	0.31%
	SS – kg / d	283	475
	% inlet SS load	0.85%	0.88%
Total	Flow-m^3/d	1,342	2,195
	% inlet SS load	1.12%	1.12%
	SS – kg / d	959	1,582
	% inlet SS load	2.90%	2.92%

4. HYDRAULIC CALCULATION

4.1 PARSHALL FLUME

4.1.1 Parshall Flume

Maximum flow Q = 196,000m^2/day
= 2,268 m^3/s

Table reads: Throat width 10 ft
Max: 8.49 m^3/s
Min: 0.167 m^3/s

Q = 1.92 m^3/s, Ha = 0.9558
Q = 2.42 m^3/s, Ha = 0.9797
Thus, Ha = 0.908

Maximum allowable figure Hb
Hb = 0.8 × 0.908 = 0.726

4.1.2 Parshall Flume– Final Sedimentation Tank

Q = 2.268 m^3/s
—> Ha = 0.908

Headloss due to speeding up
A = 4.756 × 0.908 = 4.318 m^2
Velocity V = 2.268/4.318 = 0.525 m/s
$V^2/2g$ = 0.2759/19.6 = 0.014 m

4.1.3 Headloss in Hole (800mm dia.)

Q = 2.268 m^3/s
V = 2.268 / 2.5434 = 0.891 m/s
$V^2/2g$ = 0.040 m
0.040 × 5 = 0.120

Water level upstream of flow
Headloss

$Q = 2.268\ m^3/s$

$V = 0.891\ m/s$

$V^2/2g = 0.040\ m$

$0.040 \times 5 = 0.120$

Friction head loss

$I = V^2/(85^2 \times R^{4/3}) = 0.891^2 / (85^2 \times 0.4503^{4/3})$

$= 0.7939 / 2444.7925$

$= 0.0003182\ m/m$

$0.0003182 \times 72 = 0.023\ m$

4.1.4 Headloss in Hole (1,300 mm dia.)

$Q = 1.134\ m^2/s$

$V = 0.855\ m/s$

$A = 1.327\ m^2$

$V^2/2g = 0.855^2 / 19.6 = 0.037\ m$

$0.037 \times 1.5 = 0.056\ m$

Friction headloss in 57.00 m × 1,300 mm dia.

$I = V^2 / (85^2 \times R^{4/3}) = 0.731 / (7225 \times 0.229)$

$= 0.731/1654.525$

$= 0.000442\ m/m$

$0.000442 \times 11 = 0.00486$

$= 0.005\ m$

4.2 AERATION TANK

Width $= 0.80\ m$

Total length $= 81.50 \times 2 = 163\ m$

Flow $= 0.567\ m^3/s$

Water depth $= 487.26 - 486.79 = 0.47\ m$

A $= 0.47 \times 0.80 = 0.376$

V $= Q/A = 0.754\ m/s$

Headloss due to speeding up

$V^2/2g = 0.754^2 / 19.6 = 0.0290$

Friction headloss

$I = V^2/(85^2 \times R^{4/3}) = 0.754^2$

$0.000607 \times 81.50 \times 1/3 = 0.0165$

Water level in the final sedimentation

Total length of weir = 163 m

Flow = 0.567 m^3/s

4.3 FINAL SEDIMENTATION TANKS

4.3.1 Water Level in the Aerated Chamber Outlet

Q = 2.268×2.00 (return sludge) = 4.268 m^3/s

A = $0.45 \times 1.40 \times 8 = 5.04$ m^2

Flow = $4.268 / 4 = 1.067$ m^3/s

V = $1.067 / 5.04 = 0.212$ m/s

$V^2/2g = 0.212^2 / 19.6 = 0.00229$

$= 0.0023$

Friction headloss in central column

A = 4.15 – 0.50 = 3.65 m^2

V = 0.292 m/s

$I = V^2 / (85^2 \times R^{4/3}) = 0.292^2 / (7225 \times 0.0133)$

$= 0.0853 / 96.1093$

$0.00089 \times 3.80 = 0.0034$

Headloss in hole (1,230 mm)

Q = 1.067 m^3/s

V = 0.870 m/s

$V^2/2g = 0.870^2 / 19.6 = 0.0386$ m

$0.386 \times 1.5 = 0.058$

Friction headloss in 25.00 m × 1,250 mm dia. Steel pipe

$25.00 \times 0.0008 = 0.020$

Headloss in hole (1,300 mm dia.)

Q = 1.067 m^3/s

V = 0.802 m/s

$V^2/2g = 0.802^2 / 19.6 = 0.0328$ m

$3.22 \times 0.0328 = 0.106$

Friction headloss in 105.00 × 1,300 mm dia.

Q = 1.067 m^2/s

V = 0.802 m/s

$I = V^2 / (85^2 \times R^{4/3}) = 0.802^2 / (7225 \times 0.2229)$

$= 0.6432 / 1610.426$

$= 0.000399$

105.00 m × 0.000399 = 0.042

4.4 WATER LEVEL IN AERATION TANKS

Flow Q = 1.067 m^3/s

Length of weir = 10.80 m

$$Q = 0.40 \times 10.80 \times b \sqrt{2gb}$$

$$1.067 = 0.40 \times 10.80 \times b\sqrt{(19.6 \times b)}$$

$$b \times \sqrt{(19.6 \times b)} = 0.247$$

$$b \times \sqrt{(b)} = 0.247 / \sqrt{(19.6)}$$

$$b \times \sqrt{(b)} = 0.0558$$

$$b = 0.146$$

Weir level of aeration tanks

Flow Q = 2.134 m^2/s

Length of weir = 38.60 m

$$Q = 0.40 \times 38.60 \times b \times \sqrt{(19.6 \times b)}$$

$$2.134 = 0.40 \times 38.60 \times b \times \sqrt{(b)} \times \sqrt{(19.6)}$$

$$= 15.44 \times b \times \sqrt{(b)} \times \sqrt{(19.6)}$$

$$b \times \sqrt{(b)} = 0.03117$$

$$b = 0.099$$

4.5 AERATION TANKS – PRIMARY SEDIMENTATION TANKS

Width = 1.35 m

Length of the trough b = 115.00 m

Flow in each trough = 1.134 m^3/s

Water depth in trough at the outlet = 488.70 – 487.59 = 1.11 m

Area of section trough = 1.35 × 1.1 = 1.50 m^2

Velocity in trough = 0.756 m^2/s

Headloss due to speeding up

$V^2/2g = 0.756^2 / (7225 \times 0.3175) = 0.5715 / 2293.9375$

= 0.000249 m/m

Wair level in the distribution chamber at the inlet of the aeration tanks

Flow Q = 1.134 m^2/s

Length of weir = 3.80 m

Height at sheet of water

$Q = 0.40 \times 3.80 \times b \times \sqrt{2gb}$

$1.134 = 6.729 \times b \times \sqrt{(b)}$

$b \times \sqrt{(b)} = 0.1685$

$b = 0.305$

4.6 WATER LEVEL IN THE OUTLET CHAMBER OF THE PRIMARY TANKS

Headloss in hole (200 mm dia.)

Q = 2.268 m/s

A = 3.14 m^2

V = 0.722 m^2/s

$V^2/2g = 0.722^2 / 19.6 = 0.0266$ m

$1.5 \times 0.0266 = 0.040$

Friction headloss in 40,100 mm × 2,000 mm dia. Pipe

$I = V^2 / (85^2 \times R^{4/3}) = 0.722^2 / (7225 \times 0.3973)$

$= 0.5213 / 2870.42$

= 0.000182 m/m

0.00018×40.00 m = 0.0073

4.7 WATER LEVEL IN THE CLARIFIED WATER TROUGH

Width of weir trough = 2.20 m
Flow = 1.134 m^3/s
Water depth of weir trough of the outlet = 1.16m
Section of weir trough = $2.20 \times 1.16 = 2.55\ m^2$
Velocity in weir trough = 0.445 m^2/s
Length of weir trough = 4.50 m
Friction headloss
$I = V^2 / (85^2 \times R^{4/3}) = 0.445^2 / (7225 \times 0.514)$
$= 0.1980 / 3715.71$
$0.000053 \times 4.50 = 0.0002$

Headloss due to speeding up
$V^2/2g = 0.445^2 / 19.6 = 0.010$
Width of trough = 1.10
$A = 1.1 \times 1.16 = 1.276$
Flow = $1.134 = 0.567 \times 2$
$V = 0.567 / 1.276 = 0.451$

Headloss of the outlet of the trough
$0.2 \times V^2/2g = 0.2 \times 0.451^2 / 19.6 = 0.0021$

Friction headloss in trough
$I = V^2 / (85^2 \times R^{4/3}) = 0.455^2 / 1923.08 = 0.000105$
$0.000105 \times 81.5 \times 1/3 = 0.0029$

4.8 WATER LEVEL IN THE PRIMARY SEDIMENTATION TANKS

Total length of weir =163 m
Flow = 1.134 m^2/s
Height of sheet of water
Table reads weir "C" type = 0.042

Water level in distribution chamber (between the primary tanks)
Inlet in primary sedimentation tanks
Flow = 1.134 m^3/s
Area of section = $0.34 \times 1.60 \times 8 = 4.35\ m^2$
Velocity = 0.261 m/s

$V^2/2g = 0.261^2/ 19.6 = 0.003448$

$= 0.0034$

Friction headloss in central column

Area of section = $\pi \times 1.75^2/ 4 = 2.40\ m^2$

V = 0.473 m/s

$I = V^2 / (85^2 \times R^{4/3}) = 0.473^2/ 2430$

$= 0.2237/2430$

$= 0.000092$

$0.000092 \times 8 = 0.00073$

Headloss in hole (1,750 mm dia.)

Q = 1.134 m^3/s

V = 0.473 m/s

$V^2/2g = 0.473^2/ 19.6 = 0.0114$ m

$2 \times 0.0114 = 0.023$

Friction headloss in 29.00 mm × 1,750 mm dia. Steel pipe

Table reads J = 0.00018 m

with k = 2 mm

$29 \times 0.00018 = 0.005$

Water level in distribution chamber (between the private tank) = 0.032

4.9 WATER LEVEL AFTER WAIRS AT THE OUTLET

Headloss in hole (1,600 mm dia.)

Q = 1.134 m^3/s

A = 2.01 m^2

V = 0.56 m/s

$V^2/2g = 0.56^2/ 19.6 = 0.016$ m

$0.016 \times 1.5 = 0.024$

Friction headloss in 35.00 mm × 1,600 mm dia. R.C pipe

$I = V^2 / (85^2 \times R^{4/3}) = 0.56^2/ 2112.5$

$= 0.00015$

$35 \times 0.00015 = 0.0052$

Water level after weirs at the outlet of aerated grit chambers = 0.0292

4.10 WATER LEVEL AT THE OUTLET OF AERATED GRIT CHAMBERS

Q = 2.268 m^3/s

Lot weirs = 10.30 m

$$Q = 0.40 \times 10.30 \times b \times \sqrt{(2gb)}$$

$$2.268 = 0.40 \times 10.30 \times b \times \sqrt{(2gb)}$$

$$= 4.2 \times b \times \sqrt{(2g)} \times \sqrt{(b)}$$

$$= 18.59 \times b \times \sqrt{(b)}$$

$$b \times \sqrt{(b)} = 0.1220$$

$$b = 0.246$$

4.11 WATER LEVEL IN AERATED GRIT CHAMBERS

4.11.1 Aerated Grit Chamber

Q = 2.268 / 3 = 0.756 m^3/s

Headloss in hole (1,500 × 1,500 mm)

Area of section = 1.50 × 1.50 = 2.25 m^2

$$Q = ks \sqrt{(2gb)}$$

$$0.756 = 0.62 \times 2.25 \times \sqrt{(19.6\,b)}$$

$$= 1.395 \times \sqrt{(19.6)} \times \sqrt{(b)}$$

$$\sqrt{(b)} = 0.1224095$$

$$b = 0.015$$

Water level in aerated grit chambers = 490.25

4.11.2 Aerated Grid Chamber – Screening Point

Water depth of the inlet of aerated grit chamber = 490.25 – 489.15

= 1.10 m

Width of inlet hole = 0.90 m

Area of section = $1.10 \times 0.90 = 0.99\ m^2$

V = 0.756/0.99 = 0.764 m/s

Headloss

$V^2/2g = 0.764^2 / 19.6 = 0.030$

Water level at the inlet at aerated grit chambers = 490.28

4.11.3 Water Level at Inlet of Fine Screen

Water depth: 490.28 – 489.15 = 1.13 m

Area: $1.13 \times 1.50 = 1.695\ m^2$

$Q = 2.268 / 3 = 0.756\ m^2/s$

V = 0.756 / 1.695 = 0.446 m/s

Headloss = $k1 \times k2 \times k3 \times V^2/2g$ (with k1 = 16, k2 = 0.37 and k3 = 0.61)

Headloss = $16 \times 0.37 \times 0.61 \times 0.446^2 / 19.6 = 0.0366$

4.11.4 Water Level at the Inlet of Screw

Water level at the inlet of screw = 490.32 m

4.11.5 Screening Point – Pumping Station

Waterfall after lip = 0.560 m

Discharge lip level = 490.88 m

4.11.6 Intake Level

Intake level = 482.50 m