REPUBLIC OF SERBIA
THE CITY OF BELGRADE
BELGRADE LAND DEVELOPMENT PUBLIC AGENCY (LDA)
BELGRADE WATERWORKS AND SEWERAGE (BVK)

PREPARATORY SURVEY REPORT ON THE SEWERAGE SYSTEM IMPROVEMENT PROJECT FOR THE CITY OF BELGRADE IN REPUBLIC OF SERBIA

VOLUME II APPENDIX-I

MAY 2013

JAPAN INTERNATIONAL COOPERATION AGENCY

TEC INTERNATIONAL CO., LTD.

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VOLUME I

SUMMARY & MAIN REPORT

VOLUME II

APPENDIX-I

VOLUME III

APPENDIX-II

(PRE EIA & LARAP)

VOLUME IV

DRAWINGS

Preparatory Survey Report
on the Sewerage System Improvement Project for the City of Belgrade
in Republic of Serbia

Volume II Appendix-I

Table of Contents

Chapter 7 Cost Estimation and Implementation Schedule

Chapter 8 Financial Analysis and Economic Analysis and Institution

Chapter 9 Current Engagement with CDM

Chapter 2 Project Background and Basic Information

1. Bylaws Related to Emission Limit Values (ELV)

Table 1 ELV for Certain Categories of Pollutants for Process Water before Discharge to the Public Sewer

No.	Parameters	Unit	ELV
1	pH		6.5-9.5
2	COD	mg/l	1000 (VII)
3	BOD	mg/l	500 (VII)
4	Total non organic N (NH_4-N, NO_3-N, NO_2-N)	mg/l	120
5	Total N	mg/l	150
6	Ammonium, expressed in N (NH_4-N)	mg/l	100 (I)
7	Sedimentation materials after 10 minutes	mg/l	150 (II)
8	Total P	mg/l	20
9	Extract organic solvents (oil, fat)	mg/l	50 (III)
10	Mineral oil (IV)	mg/l	30
11	Phenols	mg/l	50
12	Tar	mg/l	5
13	Total Fe	mg/l	200
14	Total Mn	mg/l	5
15	Sulphides	mg/l	5
16	Sulphates	mg/l	400 (IX)
17	Active chloral	mg/l	30
18	Total salts	mg/l	5000 (VIII, X)
19	Fluorides	mg/l	50
20	Total arsenic (VI)	mg/l	0.2
21	Total Ba	mg/l	0.5
22	Cyanides (easy volatile)	mg/l	0.1
23	Total cyanides	mg/l	1
24	Total silver	mg/l	0.2
25	Total Hg (VI)	mg/l	0.05
26	Total Zn (VI)	mg/l	2
27	Total Cd (VI)	mg/l	0.1
28	Total Cobalt	mg/l	1
29	Cr (VI)	mg/l	0.5
30	Total Cr (VI)	mg/l	1
31	Total Pb	mg/l	0.2
32	Total Sn	mg/l	2
33	Total Cu (VI)	mg/l	2
34	Total Ni (VI)	mg/l	1
35	Total Mo	mg/l	0.5
36	BTEX (benzene, toluene, ethylbenzene, and xylene)	$10^{-3}m_3/m_3$ (V)	0.1
37	Organic solvent	$10^{-3}m_3/m_3$ (V)	0.1
38	Asbestos	mg/l	30
39	Toxicity		ratio of dilution LC50% (toxicity test with fish or

No.	Parameters	Unit	ELV
			daphnia)
40	Temperature	°C	40

(I) Determined for 24h average composite sample

(II) It is determined only in the case if the volume of sediment matters, after 10 minutes of the sedimentation higher than $5x10^3$ m^3/m^3

(III) In the case of daily flow of 100m3/day for materials of biological or animal origin the value is triple and above that double

(IV) Above 10m3/day

(V) Limit value is given in 10^{-3} m3/m3

(VI) In the case of usage of waste water treatment residue generated in central facility, limit values can be stringent or if it is determined that there is disturbance in work on central treatment due to the big number of connected industries, it is necessary to reconsider given values, just in case

(VII) These values can be reconsidered taking in consideration technical, technological and economical factors that impact selection of joint communal and industrial treatment in the city waste water treatment plant, as well as infiltration of groundwater in the sewer resulting in the organic matters concentration in the influent to be low

(VIII) These values could be reconsidered taking in consideration technological factors that impact selection of joint treatment of communal and industrial waste water in the city wwtp

(IX) In the case when the discharge pipes are concrete, limit value for sulphates is 200mg/l

(X) In the case when the discharge pipes are concrete, limit value for chloride is 1000mg/l

Table 2 ELV for Communal Wastewater Discharge to the Recipient

Parameter	ELV	The lowest reduction percentage (I)
a) ELV on the secondary treatment stage		
BOD (II,VI,VII)	25mg/l O_2 40mg/l O_2 (III)	70-90
COD (VI)	125mg/l O_2	75
Total suspended solids (IV, VIII)	35mg/l (more than 10,000PE) 60mg/l (2,000 to 10,000 PE)	90 70
b) ELV on the tertiary treatment stage		
Total P	2mg/l P (10,000 to 100,000 PE) 1mg/l P (more than 100,000 PE)	80
Total N (V)	15mg/l N (10,000 to 100,000 PE) 10mg/l N (more than 100,000 PE)	70-80

(I) Reduction in relation to the load of influent

(II) Parameter can be replaced with some other parameter: total organic carbon (TOC) or total chemical oxygen demand (COD total) if the relation between BOD and these parameters can be determined

(III) If it is proven that discharged treated waste water will not have negative impact on the water quality

(IV) Suspended solids are not obligatory parameter

(V) Total nitrogen: organic N+NH4-N+NO3-N+NO2-N

(VI) Homogenized, non filtrated, non decanted sample

(VII) Adding inhibitor of nitrification

(VIII) By filtration of representative sample through the membrane filter 0.45μm. Drying on 105°C and weighting

Table 3 ELV [I] for Communal Wastewater According to the WWTP Capacity [VI]

WWTP capacity PE	COD [III]		BOD [II, III]		Total SS [III]		Total P		Total N mg/l	
	mg/l	%	mg/l	%	mg/l	%	mg/l	%	1.V-15.IX	16.XI-30.IV
<600	[IV]	70	80 [IV]	75	100	-	[IV]	[IV]	[IV]	[IV]
601-2000	[IV]	75	50 [IV]	80	75	-	[IV]	[IV]	[IV]	[IV]
2001-10000	125	75	25	70-90	60	70	[IV]	[IV]	[IV]	[IV]
10001-100000	125	75	25	70-90	35	90	2 [V]	80	15 [V]	25 [V]
>100000	125	75	25	70-90	35	90	1 [V]	80	10 [V]	20 [V]

(I) It is necessary to comply with either limit value for (average daily) concentration (mg/l) or reduction percentage (%)
(II) Parameter can be replaced by other parameter; total organic carbon TOC or total COD if the relation between BOD and these parameters can be determined
(III) In the case of determine effluent from lagoons COD and BOD should be determined in filtrated sample, but total content of suspended solids cannot exceed 150mg/l
(IV) If needed,(water with small capability for self treatment) responsible authority can determine the values for that particular case, that can be more stringent than the given value
(V) These limit values need to be secured for the sensitive area for nitrate, when capacity of the plant is above 10000PE
(VI) In the case of mixed discharge and treatment of communal and industry water, by the public sewerage system, it is needed to ass ELV for hazardous materials, from industry, agriculture and other activities by using the given limit values for each industry analyzed in the EIA study

Table 4 ELV of the Treated Communal Wastewater Discharge to the Surface Water, Used for Bath and Recreation, Water Supply and Irrigation

Parameters	Units	ELV
Coliform bacteria	number in 100ml	10,000
Coliform bacteria from feces	number in 100ml	2,000
Streptococcus from feces	number in 100ml	400

Table 5 Minimum Number of Samples of Treated Communal Wastewater Dependent of Plant Capacity

Plant size	Annual sample numbers [I]
2,000-9,999 PE	12 If in the first year is proved that quality of treated waste water does not exceed the ELV given in this regulation, next year only 4 is needed. If during the one of the following years, one of the 4 samples does not fulfill ELV for pollutants listed in this regulation, it returns to the 12 annual samples.
10,000-49,999PE	12
>50,000 PE	24

(I) 24h average value composite samplers are analyzed proportional flow or time are analyzed

Table 6 Max Number of Samples That Can Divert from the ELV for the Treated Communal Wastewater Depending of Total Sample Number (I)

Number of samples taken during one year	Max sample number exceeding ELV (II,III)	Number of samples taken during one year	Max sample number exceeding ELV (II,III)
4-7	1	172-1887	14
8-16	2	188-203	15
17-28	3	204-219	16
29-40	4	220-235	17
41-53	5	236-251	18
54-67	6	252-268	19
68-81	7	269-284	20
82-95	8	285-300	21
96-110	9	301-317	22
111-125	10	318-334	23
126-140	11	335-350	24
141-155	12	351-365	25
156-171	13		

(I) In the given evaluation of the results, the extreme values that occur a result of extraordinary circumstances (for example heavy rain above average are not taken into consideration)

(II) under the normal conditions, content of organic matters expressed by BOD5 and COD in any case cannot exceed required value by 100%, for suspended solids by 150%

(III) annual mean value concentration of N and P cannot exceed required value

Table 7 ELV for Residues of Wastewater Treatment

Parameter	Unit (I)	ELV	
		Agriculture use (II)	Other use (III)
<Non organic material>			
Pb	mg/kg	120	1,200
Cd	mg/kg	2.5	40
Cr	mg/kg	100	1,000
Ni	mg/kg	60	400
Hg	mg/kg	1.6	25
Cu	mg/kg	700	1,750
Zn	mg/kg	1,500	4,000
As	mg/kg	15	75
<Organic material>			
Adsorbing organic halogens (V)	mg/kg	400	500
PCB (VI)	mg/kg	0.1 (per congener)	0.2 (per congener)
PCCD/F (VII)	ng/kg DS	30	30

Parameter	Unit (I)	ELV	
		Agriculture use (II)	Other use (III)
<Pathogens (IV)>			
Salmonella	MPN/10g DS (VIII)	0-10	
Enterovirus	MPCN/10g DS (IX)	3	

(I) Related to the dry residue from treatment DS

(II) If used in agriculture, particular attention should be on plant seasons, where pH of soil is between 6 and7. If the residues are used on the soil with pH lower than 6, it should be taken in consideration capability the increasing mobility of metals and of plants to absorb metals, thus lower limit values should be taken in that case. Residues from the treatment are used in that way to consider plant needs for nutrients, soil quality and not to pollute surface water and ground water

(III) Residues from the treatment process can be used to cover landfill, green area in parks, improvement of soil quality when the soil will not at least one year be used for planting and cattle feeding, for landscaping. For all these cases soil pH value should be between 6 or 7

(IV) By specific use of the soil, used for example for vegetables or cattle, limitation are due to the health risk from remained pathogens. In that case residues are treated before use in order to reduce pathogens on the acceptable level.

(V) Adsorbing organic halogen AOH

(VI) PCB, each of 6 individual PCB (28,52,101,138,153 and 180) according to IUPAC nomenclature 2,4,4'Trichlorobiphenyl, 2,2'5,5'-Tetrachlorobiphenyl, 2,2'4,5,5'-Pentachlorobiphenyl, 2,2'3,4,4',5'-Hexachlorobiphenyl, 2,2,4,4',5,5'-Hexachlorobiphenyl, 2,2',3,4,4',5,5'-Heptachlorobiphenyl,

(VII) PCCD/F- polychlorinated 2benzo dioxin and furan

(VIII) MPN –most probable number

(IX) MPCN- most probable number causing cytopathogenic effect

2. Bylaws Related to Limit Values of Surface Water

Table 8 Limit Values of Pollutant for Surface Water

Parameter	Unit	Limit Values (1)				
		Class I (2)	Class II (3)	Class III (4)	Class IV (5)	Class V (6)
<General>						
pH (12)		6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	<6.5 or <8.5
Suspended solids (9) (12)	mg/l	25	25	-	-	-
<Oxygen regime>						
Dissolved oxygen	mg O_2/l	- (8) (or PN)	- (8)	5	4	<4
Oxygen saturation	%					
Epilimnion		90-110	70-90	50-70	30-50	<30
Hipolimnion		70-90	70-50	30-50	10-30	<10
Nonstrati		70-90	50-70	30-50	10-30	<10
BOD_5	mg O_2/l	- (8) (or PN)	- (8)	7	25	>25
COD (bichromate method)	mg O_2/l	10 (or PN)	15	30	125	>125
COD (permanganate method)	mg O_2/l	5 (or PN)	10	20	50	>50
Total organic carbon (TOC)	mg/l	-(8) (or PN)	- (8)	15	50	>50
<Nutrients>						
Total N	mg N/l	1 (or PN)	2	8	15	>15
Nitrate	mg N/l	- (8) (or PN)	- (8)	6	15	>15
Nitrite	mg N/l	0.01 (or PN)	0.03	0.12	0.3	>0.3
Ammonium ion	mg N/l	- (8) (or PN)	- (8)	0.6	1.5	>1.5
Non ionised ammonium (9)	mg/l NH_3	0.005	0.025	-	-	-
Total P (7)	mg P/l	- (8) (or PN)	- (8)	0.4	1	>1
Orthophosphate	mg P/l	- (8) (or PN)	- (8)	0.2	0.5	>0.5
<Salinity>						
Chlorides	mg/l	50 (or PN)	- (8)	150	250	>250
Total residue chlor (9)	mg/l HOCl	0.005	0.005	-	-	-
Sulphates	mg/l	50 (or PN)	100	200	300	>300
Total mineralization	mg/l	<1,000 (or PN)	1,000	1,300	1,500	>1,500
Conductivity on 20°C	µS/cm	<1,000 (or PN)	1,000	1,500	3,000	>3,000
<Metals>						
Arsen	µg/l	<5 (or PN)	10	50	100	>100
Bor	µg/l	300 (or PN)	1,000	1,000	2,500	>2,500
Cu	µg/l	5 (T=10) 22 (T=50) 40 (T=100) 112 (T=300)	5 (T=10) 22 (T=50) 40 (T=100) 112 (T=300)	500	1,000	>1,000
Zn	µg/l	30 (T=10) 200 (T=50) 300 (T=100) 500 (T=300)	300 (T=10) 700 (T=50) 1,000 (T=100) 2,000 (T=300)	2,000	5,000	>5,000
Cr(total)	µg/l	25 (or PN)	50	100	250	>250
Fe(total)	µg/l	200	500	1,000	2,000	>2,000
Mn(total)	µg/l	50	100	300	1,000	>1,000
<Organic materials>						
Phenol compounds (such as C_2H_5OH)	µg/l	<1	1	20	50	>50
Oil carbohydrates (9)		(10)	(10)	-	-	-
Surface active materials (such as lauryl sulphate)	µg/l	100	200	300	500	>500

Parameter	Unit	Limit Values (1)				
		Class I (2)	Class II (3)	Class III (4)	Class IV (5)	Class V (6)
AOH (ascorbic organic halogens)	μg/l	10	20	100	250	>250
<Microbiological parameters>						
Fecal Coliforms	cfu/100ml	100	1,000	10,000	100,000	>100,000
Total Coliforms	cfu/100ml	500 (11)	10,000	100,000	1,000,000	>1,000,000
Itestinal enterococci	cfu/100ml	200	400	4,000	40,000	>40,000
Number of aerobic heterotrophs (method Kohl)	cfu/100ml	500	10,000	100,000	750,000	>750,000

T：hardness of the water (mg/l $CaCO_3$)

PN：natural level

(1) If not otherwise stated, values are given as total concentration in taken sample

(2) Description of the class corresponds excellent ecological status according to the classification given in the regulation on determination of parameters of ecological and chemical status of surface water. Surface water that belongs to this class ensure on the basis of limit values of elements qualitative conditions for functioning of ecosystem, life and fish protection (salmonidae and cyprinids) and can be used in the following purpose: potable water supply with prior treatment by filtration and disinfection, bathing and recreation, watering, industrial purpose (process and cooling water)

(3) Class description corresponds to good ecological status according to the classification given in the regulation that determine parameters of ecological and chemical status for surface water. Surface water that belongs to this class determine on the basis of limit values of elements qualitative conditions for functioning of ecosystem, life and fish protection (cyprinids) and can be used for the same purpose and under same conditions as surface water that belongs to the class i

(4) Class description corresponds to moderate ecological status according to the classification given in the regulation that determine parameters of ecological and chemical status for surface water. Surface water that belongs to this class provide on the basis of limit values of qualitative elements conditions for life and Cyprinidae protection and can be used for following purposes: potable water supply with prior pre-treatment by coagulation, flocculation, filtration and disinfection, bath and recreation, watering, industrial purpose (process and cooling water).

(5) Class description corresponds to weak ecological status according to the classification given in the regulation that determine parameters of ecological and chemical status for surface water. Surface water that belong to this class on the basis of limit values of elements quality can be used in following purposes: potable water supply with combination of the prior stated treatments and advances treatments methods, watering, industrial purpose (process and cooling water)

(6) Class description corresponds to bad ecological status according to the classification given in the regulation that determine parameters of ecological and chemical status for surface water. Surface water that belongs to this class cannot be used for any other purpose.

(7) Total phosphate is analysed from filtrate, eg from diluted phase that is given by filtration through 0,45μm filter

(8) Please look at the annex 1, table 2 and table 3, in which are given limit values of pollutants for I and II class of surface water

(9) Parameters are monitored only in water surface that are defined as salmonidae and cyprinid.

(10) Oil products cannot be present in the water in such quantity to:
- form visible film layer on surface water or layers on the river and lake banks
- give the distinctive “hydrocarbon” taste to fishes
- cause damages to fishes

(11) Based on 95% estimation

(12) Allowed deviation of the limit values in the case of special geographical conditions

Table 9 Limit Values of Pollutant for Class I(1) of Surface Water

Types of surface water	pH	DO (mg/l)	BOD (mg/l)	Total organic carbon (mg/l)	Ammonium ion (NH_4-N) (mg/l)	Nitrates (NO_3-N) (mg/l)	Orthophosphates (PO_4^{3-}) (mg/l)	Total phosphate (P) (mg/l)	Chlorides (Cl) (mg/l)
Big river in low areas, dominated fine sediment (type 1)	6.5-8.5	8.5 (2)	2.0	2.0	0.10	1.0	0.02	0.05	50
Big rivers, dominated middle sediment, exception river in Pannonia basin (type 2)	6.5-8.5	8.5	1.8	2.0	0.05	1.5	0.02	0.05	50
Small and middle water courses, level above sea up to 500m, dominated big ground base (type 3)	6.5-8.5	8.5	1.5	2.0	0.05	1.5	0.02	0.05	50
Small and middle water courses, level above sea above 500m, dominated big ground base (type 4)	6.5-8.5	8.5	1.8	2.0	0.10	1.5	0.0	0.05	50
Water courses in Pannonia basin except those that are under type 1 (type 5)	6.5-8.5	8.0	2.5	3.0	0.20	1.5	0.10	0.15	50
Small water courses out of Pannonia basin that are not under type 3 and type 4, as water courses that are not determined by the Regulation on determination of water bodies of surface and ground water (Official Gazette 96/10) (type 6)	6.5-8.5	8.5	1.5	2.0	0.05	1.0	0.0	0.05	50
Lakes above the sea level up to 200 m asl, all shallow lakes (up to 10m), all paddle and swamp ecosystems	6.5-8.5	8.5(2)	2.0	2.0	0.10	1.0	0.02	0.05	50
Lakes above the sea level above 200 m asl, middle deep lakes (depth 10-30m) and deep (depth>30m)	6.5-8.5	8.5(2)	1.5	2.0	0.05	1.5	0.02	0.05	50

(1) Class description corresponds to the excellent ecological status according to the classification given in the regulation that determine parameters of ecological and chemical status for surface water. Surface water that belong to this class are provided on the basis of limit values of quality elements conditions for ecosystem functioning, life and fish protection (salmonidae and cyprinidae) and can be used in the following purposes: water supply for potable water with prior pretreatment by filtration and disinfection, bathing and recreation, watering, industrial use (process and cooling)

(2) Values of parameters can be lower if the natural value is lower

Table 10 Limit Values of Pollutant for Class II(1) of Surface Water

Types of surface water	pH	DO (mg/l)	BOD (mg/l)	Total organic carbon (mg/l)	Ammonium ion (NH_4-N) (mg/l)	Nitrates (NO_3-N) (mg/l)	Orthophosphates (PO_4^{3-}) (mg/l)	Total phosphate (P) (mg/l)	Chlorides (Cl) (mg/l)
Big river in low areas, dominated fine sediment (type 1)	6.5-8.5	7.0	5.0	5.0	0.30	3.0	0.10	0.20	100
Big rivers, dominated middle sediment, exception river in Pannonia basin (type 2)	6.5-8.5	7.0	4.5	5.0	0.10	3.0	0.10	0.20	100
Small and middle water courses, level above sea up to 500m, dominated big ground base (type 3)	6.5-8.5	7.0	5.0	6.0	0.10	3.0	0.10	0.20	100
Small and middle water courses, level above sea above 500m, dominated big ground base (type 4)	6.5-8.5	7.0	4.0	5.0	0.30	3.0	0.05	0.10	100
Water courses in Pannonia basin except those that are under type 1 (type 5)	6.5-8.5	6.0	5.0	6.0	0.40	3.0	0.20	0.30	100
Small water courses out of Pannonia basin that are not under type 3 and type 4, as well as water courses that are not determined by the Regulation on determination of water bodies of surface and ground water (Official Gazette 96/10) (type 6)	6.5-8.5	7.0	4.0	5.0	0.10	3.0	0.10	0.15	100
Lakes above the sea level up to 200 m asl, all shallow lakes (up to 10m), all paddle and swamp ecosystems	6.5-8.5	7.0	5.0	6.0	0.30	3.0	0.10	0.20	100
Lakes above the sea level up to 200 m asl, medium depth (up to 10-30m) and deep (depth>30m)	6.5-8.5	7.0	5.0	6.0	0.10	3.0	0.10	0.20	100
Accumulations formed on water body type 1	6.5-8.5	7.0	5.0	6.0	0.30	3.0	0.10	0.20	100
Accumulations formed on water body type 2	6.5-8.5	7.0	4.5	5.0	0.10	3.0	0.10	0.20	100

Types of surface water	pH	DO (mg/l)	BOD (mg/l)	Total organic carbon (mg/l)	Ammonium ion (NH_4-N) (mg/l)	Nitrates (NO_3-N) (mg/l)	Orthophosphates (PO_4^{3-}) (mg/l)	Total phosphate (P) (mg/l)	Chlorides (Cl) (mg/l)
Accumulations formed on water body type 3 and type 4	6.5-8.5	8.5[(1)]	1.5	2.0	0.05	1.5	0.02	0.05	100
Accumulations formed on water body type 5 and type 6	6.5-8.5	5.0	4.0	5.0	0.40	4.0	0.10	0.15	100
Artificial water bodies	6.5-8.5	5.0	6.0	7.0	0.20	3.0	0.20	0.30	100

(1) Class description correspond to good ecological status according to the classification given in the regulation that determine parameters of ecological and chemical status for surface water. Surface water that belong to this class ensure on the basis of the limit values of quality elements, conditions for functioning of ecosystems, life and fish protection (cyprinidae) and can be used for the same purpose and under same conditions as surface water that belongs to the class

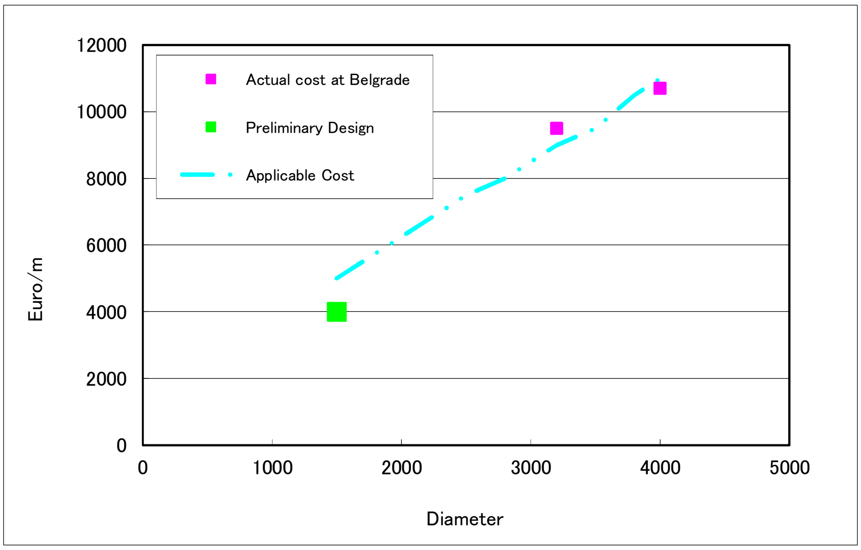
Chapter 4 Facilities Planning of Interceptor

1. Adopted unit cost for comparison of Interceptor No.1 and No.2

(1) Micro-tunneling Cost

Costs are decided by the Actual cost at Belgrade and estimated cost by Preliminary design of New Usce PS in 2009.

Shape	Estimated Cost (Euro/m)	Remarks
Dia 1500mm	5,000	1.2times in case of Arc-line
Dia 2800mm	8,000	340euro/m extra in case of mortar filling inside casing
Dia 3500mm	9,500	
Dia 4000mm	11,000	



(2) Jacking Cost for pipe protection by iron outer pipe

Costs are considered by the hearing of LDA

Shape	Estimated Cost (Euro/m)	Remarks
Dia 1500mm	1,700	Including iron pipe and jagging work
Dia 2000mm	2,300	ditto

(3) Horizontal Direction Drilling Cost

Cost estimated by Preliminary design is adopted. 275,0000euro (in 2009) x 1.3 =3,575,000 Euro.

(4) Pipe lying cost inside Casing pipe or Pipe gallery

Shape	Construction Cost (Euro/m)	Remarks
Dia 1000mm x 2Line	640	Including two pipes and fixing material

(5) Pipe lying cost at road

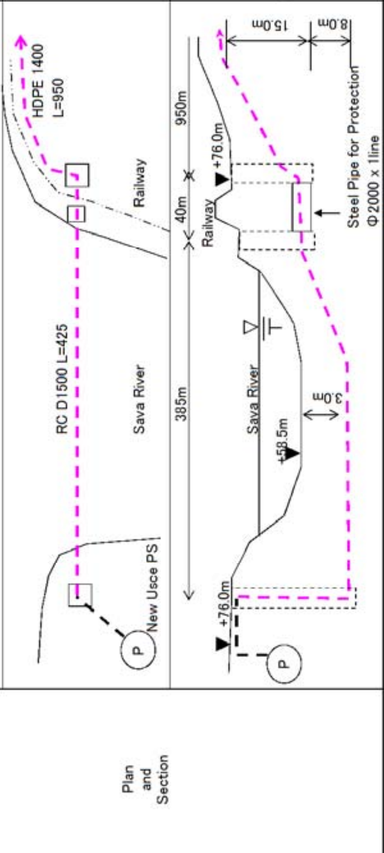
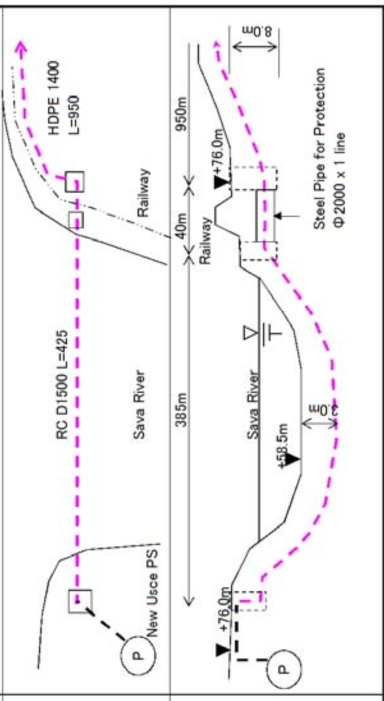
Shape	Construction Cost (Euro/m)	Remarks
Dia 1400mm x 1Line	1,350	Including a pipe material, asphalt demolition, excavation and backfilling, paving, earth retaining, and pumping work.

(6) Maintenance cost

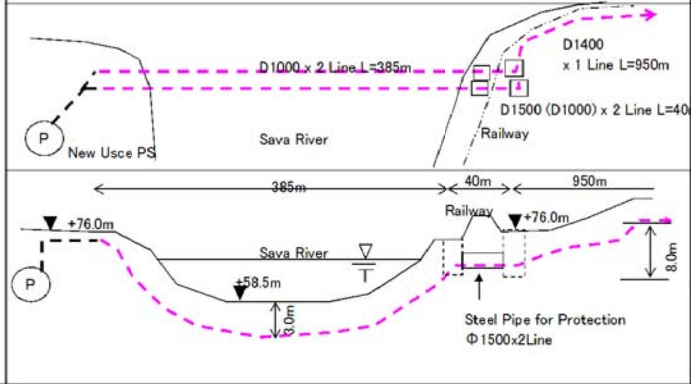
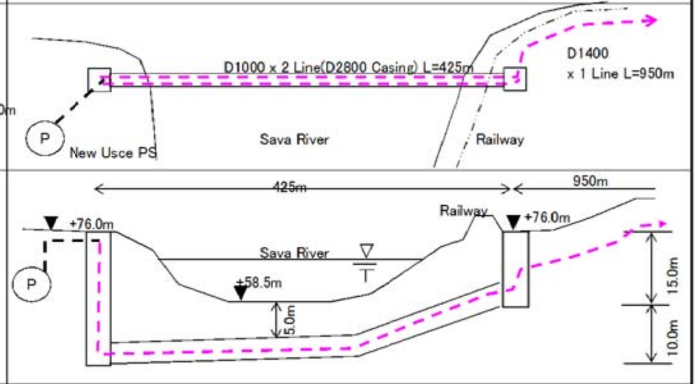
	Cost (Euro/time)	
Inspection	20,000	Including sewer discharge and ventilation inside pipe. Inspection by Human or TV camera.

2. Brake down cost for comparison of Interceptor No.1 and No.2

(1) Case1-1 and 1-2

		Case-1-1	Case-1-2
		Φ1500 Micro tunneling	Φ1500 Micro tunneling
Plan and Section			
Condition of construction		・Deep shafts near River are required, Pumping up and treatment for groundwater with frequency. ・Pipe can be laied straight line by shield or jagging method. This way is much easier than arc-shape line(Case-1-2)	・Shallow shafts are easily to construct, but micro tunneling works with arc line is too difficult to controal the machine in this short section. ・When pipe cross the railway, a casing steel pipe is necessary to cover the force main.
Operation and Maintenance		・Because of the only one line, it should be necessary to carry out inspection and cleaning periodically to extend the pipe life. ・Cleaning may be considered by the workers, it is necessary to drain the sewage inside pipe, and also ventilation. However it is very difficult to remove the sludge because of deep depth and lomg span. ・If pipe will be damaged, New pipe should be installed immidiately.	・Because of the one line installation, it need to carry out inspection and cleaning periodically to extend the pipe life. ・It is very difficult to inspect and clean the pipe by human power because of the arc-shaped pipe. Flashing or Poly-pig can be considered, but these equipments are very expensive because large diameterr. ・If pipe will be damaged, New pipe should be installed immidiately.
Construction Cost (From Left bank Shaft to Interceptor NO.2)	Pipe	RC Dia 1500 mm L= 385 m x 5,000 Euro/m = 1,925,000 Euro HDPE Dia 1400 mm L= 950 m x 1,350 Euro/m = 1,282,500 Euro Steel Dia 2000 mm L= 40 m x 2,300 Euro/m = 92,000 Euro Sub-Total 3,299,500 Euro	RC Dia 1500 mm L= 385 m x 6,000 Euro/m = 2,310,000 Euro HDPE Dia 1400 mm L= 950 m x 1,350 Euro/m = 1,282,500 Euro Steel Dia 2000 mm L= 40 m x 2,300 Euro/m = 92,000 Euro Sub-Total 3,684,500 Euro
	Shaft	H= 23 m 1 n x 522,000 Euro/nos = 522,000 Euro H= 15 m 2 n x 378,000 Euro/nos = 756,000 Euro Sub-Total 1,278,000 Euro	H= 8 m 3 n x 110,000 Euro/nos = 330,000 Euro Sub-Total 330,000 Euro
	Total	4,577,500 Euro	4,014,500 Euro
Maintainance	Inspection, Cleaning and Repairing	Inspection (not possible) Cleaning (not possible) Repairing (not possible)	Inspection (not possible) Cleaning (not possible) Repairing (not possible)
	Total	- Euro	- Euro
LCC	Construction cost	Survice Life RC Pipe 50 yrs 64,100 Euro/year HDPE 80 yrs 16,000 Euro/year Steel 40 yrs 2,300 Euro/year -Cost of shaft including RC pipe	Survice Life RC Pipe 50 yrs 52,800 Euro/year HDPE 80 yrs 16,000 Euro/year Steel 40 yrs 2,300 Euro/year -Cost of shaft including RC pipe
	Maintainance	- Euro/year	- Euro/year
	Total	82,400 Euro/year	71,100 Euro/year

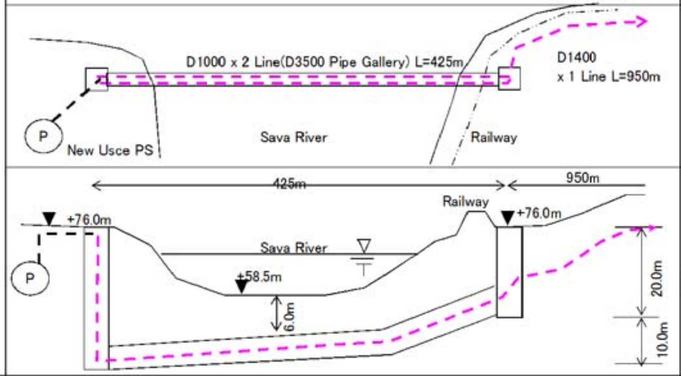
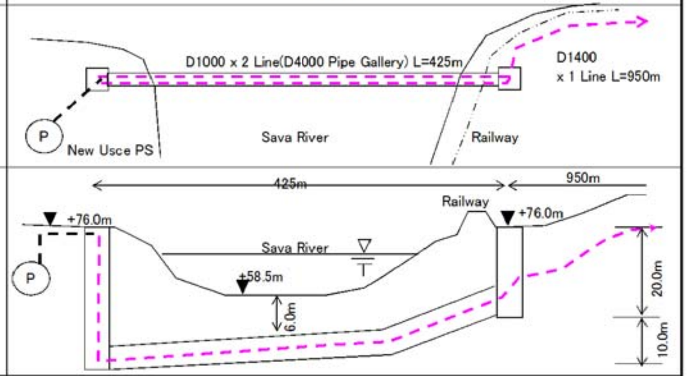
(2) Case2-1 and 2-2

		Case-2-1	Case-2-2
Description		Φ1000x2Line Holizontal Direction Driling	Φ1000x2Line(Φ2800 Casing pipe) Micro tunneling
			
Condition of construction		･Shafts are not necessary to construct by HDD method. ･HDD machine need to be selected for the soft rock. ･When pipe cross the railway, a casing steel pipe is necessary to cover the force main.	･Deep shafts near River are required pumping up and treatment for groundwater with frequency. ･One large diamter pipe will be installed instead of two pipe installation by micro tunneling. ･Inside of casing pipe need to be filled by mortar.
Operation and Maintenance		･No way to remove sewage from the pipes, so inspection is not possible. ･Cleaning can be considered by the flashing, one pipe close by using valve and pump up the sewage to get the sufficient flow velocity.	･Cleaning can be considered by the flashing, one pipe close by using valve and pump up the sewage to get the sufficient flow velocity. ･Pipe cannot be inspected from outside because pipe will be filled by mortar.
Construction Cost (From Left bank Shaft to Interceptor NO.2)	Pipe	HDPE Dia 1000 mmx2 L= 385 m — 3,575,000 Euro HDPE Dia 1400 mm L= 950 m x 1,350 Euro/m = 1,282,500 Euro Steel Dia 1500 mm L= 80 m x 1,700 Euro/m = 136,000 Euro Sub-Total 4,993,500 Euro	RC Dia 2800 mm L= 425 m x 8,320 Euro/m = 3,536,000 Euro HDPE Dia 1000 mmx2 L= 425 m x 640 Euro/m = 272,000 Euro HDPE Dia 1400 mm L= 950 m x 1,350 Euro/m = 1,282,500 Euro Sub-Total 5,090,500 Euro
	Shaft	H= 8 m 4 n x 110,000 Euro/nos = 440,000 Euro H= m n x Euro/nos = 0 Euro Sub-Total 440,000 Euro	H= 25 m 1 n x 630,000 Euro/nos = 630,000 Euro H= 15 m 1 n x 378,000 Euro/nos = 378,000 Euro Sub-Total 1,008,000 Euro
	Other	- Euro	- Euro
	Total	**5,433,500 Euro**	**6,098,500 Euro**
Maintainance	Inspection, Cleaning and Repairing	Inspection (not possible) - Euro/year Cleaning By flashing 0 Euro/year Repairing (not possible) - Euro/year	Inspection every 10 yrs 20,000 Euro/time 2,000 Euro/year Cleaning By flashing 0 Euro/year Repairing (not possible) - Euro/year
	Total	**0 Euro/year**	**2,000 Euro/year**
LCC	Construction cost	Survice Life HDPE 80 yrs 66,200 Euro/year Steel 40 yrs 3,400 Euro/year -Cost of shaft is including HDPE pipe(80yrs)	Survice Life HDPE 80 yrs 76,200 Euro/year -Cost of casing pipe and shaft are including HDPE pipe(80yrs)
	Maintainance	0 Euro/year	2,000 Euro/year
	Total	**69,600 Euro/year**	**78,200 Euro/year**

※HDD Price is adapted from Preliminary report(115RSD/Euro)and inflation(30%) is considerd

※Repairing cost are estimated 5% of total length of pipe where person will be able to access in river crossing section

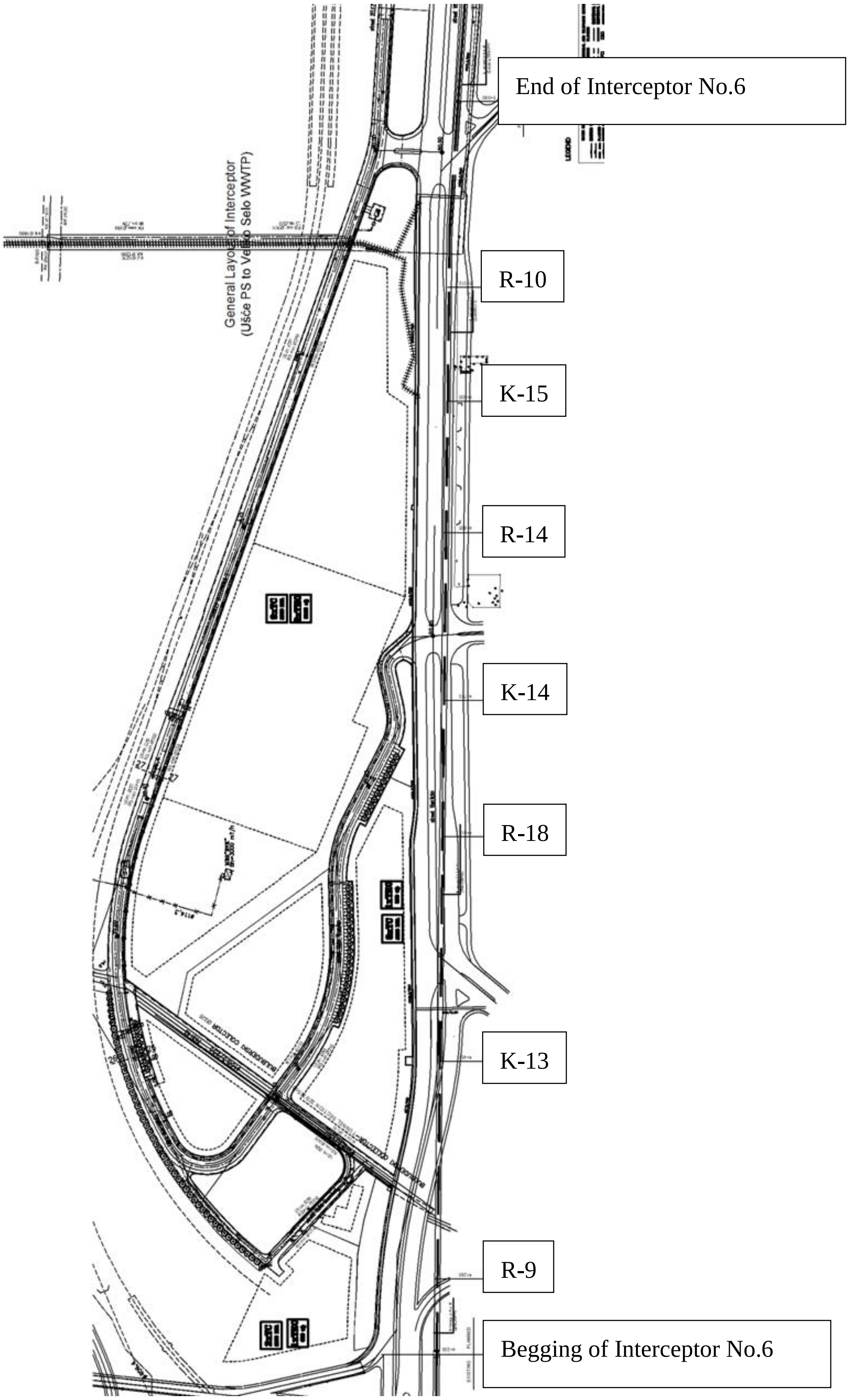
(3) Case2-3 and 2-4

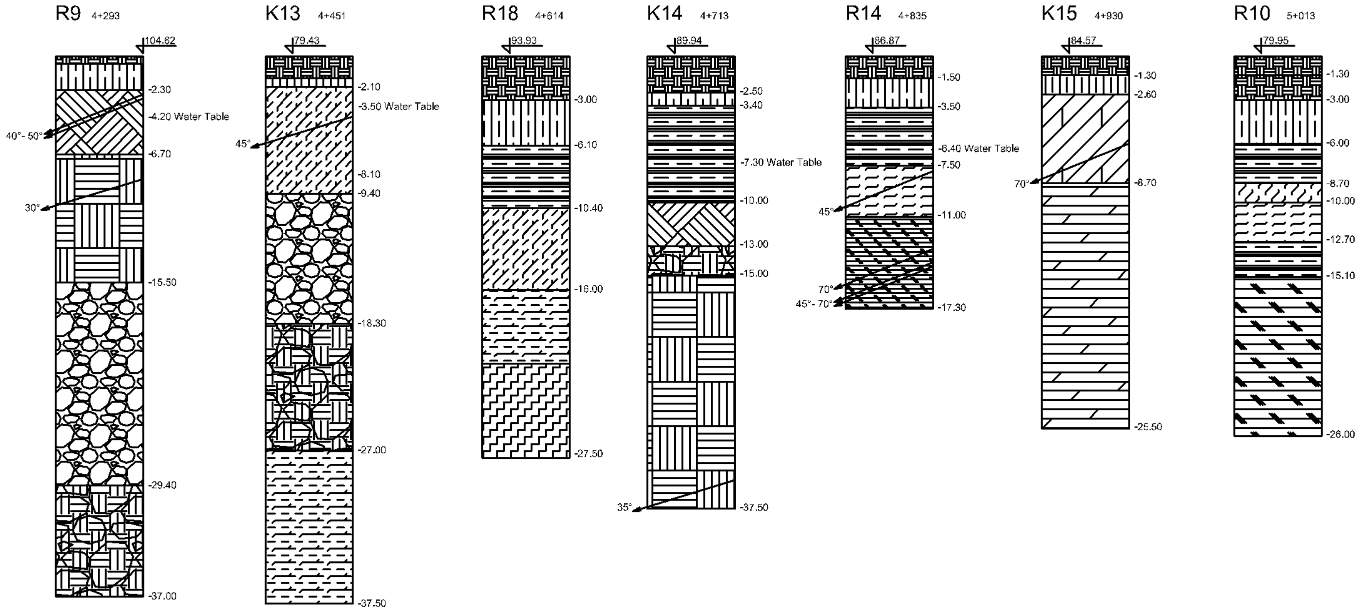
		Case-2-3	Case-2-4
Description		Φ1000x2Line(Φ3500 Pipe gallery) Micro tunneling	Φ1000x2Line(Φ4000 Pipe gallery) Micro tunneling
			
Condition of construction		・Deep shafts near the river are required pumping up and treatment for groundwater with frequency. ・One large diamter pipe will be installed instead of two pipe installation by micro tunneling.	・Deep shafts near the river are required pumping up and treatment for groundwater with frequency. ・One large diamter pipe will be installed instead of two pipe installation by micro tunneling.
Operation and Maintenance		・Cleaning can be considered by the flashing, one pipe close by using valve and pump up the sewage to get the sufficient flow velocity. ・Visually inspection of the outside pipes is possible from the pipe gallery. ・Other utilities such as optical cables can be installed at dead spaces ・Light and Ventilation are necesary to maintain in the pipe gallery	・Cleaning can be considered by the flashing, one pipe close by using valve and pump up the sewage to get the sufficient flow velocity. ・Visually inspection of the outside pipes is possible from the pipe gallery. ・Other utilities such as optical cables can be installed at dead spaces ・If pipe will be damaged, these pipe can be replaced without any difficulty. ・Light and Ventilation are necesary to maintain in the pipe gallery
Construction Cost (From Left bank Shaft to Interceptor NO.2)	Pipe	RC Dia 3500 mm L= 425 m x 9,500 Euro/m = 4,037,500 Euro HDPE Dia 1000 mmx2 L= 425 m x 640 Euro/m = 272,000 Euro HDPE Dia 1400 mm L= 950 m x 1,350 Euro/m = 1,282,500 Euro **Sub-Total 5,592,000 Euro**	RC Dia 4000 mm L= 425 m x 11,000 Euro/m = 4,675,000 Euro HDPE Dia 1000 mmx2 L= 425 m x 640 Euro/m = 272,000 Euro HDPE Dia 1400 mm L= 950 m x 1,350 Euro/m = 1,282,500 Euro **Sub-Total 6,229,500 Euro**
	Shaft	H= 30 m 1 n x 756,000 Euro/nos = 756,000 Euro H= 20 m 1 n x 500,000 Euro/nos = 500,000 Euro **Sub-Total 1,256,000 Euro**	H= 30 m 1 n x 756,000 Euro/nos = 756,000 Euro H= 20 m 1 n x 500,000 Euro/nos = 500,000 Euro **Sub-Total 1,256,000 Euro**
	Other	(Venilation, Light etc) **Sub-Total 100,000 Euro**	(Venilation, Light etc) **Sub-Total 100,000 Euro**
	Total	**6,948,000 Euro**	**7,585,500 Euro**
Maintainance	Inspection, Cleaning and Repairing	Inspection every 10 yrs 20,000 Euro/time 2,000 Euro/year Cleaning By flashing 0 Euro/year Repairing (not possible) - Euro/year	Inspection every 10 yrs 20,000 Euro/time 2,000 Euro/year Cleaning By flashing 0 Euro/year Repairing every 50 yrs 14,000 Euro/time 280 Euro/year
	Total	**2,000 Euro/year**	**2,280 Euro/year**
LCC	Construction cost	Survice Life RC Str. 100 yrs 52,900 Euro/year HDPE 80 yrs 19,400 Euro/year Other 15 yrs 6,700 Euro/year	Survice Life RC Str. 100 yrs 59,300 Euro/year HDPE 80 yrs 16,000 Euro/year HDPE 100 yrs 2,700 Euro/year Other 15 yrs 6,700 Euro/year
	Maintainance	2,000 Euro/year	2,280 Euro/year
	Total	**81,000 Euro/year**	**86,980 Euro/year**

※Repairing cost are estimated 5% of total length of pipe where person will be able to access in river crossing section

3. Soil condition of Interceptor No.6 and No.10

(1) Interceptor No.6



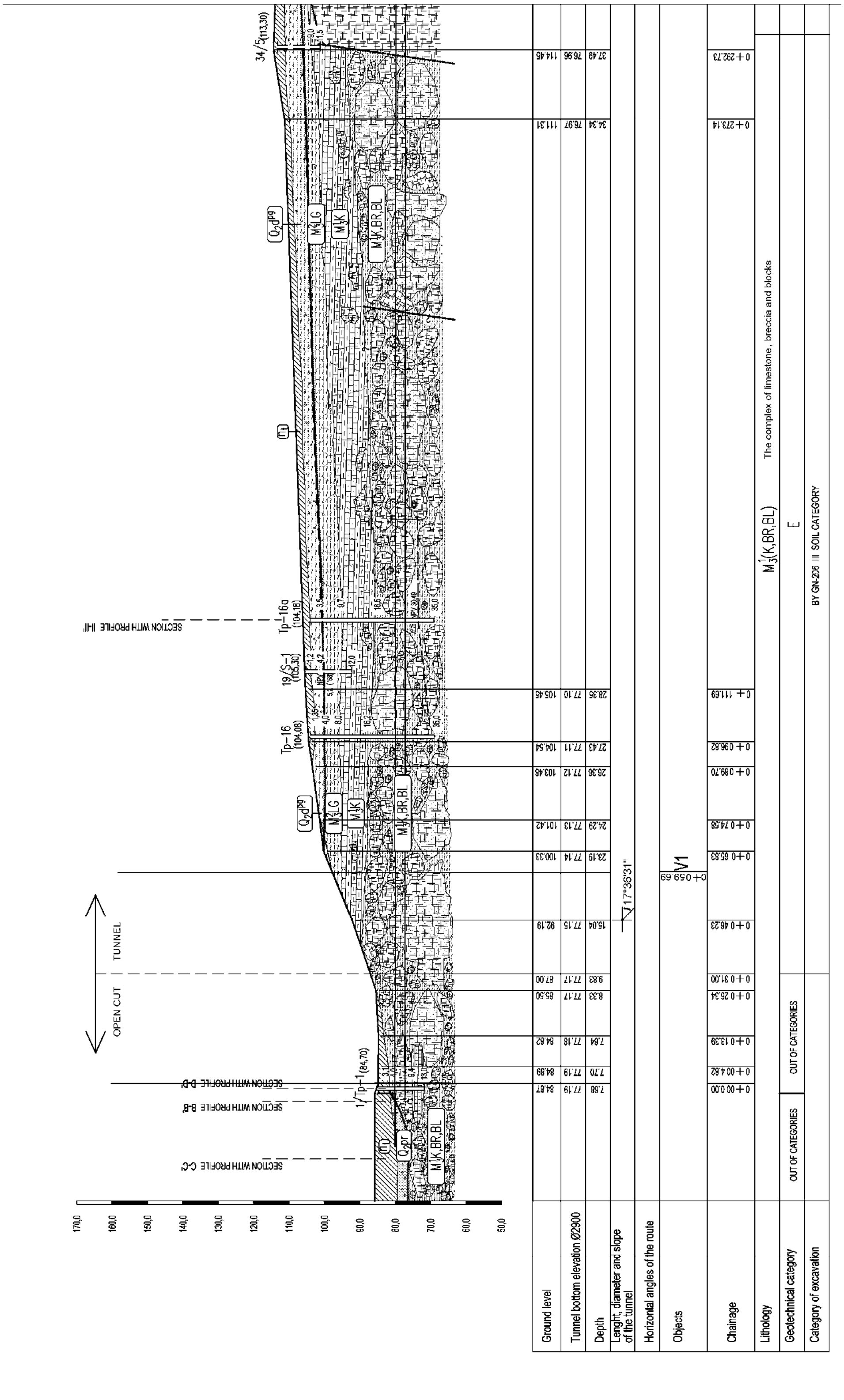


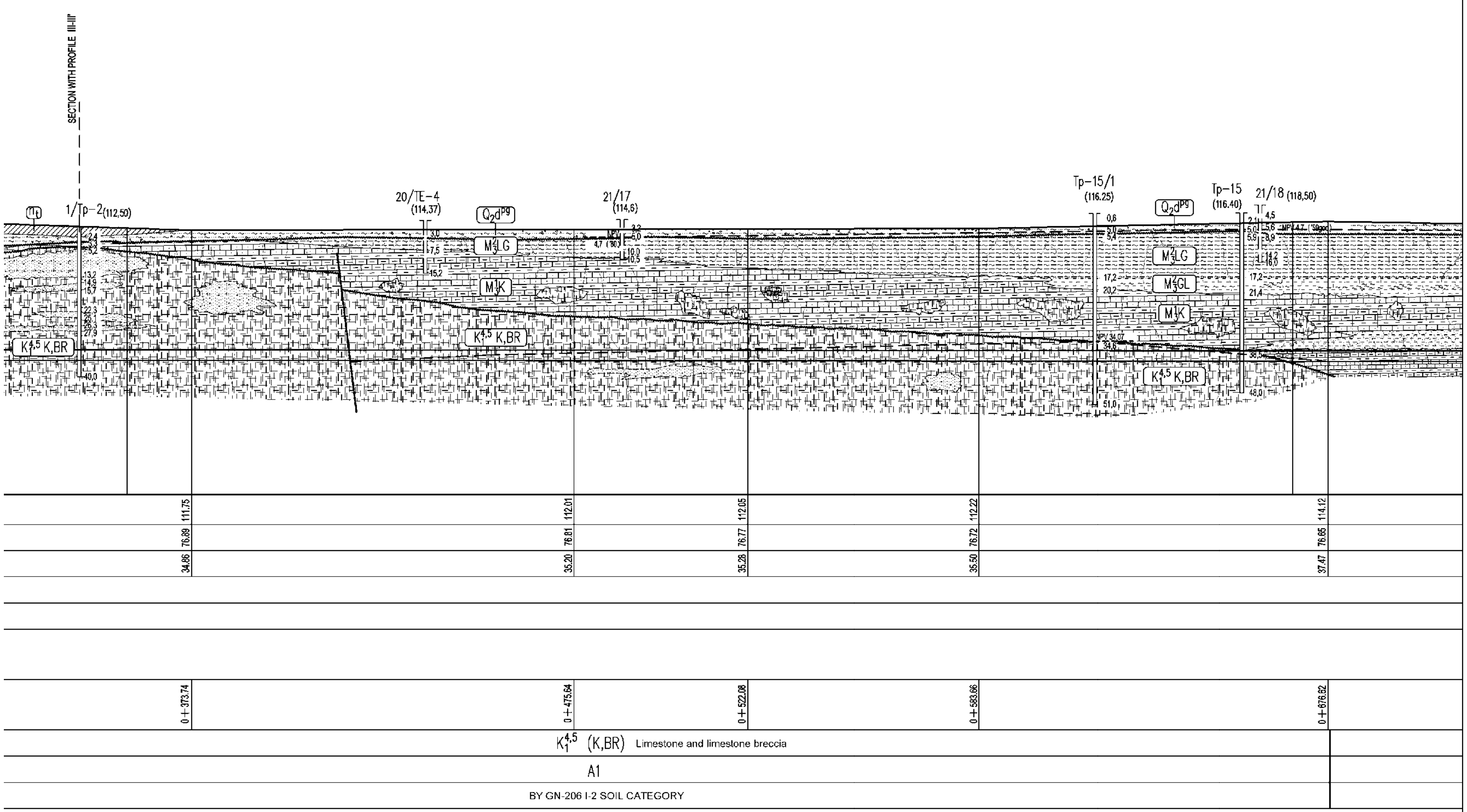
Geol. age	Genesis	Mark and the symbol	Title		Numerical values of physical and mechanical properties									
					CaCO3	W	WL	Jc	γ/γd	J	φ/c	Ms 0,5 -1,0	Ms 1,0 -2,0	Vp / Vs
Quaternary			Embankment											
	Brooks river sediments		Dusty clay		2 - 20	21 - 25	31 - 50	0,6 - 0,8 (10)	1,70 - 2,15 / 1,45 - 1,79	< 2,0	15° - 18° / 0,2 - 0,3	53 - 59	69 -110	1070
	Aeolian deposit		Loess		5 - 10	20 - 25	35 - 40	0,4 - 0,9	1,70 - 1,95 / 1,45 - 1,70	< 1,5	20° - 25° / 0,2			200 - 400 / 100 - 200
	Slope sediments (diluvium)		Loessial clay		10 - 20	18 - 25	45 - 50	0,8 - 1,0	1,95 - 2,00 / 1,50 - 1,65	0,7*- 4,0	15			
			Clays of Tertiary origin			*strength reduced under the influence of fracture porosity in the sample								
Tertiary	Sarmat, Deepwater marine sediments		Changed and fragmented with oxidation	Laminated, marly clay and marl	18 - 52	20 - 46	50 - 92	0,9-1.05	1,78 - 1,98	2,1-3,25 (10)	4° - 9° / 0,25-0,95	oxidation zone		440 -1335 / 165 - 220
			Primary			15 - 42	37 - 68	1,0 - 1,05	1,91 - 2,23	7 - 15 (10)	16° - 24° / 2,18-4,3	primary zone		1250-2400 / 315 - 790
			Bentonite		15 - 30	45	90 - 105	1,10	1,65					
			Changed and fragmented with oxidation	Solid marly clay and marl	45 - 52		42 - 71	0,9 - 1,05	2,01 - 2,07			oxidation zone		
			Primary		12 - 69	18 - 22	43 - 80	0,9 - 1,20	1,79 - 2,12	7 - 28	20° - 25° / 2,3 - 2,4	primary zone		
			Sand			*values of cavernous clayed and limestone								
			Limestone						2,33 - 2,49 / 1,65 - 1,17*	534-1068 / 179-637 / 63 - 85*		E = 178 000 / Ed=50 000-70 000* / 300 000-480 000		1800-2670 / 600 - 830
			Change of sandstone, marl, clay, marl and bentonite		35 - 45*	10 - 22	40 - 68	0,8-1,20*	2,37 - 2,64 / 2,07 - 2,30*	444 - 801 / 5 - 30*	25° / 5,20			2670
			*data obtained in clay complexes parties											
	Torton, Deepwater marine sediments		Changed and fragmented with oxidation	Laminated marly clays and marl	22 - 36	33 - 45	58 - 85	0,8	1,70 - 1,90			oxidation zone		45 - 52
			Primary		12 - 46	21 - 28	38 - 40 / 80 - 90	1,08 - 1,2	1,90 - 2,14			primary zone		45 - 52
			Changed and fragmented with oxidation	Solid marly clay and marl										
			Primary			25 - 37	44 - 70	0,95 - 1,2	1,86 - 2,2	11 - 13 / 30 - 45	28° - 30° / 0,36 - 15			1540-2100 / 420 - 860

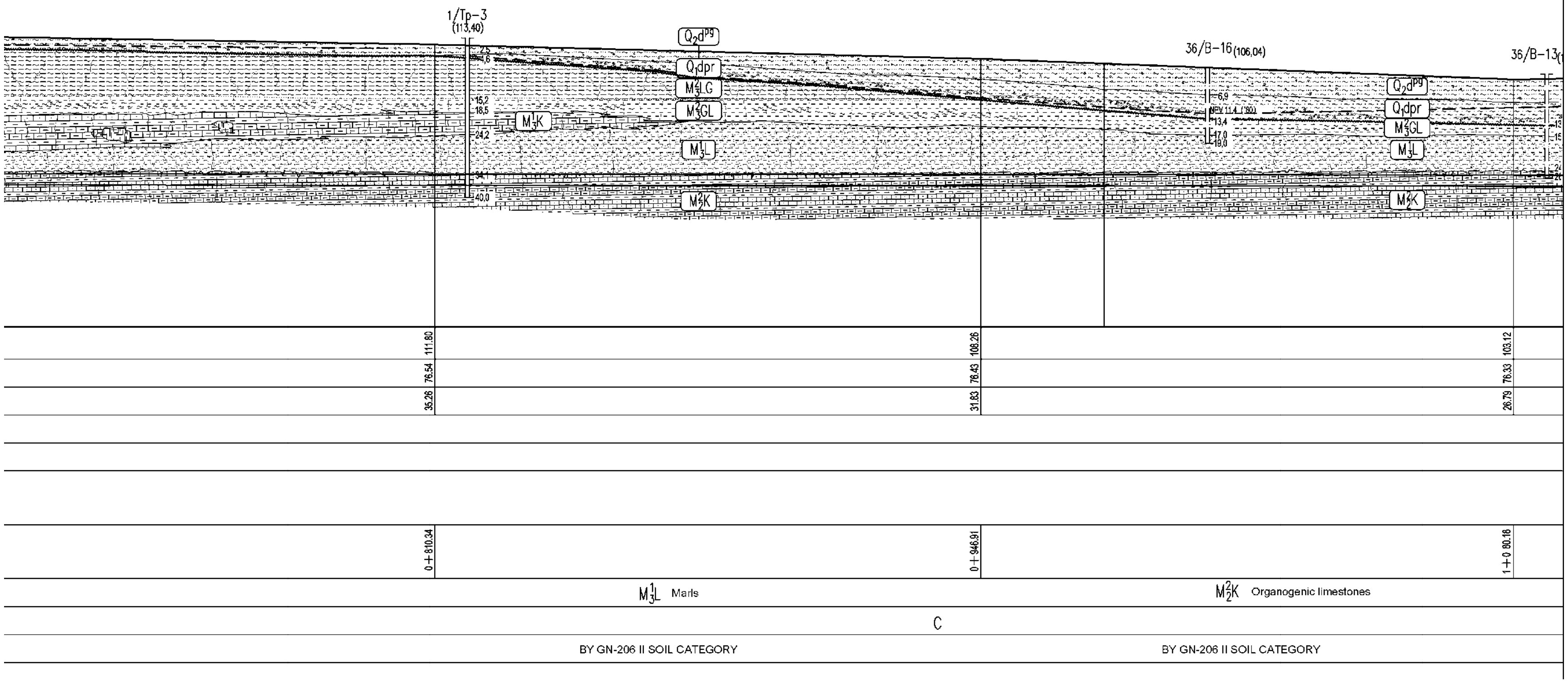
Indicators of physical and mechanical properties	
CaCO3 (%)	The content of carbonates
W (%)	Natural moisture
Wl (%)	Liquid limit
Jc	Index of consistence
γ (Mp/m³)	Bulk density in the wet state
γd (Mp/m³)	Bulk density in the dry state
J (kp/cm²)	Uniaxial strength
φ/c (kp/cm²)	The angle of internal friction / Cohesion
Ms (kp/cm²)	modul of compressibility
Vp (m/sec)	The speed of propagation of longitudinal waves
Vs (m/sec)	The speed of propagation of transverse waves
E/Ed (kp/cm²)	Modulus of elasticity Static / Dynamic

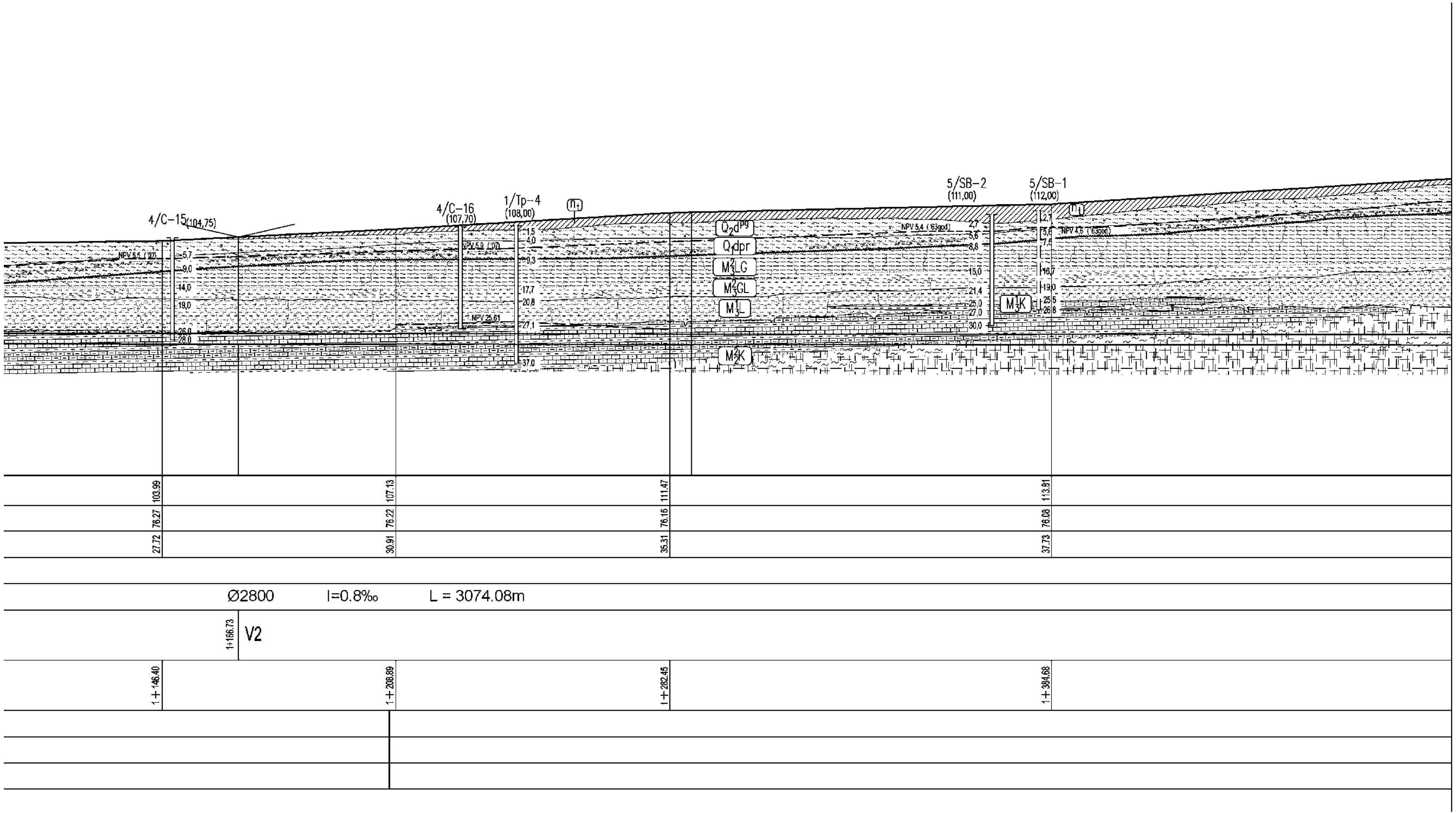
(2) Interceptor No.10

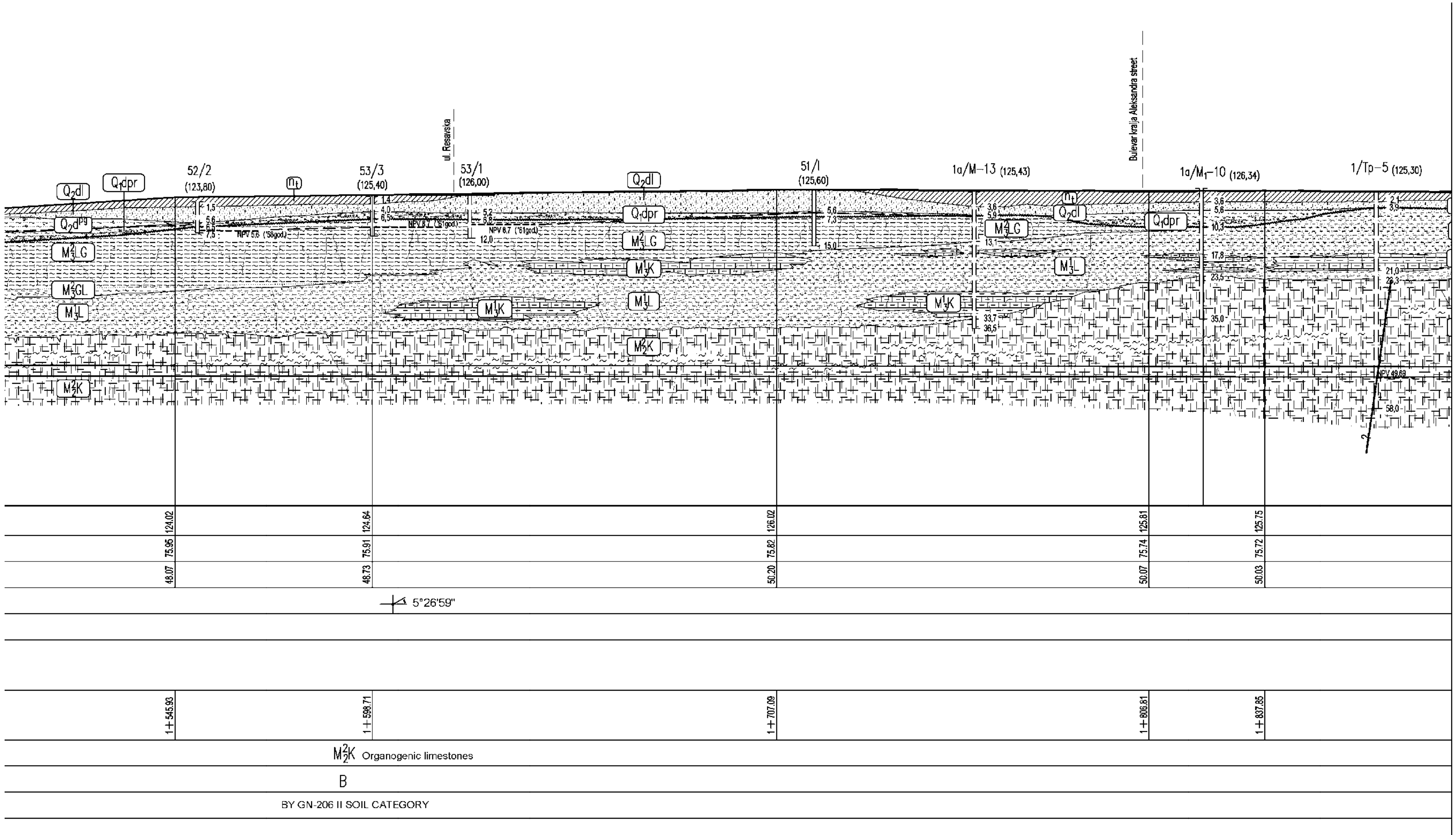
The summary of current survey documents “Soil characteristic of Interceptor No.10 in Detailed design” (Information only)

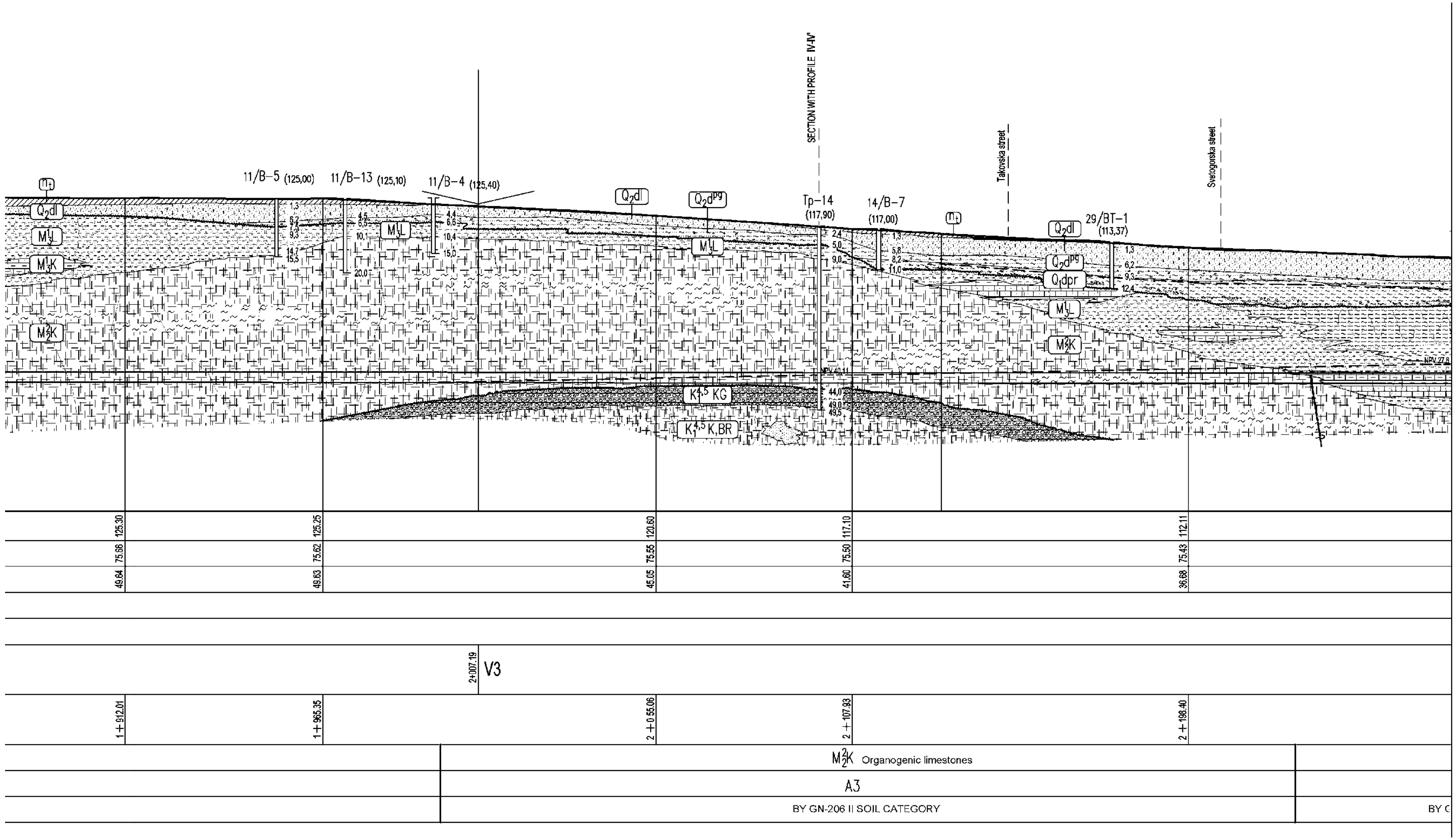


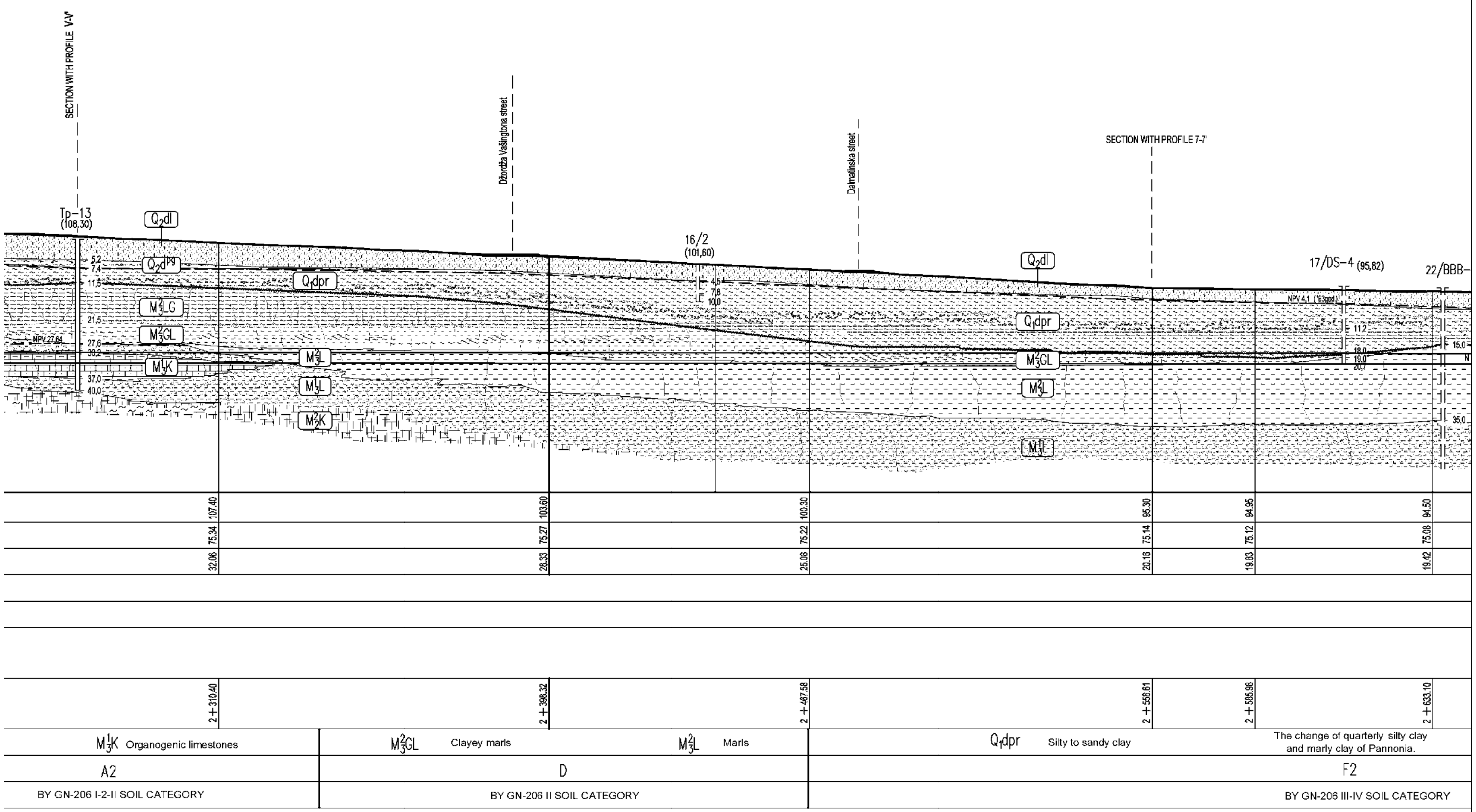

SECTION WITH PROFILE III-III'
1/Tp-2 (112,50)
20/TE-4 (114,37)
21/17 (114,6)
Tp-15/1 (116.25)
Tp-15 (116.40)
21/18 (118,50)
Q_2d^{pg}
$K_1^{4,5}$ K,BR
111.75 76.89 34.86
112.01 76.81 35.20
112.05 76.77 35.28
112.22 76.72 35.50
114.12 76.65 37.47
0+373.74
0+475.64
0+522.08
0+583.66
0+676.62
$K_1^{4,5}$ (K,BR) Limestone and limestone breccia
A1
BY GN-206 I-2 SOIL CATEGORY

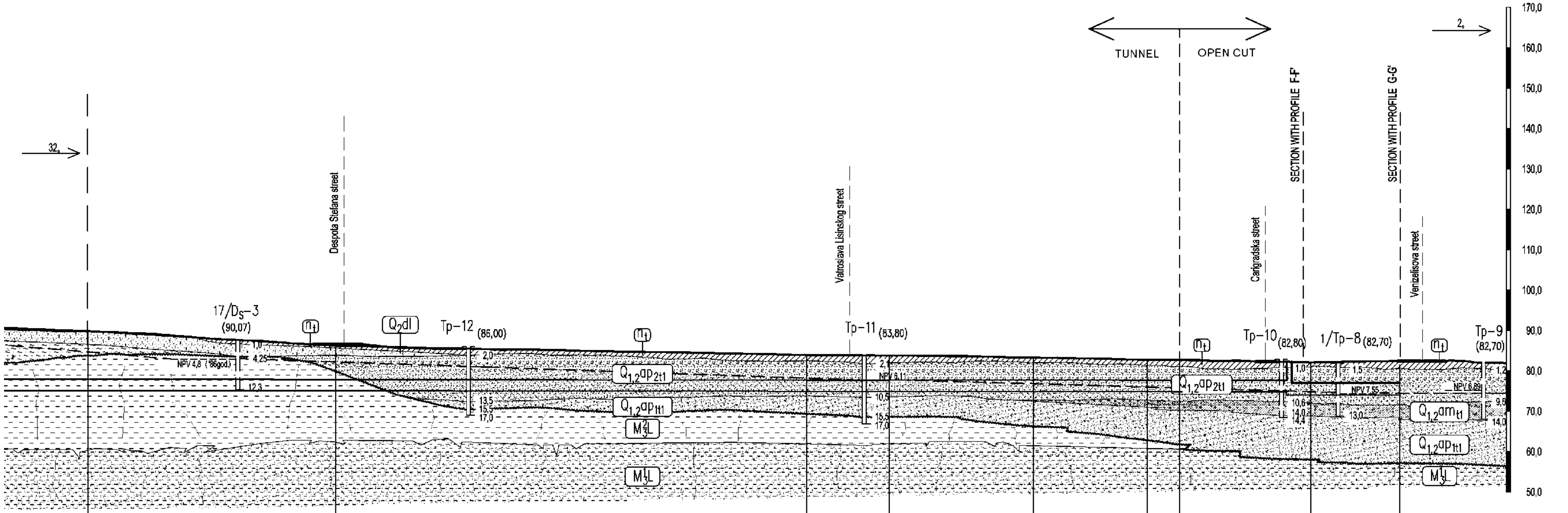

1/Tp-3
(113,40)
36/B-16(106,04)
36/B-13
Q2dpg
Q1dpr
M3 4LG
M3 3GL
M3 1L
M3 1K
M2 2K
111.80
76.54
35.26
108.26
76.43
31.83
103.12
76.33
26.79
0+810.34
0+946.91
1+0 90.18
M3 1L Marls
M2 2K Organogenic limestones
C
BY GN-206 II SOIL CATEGORY
BY GN-206 II SOIL CATEGORY


4/C-15 (104,75)
4/C-16 (107,70)
1/Tp-4 (108,00)
5/SB-2 (111,00)
5/SB-1 (112,00)
103.99
107.13
111.47
113.81
76.27
76.22
76.16
76.08
27.72
30.91
35.31
37.73
Ø2800
I=0.8‰
L = 3074.08m
1+166.73
V2
1+146.40
1+208.89
1+282.45
1+384.68


ul. Resavska
Bulevar kralja Aleksandra street
52/2 (123,80)
53/3 (125,40)
53/1 (126,00)
51/I (125,60)
1a/M-13 (125,43)
1a/M1-10 (126,34)
1/Tp-5 (125,30)
124.02 75.95 48.07
124.64 75.91 48.73
126.02 75.82 50.20
125.81 75.74 50.07
125.75 75.72 50.03
5°26'59"
1+545.93
1+598.71
1+707.09
1+806.81
1+837.85
Organogenic limestones
B
BY GN-206 II SOIL CATEGORY


SECTION WITH PROFILE IV-IV'
Takovska street
Svetogorska street
11/B-5 (125,00)
11/B-13 (125,10)
11/B-4 (125,40)
Tp-14 (117,90)
14/B-7 (117,00)
29/BT-1 (113,37)
Q2dl
Q2dpg
Q1dpr
K KG
K K,BR
125.30
125.25
120.60
117.10
112.11
75.56
75.62
75.55
75.50
75.43
49.64
49.63
45.05
41.60
36.68
2+007.19
V3
1+912.01
1+965.35
2+055.06
2+107.93
2+198.40
Organogenic limestones
A3
BY GN-206 II SOIL CATEGORY


SECTION WITH PROFILE V-V'
Tp-13
(108,30)
Džordža Vašingtona street
16/2
(101,60)
Dalmatinska street
SECTION WITH PROFILE 7-7'
17/DS-4 (95,82)
22/BBB
Q1dpr
M3K
M3GL
M3L
M3K
107.40
75.34
32.06
103.60
75.27
28.33
100.30
75.22
25.08
95.30
75.14
20.16
94.95
75.12
19.83
94.50
75.08
19.42
2+310.40
2+398.32
2+467.58
2+558.61
2+585.98
2+633.10
M3K Organogenic limestones
M3GL Clayey marls
M3L Marls
Q1dpr Silty to sandy clay
The change of quarterly silty clay and marly clay of Pannonia.
A2
D
F2
BY GN-206 I-2-II SOIL CATEGORY
BY GN-206 II SOIL CATEGORY
BY GN-206 III-IV SOIL CATEGORY



Ground level	89.90	86.20	83.96	83.86	83.31	82.82	82.67	82.16	
Tunnel bottom elevation Ø2900	74.99	74.94	74.85	74.83	74.80	74.78	74.77	74.75	
Depth	14.91	11.26	9.11	9.03	8.51	8.04	7.90	7.41	
Lenght, diameter and slope of the tunnel	34°45'58"								
Horizontal angles of the route									
Objects									
Chainage	2+752.86	2+814.43	2+930.89	2+951.28	2+987.02	3+015.16	3+023.17	3+0 55.60	
Lithology	M_3^2L Marls		Sandy and clayey dust						
Geotechnical category	F1		F3				OUT OF CATEGORIES		
Category of excavation	BY GN-206 II SOIL CATEGORY		BY GN-206 IV SOIL CATEGORY						

The categorization for defining the geotechnical conditions of tunneling (categories A, B, C, D, E and F), was performed according to the data obtained on the basis of available research, which can be evaluated differently. It is the entire categorization was conducted for the excavation by the method of mechanized shield.

The characteristics of these categories are given in the following table:

Environment	Chainage	The appearance of water in excavation (m3/dan/m ')	JA strength (MPa)	cracked-dividity	swelling (KPa)	GT Categ.	category by GN-200
M31 (K,BR,BL)	0+033,00 0+300,00	+ -	2,05; 35,3-38,2	+++	-	E	III-IV; V-VI
K14,5(K,BR)	0+300,00 0+680,00	0+420,00 0+680,00 (0,35-1,20)	17,0-52,0	++	-	A1	V, VI, VII
M22K M31L	0+680,00 1+210,00	-	(2,2-10) K (2,5-3,2) L	++	-	C	III-IV
M22K	1+210,00 2+000,00	1+210,00 1+285,00 (0,65-0,85)	1,9-2,6	++	-	B	III-IV
M22K	2+000,00 2+230,00	(245.00)	5,2-8,9	++	-	A3	III-IV
M31K	2+230,00 2+340,00	(255,00-325, 00)	11,2-23,5	+	-	A2	V-VI
M32GL, M32 L	2+340,00 2+470,00	-	1,8	-	107	C	III-IV
dpr M32GL	2+470,00 2+755,00	(0.10)	<1,8	-	100-295	F	III
M32L	2+755,00 2+820,00	-	1,8	-	-	F	III-IV
t1	2+820,00 3+020,00	(0,05-0,10) For sands (,00-10,00)	-	-	-	F	II

Geotechnical category "A"

The section with chainages 0 +300-0 +680 - A1

g= 21,7-27,7 kN/m3

f1 = 35 – 49˚

c1 = 3028- 8034kN/m2

sS=17 000 -52 000 kN/m2

Vp = 2650 – 5360 m/s   Vs = 1700 – 2700 m/s

Edyn = 16,8 – 52,7 GN/m2

The section with chainages 2 +000-2 +230 - A3

g = 19,6-21,2 kN/m3

f1 = 31 – 33˚

c = 834 - 1545 kN/m2

sS=5 289 -8 957 kN/m2

Vp = 1900 – 2160 m/s   Vs = 890 – 1000 m/s

Edyn = 4,27 – 6,64 GN/m2

n = 0,34 -0,36

The section with chainages 2 +230-2+340 -A2

g = 23,1 - 25,8 kN/m3

f1= 33-37º

c1= 3027-4572 kN/m2

sS=11 178 -23 550 kN/m2

Vp = 3160 – 3960 m/s   Vs = 1000 – 2250 m/s

Edyn = 16,02 – 34,61 GN/m2

n = 0,28 -0,35

The geotechnical category „b“

The section of chainages 1+210-2+000,00

g = 17,5-20,25 kN/m3

f = 30 – 33˚

c = 329- 405 kN/m2

sS=1 953 -2 663 kN/m2

Vp = 1780 – 2840 m/s   Vs = 820 – 1340 m/s

Edyn = 3,6 – 9,1 GN/m2

n = 0,34 -0,40

Geotechnical category „C“

The section with chainages 0 +680-1 +210.00

g = 17,2-19,5 kN/m3

	In the presence of water	Residual	In naturally moist condition
Shear strength test	φ = 10-14˚ c = 13-15 kN/m2	φrez= 7˚ crez=0 kN/m2	φ1 = 14-16˚ c1 = 325-380 kN/m2
Triaxial test	φu = 19-20˚ Cu = 18-29 kN/m2	-	-

sB= 66 kN/m2

sC=2524 - 3221 kN/m2

Vp = 1400 – 1560 m/s   Vs = 650 – 730 m/s

Edyn = 2,37 – 2,85 GN/m2

n = 0,36 -0,38

Geotechnical category „D“

The section with chainages 2+340-2 +470.00

g = 18,5-20,5 kN/m3

	In the presence of water	Residual
Shear strength test	φ = 13-19˚ c =15-30 kN/m2	φrez= 5-9˚ crez= 0 kN/m2

By GN-200 standards, the environment belongs to II-III category. According to GN-206 classification the entire complex belongs to II-III category.

Marls M32L- dusty, sporadically clayey. They are gray in color, tabular to massive, hard and brittle. With the loss of humidity they are divided into 2-5cm thick tables. Along the tables, limonite in the form of scum is deposited. In the mass, sub-vertical cracks, rough and of uneven surfaces are present. The environment is virtually incompressible, waterproof.
The values of physical and mechanical parameters are in the following range:

g= 17,9-20,8 kN/m3

	In the presence of water	In naturally moist condition
Shear strength test	φ = 10-20˚ c = 25-35 kN/m2	φ = 13˚ c = 326 kN/m2
Triaxial test	φu = 18˚ Cu = 28 kN/m2	-

sB= 107 kN/m2

sc= 1800 kN/m2

Vp = 1640 – 1650 m/s   Vs = 740 – 800 m/s

Edyn = 3,13 – 3,42 GN/m2

g = 0,35 -0,37

Geotechnical category „E“

The section with chainages 0 +033-0+300.00

g= 17,5-21,0 kN/m3

	In the presence of water	In naturally moist condition
Shear strength test	φ = 21˚ c = 4kN/m2	φ1= 21˚ c1= 4 kN/m2

sc=2 050 kN/m2

Vp = 1830 m/s   Vs = 870 m/s

Edyn = 4,35 GN/m2

n = 0,35

Geotechnical category „F“

The section with chainages 2 +470-2 +740 - F2

g = 18,4-19,8 kN/m3

	In the presence of water	Residual
Shear strength test	φ= 11-12˚ c=14-16 kN/m2	φrez= 7-10˚ crez= 0-7 kN/m2
Triaxial test	-	-

Ms = 7.000-12.000 kN/m2

sB = 100-145 kN/m2

The section with chainages 2 +740-2 +820 - F1

g= 17,9-20,8 kN/m3

	In the presence of water	In naturally moist condition
Shear strength test	φ = 10-20˚ c = 25-35 kN/m2	φ = 13˚ c = 326 kN/m2
Triaxial test	φu = 18˚ Cu = 28 kN/m2	-

sB= 107 kN/m2

sc= 1800 kN/m2

Vp = 1640 – 1650 m/s   Vs = 740 – 800 m/s

Edyn = 3,13 – 3,42 GN/m2

n = 0,35 -0,37

The section with chainages 2 +820-3 +020 - F3

g= 18.0-19.0 kN/m3

	In the presence of water	Rezidualno
Shear strength test	φ= 10-20˚ c=8-12 kN/m2	φrez= 8-11˚ crez=0-5 kN/m2
Triaxial test	φ= 22˚ c= 25 kN/m2	-

Ms= 3.500-8.000 kN/m2

sB= 110 kN/m2

Chapter 5 Facilities Planning of Pumping Station

1. Design calculation of New Usce PS

(1) Capacity Calculation

1）Inlet

	Unit	2031
Flow	(m^3/s)	3.345
Water depth	（m）	1.06
Width of Channel	（m）	2.00
Hydraulic velocity	(m/s)	1.60

2）Screen channel

	Unit	2031
Flow（Q）	(m^3/s)	3.345
Number of Channel（N）	（nos）	2
Width and Depth（B×H）	（m）	3.0×0.98
Area（a）	（m^2）	5.10
Velocity（v）＝Q/a	(m/s)	0.57

3）Sand pit

The target diameter of sand removal is above 1.0mm in this pumping station.

	Unit	2031
Flow（q）	(m^3/s)	3.345
Number of Channel（N）	（Line）	2
Size of Channel（B×L×H）	（m）	4.0×13.0×1.2
Area（a）	（m^2）	9.60
Surface Area（A）	（m^2）	104.0
Volume（Vo）	（m^3）	61.2
Load of Surface（r）＝Q/A	(m^3/m^2・day)	2,780
Velicoty（v）＝Q/a	(m/s)	0.35
Retention time（T）＝Vo/Q	(sec)	18.3
Diameter of sand	（mm）	1.0
Sink speed（vo）	(m/s)	0.1
Settling time（t）＝H/vo	(sec)	12
Ratio of sand removal d＝1-(1/(1+T/t))	（%）	60

4）Pump

	Unit	2031
Flow（Q）	(m^3/s)	3.350
Number of Pump (N)	（nos）	4Duty +1Stand-by
Flow per pump(q)	(m^3/min)	50.2
Pump Diameter (D)	(mm)	600 $146\times(50.2/1.5\sim3.0)^{0.5}$
Water level of Pump pit	（m）	+69.800
Water level of Outlet MH	（m）	+78.700
Actual head loss	（m）	8.90

Total head loss

Design criteria is listed as below

① BOP at Inflow pipe：+69.80ｍ

② Planned suction level：+69.80ｍ

③ Water level of Outlet MH：+78.70m

④ Length and Diameter of Pressured pipe：Dia1000 x 2line L=500ｍ, Dia1400 x 1 line L=950m

⑤ Total head loss

Actual head loss	ha=8.90m
Pipe loss	$hf=10.666\times130^{-1.85}$ $\times1.00^{-4.87}\times100.4^{1.85}$ ×500m=3.31m $hf=10.666\times110^{-1.85}$ $\times1.40^{-4.87}\times(200.8)^{1.85}$ ×950m=4.40m Total 7.71m
Pump loss	hp=2.0m
Confluent loss	ho=1.0m
Total head loss	H=8.90＋7.71+2.0+1.0 = 19.61m ≒20.0m

Chapter 6 Facilities Planning of Veliko Selo WWTP

1. Comparison of Sewage Treatment Process

1.1 Anaerobic Anoxic Oxic Process (A2O)

(1) Design Calculation of Bioreactor

Bioreactor	Anaerobic anoxic oxic process
Number of bioreactor tank	48 tanks
Design flow	448,700 m^3/day
MLSS concentration	3,000 mg/l
Dissolved oxygen	2.5 mg/l
Lowest monthly sewage temperature	10 degree Celsius
ASRT (aerobic solid retention time)	10.7 day
HRT (hydraulic retention time)	21.3 hour
Solid concentration of return sludge	0.9 %
Return sludge ratio	50 %
Circulation ratio	80 %
Dimension of anaerobic tank	10 mW x 9.7 mL x 6 mD
Dimension of anoxic tank	10 mW x 68.0 mL x 6 mD
Dimension of oxic tank	10 mW x 60.8 mL x 6 mD
Diffuser of oixc tank	Ultrafine bubble diffuser
Mixer of anoxic tank	Top-entry agitator
Circulation pump	Low head pump

(2) Design Calculation of Aeration Requirement

Oxygen for oxidation of organic substance	25,398 kg-O_2/day
Oxygen for nitrification of NH_4	48,803 kg-O_2/day
Oxygen for endogenous respiration of MLSS	42,035 kg-O_2/day
Oxygen for maintaining dissolved oxygen	2,580 kg-O_2/day
Total actual oxygen requirement (AOR)	118,816 kg-O_2/day
Standard oxygen requirement (SOR)	190,643 kg-O_2/day
Oxygen transfer efficiency	32.2 %
Aeration requirement	1,475 m^3/min
Blower	Multi-stage centrifugal
Specification of blower	270 m^3/min x 70 kPa x 420 kW
Number of blower	8 nos. (2 standby)

1.2 Step Feed Type Nitrification Denitrification Process with Coagulant (SFNDP)

(1) Design Calculation of Bioreactor

Bioreactor	Step feeding nitrification denitrification process
Number of bioreactor tank	48 tanks
Design flow	448,700 m^3/day
MLSS concentration	3,000 mg/l
Dissolved oxygen	2.5 mg/l
Lowest monthly sewage temperature	10 degree Celsius
ASRT (aerobic solid retention time)	10.7 day
HRT (hydraulic retention time)	17.7 hour
Solid concentration of return sludge	0.9 %
Return sludge ratio	50 %
Circulation ratio	0 %
Dimension of anoxic tank (1^{st} stage)	10 mW x 13.7 mL x 6 mD
Dimension of oxic tank (1^{st} stage)	10 mW x 13.7 mL x 6 mD
Dimension of anoxic tank (2^{nd} stage)	10 mW x 19.2 mL x 6 mD
Dimension of oxic tank (2^{nd} stage)	10 mW x 19.2 mL x 6 mD
Dimension of anoxic tank (3^{rd} stage)	10 mW x 25.7 mL x 6 mD
Dimension of oxic tank (3^{rd} stage)	10 mW x 25.7 mL x 6 mD
Diffuser of oixc tank	Ultrafine bubble diffuser
Mixer of anoxic tank	Top-entry agitator

(2) Design Calculation of Aeration Requirement

Oxygen for oxidation of organic substance	23,692 kg-O_2/day
Oxygen for nitrification of NH_4	42,036 kg-O_2/day
Oxygen for endogenous respiration of MLSS	51,255 kg-O_2/day
Oxygen for maintaining dissolved oxygen	1,683 kg-O_2/day
Total actual oxygen requirement (AOR)	118,666 kg-O_2/day
Standard oxygen requirement (SOR)	190,402 kg-O_2/day
Oxygen transfer efficiency	32.2 %
Aeration requirement	1,473 m^3/min
Blower	Multi-stage centrifugal
Specification of blower	270 m^3/min x 70 kPa x 420 kW
Number of blower	8 nos. (2 standby)

1.3 Carrier Added Activated Sludge Process (CAASP)

(1) Design Calculation of Bioreactor

Bioreactor	Carrier added activated sludge process
Number of bioreactor tank	48 tanks
Design flow	448,700 m^3/day
MLSS concentration	3,000 mg/l
Dissolved oxygen	3.0 mg/l
Lowest monthly sewage temperature	10 degree Celsius
HRT (hydraulic retention time)	8.0 hour
Solid concentration of return sludge	0.9 %
Return sludge ratio	50 %
Circulation ratio	80 %
Dimension of anaerobic tank	10 mW x 9.7 mL x 6 mD
Dimension of anoxic tank	10 mW x 22.5 mL x 6 mD
Dimension of oxic tank	10 mW x 19.5 mL x 6 mD
Inlet screen	Fine screen
Diffuser of oixc tank	Fine bubble diffuser
Mixer of anoxic tank	Top-entry agitator
Circulation pump	Air lift pump
Outlet screen	Bar screen

(2) Design Calculation of Aeration Requirement

Oxygen for oxidation of organic substance	26,168 kg-O_2/day
Oxygen for nitrification of NH_4	48,803 kg-O_2/day
Oxygen for endogenous respiration of MLSS	13,461 kg-O_2/day
Oxygen for maintaining dissolved oxygen	3,051 kg-O_2/day
Oxygen for carrier	7,507 kg-O_2/day
Total actual oxygen requirement (AOR)	98,990 kg-O_2/day
Standard oxygen requirement (SOR)	166,590 kg-O_2/day
Oxygen transfer efficiency	16.4 %
Aeration requirement	2,531 m^3/min
Aeration requirement for screen	236 m^3/min
Total aeration requirement	2,766 m^3/min
Blower	Multi-stage centrifugal
Specification of blower	510 m^3/min x 64 kPa x 720 kW
Number of blower	8 nos. (2 standby)

2. Performance Analysis of Sewage Treatment Process

2.1 Wastewater Treatment Plant

The WWTPs of each process are listed together with the design capacities in Table 1 and Table 2, respectively.

Table 1 Wastewater Treatment Plants of SFNDP

Code	Prefecture	Name	Design capacity
S01	Hokkaido	Fushikogawa WWTP	61,000 m^3/day
S02	Hokkaido	Toubu WWTP	160,000 m^3/day
S03	Miyagi	Hirosegawa WWTP	22,500 m^3/day
S04	Chiba	Nishiura WWTP	81,000 m^3/day
S05	Fukui	Tezutsu WWTP	40,925 m^3/day
S06	Gifu	Kakamigahara WWTP	214,414 m^3/day
S07	Gifu	Ogakishi WWTP	114,300 m^3/day
S08	Gifu	Tokishi WWTP	25,200 m^3/day
S09	Aichi	Yahagigawa WWTP	383,000 m^3/day
S10	Aichi	Kinuura toubu WWTP	51,500 m^3/day
S11	Aichi	Toyogawa WWTP	141,500 m^3/day
S12	Aichi	Gojogawa sagan WWTP	127,975 m^3/day
S13	Aichi	Nikkogawa jouryuu WWTP	117,250 m^3/day
S14	Aichi	Gojogawa ugan WWTP	66,800 m^3/day
S15	Aichi	Gamagorishi WWTP	46,100 m^3/day
S16	Aichi	Nanbu WWTP	32,000 m^3/day
S17	Mie	Nagashima WWTP	10,000 m^3/day
S18	Mie	Chuuou WWTP	15,000 m^3/day
S19	Shiga	Konan Chuubu WWTP	346,500 m^3/day
S20	Shiga	Kosai WWTP	75,000 m^3/day
S21	Shiga	Touhokubu WWTP	149,625 m^3/day
S22	Shiga	Takashima WWTP	25,200 m^3/day
S23	Kyoto	Rakusai WWTP	208,000 m^3/day
S24	Kyoto	Kisshoin WWTP	114,000 m^3/day
S25	Kyoto	Toba WWTP	805,000 m^3/day
S26	Kyoto	Ishida WWTP	149,900 m^3/day
S27	Osaka	Ryuge WWTP	138,000 m^3/day
S28	Osaka	Takatsuki WWTP	182,610 m^3/day
S29	Osaka	Harada WWTP	425,500 m^3/day

Code	Prefecture	Name	Design capacity
S30	Osaka	Sanbo WWTP	120,200 m^3/day
S31	Hyogo	Mukogawa Karyuu WWTP	375,300 m^3/day
S32	Wakayama	Ito WWTP	34,000 m^3/day
S33	Wakayama	Naga WWTP	18,150 m^3/day
S34	Shimane	Toubu WWTP	81,000 m^3/day
S35	Okayama	Kojima WWTP	41,900 m^3/day
S36	Okayama	Mizushima WWTP	57,900 m^3/day
S37	Okayama	Tamashima WWTP	43,920 m^3/day
S38	Okayama	Sanyo WWTP	16,990 m^3/day
S39	Hiroshima	Takehara WWTP	1,880 m^3/day
S40	Yamaguchi	Sanin WWTP	63,400 m^3/day
S41	Yamaguchi	Yamaguchishi WWTP	53,080 m^3/day
S42	Yamaguchi	Iwakuni minami WWTP	11,500 m^3/day
S43	Yamaguchi	Sanyo WWTP	6.200 m^3/day
S44	Tokushima	Hokubu WWTP	38,200 m^3/day
S45	Ehime	Seibu WWTP	52,850 m^3/day
S46	Ehime	Hokubu WWTP	11,400 m^3/day
S47	Ehime	Hokubu WWTP	7,125 m^3/day
S48	Kochi	Takasu WWTP	28,260 m^3/day
S49	Kochi	Geji WWTP	78,800 m^3/day
S50	Fukuoka	Fukuma WWTP	2,100 m^3/day
S51	Kumamoto	Kumamoto hokubu WWTP	113,500 m^3/day

Table 2 Wastewater Treatment Plants of A2O

Code	Prefecture	Name	Capacity
A01	Hokkaido	Abashiri WWTP	20,265 m^3/day
A02	Miyagi	Senshio WWTP	222,000 m^3/day
A03	Ibaragi	Kasumigaura WWTP	152,000 m^3/day
A04	Ibaragi	Yasato WWTP	6,480 m^3/day
A05	Chiba	Nanbu WWTP	261,000 m^3/day
A06	Chiba	Takase WWTP	102,900 m^3/day
A07	Chiba	Kisarazu WWTP	57,000 m^3/day
A08	Chiba	Matsugoshima WWTP	53,200 m^3/day
A09	Tokyo	Mimamitama WWTP	162,450 m^3/day
A10	Tokyo	Kitatama No.1 WWTP	260,700 m^3/day
A11	Tokyo	Tamagawa jouryuu WWTP	261,900 m^3/day

Code	Prefecture	Name	Capacity
A12	Tokyo	Kitatama No.2 WWTP	80,800 m^3/day
A13	Tokyo	Asaka WWTP	133,900 m^3/day
A14	Tokyo	Hachiouji WWTP	160,000 m^3/day
A15	Tokyo	Kiyose WWTP	327,800 m^3/day
A16	Tokyo	Mikawashima WWTP	800,000 m^3/day
A17	Tokyo	Morigasaki WWTP	1,540,400 m^3/day
A18	Tokyo	Ariake WWTP	120,000 m^3/day
A19	Tokyo	Ukima WWTP	220,000 m^3/day
A20	Tokyo	Narise WWTP	109,500 m^3/day
A21	Kanagawa	Hokubu No.1 WWTP	81,200 m^3/day
A22	Kanagawa	Kohoku WWTP	284,500 m^3/day
A23	Kanagawa	Kanazawa WWTP	265,900 m^3/day
A24	Kanagawa	Hokubu No.2 WWTP	388,400 m^3/day
A25	Kanagawa	Ezaki WWTP	318,600 m^3/day
A26	Kanagawa	Asao WWTP	62,800 m^3/day
A27	Fukui	Takahamachou WWTP	6,629 m^3/day
A28	Gifu	Kakamigahara WWTP	214,414 m^3/day
A29	Gifu	Mizunamishi WWTP	15,300 m^3/day
A30	Aichi	Kinuura seibu WWTP	103,600 m^3/day
A31	Aichi	Nishiyama WWTP	60,000 m^3/day
A32	Aichi	Shibata WWTP	210,000 m^3/day
A33	Aichi	Nanbu WWTP	14,900 m^3/day
A34	Mie	Hokubu WWTP	178,000 m^3/day
A35	Mie	Nanbu WWTP	78,800 m^3/day
A36	Mie	Kumodegawa sagan WWTP	55,140 m^3/day
A37	Mie	Matsusaka WWTP	56,100 m^3/day
A38	Mie	Miyakawa WWTP	40,200 m^3/day
A39	Shiga	Konan Chuubu WWTP	346,500 m^3/day
A40	Kyoto	Toba WWTP	805,00 m^3/day
A41	Osaka	Nawate WWTP	76,000 m^3/day
A42	Osaka	Chuuou WWTP	302,360 m^3/day
A43	Osaka	Nagisa WWTP	198,200 m^3/day
A44	Osaka	Harada WWTP	425,500 m^3/day
A45	Osaka	Sayama WWTP	111,500 m^3/day
A46	Osaka	Imaike WWTP	206,000 m^3/day
A47	Osaka	Oui WWTP	100,000 m^3/day
A48	Osaka	Chuubu WWTP	70,200 m^3/day

Code	Prefecture	Name	Capacity
A49	Osaka	Nanbu WWTP	38,100 m^3/day
A50	Osaka	Senboku WWTP	145,900 m^3/day
A51	Hyogo	Tamazu WWTP	122,750 m^3/day
A52	Nara	Yamatogawa No.1 WWTP	370,200 m^3/day
A53	Nara	Yamatogawa No.2 WWTP	174,200 m^3/day
A54	Nara	Udagawa WWTP	12,100 m^3/day
A55	Okayama	Yoshiigawa WWTP	7,000 m^3/day
A56	Tokushima	Yoshinogawa WWTP	11,000 m^3/day
A57	Fukuoka	Mikasagawa WWTP	283,600 m^3/day
A58	Fukuoka	Tataragawa WWTP	67,100 m^3/day
A59	Fukuoka	Fukudou WWTP	27,000 m^3/day
A60	Fukuoka	Yabegawa WWTP	19,200 m^3/day
A61	Fukuoka	Onogawa chuuryuu WWTP	37,600 m^3/day
A62	Fukuoka	Toubu WWTP	195,300 m^3/day
A63	Fukuoka	Seibu WWTP	296,800 m^3/day

2.2 Annual Average Qualities

Annual average values of influent and effluent qualities of the WWTPs are summarized in Table 3 and Table 4, respectively.

Table 3 Annual Average Qualities of SFNDP

Code	BOD_5 [mg/l]		COD_{Mn} [mg/l]		SS [mg/l]		TN [mg/l]		TP [mg/l]	
	In	Out	In	Out	In	Out	In	Out	In	Out
S01	170	3.4	NA	NA	140	ND	26.0	7.8	2.8	0.2
S02	270	3.0	NA	NA	200	ND	36.0	8.4	8.4	3.0
S03	210	1.1	130	5.3	220	ND	37.0	1.8	4.7	1.8
S04	249	1.1	150	5.8	378	2.7	43.9	7.2	8.8	0.5
S05	193	2.7	142	8.5	150	2.5	29.1	4.8	5.8	0.5
S06	140	ND	92	5.4	180	ND	32.0	6.4	3.9	0.8
S07	82	1.8	60.4	5.4	121	1.9	20.1	6.7	3.0	1.0
S08	143	5.4	88	9.5	147	4.3	23.4	6.2	3.1	1.0
S09	190	ND	95	6.8	180	1.5	28.0	6.3	4.4	0.3
S10	270	2.8	140	9.5	200	3.1	50.0	6.1	10.0	0.2
S11	230	ND	110	7.9	170	1.1	37.0	6.8	5.3	0.3
S12	190	1.6	110	7.4	200	ND	38.0	6.5	4.1	0.3
S13	170	ND	100	7.1	160	2.1	41.0	6.7	4.5	ND

S14	320	1.8	160	7.7	290	2.7	44.0	6.2	5.3	0.2
S15	166	1.1	85	7.8	77.0	1.1	42.5	7.6	4.2	0.2
S16	165	12.6	99.2	8.1	108	2.4	42.0	9.0	4.5	0.2
S17	130	3.0	79	8.0	134	3.0	36.0	5.7	3.8	0.4
S18	132	2.4	111.7	8.8	168	3.9	27.5	2.3	3.6	0.6
S19	170	0.9	88.9	5.2	179	0.6	29.9	5.5	3.2	0.1
S20	150	1.0	85.0	5.7	147	ND	25.6	3.9	3.0	0.1
S21	130	0.6	77.3	4.8	146	0.6	26.8	2.2	2.6	0.1
S22	160	1.0	77.5	5.7	118	ND	26.1	3.6	2.6	0.0
S23	101	1.9	61.6	9.5	86	ND	19.2	10.0	2.2	1.2
S24	89	3.9	54	6.6	73	2.0	16.0	7.8	1.6	0.6
S25	115	2.9	67.5	6.5	129	1.7	16.5	7.4	2.1	0.4
S26	190	3.7	94	8.0	214	5.0	21.0	8.5	2.9	0.9
S27	100	1.0	55	6.2	55	1.0	25.0	5.9	2.4	0.1
S28	361	5.0	146	8.0	280	2.0	30.0	8.4	6.5	1.0
S29	182	2.7	94	11.0	205	2.0	28.0	12.0	3.7	0.4
S30	123	2.7	80	16.9	92	2.0	23.0	6.7	3.1	0.4
S31	110	2.0	54	6.6	130	1.5	22.0	6.8	3.1	0.5
S32	143	1.9	82.5	7.3	138	1.1	30.5	4.2	3.0	0.5
S33	67	1.2	42	4.6	22	1.0	26.1	3.1	2.1	0.3
S34	154	1.5	100	8.6	203	1.2	33.1	6.2	3.8	0.2
S35	136	3.0	57	7.2	102	1.0	36.0	7.4	3.3	0.2
S36	145	2.6	56.8	8.3	62	2.0	30.2	6.0	2.9	0.2
S37	229	3.5	102	8.5	151	2.2	49.6	5.6	4.7	0.4
S38	234	0.5	132	6.6	232	ND	41.0	3.5	5.4	0.5
S39	102	5.2	73	7.5	84	5.0	32.5	4.0	3.3	0.3
S40	200	4.3	120	11.5	180	3.0	56.5	16.0	5.6	1.0
S41	133	3.0	83.6	9.3	115	1.6	25.0	17.0	2.5	1.2
S42	170	3.0	168	10.0	192	4.0	23.0	4.0	4.0	1.0
S43	115	2.1	64	6.5	113	1.9	34.0	6.0	3.3	0.9
S44	150	3.4	65.3	5.7	141	1.9	20.0	5.3	3.6	0.8
S45	244	1.8	184.2	8.8	247	1.0	57.8	12.0	6.4	0.6
S46	160	1.0	110	8.0	150	1.0	36.6	3.5	4.1	0.2
S47	207	5.1	101.2	8.9	175	4.4	43.5	11.9	4.1	1.9
S48	204	1.1	111.8	7.9	259	1.5	26.0	5.8	3.6	0.7
S49	129	3.6	63.9	7.1	108	3.3	21.9	7.4	2.6	0.7
S50	208	0.6	120	6.3	108	3.3	21.9	7.4	2.6	0.7
S51	133	4.8	74	7.5	169	2.6	30.0	18.0	3.0	0.8

Table 4 Annual Average Qualities of A2O

Code	BOD_5 [mg/l]		COD_{Mn} [mg/l]		SS [mg/l]		TN [mg/l]		TP [mg/l]	
	In	Out	In	Out	In	Out	In	Out	In	Out
A01	310	6.0	170	17.0	230	6.0	42.0	23.0	4.8	2.7
A02	180	1.9	130	11.0	190	2.0	46.0	15.0	5.6	2.0
A03	153	0.7	95.1	6.1	173	NA	31.7	5.3	3.3	0.1
A04	90	0.9	58.2	6.0	83	2.0	20.0	8.2	2.7	0.2
A05	166	0.9	107	8.3	165	0.8	39.0	8.0	3.9	1.0
A06	235	1.3	133	7.2	213	1.8	39.4	6.8	5.8	0.4
A07	110	1.5	56.2	6.2	61	1.5	21.2	6.8	2.3	0.1
A08	230	3.2	117	10.1	144	2.1	40.7	10.4	7.7	0.5
A09	185	1.0	89	9.0	145	1.0	34.0	11.0	3.4	0.9
A10	160	1.0	90	8.0	140	1.0	30.0	10.0	3.5	0.6
A11	210	2.0	97	8.0	150	2.0	23.0	0.4	3.3	1.0
A12	140	2.0	85	8.0	120	2.0	30.0	0.4	3.0	0.4
A13	230	2.0	110	9.0	190	2.0	31.0	13.0	3.9	0.7
A14	260	2.0	110	9.0	250	1.0	29.0	10.0	3.9	1.1
A15	180	1.0	100	8.0	150	1.0	33.0	9.3	3.5	0.3
A16	183	2.5	82	9.5	122	2.0	31.2	13.4	3.4	0.4
A17	115	4.5	74	9.5	105	2.5	28.6	13.5	3.0	1.5
A18	110	ND	92	9.0	110	ND	33.8	10.4	4.0	0.3
A19	95	2.0	66	9.0	57	1.0	25.0	10.6	2.8	0.1
A20	200	1.8	120	7.6	200	2.2	38.3	11.7	4.4	0.8
A21	121	3.5	63	7.3	97	1.0	18.2	6.9	2.5	0.6
A22	160	2.8	72	7.0	129	2.0	25.2	7.0	3.7	0.5
A23	145	3.7	84.2	9.3	130	3.0	27.1	9.7	4.1	1.9
A24	114	4.0	67.2	11.0	110	3.0	25.1	15.2	4.2	3.3
A25	225	4.9	90	8.7	175	3.5	30.0	9.6	7.4	1.7
A26	220	4.5	110	8.9	190	3.0	35.0	8.2	3.9	1.0
A27	173	1.2	29.5	6.3	103	0.2	40.0	3.3	2.8	0.7
A28	140	ND	92	5.4	180	ND	32.0	6.4	3.9	0.8
A29	190	17.1	104.4	9.3	266	4.0	32.3	10.5	6.9	0.5
A30	270	2.5	120	7.8	170	2.5	42.0	6.8	5.1	0.3
A31	130	1.7	75	6.0	133	ND	31.8	7.1	3.0	0.2
A32	94	2.6	64	11.0	109	3.0	23.9	10.7	2.9	2.0
A33	191	5.8	70.6	7.4	131	3.0	31.6	13.7	2.8	0.3
A34	170	1.7	96	7.0	180	2.0	27.0	6.9	3.2	0.5

Code	BOD_5 [mg/l]		COD_{Mn} [mg/l]		SS [mg/l]		TN [mg/l]		TP [mg/l]	
	In	Out	In	Out	In	Out	In	Out	In	Out
A35	127	2.2	79	7.6	108	2.0	29.0	4.8	3.2	0.4
A36	168	1.3	109.7	7.2	203	ND	31.8	7.5	4.4	0.4
A37	170	0.8	98	6.2	150	ND	33.0	7.6	3.7	ND
A38	130	0.8	110	6.7	190	ND	36.0	6.7	4.1	0.1
A39	170	0.9	88.9	5.2	179	0.6	29.9	5.5	3.2	0.1
A40	115	2.9	68	6.5	129	1.7	16.5	7.4	2.1	0.4
A41	170	0.9	110	9.0	158	ND	36.0	8.7	4.0	0.3
A42	150	ND	75	6.9	166	ND	25.0	7.1	4.9	0.8
A43	160	1.0	97	6.7	178	1.0	30.0	7.3	3.5	0.6
A44	182	2.7	94	11.0	205	2.0	28.0	12.0	3.7	1.1
A45	175	1.4	110	8.2	183	1.5	33.5	10.4	3.8	0.6
A46	170	2.7	130	11.5	179	1.5	34.0	15.4	3.8	0.3
A47	190	1.1	120	8.0	200	ND	38.0	7.4	4.8	0.3
A48	130	1.0	100	10.0	139	1.0	27.0	7.9	4.0	0.2
A49	230	2.1	95	7.0	198	ND	29.0	5.9	3.3	0.3
A50	235	2.9	155	10.0	220	2.0	37.0	14.3	4.2	0.4
A51	190	1.5	93	8.2	150	ND	31.0	16.0	3.4	0.5
A52	178	4.7	43.2	8.1	186	7.0	34.4	7.1	4.3	0.8
A53	258	2.5	87.2	8.6	150	1.0	33.5	7.8	5.6	0.7
A54	141	0.6	65.4	5.6	147	ND	29.1	8.0	2.8	ND
A55	280	1.5	140	5.6	190	ND	40.0	4.7	4.4	0.1
A56	69	2.8	50.9	8.6	75	2.0	32.2	7.0	3.4	0.3
A57	215	1.9	99	7.7	175	2.0	37.5	9.5	4.6	0.8
A58	250	0.4	140	7.4	250	0.0	38.0	9.0	4.6	0.4
A59	210	1.0	100	6.3	140	ND	36.0	6.2	3.4	0.6
A60	210	0.6	100	4.8	170	ND	34.0	8.1	3.1	0.6
A61	306	3.0	125	9.7	290	1.7	47.0	5.1	3.9	1.0
A62	180	3.0	120	11.0	190	3.0	38.4	15.4	5.6	0.3
A63	190	4.6	140	11.0	200	2.0	37.0	17.5	4.9	0.6

3. Design Calculation of Veliko Selo WWTP

3.1 Basics for Planning

(1) Design Flow

Year	2015	2021	2031
Daily average flow	394,000 m^3/day	409,000 m^3/day	448,700 m^3/day
Daily maximum flow	464,000 m^3/day	474,000m^3/day	521,200 m^3/day
Hourly maximum flow	696,000m^3/day	717,100 m^3/day	788,800 m^3/day
Wet weather flow	1,209,600m^3/day	1,252,800m^3/day	1,341,100 m^3/day

(2) Design Water Quality

Item	Influent characteristic	Effluent standard
BOD_5	192 mg/l	25 mg/l
COD_{Cr}	385 mg/l	125 mg/l
SS	224 mg/l	35 mg/l
T-nitrogen	35 mg/l	10 mg/l
T-phosphorus	8 mg/l	1 mg/l

(3) Design Water Temperature

	Temperature
Maximum	24 degree Celsius
Average	17 degree Celsius
Minimum	10 degree Celsius

3.2 Design Calculation of Sewage Treatment Facilities

(1) Lift Pumping Station

Lift pump	Submersible pump (dry installation)
Design flow in rainy weather day	1,341,800 m^3/day
Design flow in dry weather day	788,800 m^3/day
Specification of lift pump	94 m^3/min x 18 mH x 400 kW
Number of pump	12 nos. (2 standby)
Coarse screen	Mechanical screen
Specification of coarse screen	Channel: 4.5 m / Opening: 100 mm

Number of screen	3 nos.

(2) Pretreatment Facility

Grit chamber	Aerated grit chamber
Design flow in rainy weather day	1,341,800 m^3/day
Design flow in dry weather day	788,800 m^3/day
Hydraulic overflow rate (rainy)	3,600 m^3/m^2/day
Hydraulic overflow rate (dry)	1,800 m^3/m^2/day
Dimension of grit chamber	3.5 mW x 18 mL
Number of grit chamber	6 channels
Fine screen	Mechanical screen
Specification of fine screen	Channel: 2.5m / Opening: 20mm
Number of screen	6 nos.

(3) Primary Settling Tank

Primary settling tank	Circular settling tank
Daily average flow	448,700 m^3/day
Daily maximum flow	521,200 m^3/day
Hourly maximum flow	788,800 m^3/day
Hydraulic surface loading	50 m^3/m^2/day
Weir overflow rate	250 m^3/m/day
Dimension of primary settling tank	Diameter 34 m x 3.5 mD
Number of primary settling tank	12 tanks
Sludge collector	Circular sludge scraper
Raw sludge production	68,782 DS-kg/day
Solid concentration of raw sludge	2.0 %

(4) Bioreactor

Bioreactor	Step feeding nitrification denitrification process
Number of bioreactor tank	48 tanks
Design flow	448,700 m^3/day
MLSS concentration	3,000 mg/l
Dissolved oxygen	2.5 mg/l
Lowest monthly sewage temperature	10 degree Celsius
ASRT (aerobic solid retention time)	10.7 day
HRT (hydraulic retention time)	17.7 hour

Solid concentration of return sludge	0.9 %
Return sludge ratio	50 %
Circulation ratio	0 %
Dimension of anoxic tank (1st stage)	10 mW x 13.7 mL x 6 mD
Dimension of oxic tank (1st stage)	10 mW x 13.7 mL x 6 mD
Dimension of anoxic tank (2nd stage)	10 mW x 19.2 mL x 6 mD
Dimension of oxic tank (2nd stage)	10 mW x 19.2 mL x 6 mD
Dimension of anoxic tank (3rd stage)	10 mW x 25.7 mL x 6 mD
Dimension of oxic tank (3rd stage)	10 mW x 25.7 mL x 6 mD
Diffuser of oixc tank	Ultrafine bubble diffuser
Mixer of anoxic tank	Top-entry agitator

(5) Secondary Settling Tank

Secondary settling tank	Circular settling tank
Daily average flow	448,700 m^3/day
Daily maximum flow	521,200 m^3/day
Hourly maximum flow	788,800 m^3/day
Hydraulic surface loading	20 m^3/m^2/day
Weir overflow rate	150 m^3/m/day
Dimension of primary settling tank	Diameter 49 m x 4.0 mD
Number of primary settling tank	12 tanks
Sludge collector	Circular sludge scraper
Excess sludge production	49,069 DS-kg/day
Solid concentration of excess sludge	0.9 %
Return sludge pump	Submersible pump (dry installation)
Specification of lift pump	16.5 m^3/min x 8 mH x 37 kW
Number of pump	24 nos.

(6) Filtration

Filtration	Disc filter
Design flow	788,800 m^3/day
Filtration speed	500 m/day
Filtration area	114 m^2
Number of disc filter	16 nos. (2 standby)

3.3 Design Calculation of Aeration Requirement

Oxygen for oxidation of organic substance	23,692 kg-O_2/day
Oxygen for nitrification of NH_4	42,036 kg-O_2/day
Oxygen for endogenous respiration of MLSS	51,255 kg-O_2/day
Oxygen for maintaining dissolved oxygen	1,683 kg-O_2/day
Total actual oxygen requirement (AOR)	118,666 kg-O_2/day
Standard oxygen requirement (SOR)	190,402 kg-O_2/day
Oxygen transfer efficiency	32.2 %
Aeration requirement	1,473 m^3/min
Blower	Multi-stage centrifugal
Specification of blower	270 m^3/min x 70 kPa x 420 kW
Number of blower	8 nos. (2 standby)

3.4 Design Calculation of Sludge Treatment Facilities

(1) Gravity Thickener

Gravity thickener	Gravity sludge thickener
Solid content of raw sludge	68,782 kg-DS/day
Volume of raw sludge	3,439 m^3/day
Solid concentration of raw sludge	2.0 %
Solid surface loading	50 kg/m^2/day
Solid recovery rate	85 %
Dimension of primary settling tank	Diameter 21 m x 4.0 mD
Number of primary settling tank	4 tanks
Sludge collector	Circular sludge scraper
Solid content of thickened sludge	58,464 kg-DS/day
Volume of thickened sludge	1,462 m^3/day
Solid concentration of excess sludge	4.0 %

(2) Mechanical Thickener

Mechanical thickener	Belt thickener
Solid content of excess sludge	49,069 kg-DS/day
Volume of excess sludge	5,452 m^3/day
Solid concentration of excess sludge	0.9 %
Solid recovery rate	95 %
Polymer dosing rate	0.3 %

Operation hour	24 hour
Specification of mechanical thickener	Capacity: 40 m^3/hour
Number of mechanical thickener	7 nos. (1 standby)
Solid content of thickened sludge	46,755 kg-DS/day
Volume of thickened sludge	1,169 m^3/day
Solid concentration of thickened sludge	4.0 %

(3) Anaerobic Digestion

Anaerobic digestion	Heated sludge digester
Solid content of thickened sludge	105,219 kg-DS/day
Volume of thickened sludge	2,630 m^3/day
Solid concentration of thickened sludge	4.0 %
HRT (hydraulic retention time)	20 day
Sludge heating temperature	35 degree Celsius
Volatile total solid	70 %
Digestion rate	50 %
Volume of sludge digester	6,600 m^3
Number of sludge digester	8 tanks
Digester mixer	Top-entry agitator
Gas calorific value	21,000 kJ/m^3
Gas production rate	0.50 m^3/kg
Volume of gas holder	3,000 m^3
Number of gas holder	4 nos.
Cogeneration system	Combined heat and power system
Specification of cogeneration system	1,000 kVA
Number of mechanical thickener	4 nos.
Solid content of digested sludge	68,393 kg-DS/day
Volume of digested sludge	2,630 m^3/day
Solid concentration of digested sludge	2.6 %

(4) Mechanical Dewatering

Mechanical dewatering	Screw press dewatering
Solid content of digested sludge	68,393 kg-DS/day
Volume of digested sludge	2,630 m^3/day
Solid concentration of digested sludge	2.6 %
Solid recovery rate	95 %
Polymer dosing rate	1.5 %

Operation hour	24 hour
Specification of mechanical dewatering	Diameter: 1,000 mm / 836 kg-DS/hour
Number of mechanical thickener	5 nos. (1 standby)
Solid content of sludge cake	65,948 kg-DS/day
Volume of sludge cake	314 m^3/day
Moisture content of sludge cake	79 %

3.5 Calculations

1 DESIGN CALCULATIONS OF WATER TREATMENT FACILITIES

1.1 Pretreatment

(1) Design Bases

Hourly maximum flow	Q_{hm} =	788,800 m^3/d		
Hydraulic overflow rate	q_o =	1,800 $m^3/m^2/d$		
Average flow rate	v_o =	0.3 m/s		
Total number of chamber	n =	6 channel		
Hydraulic load on each channel is	=	788,800 / 6	=	131,467 m^3/d
Required surface area of each chan	=	131,467 / 1800	=	73.0 m^2

(2) Tank Geometry

Width of chamber	W =	3.5 m
Effective depth	d =	1.0 m
Lenghh of chamber	L =	21.0 m
Hydraulic capacity of chamber	Q_p =	74 m^3

Tank Shape and Dimensions

Width of chamber	3.5 m
Effective depth	1.0 m
Length of chamber	21.0 m
Capacity of chamber	73.5 m^3
Number of Units	6 channels

1.2 Primary Settling Tank

(1) Design Bases

Daily average flow	Q_{da} =	448,700 m^3/d			
Daily maximum flow	Q_{dm} =	521,200 m^3/d			
Hourly maximum flow	Q_{hm} =	788,800 m^3/d			
Wet weather flow	Q_{ww} =	1,341,800 m^3/d			
Hydraulic overflow rate	q_o =	50 $m^3/m^2/d$			
Total number of tanks	n =	12 units		6 tank x	2 train
Hydraulic load on each tank is	=	521,200 / 12	=	43,433 m^3/d	
Required surface area of each tank	A =	43,433 / 50	=	869 m^2	

(2) Tank Geometry

Internal diameter	D =	34.0 m		
Effective depth	d =	3.5 m		
Number of basins	n =	12 tanks		
Surface area of each tank	A =	908 m^2		
Hydraulic capacity of each tank	Q_p =	3,178 m^3		
Overflow rate for wet wether flow	Q_{ww} =	111,817 / 908.0 =	123.1	$m^3/m^2/d$

Tank Shape and Dimensions

Shape of tank	Circular tank
Number of Units	12 tanks
Internal diameter	34.0 m
Effective depth	3.5 m

1.3 Bioreactor

(1) Design Bases

Design flow	Q_{in} =	448,700 m^3/d
BOD concentration	$C_{BOD, in}$ =	126 mg/L

S-BOD concentration (= 66.7%)	$C_{S\text{-}BOD,\ in}$ =	84	mg/L
SS concentration	$C_{SS,\ in}$ =	122	mg/L
P concentration	$C_{P,\ in}$ =	6.4	mg/L
S-P concentration (=78.0%)	$C_{SP,\ in}$ =	5.0	mg/L
MLSS concentration of 3rd stage	X =	3,000	mg/L
T - Nitrogen (in)	$C_{TN,\ in}$=	30	mg/L
Un removable Nitrogen	$C_{OrgN,\ out}$=	1	mg/L
Stage of aeration tank	N=	3	stage
Return sludge ratio	r=	50	%
Internal circulation ratio	R_N=	0	%

(2) Effluent of T-Nitrogen

T - Nitrogen (excess sludge)	$C_{TN,\ EX}$ =	8.5	mg/L
T - Nitrogen (nitrification)	$C_{TN,\ ni}$ =	20.5	mg/L
T - Nitrogen (denitrification)	$C_{TN,\ deni}$ =	16.0	mg/L
NO_3-N (eff)	$C_{NO3N,\ eff}$=	4.5	mg/L
T - Nitrogen (eff)	$C_{TN,\ eff}$=	5.5	mg/L

(3) Removal Ratio of Nitrogen

The removal ratio of Nitrogen can be calculated by the following equation:

S_{DN} = $1 - (1 / N \cdot (1 + r + R_N)$ S_{DN}= 0.78

where,

N :	Stage of aeration tank	=	3	stage
r :	Return sludge ratio	=	50	%
R_N :	Internal circulation ratio	=	0	%

(4) MLSS Concentration of 3rd Stage

The SS ratio of return sludge can be calculated by the following equation:

X_R = $(1 + 0.5) / 0.5 * X_N$ X_R= 9,000 mg/L

where,

X_N : MLSS concentration = 3,000 mg/L

(5) ASRT

ASRT can be calculated by the following equation:

θ_{XA} = $29.7\, e^{(-0.102T)}$ = 10.7 day

where,

T : Monthly lowest sewage temperature = 10 C degree

(6) Capacity of 3rd Stage of Oxic Tank

The capacity of 3rd stage of oxic tank can be calculated by the following equation:

V_{AN} = $Q_{in} \cdot \theta_{XA} \cdot (a \cdot C_{S\text{-}BOD,\ in} + b \cdot C_{SS,\ in} + g \cdot C_{Me}) / N \cdot X_N \cdot (1+c \cdot \theta_{XA})$
= 71,188 m^3/d

where,

Q_{in} :	Design flow	=	448,700	m^3/d
θ_{XA} :	A-SRT (aerobic solid retation time)	=	10.7	day
$C_{S\text{-}BOD,\ in}$:	Influent S-BOD concentration to aeration tank	=	84	mg/L
$C_{SS,\ in}$:	Influent SS concentration to aeration tank	=	122	mg/L
a :	Biomass yield coefficient of S-BOD	=	0.5	g MLSS/g BOD
b :	Biomass yield coefficient of SS	=	0.95	g MLSS/g SS
c :	Sludge reduction coefficient due to endogenous respiration of micro-organisms	=	0.04	1/d
g :	production ratio of solid matrial	=	5	times
X :	MLSS concentration of 3rd stage	=	3,000	mg/L
N :	Stage of aeration tank	=	3	stage

C_{Me} = $C_{SP,\ in} / P * m * Me$ = 6.5 mg/L where,

$C_{SP,in}$:	Dissoluble phosphorous	=	5.0 mg/L
P :	Atomic mass of phosphorous	=	31
m :	Mole ratio	=	1.5
Me :	Atomic mass of coagulant	=	27

(7) MLSS Concentration of 1st Stage and 2nd Stage

The MLSS concetration of 1st stage and 2nd stage can be calculated by the following equation:

$$X_k = (r + 1) / (r + k/N) * X_N$$

where,

X_1 = 5,400 mg/L
X_2 = 3,857 mg/L

(8) Capacity of 1st stage and 2nd stage of Oxic Tank

The capacity of 1st stage and 2nd stage of oxic tank can be calculated by the following equation:

$V_{A1} = X_N / X_1 * V_{AN}$ = 39,549 m^3/d
$V_{A2} = X_N / X_2 * V_{AN}$ = 55,370 m^3/d

(9) Capacity of Anoxic Tank

The capacity of anoxic tank can be equal to the capacity of oxic tank:

$V_{D1} = V_{A1}$ = 39,549 m^3/d
$V_{D2} = V_{A2}$ = 55,370 m^3/d
$V_{DN} = V_{AN}$ = 71,188 m^3/d

(10) Tank Geometry

Total capacity of anoxic tank	V_{DN} =	166,107 m^3			
Tank width	W =	10.0 m			
Tank effective depth	d =	6.0 m			
Tank cross sectional area	A =	60.0 m^2			
Number of tanks	n =	48 units		24 tank x	2 train
Capacity of each tank	V_e =	166,107 / 48 =	3,461 m^3		
Tank length		3,461 / 60 =	57.7 m		
Total capacity of oxic tank	V_A =	166,107 m^3			
Tank width	W =	10.0 m			
Tank effective depth	d =	6.0 m			
Tank cross sectional area	A =	60.0 m^2			
Number of tanks	n =	48 units		24 tank x	2 train
Capacity of each tank	V_e =	166,107 / 48 =	3,461 m^3		
Tank length		3,461 / 60 =	57.7 m		
Total of tank length		115.4 m →	115 m		

Tank Shape and Dimensions

Width	10.0 m
Depth	6.0 m
Tank capacity	6,900 m^3
Tank length	115 m
No. of tank units and clusters	48 tanks

1.4 Secondary Settling Tank

(1) Design Bases

Daily average flow	Q_{da} =	448,700 m^3/d
Daily maximum flow	Q_{dm} =	521,200 m^3/d
Hourly maximum flow	Q_{hm} =	788,800 m^3/d

Hydraulic overflow rate	=	20 $m^3/m^2/d$		
Total number of tank	n =	12 units	6 tank x	2 train
Hydraulic load on each tank is	=	448,700 / 12 =	37,392 m^3/d	
Required tank surface area	A =	37,392 / 20 =	1,870 m^2	

(2) Tank Geometry

Internal diameter	D =	49.0 m
Effective depth	d =	4.0 m
Number of basins	n =	12 tanks
Surface area of each tank	A =	1,886 m^2
Hydraulic capacity of each tank	Q_p =	7,544 m^3

Tank Shape and Dimensions

Shape of tank	Circular tank
Number of Units	12 tanks
Internal diameter	49.0 m
Effective depth	4.0 m

1.5 Filtration

(1) Design Bases

Daily average flow	Q_{da} =	448,700 m^3/d
Daily maximum flow	Q_{dm} =	521,200 m^3/d
Hourly maximum flow	Q_{hm} =	788,800 m^3/d
Filtration speed	=	500 m/day

(2) Disc filter

Required surface area	A =	1,578 m
Surface area of filter	a =	114 m^2
Number of filters	n =	16 nos. (2 standby)

Filtration Unit

Filtration	Disc filter
Number of Units	16 nos. (2 standby)
Area of filter	114.0 m^2

2 DESIGN CALCULATIONS OF SLUDGE TREATMENT FACILITIES

2.1 Design Bases

(1) Raw Sludge

Sludge solids production	=	563,025 x 244 x 10^{-6} x 0.50
	=	68,782 kg/d
Solids concentration of sludge	=	2.0 %
Raw sludge generation	=	68,782 / 10 / 2.0 = 3,439 m^3/d

(2) Waste Sludge

The volume of waste sludge can be estimated by the following equation:

$$Q_w \cdot X_w = (a \cdot C_{S\text{-}BOD,\,in} + b \cdot C_{SS,\,in} - c \cdot \theta \cdot X)\,Q_{in}$$

where,

Q_w :	Excess sludge volume (m^3/d)		
X_w :	Average solids concentration of waste sludge	=	0.9 %
Q_{in} :	Inflow rate to reactor basisns	=	559,586 m^3/d
X :	MLSS concentration in reactor basins	=	3,000 mg/L
$C_{S\text{-}BOD,\,in}$:	Influent S-BOD concentration to reactor basins	=	84 mg/L
$C_{SS,\,in}$:	Influent SS concentration to reactor basins	=	122 mg/L
a :	Biomass yield coefficient of S-BOD	=	0.5 mgMLSS/mgBOD
b :	Biomass yield coefficient of SS	=	0.95 mgMLSS/mgSS
c :	Sludge reduction coefficient due to endogenous respiration of micro-organisms	=	0.04 L/d
θ :	Hydraulic retention time (HRT) in reactors	=	17.7 hour

$Q_w X_w$ = 38,793 kg/d

The volume of sludge generated from coagulant can be estimated by the following equation:

X_w = Q_{in} x $C_{SP,\,in}$ x 0.77 x 27 / 31 x 1.5 x 5 / 1(= 16,939 kg/d

where,

Q_{in} :	Design flow	=	521,200 m^3/d
$C_{SP,\,in}$:	Inflow concetration of phosphorous	=	5.0 mg/L

Sludge solids in effluence flow	=	554,132 x 12 x 10^{-6} = 6,650 kg/d
Sludge solids production	=	49,082 kg/d
Solids concentration of sludge	=	0.9 %
Waste sludge generation	=	49,082 / 10 / 0.9 = 5,454 m^3/d

(3) Return Sludge

Sludge return ratio	=	50 %
Return sludge volume	=	559,586 x 0.50 = 279,793 m^3/d = 194 m^3/min

2.2 Gravity Thickener

(1) Design Bases

Input sludge solids	=	68,782 kg/d
Input sludge Volume	=	3,439 m^3/d
Input sludge solids concetration	=	2.0 %
Thicken sludge solids concentrat	=	4.0 %
Solids recovery rate	=	85 %
Solids surface loading	=	50 $kg/m^2/day$
Required surface area	=	1,376 m^2

(2) Tank Geometry

Internal diameter	=	21.0	m
Effective depth	=	4.0	m
Number of tanks	=	4	tanks
Water surface area	=	1,385	m^2

Tank Shape and Dimensions

Internal diameter	21.0	m
Efficent depth	4.0	m
Tank capacity	1,385	m^3
No. of tank units	4	tanks

(3) Thickened Sludge

Output sludge solids	=	58,464	kg/d
Output sludge volume	=	1,462	m^3/d

(4) Side Stream

Sludge solids in side stream	=	10,317	kg/d
Side stream volume	=	1,977	m^3/d

2.3 Mechnical Thickener

(1) Design Bases

Input sludge solids	=	49,082	kg/d
Input sludge volume	=	5,454	m^3/d
Input sludge solids concetration	=	0.9	%
Operation day per week	=	7.0	days
Operation hour per day	=	24.0	hour
Thicken sludge solids concentrat	=	4.0	%
Solids recovery rate	=	95.0	%
Polymer dosing rate	=	0.3	%

(2) Thickening Machine

Required capacity	=	227	m^3/hour
Capacity of thickening machine	=	40.0	m^3/hour
Number of thickening machine	=	7.0	nos. (1 standby)

(3) Thickened Sludge

Output sludge solids	=	46,768	kg/d
Output sludge volume	=	1,169	m^3/d

(4) Side Stream

Sludge solids in side stream	=	2,461	kg/d
Side stream volume	=	4,284	m^3/d

Specification of Thickening Machine

Type	Belt thickening	
Capacity	40	m^3/hour
No. of thickening machine	7	nos. (1 standby)

2.4 Anaerobic Digester

(1) Design Bases

Thicken sludge from gravity thickner and mechanical thickener

Input sludge solids	=	105,232	kg/d

Input sludge volume	=	2,631	m^3/d
Input sludge solids concetration	=	4.0	%
Hydraulic retention time of prim	=	20	days
Sludge heating temperature	=	35	C
Volatile material contents	=	70	%
Digestion rate	=	50	%
Required digester capacity	=	52,616	m^3
Gas production rate (average)	=	0.50	m^3/kg-vs
Gas production rate (maximum)	=	0.60	m^3/kg-vs
Gas calorific value	=	21,000	kJ/m3

(2) Tank Geometry

Number of tanks	=	8	tanks
Digester tank capacity	=	6,577	m^3

Tank Shape and Dimensions

Tank capacity	6,577 m^3
No. of tank units	8 tanks

(3) Digested Sludge

Digested sludge solids = 105,232 x (1.0 - 0.7 x 0.5) = 68,401 kg/d

Digested sludge volume = 2,631 m^3/d

Digested sludge solids concetratic = 2.6 %

(4) Gas Holder

Maximun gas production = 105,232 x 0.7 x 0.60

= 44,198 m^3/d

Gas retention time in tank = 6 hr

Storage capacity = 44,198 x 6 / 24 = 11,049 m^3/d

Specification of Gas Holder

Type	Water Seal Type
Diameter	16.5 m
Height	22.9 m
Tank capacity	3,000 m^3
No. of Gas Holder	4 tanks

(5) Biogas Generator

Aerage gas production = 105,232 x 0.7 x 0.50

= 36,831 m^3/d

Gas calorific value = 21,000 kJ/m^3

Total gas energy production = 773,457 MJ/day

Power production efficiency = 35 %

Possible electric power production = 75,197 kWh/day = 3,133 kW

Number of biogas generator = 4 nos.

Capacity of biogas generator = 1,000 kWh

Specification of Biogas Generator

Type	Biogas Generator
Capacity	1000 kW
Power generation efficiency	35 %
Total heat energy usage efficiency	30 %
No. of generator set	4 nos.

4.5 Mechnical Dewatering

(1) Design Bases

Digested sludge from anaerobic digester

Input sludge solids	=	68,401	kg/d
Input sludge volume	=	2,631	m^3/d
Input sludge solids concetration	=	2.6	%
Operation day per week	=	7.0	days
Operation hour per day	=	24.0	hour
Moisture content of sludge cake	=	79.0	%
Solids recovery rate	=	95.0	%
Polymer dosing rate	=	1.5	%

(2) Dewatering Machine

Filtration rate (Dia.1000m)	=	836	kg-DS/hour
Number of dewatering machine	=	5.0	nos. (1 standby)

(3) Sludge Cake

Solid content of sludge cake	=	65,956	kg/d
Volume of sludge cake	=	314	m^3/d

(4) Side Stream

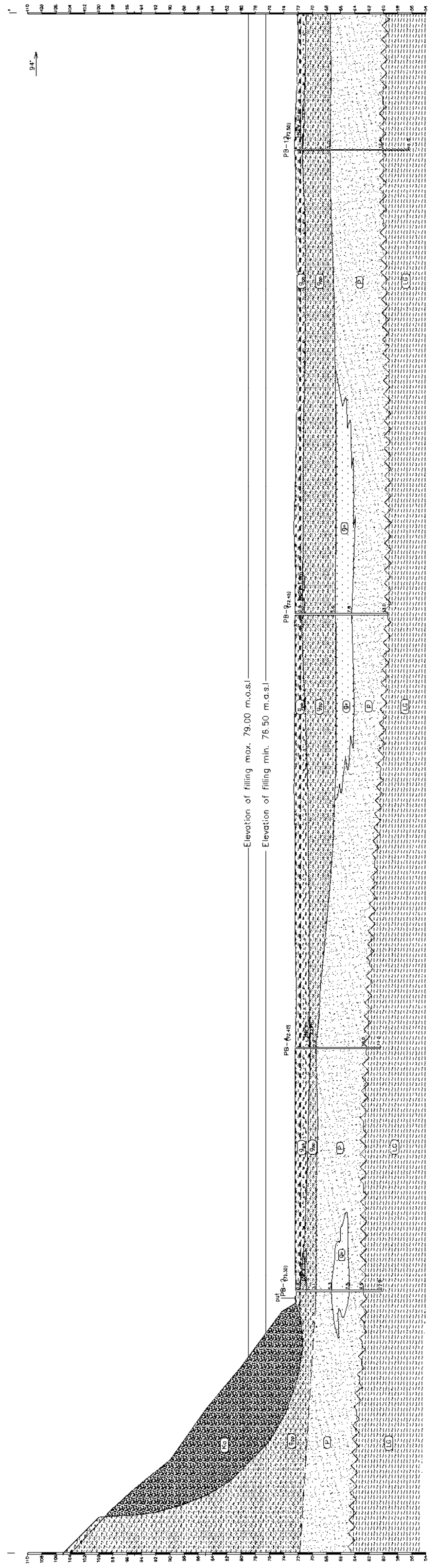
Sludge solids in side stream	=	3,471	kg/d
Side stream volume	=	2,317	m^3/d

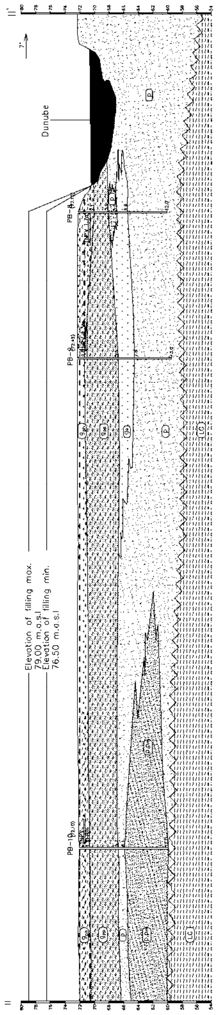
Specification of Dewatering Machine

Type	Screw press dewaterning
Capacity (diameter)	1,000 mm
No. of dewatering machine	5 nos. (1 standby)

4. Soil Condition

Summary of current survey documents “Geological and geotechnical documentation as a basis for the Preliminary design for the construction of wastewater treatment plants - "Veliko Selo"” in 2007” (information only)





LEGEND SORTED ENGINEERING–GEOLOGICAL UNITS

GEOL. AGE	Name and description of lithology complex		PROPERTIES OF THE LITOLOGY COMPLEX
QUATERNARY	g_{ph}	SANDY DUST	Arable layer in the surface layer, dark brown, easily crushed, interganular porosity.
	g_{pp}	DASTY CLAY	Darkly brown color, with a higher content of organic matter, with few concretions of CaCO3, 1–2 mm in size and remains shell fauna, with local limonite in mind rarer cover, tubular pores. The floor seam section is equal to the limonite as a cover, with gray jets, wet, capillary porosity, light brown to gray–brown in color.
	go	ORGANIC CLAY	Silty clay, light gray, moist, soft, and capillary porosity.
	p	SAND	Light gray, mostly fine–grained, uniform dusty, intergranular porosity, saturated with water
	p,pm	SAND	Light gray, mostly fine–grained, locally with layers of sandy silt in the area of 6.2–6.4m 8.0–8.2m. Intergranular porosity, saturated with water.
NEOGEN	LG	MARLY CLAY	Gray – brown uniform with limonite, with CaCO3 in the form of powder locally hardened. Clay irregular fragmented system of fissures and cracks, hard, dusty–consolidated.

OTHER SYMBOLS

	Defined boundaries of lithology complex
NPV	Groundwater level
PB – $2_{(72.30)}$ NPV	Wells taken from existing documentation and labeled with the elevation of the terrain and the level of groundwater.
	Elevation of filling max. 79.00 m.a.s.l
	Elevation of filling min. 76.50 m.a.s.l
Ka	Drift from active landslide

Silty sand) (g_{ph}), the highly humidified near to surface part of the terrain (arable layer), where the participation of the roots of and venation of plants in the different stages of decomposition, is intense. The determined thickness of the layer was from 0.8 to 2.1 m. This layer is of heterogeneous lithological composition, with irregular ratio of clay, dust and sand fractions (in the zone closer to Dunavac is dominant the share fine sand fraction). Dust is easily crushed, of pseudo fracture porosity, with the local participation of residual small, tubular, porosity, and in the part where the share of the sandy fraction is dominant, the intergranular type of porosity is represented.

Newly performed laboratory tests

Bulk density

naturally moist .... **g** = 20.6 kN/m^3

dry.. g_d = 16.3 kN / m^3

Shearing strength

angle of internal friction .... **f** = 24˚

cohesion .... c .. = 7kN/m^2

Static penetration test .... Ckd = 2 - 2.5 Mpa

Silty clay (GPP), of heterogeneous lithological composition, with irregular and uneven participation and clay and silty components, with locally higher content of sandy fraction and muddy clay in the form of irregular interlayers or layers whose presence is significantly in the area of the old still waters and swamps. Clay is determined directly under a layer of silty sand (dust) (gph) at a depth of 0.8 to 2.1 m, with determined thickness of 1.8 to 4.8 set m. Clay is of massive structure, with local, poorly-defined, layering, in the zone of oscilating of groundwater of significant pseudo fracture porosity along which it crumbles easily under your fingers into small monoliths, mostly middle plastic, easy to difficult to squash, unconsolidated to poorly consolidated, more compressible, of relatively uniform resistance characteristics.

By geomechanical laboratory testing were determined the following values of physical and mechanical sediment parameters of this facies:

Previously performed laboratory tests

Bulk weight

naturally moist .... **g** = 19.0 to 19.5 kN/m^3

dry .... g_d = 13.0 to 15.6 kN/m^3

Shear strength

angle of internal friction .... **f**=18-24˚

cohesion .... c= 12 - 18kN/m^2

Oedometer compressibility test

compressibility modulus for the specified range of load

• naturally moist

$M_{s\ (100-200)}$ = 4 000-7 000kN/m^2

• underwater

$M_{s\ (100\text{-}200)}$ = 3 000-5 500kN/m^2

Filtration coefficient .... k^f=10^{-4}-10^{-6}cm/sec

The newly performed laboratory tests

Bulk weight

naturally moist .... **g** = 15.1 to 16.6 kN/m^3

dry .... $\mathbf{g_d}$ = 12.4 to 13, 4kN/m^3

Shearing strength

angle of internal friction .... **f**= 18-19 ˚

cohesion .... c = 10kN/m^2

Filtration coefficient .... k_f= 10^{-6}-10^{-7}cm/sec

Dynamic penetration test

Number of strokes .... N = 5-14

Static penetration tests .... CKD = 0,5- 7 MPa;

Riverbed facies (ak)

Riverbed facies (a_k) is represented by close-grained sand to silty sand (p_p), close-grained sand to medium-grained (p) and gravel sand (P_{sh}).

Close-grained to silty sand (p_p), build the highest parts of trough facies, immediately below the flood facies. Sand is mostly poorly granulated, locally inconsistently mud silted (p_m), unbound, intergranulary porous, of gray-blue color, constantly saturated with water.

By geomechanical laboratory testing the following values of physical and mechanical sediment parameters of this facies were determined:

Previously performed laboratory tests

Bulk density

naturally moist .... **g** = 18,5 -19,7 kN/m^3

dry .... $\mathbf{g_d}$ = 13,2 -15,0 kN/m^3

Shear strength

angle of internal friction .... **f**= 18-22 ˚

cohesion .... c = 0-5kN/m^2

Oedometer compressibility test

compressibility modules for the specified range of load

- naturally moist

$M_{s\ (100\text{-}200)}$ = 5 500-7 000kN/m^2

Filtration coefficient

k_f = 10^{-3}cm/sec

The newly performed laboratory tests

Bulk weight

naturally moist .... **g** = 15,1 – 16,6 kN/m^3

dry .... **gd** = 12,4 - 13, 4kN/m^3

Shear strength

angle of internal friction .... **f**=18-19 ˚

cohesion .... c = 10kN/m^2

Oedometar compressibility test

compressibility modules for the specified range of load

• naturally moist

$M_{s(100-200)}$ = 5 500-7 000kN/m^2

Filtration coefficient .... k_f= 10^{-5}-10^{-6}cm/sec

Dynamic penetration test

Number of strokes .... N = 12-14

Static penetration test .... Ckd = 1,5-3MPa

Note: for the needs of higher levels of design (main construction project) is necessary to conduct vulnerability assessment of this layer to suffosion and liquefaction.

Sand (p), close to medium grained, with depth the participation of coarse grained fractions is increasing. The sand is poorly clayed (up to 5% clay), sharp under fingers, of intergranular porosity, loose, well-compacted, more water permeable, permanently saturated with water.

By geomechanical laboratory testing the following values of physical and mechanical sediment parameters of this facies are determined:

Previously performed laboratory tests

Bulk weight

naturally moist .... **g** = 18,7 to 19,7 kN/m^3

Shear strength

angle of internal friction .... **f**= 26-30 ˚

cohesion

c = 0 -10kN/m^2

Oedometer compressibility test

compressibility modules for the specified range of load

• naturally moist

$M_{s(100-200)}$ = 8 000-12 000kN/m^2

Filtration coefficient

k_f = 10^{-2}cm/sec

<u>The newly performed laboratory tests</u>

Bulk weight

naturally moist .... **g** = 15,1 to 16,6 kN/m^3

dry .... **gd** = 12,4 to 13, 4kN/m^3

Shear strength

angle of internal friction .... **f**= 18-19 °

cohesion .... c = 10kN/m^2

Oedometer compressibility test

compressibility modules for the specified range of load

• naturally moist

$M_{s(100-200)}$ = 5 500-7 000kN/m^2

Filtration coefficient .... kf= 10^{-2}-10^{-6}cm/sec

Dynamic penetration test

Number of strokes .... N = 12-28

Static penetration tests .... Ckd = 3-11MPa

Gravelly sand (psh), builds the lowest parts of the alluvial sediments, as determined in previous research in the immediate surroundings of the investigated space, while in the latest research this layer was not determined. The sand is medium grained to coarse, well granulated, with uneven and irregular participation of gravel components (participation of gravel component ranges up to 65%). Gravel is well rounded, up to 2 cm (rarely up to 5 cm), of heterogeneous petrographic composition mainly of limestone. The soil is unbouned, more water permeable, and is suitable as a building material.

By geomechanical laboratory testing the following values of physical and mechanical sediment parameters of this facies were determined:

<u>Previously performed laboratory tests</u>

Bulk weight

naturally moist .... **g** = 19,5 to 21,0 kN/m^3

Shear strength

angle of internal friction .... **f**= 28-33 °

cohesion .... c = 0kN/m^2

Oedmeter compressibility test

compressibility module for the specified range of load

• naturally moist

$M_{s(100-200)}$ = 10 000-18 000kN/m^2

Filtration coefficient

k_f = 10^{-2}cm/sec

Tertiary age sediments

Tertiary age sediments build the geological terrain in the area designated for the construction of wastewater treatment plant – Veliko selo and they are presented by marl-clay sediments, which are characterized by heterogeneous composition and irregular and frequent changes of lithological members in horizontal and vertical directions. The newly performed tests in exploratory holes B-and-B, as well as the static penetration tests confirmed the presence of marl clay at a depth of..... m.

Marly clay (LG), determined on the depth of 9.5 to 13.9 m, intensive physical-chemically and mechanically modified in near to surface part of the layer ("weathering crust"), lowered values of shear strength parameters. In this part of the layer fissure-crack system is presented, along which the CaCO3 powder is precipitated in the form of accumulation, locally hardened due to groundwater circulation. Along this system is the extensively precipitation of Fe and Mn in the form of spots and films, and in the zone of significant limonitization in the form of small oolites. Determined thickness of the zone change is up to 2m. The main mass is hard, preconsolidated ,of favorable physical and mechanical characteristics.

Chapter 7 Cost Estimation and Implementation Schedule

1. Estimated Project Cost of All Components

Item Description		Amount (Euro)		Total Amount (Euro)
		L.C	F.C	
1	**Construction Cost**			
A	Veliko Selo WWTP			
-A1	Site preparation work			
	Civil & Architecture works	15,386,000	0	15,386,000
	Sub Total of -A1	**15,386,000**	**0**	**15,386,000**
-A2	Lift pump facility			
	Civil works	1,278,000	0	1,278,000
	Architecture works	71,000	0	71,000
	Mechanical works	858,000	4,455,000	5,313,000
	Electrical works	317,000	1,645,000	1,962,000
	Sub Total of -A2	**2,524,000**	**6,100,000**	**8,624,000**
-A3	Pretreatment facility			
	Civil works	1,892,000	0	1,892,000
	Architecture works	92,000	0	92,000
	Mechanical works	237,000	1.231,000	1,468,000
	Electrical works	33,000	171,000	204,000
	Sub Total of -A3	**2,254,000**	**1,402,000**	**3,656,000**
-A4	Primary settling tank			
	Civil works	5,537,000	0	5,537,000
	Mechanical works	236,000	1,226,000	1,462,000
	Electrical works	74,000	386,000	460,000
	Sub Total of -A4	**5,847,000**	**1,612,000**	**7,459,000**
-A5	Bioreactor			
	Civil works	25,674,000	0	25,674,000
	Mechanical works	1,912,000	9,925,000	11,837,000
	Electrical works	166,000	861,000	1,027,000
	Sub Total of -A5	**27,725,000**	**10,786,000**	**38,511,000**
-A6	Blower facility			
	Civil works	857,000	0	857,000
	Architecture works	179,000	0	179,000
	Mechanical works	428,000	2,221,000	2,649,000
	Electrical works	380,000	1,973,000	2,353,000
	Sub Total of -A6	**1,844,000**	**4,194,000**	**6,038,000**
-A7	Secondary settling tank			
	Civil works	8,307,000	0	8,307,000
	Architecture works	116,000	0	116,000
	Mechanical works	575,000	2,985,000	3,560,000
	Electrical works	83,000	429,000	512,000
	Sub Total of -A7	**9,081,000**	**3,414,000**	**12,495,000**
-A8	Filtration			
	Civil works	964,000	0	964,000
	Architecture works	56,000	0	56,000
	Mechanical works	1,226,000	6,363,000	7,589,000
	Electrical works	105,000	550,000	655,000
	Sub Total of -A8	**2,351,000**	**6,913,000**	**9,264,000**
-A9	Gravity thickener			
	Civil works	759,000	0	759,000
	Mechanical works	72,000	372,000	444,000

Item Description		Amount (Euro)		Total Amount (Euro)
		L.C	F.C	
	Electrical works	11,000	55,000	66,000
	Sub Total of -A9	**842,000**	**427,000**	**1,269,000**
-A10	Anaerobic digester			
	Civil works	23,410,000	0	23,410,0000
	Architecture works	814,000	0	814,000
	Mechanical works	2,131,000	11,059,000	13,190,000
	Electrical works	67,000	349,000	416,000
	Sub Total of -A10	**26,422,000**	**11,408,000**	**37,830,000**
-A11	Sludge treatment facility			
	Civil works	31,000	0	31,0000
	Architecture works	1,297,000	0	1,297,000
	Mechanical works	740,000	3,842,000	4,582,000
	Electrical works	209,000	1,083,000	1,292,000
	Sub Total of -A11	**2,277,000**	**4,925,000**	**7,202,000**
-A12	Pipe work			
	Civil works	6,418,000	14,386,000	20,804,000
	Sub Total of -A12	**6,418,000**	**14,386,000**	**20,804,000**
-A13	Administration building			
	Architecture works	1,626,000	0	1,626,000
	Electrical works	260,000	3,937,000	4,197,000
	Sub Total of -A13	**1,886,000**	**3,937,000**	**5,823,000**
-A14	Substation and generator building			
	Architecture works	844,000	0	844,000
	Electrical works	781,000	5,275,000	6,056,000
	Sub Total of -A14	**1,625,000**	**5,275,000**	**6,900,000**
-A15	Cogeneration building			
	Architecture works	316,000	0	316,000
	Electrical works	357,000	1,853,000	2,210,000
	Sub Total of -A15	**673,000**	**1,853,000**	**2,526,000**
-A16	Landscaping work			
	Civil works	2,015,000	0	2,015,000
	Sub Total of -A16	**2,015,000**	**0**	**2,015,000**
	Sub Total of A	**109,170,000**	**76,632,000**	**185,802,000**
	Civil works	**92,501,000**	**14,386,000**	**106,887,000**
	Architecture works	**5,411,000**	**0**	**5,411,000**
	Mechanical works	**8,415,000**	**43,679,000**	**52,094,000**
	Electrical works	**2,843,000**	**18,567,000**	**21,410,000**
B	Interceptor			
-B1	Interceptor No.1			
	Civil works	6,416,000	4,623,000	11,039,000
	Sub Total of -B1	**6,416,000**	**4,623,000**	**11,039,000**
-B2	Interceptor No.2			
	Civil works	3,981,000	351,000	4,332,000
	Sub Total of -B2	**3,981,000**	**351,000**	**4,332,000**
-B3	Interceptor No.3			
	Civil works	7,752,000	0	7,752,000
	Sub Total of -B3	**7,752,000**	**0**	**7,752,000**
-B4	Interceptor No.4			
	Civil works	9,752,000	0	9,752,000
	Sub Total of -B4	**9,752,000**	**0**	**9,752,000**
-B5	Interceptor No.6			
	Civil works	3,874,000	10,587,000	14,461,000
	Sub Total of -B5	**3,874,000**	**10,587,000**	**14,461,000**

Item Description		Amount (Euro)		Total Amount (Euro)
		L.C	F.C	
-B6	Interceptor No.10 included collector			
	Civil works	5,957,000	18,906,000	24,863,000
	Sub Total of -B6	**5,957,000**	**18,906,000**	**24,863,000**
	Sub Total of B	**37,732,000**	**34,467,000**	**72,199,000**
	Civil Works	**37,732,000**	**34,467,000**	**72,199,000**
C	Pumping station			
-C1	Usce pumping station			
	Civil works	2,216,000	149,000	2,365,000
	Architecture works	503,000	0	503,000
	Mechanical works	261,000	1,354,000	1,615,000
	Electrical works	228,000	1,303,000	1,531,000
	Sub Total of -C1	**3,208,000**	**2,806,000**	**6,014,000**
-C2	Mostar pumping station			
	Civil works	490,000	0	490,000
	Architecture works	242,000	0	242,000
	Mechanical works	206,000	1,068,000	1,274,000
	Electrical works	214,000	1,232,000	1,446,000
	Sub Total of -C2	**1,152,000**	**2,300,000**	**3,452,000**
	Sub Total of C	**4,360,000**	**5,106,000**	**9,466,000**
	Civil works	**2,706,000**	**149,000**	**2,855,000**
	Architecture works	**745,000**	**0**	**745,000**
	Mechanical works	**467,000**	**2,422,000**	**2,889,000**
	Electrical works	**442,000**	**2,535,000**	**2,977,000**
	Sub Total of Construction Cost	**151,262,000**	**116,205,000**	**267,467,000**
	Civil works	**132,939,000**	**49,002,000**	**181,941,000**
	Architecture works	**6,156,000**	**0**	**6,156,000**
	Mechanical works	**8,882,000**	**46,101,000**	**54,983,000**
	Electrical works	**3,285,000**	**21,102,000**	**24,387,000**
2	**Administration Cost**			
	Administration Cost	16,799,000	0	16,799,000
	Sub-Total	**16,799,000**	**0**	**16,799,000**
3	**Consulting Cost**			
	Base cost	6,334,000	7,669,000	14,003,000
	Price escalation	601,000	712,000	1,313,000
	Physical contingency	347,000	419,000	766,000
	Sub-Total	**7,282,000**	**8,800,000**	**16,082,000**
4	**Physical Contingency for construction**			
	Physical contingency	8,456,000	6,562,000	15,018,000
	Sub-Total	**8,456,000**	**6,562,000**	**15,018,000**
5	**Price Escalation for construction**			
	Price escalation	16,726,000	13,522,000	30,248,000
	Sub-Total	**16,726,000**	**13,522,000**	**30,248,000**
6	**Land Acquisition**			
	Base cost	6,816,000	0	6,816,000
	Price escalation	136,000	0	136,000
	Physical contingency	348,000	0	348,000
	Sub-Total	**7,300,000**	**0**	**7,300,000**
7	**Interest During Construction**			
	Interest during construction (const)	0	14,109,000	14,109,000
	Interest during construction (consul)	0	7,000	7,000
	Sub-Total	**0**	**14,116,000**	**14,116,000**
8	**Commitment Charge**			
	Commitment Charge	0	2,742,000	2,742,000

Item Description	Amount (Euro)		Total Amount (Euro)
	L.C	F.C	
Sub-Total	**0**	**2,742,000**	**2,742,000**
9 Tax			
VAT	67,198,000	0	67,198,000
Sub-Total	**67,198,000**	**0**	**67,198,000**
Total of 1+2+3+4+5+6+7+8+9	**275,023,000**	**161,947,000**	**436,970,000**
(including TAX)			
Total of 1+2+3+4+5+6+7+8	**207,825,000**	**161,947,000**	**369,772,000**
(excluding TAX)			

2. Estimated Project Cost of Phase-1 Project

Item Description		Amount (Euro)		Total Amount (Euro)
		L.C	F.C	
1	**Construction Cost**			
A	Veliko Selo WWTP			
-A1	Site preparation work			
	Civil & Architecture works	12,163,000	0	12,163,000
	Sub Total of -A1	**12,163,000**	**0**	**12,163,000**
-A2	Lift pump facility			
	Civil works	1,287,000	0	1,287,000
	Architecture works	71,000	0	71,000
	Mechanical works	467,000	2,424,000	2,891,000
	Electrical works	158,000	822,000	980,000
	Sub Total of -A2	**1,983,000**	**3,246,000**	**5,229,000**
-A3	Pretreatment facility			
	Civil works	1,923,000	0	1,923,000
	Architecture works	92,000	0	92,000
	Mechanical works	181,000	939,000	1,120,000
	Electrical works	16,000	86,000	102,000
	Sub Total of -A3	**2,212,000**	**1,025,000**	**3,237,000**
-A4	Primary settling tank			
	Civil works	2,872,000	0	2,872,000
	Mechanical works	118,000	613,000	731,000
	Electrical works	37,000	193,000	230,000
	Sub Total of -A4	**3,027,000**	**806,000**	**3,833,000**
-A5	Bioreactor			
	Civil works	13,459,000	0	13,459,000
	Mechanical works	956,000	4,962,000	5,918,000
	Electrical works	83,000	431,000	514,000
	Sub Total of -A5	**14,498,000**	**5,393,000**	**19,891,000**
-A6	Blower facility			
	Civil works	444,000	0	444,000
	Architecture works	89,000	0	89,000
	Mechanical works	214,000	1,110,000	1,324,000
	Electrical works	190,000	986,000	1,176,000
	Sub Total of -A6	**937,000**	**2,096,000**	**3,033,000**
-A7	Secondary settling tank			
	Civil works	4,416,000	0	4,416,000
	Architecture works	58,000	0	58,000
	Mechanical works	288,000	1,493,000	1,781,000
	Electrical works	41,000	215,000	256,000
	Sub Total of -A7	**4,803,000**	**1,708,000**	**6,511,000**
-A8	Filtration			
	Civil works	1,014,000	0	1,014,000
	Architecture works	56,000	0	56,000
	Mechanical works	618,000	3,206,000	3,824,000
	Electrical works	95,000	493,000	588,000
	Sub Total of -A8	**1,783,000**	**3,699,000**	**5,482,000**
-A9	Gravity thickener			
	Civil works	394,000	0	394,000
	Mechanical works	38,000	197,000	235,000
	Electrical works	5,000	27,000	32,000
	Sub Total of -A9	**437,000**	**224,000**	**661,000**
-A10	Anaerobic digester			

Item Description		Amount (Euro)		Total Amount (Euro)
		L.C	F.C	
	Civil works	11,817,000	0	11,817,000
	Architecture works	407,000	0	407,000
	Mechanical works	1,065,000	5,530,000	6,595,000
	Electrical works	34,000	174,000	208,000
	Sub Total of -A10	**13,323,000**	**5,704,000**	**19,027,000**
-A11	Sludge treatment facility			
	Civil works	75,000	0	75,000
	Architecture works	1,297,000	0	1,297,000
	Mechanical works	484,000	2,514,000	2,998,000
	Electrical works	177,000	918,000	1,095,000
	Sub Total of -A11	**2,033,000**	**3,432,000**	**5,465,000**
-A12	Pipe work			
	Civil works	4,601,000	7,119,000	11,720,000
	Sub Total of -A12	**4,601,000**	**7,119,000**	**11,720,000**
-A13	Administration building			
	Architecture works	1,626,000	0	1,626,000
	Electrical works	205,000	2,745,000	2,950,000
	Sub Total of -A13	**1,831,000**	**2,745,000**	**4,576,000**
-A14	Substation and generator building			
	Architecture works	844,000	0	844,000
	Electrical works	427,000	3,438,000	3,865,000
	Sub Total of -A14	**1,271,000**	**3,438,000**	**4,709,000**
-A15	Cogeneration building			
	Architecture works	316,000	0	316,000
	Electrical works	179,000	927,000	1,106,000
	Sub Total of -A15	**495,000**	**927,000**	**1,422,000**
-A16	Landscaping work			
	Civil works	2,015,000	0	2,015,000
	Sub Total of -A16	**2,015,000**	**0**	**2,015,000**
	Sub Total of A	**67,412,000**	**41,562,000**	**108,974,000**
	Civil works	**56,480,000**	**7,119,000**	**63,599,000**
	Architecture works	**4,856,000**	**0**	**4,856,000**
	Mechanical works	**4,429,000**	**22,988,000**	**27,417,000**
	Electrical works	**1,647,000**	**11,455,000**	**13,102,000**
B	Interceptor			
-B1	Interceptor No.4			
	Civil works	9,752,000	0	9,752,000
	Sub Total of -B1	**9,752,000**	**0**	**9,752,000**
-B2	Interceptor No.6			
	Civil works	3,874,000	10,587,000	14,461,000
	Sub Total of -B2	**3,874,000**	**10,587,000**	**14,461,000**
-B3	Interceptor No.10 included collector			
	Civil works	5,957,000	18,906,000	24,863,000
	Sub Total of -B3	**5,957,000**	**18,906,000**	**24,863,000**
	Sub Total of B	**19,583,000**	**29,493,000**	**49,076,000**
	Civil Works	**19,583,000**	**29,493,000**	**49,076,000**
C	Pumping station			
-C1	Mostar pumping station			
	Civil works	490,000	0	490,000
	Architecture works	242,000	0	242,000
	Mechanical works	206,000	1,068,000	1,274,000
	Electrical works	214,000	1,232,000	1,446,000
	Sub Total of -C1	**1,152,000**	**2,300,000**	**3,452,000**

Item Description	Amount (Euro)		Total Amount (Euro)
	L.C	F.C	
Sub Total of C	**1,152,000**	**2,300,000**	**3,452,000**
Civil works	490,000	0	490,000
Architecture works	242,000	0	242,000
Mechanical works	206,000	1,068,000	1,274,000
Electrical works	214,000	1,232,000	1,446,000
Sub Total of Construction Cost	**88,147,000**	**73,355,000**	**161,502,000**
Civil works	**76,553,000**	**36,612,000**	**113,165,000**
Architecture works	**5,098,000**	**0**	**5,098,000**
Mechanical works	**4,635,000**	**24,056,000**	**28,691,000**
Electrical works	**1,861,000**	**12,687,000**	**14,548,000**
2 Administration Cost			
Administration Cost	10,608,000	0	10,608,000
Sub-Total	**10,608,000**	**0**	**10,608,000**
3 Consulting Cost			
Base cost	6,344,000	7,669,000	14,003,000
Price escalation	601,000	712,000	1,313,000
Physical contingency	347,000	419,000	766,000
Sub-Total	**7,282,000**	**8,800,000**	**16,082,000**
4 Physical Contingency for construction			
Physical contingency	4,895,000	4,095,000	8,990,000
Sub-Total	**4,895,000**	**4,095,000**	**8,990,000**
5 Price Escalation for construction			
Price escalation	9,747,000	8,536,000	18,283,000
Sub-Total	**9,747,000**	**8,536,000**	**18,283,000**
6 Land Acquisition			
Base cost	6,816,000	0	6,816,000
Price escalation	136,000	0	136,000
Physical contingency	348,000	0	348,000
Sub-Total	**7,300,000**	**0**	**7,300,000**
7 Interest During Construction			
Interest during construction (const)	0	8,516,000	8,516,000
Interest during construction (consul)	0	7,000	7,000
Sub-Total	**0**	**8,523,000**	**8,523,000**
8 Commitment Charge			
Commitment Charge	0	1,707,000	1,707,000
Sub-Total	**0**	**1,707,000**	**1,707,000**
9 Tax			
VAT	42,430,000	0	42,430,000
Sub-Total	**42,430,000**	**0**	**42,430,000**
Total of 1+2+3+4+5+6+7+8+9	**170,409,000**	**105,016,000**	**275,425,000**
(including TAX)			
Total of 1+2+3+4+5+6+7+8	**127,979,000**	**105,016,000**	**232,995,000**
(excluding TAX)			

Chapter 8 Financial Analysis and Economic Analysis and Institution

1. Willingness To Pay Survey Formats

(1) English Version

Interviewer will explain the purpose the survey as follows;

"This interview is to ask the residents of the city of Beograd to measure their person value for the proposed new project of a sewerage treatment plan, Veliko Selo. The interviewer will tell the respondent, "The interview will take about ten minutes or less. If you spare the time, your answers will greatly support accurate social evaluation of the project. The information you will provide us will be treated anonymous and confidential and will be used only for project evaluation purpose"

Q 0. Is your house connected to sewer system now? 1. Yes 2. No

Q 1. Do you know how much your family pays per month for water and sewerage service from the city? 1. Yes 2. No

Q2. If "yes " in Q1, How much is it ? RSD

Q3. How do you perceive the current tariff? 1. Appropriate, 2. Very Affordable, 3. Expensive,

Q4. At present, all the collected sewage is directly discharged to the Danube River. The proposed project is aimed at cleaning the effluent and to discharge to the river. Naturally, if the project is implemented the cost of sewage treatment will increase. Would you accept the increase of 50% to the current tariff of water and sewage combined? 1 Yes 2. No

-□ If Yes, then would you accept 75% increase?

-□ If No, then would you accept 25% increase?

Q5.

Q6. The establishment of sewerage treatment capacity has another social importance in terms of accession to EU. The environmental compliance to EC directives is a prerequisite to the accession. Acknowledging this fact, what would be your final answer to your acceptable increases in terms of percentage?

%

Please give us your brief profile:

Occupation

Age

Number of family members sharing the same water source

Date: Signature

(2) Serbian Version

Spremnost na plaćanje za projekat postrojenja Veliko Selo

Anketar će objasniti svrhu ankete prema sledećem;
"Ovaj upitnik je namenjen stanovnicima grada Beograda da oceni ličnu vrednost predloženog projekta za postrojenje za tretman otpadnih voda Veliko Selo. Anketa traje 10 minuta ili kraće. Ukoliko imate slobodno vreme, vaši odgovori će biti važna podrška preciznoj sociološkoj proceni projekta. Informacije koje ćete nam dati biće tretirane kao anonimne i poverljive i biće korišćene samo za svrhu evaluacije projekta"

Q 0. Da li je vaše domaćinstvo priključeno na kanalizacionu mrežu? 1. Da 2. Ne

Q 1. Da li ste upoznati sa tim koliko vaša porodica plaća mesečno za usluge vode i kanalizaciju gradu? 1. Da 2. Ne

Q 2. Ukoliko "da " u Q1, koliko iznosi ? RSD/mesecno

Q 3. Kako Vi vidite trenutne tarife? 1. odgovarajuće, 2. povoljne, 3. skupe

Q 4. Trenutno, sva otpadna voda se direktno ispušta u reku Dunav bez tretmana. Predloženi projekat ima za cilj tretiranje otpadne vode i ispuštanje prečišćene vode u reku. Naravno, ukoliko se projekat sprovede, troškovi tretiranja otpadne vode iz kanalizacije će se povećati.
a Da li ste upoznati sa činjenicom da se otpadne vode iz gradske kanalizacije ispuštaju bez bilo kakve prerade u reku Dunav? 1. Da 2. Ne
b. Da li bi ste bili spremni da prihvatite povećanje od 50% na trenutnu tarifu koju plaćate za vodu i kanalizaciju kombinovano? 1 Da 2. Ne
b1. Ukoliko da, da li bi ste prihvatili 75% uvećanja? 1 Da 2. Ne
b2. Ukoliko ne, da li bi ste prihvatili 25% uvećanja? 1 Da 2. Ne

Q 5. Uspostavljanje tretmana otpadnih voda iz kanalizacionog sistema ima još jedan društveni aspekt u smislu podrške pridruživanja EU. Uspostavljanje standarda zaštite životne sredine u skladu sa zakonodavstvom EU je jedan od preduslova pristupanju EU. Imavši na umu ovu činjenicu, koji bi bio Vaš konačni odgovor za prihvatljivo povećanje cene u smislu procenta,? %

Q 6. Molimo Vas samo osnovne podatke o Vama:
a) zanimanje

b) **godište**

c) **broj članova istog domaćinstva koja koristi usluge vode i kanalizacije**

d) **lokacija stanovanja**

2. Willingness To Pay Survey Results

(1) The Results of Willingness To Pay

The results of the willingness to pay are shown in Table 1.

The question is asked after explaining the current sewage disposal into the rivers and positive environmental impacts to be brought out by the Project, “How much are you willing to pay more in addition to the current payment for water and sewerage services?”

Table shows the distribution of the responses which are listed in the descending order. The cumulative distribution shows the share of the responses with WTP values equal or higher to the particular WTP. For example, the benchmark of 25% more WTP bracket has a cumulative distribution of 79.4%. It means that 79.4% of the respondents are willing to pay no less than 25% for the Project benefits.

Table 1 Results of Willingness to Pay For Project

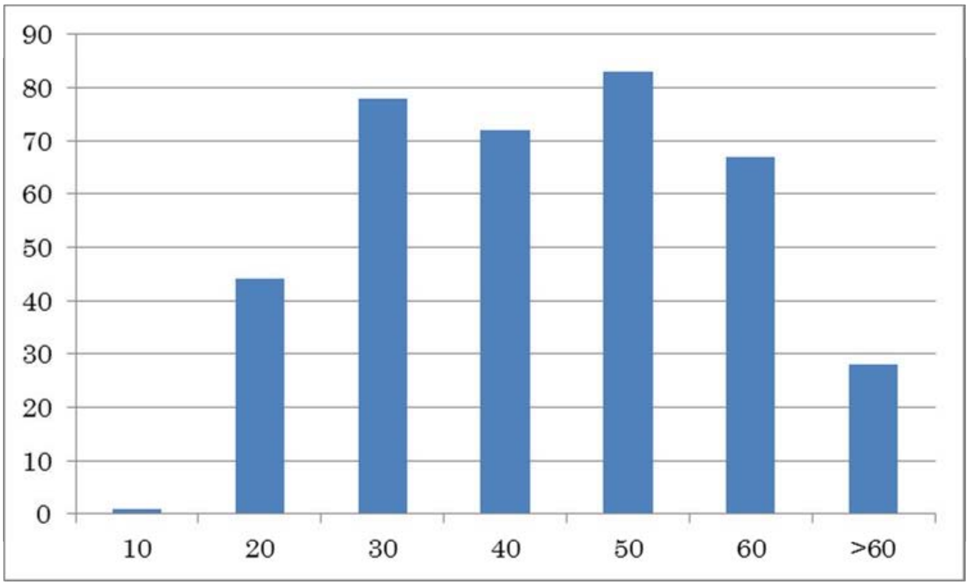
WTP	Number of	Share of Total	Cumulative
100%	36	10%	10%
90%	1	0%	10%
80%	5	1%	11%
75%	56	15%	26%
65%	1	0%	26%
60%	8	2%	29%
50%	131	35%	64%
35%	2	1%	64%
30%	9	2%	67%
27%	1	0%	67%
25%	47	13%	79.4%
20%	3	1%	80%
15%	5	1%	82%
10%	15	4%	86%
5%	5	1%	87%
2%	3	1%	88%
1%	3	1%	89%
0%	43	11%	100%
Total	374	100%	100%

Source: WTP Survey by JICA Study Team

(2) Profile of Respondents

Age Distribution

The age distribution of the respondent in Figure 1 shows relative wide coverage of age groups for the survey.



Source: WTP Survey by JICA Study Team

Figure 1 Age Distribution of Respondents

Employment Situation

Table 2 shows the job retention situation of the respondents. 27% of the respondents do not have jobs, being unemployed, students or retired.

Table 2 Employment Situation of Respondents

No job	102	27%
Job	269	73%
Total	371	100%

Source: WTP Survey by JICA Study Team

Sewer Connections

The distribution of the respondent in Table 3 shows the connection to sewers. 95% connection is slightly higher the average connection rate.

Table 3 Sewer Connection Distribution of Respondents

Sewer Connection	286	95%
No Connection	15	5%
Total	301	100%

Source: WTP Survey by JICA Study Team

Family Size

Table 4 shows the distribution of family size of the respondents. The average size of the family is 3.2 persons per family.

Table 4 Family Size Distribution of Respondents

1	30	8%
2	97	27%
3	86	24%
4	96	27%
5	33	9%
6	11	3%
7	4	1%
8	1	0%
9	2	1%
Total	360	100%

Source: WTP Survey by JICA Study Team

Perception of Current Water/Sewerage Tariff

Table 5 shows the respondents’ perception of the current tariff. 71% of the respondents feel are satisfied with the current tariff level, feeling either “acceptable”, or “inexpensive.”

Table 5 Perception of Current Water/Sewerage Tariff

Acceptable	154	42%
Inexpensive	106	29%
Expensive	108	29%
Total	368	368

Source: WTP Survey by JICA Study Team

Current Average Payment

The average pay for water and sewerage service by the respondents is RSD 1102 per month per family.

Chapter 9 Current Engagement with CDM

1. Project Design Document (PDD)

PROJECT DESIGN DOCUMENT FORM
FOR SMALL-SCALE CDM PROJECT ACTIVITIES (F-CDM-SSC-PDD)
Version 04.1

Provisional

PROJECT DESIGN DOCUMENT (PDD)

Title of the project activity	Methane Gas Capture and Electricity and Heat Production at Veliko Selo Wastewater Treatment Plant, Serbia
Version number of the PDD	Version 0
Completion date of the PDD	xx December 2012
Project participant(s)	Belgrade Land Development Public Agency (LDA) Belgrade Waterworks and Sewerage (BVK)
Host Party(ies)	Government of the City of Belgrade, Serbia
Sectoral scope(s) and selected methodology(ies)	Type I.- Renewable Energy Projects Category I.C "*Thermal energy production with or without electricity*" Version 19 (provisional)
Estimated amount of annual average GHG emission reductions	17,095 tCO_2/yr

SECTION A. Description of project activity

A.1. Purpose and general description of project activity

The project deals with methane capture, GHG emission reduction and electricity production at the Veliko Selo Wastewater Treatment Plant, Serbia.

Sewage from the City of Belgrade, with which is stocked into the Danube and the Sava River as untreated at the moment will be treated in the newly-built Veliko Selo Wastewater Treatment Plant including advanced treatment which treated water is planned to be released into the Danube. Sewage treatment system is a usual premium treatment with addition of the advanced treatment, which has functions of phosphorus and nitrogen removal. Wastewater treatment consists of three parts, which are primary settling tank, bioreactor and final settling tank.

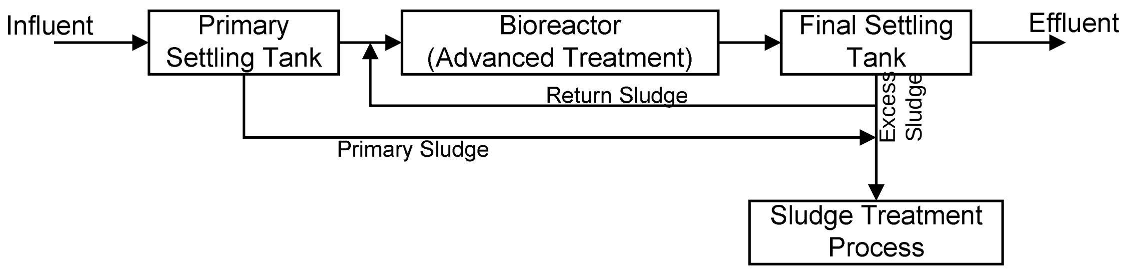


Figure1. Diagram of Wastewater Treatment Process

Sludge is produced in both two settling tanks, joined to one and sent to the sludge treatment process.

The sludge process, originally consisting of mechanical dehydration which can dehydrate the sludge to approximately 80% moisture content and disposal by landfill of waste disposal facility is introduced anaerobic digestion and the produced biogas from digester is used for warming the injection sludge to the digester and the surplus biogas is treated by flare facility (stack). (see below figure) In these sludge warming and flare treatment, CO_2 emissions are not counted as burning carbon-neutral methane.

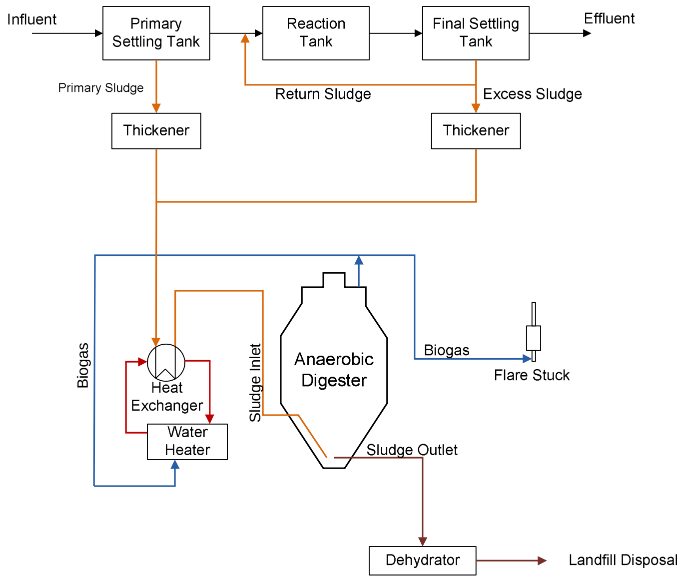


Figure2. Diagram of Sludge Treatment Process

In a general way, the objectives of adopting anaerobic digestion from the aspect of sludge treatment are 1) sludge volume reduction, 2) sludge stabilization in disposal and 3) reduction of methane production when landfill disposal, which means the methane avoidance in terms of climate change.
In the project the produced biogas supplied to co-generation facilities, **electrical energy** by biogas generation and **heat energy** by exhaust heat recovery are obtained. The electricity is sold to the connected grid and the exhaust heat is used for warming of injection sludge to the digester. This enables an alternative of a portion of power consumption in WWTP by co-generation.

Contribution to Sustainable Development

The project can obtain the energy of both electricity and heat by the biogas from the digestion of sludge, which is utilized only for warming the sludge injected into digester. It is expected that the Project can provide direct local environmental benefits as follows:

- ✓ Contributing to alternatives of the electricity consumed in Veliko Selo WWTP. This will result in reduced local air pollution from sulphur dioxide and particulate emissions that would otherwise be emitted as a result of combustion of coal in Serbia.
- ✓ Contributing to the financial strength on the operation of WWTP. The electricity generated by co-generation will be connected to the existing grid and sold to the power company that would be the successive incomes.

A.2. Location of project activity

A.2.1. Host Party(ies)

Veliko Selo Wastewater Treatment Plant

A.2.2. Region/State/Province etc.

Veliko selo (Vinča), Palilula

A.2.3. City/Town/Community etc.

The site is located in the eastern area of the City of Belgrade.

A.2.4. Physical/ Geographical location

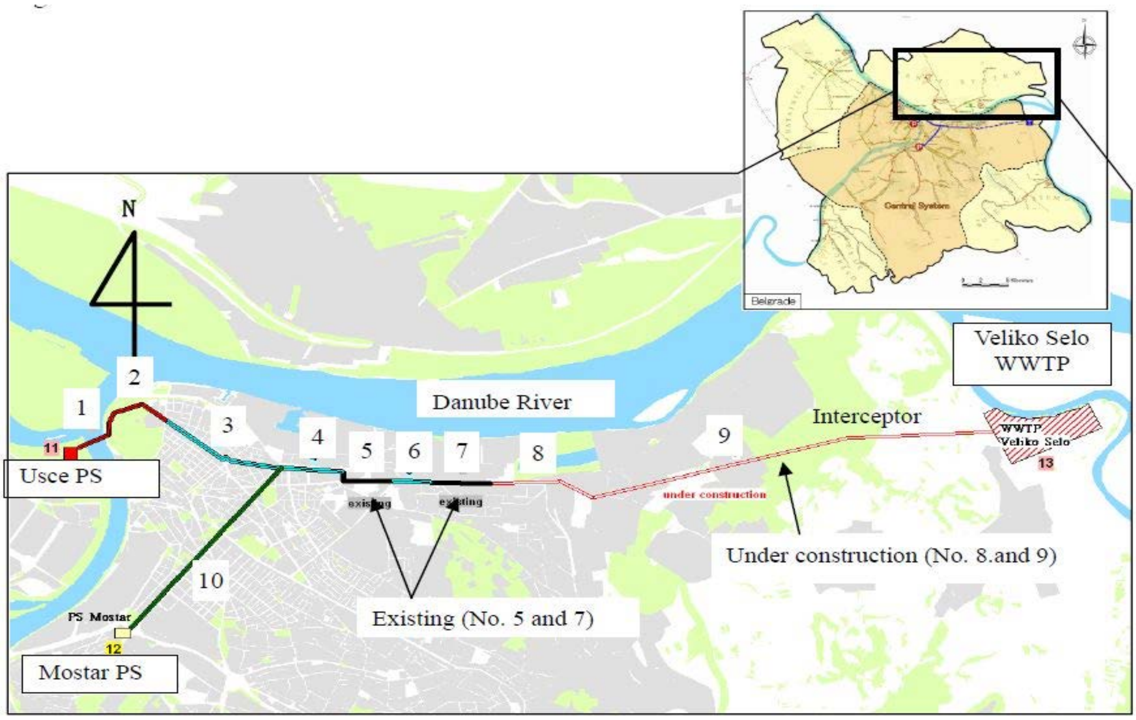


Figure3. Map of the project location in the City of Belgrade

A.3. Technologies and/or measures

Technology adopted to the project is co-generation system using biogas from digester as fuel.

Electricity produced by co-generation is connected to the grid and sold as biomass energy and furthermore, the exhaust heat produced by co-generation is used for warming the injection sludge to the digester.

Type I. – Renewable Energy Projects

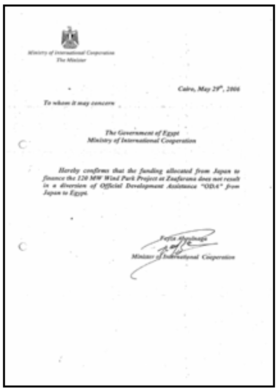
Category I.C "*Thermal energy production with or without electricity*" Version 19 (provisional)

A.4. Parties and project participants

Party involved (host) indicates a host Party	**Private and/or public entity(ies) project participants (as applicable)**	**Indicate if the Party involved wishes to be considered as project participant (Yes/No)**
Government of the City of Belgrade, Serbia (host)	Belgrade Land Development Public Agency (LDA)	No
Government of the City of Belgrade, Serbia (host)	Belgrade Waterworks and Sewerage (BVK)	No
Government of the City of Belgrade, Serbia (host)	Veliko Selo Wastewater Treatment Plant	No
Japan		

A.5. Public funding of project activity

✓ Acquire the letter of telling that the project fund is not diverted from ODA fund from MOFA
Sample:



Ministry of International Cooperation
The Minister

Cairo, May 29th, 2006

To whom it may concern

The Government of Egypt
Ministry of International Cooperation

Hereby confirms that the funding allocated from Japan to finance the 120 MW Wind Park Project at Zaafarana does not result in a diversion of Official Development Assistance "ODA" from Japan to Egypt.

Minister of International Cooperation

A.6. Debundling for project activity

The proposed project activity is not a debundled component of a large project activity. According to Appendix C of the Simplified Modalities and Procedures for Small-Scale CDM Project Activities, a proposed small-scale project activity is considered a debundled component of a large scale project activity if there is a registered small-scale CDM project activity or an application to register another small-scale project activity:

- With the same project participants;
- In the same project category and technology/measure; and
- Registered within the previous 2 years; and
- whose project boundary is within 1 km of the project boundary of the proposed small-scale activity at the closest point

Since none of the above is true for the proposed CDM project activity, it is not a debundled component of a large project activity.

SECTION B. Application of selected approved baseline and monitoring methodology

B.1. Reference of methodology

The baseline and monitoring methodologies applied for the project is based on the most recent list of the small-scale CDM project activity categories contained in Appendix B of the Simplified Modalities and Procedures for Small-Scale CDM Project Activities.

The project falls under,

Type I – Renewable Energy Projects

Category I. C. – "*Thermal energy production with or without electricity*" Version 19 (provisional)

The approved baseline and monitoring methodology, given in Appendix B of the Simplified Modalities and Procedures for Small-Scale CDM Project Activities, relevant to this project are available at: http://cdm.unfccc.int/filestorage/G/U/9/GU9MEH14PBSNCKJIOV3L7W82RTZY06/EB61_repan16_Revision_AMS-I%20C_ver19.pdf?t=VUl8bWVtM2xlfDCCImT5vTBKnja9mLh4Ic-c

B.2. Project activity eligibility

According to Appendix B of the Simplified Modalities and Procedures for Small-Scale CDM Project Activities, Category I. C. "Thermal energy for the user" comprises "renewable energy technologies that supply individual households or users with thermal energy that displaces fossil fuels. Biomass-based co-generating systems that produce heat and electricity for use on-site are included in this category. For co-generation systems and/or co-fired systems to qualify under this category, the energy output shall not exceed 45 $MW_{thermal}$.

B.3. Project boundary

According to the baseline methodology for project category I.C., "The physical, geographical site of the renewable energy generation delineates the project boundary" The physical project boundary selected for the project activity is the sludge treatment process centered on the anaerobic digester of the Veliko Selo WWTP before the dehydration process.

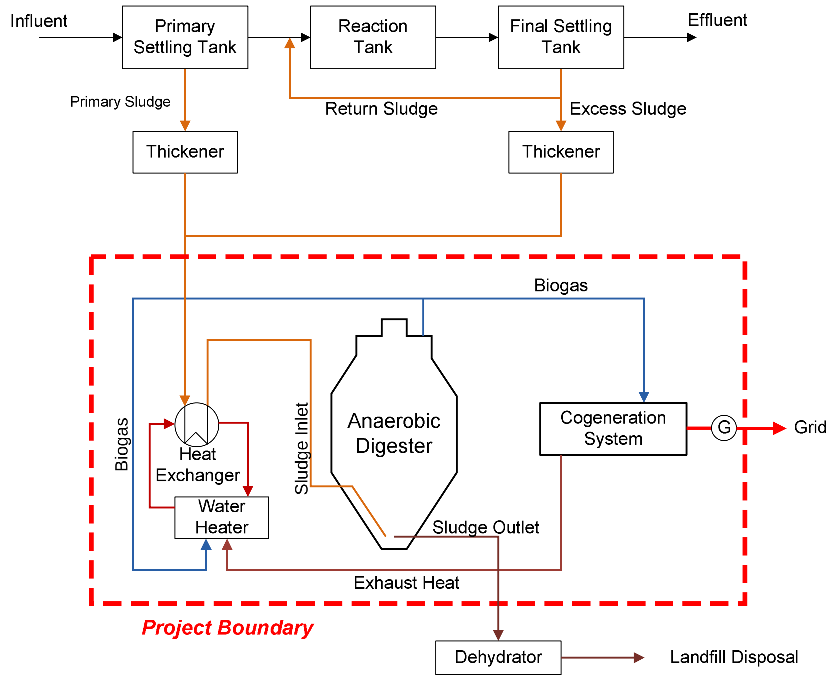


Figure4. Project Boundary

B.4. Establishment and description of baseline scenario

The baseline of the project will be identified by the following procedures:

First of all, scenarios legitimate and presumable in Serbia the Host country will all be enumerated. The project scenario should also be included in these scenarios.

Any possible scenario is enumerated as the below Table:

Among the below scenarios, a reason will be suggested on the scenario thought of as improbable as baseline.

- Conditions of Serbia

At the present sewage sludge (derived from sewage) is not accepted as biomass even if after dehydrated or after composting in Serbia. There is no disposal method other than disposal by landfill as (industrial) waste substances. Meanwhile, methane gas produced by anaerobic digestion of sludge is accepted as biogas, by which as fuel of co-generator and/or generator generated electricity is made possible to purchase by high price as biomass generated electricity.

Table1. Legitimate and Presumable Scenarios in Serbia

Scenario No.	Contents of Scenario	Reason on the Scenario thought to be unlikely as Baseline, unnecessary to implement Barrier Analysis
Scenario 1	***Status quo***. i.e. Sewage in Belgrade is released as untreated into the Danube and the Sava.	Releasing untreated sewage progresses the contamination of (international) rivers, which means contradictory to the national

		environmental policy. Unlikely as baseline.
Scenario 2	***M/P scheme***. i.e. Sewage is treated by secondary biological treatment with advanced treatment and sludge is treated by anaerobic digestion after thickening and disposed by landfill after dehydration. Biogas produced from digester is utilized for warming sludge injected into digester and/or combusted by flare treatment.	(presumable as baseline, it is necessary to examine in next step)
Scenario 3 (this project)	***Co-generation introduction scheme***. i.e. Sewage is treated by secondary biological treatment with advanced treatment and sludge is treated by anaerobic digestion after thickening and disposed by landfill after dehydration. Biogas from digester produces electricity and heat by introduced co-generator and the electricity is connected to the existing grid and the exhaust heat is utilized for warming sludge injected into digester.	(presumable as baseline, it is necessary to examine in next step)
Scenario 4	***Composting introduction scheme***. i.e. Sewage is treated by secondary biological treatment with advanced treatment and sludge is dehydrated after thickening and dehydrated sludge cake is treated by composting. Biogas produced from digester is utilized for warming sludge injected into digester and/or combusted by flare treatment.	(presumable as baseline, it is necessary to examine in next step)
Scenario 5	***Drying process (sludge fuel conversion) introduction scheme***. i.e. Sewage is treated by secondary biological treatment with advanced treatment and sludge is dehydrated after thickening and dehydrated sludge cake is dried by newly-introduced sludge drying equipment. Biogas produced from digester is utilized for warming sludge injected into digester and/or combusted by flare treatment.	The product of dried sludge has no application as fuel. Unlikely as baseline by reason of no economic benefit even if dried.

Next, the barrier analysis of reckoned scenarios will be implemented. Investment analysis of ones having the least barrier will be implemented and the one of the highest investment efficiency will be baseline scenario. The result of barrier analysis is shown as follows:

Table2. Barrier Analysis of Scenarios

Scenario No.	Contents of Scenario	Presumable Barrier
Scenario 2	***M/P scheme***. i.e. Sewage is treated by secondary biological treatment with advanced treatment and sludge is treated by anaerobic digestion after thickening and disposed by landfill after dehydration. Biogas produced from digester is utilized for warming sludge injected into digester and/or combusted by flare treatment.	No technical barrier. Making a study of whether the project is formed economically or not is required.
Scenario 3 (this project)	***Co-generation introduction scheme***. i.e. Sewage is treated by secondary biological treatment with advanced treatment and sludge is treated by anaerobic digestion after thickening and disposed by landfill after dehydration. Biogas from digester produces electricity and heat by introduced co-generator and the electricity is connected to the existing grid and the exhaust heat is utilized for warming sludge injected into digester.	No technical barrier. Making a study of whether the project is formed economically or not is required.
Scenario 4	***Composting introduction scheme***. i.e. Sewage is treated by secondary biological treatment with advanced treatment and sludge is dehydrated after thickening and dehydrated sludge cake is treated by composting. Biogas produced from digester is utilized for warming sludge injected into digester and/or combusted by flare treatment.	The barrier is existing. Sludge derived from sewage or wastewater treatment is not biomass in Serbia and no sludge composting is implemented. The reason is nonexistence of composting technology and social system.

The result of investment analysis on scenario 2 and 3 is shown as follows:

Table3. Investment Analysis of Scenarios

Scenario No.	Contents of Scenario	Additional Expense	Additional Revenue	Post-tax IRR
Scenario 2	***M/P scheme***. i.e. Sewage is treated by secondary biological treatment with advanced treatment and sludge is	Initial Construction Cost 300,000 k€	NA	IRR calculation is incapable.

	treated by anaerobic digestion after thickening and disposed by landfill after dehydration. Biogas produced from digester is utilized for warming sludge injected into digester and/or combusted by flare treatment.			
Scenario 3 (this project)	***Co-generation introduction scheme***. i.e. Sewage is treated by secondary biological treatment with advanced treatment and sludge is treated by anaerobic digestion after thickening and disposed by landfill after dehydration. Biogas from digester produces electricity and heat by introduced co-generator and the electricity is connected to the existing grid and the exhaust heat is utilized for warming sludge injected into digester.	Initial Construction Cost 302,000 k€	Power purchase cost and cost of fuel for warming sludge are reduced by the efficient use of biogas. Revenue of electrical power selling; 1,212 k€/yr (0.067 €/kWh)	IRR calculation is incapable.

The study mentioned above concluded the baseline scenario was the ***M/P scheme***.

B.5. Demonstration of additionality

Secondly, the additionality will be demonstrated. The project is scenario 3. As it became clear that the scenario 3 was not the baseline scenario, it has already been confirmed that the project was additionality, however, “GHG emissions can be reduced additionally” will be demonstrated through the scenario 3.

Mathematically, if the following formula become clear, the additionality can be verified.

Baseline Emissions + Baseline Leakage > Project Emissions + Project Leakage
(1)

where

Baseline Emissions (tCO_2/yr) $BE_{i,y} = EG_{i,y} * EF_{BL,i,FC} = 0$
(2)

Baseline Leakage (tCO_2/yr) $BL_y = P_y * EF_{grid,y}$
(3)

Project Emissions (tCO_2/yr) $PE_{i,y} = EG_{j,y} * EF_{BL,i,FC} = 0$
(4)

Project Leakage (tCO_2/yr) $PL_y = 0$
(5)

As described above, it is obvious that $P_y * EF_{grid,y} > 0$ leads to the additionality.

where

$BE_{i,y}$ = Baseline emissions from electricity and thermal energy displaced by the project activity during the year y (tCO_2)

$EG_{i,y}$ = Amount of fuel i of water heater used for warming sludge (mass or volume unit/yr)

$EF_{BL,i,FC}$= Emission factor of fuel i (tCO_2/mass or volume unit/yr)
Emission factor of biogas fuel is 0

BL_y = Baseline leakage during the year y (tCO_2/yr)

P_y = Net supplied power by the project co-generation system in the year y (MWh/yr)

$EF_{grid,y}$ = Emission factor of the baseline grid during the year y (tCO_2/MWh)

$PE_{i,y}$ = Project emissions in the year y (tCO_2/yr)

$EG_{j,y}$ = Amount of exhaust heat energy j in the year y (mass or volume unit/yr)

PL_y = Project leakage during the year y (tCO_2/yr) = 0

In the baseline, anaerobic digestion implemented with the purpose of sludge stabilization, the produced biogas is used for warming sludge injected into digester and its surplus is treated by flare combustion. On the other hand, in the project, the produced biogas is supplied to the co-generation system, and the power energy generated by biomass generation and the heat energy by recovered exhaust heat are obtained. Electricity is connected to the existing grid and sold, and exhaust heat is used for warming the sludge injected into digester. Herewith, a part of power consumption is substituted by co-generation. Consequently, the project is additionality.

B.6. Emission reductions

B.6.1. Explanation of methodological choices

According to Appendix B of the Simplified Modalities and Procedures for Small-Scale CDM Project Activities, Category I-C. "*Thermal energy production with or without electricity*" comprises "renewable energy technologies that supply users with thermal energy that displaces fossil fuel use. These units include technologies such as solar thermal water heaters and dryers, solar cookers, energy derived from renewable biomass and other technologies that provide thermal energy that displaces fossil fuel.

The applicability is limited to biomass co-generation units that the total installed energy capacity (thermal and electrical) of the project shall not exceed 45 MW thermal. Incidentally, for the purpose of calculating this capacity limit the conversion factor of 1:3 shall be used for converting electrical energy to thermal energy (i.e. for renewable energy project activities, the maximal limit of 15

MW(e) is equivalent to 45 MW thermal output of the equipment or the plant).

The proposed project activity involves 4 (four) units of 1 MW co-generation equipment. Then the total capacity of the project activity is 4 MW(e). As such this project qualifies under Category I.C. of Appendix B of the small-scale guidelines.

B.6.2. Data and parameters fixed ex ante

Data / Parameter	$EF_{BL,i,FC}$
Unit	tCO_2/mass or volume unit
Description	CO_2 emission factor of fuel type *i*
Source of data	AMS-I.C.
Value(s) applied	0
Choice of data or Measurement methods and procedures	Since fuel for warming the sludge injected into digester is biogas, no CO_2 emission factor is to be considered.
Purpose of data	Calculation of baseline and project emissions
Additional comment	

Data / Parameter	$EF_{grid,y}$
Unit	tCO_2/MWh
Description	Emission factor of Serbian power grid during the year *y*
Source of data	Technical Assistance of the Revision of Project Design Documents (PDDs). Calculation of the Carbon Emission Factor for the Serbian Power Grid; Rev.0 - JUNE 2011, Serbian Ministry of Environment, Mining and Spatial Planning Belgrade, Serbia (i.e. Ministry of Energy Development and Environmental Protection of the Republic of Serbia *at present*)
Value(s) applied	0.945
Choice of data or Measurement methods and procedures	This item should be decided based on the method mentioned in the Baseline Methodology.
Purpose of data	Calculation of emission reduction of the project
Additional comment	

Data / Parameter	PL_y
Unit	tCO_2/yr
Description	Project leakage during the year *y*
Source of data	AMS-I.C.
Value(s) applied	0
Choice of data or Measurement methods and procedures	If the energy generating equipment is transferred from another activity, leakage is to be considered.
Purpose of data	Calculation of emission reduction of the project
Additional comment	

B.6.3. Ex-ante calculation of emission reductions

1. Baseline emissions

Baseline emissions for heat produced using biomass fuel shall be calculated as follows:

$$BE_{i,y} = EG_{i,y} * EF_{BL,i,FC}$$

where

$BE_{i,y}$ = The baseline emissions from heat displaced by the project activity during the year *y* (tCO_2/yr)

$EG_{i,y}$ = The net quantity of heat supplied by the project activity during the year *y* (mass or volume unit/yr)

$EF_{BL,i,FC}$ = The CO_2 emission factor of the fuel that would have been used in the baseline plant. (tCO_2/mass or volume unit)

Since the fuel is biogas, the emission factor is 0

This shows that the fuel of hot water heater required for warming the sludge injected into anaerobic digester is covered by the biogas. Adopting the method of utilizing biogas for warming sludge into digester, no GHG emission is to be considered. Such condition setting is consistent with the simplification of this GHG reduction projects.

2. Baseline leakage

Baseline leakage shall be calculated as follows:

$$BL_y = P_y * EF_{grid,y}$$

where

BL_y = Baseline leakage during the year *y* (tCO_2/yr)

P_y = Net supplied power by the project co-generation system in the year *y*

(MWh/yr)

$EF_{grid,y}$ = Emission factor of Serbian power grid during the year y (tCO_2/MWh)

■ **Regarding P_y:**

The capacity of co-generation system planned in the main project (Veliko Selo WWTP Project) is as follows:

1,000 kW x 4 units total 4,000 kW (at peak time)

When assuming the generation capacity is 2,500 kW in normal operation, the annual operating time is 8,040 hrs (335-day running) and the self-consumption ratio is 10 %;

2,500 kW x 8,040 hrs x (1-0.1) = 18,090 MWh/yr

And the emission factor of Serbian power grid $EF_{grid,y}$ is;

$EF_{grid,y}$ = 0.945 tCO_2/MWh[1]

thus

BL_y = 17,095 tCO_2/yr

3. Project emissions

Project emissions shall be calculated as follows:

$$PE_{i,y} = EG_{j,y} * EF_{BL,i,FC} = 0$$

Thus no project emission is to be considered.

4. Project leakage

If the energy generating equipment is transferred from another activity, leakage is to be considered.

Thus no project leakage is to be considered.

$$PL_y = 0$$

5. Emission reduction

[1] Technical Assistance of the Revision of Project Design Documents (PDDs), Calculation of the Carbon Emission Factor for the Serbian Power Grid; Rev.0 – JUNE 2011, Serbian Ministry of Environment, Mining and Spatial Planning Belgrade, Serbia

GHG emission reduction shall be calculated as follows:

Emission reduction = (Baseline emissions + Baseline leakage) – (Project emissions + Project leakage)

thus

GHG emission reduction ER_{CO2} = $\underline{17{,}095\ tCO_2/yr}$

B.6.4. Summary of ex-ante estimates of emission reductions

Year	Baseline emissions (tCO_2 e)	Project emissions (tCO_2 e)	Leakage (tCO_2 e)	Emission reductions (tCO_2 e)
2019	0	0	17,095	17,095
2020	0	0	17,095	17,095
2021	0	0	17,095	17,095
2022	0	0	17,095	17,095
2023	0	0	17,095	17,095
2024	0	0	17,095	17,095
2025	0	0	17,095	17,095
Total				119,665
Total number of crediting years	7 years			
Annual average over the crediting period				17,095

B.7. Monitoring plan

B.7.1. Data and parameters to be monitored

Data / Parameter	P_y
Unit	MWh/yr
Description	Net supplied power by the project co-generation system in the year *y*
Source of data	Indicated value of sold electric power meter
Value(s) applied	18,090
Measurement methods and procedures	Measurement data should be stored as electronic data and kept them for two years after the crediting period.
Monitoring frequency	Once a year
QA/QC procedures	Instrument should be corrected proofs periodically.
Purpose of data	Calculation of emission reduction of the project
Additional comment	

Data / Parameter	$EF_{grid,y}$
Unit	tCO_2/MWh
Description	Emission factor of Serbian power grid during the year *y*
Source of data	Technical Assistance of the Revision of Project Design Documents (PDDs). Calculation of the Carbon Emission Factor for the Serbian Power Grid; Rev.0 - JUNE 2011, Serbian Ministry of Environment, Mining and Spatial Planning Belgrade, Serbia (i.e. Ministry of Energy Development and Environmental Protection of the Republic of Serbia *at present*)
Value(s) applied	0.945
Measurement methods and procedures	This item should be decided based on the method mentioned in the Baseline Methodology. Measurement data should be stored as electronic data and kept them for two years after the crediting period.
Monitoring frequency	Once a year
QA/QC procedures	Calculating based on the Baseline Methodology
Purpose of data	Calculation of emission reduction of the project
Additional comment	

B.7.2. Sampling plan

The framework of quality control and quality assurance on the monitoring are as follows:

Where "Administrator" means the administration division of Belgrade Waterworks and Sewerage

(BVK) and “Operator” means operators of Veliko Selo WWTP those who implement the monitoring under the directions of the administration division of BVK.

- ✓ Project implement bodies consist of the operator and the administrator.
- ✓ Administrator develops a procedure for facility operation.
- ✓ In the procedure, daily work contents, maintenance methods and various types of criteria for judgement are described and formatted appropriately.
- ✓ The operator should be assured of chances for receiving training and education periodically to take every available step to work in accordance with the above procedure.
- ✓ Operator should carry out the daily works and report the results to the administrator in accordance with the procedure.
- ✓ Administrator should check the report from the operator and make judgements whether having problems with or not in accordance with the procedure, and as a result of checking, develop an appropriate response at an appropriate time in the event of problems.
- ✓ Administrator should file the report from the operator daily and store them in accordance with the procedure.
- ✓ Administrator should take a tour of the sites, visit the site at an appropriate time and audit whether the operator’s works properly in accordance with the procedure. As a result of auditing, the administrator should develop an appropriate response at an appropriate time in the event of problems.
- ✓ When an accident occurs (including unexpected GHG discharge), administrator should find out the cause and give the operator the direction of countermeasure and implementation.
- ✓ If an emergency arises (including unexpected GHG discharge), operator should take emergency measures and implement the countermeasures under the administrator’s direction.
- ✓ Instrument should properly be corrected proofs periodically in accordance with the procedure. A period and a method of the proofreading should accordance with the monitoring plan.

B.7.3. Other elements of monitoring plan

NA

SECTION C. Duration and crediting period

C.1. Duration of project activity

C.1.1. Start date of project activity

xx / 01 / 2019

C.1.2. Expected operational lifetime of project activity

7 years

C.2. Crediting period of project activity

C.2.1. Type of crediting period

CER

C.2.2. Start date of crediting period

dd / 01 / 2019

C.2.3. Length of crediting period

7 years

SECTION D. Environmental impacts

D.1. Analysis of environmental impacts

NA

SECTION E. Local stakeholder consultation

E.1. Solicitation of comments from local stakeholders

NA

E.2. Summary of comments received

NA

E.3. Report on consideration of comments received

NA

SECTION F. Approval and authorization

NA

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Appendix 1: Contact information of project participants

Organization	
Street/P.O. Box	
Building	
City	
State/Region	
Postcode	
Country	
Telephone	
Fax	
E-mail	
Website	
Contact person	
Title	
Salutation	Ms.
Last name	
Middle name	
First name	
Department	
Mobile	
Direct fax	
Direct tel.	
Personal e-mail	

Appendix 2: Affirmation regarding public funding

NA

Appendix 3: Applicability of selected methodology

NA

Appendix 4: Further background information on ex ante calculation of emission reductions

NA

Appendix 5: Further background information on monitoring plan

NA

Appendix 6: Summary of post registration changes

NA

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History of the document

Version	Date	Nature of revision
04.1	11 April 2012	Editorial revision to change history box by adding EB meeting and annex numbers in the Date column.
04.0	EB 66 13 March 2012	Revision required to ensure consistency with the "Guidelines for completing the project design document form for small-scale CDM project activities" (EB 66, Annex 9).
03	EB 28, Annex 34 15 December 2006	• The Board agreed to revise the CDM project design document for small-scale activities (CDM-SSC-PDD), taking into account CDM-PDD and CDM-NM.
02	EB 20, Annex 14 08 July 2005	• The Board agreed to revise the CDM SSC PDD to reflect guidance and clarifications provided by the Board since version 01 of this document. • As a consequence, the guidelines for completing CDM SSC PDD have been revised accordingly to version 2. The latest version can be found at <http://cdm.unfccc.int/Reference/Documents>.
01	EB 07, Annex 05 21 January 2003	Initial adoption.
Decision Class: Regulatory **Document Type:** Form **Business Function:** Registration		