Project Technical Analysis

Project Number: 50176-002
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KGZ: Issyk-kul Wastewater Management Project

WASTEWATER SYSTEM IN BALYKCHY AND KARAKOL

1 INTRODUCTION

1. This report is an Appendix to the draft final report package of the *Asian Development Bank (ADB) KGZ-9169: Second Issyk-Kul Sustainable Development Project* (project). The project's objective is to assist the Government of the Kyrgyz Republic and the Asian Development Bank (ADB) to formulate sustainable wastewater improvements for two lakeshore cities of Issyk-Kul Lake, located in the eastern region of the Kyrgyz Republic. These cities are Balykchy and Karakol, which are situated on the western and eastern shoreline of the lake, respectively.

2. The Second Issyk-Kul Sustainable Development Project is primarily focused on the rehabilitation of the wastewater treatment facilities in the two cities. These wastewater treatment facilities were constructed during the 1980s towards the end of the Soviet era. While they were intended to provide secondary treatment to allow effluent discharge to irrigation areas, the treatment plants were never fully operated and have fallen into disrepair over the subsequent period. While some minimal treatment is provided by the existing plants and the effluent is used for irrigation, the effluent does not meet the prescribed effluent discharge standards of the Kyrgyz Republic and therefore represents a health hazard for the residents in the vicinity of the treatment plants and those farmers using the effluent for irrigation.

3. Proposals made for wastewater treatment during the Interim Stage of this study recommended a secondary treatment process that would provide an effluent standard in accordance with international standards for discharge to irrigation areas. In particular, the secondary treatment process proposed was intended to provide an ammonia concentration of the effluent of no greater than 3 mg/L. However, following meetings with the State Sanitary and Epidemiological Service (SESS) and the State Agency on Environmental Protection and Forestry who now have responsibility for effluent discharge standards, it was advised that the Kyrgyz standards for effluent discharge to irrigation requires an effluent standard of 0.1 mg/L measured at the point of discharge to the irrigation area. All other discharge parameters for use of effluent for irrigation could be achieved through secondary treatment.

4. Since in each city, the effluent will be mixed with surface water prior to discharge to the irrigation areas, it is possible that with dilution a secondary treatment process could meet Kyrgyz standards for ammonia. However, this cannot be guaranteed since the extent of dilution may vary throughout the year and may be insufficient to deliver the prescribed ammonia limit. As a result, it was agreed to consider an option of additional tertiary treatment at each of the three wastewater treatment plants that will ensure an ammonia concentration of no more than 0.1 mg/l at the point of discharge to the irrigation areas in accordance with Kyrgyz standards.

5. This report provided estimates for the quantities of wastewater produced by the two cities during the period 2018-2038, the required capacities of the wastewater treatment plants over the design period and a suggested phasing plan, details of the treatment process for primary, secondary and tertiary treatment and capital and operation and maintenance costs for the proposed treatment facilities

2 POPULATION PROJECTIONS

2.1 City Residents

6. Population data and projections for 2018, 2028 and 2038 have been developed for Balykchy and Karakol (**Table 2.1**). The estimates and projections are based on official population data obtained from the National Statistics Committee (NSC) of the Kyrgyz Republic, together with the 2013 to 2017 population data provided by the local administrations.

7. The earlier ISDP-2 reports[1] developed 'Business as Usual' and 'Pole of Development' scenarios for population projections, which will be referred to in this report as 'Low Growth' and 'High Growth' scenarios, respectively. The Low Growth scenario assumes that the recent annual population growth rate from 2013 to 2017 will be extended over a longer period of time. The High growth scenarios are alternative growth rates assumptions which consider the possibility of accelerated regional growth stimulated by medium to large scale investments into the economy, due to better city infrastructure and services.

8. Existing and projected population growth rates for the Low Growth and High Growth scenarios are shown in **Table 2.1.**

Table 2.1 – Population Growth Rates in Balykchy and Karakol

Location	Population Growth Rates (% p.a)			
	2009-2013 (Actual)	Projected Low Growth	Projected High Growth	
			2018-2028	2029-2038
Karakol	1.71	1.87	2.20	2.00
Balykchy	0.94	0.90	1.20	1.15

Source:, Population Projection, Ministry of Finance, Krgyz Republic PMO, June 2014. Low growth rate scenario based on actual growth rates over 5 years (except Kara-oy for which Cholpon-Ata growth rate used. High growth rates generated by PPTA consultants.

9. Based on the above growth rates, the projected residential populations for the low growth and high growth scenarios are shown in **Table 2.2** below.

Table 2.2 – Population Projections for Balykchy and Karakol

Location	Population ('000)						
	2017 census	2018		2028		2038	
		Low Growth	High Growth	Low Growth	High Growth	Low Growth	High Growth
Karakol	74.1	75.5	75.7	90.9	94.1	109.3	114.8
Balykchy	46.9	47.3	47.5	51.7	53.5	56.6	60.2

Source:PPTA Consultants

10. These population projections were discussed with the Mayors of Karakol and Balykchy. It was agreed that the high growth projections would be used for both cities.

[1] ISDP-2, Population Projection, Ministry of Finance, Krgyz Republic PMO, June 2014

2.2 Tourism Projections

11. The Issyk-Kul Oblast experiences high levels of tourism during the summer period (June to August), the majority of whom stay in Cholpon-Ata and its surrounding villages and in Karakol. Balykchy experiences few tourism visitors. High growth and low growth projections have also been developed for tourism numbers.

12. The Low Growth projection assumes that the rate of increase in tourists will generally follow the demographic trend in the Kyrgyz Republic. The High Growth projection assumes that available tourist accommodation in the Issyk-Kul Oblast will increase responding to the increasing demand.

13. Based on these scenarios and considering the actual data for tourist numbers provided by NSC for 2012, tourist projections for both scenarios are shown in **Table 2.3.** The low growth scenario assumes 2.3% growth in tourist numbers from 2012 to 2038. The high growth scenario assumes 3% growth from 2018-2021, 5% growth from 2022 to 2028 and 1.8% growth from 2029 to 2035. Of the total tourists in the Issyk-Kul Oblast, it is reported that 49% visit other towns on the north shore and 10% visit other locations in the Oblast

Table 2.3 – Tourism Projections for Greater Cholpon-Ata and Karakol

Item	Number of Tourist and Available Beds in Greater Cholpon-Ata and Karakol ('000)							
	2012		2018		2028		2038	
	Low Growth	High Growth	Low Growth	High Growth	Low Growth	High Growth	Low Growth	High Growth
No. of Tourists in Issyk-Kul Oblast	688.7	688.7	734.9	790.8	862.9	1,215.8	1,102.1	1,448.0
No. of tourists in Balykchy, Cholpon-Ata and Karakol	282.3	282.3	301.3	324.2	353.8	498.5	451.9	593.7
No. of Beds (hotels formal)	14.1	14.1	15.0	16.2	19.4	42.7	24.8	50.9
No of Beds (informal)	79.2	79.2	84.5	90.9	108.7	151.2	138.8	180.1

Source: Consultant estimate based on ISDP-2, Population Projection, Ministry of Finance, Krgyz Republic PMO, June 2014

14. It has been reported that about 41% of tourists visiting the Issyk-Kul Oblast stay in the towns of Cholpon-Ata and Karakol. 90% of these tourists visit Issyk-Kul during the months of June, July and August and stay an average of 7 nights. **Tables 2.4 and 2.5** show the projected number of tourists staying in Balykchy and Karakol during 2018, 2028 and 2038.

Table 2.4 – Total Number of Tourists Visiting the Towns and Karakol

Location	Number of Tourists			
	2012	2018	2028	2038
Total for Issyk-Kul Oblast	688,700	790,800	1,215,000	1,498,000
Total for Balykchy and Karakol	282,300	342,200	498.500	593,700
Balykchy				
Total	0	0	0	0
June – August	0	0	0	0
September – May	0	0	0	0
Karakol				
Total	70,575	85,550	124,625	148,425
June – August	63,518	76,995	112,163	133,583
September – May	7,058	8,555	12,463	14,843

Source: Consultant estimate based on ISDP-2, Population Projection, Ministry of Finance, Krgyz Republic PMO, June 2014

Table 2.5 – Total Number of Tourist Nights

Location	Number of Tourist Nights			
	2012	2018	2028	2038
Balykchy				
Total	0	0	0	0
June – August	0	0	0	0
September – May	0	0	0	0
Karakol				
Total	5,489	6,654	9,693	11,544
June – August	4,940	5,989	8,724	10,390
September – May	549	665	969	1,154

Source: Consultant estimate based on ISDP-2, Population Projection, Ministry of Finance, Krgyz Republic PMO, June 2014

For wastewater production each tourist will be taken as equivalent of a residential population.

2.3 Institutional, Commercial and Industrial Establishments

15. In addition to wastewater inflows from residences and tourism establishments, institutional (government buildings, schools, hospitals, etc.), commercial and industrial establishments will also contribute to the quantity of wastewater to be collected and treated. Information has not been identified in this analysis to indicate that new industries are planned in any of the three towns (aside from the tourism industry) and in the absence of an industrial development strategy, it seems unlikely that major industrial facilities will be developed. The EBRD Water Sub-project Feasibility Study[2] in Balykchy discusses the reported interest of owners of some of the defunct industries in Balykchy to recommence operations such as a meat processing facility, flour mill and dairy as well as the 500 ha that has been reserved for the establishment of a Free Economic Zone. However, there has been little practical progress in this regard. Nevertheless, there is substantial commercial activity and a presence of many government buildings, especially in Karakol. An allowance for wastewater production from the institutional establishments has been made and is discussed in Chapter 4.

[2] Balykchy Water Sub-Project Feasibility Study Final Report, EBRD, 2015

3 WASTEWATER QUALITY AND EFFLUENT STANDARDS

16. The Kyrgyz Republic design standards to estimate pollutant loading is outlined under the regulatory framework SNiP 2.04.03-85. This shown below in **Table 3.1.**

Table 3.1 – Unit Pollutant Loadings

Parameter	Unit Load (g/capita/day)
Suspended solids	65
$BOD_{ultimate}$ of raw sewage	75[3]
$BOD_{ultimate}$ of treated sewage	40
$N\text{-}NH_3$	8
Phosphates	3.3
P arising from detergents	1.6
Chlorides	9
Surfactants	2.5

Source: SNiP 2.04.03-85

17. For instance, SNiP 2.04.03-85 identifies a seven-day design norm for $BOD_{ultimate}$ of 75 g/capita/day. The five-day BOD or BOD_5 can be determined from the fact that the reaction follows first-order kinetics.

BOD_5 = 75 g/capita/day *(1- exp (-k*5days); where k = 0.23 d^{-1} (rate constant often used for BODs)
$\Rightarrow BOD_5 = 68\% * BOD_{ultimate}$ or 51 g/capita/day.

18. However, we note that the measured BOD generation was reported in the 2015 Phase II report[4] as closer to 35 g/capita/day and the SS generation was generally around 25 to 30 g/capita/day.

19. Pollution figures closer to the measured water qualities (**Table 3.2**) were used for designs in this study as are seen in **Table 4.3** for Balykchy, and **Table 4.6** and **Table 4.7** for Karakol and summarized in **Table 4.8** and **Table 4.9** for BOD_5, TKN (which ammonia is a part) and SS.

Table 3.2 – Summary of water quality data (95%tiles)

Parameters (all mg/L)	Balykchy	Karakol
BOD_5	120	123
Suspended Solids	115	97
Ammonia	20	26

20. The designs herein therefore assumed human pollution generation figures of 35 $gBOD_5$/capita/day (not including septage), 6 TKN/capita/day and 3.2 gNH4-N/capita/day, that are more consistent with the current influent qualities.

3 Note this is the equivalent of BOD_5 – 51 g/cap/day

4 "Feasibility Study: Wastewater Treatment in Balykchy, Cholpon-Ata and Karakol". Issyk-Kul Sustainable Development Project Phase II Feasibility Study and Design Consultancy (FSDC), Kyrgyz Republic Ministry of Finance (Sept. 2015), Table 25, pg. 56.

21. Population growth figures used are based on the projections shown above in **Table 2.2**. It should also be pointed out that it is more efficient to pick up future increases in sewage flow by phasing expansions of the WWTPs as opposed to building a WWTP for 2038 and it be grossly oversized for 2018. Each WWTP was subsequently phased in a logical manner, sympathetic with the infrastructure and equipment. The WWTPs were generally phased whereby infrastructure was proposed in an initial Phase I to cover the time periods 2018 to 2028. A second phase, Phase II, was then proposed to cover the time period up to 2038.

22. Due to the dilute nature of the inflows to the existing STPs, a 10% allowance for stormwater ingress and a 25% allowance for ground water infiltration was made. The groundwater allowance was consistent with about 1.5 m^3/ha/day sewered area calculation and is realistic considering the likely status of the existing sewerage and the dilute nature of the inflows to the WWTPs as seen in **Table 3.2**.

23. The projected future inflows to the WWTPs were adjusted to be more reflective of the existing and future sewer connection rates as opposed to the ultra-conservative sewer connection rates used in the Phase II study report of 2015[5]. This adjustment was done using the actual inflows to the WWTP as well as a report done by the World Bank[6]. Connecting people to the sewer can be a laborious and slow process and overly optimistic connection rates sought are not always achieved.

24. It has been assumed that everyone not on the sewer has a septic tank or latrine (like an aqua privy or other) that can have its solids pumped out. This is in reality not always the case but again is conservative and is borne out by the socio-economic/willingness to pay survey conducted under the PPTA.[7] An allowance for all the WWTPs to have a vacuum truck off-loading station has been made. It is recognized that the current practice is to off-load the trucks into a sewer manhole. However, septage is a concentrated and complicated waste that is better received with specialized equipment. The other main assumption here is that all the septic tanks and latrines are pumped out annually and all solids are received at the STPs. This is again a conservative approach. The socio-economic/willingness to pay survey showed that about 50% of households had their septic tanks/pit latrines pumped out annually, 75% within 3 years and the remainder within four years.

4 WASTEWATER FLOWS AND POLLUTION LOADING PROJECTIONS

4.1 Balykchy

25. Data for the influent and effluent of the Balykchy Wastewater Treatment Plant (BASTP) was given in the Field Survey WP08/WP10 Report (2014) Appendix and was analyzed further as summarized in **Table 4.1**. Wastewater quality analyses were also conducted by the PPTA team[8] based on samples taken on 12 April 2017 and 4 September 2017. These results are shown in **Table 4.2.**

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[5] Time horizon numbers were interpolated/extrapolated from "Feasibility Study: Wastewater Treatment in Balykchy, Cholpon-Ata and Karakol". Issyk-Kul Sustainable Development Project Phase II Feasibility Study and Design Consultancy (FSDC), Kyrgyz Republic Ministry of Finance (Sept. 2015), Table 31, pg. 67

[6] The Kyrgyz Republic: Insights on Household Access to Water Supply and Sanitation, Poverty Global Practice, Europe and Central Asia Region, Report No. 99774-KG (April 2015).

[7] Socio-Economic Survey and Willingness to Pay (WTP) for Wastewater Services in Cholpon-Ata, Balykchy and Karakol, Rich Research, GlobalWorks International, October 2017.

[8] Sampling and testing undertaken by Issyk-Kul Territorial Department of the State Agency for Environmental Protection and Forestry, Laboratory for Environmental Monitoring, Cholpon-Ata.

Table 4.1 – 90% tile data from samples taken on Oct. 2012 and April 2014

No.	Parameter	Unit	90%tiles (2 points only)	
			Influent	Effluent
1	Temperature	^0C	11	9
2	pH	-	6.8	7.3
3	Ammonium NH_4	mg/L	20	18
4	Nitrite-NO_2	mg/L	0.5	0.7
5	Nitrate-NO_3	mg/L	2	1
6	BOD_5	mg/L	120	65
7	Suspended Solids	mg/L	115	37

Table 4.2 – Wastewater Quality Results at Balykchy WWTP – April 2017 and September 2017

Parameter	Balykchy							
	Inlet		Before Biological Ponds		After Biological Ponds		In Irrigation Channel	
	April 2017	Sept 2017	April 2017	Sept 2017	April 2017	Sept 2017	April 2017	Sept 2017
Temperature (^oC)	11	18.5	11.5		14.5			
pH	6.59	7.37	6.94		7.57	8.04		8.07
Total Suspended Solids (mg/L)	118	83	62		57	10		106
Total Dissolved Solids (mg/L)	525	246	548		381	267		165
BOD (mg/L)	76.75	128.3	83.78		35.06	80.7		5.6
COD (mg/L)	135.8	169.6	150.4		59.3	101.4		15.1
Ammonia (mg/L)	20.52	23.6	22.4		6.78	20.38		0.74
Nitrite (mg/L)	0.09	0.001	0.15		0.21	0.001		0.001
Nitrate (mg/L)	7.09	0.05	2.75		11.16	0.05		0.05
Oil and Grease (mg/L)	8	13.5	4.5		2.0	3.0		0.5
Alkalinity (mg/L)	300	201	275		180	288		155
Total Phosphorus (mg/L)	2.9	2.9	3.7		1.7	2.0		0.05
Total Nitrogen (mg/L)	11.5	25.0	12.0		9.1	18.8		0.8
Conductivity (uS/cm)	821	764.8	856		595	866.3		405.1

26. The data size is small but it does show that the current process with the primary sedimentation tank and lagoons removes about 50% of the BOD and 50-60% of the SS. Ammonia removal (65%) was much higher for the April 2017 results than for the earlier tests (10%), although the September 2017 results were more in line with earlier testing. However, the September 2017 testing showed significant removal of ammonia through dilution in the irrigation canal (from 20.38 mg/L to 0.74 mg/L). Of the WWTPs in the two cities, this treatment plant provides the best existing sewage treatment. However both the 2017 results and the earlier results indicate dilute feed sewage.

27. This study projected the potential future average dry weather flows (ADWF) BOD_5, suspended solids and ammonia loading into this WWTP as shown in **Table 4.3.** There is no seasonal tourist element here so the flows would be considered to apply throughout the year.

Flow to the treatment works is highly dependent on the population projections and sewerage connection percentage.

Table 4.3 – Preliminary projected inflows and loads into BAWWTP all year

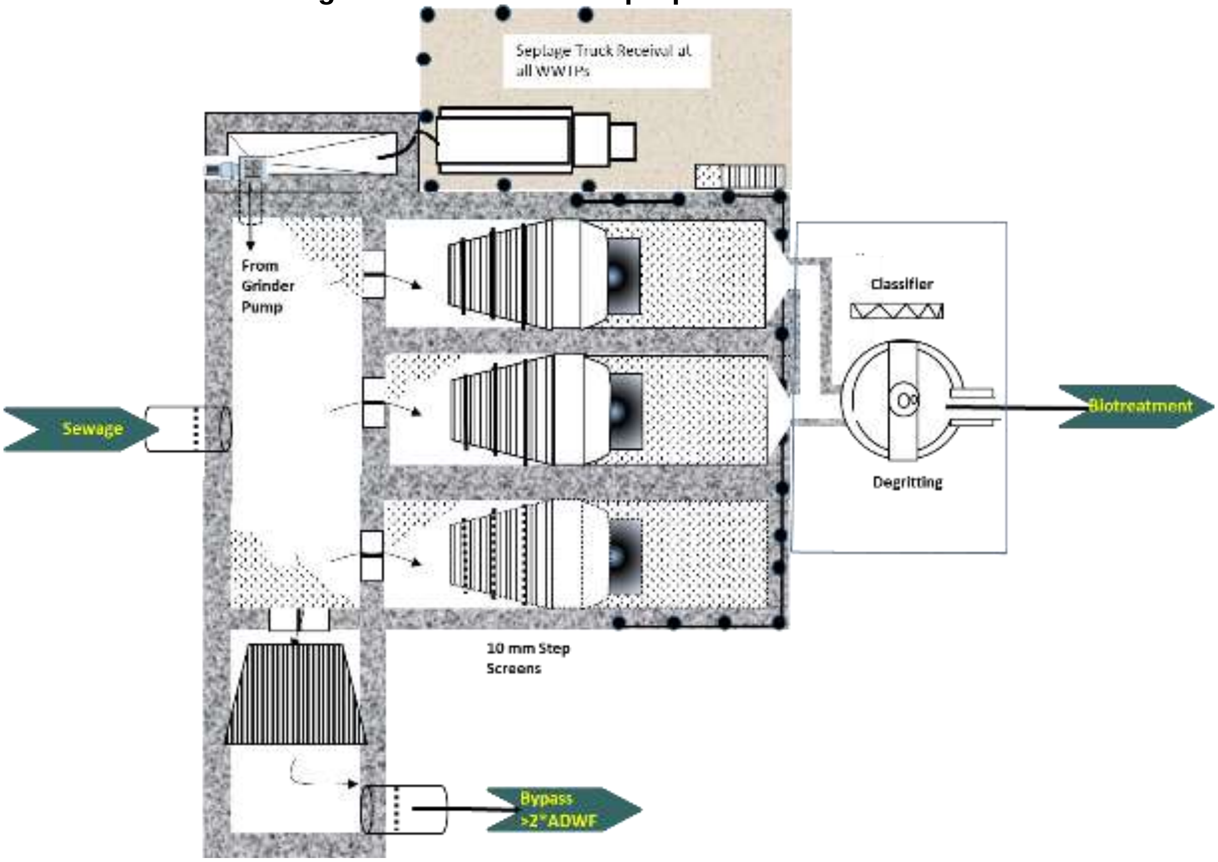
Period June to May	Balykchy		
	2018	2028	2038
Estimated Resident Population	46,895	53,470	60,244
Tourist Population	0	0	0
Total Population	46,895	53,470	60,244
Water Demand (lpcd)	180	200	200
Total Domestic Sewage Generation (m^3/day) at 80% of Water Demand	6,753	8,555	9,639
Sewerage Connection Rate (% of population)	25%	40%	55%
Sewage Generation to Treatment (m^3/day)	1,688	3,422	5,302
Commercial & Institutional Wastewaters in Sewer (20% over Treated Domestic, m3/day)	338	684	1,060
Industrial (m3/day)	0	0	0
TOTAL GENERATED SEWER FLOWS	2,026	4,107	6,362
Stormwater Infiltration Allowance (10% over total, m^3/day)	203	411	636
Groundwater Infiltration Allowance (25% over total, m^3/day)	506	1,027	1,590
TOTAL ADWF (m^3/day)	2,735	5,544	8,588
Estimated Treated Domestic Load (that gets to STP) @35gBOD/p/d (kgBOD/day)	410	749	1,160
Estimated Septage Load to STP via Pumpout Truck @6,000 mgBOD/L (kgBOD/day)	380	346	293
No. of Tankers Reqd – 3m^3 ea./ 2 trips per day	14	13	11
Estimated Commercial/Institutional load at 300 mgBOD/L (kgBOD/day)	101	205	318
Estimated Industrial Load (kgBOD/day)	0	0	0
TOTAL BOD LOAD, kg/day (with septage)	891	1,300	1,771
Est. Influent BOD, mg/L (with septage)	326	235	206
Estimated Treated Domestic Load @30 gSS/p/d (kgSS/day) + Septage	1,765	1,771	1,722
Estimated Treated Domestic Load @12g TKN/p/d (kgTKN/day) + Septage	324	360	395

28. The estimated septage load calculation was also included in **Table 4.3**. Both the private sector and the Vodokanals operate pumpout (vacuum) trucks and it was assumed that future septage loads would be accepted at a rehabilitated BAWWTP with a special septage receival station as shown in **Figure 4.1**. The city's septage load would proportionally decrease as the sewer connections increased. The current number of vacuum trucks operating in each city is shown below. This is significantly less that the required number as shown in **Tables 4.3 and 4.6.**

Table 4.4 – Current Number of Vacuum Trucks in Cities

City	City Operated	Private Sector Operated	Total
Balykchy	2	2	4
Karakol	2	6	8

Figure 4.1 – Inlet works proposed for all WWTPs



4.2 Karakol

29. Data for the influent and effluent of the Karakol Wastewater Treatment Plant (KKWWTP) was given in the Field Survey WP08/WP10 Report (2014) Appendix and analyzed further as summarized in **Table 4.4**. Wastewater quality analyses were also conducted by the PPTA team[9] based on samples taken on 12 April 2017 and 28 August 2017. These results are shown in **Table 4.5.**

Table 4.4 – 90% tile data from samples taken on 2011 and 2014

No.	Parameter	Unit	90%tiles (11 points)		
			STP Influent	STP Effluent	Pond Effluent
1	Temperature	^0C	-	-	-
2	pH	-	-	-	-
3	Ammonium NH_4	mg/L	26	21	27
4	Nitrite-NO_2	mg/L	0.4	0.3	0.7
5	Nitrate-NO_3	mg/L	4	3	3
6	BOD_5	mg/L	123	83	79
7	Suspended Solids	mg/L	97	39	49

9 Sampling and testing undertaken by Issyk-Kul Territorial Department of the State Agency for Environmental Protection and Forestry, Laboratory for Environmental Monitoring, Cholpon-Ata.

Table 4.5 – Wastewater Quality Results at Karakol WWTP – April 2017 and August 2017

Parameter	Karakol								
	Inlet		Before Biological Ponds		After Biological Ponds		At Storage Lagoon	At Mixing Point	Karakol River
	April 2017	Aug 2017	April 2017	Aug 2017	April 2017	Aug 2017	Aug 2017	Aug 2017	Aug 2017
Temperature (°C)	9.8	13	10.5		12	15			
pH	7.19	7.43	6.91		7.12	7.14	7.77	7.9	8.01
Total Suspended Solids (mg/L)	76	128	75		22	78	12	26	42
Total Dissolved Solids (mg/L)	348	704	373		353	643	528	213	160
BOD (mg/L)	109.6	97.2	86.9		49.5	55.1	29.2	16.1	2.4
COD (mg/L)	184.0	129.5	176.3		80.3	72.8	43.4	25.1	3.5
Ammonia (mg/L)	13.7	10.66	11.3		11.6	8.8	17.04	4.91	<0.039
Nitrite (mg/L)	0.195	0.001	0.15		0.10	0.001	0.2	0.08	<0.001
Nitrate (mg/L)	4.16	2.2	4.47		2.61	1.1	0.9	<0.1	<0.1
Oil and Grease (mg/L)	19.5	8.0	14.0		2.5	2.5	0.5	5.0	<0.05
Alkalinity (mg/L)	175	285	165		170	271	328	174	89
Total Phosphorus (mg/L)	2.6	0.7	3.7		2.8	0.9	2.8	1.4	0.03
Total Nitrogen (mg/L)	12.7	9.5	15.6		14.0	8.9	15.5	5.0	0.1
Conductivity (uS/cm)	538	654.3	583		552	509.6	714.3	452	159.7

30. The data size is eleven points for the influent and pond effluent and three points only for the WWTP effluent (which goes to the ponds). There is currently no aeration in the activated sludge process element. Based on the earlier data, the WWTP process removes about 33% of the BOD_5 and the pond 5% of the incoming BOD_5 for a total of 36% BOD_5 removal. However, the April 2017 results showed that the plant removed only about 15% BOD_5 and the ponds another 40%. BOD_5 removal from the inlet to downstream of the ponds was 37% for the August 2017 testing. This was further reduced by an additional 33% in the storage lagoon. Statistically the whole of the process removes little of the ammonia, which actually was shown to increase in the August 2017 testing, although when mixed with surface runoff water reduced from 17.04 mg/L to 4.91 mg/L. The earlier results showed that the activated sludge process removes about 60% of the SS but passage through the pond reduces this to 49% or a 26% increase in SS in the pond. Again this differed from the 2017 results whereby the activated sludge process removed little of the suspended solids, but more than 60% was removed by the ponds. The August 2017 result showed a 40% reduction in suspended solids through the treatment process. The 2017 tests confirmed the dilute nature of the raw sewage observed from earlier tests.

31. Future pollution load projections for this WWTP are given in **Table 4.6** for the tourist season and **Table 4.7** for the off-peak season.

Table 4.6 – Preliminary projected inflows and loads into KKWWTP in tourist season

Period June to August	Karakol		
	2018	2028	2038
Estimated Resident Population	74,104	94,146	114,763
Tourist Population	5,989	8,724	10,390
Total Population	80,093	102,870	125,153
Water Demand (lpcd)	180	200	200

Period June to August	Karakol		
	2018	2028	2038
Total Domestic Sewage Generation (m^3/day) at 80% of Water Demand	11,533	16,459	20,025
Sewerage Connection Rate (% of population)	45%	60%	75%
Sewage Generation to Treatment (m^3/day)	5,190	9,876	15,018
Commercial & Institutional Wastewaters in Sewer (20% over Treated Domestic, m3/day)	1,038	1,975	3,004
Industrial (m3/day)	45	68	90
TOTAL GENERATED SEWER FLOWS	6,273	11,918	18,112
Stormwater Infiltration Allowance (10% over total, m^3/day)	623	1,185	1,802
Groundwater Infiltration Allowance (25% over total, m^3/day)	1,557	2,963	4,506
TOTAL ADWF (m^3/day)	8,463	16,066	24,420
Estimated Treated Domestic Load (that gets to STP) @35gBOD/p/d (kgBOD/day)	1,261	2,160	3,285
Estimated Septage Load to STP via Pumpout Truck @6,000 mgBOD/L (kgBOD/day)	445	411	310
No. of Tankers Reqd – 3m^3 ea./ 2 trips per day	16	15	11
Estimated Commercial/Institutional load at 300 mgBOD/L (kgBOD/day)	311	593	901
Estimated Industrial Load (kgBOD/day)	36	54	72
TOTAL BOD LOAD, kg/day (with septage)	2,018	3,164	4,496
Est. Influent BOD, mg/L (with septage)	239	197	184
Estimated Treated Domestic Load @30 gSS/p/d (kgSS/day) + Septage	2,445	2,693	2,744
Estimated Treated Domestic Load @6g TKN/p/d (kgTKN/day) + Septage	648	807	962

Table 4.7 – Preliminary projected inflows and loads into KKWWTP in off season

Period September to May	Karakol		
	2018	2028	2038
Estimated Resident Population	74,104	94,146	114,763
Tourist Population	665	969	1154
Total Population	74769	95,115	115,917
Water Demand (lpcd)	180	200	200
Total Domestic Sewage Generation (m^3/day) at 80% of Water Demand	10,767	15,218	18,547
Sewerage Connection Rate (% of population)	45%	60%	75%
Sewage Generation to Treatment (m^3/day)	4,845	9,131	13,910
Commercial & Institutional Wastewaters in Sewer (20% over Treated Domestic, m3/day)	969	1,826	2,782
Industrial (m3/day)	45	68	90
TOTAL GENERATED SEWER FLOWS	5,859	11,025	16,782
Stormwater Infiltration Allowance (10% over total, m^3/day)	581	1,096	1,669
Groundwater Infiltration Allowance (25% over total, m^3/day)	1,454	2,739	4,173
TOTAL ADWF (m^3/day)	7,894	14,860	22,624
Estimated Treated Domestic Load (that gets to STP) @35gBOD/p/d (kgBOD/day)	1,178	1,997	3,043

Estimated Septage Load to STP via Pumpout Truck @6,000 mgBOD/L (kgBOD/day)	441	407	310
No. of Tankers Reqd – 3m[3] ea./ 2 trips per day	16	15	11
Estimated Commercial/Institutional load at 300 mgBOD/L (kgBOD/day)	291	548	835
Estimated Industrial Load (kgBOD/day)	36	54	72
TOTAL BOD LOAD, kg/day (with septage)	1,909	2,952	4,188
Est. Influent BOD, mg/L (with septage)	242	199	185
Estimated Treated Domestic Load @30 gSS/p/d (kgSS/day) + Septage	2,129	2,280	2,259
Estimated Treated Domestic Load @16g TKN/p/d (kgTKN/day) + Septage	648	807	962

32. A summary of the projected BOD_5 and ammonia loads for the two towns over the three planning time horizons are shown in **Table 4.8** for the tourist season and **Table 4.9** for the off-peak season.

Table 4.8 – Summary of preliminary design flow and load projections (tourist season, includes septage)

	Balykchy	Karakol
ADWF (MLD) 2018	2.74	8.45
BOD Load (kg/day)	891	2,018
Ammonia Load (kg/day)	157	265
ADWF (MLD) 2028	5.54	16.07
BOD Load (kg/day)	1,300	3,164
Ammonia Load (kg/day)	178	337
ADWF (MLD) 2038	8.59	24.42
BOD Load (kg/day)	1,546	4,496
Ammonia Load (kg/day)	198	406

Table 4.9 – Summary of preliminary design flow and load projections (off season, includes septage)

	Balykchy	Karakol
ADWF (MLD) 2018	2.74	7.89
BOD Load (kg/day)	891	1,909
Ammonia Load (kg/day)	157	248
ADWF (MLD) 2028	5.54	14.86
BOD Load (kg/day)	1,300	2,952
Ammonia Load (kg/day)	178	312
ADWF (MLD) 2038	8.59	22.62
BOD Load (kg/day)	1,546	4,188
Ammonia Load (kg/day)	198	377

33. A check of the various projected flows and loads is shown in **Table 4.10**. This table compares current flows against those projected into the future as well as the flows derived from this project as opposed to those extracted from the 2015 Phase II project report for the common year of 2028. The projected flows for Balykchy appear somewhat high but those for Karakol are reasonable. Judgment can only be made against the current inflows that were given to the consultant and there is likely uncertainty in these numbers.

Table 4.10 – Projected flows comparison

	2017 ADWF Current Estimate (MLD)*	2018 ADWF Projection (MLD)*	2028 Projection (MLD)*	2038 Projection (MLD)*
Balykchy	2.5	2.8 / 2.8	5.5 (4.8)	8.6/ 8.6
Karakol	7 to 8	8.5 / 8.0	16.1/14.9 (17.8/16.4)	23.6 / 19.3
*Tourist Season/Off Season ; (Figures from 2015 Study)				

5 Effluent Discharge Standards

5.1 Water

5.1.1 Kyrgyz and International Standards

34. The ultimate objective of treating sewage or wastewater is to allow its beneficial reuse. Besides the usual water quality parameters that must be met such as carbon (BOD & COD), suspended solids (SS), acidity (pH), nitrate (NO_3), ammonia (NH_3) and phosphorus (P), etc., the microbiological content of the water is amongst the most important, particularly if there is possibility for human contact. Both WWTPs considered in this study (at Balykchy and Karakol), once upgraded, will not directly discharge into surface waters but into storage reservoirs/irrigation canals prior to reuse in agriculture.

35. The team met with the State Sanitary and Epidemiological Service (SESS) of the Ministry of Health in Bishkek, Cholpon-Ata and Karakol regarding the discharge standards with which the WWTP discharges would have to comply. Discussions were also conducted with the State Agency on Environmental Protection and Forestry who now have responsibility for effluent discharge standards. Local representatives of the SESS were also present during public hearings in each city on environmental issues. The Kyrgyz Republic Standards for irrigation water at the time of this writing is summarized in **Table 5.1.**

Table 5.1 – Kyrgyz Republic Standards for irrigation water quality Indicators characterizing the content of substances and chemical elements necessary for the normal growth and development of crops and the functioning of the ameliorative system (Group I)

№	Characteristics	Unit	Optimal range	Allowed value
1	Hydrogen pH	$-log[H^+]$	6.5-8.0	6.5-8.4
2	Temperature	°C	15-30	15-35
3	Mineralization	mg/L	200-500	1000
4	Hydrocarbonates	-//-	50-250	300
5	Carbonates	-//-	non-availability	6.0
6	Sulphates (anion)	-//-	30-300	500
7	Chlorides (anion)	-//-	10-200	250
8	Sodium	-//-	10-100	150
9	Calcium	-//-	50-200	300

№	Characteristics	Unit	Optimal range	Allowed value
10	Magnesium	-//-	20-100	150
11	Potassium	-//-	10-20	30
12	Phosphates	-//-	5-10	10
13	Nitrates	-//-	30-40	45
14	Nitrite	-//-	0.2-0.3	0.5
15	Ammonium	-//-	0-0.1	0.1
16	Iron total	-//-	1.0-2.0	2.0
17	Zinc	-//-	0.1-1.0	1.0
18	Copper	-//-	0.5-1.0	1.0
19	Boron	-//-	0.5-1.0	1.0
20	Fluorine	-//-	0.7-1.0	1.5
21	Manganese common	-//-	0.1	0.1
22	Cobalt	-//-	0.1	0.2
23	Molybdenum	-//-	0.2	0.5
25	*E. coli.*	CFU / 100 mL		$\leq$1,000

36. Note that the microbiological indicator organisms, fecal coliforms and total coliforms are not currently used. However, *E coli* is specified by the Law on Water, No. 1422-XII of 1994 as shown.

37. We subsequently consulted the WHO Guidelines[10] for additional guidance. The guidelines state on page 69 that *E. coli* can be used as a disinfection indicator organism as shown in **Table 5.2.**

Table 5.2 – Verification monitoring of wastewater treatment (*E. coli* numbers per 100 mL of treated wastewater) for the various levels of wastewater treatment

Type of Irrigation	Option (Figure 4.1)	Required pathogen reduction by treatment (log units)	Verification monitoring level (*E. coli* per 100 mL)	Notes
Unrestricted	A	4	$\leq 10^3$	Root Crops
	B	3	$\leq 10^4$	Leaf Crops
	C	2	$\leq 10^5$	Drip irrigation of high-growing crops
	D	4	$\leq 10^3$	Drip irrigation of low-growing crops
	E	5 or 7	$\leq 10^1$ or $\leq 10^0$	Verification level depends on the requirements of the local regulatory agency[11]
Restricted	F	4	$\leq 10^4$	Labor intensive agriculture (protective of adults and children under 15)
	G	3	$\leq 10^5$	Highly mechanized agriculture

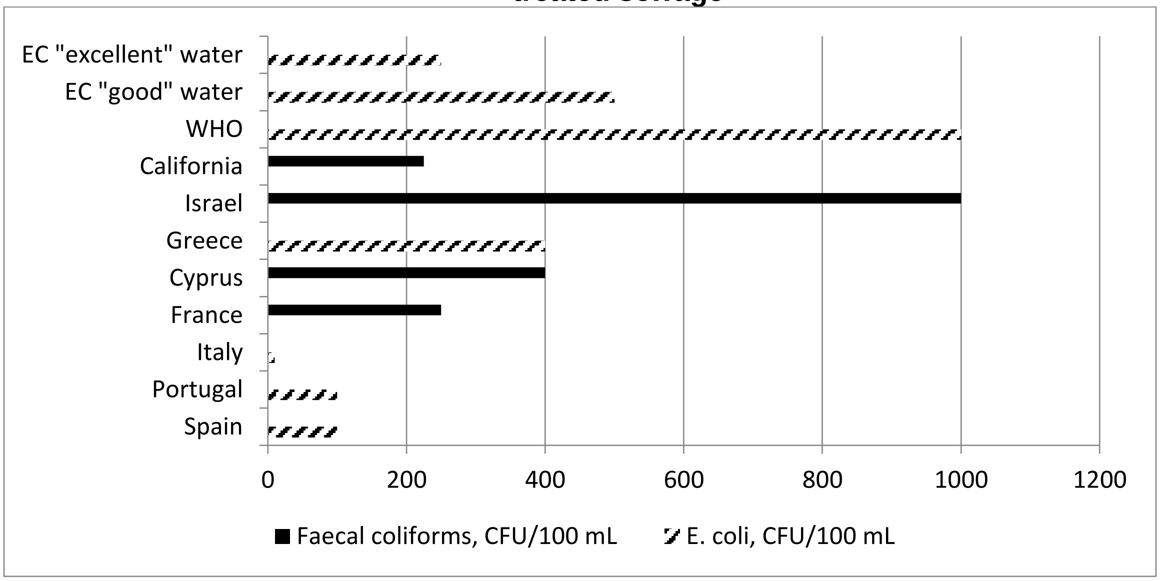
10 The WHO Guidelines for Safe Use of Wastewater, Excreta and Greywater, Volume II, Wastewater Use in Agriculture (2006).

11 For example, for secondary treatment, filtration and disinfection: BOD <10 mg/L; turbidity < 2 NTU; chlorine residual of 1 mg/L; pH of 6-9; and Fecal coliforms, not detectable in 100 mL.

Type of Irrigation	Option (Figure 4.1)	Required pathogen reduction by treatment (log units)	Verification monitoring level (*E. coli* per 100 mL)	Notes
	H	0.5	$\leq 10^6$	Pathogen removal in a septic tank

38. A recent French study[12] pointed out that countries which recycle / reuse the largest volumes of treated wastewater (Israel being the leader, Italy recycling the least) are those which have the lowest number of mandatory quality criteria and the easiest parameters to monitor. Israel defines less than a dozen parameters; Italy defines more than 50 parameters. **Figure 5.3** summarizes the microbiological requirements for recycling treated sewage or wastewater for a number of countries, either through monitoring of Fecal coliform or *E. coli*.

Figure 5.3 – Comparison of disinfection requirements to allow unrestricted irrigation of treated sewage[13]



39. The Kyrgyz Republic legal framework defines the calculation of per capita generation of pollutants such as BOD and suspended solids that can end up in sewage (via SNiP 2.04.03-85). There are also discharge standards that are dependent on the subsequent use of the treated water, either for agricultural irrigation (**Table 5.2**) or as water for a fishery. The waters that would be used for a fishery could be broadly interpreted as being [at least similar to] the discharge into a surface water.

40. The Kyrgyz Republic water quality standards are compared with other more overt or obvious discharge design standards in **Table 5.3**. The European Union standards were designed to bring member countries into compliance in a realistic and timely manner as several, particularly

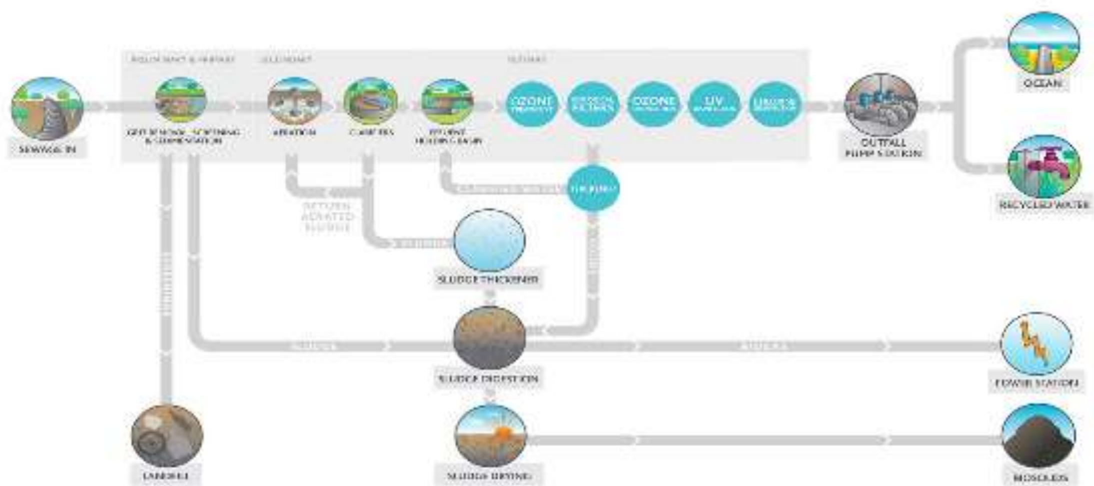
[12] French Environment Ministry (2014) Panorama international de la réutilisation des eaux usés et enseignements pour la France; accessed through via http://ec.europa.eu/environment/water/blueprint/pdf/BIO_IA%20on%20water%20reuse_Final%20Part%20I.pdf (April 2017).

[13] Extracted from http://ec.europa.eu/environment/water/blueprint/pdf/BIO_IA%20on%20water%20reuse_Final%20Part%20I.pdf, Figure 13, page 146 (accessed April 2017)

Eastern European countries, had not in the past focused much in this area. The South African standards were shown as this country has for some time been at the forefront of sewage treatment and biological nutrient removal. Ontario, Canada standards are shown as the location is similar to Kyrgyzstan and the influent is dilute. The Kyrgyz Republic standard for ammonia in irrigation water is quite low and could only be met coming out of the WWTP with advanced tertiary treatment after biological treatment.

41. A recent example of where this was done (2012) is the Eastern Treatment Plant in Melbourne, Australia **(see Figure 5.4)**. The Eastern Treatment Plant treats 40 percent of Melbourne's water, a city with a population close to 4 million or 360 MLD. Melbourne Water identified early that to reduce their ammonia levels below a median of about 13 mg/L[14] they would have add more aeration. To reduce ammonia still further that would allow more industrial and purple pipe recycling (amongst other issues), bench-scale trials and subsequent pilot trials were conducted. The most plausible process to reduce the ammonia to the levels given in the Kyrgyz standard for ammonia out of a WWTP (as well reducing BOD, color levels and pathogenic content) would have to be a "bolt on" tertiary process. This "bolt on" tertiary process for Melbourne Water consisted of ozonation, followed by multi-media biological media filtration [to reduce ammonia, BOD, toxicity, odour and suspended solids], followed by secondary ozonation [for color], followed by disinfection with ultraviolet (UV) irradiation [for viruses and bacteria] and chlorine as a residual [bacteria] to meet the pathogenic risk factors for a Class A recycled water (see **Figure 5.2**). This water could then be used to offset the use of potable water by industries and purple pipe users. The Melbourne tertiary process came at a cost of about $US0.93 million per MLD of capacity.

Figure 5.4 – The overall treatment process at the Eastern Treatment Plant in Melbourne, Australia[15]



[14] See report "Guidance for the use of recycled water by industry, Institute for Sustainability and Innovation, Victoria University and CSIRO Land and Water (2009); https://www.vu.edu.au/sites/default/files/Guidance%20for%20the%20Use%20of%20Recycled%20Water%20by%20Industry.pdf, accessed July 2017.

[15] Picture taken from https://www.melbournewater.com.au/whatwedo/treatsewage/PublishingImages/etp_process_large.jpg, accessed July 2017.

Table 5.3 – Consideration of project design standards

Parameter, mg/L or as stated	EEC Stds[16]	South Africa DWA (2010)[17]	Ontario Extended Aeration (Influent: 150 - 200 mg BOD/L)	Kyrgyz Republic (Agricultural)	Kyrgyz Republic (water for fish)	Proposed Design Maximums for this study
Biological Oxygen Demand (BOD_5)	70-90% reduction[18] 25	Not used	25	Not stated	Not stated	25
Chemical Oxygen Demand (COD)	75% reduction 125	75	Not used	Not stated	Not stated	125
Suspended Solids (SS)	90% reduction (optional) 35	25	25	Not stated	Not stated	35
Total Nitrogen (TN)	70-80% reduction[19] 15	Not used	20	Not used	Not used	$\leq$15
Ammonia (as NH_3-N)	Not used	3.0	3.0	0.1	0.5	3 for secondary; 0.1 for tertiary
Nitrate (as NO_3-N)	Not used	15		10	9	10
Total Phosphorus (TP)	80% reduction[20] 2	10([21])	3.5	10	0.2 (eutrophic)	10 for Irrigation; 2 for river
Fecal coliform (as CFU/100 mL)	See **Figure 5.2**	1000	Not sighted	Not stated	Not stated	Not used
E. coli (CFU/100 mL)	See **Figure 5.2**	Not used	Not sighted	<1,000[22]	Not stated	1,000

16 Council Directive Concerning Urban Wastewater Treatment, Directive 91/27/EEC: Annex I and Annex II, Brussels (1991); see also http://www.euwfd.com/IWA_Krakow_Sep_2005_REV.pdf (accessed April 2017).
17 South Africa standards for wastewater treatment (2010); http://www.wateronline.co.za/wastewater/downloads/dwa-general-standards-2010.pdf (accessed April 2017).
18 Twenty-four hour average; either concentration or percent reduction applies. Note EU Directive has this as a minimum design requirement that also includes COD.
19 Given for plants for treatment plants for 10,000 to 100,000 PE. EU Directive has this as an additional requirement for sensitive waters for treatment plan over 10,000 PE that also includes phosphorus; annual averages, either concentration or percent reduction applies.
20 *Ibidem.*
21 Given in DWAF standards or 1999; not listed in DWA (2010) at this source.
22 Law on Water, No. 1422-XII of 1994, Government of Kyrgyz Republic.

42. Disinfection in some form is required for the upgraded WWTPs to meet the *E. coli* delimit of 1,000 CFU/100 mL. Meeting this *E. coli* limit would directly comply with the Kyrgyz Republic standard as well as to lower the risk for use of the treated effluent on a number of plant types as shown in the WHO Guidelines in **Table 5.2.**

43. All the sewage treatment options considered herein for upgrading the WWTPs at Balykchy and Karakol will have to be able to meet the selected standards given in **Table 5.3**. All the selected design standards are within international guidelines and can be achieved without employing overly complex process configurations or excessive operating and maintenance costs.

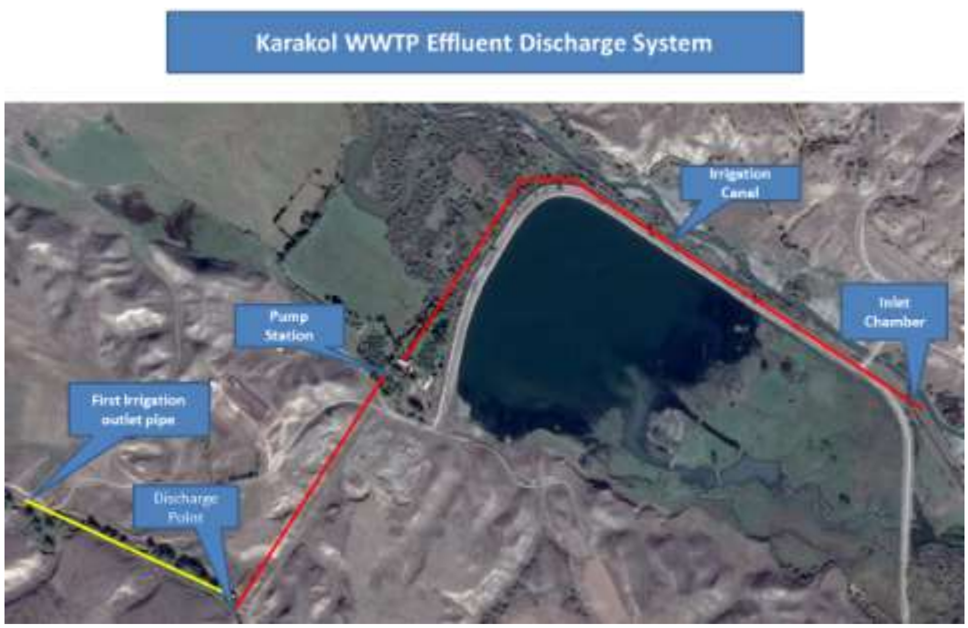
5.1.2 Effluent Measuring Points

44. Secondary treatment processes will be designed to meet all the Kyrgyz effluent standards for irrigation use shown above in Table 4.3 with the exception of ammonia. In the case of ammonia, the secondary treatment process with achieve an ammonia concentration of 3 mg/L in accordance with international standards, but not the Kyrgyz standard of 0.1 mg/L. However, given that the effluent is to be stored and diluted with surface runoff water prior to use for irrigation, the 0.1 mg/L standard could still be achieved depending on the location of the measuring point and the extent of the dilution. Discussions on the location of the measuring points were conducted with the State Agency for Environmental Protection and Forestry and the State Sanitary and Epidemiological Service and a field visit conducted to determine the location of these measuring points. The proposed measuring points for each of the three cities are shown in **Figures 5.5 and 5.6.**

45. During the winter months when irrigation does not occur (4-6 months), the effluent will need to be stored as it will not be used for irrigation. At each of the three sites (assuming that additional ponds are constructed in Balykchy at the site of the existing sludge drying beds), sufficient storage should be available during the initial years to store effluent during the non-irrigation season. However, as wastewater flows increase over time, this storage will eventually become inadequate. This may require the need to provide additional storage or allow limited discharge to land in the case of Karakol and to the irrigation canal and eventually to the Chui River in the case of Balykchy. With the dilution and storage at Balykchy, the required effluent concentration of 0.5 mg/L for discharge to water bodies should be reliably achieved.

Figure 5.5 – Proposed Effluent Measuring Point at Balykchy

Figure 5.6 – Proposed Effluent Measuring Point at Karakol



46. No formal response has yet been received from either agency on the location of the measuring points. Given the available storage and dilution, it could be expected that an ammonia concentration of 0.1 mg/L could be achieved most of the time at the proposed measuring points at Balykchy. This is less likely at Karakol and will depend to a large extent on the amount of mixing surface water generated and the reliability of the surface water being provided.

47. In the event that the prescribed effluent standards are deemed not to be achievable with secondary treatment, a tertiary treatment component that could follow secondary treatment can be provided and this is discussed in further detail later in the report.

4.2 Biosolids

48. There are currently no Kyrgyz Republic Standards for biosolids. It is proposed that the rehabilitated WWTPs produce stabilized biosolids in that primary solids will not be allowed to be recycled directly. It is recommended that all biosolids meet at least USEPA Class B[23] with respect to pathogens and stability by one of the five biosolids management approaches as given below.

1. **Aerobic Digestion**: Biosolids are agitated with air or oxygen to maintain aerobic conditions for a specific mean cell residence time (MCRT or sludge age) at a specific temperature. Values for MCRT and temperature shall be between 40 days at 20°C and 60 days at 15°C.
2. **Air Drying**: Biosolids are dried on sand beds or on paved or unpaved basins. The biosolids dry for a minimum of 3 months. During 2 of the 3 months, the ambient average daily temperature is above 0°C.
3. **Anaerobic Digestion**: Biosolids are treated in the absence of air for a specific mean cell residence time at a specific temperature. Values for the mean cell residence time and temperature shall be between I5 days at 35°C to 55°C and 60 days at 20°C.
4. **Composting**: Using either the within-vessel, static aerated pile, or windrow composting methods, the temperature of the biosolids is raised to 40°C or higher and maintained for 5 days. For 4 hours during the 5-day period, the temperature in the compost pile exceeds 55°C.
5. **Lime Stabilization**: Sufficient lime is added to the biosolids to raise the pH of the biosolids to 12 after 2 hours of contact.

49. This will also reduce potential odor from the biosolids. Class B sludge under the USEPA Part 503 Rule when land applied has its own restrictions[24] such as food crops, feed crops, and fiber crops, whose edible parts do not touch the surface of the soil, shall not be harvested until 30 days after biosolids application, animals shall not be grazed on land until 30 days after application of biosolids and others that involve longer periods of avoiding contact the closer the plant is to the biosolids (i.e. crops grown near the ground) or the greater the potential for human contact (e.g use on parks or sports fields).

50. It is envisioned that all solids from the WWTPs at Balykchy and Karakol will be treated via options 1 to 3 to achieve Class B.

6 EXISTING WASTEWATER FACILITIES

6.1 Balykchy

6.1.1 Sewerage Collection System

51. Currently in Balychy, a total of 3325 households and 106 commercial/industrial/institutional/tourist entities are connected to the sewerage network. This represents about 30% of the population of Balykchy. The remaining households use septic tanks or cesspools which are serviced, when necessary, by the Vodokanal or private sector operated

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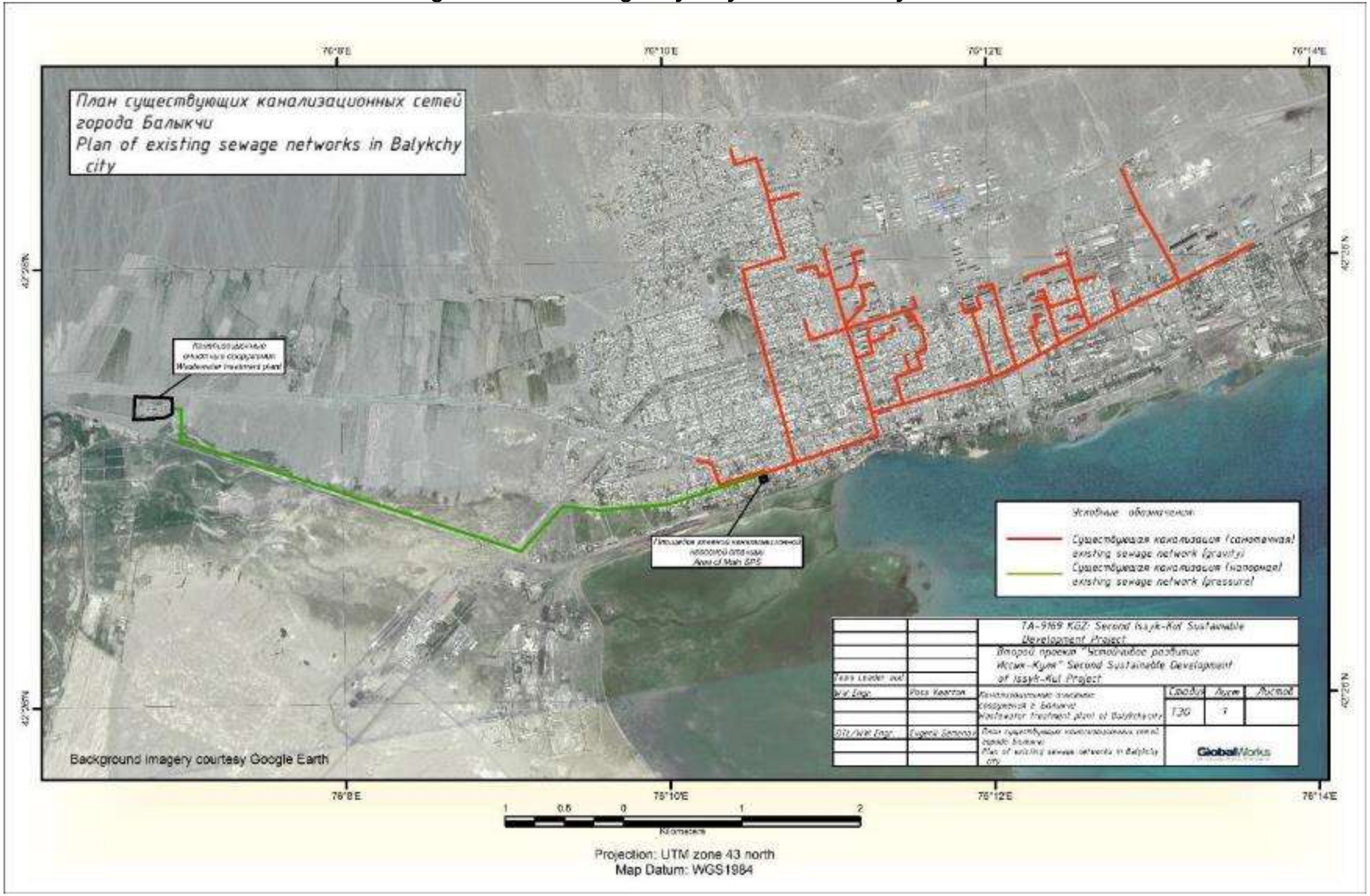
23 USEPA Guide to the Part 503 Rule, page 119; https://www.epa.gov/sites/production/files/2015-05/documents/a_plain_english_guide_to_the_epa_part_503_biosolids_rule.pdf (accessed April 2017).

24 Ibidem, Figure 2-4, page 38.

vacuum trucks for de-sludging. The sewerage network comprises 64 km of gravity wastewater network of vitrified clay, asbestos-cement, steel, and concrete sewers constructed in the 1970s. There is one wastewater pumping station (WWPS), located in the city on Ozernaya Street, and a WWTP is located 6 km to the west of Balykchy near the Bishkek-Balykchy Road. The wastewater pumping station was replaced under ISDP-1 with a new facility and collects all sewage from the collection system and pumps to the WWTP. A layout of the system is shown below as **Figure 6.1.** Large areas of the eastern and southern sectors of the town are not covered by the sewerage network. During the presentation of the Interim Report, the City officials requested that the project include some expansion of the sewerage system.

Figure 6.1 – Existing Balykchy Wastewater System



52. The existing WWTP, with a design capacity of 34,000 m^3/day, was built in 1989 but was never fully commissioned. Initially, it was planned that the treated wastewater would be discharged into biological ponds (about 10 hectares), subsequently discharging the treated wastewater into an irrigation channel. Sludge beds are located on 8 hectares of land near the biological ponds. At present, wastewater passes through the WWTP with only primary sedimentation and is discharged directly into six ponds, four of which were built in 1978, and two in 1989, together with the WWTP.

53. During the non-irrigation period, wastewater accumulates in the biological ponds for post-treatment. During the irrigation period, the treated wastewater is discharged into a supply channel from the Chui River leading to an irrigation pumping station from where effluent is transported by a 1,300 m pressure pipeline to an irrigation channel about 15 km in length where it irrigates about 70 ha of land. The mixed effluent is also used for greening of city parks and gardens. Usually the irrigation period starts at the end of March and lasts until the end of October/early November. The Department of Water Resources operates the pumping and irrigation systems. There is no system for the utilization or removal of sludge from biological ponds.

6.1.2 Balykchy Wastewater Treatment Plant (BAWWTP)

54. BAWWTP is located between the main highway and the Bishkek / Balykchy railway line at an elevation of 1,625 m. The treatment plant consists of:

(a) Non-functional activated sludge (AS) system in an elevated area north of the railway tracks in the top right of **Figure 6.2**, followed by
(b) Lagoon system and drying beds south of the railway tracks.

55. The AS area is about 320 m x 130 m or 4.1 ha and designed to treat a capacity of 34 MLD for a served population of about 90,000 EP[25]. This translates into an allowance of 400 L/EP/d. The current functioning components of the activated sludge system includes 16 mm coarse screens with manual cleaning (only one in use), vortex degritting with manual cleaning (two units, one used at a time) and primary sedimentation (two units, one used). The aeration tanks and secondary clarifiers have never been used and reportedly leak and likely the utilized primary clarifier tanks do also. After primary sedimentation the flow is bypassed to the lagoons or ponds. Primary sludge is fed to any one of six sludge lagoons of 62 m W x 250 m L each, covering a total area of about 400 mW by 200 mL or 8 ha.

[25] ISDP Phase I CLIP Report, 2009

Figure 6.2 – Satellite view of the BAWWTP

56. The ponds take up an area of about 285 m W x 340 m L or nearly 10 ha and were put in during the 1990s as shown in the bottom left of **Figure 6.2**. Overflow from the primary sedimentation tank is directly fed to the lagoons; primary sludge to the drying beds (lower right of **Figure 6.2**).

57. The lagoons were originally designed to operate in three series of two ponds each: a facultative/aerobic pond, followed by a maturation pond. The first series (most northern of **Figure 6.2**) is about 64 m wide by 160 m long, each pond; the second series is 75 m wide x 160 m long, each pond and the third series 83 m wide by 160 m long, each pond. The third series (the most southern) actually is hydraulically connected to the second series through pipes on the 160 m long side and is not directly fed. There are therefore actually then only two series of lagoons that are directly fed from the primary sedimentation tanks as summarized in **Table 6.1**. This arrangement is presumably because discharge from the STP is only allowed during the summer, whilst in the winter the lagoons actually impound the STP flow for storage. All the existing infrastructure for feeding the ponds is in need of rehabilitation.

Table 6.1 – Details of treatment lagoons at BAWWTP

Series	No. of ponds each	Biological Design Intent	Dimensions (m)	Estimate Original Depth (m)	Surface Areas (ha)
1	2	Facultative or Aerobic / Maturation	2 x 64 x 160	2.5 / 1.5	1.02 / 1.02
2	2	Facultative or Aerobic / Maturation	2 x 75 x 160	2.5 / 1.5	1.20 / 1.20
2 (connected to 2)	2	Facultative or Aerobic / Maturation / Storage	2 x 83 x 160	2.5 / 1.5	1.33 / 1.33

Industrial Discharges

58. There are no industries within the catchment of BAWWTP; the last industry closed in 2007 as shown in **Table 6.2**. It was previously assumed that within the then design horizon of 2035 and beyond that no major industry would be established in the area that would add to the discharges and we have accepted this assumption for our calculations. We were told that the city government wants to put in an abattoir (a highly polluting industry) but no data is available to include this into the projections. During the presentation of the Interim Report, the City officials also outlined a plan to develop an industrial zone within the City but planning for this seems still to be in the very preliminary stages.

Table 6.2 – Previous industrial discharges given in WP08/WP10 Field Survey (2014)

#	Type of Industry	Name of the Industy (LLC, JSC, company, etc.)	Location, Address	Amout of Wastewater (m^3/day)	Closing Year Of Production
1	Meat	Meat processing plant LLC	Frunzenskaya street	2,000	1991
2	Flour	LLC Dan-Azyk	Frunzenskaya street	280	1998
3	Juice, Jam, compote	Fruits wine factory	Jamanbaeva street	390	1999
4	Vodka	Distillery	Kulakunova street	560	2007

Odor Receptors

59. The BASTP is located adjacent to the central Bishkek-Balykchy highway in an area with few human settlements. The area adjacent to the STP is cropping and grazing land and tree plantations. It is therefore assumed that this is not a potential problematic issue for a future upgrade of the STP.

Biosolids Treatment

60. Secondary biosolids are contained within the current operating ponds. Only one pond has ever been desludged and that was 10 years ago. The primary solids are pumped into the existing sludge lagoons but have never been removed.

61. The ponds are in need of desludging to become fully functional. Sludge content lowers the pond volumes and treatment effectiveness. This presumption is strengthened by an observation in a visit report that in 2014 anaerobic (septic) conditions existed, "indicating that the cells are too small for the pollution load discharged into them". The consultant also observed during the visit in April 2017 that the discharge from the ponds was highly turbid, containing a large concentration of suspended solids. Previous monitoring shows the lagoons remove about 50% of the BOD. As there are no metal industries in the area, the biosolids when they are extracted, can be dewatered in the existing lagoons and land applied, likely on the site of the WWTP or on adjacent farm land.

Treated Water Reuse

62. WWTP discharge is used for agricultural land during the growing season. The water remains impounded in the lagoons during the winter. The lagoons are manually decanted during the summer season into a canal containing water from the Chu River, which is nearby. The water from this canal is pumped to neighboring orchards and to a village for use for growing animal feed but also for parks during the summer. The pump station (PS) is owned by the Department of Irrigation under the Ministry of Agriculture. This PS can pump 720 L/s and currently the Balykchy STP only receives 2.5 MLD or about 29 L/s, which constitutes about 4% of the total agricultural flow.

63. Greater flows in the future could require discharge directly to the Chu River during the winter, although there is also scope for expansion of the lagoon volume by constructing new lagoons on the site of the existing sludge drying beds.

Current Operating Status & Condition

64. The general status of the civil structure of activated sludge facilities appears poor, particularly with metal or mechanical components. The possibility of recovery or rehabilitation for BAWWTP has previously been considered "low to unrecoverable" by the 2015 Phase II project report. However, the tanks appear structurally sound (which has to be verified) and with a proper membrane liner, the volumes could be used (for the first time) in a reconfigured activated sludge design.

65. The coarse screens are in operation but are old and manually cleaned. The degritting tanks are concrete, which are in poor condition and in need of rehabilitation as are the primary sedimentation tanks.

66. The lagoons are likely full of sludge and have only a small fraction of their original treatment volumes. All penstock valves need to be replaced and the feed inlet distribution system to the lagoons is derelict and needs to be rehabilitated.

67. It appears that only two of the six sludge shallow lagoons have ever been used for primary sludges and have themselves never been desludged. They are currently allowed to dry out, grass to grow and then grazed by cattle.

Septage

68. Septage is collected both by the Vodokanal and by private operators of vacuum trucks and discharged into a sewer manhole. Both the Vodokanal and the private sector have 2 vacuum tankers each which is inadequate for a full septage collection and disposal system.

6.2 Karakol

6.2.1 Karakol Wastewater Collection System

69. The wastewater system in Karakol is operated by the city Vodokanal (KVK) and consists of a gravity and pressure wastewater system, four wastewater pumping stations and a wastewater treatment plant with mechanical and full biological wastewater treatment. About 35% of all households in Karakol are connected to the wastewater system through 7190 connections, most of which live in multi-dwelling houses. Therefore at present, about 25,000 people receive services though connection to the centralized wastewater system. In addition, KVK provides wastewater services to 251 commercial entities, 1 industrial enterprise and government institutions, including schools and hospitals. The total discharge of effluent from industrial plants is estimated to be 1,000m^3/day.

70. The entire city of Karakol, except for the Pristan area, is served by a gravity wastewater system going from the south to the north where the WWTP is located. The length of the wastewater network of the city is 110 km. The serviced areas are mainly the central and north-eastern sectors of the town. The existing network consists mainly of cast-iron and asbestos-cement pipes. In addition, within the first phase of the ISDP-1, 12 km of new sewers were constructed covering the area to the west of the Karakol River.

71. In addition to the gravity wastewater system in Karakol, the village of Pristan is served by a pressure system. This system includes 4 pumping stations, of which 3 were rehabilitated under the first phase of ISDP-1. The fourth wastewater pumping station is located close to the Issyk-Kul Lake and is in a damaged, non-operating condition. In this connection, the construction of a new wastewater pumping station in a new location is required.

72. In summary, the sewerage system that supplies KKWWTP consists of:

(a) A gravity public sewerage network, with a total length of sewers of 71.4 km with pipe diameters ranging from 100 mm up to 700 mm;

(b) A pressure sewerage system that serves the rural areas of Pristan. The system consists of 10 km of 200 mm diameter pipe, 28 km of 300 mm diameter pipe and four pumping stations. Two of the pumping stations are at the end of the system and the other two are intermediate booster pumping stations. Three of the four pumping stations have a wet well of 40 m^3, whereas the other one has a well capacity of 130 m^3. The total length of rising mains is approximately 14.5 km;

(c) Latrines and septic tanks that service the other non-sewered areas and

(d) A need for a new sewage pump station (SPS 4) near the old torpedo testing facility as shown in **Figure 6.3**. Currently the sewage from an adjacent neighborhood is pumped and transported twice per week by vacuum pump out trucks. SPS 4 would accommodate about 2,000 EP. The size of the pipe that collects the sewage from the neighborhood is a 350 mm φ asbestos pipe, whilst the pipe to the KKWWTP is a 300 mm φ steel pipe.

73. A layout of the Karakol wastewater system is shown in the following Chapter as **Figure 7.3**

6.3.2 Karakol wastewater treatment plant (KKWWTP)

74. The KKWWTP in Karakol was originally constructed with an estimated treatment capacity for a 55,000 equivalent population (EP) or a design capacity of 22 MLD at 400 L/p/d (**Figure 6.2**). The treatment plant is located about 7 km NW of the city center, along the Karakol River. The influent in 2009 was estimated by Vodokanal to be between 7 to 8 MLD. KKWWTP is located on approximately 13 hectares, along the southern slopes of a local river valley.

Figure 6.3 – Location of future sewage pump station at Pristan

Sewage Treatment & Current Capacity

75. The existing treatment process shown in **Figure 6.4** consists of activated sludge, followed by impoundment in lagoons for polishing before discharge. The flow enters the inlet works and passes through a single [but rather battered] coarse screen before entering a diversion channel to one of two vortex degritting units. This is followed by three primary sedimentation tanks, of which only one is in service. Corrosion of the metal components is evident as is the degrading concrete structures in the various units.

Figure 6.4 – Location and layout of the Karakol WWTP

76. Flow enters the aeration tank after the PSTs but is not aerated. The aeration system has been dysfunctional for many years. The concrete in the aeration tank appears particularly degraded in a number of areas. Four clarifiers of which one is functional follow the aeration tank. No chlorination is provided after clarification and the flow is directed into a storage lagoon. The lagoons have a working level of between 1 and 2 m and are apparently inter-connected but do not work in series or in parallel. Only one of them is connected before final discharge. The ponds have an estimated volume of 40 ML at a 1.5 m depth and a surface are of about 2.7 ha.

Industrial Discharges

77. There are 21 factories in operation in Karakol, mostly mill flour. Total industrial wastewater production was estimated as small at about 45 m^3/d, the detailed list of which was given in the WP08/WP10 Field Survey (2014). In summary, the industries have the following makeup:

Flour mills	41%
Bakeries:	28%

Abattoirs:	9%
Textiles:	2%
Spirits:	10%
Miscellaneous:	10% (wood, concrete blocks and electrical)

Biosolids Treatment

78. Current treatment facilities include two dysfunctional (2) 15 m φ anaerobic digesters and 10 off 35 m x 9 m sludge drying beds. The drying beds receive primary sludge from the PSTs.

Treated Water Reuse

79. The effluent is discharged from the final settling tank to a holding lagoon below the drying beds. From this pond, flow is conveyed by pipe under the Karakol River to discharge into a further large reservoir, some 2 km to the NW, operated by the Department of Irrigation, into which 5 small streams also discharge. Water is pumped for the irrigation of agricultural lands from March till November; in the other months, it is assumed that the water percolates into the ground of the four holding lagoons that are connected hydraulically along with evaporation. The Karakol River flows close to the KKSTP but there is no interconnection. Similarly, there is no outlet or connection between the holding lagoon and Lake Issyk-Kul. Until recently, the semi-treated effluent was discharged without dilution into the irrigation system. Recently the system to provide mixing water from surface runoff has been restored to enable a better quality of water to be discharged for irrigation.

Current Operating Status & Condition

80. KKWWTP is generally in poor condition. The aeration system is non-functional. All buildings including: blower building, chlorination building, sludge building, transformer building and administration building are in poor condition. Concrete quality of the existing tanks is perceived to be in a poor state with leakage.

81. It is the opinion of the consultant that there is a general need for complete replacement of this sewage treatment process with possible rehabilitation of some of the ancillary components.

Septage

82. Septage is collected both by the Vodokanal and by private operators of vacuum trucks and discharged into a sewer manhole. The Vodokanal has 2 vacuum tankers, whilst 6 vacuum tankers are operated by the private sector. These are considered inadequate to meet the needs of the City.

7 PROPOSED SUB-PROJECTS FOR INCLUSION IN THE LOAN

83. The Inception Report[26] for this PPTA outlined a number of options for the provision of improved wastewater facilities in the two towns. This was followed by detailed discussion with the municipal administrations, Vodokanals and other stakeholders in each of the towns and ultimately with a Project Working Group at the end of an Inception Mission conducted between 22-30 May 2017[27]. Following these discussions, preferred options were agreed and

[26] TA9169 KGZ – Second Issyk-Kul Sustainable Development Project, GlobalWorks, May 2017
[27] Aide-Memoire, KGZ: Second Issyk-Kul Sustainable Development Project, ADB, May 2017

conceptual designs and cost estimates undertaken for proposed sub-projects in each town based on these preferred options. These sub-projects largely fall into the following categories:

- Rehabilitation of wastewater treatment plants and effluent disposal systems.
- Priority sewerage infrastructure comprising pumping stations and sewer pipelines

84. Following the Interim Report submission, while the secondary treatment process proposed at the Inception Stage remained the same, the need to meet the required effluent standards for irrigation use, in particular, the ammonia concentration was discussed in detail with the State Agency for Environment and Forestry. This included determining the appropriate point at which the effluent standards should be measured (see Section 4.2.2 above) which would in turn determine the standards which need to be met by the treatment process.

85. Details of the proposed sub-projects are described below.

7.1 Wastewater Collection Systems

7.1.1 Balykchy

86. The existing sewerage collection system in Balykchy is described in Section 6.1.1. It is essentially a gravity system with only one main pumping station to pump to the WWTP. This pump station and pumping main were rehabilitated under ISDP-1 and are in good operating condition. Currently only about 30% of the residents are connected to the sewerage system which serves primarily the eastern part of the town. This system comprises 64 km of sewer pipes constructed up to 40 years ago. Much of this network may now be in poor condition and the main collector pipelines may be oversized due to the previously planned industrialization of Balykchy during the Soviet era. The EBRD estimated that about 50% of the existing network needs to be replaced[28] but this would need to be confirmed by a CCTV survey of existing sewers. Expansion of the system to increase service coverage would need to be in the western part of the city. Some southern portions are also uncovered but these are generally at a lower level than the main collector mains and would require pumping. These residences are closer to the lake and, although possibly more economic, ineffective on-site sanitation may present a risk of pollution to the lake. On the other hand there are proposals by the city government to relocate these residents due to the risk of flooding.

87. During the Interim Report presentation, the City officials requested some expansion of the existing sewerage system. This was further investigated and an additional 10.3 km of sewer pipes were proposed to be included as shown in **Figure 7.1**

88. There is also need to deal more effectively with the 70% of residents utilizing on-site sanitation. This will require improving the effectiveness of the septic tank pump-out program, including the provision of septage receiving facilities, preferably at the wastewater treatment plant and either increasing the capacity of the Vodokanal to undertake septage collection or regularizing the private septage operators such that they dispose of septage in a controlled manner. In addition, up to 3 additional vacuum tankers will be provided for the Vodokanal, depending on funding availability.

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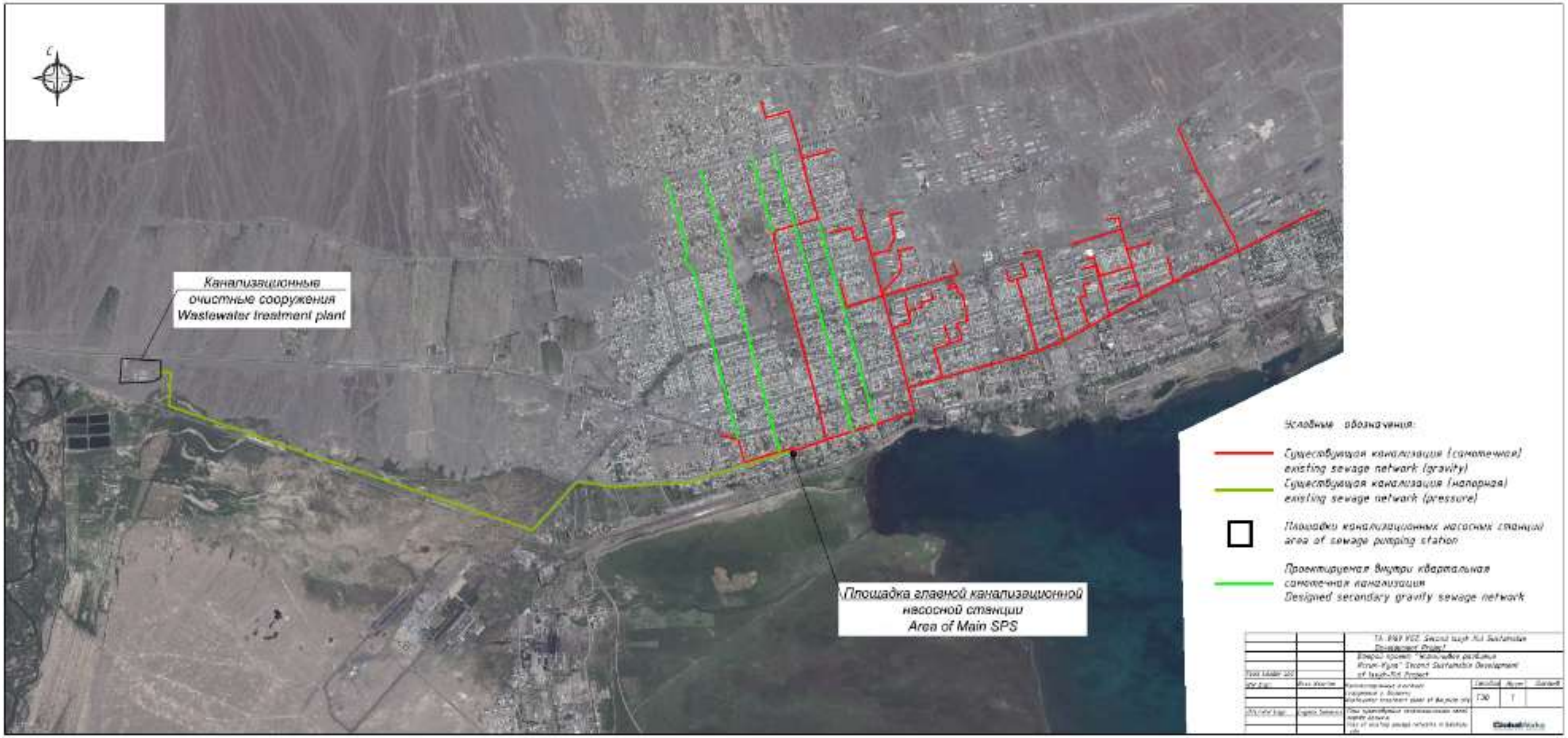
[28] Balykchy Water Sub-Project Review Feasibility Study, Final Report, EBRD, Grontmij, February 2016

Figure 7.1 – Balykchy Sewer Layout



7.1.2 Karakol

89. It is reported that about 45% of households in Karakol are connected to the sewerage system, with the remaining having septic tanks or pit latrines. The current collection system comprising about 100km of cast iron, asbestos cement, concrete and vitrified clay pipes serves mainly the central and north-east sectors of the city. Under ISDP-1, 12 km of new sewer main was constructed in the unserved areas west of Karakol River. However, secondary sewers and house connections were not provided meaning that sewerage coverage was not effectively increased. Moreover, since these sewer mains are not carrying sewage, these is a high risk that they will become filled with garbage and silt and become dysfunctional over time. A high priority will be to provide the necessary secondary sewers and encourage houses to connect such that this expanded system will become functional. ISDP-1 also constructed 5.7 km of replacement main and secondary pipelines in the eastern part of the city.

90. The existing network was mainly constructed in the 1980’s when increased industrial development of the city was envisaged and the main sewer pipes therefore have sufficient or over-capacity for the foreseeable future. However, the over-capacity can have a detrimental effect on the sewer pipes due to low flows in the sewer increasing the risk of corrosion. It is likely therefore that replacement of some of the existing sewers will be required after inspection.

91. The Pristan system was partially rehabilitated under ISDP-1 with the improvements made to three of the four pumping stations. However PS-4 was not rehabilitated with the result that raw sewage is discharged into a pit close to the lake shore which requires daily pump-outs by the Vodokanal. It is critical that rehabilitation of PS-4 is undertaken as a priority.

92. Under ISDP-1, a vacuum tanker was provided to improve the capability of the Vodokanals to undertake septage management. Septage collection services are also conducted by private companies who often dispose of the septage indiscriminately or illegally in the sewer manholes. While the Vodokanal believes that the private companies have a role to play in septage management, these services need to be regularized.

93. The following sub-projects related to the wastewater collection system are therefore proposed for Karakol.

1. Provision of 11.3 km of secondary sewers connecting to the primary sewers constructed under ISDP-1.
2. Construction of a new submersible pumping station No.4 in Pristan to collect sewage from up to 100 households not currently connected to the Pristan wastewater system.
3. Provision of 4 vacuum tankers for use by the Vodokanal.

94. These subprojects are described in more detail below.

New Secondary Sewers in Karakol City to complement ISDP-1 Collector Sewers

95. The project proposes construction of a new secondary sewerage network made from polyethylene pipes with 200mm diameter and total length of 11.3 km. This will include 86 manholes with a diameter of 1 m and an average depth of 2.25 m to be connected to the new 12 km sewage collector constructed under ISDP-1.

96. The proposed location of the secondary sewers is shown in purple in **Figure 7.3**

New sewage pumping station No.4 in Karakol city (Pristan).

97. The project proposes the construction of a new Sewage Pumping Station No. 4 in Pristan settlement of Karakol city. The pumping station will have a diameter of 6m and will be fitted with two submersible pumps (one duty, one standby). The sewage collector pipeline will have a depth of 4m at the entry to the pumping station,

A location plan is included as **Figure 7.4** and a typical layout of the pump station as **Figure 7.2.**

Figure 7.2 – Typical Submersible Pumping Station

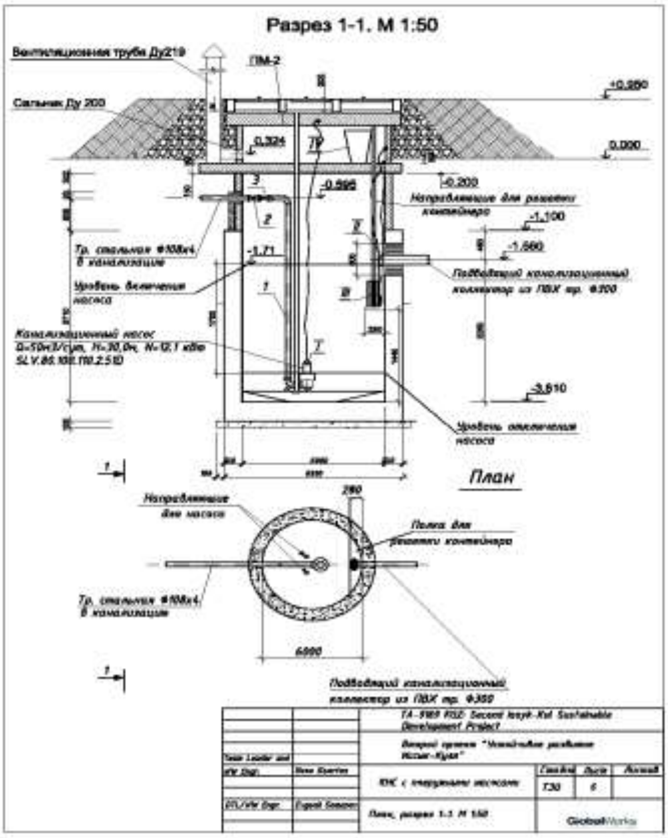


Figure 7.3 – Karakol Sewer Layout

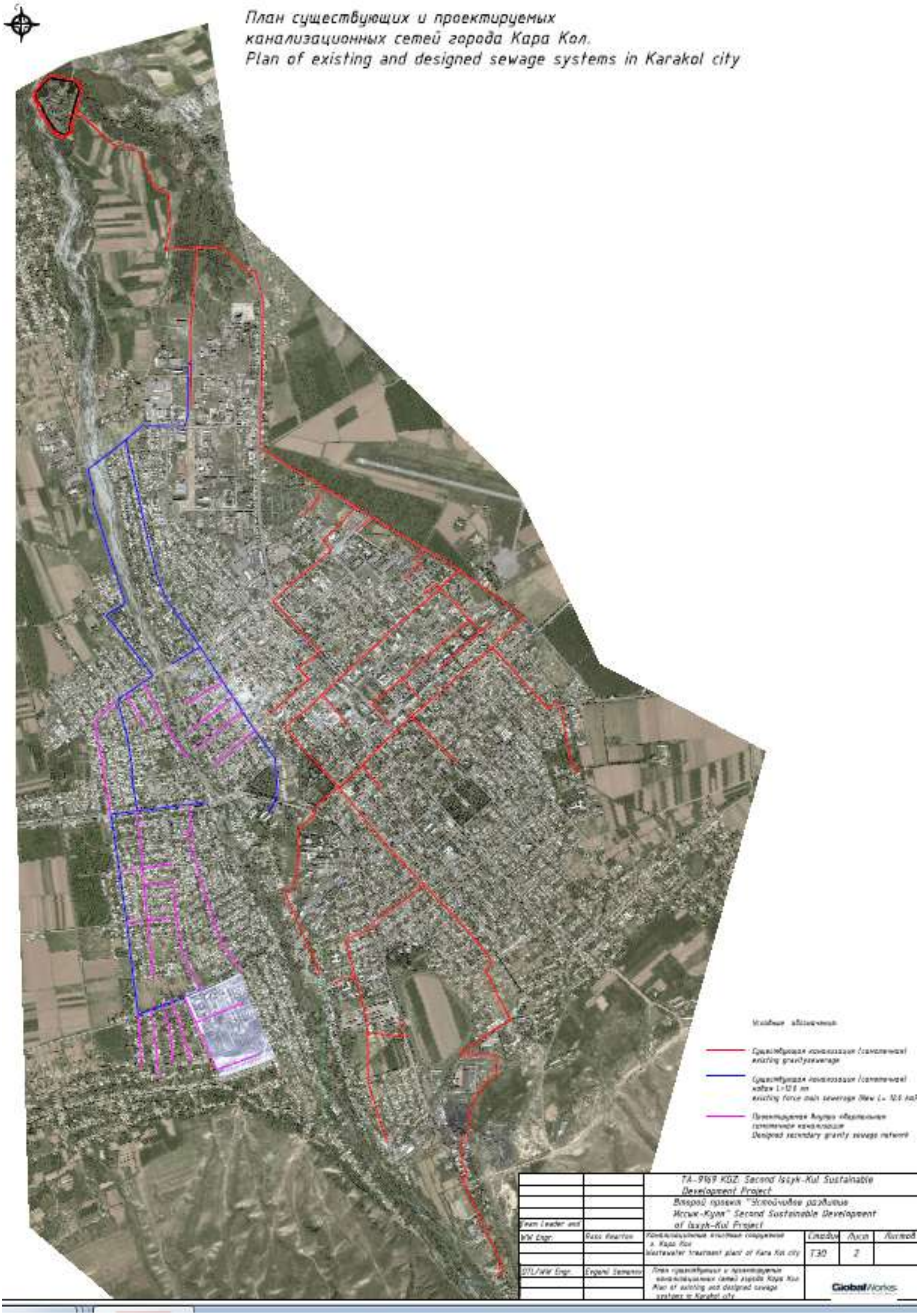


Figure 7.4 - Pristan Pumping Station No.4

7.2 Wastewater Treatment Plants

7.2.1 Preliminary Treatment Options Analysis

98. The major considerations for selecting the options have taken in account the below circumstances.

- The consultant has taken the approach for this study to whenever possible consider the possible reuse of current WWTP components as one of the options in addition to an option for total replacement.
- Each of the existing WWTPs employs activated sludge processes, followed by impoundment ponds
- The existing activated sludge tanks are large but in various states of disrepair and usefulness.
- All existing mechanical equipment is corroded, dysfunctional or antiquated and will need replacement.
- All treated discharges are currently [or could be] reused for agricultural irrigation. The consultant believes this approach should be continued and promoted.
- The Kyrgyz Republic standards for agricultural irrigation are only strict in terms of the maximum allowed ammonia (**Table 5.3**) of only 0.1 mg/L, nitrate of 10 mg/L and *E. coli* of 1,000 CFU/100 mL. Phosphorus concentration of raw sewage measured in 2017 was well within the 10mg/L discharge limit for irrigation and will not likely require particular process attention (e.g. removal of phosphorus biologically or with metal

salts) for its removal. The low ammonia level requirement drives the overall treatment plant design by making the tanks much larger or necessitating the inclusion of a tertiary treatment process as opposed to the design based on incoming BOD_5. This is particularly relevant during the winter when temperatures drop and nitrification becomes more difficult. This was the main reason the proposed design maximum for ammonia herein was originally at the Interim Stage selected to be similar to the South African or Ontario, Canada standards at a 3 mg/L maximum (**Table 4.3**).

- We have allowed in our aeration designs capacity enough for an influent TKN of over 80 mg/L, even though the ammonia has only been measured at about 21 mg/L. This should be more than enough to achieve maximum conversion of ammonia to nitrate, although it is more difficult for nitrification to occur at lower temperatures.
- The Consultant notes that "sensitive crops" (that includes sugarbeets and grapes) may be affected by nitrogen concentrations above 5 mg/L but most other crops are relatively unaffected until nitrogen exceeds 30 mg/L. Apricot, citrus and avocado can be delayed and the fruit may be poorer in quality, thus affecting the marketability and storage life if the water nitrogen exceeds 30 mg/L[29].
- While the Consultant has the view that a discharge standard for ammonia of 3 mg/L in accordance with international standards is acceptable for irrigation purposes, it is acknowledged that the Kyrgyz standards do require an ammonia discharge standard of 0.1 mg/L for irrigation. Consequently, we have made allowance for the inclusion of a tertiary treatment process that will meet this standard, but which will involve additional cost.
- The *E. coli* discharge delimit would normally require disinfection at all the WWTPs, even with agricultural irrigation reuse, likely by the use of chlorine, although Balykchy uses lagoons. However, there are scenarios in which the treated effluent is further diluted and/or impounded in reservoirs that could allow not using disinfection at the STP.
- All the inflows to all the STPs are considered to be dilute (**Table 3.2**), with an average 95%tile BOD_5 of around 120 mg/L and ammonia at 21 mg/L. These are 95%tile numbers, i.e., the average plus a standard deviation, so they can be a lot more dilute.
- Typical activated sludge processes do NOT do well with dilute feed as evidenced by the operations by Manila Water in Manila, Philippines who almost exclusively employ activated sludge on dilute combined sewage/drainage of BOD_5 concentrations less than 100 mg/L. In Manila, they have difficulty in growing enough mixed liquor suspended solids (MLSS), the mixed liquor active biomass, to keep the process 100% active and well settling. This can be mostly overcome by employing larger activated sludge tanks as are used with sequencing batch reactors (SBRs) or intermittently decanted aerated reactors (IDEALs) as seen in **Figure 7.5**. Attached biomass systems like trickling filters (TFs), biological aerated filters (BAFs) and moving bed biofilm reactors (MBBRs) operate efficiently with dilute feeds as seen in **Figure 7.6**, **Figure 7.8** and **Figure 7.9**, respectively, but the vodokanals are not used to seeing these configurations. Lagoons, due to their large volumes, can cope well with dilute feeds as is seen with the current performance at the Balykchy WWTP, but Balykchy will receive a new treatment process before the lagoons. A pure lagoon or pond process configuration is shown in **Figure 7.7**.
- A workshop was held with the Vodakanals concerning the selection of a preferred process. The decision support system used in selecting the preferred process was multi-criteria analysis in which the Vodokanal senior management participated during the workshop. The outcome of this analysis is shown in **Table 7.10** in which the use of a SBR/IDEAL process was selected (see **Figure 7.5**). IDEAL/SBR biological

[29] Ayers, R.S. and D.W. Westcot 1994. "Water quality for agriculture", Food and Agriculture Organization of the United Nations (FAO) Corporate Document Repository, FAO Irrigation and Drainage Paper 29, Rev. 1, ISBN 92-5-102263-1; http://www.fao.org/docrep/003/T0234E/T0234E00.htm and http://www.fao.org/docrep/003/T0234E/T0234E06.htm, accessed July 2017.

process configurations employ cycled aeration. When the air is turned off and the biomass settles, the treated and clarified supernatant is decanted. A separate clarifier is unnecessary.

- Rehabilitation / renewal of all the WWTPs will include septage receival facilities. This has been projected to increase solids loading by around four times over simple septage (septage is around 4% solids), but gradually decrease as sewer connections rise.
- As there are no current Kyrgyz Republic standards for the management of waste biomass, the consultant recommends the use of USEPA guidelines and the production of Class B sludges by one of the following processes:
  a. Aerobic digestion,
  b. Air drying (this process is currently in use by Vodokanals through the use of drying beds at all of the WWTPs) or
  c. Anaerobic digestion.

99. This will lower the risk factor for the reuse of the biosolids on pastures, tree plantations and parks.

100. Air drying is recommended for all the WWTPs and anaerobic digestion and air drying is recommended as an option for Karakol due to its past history with this technology.

101. A Design Summary for the proposed wastewater facilities is shown for each of the cities in **Annex 1** to this Report.

Figure 7.5 – Process flow diagram of a typical Intermittent Decanted Extended Aeration (IDEAL) activated sludge system

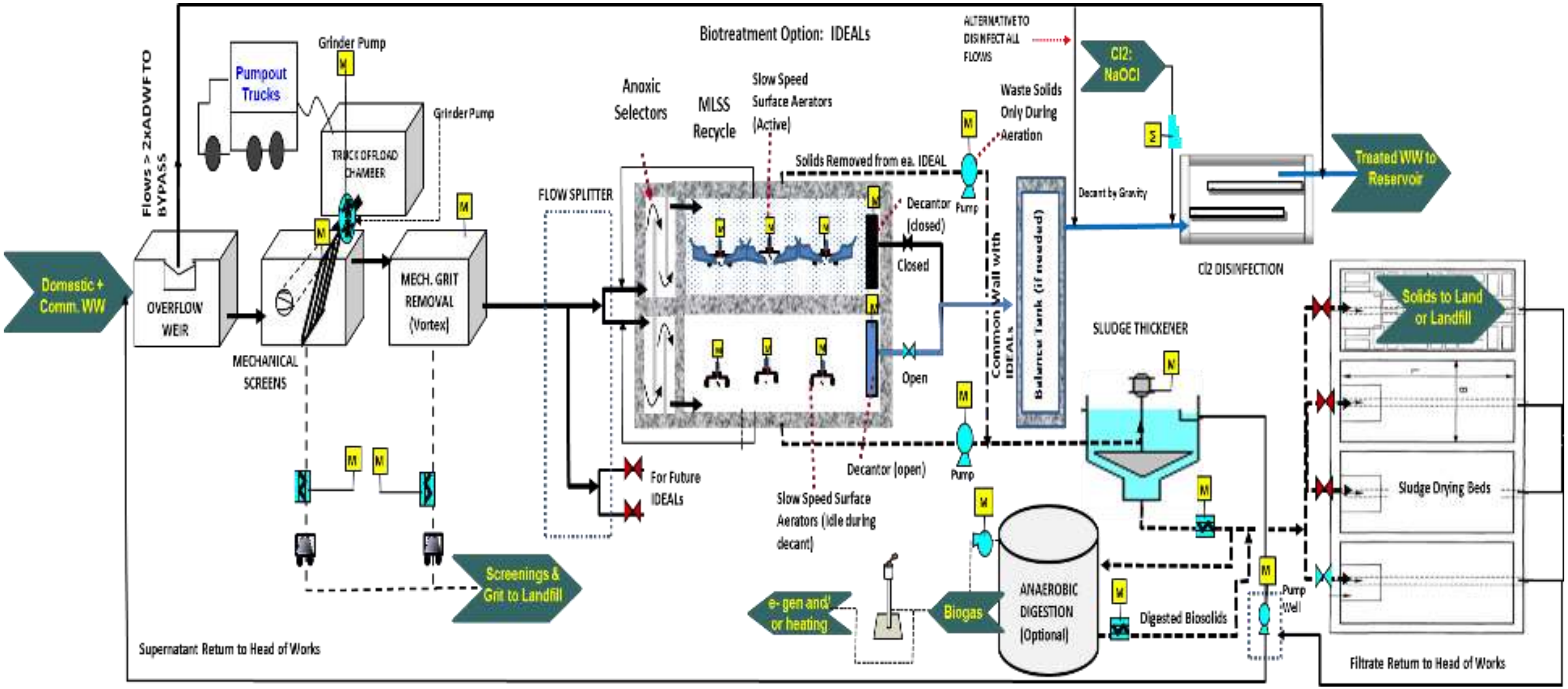


Figure 7.6 – Process flow diagram of a Imhoff tank [for primary solids separation] followed by a covered trickling filter

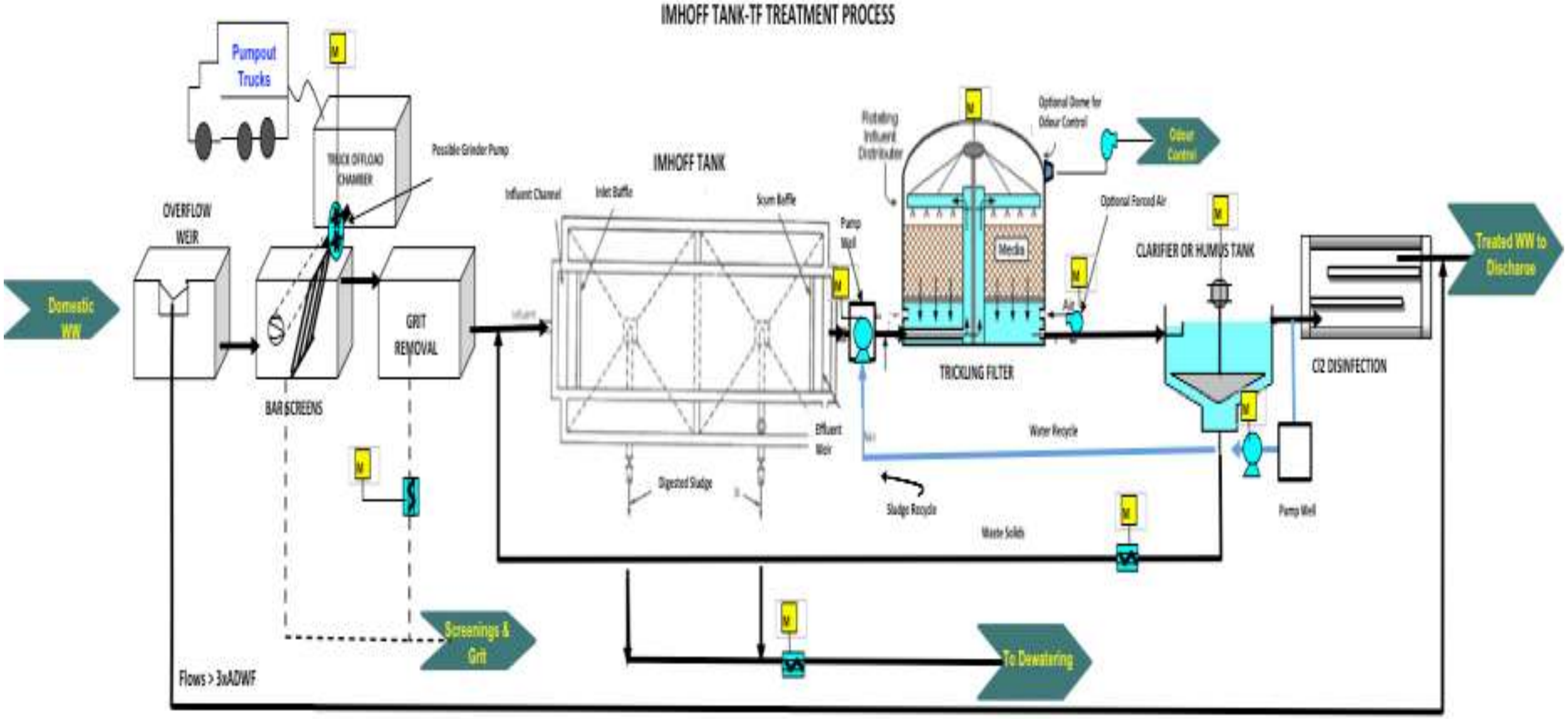


Figure 7.7 – Process flow diagram of a lagoon treatment system with optional odor control on anaerobic lagoon

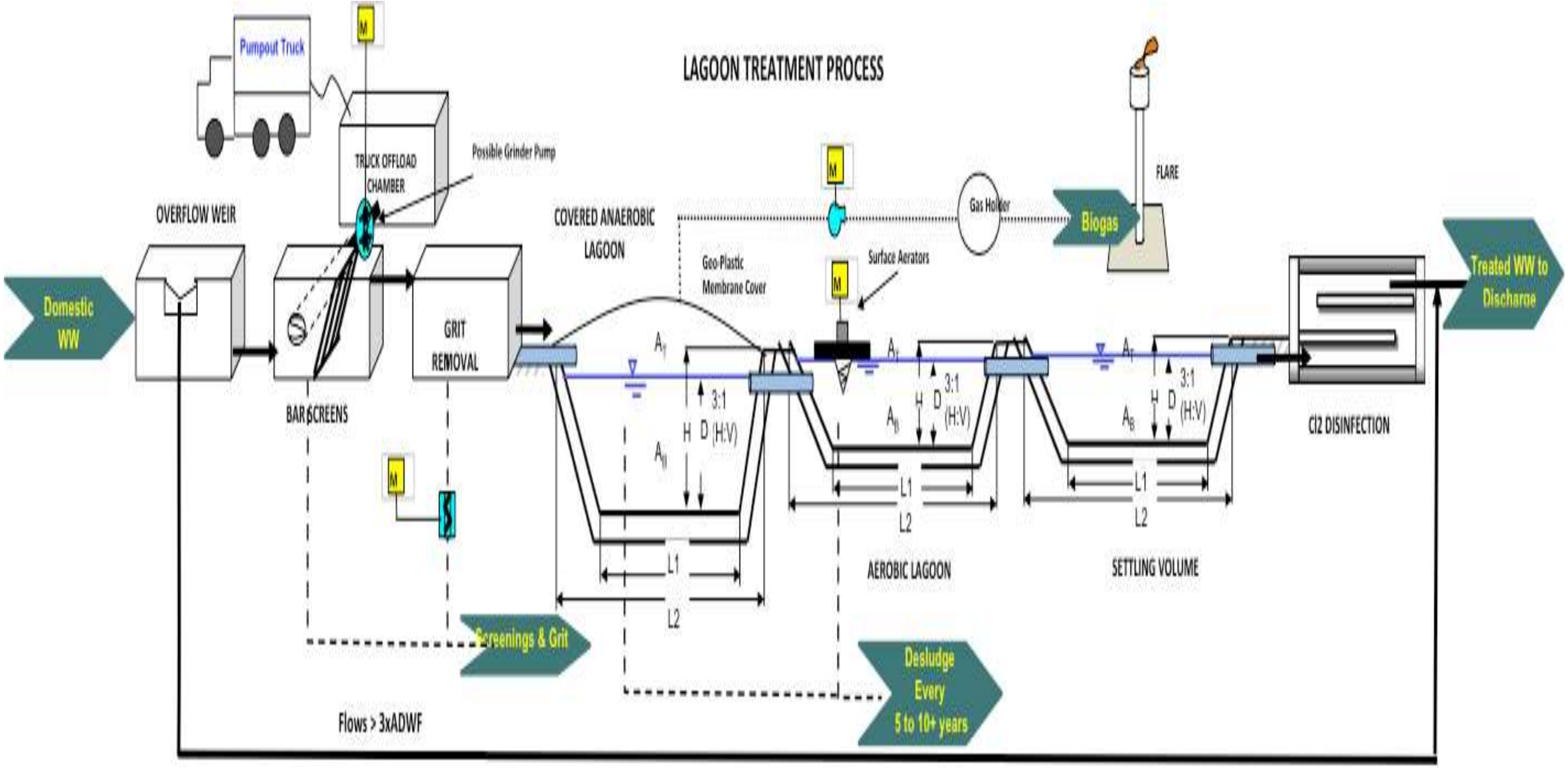


Figure 7.8 – Process flow diagram of a Biological Aerated Filter

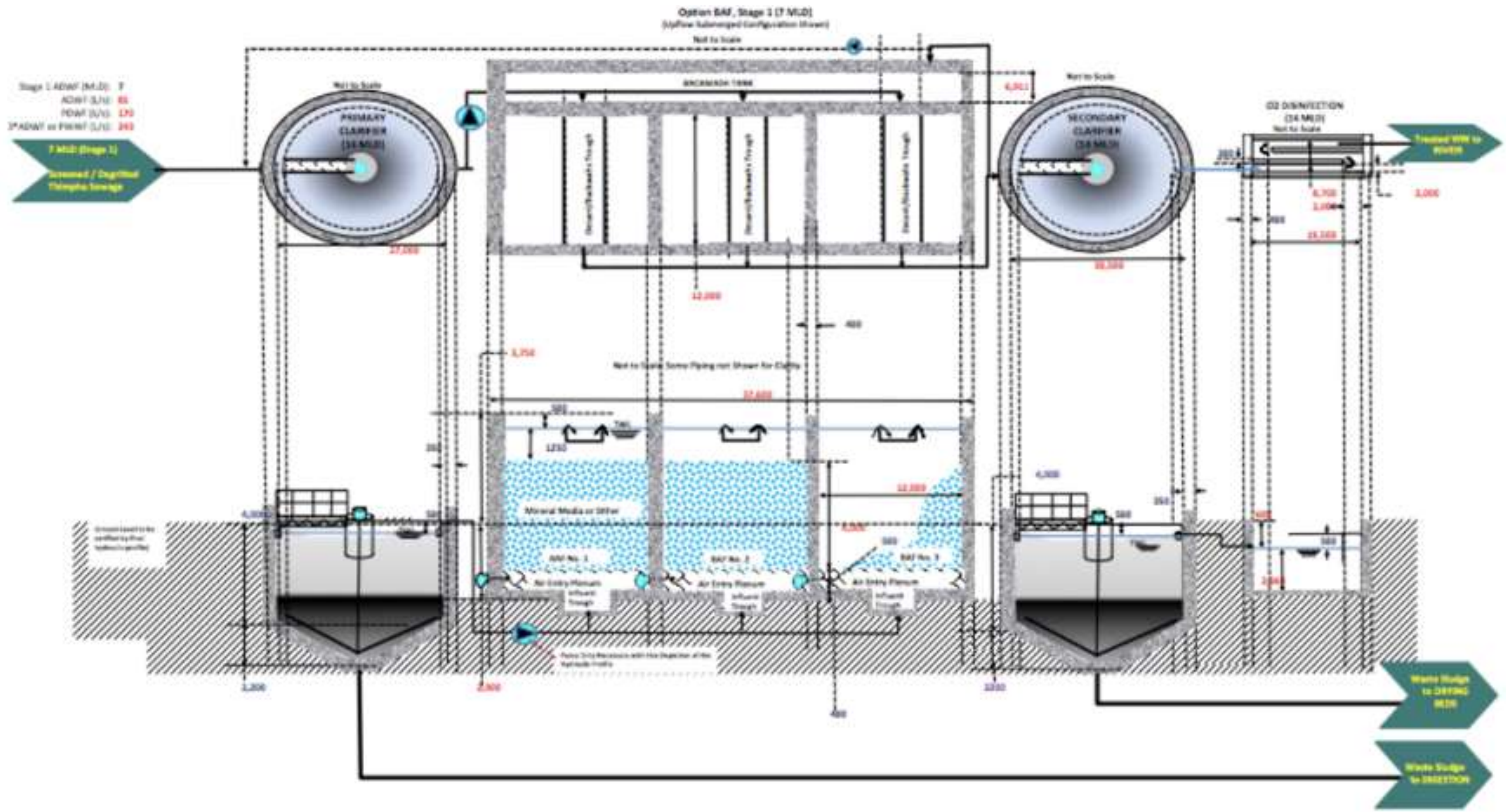


Figure 7.9 – Process flow diagram of a Moving Bed Biofilm Reactor

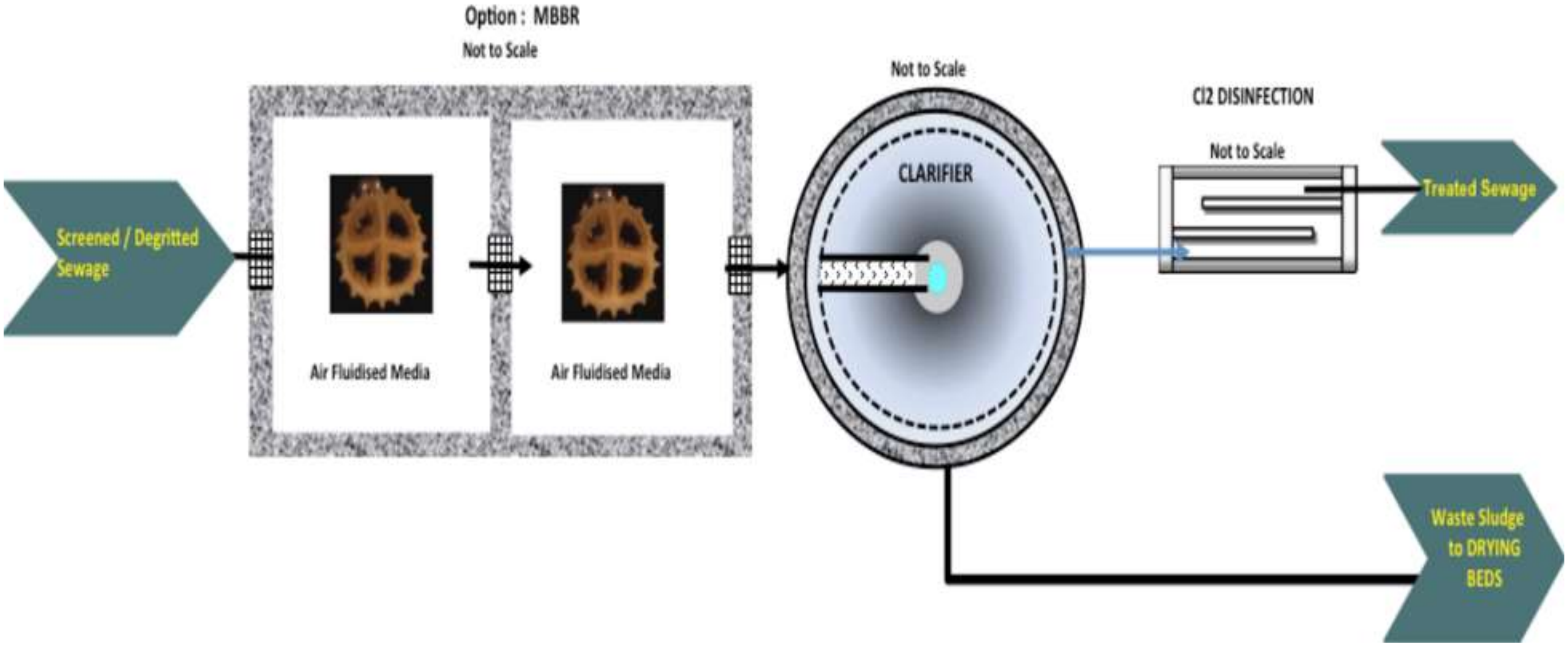


Figure 7.10 –Multi-criteria analysis of process treatment options

DILUTE STP INFLUENT TREATMENT OPTIONS (NOT INCLUDING PONDS): PRELIMINARY ANALYSIS VIA MULTI-CRITERIA ANALYSIS OR MCA		Selected Weighting	Judgement Rankings (Prof. Opinion of Consultant)			COMMENTS
	1) All assumed with ability to meet effluent standards *2) All assumed to require operator training* *3) All assumed will operate at cooler temperatures*		BIOTOWER or BIOLOGICAL AERATED FILTER (BAF)	MOVING BED BIOFILM REACTOR (MBBR)	INTERMITTENT DECANTED EXTENDED AERATION REACTOR (IDEAL)	
No.	**Multi-criteria Analysis of Constraints**	(x / 100)				
1	CAPEX	30	8.5	8.5	10.0	*Lowest cost IDEAL assigned a "10", others proportioned against this *Plastic packing expensive *Size comparison for 7 MLD unit
2	OPEX	20	10.0	9.6	7.4	*Lowest cost BAF assigned a "10", others proportioned against this *Size comparison for 7 MLD unit
3	PROVEN PERFORMANCE FOR DILUTE INFLUENT	10	10.0	10.0	9.0	*Fixed film processes superior to suspended biomass systems
4	EASE OF OPERATION	10	9.0	7.0	8.5	*MBBR can be subject to foaming and poor settling biosolids *IDEAL has timed aeration that must be monitored
5	PROCESS COMPLEXITY & CONTROL	5	8.0	9.0	10.0	*IDEAL one tank; MBBR two tanks; BAF four tanks
6	ABILITY TO COPE WITH HI TOURIST LOADS WITHOUT ANOTHER TANK	5	9.5	10.0	6.0	*MBBR by far more adaptable to load changes, followed by BAF *IDEAL design could also accommodate seasonal loads but extremes would require additional tank that would be started in summer, decommissioned in winter
7	VODAKANAL FAMILIARITY	5	7.0	7.0	9.0	*IDEAL similar to traditional activated sludge process
8	AMOUNT OF WASTE BIOSOLIDS	5	9.0	9.5	8.0	*BAF has primary solids issue
9	ODOUR GENERATION POTENTIAL	5	7.0	9.0	9.0	*Primary sedimentation with BAF that requires special management
10	STABILITY OF BIOSOLIDS	5	9.0	10.0	10.0	*BAF primary solids require digestion to stabilise
	TOTAL WEIGHTING (should be 100):	**100**				
	INDIVIDUAL SCORES (x / 1000 max):		**893**	**929**	**934**	
	Ranking Preference:		**3**	**2**	**1**	
	HIGHEST SCORE:			**934**		

7.2.2 Balykchy Wastewater Treatment Plant (BAWWTP)

102. The projected pollution and flow loads for this plant is given in **Table 7.1**.

Table 7.1 – Design criteria for BAWWTP

Planning Year	Projected Flow (MLD)	BOD Load (kg/day)	TKN (kg/day)	Suspended Solids (kg/day)*
Balykchy WWTP (Tourist Season)				
2018	2.74	891	324	1,765
2028	5.54	1,300	360	1,771
2038	8.59	1,771	395	1,722
Balykchy WWTP (Off-peak Season)				
2018	2.74	891	324	1,765
2028	5.54	1,300	360	1,771
2038	8.59	1,771	395	1,722
*(Sewage Solids + Septage Solids)				

Option BA1: Reuse of Many of the Current Facilities at Balykchy Sewage Treatment Plant

103. The existing activated sludge facilities are shown in **Figure 7.11** and **Figure 7.12**. They were originally designed to treat a capacity of 36 MLD for a served population of about 90,000 EP at 400 L/capita/day. Current sewage generation figures are less than half of this or about 160 L/capita/day. There are 16 mm coarse screens in use but without mechanical cleaning. One cyclone grit chamber is being used at any one time and one primary sedimentation tank. The large rectangular tankage and three circular clarifiers have never been used. Surface area dimensions are given in **Table 7.2**. The depth is given as 6 m but usually is between 3 and 4.5 m. The two aeration tanks are 20 mW x 60 mL x 6mD have a concrete petition wall down much of the center (**Figure 7.11**). The tanks appear structurally sound but do not hold water. An attempted render sealing was applied some years ago without success. If each tank were run with more freeboard as 19.5mW x 60mL x 4.5mH (active depth + 1.5m freeboard; take off 0.5 m from width for petition wall), this would put its volume at 5,265 m^3 or 10,530 m^3 for two tanks (as opposed to 6,435 m^3 or a total of 12,870 m^3 using a depth of 5.5m and freeboard of 0.5m). Some preliminary calculations were conducted with using the two existing tanks as IDALs (intermittent decanted extended aeration reactors, no clarifiers needed), with a 20 day MCRT (mean cell residence time or sludge age) and a 2038 inlet feed of 5.2 tons/day of COD (2 x 2038 BOD load of 2,603 kg/d). The volume required is roughly 9,700 m^3, close to the 10,530 m^3 with 1.5 m of freeboard. The current two tanks are about the right size for the projected 2038 flows in **Table 7.3** and suitable for two lots of phasing or 6.5 MLD per phase. Only one tank would initially be renovated and the other tank brought into service when it is needed. The air requirements for the 2038 flows are about 110 kW. This is assuming that the reactor takes the BOD down to 30 mg/L with no primary sedimentation.

Figure 7.11 – Current Balykchy aeration tank

Table 7.2 – Existing facilities within the BAWWTP

No	Unit	No of each	Type	Dimensions (m)
1	Inlet Chamber	1	-	5 x 2 x 3D
2	Screen Building	2	In one building	20 x 7 x 4D
3	Cyclone Grit Separator	2	Circular	6φ x4D
4	Primary Settling Tanks	2	Circular	17φ x 5
5	Aeration Tanks	2	Rectangular	60 x 20 x 6
6	Regenerations Tanks	2	Rectangular	60 x 8.5 x 6
7	Final Settling Tanks	3	Circular	18 φ x 5
8	Sand Dry Beds	2	Rectangular	15 x 15 x2
9	Administration & Sludge Dewatering Building	1	Building	25 x 17
10	Pumping Station	1	Building	20 x 7 x 4
11	Blowers Building	1	Building	17 x 7 x 6H
12	Transformer Site	1	Building	10 x 5 x 2H
13	Effluent Chamber	1	-	10 x 2 x 3

104. The other tanks on site: two 17m ϕ primary clarifiers, the three 18m ϕ secondary clarifiers and the two 60m x 8.5m regeneration tanks would become redundant and could be demolished. The total material from a demolition of these components would amount to about 2,100 m^3 as was estimated by the 2015 Phase II report. There is plenty of room for a balance tank and a chlorine contact tank or one of the existing secondary clarifiers could be rehabilitated and used.

Figure 7.12 – Satellite imagery of existing BAWWTP activated sludge system (just prior to lagoons)

Option BA2: Complete new IDEAL & Demolishing of Existing Facilities

105. This option involves demolishing the whole of the existing works and building a whole new activated sludge system, based again on the IDEAL process configuration as shown in **Figure 7.5** but without the anaerobic digestion. On the front of this process would be new screening and degritting facilities. Phase 1 would include the Stage 1 and part of the Stage 2 time periods (see **Table 7.1**) and would be for 4 MLD but would include components of Phase 2 for another 4 MLD such as screening and building rehabilitations. **Figure 7.13** gives an idea of how the IDEALs would sit on site. Tertiary treatment is shown with trickling filters. If tertiary treatment is not selected, the discharge from the IDEALs would go directly to the ponds. The IDEALs are sized for a 20 day MCRT (or sludge age reflecting extended aeration to give stability to the waste activated sludge or WAS. The WAS would be taken during the aeration phase and would be thickened before the drying beds. The proposed drying beds are sized for a 20 day rotation period (22 beds with 2 extra for the cleaning process). This gives a total minimum solids treatment period of 40 days. The supernatant from the thickener and the filtrate from the drying beds would be pumped back to the head of works. **Figure 7.14** shows the additional ponds required for storage of the treated effluent during the winter season. The proposed extra ponds would increase the storage as shown in **Table 7.3**. Note that the existing ponds need desludging and the volume of storage is less than the clean volume shown in **Table 7.3**. Adding the two additional ponds in Phase II would be additional to the storage capacity calculated in **Table 7.3**.

Table 7.3 – Pond storage clean volume capacity at the BAWWTP (evaporation and seepage not included)

Scenario	Total Clean Volume (m3)	Storage Time at 2018 Flows (months)	Storage Volume at 2028 Flows (months)	Storage Volume at 2038 Flows (months)
Existing Ponds	173,844	2.3	1.1	0.7

Scenario	Total Clean Volume (m3)	Storage Time at 2018 Flows (months)	Storage Volume at 2028 Flows (months)	Storage Volume at 2038 Flows (months)
Existing + Proposed Three Additional Ponds for Phase I	284,833	3.7	1.7	1.2

Figure 7.13 – Preliminary process layout after screening and degritting for Option BA2

Figure 7.14 – Proposed additional ponds for effluent storage for Options BA1 and BA2

106. The actions required for Option BA1 and Option BA2 are summarized in **Table 7.4.** Details of the proposed treatment units are shown in **Appendix 1.**

Table 7.4 – Preliminary list of works required for Option BA1 and Option BA2 (not inclusive)

Actions	Details	Comments
1. New channels and mechanical screens, 2 off 10 mm, duty/standby and place for a third screen for Phase II (see **Figure 4.1**)	Existing 16 mm screen works but automatic mechanical component has long since ceased.	Having a 10 mm screen would avoid potential problems in the downstream IDEAL(s)
2. Renew existing screen building 20m x 7m, replace with 20m x 15m	Modifications needed to house three channels of 10 mm step screens (**Figure 4.1**). Two channels to be brought on line for duty/standby. Includes channel with manual screen for >2ADWF bypass.	Inspection by structural engineer needed if existing building to be reused
3. New mechanical vortex degritting units, 1 for Phase I, another for Phase II.	The concrete on the existing cyclone grit units (6m φ) to be demolished and replaced with a single mechanical vortex degritter	

Actions	Details	Comments
	and grit classifier for Phase I and another for Phase II.	
4. Primary sedimentation units are not needed (17m ϕ)	The whole sewage flow after screening and degritting would be put directly into the IDEALs	Primary sludge is currently sent to drying beds but this practice to be discontinued
5. Renovation of aeration tanks as IDALs (20mW x46m Lx~5mD) would be Option BA1 or replace aeration tanks as Option BA2. New (2 No) aeration tanks for BA2 to be 14.5mW x 46mL x 5mD.	The existing tanks if reused would need cleaned and sealed around the inside with an appropriate membrane liner. Existing tanks to be demolished if Option BA2 selected for new tanks	Reuse of tanks would require structural engineer inspection
6. Installation of an intermediate aeration system, slow speed surface aerators (SOTR of ca. 417 kg O_2/hr [136 kW] at an 1,700 m altitude and 4.5 m average active tank depth or TWL of 5 m)	A diffused aeration system would be needed with rubber diffusers for Option BA1. Tanks are too narrow for surface aeration. Slow speed surface aerators are nominated for Option BA2, which would use 4 x 11 kW aerators per IDEAL	Slow speed surface aerators to be mounted with crossbar as shown in **Figure 7.5**.
7. Renovation of existing blower building (17m x 7m) as an option. Preferred aeration is by slow speed aerators	The building appears structurally sound If suitable the building would require renovation/modification, including a new roof. This would not be required in Option BA2 if surface aeration is selected.	Inspection by structural engineer
8. Installation of a decanter mechanisms in the IDEALs + associated piping	A metal decanting mechanism would be mechanically raised and lowered to decant off supernatant from the tank after a settlement period.	Ancillary piping also needed; decanters along long side in Option BA1, short side in BA2
9. A chlorine contact (CCT)	This would be necessary if chemical disinfection is selected over that obtained by the ponds, plus canal dilution during irrigation period. Preliminary sizing puts the tank as 7.5mW x 16.5mL x 2mD to get a 30 min residence time.	Optional Additional ponds would eventually need to be enlarged or disinfection implemented for river discharge to accommodate future larger flows
10. New chlorine building	This could be made optional, as the ponds could act as the primary	Optional

Actions	Details	Comments
	source of disinfection if properly renovated. Building would be required to house gaseous chlorine cylinders, likely the 720 kg version (to be determined).	Renovation of existing chlorination building is an option.
11. New chlorine gas dissolution system is needed.	This could be made optional, as the ponds could act as the primary source of disinfection if properly renovated. This system converts liquid chlorine into gas to where it can be dissolved in a water stream that would be directed to the CCT.	Optional
12. New sludge thickener required	New 9 m dia. thickener in Phase I and another in Phase II. Waste sludge from IDEALs wasted during aeration to be directed here, with supernatant returned to head of works and solids to drying beds	
13. Administration facilities / Laboratory (25m x 17m)	If suitable, it would need rehabilitation and modification to house a small laboratory.	A structural engineer needs inspection of the existing building
14. Process Automation	The treatment would be fully automated with a SCADA in the Administration Building.	
15. The 6 existing drying beds, 62 mW x 250 mL each, would be made redundant.	Twenty two new beds are proposed for the top of the site, each with an area of about 24m long x 6m wide.	Twenty day rotation with twenty two beds (two for cleaning allowance)
16. New penstock valves and hydraulic rehabilitation of pond hydraulics for discharge	Current penstocks are corroded and likely dysfunctional. The feed distribution channel to the ponds is in need of complete renovation or replacement. The discharge pipework from the ponds are also in a bad state and needs rehabilitation.	Priority. Feed channels all to be modified when new ponds are added
17. Inspection and review of existing pumping station	This pumping station would become redundant	Needs to be reviewed
18. Inspection of power transmission facilities	To determine whether this is suitable for future long-term use and if there is any rehabilitation needs.	Priority.
19. Demolition of unnecessary site infrastructure	Option BA1 would make redundant the 17m ϕ primary clarifiers, the 18m ϕ secondary clarifiers and the	Redundant structures should be

Actions	Details	Comments
	60m x 8.5m regeneration tanks. If demolished this would amount to about 2,100 m^3 needing to be landfilled. Option BA2 would require more demolition with about 3,526 m3	demolished or re-purposed for safety reasons

107. It has been assumed at this stage that the Vodokanal would prefer Option BA2 and this option has been assumed in the development of cost estimates. Both options BA1 and BA2 are designed to produce an effluent out of secondary treatment with ammonia concentration of 3 mg/L. When the effluent is discharged into the irrigation channel, it is expected to be diluted by a factor of about 30, which should enable an ammonia concentration of 0.1 mg/L to be achieved in accordance with Krygz standards. Tests conducted on the effluent from the Balykchy WWTP in September 2017 showed the ammonia concentration reducing from 20mg/L downstream of the biological ponds to 0.74 mg/L in the irrigation channel (see **Table 4.2**). However, in order to be certain of achieving the required ammonia concentration in the effluent, a tertiary treatment component has been included. This is discussed further below in Section 7.3.

7.2.4 Karakol Sewage Treatment Plant (KKWWTP)

108. The projected pollution and flow loads for this plant are given in **Table 7.5**.

Table 7.5 – Design criteria for KKWWTP

Planning Year	Flow (MLD)	BOD Load (kg/day)	TKN (kg/day)	Suspended Solids (kg/day)*
Karakol STP (Tourist Season)				
2018	8.45	2,018	531	2,445
2028	16.07	3,164	664	2,693
2038	24.42	4,496	786	2,744
Karakol STP (Off-peak Season)				
2018	7.89	1,909	648	2,129
2028	14.86	2,952	807	2,280
2038	22.62	4,188	962	2,259
*(Sewage Solids + Septage Solids)				

109. Details of the process components at the KKWWTP are given in **Table 7.6**.

Table 7.6– Existing process component details of the KKWWTP

No	Unit	No of each	Type	Extent (m)	Status
1	Inlet, Screen & Bypass chamber	1	-	10x2x3D	Poor condition
2	Cyclone Grit Separator	2	Circular	5φx2D	Poor condition
3	Primary Settling Tanks	3	Circular	16φx5D	1 of 3 works, concrete poor
4	Aeration Tanks	4	Rect.	48x18x6	No air, poor concrete

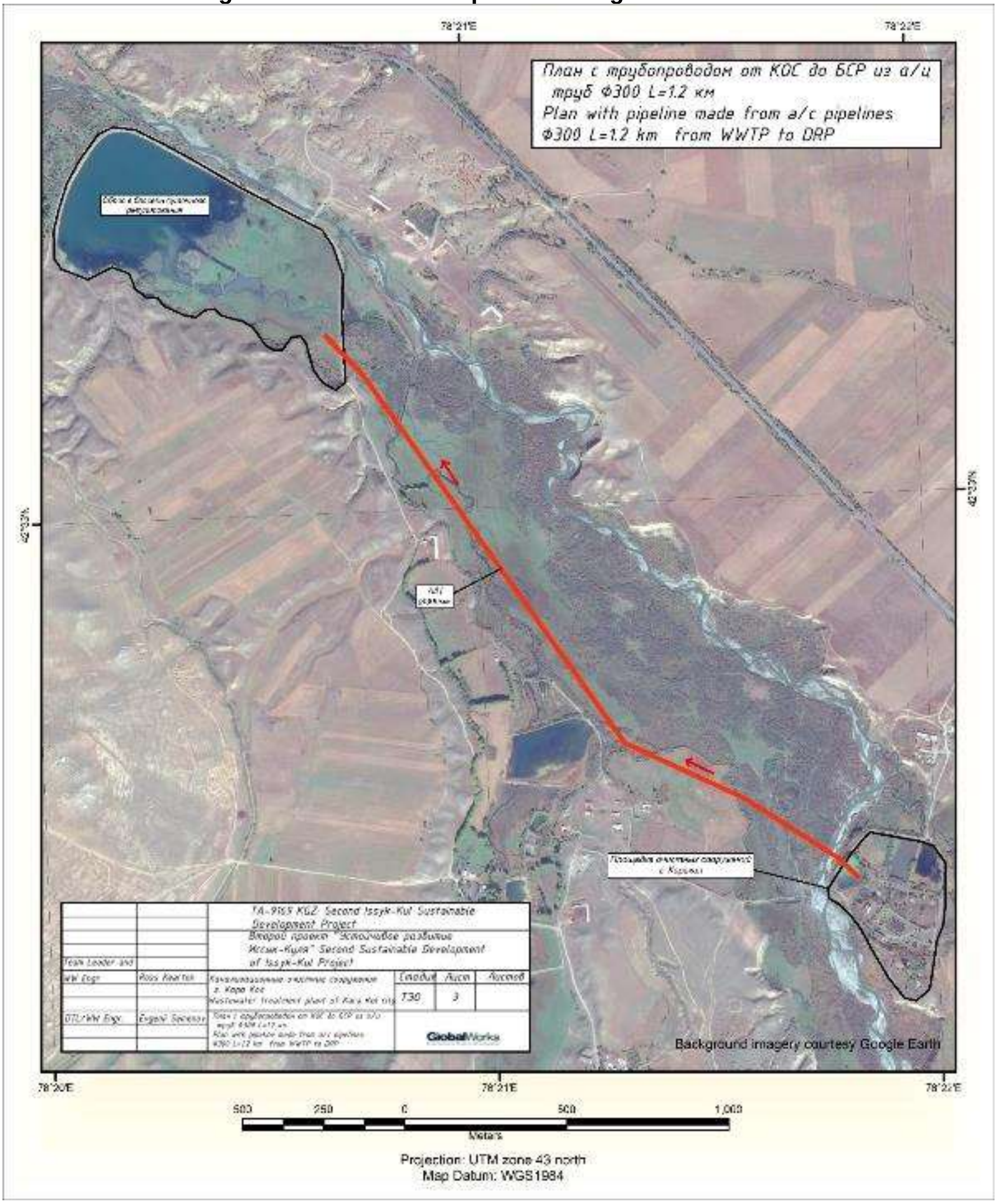
No	Unit	No of each	Type	Extent (m)	Status
5	Final Settling Tanks	4	Circular	~16φx5D	1 of 4 works, concrete poor
6	Venturi meter	1	---	10x2x3D	Not sighted
7	Chlorine Contact Tank	1	Circular	16φx5D	No chlorine dosed
8	Digesters	2	Circular	15φx18H	Out of service
9	Sludge drying beds	10	Rect. basins	35x9x3	Rehabilitate
10	Blower Building	1	Building	30x14x6H	Out of service
11	Chlorination Building	1	Building	21x11x6H	Out of service
12	Boilers Building	1	Building	20x10x6H	Out of service
13	Administration building	1	Building	17x8x6H	Out of service, needs rehab.
14	Sludge Dewatering Building	1	Building	10x6x6H	Not viewed

Source: Modified for 2015 Phase II project report

110. **Table 3.2** gives the 95%tile influent KKWWTP BOD_5 as only 123 mg/L. The treatment plant is near the river but has a good buffer around from nearby residents. The effluent after treatment is impounded in four ponds with an estimated volume of 40 ML at a 1.5 m depth and a surface are of about 2.7 ha as shown in **Figure 7.15**. Retention time in these ponds for 2018 tourist flows amounts to about 4.8 days and 2.2 days for the to 2028 if the volume were 100 percent available (ponds need desludging). The flow from these ponds is pumped to an irrigation reservoir into which 5 fresh water streams also discharge (see **Figure 7.16**). The reservoir from Google Earth looks to be about 1100 ML, assuming a 3 m depth, so provides dilution and more residence time for the KKWWTP treated effluent.

Figure 7.15 – Focus on the existing ponds at KKWWTP

Figure 7.16 – Effluent Pipeline to Irrigation Reservoir



111. Again, taking into consideration the dilute influent and the difficulties of treating it as well as the reuse possibilities of the treated sewage, we can remain consistent with the proposed use of IDEALs. The existing KKWWTP included anaerobic digestion and originally the Vodokanal requested that this be incorporated into the rehabilitated WWTP. This option

would require the construction of primary sedimentation tanks and anaerobic digesters, but would allow for a reduction in the size of the aeration tanks. Nevertheless there would be an additional capital cost for inclusion of this facility. Inclusion of anaerobic digestion does allow for the generation of power from the production of methane, but any financial benefit for a WWTP the size of Karakol is likely to be marginal. Therefore, while this option is discussed below, ultimately the Vodokanal opted to not include this in the project

Process Options: New Pretreatment, New Primary Sedimentation Tanks, New IDEAL Biological Treatment, New Sludge Thickeners, New Mesophilic Anaerobic Digesters (Optional), Demolition of Many of the Existing Process Components and Reuse of Some Ancillary Buildings and Sludge Beds

112. This option is best explained by first viewing the proposed process layout with anaerobic digestion in **Figure 7.17**, a fully aerobic option in **Figure 7.18** and general process flow diagram (PFD) in **Figure 7.19**. These layout figures include a tertiary treatment process.

113. The projected flows given in **Table 7.5** indicate a need for a treatment capacity of 8.5 MLD by 2018 and 16 MLD by 2028. **Figure 7.7** shows Stage 1 as 8.1 MLD and Stage 2 adding two more IDEALs for 16.2 MLD of capacity. However, it is proposed to provide a 12 MLD WWTP in Stage 1 which will provide sufficient capacity for up until at least 2025. The IDEALs (not extended aeration) that include anaerobic sludge digestion each measure about 18W x 57L x 5D or about 4 MLD of treatment capacity for a total capacity of 12 MLD for two tanks or 24 MLD for four tanks. If the anaerobic solids digestion is not included the tanks increase slightly as extended aeration is used at to 18W x 60L x 5D. The big difference between these two choices is that with anaerobic solids digestion, the aeration requirement is about 50% of that required by the fully aerobic option.

114. The anaerobic solids digestion and fully aerobic options both include new pretreatment (step screening and vortex degritting) in a new building with septage truck receival facility. The anaerobic solids digestion option has three off 21 φm primary sedimentation tanks, two off new 18 φm sludge thickeners, a new chlorine contact tank (of sufficient size for 2038 flows), two off 13 φm anaerobic digesters (and ancillaries) and renovation of the chlorine building and the existing administration office and laboratory. The fully aerobic option does not require the primary sedimentation tanks nor the anaerobic digesters and the sludge thickeners are 3 off, 10 φm.

115. The anaerobic solids digestion option would have the sewage screened and degritted (refer to **Figure 7.19**) and then fed directly into new Primary Sedimentation Tanks (PSTs) for separation of the primary sludge. This amounts to about a third of the incoming COD normally. The primary sludge will be subsequently fed to a sludge thickener, where it will be joined by waste biomass from the IDALs with a ten day MCRT. This lower sludge age is good for anaerobic digestion but negative for nitrification and an extended aeration mode may have to be adopted, depending on the final agreement for the discharge of ammonia. The IDEAL anoxic waste solids will prevent the thickeners from going anaerobic. Supernatant from the thickeners will be fed back to the head of works and the thickened sludge to two new MADs (mesophilic anaerobic digesters) to be treated for 20 days. Anaerobically digested sludge after twenty days, now about 45% of its original volume, will be finally dewatered in the renovated sludge drying beds and the filtrate sent back to the head of works (this usually has a high ammonia content).

116. Heating would be required for feed to the anaerobic digesters and either biogas (estimated at ca. 2,373 m3/day in 2038) and/or an alternative fuel source would be needed. By 2038 only 12% of the biogas will be required for heating the incoming feed from about 18°C from about 35°C and the rest of the gas can be used for other purposes. A district heating

system was present in the past. If used for electrical generation, the capacity is estimated to be a little over 200 kW but the gas would need to be treated for removal of hydrogen sulfide. There is also the potential for the generation of carbon credits, once registration is accomplished (which can be expensive).

117. Most of the existing process components would be made redundant. A small laboratory would be resurrected in the Administration Building as there once was one there as well as a bore to supply potable water. The system would be fully automated with a SCADA housed in the Administration Building.

Figure 7.17 – Potential layout of anaerobic process option

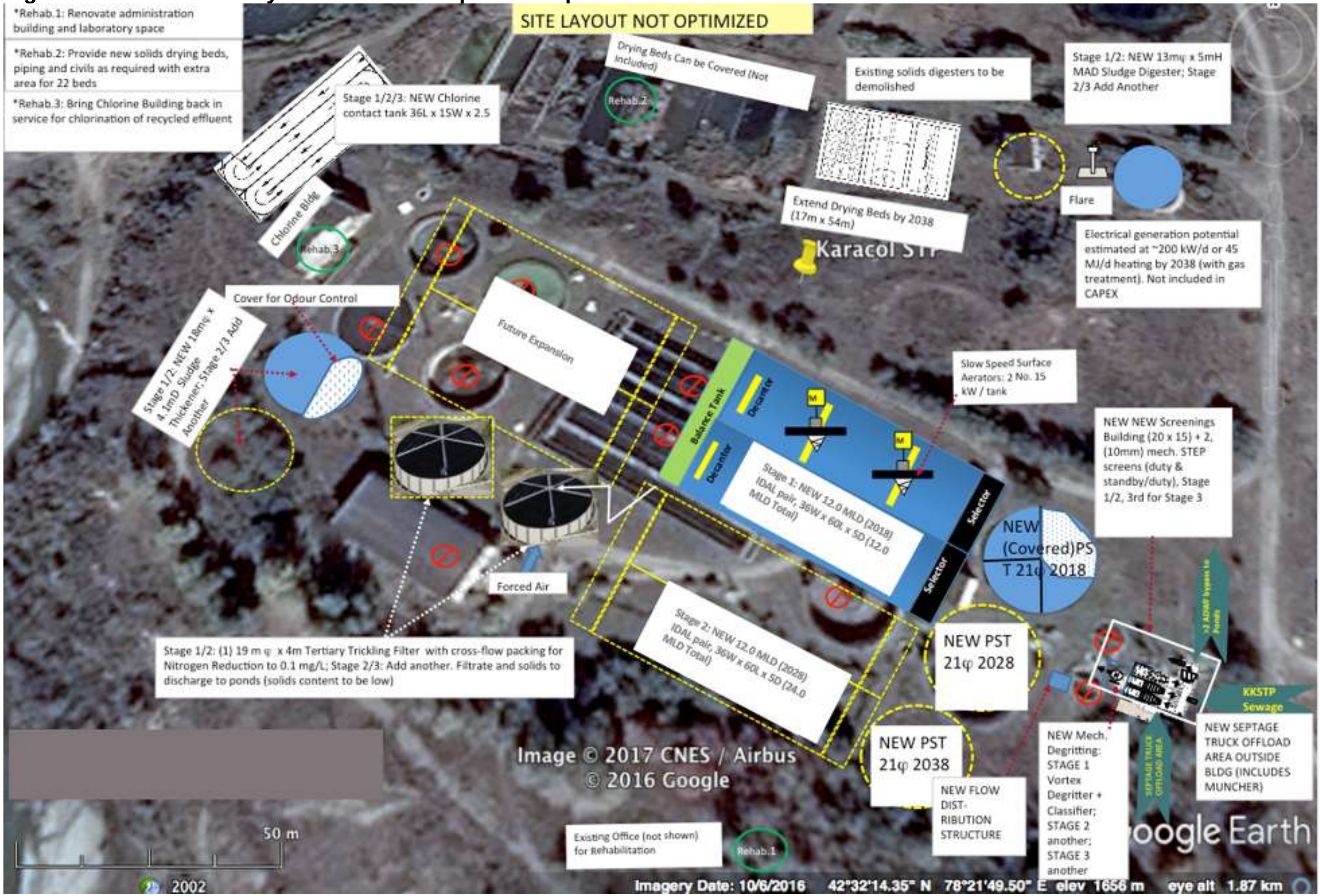
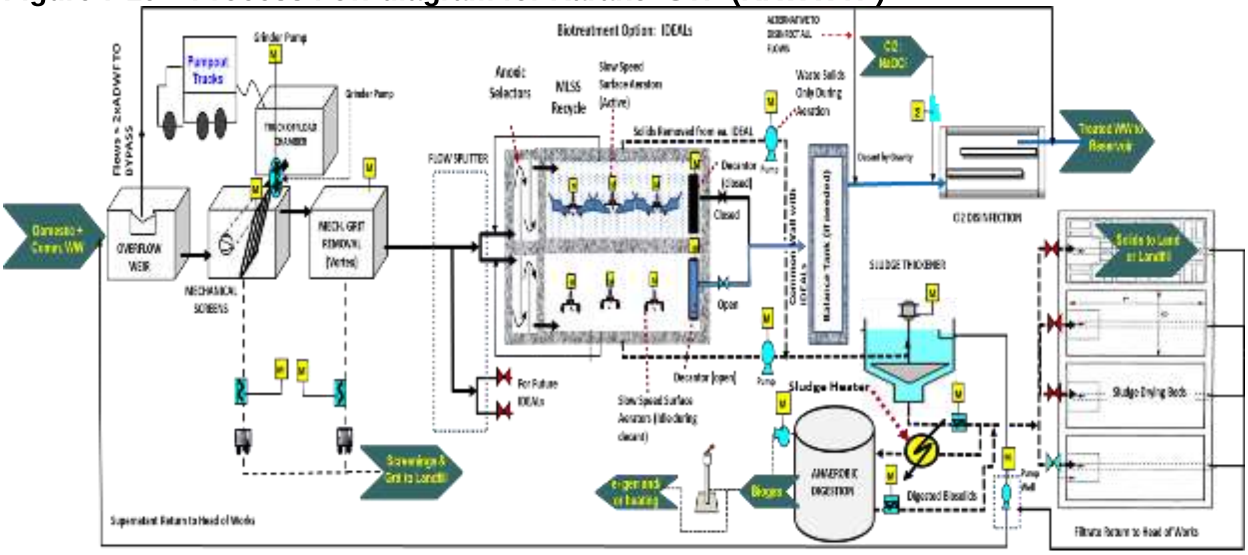


Figure 7.18 – Potential layout of fully aerobic process option

Figure 7.19 – Process flow diagram for Karakol STP (KKWWTP)



118. The works proposed for preferred treatment option for Karakol sewage treatment plant are shown in **Table 7.6**. Note the previous comments about during the construction period the current plant could be kept in operation or the inflow directed temporarily to the ponds (less preferred).

Table 7.6 – Preliminary list of works required for Karakol (aerobic option)

Actions	Details	Comments
1. New channels and mechanical screens, 2 off 10 mm, duty/standby and place for a third screen for Phase II (see **Figure 4.1**). All flows >2ADWF to be bypassed to the ponds.	Existing single 16 mm screen is to be replaced with pair of automatic screens inside a covered building. A septage truck off loading area to be available with a mulcher pump before the step screens.	Having a 10 mm screen would avoid potential problems in the downstream IDALs/IDEAL(s)
2. New mechanical vortex degritting units, one in Phase I in 2018 and the second in Phase II around 2038	The concrete on the existing cyclone grit units (5m φ) appears is in poor condition	Existing units to be demolished.
3.Construction of two IDEALs with a total treatment capacity of 12.1 MLD in Phase 1 (2018); another 12.1 MLD would be added in Phase II.	IDALs to be about 18W x 57L x 5.5D including freeboard.	See **Figure 7.17**
5. Installation of an intermediate aeration system (SOTR of ca. 580 kg O_2/hr [190 kW] at an ca. 1,700 m altitude and 4.5m avg. tank depth, TWL at 5 m).	A diffused aeration system would that the IDALs be equipped with rubber diffusers that would seal when the air is cycled on/off. These have to be replaced every three years or so. SOTR is to be supplied by two 22 kW slow speed surface aerators per IDAL.	This would include all relevant pipework and blowers
6. Installation of a decanter mechanism in each IDEAL + associated piping	A metal decanting mechanism would be mechanically raised and lowered to decant off supernatant from the tank after a settlement period.	Ancillary piping tie-ins also needed

Actions	Details	Comments
7. Renovation of existing blower building (30m x 14m)	The building may be reusable but new blowers would be called for if diffused aeration is selected. This building would not be needed with surface aeration. Part of this building could be petitioned off for a control room.	Inspection by structural engineer
8. Existing chlorine contact (CCT): circular 16φx5D	The existing tank (if not reusable) to be replaced by a new 15.5W x 36.5L x 2mD CCT	Inspection by structural engineer
9. Existing chlorine building (21m x 11m)	This building would be required to house gaseous chlorine cylinders t for disinfection.	Inspection by structural engineer required
10. New chlorine gas dissolution system is needed.	This system converts liquid chlorine into gas to where it can be dissolved in a water stream that would be directed into the CCT.	
12. Existing sludge drying beds, 10 off: 9mW x 35mL x 3mD	Existing beds to be rehabilitated. A combination of IDAL waste solids and primary solids after twenty days of anaerobic treatment to be dewater on the sludge drying beds. Add additional beds by 2038.	Facility would be better covered with good vehicular access
13. Administration facilities / Laboratory (17m x 8m)	The building looks suitable for rehabilitation The building would also house a small laboratory. Potable water is available on site.	A structural engineer needs inspection of the existing building
14. Sludge thickeners to be added, one 15 m φ in Phase I and another similarly sized unit in Phase II.	Waste sludge from IDALs wasted during aeration to be directed here along with primary sludge, with supernatant returned to head of works and solids to anaerobic digesters.	
15. Inspection of power transmission facilities	To determine whether this is suitable for future long-term use and if there is any rehabilitation needs.	Priority
16. Process Automation	The treatment would be fully automated with a SCADA in the Administration Building.	

119. As for Balykchy, the secondary treatment process described above will produce an effluent that meets Kyrgyz effluent discharge standards for irrigation, except for ammonia. The WWTP will produce an ammonia effluent with concentration of not greater than 3 mg/L compared with the Kyrgyz standard of 0.1 mg/L for irrigation use. After storage in the irrigation pond and dilution with surface water planned to be diverted to mix with the sewage effluent, an ammonia concentration significantly lower than 3 mg/L will be achieved, but cannot be

guaranteed to be 0.1 mg/L at the proposed measuring point shown in **Figure 5.6**. Therefore a tertiary treatment component to the treatment plant will be included so that WWTP will provide the specified ammonia concentration at the discharge point from the plant. This is further discussed in Section 7.3

7.3 Tertiary Treatment

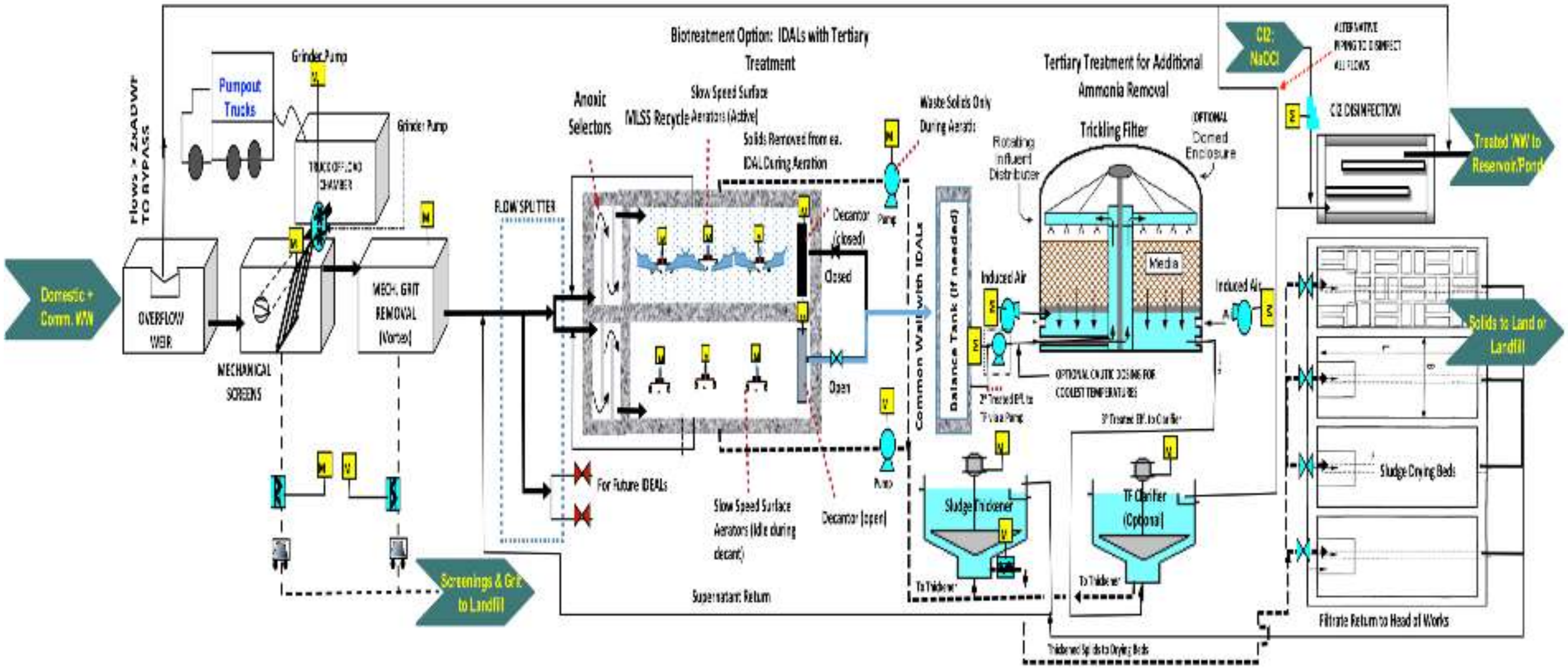
120. The proposed main biological secondary treatment processes described above for each of the three STPs will remove BOD to below the existing standards and reduce ammonia levels to about 3 mg/L at the discharge. It was then subsequently expected that through dilution the desired level of 0.1 mg NH4-N/L could be achieved. However, the apportioning of river water with treated sewage effluent cannot be closely controlled. An “add on” tertiary process can reduce the ammonia levels still further to the levels sought by the prevailing standards for irrigation waters if that is the selected way forward.

121. Tertiary treatments are expensive and typically only employed when the treated effluent is to be reused by industries to off-set their use of valuable potable water and/or as a “third pipe”, often purple in colour, to provide a water source that can be employed for the watering of vegetables and livestock.

122. Numerous biological process approaches are possible to reduce ammonia to very low levels but inevitably they all involve the use of sessile organisms or those bacteria that grow on to a support or packing. The most well known example of this treatment process is the traditional trickling filter or TF. TFs in the past mostly employed rock media as support. Sewage (or wastewater) that was to be treated was ideally trickled uniformly over the top of the filter, where it would run through the media along a tortuous route, through media encrusted with sessile bacteria, before exiting into a clarifier for separation of any sloughed off solids from the packing. The TF design has the provision to recycle a portion of the exiting effluent from the clarifier to achieve still greater treatment levels.

123. The use of TFs for tertiary treatment specifically for reduction of ammonia levels is well known and is shown in **Figure 7.20**. **Figure 7.13** for Balykchy, and **Figures 7.17** and **7.18** (anaerobic solids digestion option and fully aerobic option, respectively) layouts all show the provision for adding tertiary treatment via a trickling filter arrangement. The application of the technology after initial IDEAL treatment can be designed to reduce the ammonia (and BOD to some extent) down from 3 mg NH4-N/L to the desired 0.1 mgNH4-N/L delimits. However, during the low temperatures that would be present during the coldest of winter, the size of the TFs becomes uneconomical if biology is relied on entirely, i.e., too large, if a 0.1 mgNH4-N/L is insisted as a 100%tile delimit. One way of getting around this is to design the TFs for a temperature of around 10 to 12°C and then employ ammonia stripping during the lowest of water temperatures. Ammonia stripping occurs when the pH of the water is elevated to above 8 and then the water is subjected to a process (like a trickling filter) whereby the liquid surface is disturbed. More turbulence is induced if the air flow through the trickling filter is fan forced as opposed to natural draft.

Figure 7.20 – Typical process flow diagram (PFD) for IDEAL secondary treatment following by tertiary trickling filter treatment for additional ammonia reduction



124. An induced draft TF tertiary treatment system has been designed for each of the STPs at Balykchy and Karakol. The discharge from the IDEAL treatment would be pumped to the top of 4m tall TFs (one unit for Stage 1 and another added for Stage 2/3) to trickle down through plastic cross-flow packing. No recycle of the TF effluent has been included in the current design. The TFs would generate very low solids and malodour would not be an issue as the water has already received secondary treatment. Moreover, to save CAPEX, tertiary clarifiers would likely not be required and have not been included in the CAPEX. Balykchy for instance drains into holding ponds and Karakol also drains to ponds.

125. The pumping to the top of the TFs is what constitutes its major OPEX. The additional OPEX is small but there is a significant CAPEX element. Prior to each TF could also optionally be added a caustic dosing system. The caustic system would consist of a caustic tank, dosing pump, in-line mixer and pH probe and its feed-back loop. The caustic strength employed would have to be such to avoid its freezing (not too concentrated) during the winter. The combination of both the biological removal of ammonia (i.e., nitrification) as well as the caustic dosing system (stripping) could consistently deliver a STP discharge of 0.1 mgNH4-N/L year around if that is what is eventually dictated by the discharge standards.

7.4 Septage Management

126. With only in the order of 30% coverage of sewerage in the three towns, most households still currently rely on septic tanks and pit latrines for disposal of wastewater. Effective operation of septic tanks relies on an efficient septage management program supported by appropriate ordinances at the municipal level. While the rehabilitation of the wastewater treatment plants and expansion of the wastewater collection systems will provide significant environmental and health benefits, this will be limited while up to 70% of the population rely on poorly constructed and operating septic tanks.

127. **Figures 4.3, 4.6 and 4.7** in Chapter 4 show the amount of septage that is expected to be produced in each of the towns in 2018, 2028 and 2038. This is significant and will depend on how quickly sewerage infrastructure will be developed in each town.

128. Septic tanks can operate effectively if they are well designed and regularly emptied and regulations and infrastructure are in place to ensure appropriate disposal and treatment of septage and the biosolids after treatment. This requires the development and implementation of a Septage Management Framework.

129. The framework for sustainable city-wide septage management programs has at its core the main service activities:

- **Septage collection;**
- **Septage transportation;**
- **Septage treatment; and**
- **Dispersal, reuse and recycling** of the byproducts and residuals of the treatment process

within an enabling environment that is established through:

- A **local ordinance** on septage management;
- Ongoing and targeted **promotional campaigns** to raise awareness and willingness to pay for the service;
- **Treatment Infrastructure and collection equipment** that is appropriate for the specific needs of the community; and
- **Tariff and fee structure** and collection mechanism that covers the cost of operations and maintenance, and debt service and depreciation of the treatment and collection equipment.

130. Preparation of the septage management framework will include:

- A review of the current septage management practices in Issyk-Kl including existing regulatory arrangements, analysis of septage characteristics and composition, details of the current de-sludging practices and opportunities for improvement and operator health and safety.
- Outlining the institutional arrangements and regulatory strengthening including the current role of the Vodokanals in septage management, engaging with the private sector, tariffs and payments, promotional activities, development of ordinances on septage management.
- Details of the septage collection and transportation arrangements including number and types of vehicles, equipment needs.
- Septage disposal and treatment arrangements – co-treatment with wastewater, stand-alone septage treatment facilities.
- Disposal, re-use and regulation of biosolids and by-products of septage.
- Scheduled de-sludging arrangements for the three towns and neighbouring villages.
- Implementation road map for the Septage Management Framework and the next steps for implementation.

131. It is proposed that the Septage Management Framework be developed during the implementation of the wastewater sub-projects.

132. It is also proposed that vacuum trucks will be provided to the Vodokanals in order that the septage management framework can be adequately implemented. At the same time, private sector input into septage management will be hopefully strengthened and regularized. The current situation with regard to availability of vacuum tankers and proposed augmentation is shown below in **Table 7.14.** The table indicates that even with provision of additional tankers to the Vodokanals, there will still need to still be substantial investment by the private sector in septage management.

Table 7.14 – Provision of Vacuum Tankers

Location	Current Vacuum Tankers		No. of Vacuum Tankers Required[30]			Proposed Augmentation	
	Vodokanal	**Private**	**2018**	**2028**	**2038**	**Vodokanal**	**Private**
Balykchy	2	2	14	12	10	3	TBD
Karakol	2	6	16	15	11	4	TBD
Total	**4**	**8**	**30**	**27**	**21**	**7**	

Source: Vodokanals, PPTA Consultant

8 COST ESTIMATES

8.1 Cost Estimate of Treatment Options

133. The options considered for the early inception period included the ones listed below for each of the two treatment plants. These options arose from the existing set of constraints, including:

- Employing technologies that would be good with dilute influent;

[30] See Tables 3.3, 3.6, 3.10

- The state of the existing process components and equipment and a desire to reuse if possible rather than demolish;
- Meeting the existing standards for treated effluent reuse for agricultural irrigation;
- Providing USEPA Grade B biosolids for their reuse on neighboring apricot tree plantations (or similar)
- Configuring a new treatment plant at each location that would properly treat the sewage but not offend neighbors;
- Present a sewage treatment plant (or a wastewater treatment plant) that is uncomplicated to own and operate, and
- Reduce the risks associated with the current and future reuse of biosolids.
- Providing a tertiary treatment component to be included if effluent standards in accordance with Kyrgyz could not be guaranteed with the proposed secondary treatment process.

134. The preferred option for each treatment plant was selected in a workshop with the vodakanals to be an IDEAL (extended aeration) configuration.

135. Balykchy Sewage Treatment Process (BAWWTP)
- Option BA1: IDEAL WWTP with reuse of existing aeration tank and some other current Facilities at Balykchy Sewage Treatment Plant:
- Option BA2: Complete new IDEAL & demolishing of existing facilities:
- Option BA3; As Option BA2, but with incorporation of a tertiary treatment component utilizing tricking filters.

136. Karakol Sewage Treatment Process (KKWWTP)
- Option KK1: Complete new IDEAL but without anaerobic digestion
- Option KK2: Complete new IDEAL but with anaerobic digestion
- Option KK3; As with Option KK1, but with incorporation of a tertiary treatment component utilizing tricking filters

137. A cost comparison of these options is given in **Table 8.1.** Note that these estimates are shown for both Phases 1 and 2 which would provide wastewater treatment capacity up until 2038. The current loan will only include the Phase 1 development. The costs do not include contingency which is allied to all components in the cost estimate shown in the Main Report.

Table 8.1 – Cost Comparison of Options

Option	Capital Cost (USD)		
	Stage 1	Stage 2	Total
BA1	4.52	3.58	9.28
BA2	5.17	3.58	9.93
BA3	6.33	4.73	12.76
KK1	8.29	6.98	15.27
KK2	10.08	8.25	18.33
KK3	11.03	8.96	19.99

138. **Table 8.2** provides details of the capacity and phasing scenarios for the preferred options for the WWTPs in Balykchy and Karakol on the basis of including the tertiary treatment component for both facilities. The preferred option for Karakol does not include anaerobic digestion on the basis of the latest advice from the Karakol Vodokanal.

Table 8.2 – Cost estimates of WWTP preferred options Balykchy and Karakol

City	Option	Proposed Phasing	Total Inflow Treatment Capacity (MLD)	Estimated Cost ($US mil.)	Proposed Phasing Scenario	Comments
Balykchy	• **Option BA3 (preferred):** Complete new IDEALs & demolition of redundant facilities. Tertiary treatment included using trickling filter technology with allowance for caustic soda dosing for ammonia stripping at low temperatures	1 2	4.2 8.4	$ 6.33 $ 4.73	About 2018: Construct two IDEALs for 4.2 MLD, screening & degritting civils for 8.4 MLD, duty/standby step screens and single mechanical vortex degritting for 4.2 MLD, septic truck unloading facility part of pre-treatment, new sludge thickener, new drying beds on top of site, 2 TFs for tertiary treatment, three new ponds for effluent storage, rehab all required all buildings and flow structures, demolish superfluous structures and desludge existing ponds. About 2035: In Phase II, construct another two additional IDEALs alongside Phase 1 IDEALs, another step screen for existing building, another mechanical vortex degritter, another sludge thickener. Additional 2 TFs added for tertiary treatment	Current process to continue during initial construction period. Aeration to be supplied by slow speed surface aerators.
			Total Estimate Option BA3 (Preferred): :	**$ 11.06**		
Karakol	• **Option KK2: Preferred Process Option:** New Pretreatment, New	1 2	12.1 24.3	$ 10.08 $ 8.25	About 2018: Phase I will build two IDEALs for 12 MLD , new screening building and civils for 24 MLD with duty/standby step screens and bypass, one mechanical vortex	

City	Option	Proposed Phasing	Total Inflow Treatment Capacity (MLD)	Estimated Cost ($US mil.)	Proposed Phasing Scenario	Comments
	IDEAL Biological Treatment, New Sludge Thickeners, Demolition of many of the existing process components and reuse of some ancillary buildings and sludge beds. Tertiary treatment included using trickling filter technology with allowance for caustic soda dosing for ammonia stripping at low temperatures				degritting unit for 12 MLD, septic truck unloading facility to be part of pre-treatment building, one new chlorine contact tank, rehab. required building [admin./lab building, chlorine building], 2 TFs for tertiary treatment demolish redundant structures and components. About 2038: Build two more similar IDEALs as Phase II, one more step screen, and one more sludge thickener. Additional 2 TFs added for tertiary treatment	
Total Estimate Option KK3 (Preferred):				**$ 18.33**		
TOTAL ESTIMATED BASE COST FOR STAGE 1				**$ 16.41**		
TOTAL ESTIMATED BASE COST FOR STAGE 2				**$ 29.39**		

8.2 Cost Estimates for Proposed Sub-Projects

8.2.1 Capital Costs

139. A summary of cost estimates for the proposed sub-projects is shown in **Table 8.3** below. Note that these are base costs and do not include contingency or taxes. **Table 8.3** includes the cost for incorporating a tertiary treatment component.

Table 8.3 – Cost Estimates – Tertiary Treatment

Sub-Project		Cost Estimate	
		KGS (mill)	USD (mill)
1.	**Balykchy**		
1.1	Wastewater Treatment Plant (IDEAL) – 4.2 MLD capacity (Stage 1)	410.48	6.01
1.2	Biological Ponds	70.35	1.03
1.3	Outfall Pipeline (600mm dia R.C)	8.20	0.12
1.4	Extension of sewerage network	144.80	2.12
	Sub-Total Balykchy	**640.3**	**9.28**
2	**Karakol**		
2.1	Wastewater Treatment Plant (IDEAL) – 12 MLD (Stage 1)	695.52	10.08
2.3	Secondary/Tertiary Sewers and Manholes (11.3 km of 200 mm dia sewer)	191.82	2.78
2.4	Sewage PS-4 Pristan and Pumping Main	27.6	0.40
2.5	Effluent Pipeline to Irrigation Lagoon	17.25	0.25
2.6	De-Sludging of Irrigation Pond	34.50	0.50
	Sub-Total Karakol	**966.69**	**14.01**
3	**Septage Management**		
3.1	Septage Management Framework	17.25	0.25
3.2	Provision of Vacuum Tankers (7 No.)	28.69	0.42
	Sub-Total Septage Management	**45.94**	**0.67**
	TOTAL	**1,671.98**	**21.93**

*Conversion Rate 1 USD = 68.3 KGS

8.2.2 Operating Costs

140. Annual operating costs for the wastewater treatment plants for each city at each development stage is shown below in **Table 8.4**

Table 8.4 – Wastewater Treatment Plants Operating Costs -Balykchy

Category	Balykchy		Karakol	
	Stage 1	Stage 2	Stage 1	Stage 2
	Annual Cost (USD)		Annual Cost (USD)	
Power	26,108	63,079	38,500	82,500
Labour	104,400	104,400	129,600	129,600
Chemicals	0	0	39,913	79,826
Maintenance	40,133	77,759	65,217	117,832
Total	**170,633**	**245,230**	**273,230**	**409,778**

9 PROCUREMENT OPTIONS FOR WASTEWATER TREATMENT PLANTS

141. The traditional and conventional way of procuring civil works infrastructure, such as WWTPs, is through the '*Procurement of Works*' methodology, which involves construction of infrastructure following designs and specifications prepared by design consultants or by an employer directly. This type of procurement is generally appropriate for (i) works that cannot be well defined at the pre-design stage, (ii) where operational issues related to infrastructure are not complex, and (iii) where an employer is experienced in operating the works/equipment being constructed. Such contracts take time to implement however, as they require recruitment of design consultants, followed later by recruitment of construction contractors. Conventionally, the vehicle utilized for '*Procurement of Works*' contracts is the International Federation of Consulting Engineers (FIDIC), Conditions of Contract for Works for Civil Engineering Construction: *The Red Book* (1987).

142. Alternative types of construction modalities include '*Design-Build*' (DB) and '*Design-Build-Operate*' (DBO) contracts. These are generally suitable for works that include a significant amount of mechanical and electrical plant, and where specialist contractors can be given some flexibility in the design approach provided specified performance criteria are met. DBO contracts extend this further, such that a contractor will actually operate the works for a specified time period after construction. DBO contracts are therefore particularly useful when specialized equipment has been provided for which an employer does not initially have the skills to operate effectively.

143. The DBO approach therefore involves the design, build and subsequent operation of a facility or system for the initial part of a facility's life cycle.[31] DB and DBO contracts are covered partially by the FIDIC *Silver* and *Yellow Books,* and DBO specifically by the FIDIC Conditions of Contract for Design, Build and Operate Contracts *Gold Book*.[32] The *Gold Book* emphasizes a contractor's responsibility not only in design and construction, but also up to and including the operation of a facility/system, including the provision of necessary asset replacement during the operation service period. DB and DBO contracting is a new and growing area for ADB projects,[33] and new documents are being developed by ADB specifically to improve procurement and implementation of such projects, not just being limited to ADB plant documents.[34]

144. Utilizing DB or DBO contracting modalities reduces procurement duration, and places sole responsibility for the design, construction and in the case of DBO, successful operation of a facility or system onto a single contractor. This in turn incentivizes a contractor to optimize its design, construction and operation activities, and reduce overall operation and maintenance costs. It is a particularly beneficial option for utilities with technical resource and maintenance culture limitations, as it fills an immediate deficiency gap and provides an opportunity to train utility staff prior to system handover.

145. Regarding the proposed WWTPs in Balykchy and Karakol, a DBO procurement process would potentially offer several key advantages. The required performance of each WWTP could be specified by the utilities directly, and it will then be the responsibility of the contractor to meet that performance level during the operations phase of the contract. Also, the treatment process may only need to be specified generally, providing the contractor with

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[31] Normally, until the employer has set-up and trained skilled personnel to continue to operate it.

[32] The *Gold Book* is however written specifically for a 20-year operation period, and may not be suitable for shorter DBO contracts.

[33] DBO approaches in the WSS sector have been successful worldwide, including for example in the Philippines, Sri Lanka and India. ADB is currently implementing a wastewater treatment plant in Thimphu, Bhutan using a DBO approach.

[34] User's Guide to Procurement of Design, Build and Operate (DBO) Contracts for Water and Wastewater Greenfield Infrastructure Projects.

the opportunity and incentive to design and operate the facilities to deliver the required effluent standard with least life cycle costs. None of the three Vodokanals have any recent experience in operating WWTPs, as the existing plants have been effectively non-operational for over two decades. A DBO contract would therefore allow the Vodokanals to gradually build up human resource capacity, so that it could successfully take over facility operations at the completion of the DBO contract period.

146. A primary disadvantage of DBO contracts is however the lack of control over the treatment process and facility operations during the operational phase. Also, as DBO contracts usually extend up to 20-years in duration, there is a risk that a financially constrained or otherwise poorly performing contractor could jeopardize the successful project implementation over the long term. The latter risk can however be reduced by staging the DBO contract, for example for an initial three-years of operation, with the option of the employer to extend by successive periods of five-years, depending on contractor performance.

147. It is therefore recommended that the Government and ADB now consider DBO contracting modalities for the development of all three WWTPs in Balykchy and Karakol, following which procurement process due diligence can be completed, potentially leading contract formulation in the medium term.

ANNEX 1

DESIGN CHARACTERISTICS OF PROPOSED WASTEWATER TREATMENT PLANTS AT BALYKCHY AND KARAKOL

PROJECTED QUANTITIES	Balykchy			Karakol (fully aerobic)			Karakol (w- anaerobic solids digestion)		
	Phase 1 2018	Phase 2 2028	Phase 3 2038	Phase 1 2018	Phase 2 2028	Phase 3 2038	Phase 1 2018	Phase 2 2028	Phase 3 2038
Population (1000)	46.9	53.5	60.2	74.1	94.1	114.8	74.1	94.1	114.8
Tourist Pop., Jun-Aug/Sept-May (1000)	0 / 0	0 / 0	0 / 0	6.0 / 0.7	8.7 / 1.0	10.4 / 1.2	6.0 / 0.7	8.7 / 1.0	10.4 / 1.2
Sewerage Connection, % of Pop.	25%	40%	55%	45%	60%	75%	45%	60%	75%
ADWF, Jun-Aug/Sept-May, MLD	2.7	5.5	8.6	8.5 / 7.9	16.1 / 14.9	24.4 / 22.6	8.5 / 7.9	16.1 / 14.9	24.4 / 22.6
Septage Accept., Jun-Aug/Sept-May , m3/d	84	77	65	99 / 98	91 / 90	69 / 69	99 / 98	91 / 90	69 / 69
Max. BOD (with septage), kg/d	891	1,300	1,771	2,018	3,164	4,496	2,018	3,164	4,496
Max. COD (with septage), kg/d	1,872	2,731	3,718	4,237	6,644	9,442	4,237	6,644	9,442
Max. TSS (with septage), kg/d	1,765	1,771	1,722	2,445	2,693	2,744	2,445	2,693	2,744
Max. TKN (with septage), kg/d	324	360	395	531	664	786	531	664	786
Max. NH4-N (with septage), kg/d	157	178	198	265	337	406	265	337	406
PROPOSED EQUIPMENT & WORKS									
Mechanical Screening, 10 mm	2	No Works Proposed	1	2	No	1	2	No	1
Vortex Degritters approx. (j, m / Depth, m)	2 / 3.2		2 / 3.2	2 / 3.2	2 / 3.2	2 / 3.2	2 / 3.2	2 / 3.2	2 / 3.2
Primary Sed. (4.5 m deep), j m	No to IDAL		No to IDAL	No to IDAL	No to IDAL	No to IDAL	21	Add 21	Add 21
IDAL with Anoxic Selector & End Balance	2 off		2 more	2 off	2 more	2 more	2 off	2 more	2 more
Total Treatment Capacity, MLD	4.2		8.4	8.1	16.2	24.3	8.1	16.2	24.3
Extent (Wm x Lm x TWLm)	14.5 x 46 x 5		14.5 x 46 x 5	18 x 60 x 5	18 x 60 x 5	18 x 60 x 5	18 x 57 x 5	18 x 57 x 5	18 x 57 x 5
Sludge Age, days	20		20	20	20	20	10	10	10

PROJECTED QUANTITIES	Balykchy			Karakol (fully aerobic)			Karakol (w- anaerobic solids digestion)		
	Phase 1 2018	Phase 2 2028	Phase 3 2038	Phase 1 2018	Phase 2 2028	Phase 3 2038	Phase 1 2018	Phase 2 2028	Phase 3 2038
Slow Speed Surf. Aerators (SNo. / kW ea.)	8 / 11		8 / 11	4 / 15	4 / 15	4 / 15	2 / 15	2 / 15	2 / 15
Sludge Thickener (4.2 m deep), j m	9		9	10	1 more 10	1 more 10	18	No	1 more 18
Sludge Drying Beds (Wm x Lm)	3.1 x 12.5, 22 no.		More 3.1 x 12.5, 22 no.	Rehab. existing 10 beds and with extra area to make 22 beds (20 day rotation)			Rehab. existing 10 beds and with extra ca. 17 x 54 area make 22 beds (20 day rotation)		
Caustic Dosing System Prior to TF (for stripping ammonia)	*Option, not costed*		*Option as 0.1 mgNH4-N will be difficult to achieve biologically in winter. During the lowest temperatures of winter, caustic can be DOSED to strip out the ammonia further in the trickling filter. This would ensure 0.1 mgNH4-N/L level year around from STP discharge.*						
Tertiary Trickling Filter for Nitrification Enhancement, Fan Forced Air (j m x Hm)	11.3 x 4		11.3 x 4	19 x 4	No	19 x 4	19 x 4	No	19 x 4
Trickling Filter Clarifier (4.5 m deep), j m (mostly sized only, not included in CAPEX to keep down costs as not absolutely necessary). It means some solids in ponds and CASTP storage tank.	To Ponds		To Ponds	23 (not allowed in CAPEX, to ponds)	No	23 (not allowed in CAPEX, to ponds)	No room top of site; few solids generated with TFs. Option to put directly in ponds.		
Chlorine Contact Tank (Lm x Wm x Dm)	Ponds		Ponds	36 x 15 for all phases			36 x 15 for all phases		
Extra Ponds (Wm x Lm x Dm): Storage of effluent for winter / irrigation	3 off (75 x 160 x 2.5)		2 off (75 x 160 x 2.5)	No but existing pond desludging			No but existing pond desludging		
Treated Effluent Pumping	Gravity to ponds		Gravity to ponds	Yes to Irrigation Reservoir			Yes to Irrigation Reservoir		
Solids Anaerobic Digesters + Flare, j m x mH		None		None			13 x 5 (660 m3)	No	13 x 5 (660 m3)

PROJECTED QUANTITIES	Balykchy			Karakol (fully aerobic)			Karakol (w- anaerobic solids digestion)		
	Phase 1 2018	Phase 2 2028	Phase 3 2038	Phase 1 2018	Phase 2 2028	Phase 3 2038	Phase 1 2018	Phase 2 2028	Phase 3 2038
Treatment Process By-products	1) USEPA Grade B sludge to land (1.2 tonnes/day) 2) Water for irrigation			1) USEPA Grade B sludge to land (2.9 tonnes/day) 2) Water for irrigation			1) USEPA Grade B sludge to land (2.3 tonnes/day) 2) Water for irrigation 3) 200 kW (1,740 m3) of biogas by 2038 4) Less overall grid electricity usage		
Rehabilitation Works	*Admin. bldg. / Lab. *Opt. repurpose/reuse of existing clarifiers *Pond hydraulic works (front/back) *Pond desludging *Roads and site fencing			*Admin bldg. / Laboratory *Drying beds *Chlorine building *Possibly transformer building *Possibly blower bldg if diff. aeration is used *Possibly sludge dewatering bldg. if drying beds not used *Roads and site fencing *Desludging of ponds			*Admin bldg. / Laboratory / Bore pump *Drying beds *Chlorine building *Possibly transformer building *Possibly blower bldg if diff. aeration is used *Possibly sludge dewatering bldg. if drying beds not used *Roads and site fencing *Desludging of ponds		
New Building & Civil Works	*Inlet and bypass chamber *Screenings Bldg *Sludge drying beds, top of site *Landscaping			*Inlet and bypass chamber *Screenings Bldg *Landscaping			*Inlet and bypass chamber *Screenings Bldg *Landscaping		
Demolition of Existing Works (All Stage 1)	*Screenings building *Degritters *Primary clarifiers *Tanks (or rehab. for reuse) *Secondary clarifiers or rehab./reuse		*Sludge beds *Blowers bldg or rehab./reuse if diff. air used *Pumping station	*Inlet and bypass chamber *Screenings building *Degritters *Primary clarifiers *Sludge regeneration tanks *Chlorine contact tank		*Two brick anaerobic digesters *Boilers building *Possibly blower bldg *Possibly sludge	*Inlet and bypass chamber *Screenings building *Degritters *Primary clarifiers *Sludge regeneration tanks *Chlorine contact tank		*Two brick anaerobic digesters *Boilers building *Possibly blower bldg *Possibly sludge

PROJECTED QUANTITIES	Balykchy			Karakol (fully aerobic)			Karakol (w- anaerobic solids digestion)		
	Phase 1 2018	Phase 2 2028	Phase 3 2038	Phase 1 2018	Phase 2 2028	Phase 3 2038	Phase 1 2018	Phase 2 2028	Phase 3 2038
						dewatering bldg			dewatering bldg

ANNEX 2

WASTEWATER FLOWS AND LOADINGS AT BALYKCHY AND KARAKOL

Wastewater Flows & Loads (June to August)		Balykchy	Pop.Grwth Taken from 28Aug17 Recalc		Karakol	Pop.Grwth Taken from 28Aug17 Recalc	
		2018	2028	2038	2018	2028	2038
Estimated Resident Population		46,895	53,470	60,244	74,104	94,146	114,763
Tourist PE		0	0	0	5,989	8,724	10,390
TOTAL POPULATION		46,895	53,470	60,244	80,093	102,870	125,153
Water Demand (lpcd)		180	200	200	180	200	200
Total Domestic Sewage Generation (m^3/day) at 80% of Water Demand		6,753	8,555	9,639	11,533	16,459	20,025
Sewerage Connection Rate		25%	40%	55%	45%	60%	75%
Sewage Generation to Treatment (m^3/day)		1,688	3,422	5,302	5,190	9,876	15,018
Commercial & Institutional Wastewaters in Sewer (Max 20% over Treated Domestic)	20%	338	684	1,060	1,038	1,975	3,004
Industrial (m3/d)		0	0	0	45	68	90
TOTAL GENERATED SEWER FLOWS, m3/day		**2,026**	**4,107**	**6,362**	**6,273**	**11,918**	**18,112**
Stormwater Infiltration Allowance (10% over total, m^3/day)	10%	203	411	636	623	1185	1802
Groundwater Infiltration Allowance (25% over total, m^3/day)	25%	506	1027	1590	1557	2963	4506
TOTAL ADWF to STPs (m3/day)		**2,735**	**5,544**	**8,588**	**8,453**	**16,066**	**24,420**
CARBON: BOD							
Estimated Treated Domestic Load @35gBOD/p/d (kgBOD/day)	35	410	749	1,160	1,261	2,160	3,285
Estimated Septage Actually Pumped of Total Available, on 3 yr cycle	**75%**						
Est. Septage Load to STP via Pumpout Truck @6,000 mgBOD/L, (kgBOD/day)	6000	380	346	293	445	411	310
Estimated Septage Load to STP via Pumpout Truck @4600 mgBOD/L Total but Filtrate Only 1400 mg/L (kgBOD/day)	1,396	88	81	68	103	96	72
No. of Tankers - 3m3 (2 trips/day)		14	13	11	16	15	11
Estimated Commercial/Institutional load at 300 mgBOD/L (kgBOD/day)	300	101	205	318	311	593	901
Estimated Industrial Load (kgBOD/day)		0	0	0	36	54	72
TOTAL BOD LOAD AT STP, kg/day (NO SEPTAGE)		**512**	**954**	**1,478**	**1,573**	**2,753**	**4,186**
Est. Influent BOD (NO SEPTAGE), mg/L		187	172	172	186	171	171
TOTAL BOD LOAD, kg/day (WITH SEPTAGE)		**891**	**1,300**	**1,771**	**2,018**	**3,164**	**4,496**

Wastewater Flows & Loads (June to August)		Balykchy	Pop.Grwth Taken from 28Aug17 Recalc		Karakol	Pop.Grwth Taken from 28Aug17 Recalc	
Est. Influent BOD (WITH SEPTAGE), mg/L		326	235	206	239	197	184
TOTAL BOD LOAD, kg/day (WITH SEPTAGE FILTRATE ONLY)		**600**	**1,035**	**1,546**	**1,676**	**2,848**	**4,258**
Est. Influent BOD (WITH SEPTAGE FILTRATE ONLY), mg/L		219	187	180	198	177	174
COD							
SCOD LOAD AT STP: No Industrial, COD = 2*BOD, kg/day (NO SEPTAGE)	2.0	**1,023**	**1,908**	**2,956**	**3,146**	**5,506**	**8,373**
Est. Influent COD (NO SEPTAGE), mg/L		374	344	344	372	343	343
SCOD LOAD AT STP: No Industrial, kg/day (WITH SEPTAGE)	2.1	**1,872**	**2,731**	**3,718**	**4,237**	**6,644**	**9,442**
Est. Influent COD (WITH SEPTAGE), mg/L		685	493	433	501	414	387
SCOD LOAD AT STP: No Industrial, kg/day (WITH SEPTAGE FILTRATE ONLY)	2.3	**1,227**	**2,093**	**3,112**	**3,384**	**5,726**	**8,539**
Est. Influent COD (WITH SEPTAGE), mg/L		448	378	362	400	356	350
TOTAL SOLIDS							
TOTAL Treated Domestic Load @15gSS/p/d, kgSS/day (NO SEPTAGE)	**15**	**703**	**802**	**904**	**1,201**	**1,543**	**1,877**
Est. Influent TS (NO SEPTAGE), mg/L		257	145	105	142	96	77
Potential Septage Solids (at Pumpout Rate of 50%) @1.7% solids, kg/d	**16,775**	**1,062**	**969**	**819**	**1,243**	**1,150**	**867**
TOTAL Solids Load to Treatment Plant, kg/d, (WITH SEPTAGE)		**1,765**	**1,771**	**1,722**	**2,445**	**2,693**	**2,744**
Est. Influent TS (WITH SEPTAGE), mg/L		646	319	201	289	168	112
NITROGEN							
Esti. Treated Domestic TKN @8 TKN/p/d (kgTKN/day) (NO SEPTAGE)	**6**	**281**	**321**	**361**	**481**	**617**	**751**
Est. Influent TKN (NO SEPTAGE), mg/L		103	58	42	57	38	31
TOTAL Trtd Domestic @678 mgTKN/L, kgTKN/day (WITH SEPTAGE)	**678**	**324**	**360**	**395**	**531**	**664**	**786**
Est. Influent TKN (WITH SEPTAGE), mg/L		119	65	46	63	41	32
TOTAL Trtd Domestic @136 mgTKN/L, kgTKN/day (W- SETTLED SEPTAGE)	**136**	**290**	**329**	**368**	**491**	**627**	**758**
Est. Influent TKN (WITH SEPTAGE), mg/L		106	59	43	58	39	31
TOTAL Trtd Domestic NH3 @3.2 gSS/p/d, kgNH3-N/day (NO SEPTAGE)	**3.2**	**150**	**171**	**193**	**256**	**329**	**400**
Est. Influent NH3-N (NO SEPTAGE), mg/L		55	31	22	30	20	16

Wastewater Flows & Loads (June to August)		Balykchy	Pop.Grwth Taken from 28Aug17 Recalc		Karakol	Pop.Grwth Taken from 28Aug17 Recalc	
TOTAL Trtd Domestic @115 mgNH3-N/L, kgNH3-N/day (WITH SEPTAGE)	**115**	**157**	**178**	**198**	**265**	**337**	**406**
Est. Influent NH3-N (WITH SEPTAGE), mg/L		58	32	23	31	21	17

Wastewater Flows & Loads (September to May)		Balykchy	Pop.Grwth Taken from 28Aug17 Recalc		Karakol	Pop.Grwth Taken from 28Aug17 Recalc	
Residential population		46,895	53,470	60,244	74,104	94,146	114,763
Tourist PE		0	0	0	665	969	1154
TOTAL POPULATION		46,895	53,470	60,244	74,769	95,115	115,917
Water Demand (lpcd)		180	200	200	180	200	200
Potential Wastewater Generation (m3/day)		6,753	8,555	9,639	10,767	15,218	18,547
Sewerage Connection Rate		25%	40%	55%	45%	60%	75%
Actual Wastewater Generation (m3/day)		1,688	3,422	5,302	4,845	9,131	13,910
Commercial & Institutional Wastewaters in Sewer (Max 20% over Treated Domestic)	20%	338	684	1060	969	1826	2782
Industrial (m3/d)		0	0	0	45	68	90
TOTAL GENERATED SEWER FLOWS, m3/day		**2,026**	**4,107**	**6,362**	**5,859**	**11,025**	**16,782**
Stormwater Infiltration Allowance (10% over total, m^3/day)	10%	203	411	636	581	1096	1669
Groundwater Infiltration Allowance (25% over total, m^3/day)	25%	506	1027	1590	1454	2739	4173
TOTAL ADWF to STPs (m3/day)		**2,735**	**5,544**	**8,588**	**7,894**	**14,860**	**22,624**
CARBON: BOD							
Estimated Treated Domestic Load @35gBOD/p/d (kgBOD/day)	35	410	749	1,160	1,178	1,997	3,043
Estimated Septage Actually Pumped of Total Available, on 3 yr cycle	**75%**						
Est. Septage Load to STP via Pumpout Truck @6,000 mgBOD/L, (kgBOD/day)	6000	380	346	293	441	407	310
Estimated Septage Load to STP via Pumpout Truck @4600 mgBOD/L Total but Filtrate Only 1400 mg/L (kgBOD/day)	1,396	88	81	68	102	95	72
No. of Tankers - 3m3 (2 trips/day)		14	13	11	16	15	11
Estimated Commercial/Institutional load at 300 mgBOD/L (kgBOD/day)	300	101	205	318	291	548	835
Estimated Industrial Load (kgBOD/day)		0	0	0	36	54	72

Wastewater Flows & Loads (September to May)		Balykchy	Pop.Grwth Taken from 28Aug17 Recalc		Karakol	Pop.Grwth Taken from 28Aug17 Recalc	
TOTAL BOD LOAD AT STP, kg/day (NO SEPTAGE)		**512**	**954**	**1,478**	**1,468**	**2,545**	**3,877**
Est. Influent BOD (NO SEPTAGE), mg/L		187	172	172	186	171	171
TOTAL BOD LOAD, kg/day (WITH SEPTAGE)		**891**	**1,300**	**1,771**	**1,909**	**2,952**	**4,188**
Est. Influent BOD (WITH SEPTAGE), mg/L		326	235	206	242	199	185
TOTAL BOD LOAD, kg/day (WITH SEPTAGE FILTRATE ONLY)		**600**	**1,035**	**1,546**	**1,571**	**2,640**	**3,950**
Est. Influent BOD (WITH SEPTAGE FILTRATE ONLY), mg/L		219	187	180	199	178	175
COD							
SCOD LOAD AT STP: No Industrial, COD = 2*BOD, kg/day (NO SEPTAGE)	2.0	**1,023**	**1,908**	**2,956**	**2,937**	**5,091**	**7,755**
Est. Influent COD (NO SEPTAGE), mg/L		374	344	344	347	317	318
SCOD LOAD AT STP: No Industrial, kg/day (WITH SEPTAGE)	2.1	**1,872**	**2,731**	**3,718**	**4,009**	**6,200**	**8,795**
Est. Influent COD (WITH SEPTAGE), mg/L		685	493	433	474	386	360
SCOD LOAD AT STP: No Industrial, kg/day (WITH SEPTAGE FILTRATE ONLY)	2.3	**1,227**	**2,093**	**3,112**	**3,172**	**5,308**	**7,921**
Est. Influent COD (WITH SEPTAGE), mg/L		448	378	362	402	357	350
TOTAL SOLIDS							
TOTAL Treated Domestic Load @12gSS/p/d, kgSS/day (NO SEPTAGE)	**12**	**563**	**642**	**723**	**897**	**1,141**	**1,391**
Est. Influent TS (NO SEPTAGE), mg/L		206	116	84	114	77	61
Potential Septage Solids (at Pumpout Rate of 50%) @1.7% solids, kg/d	**16,775**	**1,062**	**969**	**819**	**1,232**	**1,138**	**868**
TOTAL Solids Load to Treatment Plant, kg/d, (WITH SEPTAGE)		**1,625**	**1,610**	**1,542**	**2,129**	**2,280**	**2,259**
Est. Influent TS (WITH SEPTAGE), mg/L		594	290	179	270	153	100
NITROGEN							
Esti. Treated Domestic TKN @8 TKN/p/d (kgTKN/day) (NO SEPTAGE)	**8**	**375**	**428**	**482**	**598**	**761**	**927**
Est. Influent TKN (NO SEPTAGE), mg/L		137	77	56	76	51	41
TOTAL Trtd Domestic @678 mgTKN/L, kgTKN/day (WITH SEPTAGE)	**678**	**418**	**467**	**515**	**648**	**807**	**962**
Est. Influent TKN (WITH SEPTAGE), mg/L		153	84	60	82	54	43
TOTAL Trtd Domestic @136 mgTKN/L, kgTKN/day (W- SETTLED SEPTAGE)	**136**	**384**	**436**	**489**	**608**	**770**	**934**
Est. Influent TKN (WITH SEPTAGE), mg/L		140	79	57	77	52	41

Wastewater Flows & Loads (September to May)		Balykchy	Pop.Grwth Taken from 28Aug17 Recalc		Karakol	Pop.Grwth Taken from 28Aug17 Recalc	
TOTAL Trtd Domestic NH3 @3.2 gSS/p/d, kgNH3-N/day (NO SEPTAGE)	**3.2**	**150**	**171**	**193**	**239**	**304**	**371**
Est. Influent NH3-N (NO SEPTAGE), mg/L		55	31	22	30	20	16
TOTAL Trtd Domestic @115 mgNH3-N/L, kgNH3-N/day (WITH SEPTAGE)	**115**	**157**	**178**	**198**	**248**	**312**	**377**
Est. Influent NH3-N (WITH SEPTAGE), mg/L		58	32	23	31	21	17

Septage Quantities (June to August)		**Balykchy**			**Karakol**		
		2018	**2028**	**2038**	**2018**	**2028**	**2038**
Resident Population		46,895	53,470	60,244	74,400	94,200	112,600
No. of Households (at 5 people / household)		9,379	10,694	12,049	14,880	18,840	22,520
Tourist PE		0	0	0	5,500	8,326	11,500
No. of tourist establishments (7 days stay; 50 guests av)		0	0	0	16	24	33
Sewerage Connection Rate		25%	40%	55%	45%	60%	75%
% households/resorts with septic tanks (assumes on sewer or septic tank)		75%	60%	45%	55%	40%	25%
Houshold septage (annual pump out, 3 m3 tank, 250 days) - m3/day		84	77	65	98	90	68
Tourist Resorts Septage (6 month pump out, 10 m3 ST, 250 days)		0	0	0	1	1	1
Total Septage (m3/day)		**84**	**77**	**65**	**99**	**91**	**69**
No. of Tankers - 3m3 (2 trips/day)		14	13	11	16	15	11
Septage Quantities (September to May)							
Residential population		46,895	53,470	60,244	74,104	94,146	114,763
No. of Households (at 5 people / household)		9,379	10,694	12,049	14,821	18,829	22,953
Tourist PE		0	0	0	665	969	1154
No. of tourist establishments (7 days stay; 50 guests av)		0	0	0	2	3	3
Sewerage Connection Rate		25%	40%	55%	45%	60%	75%
% households/resorts with septic tanks		75%	60%	45%	55%	40%	25%
Houshold septage(annual pump out, 3 m3 tank, 250 days) - m3/day		84	77	65	98	90	69
Tourist Resorts Septage (6 month pump out, 10 m3 ST, 250 days)		0	0	0	0	0	0
Total Septage (m3/day)		**84**	**77**	**65**	**98**	**90**	**69**

No. of Tankers - 3m3 (2 trips/day)			14	13	11	16	15	11

1) Reduced sewage connection in 2018 of 46% for all (previous study used 64% for all) to 25% for BASTP, 45% for CASTP and KKSTP. This was based on a World Bank report "The Kyrgyz Republic: Insightes on household access to water supply and sanitation", April 2015, http://documents.worldbank.org/curated/en/680561468184774661/pdf/99774-WP-P147694-Box393219B-PUBLIC-KG-WaterAccess-100115-ENGL.pdf, pg 9, Figure 2.1, accessed July 2015.

Balykchy Actual = 2.5 MLD @ 120 mgBOD/L	Estimated Q =	2.7	MLD (2018 projected) @ 25% sewerage
Karakol Actual = 7 to 8 MLD @ 97 mgBOD/L	Estimated Q =	8.5	MLD (2018 projected for high) @ 45% sewerage

2) Revised population estimations to reflect latest estimates (original number of tourists remained the same)

3) Our estimated flows were conderably reduced by decreasing the existing sewerage from an estimated 2028 of 13.1 MLD to 5.4 MLD for BASTP.