Table V.2.9 Pollution load generated and collected by sanitary sewer system

Year	Total Population	Served Population (% served)	Wastewater Flow (l/s)	BOD_5 (kg/day)		T-N (kg/day)		T-P (kg/day)	
				generated	collected	generated	collected	generated	collected
1998	108,457	50,107 (46 %)	77.2	4,881	2,255	1,193	551	136	63
2008	139,076	97,631 (70 %)	128.6	6,258	4,393	1,530	1,074	174	122
2015	160,508	125,731 (78 %)	170.0	7,223	5,658	1,766	1,383	201	157
2025	185,004	157,253 (85 %)	224.0	8,325	7,076	2,035	1,730	231	197

For future large-scale developments in industry and tourism sectors, acceptance of their wastewater to sanitary sewer system shall be carefully studied as provision of individual treatment facilities by the developers can be more economically viable.

2.2.5 SYSTEM CONSIDERATIONS

Sanitation systems can be divided into 2 major categories, namely on-site (treatment) system and off-site (treatment) system. The former treats and disposes excreta at the source (each household) while the latter collects wastewater and conveys it to points of treatment and disposal.

At present, conventional sewerage (off-site system) and on-site systems, such as sanitary toilets (*Figure* IV.1.2) and a few septic tanks serve the planning area.

The above existing systems and other alternative sanitation technologies are reviewed for possible application to Puno City.

(1) On-site systems

Available technologies for on-site sanitation systems for Puno City are:

1. Simple pit latrines (called "sanitary toilet" in Puno)

   Latrine with a pit for accumulation and decomposition of excreta and from which liquid infiltrates into the surrounding soil

2. Lid-covered pit latrines (*Figure V.2.2*)

   Pit latrine with tight-fitting lid to seal pit to control odor and insects

3. Ventilated improved pit (VIP) latrines (*Figure V.2.5*)

   Pit latrine with a screened vent pipe and a partially dark interior to the superstructure

4. Pour-flush (PF) latrines (single or double pit) (*Figure V.2.3, 4*)

   Latrine with a small quantity of water is poured in to flush excreta through a water seal into a pit.

5. Cistern-flush toilet to septic tank (*Figure V.2.6*)

   Cistern-flush toilet connected to a septic tank, which is watertight chamber for the retention, partial treatment: effluent infiltrates from the tank into the surrounding ground through soakage pits or trenches

Composting latrines and aqua-privies are ruled out for use in Puno City from the following observations.

	Description	Observation
Composting latrines	Excreta fall into a watertight tank to which ash of vegetable matter is added	– Not easy to operate – Lack of an adequate composting period has resulted in high level of worm infection.
Aqua-privies	Latrine in which excreta fall directly through a submerged pipe into a watertight settling chamber below the floor, and from which effluent overflows to a soakaway	– Reputed for poor operation – Need for large quantities of water for cleaning the drop pipe

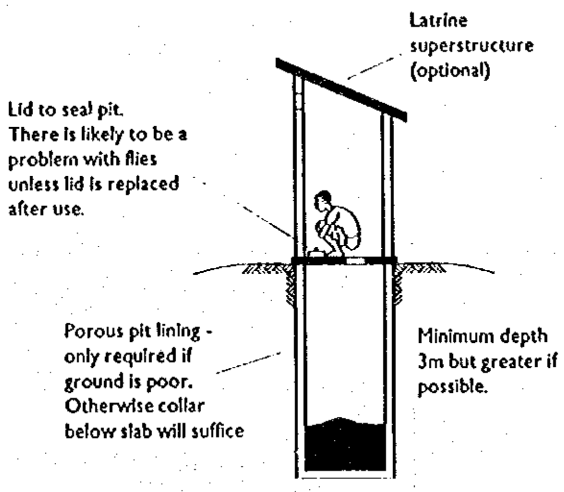


Figure V.2.2 Lid covered pit latrine

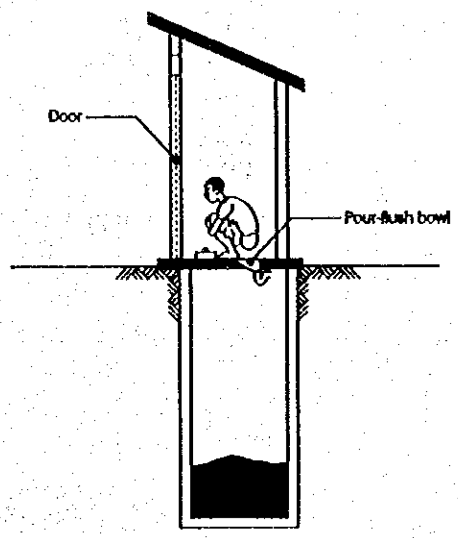


Figure V.2.3 Pour flush latrine with pit beneath the superstructure

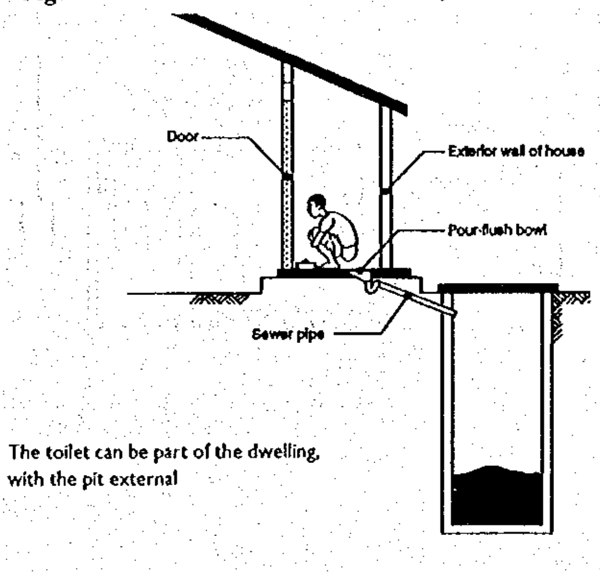


Figure V.2.4 Offset pour flush latrine

Source: WEDC (1995)

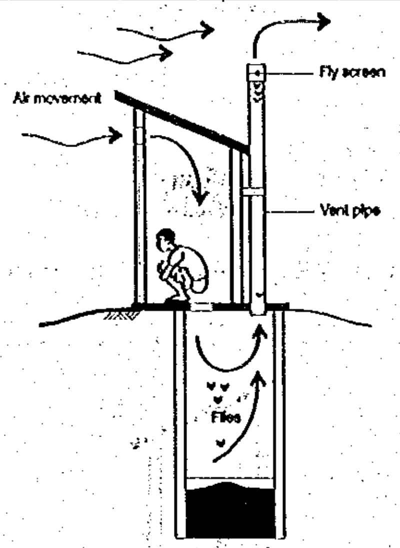


Figure V.2.5 Ventilated improved pit latrine (VIP)

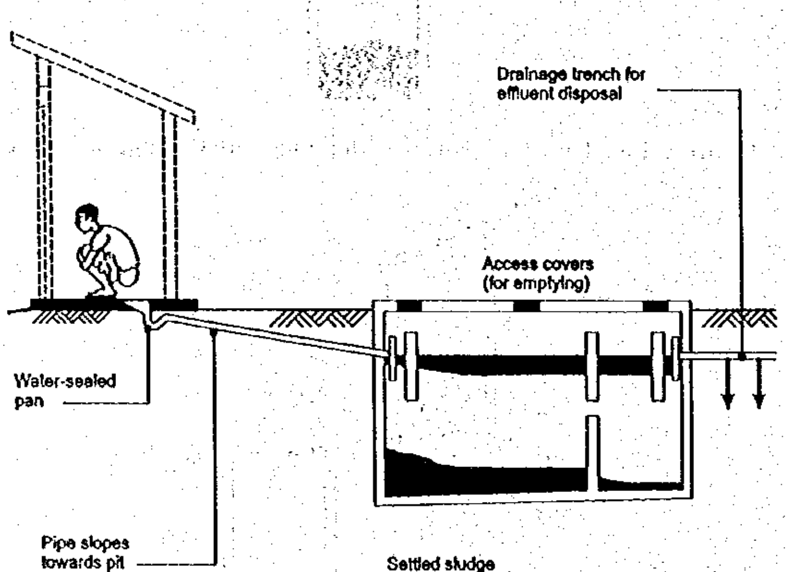


Figure V.2.6 Septic tank

Source: WEDC (1995)

a) System Selection

For selecting appropriate sanitation system, one must consider the community's water supply service level, as some sanitation technologies are not compatible with some service levels.

The possible levels of water supply service are:

1. Hand-carried supplies (standpipes, wells)
2. On-plot supplies (basically one tap per household or compound)
3. Multiple-tap, in-house supplies

Comparison of the on-site sanitation systems is summarized in *Table V.2.10.* With its low construction cost and area requirement, simple pit latrine, possibly with a tight fitted lid, is recommended where ground water level is at least 2 meters below ground. Where ground water level is high, within 2 meters of the ground surface, pour flush latrine with double pits is recommended. Alternating use of twin pits allows the full pit to "rest" for about 2 years until the excreta has decomposed and can be handled without health risk while the other pit is in use.

Installation of cistern flush toilet without sewer connection may require a septic tank because of larger flush water volume. This option is only considered when sewer connection is not expected in the near future.

Table V.2.10 Comparison of on-site systems

Sanitation System	Water supply Service level*1	Odors/ Insects	Site requirement		Construc-tion Cost	Mainte-nance Cost	Required skills for construc-tion	Sullage treatment	Pit emptying	Require-ment for sludge treatment
			Area	Minimum ground water depth						
Simple pit latrine	HC/OP	High	Low	2m <	Low	Low	Low	No	Vacuum tanker	Yes (no)*3
Lid-covered pit latrine	HC/OP	Medium	Low	2m <	Low	Low	Low	No	Vacuum tanker	Yes (no)*3
VIP latrine	HC/OP	Medium	Medium	2m <	Medium	Low	Low	No	Vacuum tanker	Yes (no)*3
Pout flush latrine										
with single pit	HC/OP /(MT)	Medium to Low	Low to Medium	2m <	Low	Low	Low to Medium	No	Vacuum tanker	Yes (no)*3
with double pit			Medium	1m <	Low to Medium	Low	Low to Medium	No	Vacuum tanker / Manual*2	No
Cistern flush to septic tank	MT	Low	High	1m <	High	High	High	Yes	Vacuum tanker	Yes (no)*3

*1 HC : Hand carried
OP : On-plot
MT : Multiple taps
*2 after and adequate "rest" period (normally 2 years)
*3 not required if pit is abandoned after use
*4 minimum depth of ground water level

b) Upgrading of sanitation systems

Possible upgrading sequence of sanitation system is show in *Table V.2.11.*

Table V.2.11 Sanitation upgrading sequence

Sanitation system	Water supply level		
	Hand-carried	On-plot	Multiple tap
Pit latrine	● →	● ↓	
PF latrine	● →	● →	● ↓
Sewerage			●

Pit latrine can be upgraded directly to sewerage system when its service is available in the area.

c) Pit emptying and sludge disposal

When a pit latrine becomes full, it must be either taken out of use and a new pit dug or the pit emptied. The practice of emptying pits manually (by hand) can present serious health hazards if the fecal matter has not been rested for at least two years.

In agricultural area of Puno City, especially zone I, II, III, IV in *Figure V.2.1* where normally land is available for a new pit, pit emptying may not be necessary. But in the urban area where available land is limited to dig a new hole, pit shall be emptied. High-performance vacuum tankers or small pit emptying machines with a mobile tanker can empty pit and transport the sludge to the treatment site.

Sludge from single pits, septic tanks are not microbiologically safe, so disposal is only possible to sanitary land fills or tree belts to which the public does not have access. On the other hand, sludge from alternating double pits is generally pathogen-free, so disposal could be either on-site, to a vegetable garden etc. or off-site to agriculture land and landfills.

d) Ground water pollution

On-site sanitation system is a potential source for ground water pollution. Contaminants contained is liquids percolating into the soil from on-site systems are categorized as follows:

- Microbiological contaminants:	Fecal microorganism including viruses, bacteria, protozoa and helminthes
- Chemical contaminants:	Nitrogen, Phosphorus, etc.

Virus normally die-off within three meters of the pollution sources. Bacterial contamination is normally removed through physical filtration given sufficient depth of unsaturated soil (at least 2 meters) between a pollution source and a water point.

Chemical pollution extends much further than pollution by microorganisms. In areas with high pit latrine densities, nitrate concentrations of ground water may build up. A minimum distance of 15 meters between a pollution source and a well should be kept as recommended by the sanitation standard S.123.

To minimize ground water pollution, the pit base can be sealed by lean concrete and 0.5-m width of sand is placed between the surrounding soil and the pit lining when the lining exists.

(2) Off-site treatment system

Available technologies for off-site systems for Puno City are:

1. Conventional sewerage

   Conventional sewerage system comprises house connections, public sewers, pumping stations, and wastewater treatment works. The existing off-site system in Puno City is a conventional sewerage.

2. Simplified sewerage (*Figure V.2.7*)

   Simplified sewerage is designed to receive all household wastewater without settlement in solids interceptor tanks. Small diameter sewers laid at shallow gradients are used to convey the wastewater by gravity; these sewers are often laid inside housing blocks (called "condominial sewerage") or they may be laid outside the block usually under sidewalks. Simple junction boxes are used to connect house connections to simplified sewerage or one sewer to another sewer instead of manholes.

3. Settled sewerage (*Figure V.2.8*)

   Settled sewerage is a system of interceptor tanks and small diameter collection mains. The interceptor tanks, located upstream of each connection and usually on the property served, remove grease and settleable solids from the raw wastewater. The settled wastewater is discharged from each tank via gravity or by pump (septic tank effluent pumping [STEP] unit) into the gravity collector mains usually located in the public streets. The mains transport the tank effluent to a treatment facility or connection with a conventional gravity sewer interceptor.

4. Pressure sewerage (*Figure V.2.9*)

   Each home uses a small pump to discharge to the main. This may be a grinder pump, which grinds the solids present in wastewater to slurry, or a septic tank and effluent pump (STEP) system may be used. The septic tank of a STEP system captures the solids, grit, grease, and stringy material that could cause problems in pumping and conveyance through the small diameter piping.

5. Vacuum sewerage (*Figure V.2.10*)

Vacuum sewerage is a mechanized system of wastewater transport, which uses differential air pressure to move wastewater. It requires a central source of power to run vacuum pumps, which maintain vacuum on the collection system (*Figure 3-1*). The system requires a normally closed vacuum/gravity interface valve at each entry point to seal the lines so that vacuum is maintained. These valves, located in a pit, open when a predetermined amount of wastewater accumulates in the collecting sump. The resulting differential pressure between atmosphere and vacuum becomes the driving force that propels the wastewater towards the vacuum station.

Simplified sewerage, settled sewerage, pressure sewerage and vacuum sewerage are originally developed for small communities as a low cost alternative to conventional sewerage system.

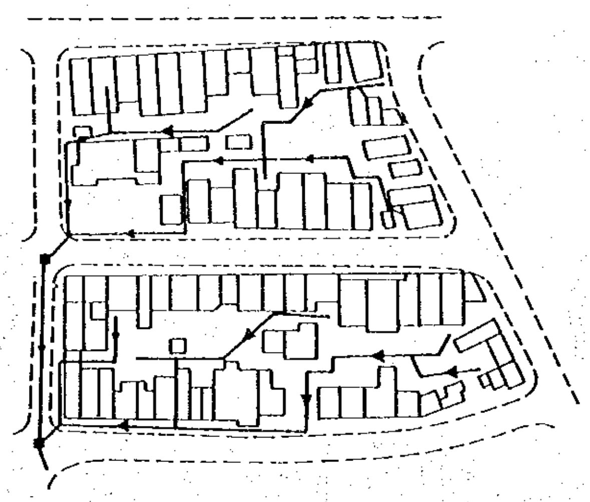


Figure V.2.7 Sample layouts of simplified (condominial) sewerage

Source: Mara (1996)

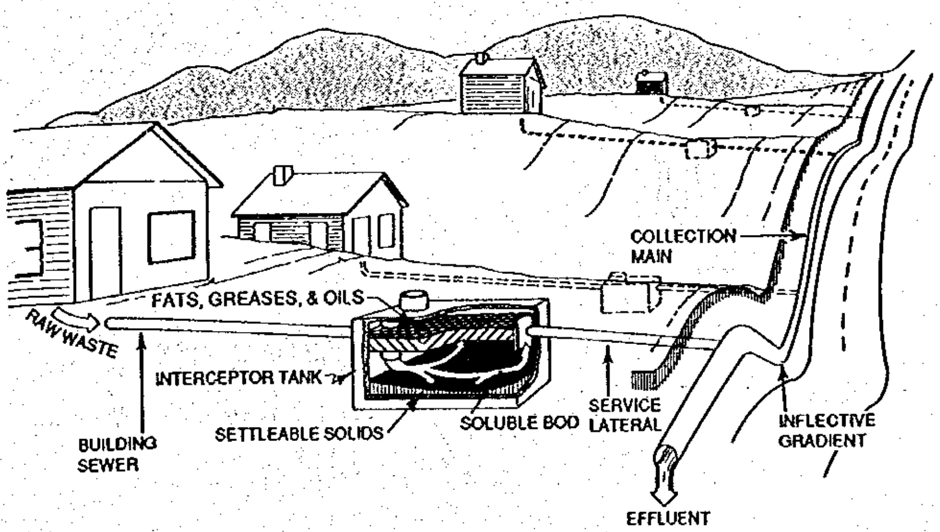
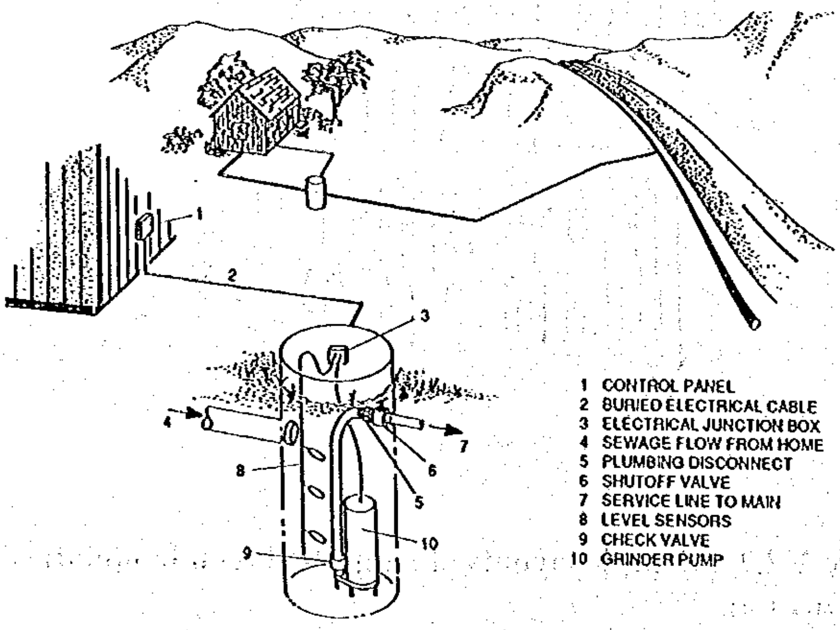


Figure V.2.8 Schematic of settled sewerage

Source: US EPA (1991)

Grinder Pump (GP) system.



Septic Tank Effluent Pump (STEP) system.

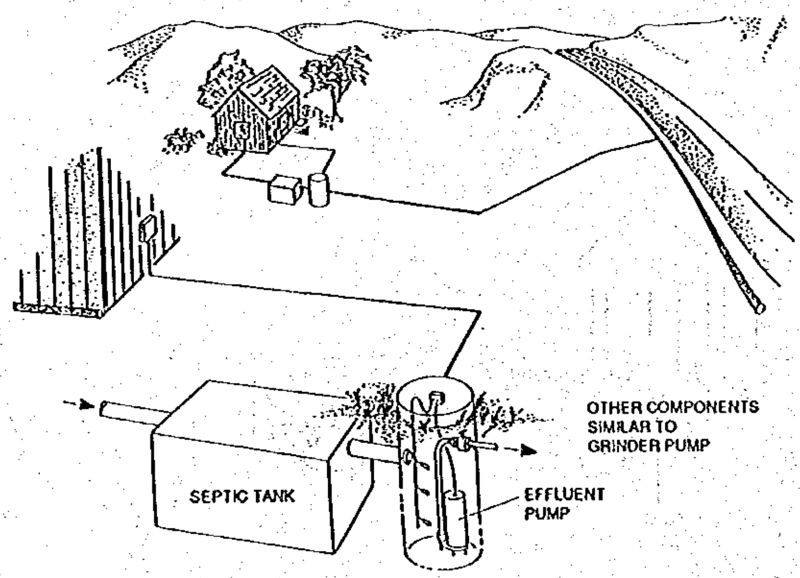


Figure V.2.9 Schematics of pressure sewerage

Source: US EPA (1991)

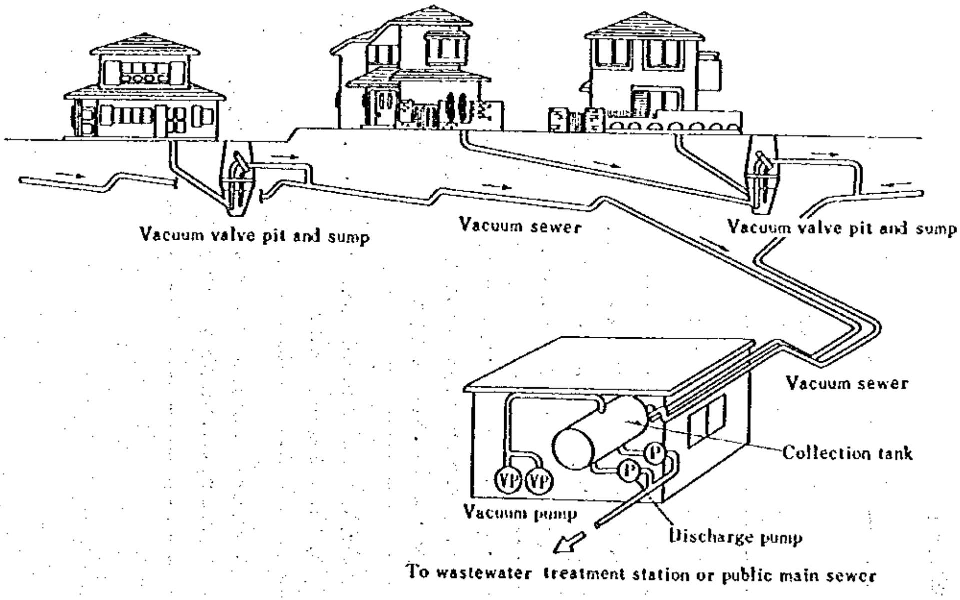


Figure V.2.10 Schematic of vacuum sewerage

Source: Ushitora et. al. (1989)

a) System selection.

The comparison of the above off-site systems is shown in Table V.2.12. Pressure sewerage and vacuum sewerage require high operation cost, qualified personnel and appropriate equipment maintenance.

Settled sewerage is most appropriate for low-density areas that already have septic tanks, which is not the case for Puno City. Desludging of the interceptor (septic) tanks by vacuum tankers is required periodically.

Simplified sewerage is appropriate for high-density housing area. Condominial sewerage may solve house connection problems of conventional sewerage in congested housing areas.

For the expansion of the existing sewerage system in Puno City, conventional sewerage is considered appropriate. Simplified sewerage is applicable for the high-density areas when approach from street sewer to houses inside the block is only possible through private properties. Collected wastewater by simplified sewerage will be discharged to the conventional sewerage.

Table V.2.12 Comparison of off-site systems

System	Construction Cost	O&M Cost	Required skill level for O&M	Infiltration	Maximum pipe depth	Pipe diameter	H_2S generation	Remarks
Conventional sewerage	High	Medium	Medium	High	Deep	Medium to Large	Low	Most expensive, but no limits for application.
Simplified sewerage	Medium to Low	Low	Low	Medium	Shallow	Small to Medium	Medium	Sewers are often laid inside housing block (condominial sewerage) or sidewalks. Appropriate for high-density housing area.
Settled sewerage	Medium to Low	Medium	Medium	Medium	Shallow	Small	High	Appropriate for low-density residential areas with septic tanks installed, interceptor tank (septic tank) is required.
Pressure sewerage	Medium	High	High	Low	Shallow	Small	High	O&M require highly skilled labor. Can not be applied to down slope.
Vacuum sewerage	Medium	High	High	Low	Shallow	Small	Low	Vacuum toilet requires less flushing water. Vacuum should be maintained.

2.2.6 DESIGN CRITERIA

The following design criteria have been adopted with due respect to the Peruvian regulations and practices of EMSAPUNO.

(1) Sewer design

a) Design Flow

Maximum hourly wastewater flow is adopted as design flow for sewer design. Maximum hourly flow is calculated as 1.8 times of average daily wastewater flow plus infiltration flow as specified in "Reglamento Nacional de Construcciones" (R.N.C) S.100.

b) Flow Calculation

Hydraulic calculation of wastewater flow uses Manning formula for open-channel and pipe flow, except for pressure pipe flow calculated by Hazen-Williams formula.

$V = 1/n \times R^{2/3} \times S^{1/2}$ (Manning formula)

$V = 0.85\ CR^{0.63} \times S^{0.54}$ (Hazen-William formula)

Where:

V: Flow velocity (m/s)
R: Hydraulic radius (m)
S: Slope
n: Manning coefficient
C: Hazen-Williams coefficient

Table V.2.13 Values of Manning coefficient, n

Conduit material	n
Concrete	0.013
PVC pipe	0.010

Table V.2.14 Values of Hazen-Williams coefficient, C

Pipe material	C
PVC	140
Polyethylene	140
Ductile iron	130
Concrete	110

c) Flow velocity

Maximum flow velocity: 3.0 m/s
Minimum flow velocity: 0.6 m/s

d) Depth of flow in pipes

Sanitary sewers are designed to flow less than 75% full in depth.

$d_s/D * 0.75$

Where:

d_s: depth of flow (m)
D: pipe diameter (m)

e) Type of conduit

The following pipes are used according to diameters for gravity sewer lines.

Type	Diameter
PVC pipe	150 mm - 400 mm
Reinforced concrete (RC)	450 mm -

For pressure sewer, high-density polyethylene pipes (HDPE), ductile iron pipes and PVC pipes are used.

Open-channels shall be made of reinforced concrete.

f) Minimum diameter of pipes

Minimum diameter of pipes is set as 150 mm

g) Depth of sewer

The top of the sanitary sewer shall not be less than 1 m below the ground level.

h) Manholes

Manholes shall be installed at the junction of sanitary sewers and at changes in grade or alignment. Minimum spacing of manholes is shown in *Table V.2.15*.

Table V.2.15 Minimum manhole spacing

Sewer diameter	Spacing
150 mm	80 m
200 mm - 250 mm	100 m
300 mm - 600 mm	150 m
600 mm <	250 m

Source: RNC S.124

Types of manholes are shown in *Table V.2.16* according to sewer diameters.

Table V.2.16 Type of Manholes

	Manhole		Sewer diameter
	Depth	Diameter	
Type I	< 3.0 m	1.2 m	* 600 mm
	3.0 m *	1.5 m	
Type II	< 3.0 m	1.2 m	650 mm - 1,200 mm
	3.0 m *	1.5 m	
Type III	All depth	1.5 m	1,300 mm *

Source: SEDAPAL (1994)

(2) Pumping station design

Pumping stations for sanitary sewer shall be designed to carry the peak hourly design flow.

a) Station type

Pumping stations are designed with wet wells with large solid removal devices and submersible pumps. Submersible pumps shall be readily removable for maintenance and replacement without emptying the wet well.

b) Pumps

Minimum 2 units of pumps shall be installed. Pumps shall be designed to handle 100% of the peak design flow even if any one of pumps breaks down.

c) Wet wells

Retention time of wet wells shall not exceed 30 minutes. Floor shall have slope towards pumps.

d) Solid removal

Solid removal device, such as screens, trash rack and clean out bucket, shall be provided to wet wells.

e) Ventilation

Adequate ventilation shall be provided for all pump stations.

f) Flow velocity in force mains

Maximum flow velocity:	3.0 m/s
Minimum flow velocity:	0.6 m/s

2.3 Alternative Plans for Structural Measures

2.3.1 Possible Measures

(1) On-site system options

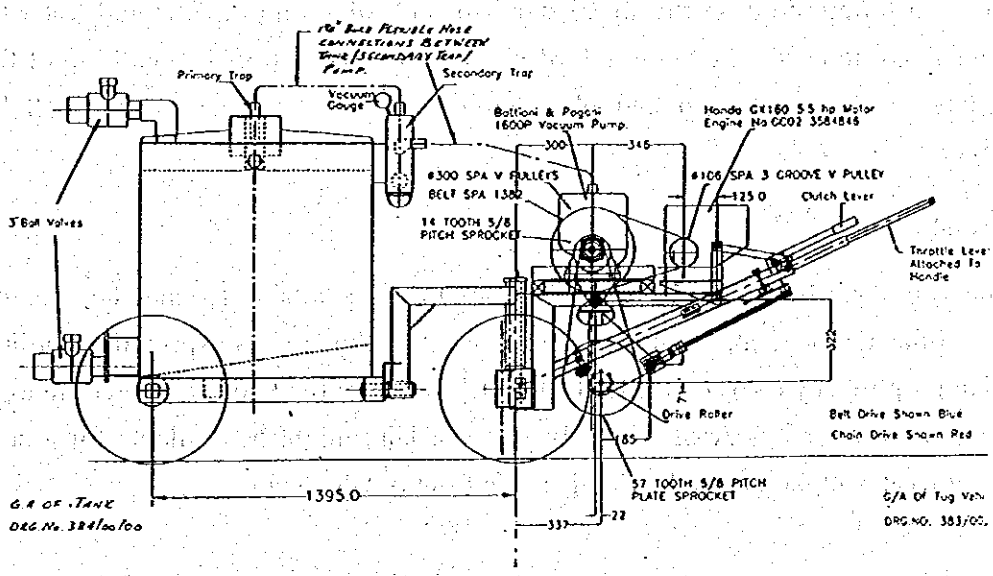
Selected measures for on-site treatment system, as discussed in Section 2.2.5 are:

- Pit latrine
- Pour flush toilet

Introduction of septic tanks is considered only when cistern flush toilet is installed before sanitary sewer service is available.

Pit emptying is required in the urban area where land for a new pit is not available. Pit emptying can be done by high-performance vacuum tankers or manually operated vacuum pit emptying machine (Figure V.2.11). Pits of double-pit system can be manually emptied after sufficient resting period. Proper sludge disposal shall be proposed such as co-disposal with solid wastes, land disposal. Effect of leached from the dumping site to downstream waters must be studied to avoid serious environmental damage.

Figure V.2.11 Vacuum pit emptying machine



Source: IRC (1999)

(2) Off-site system options

Possible measures for off-site treatment systems are discussed separately for wastewater collection system (sanitary sewer) and wastewater treatment system.

a) Wastewater collection system options

Conventional sanitary sewer system in combination with simplified sewer system will be used for Puno City as previously discussed in Section 2.2.5.

b) Wastewater treatment system options

Requirements for wastewater treatment system

Although water quality standard values had not been set for Puno interior bay, setting of water quality target by Ministry of Health is foreseen in the near future. As discussed in Chapter II, expected target water quality (category IV) values are:

Total coliform:	5,000 MPN/100ml
Fecal coliform:	1,000 MPN/100ml
BOD_5:	10mg/l
Dissolved oxygen:	3mg/l

In case that treated wastewater is discharged into the interior bay of Puno, it is desirable for treated wastewater to meet the above standard since dilution of the treated water by lake water is not to be significant. In order to improve the eutrophic condition of the interior bay of Puno, nitrogen and phosphorus removal from wastewater shall be considered.

Land availability

In the interior Puno bay, area for treatment facilities is available around the existing Espinar stabilization lagoon. Tourism development of this area is expected according to the plan proposed by INADUR, PELT (1997). South of the Espinar is totara field, a proposed natural reserve. Approximately 10 ha of land might be available for a new wastewater treatment facility in the flood area in front of Chejona.

Wastewater treatment processes

Wastewater treatment processes for municipal wastewater installed (or to be installed) in United States and Japan are summarized in Table V.2.17 and V.2.18 respectively. Among the processes with installation records of 10,000 – 100,000 m^3/d capacity plants in Japan, the following processes are studied for use in Puno City, where approximately 25,000 m^3/d capacity plant is required in year 2025.

1. Activated sludge Processes
   - Conventional activated sludge
   - Oxidation ditch
2. Biological Fixed Film Processes
   - Trickling filter
   - Rotating biological contractor
3. Natural systems
   - Facultative lagoon
   - Aerated lagoon
   - Constructed wetland

Table V.2.17 Summary of biological unit processes (U.S. EPA, 1984)

Process	Now in use		To be built	
	Number	Flow, mgd[a]	Number	Flow, mgd[a]
Stabilization ponds	5 298	3 138	2 783	118
Aerated lagoons	1 368	1 516	1 494	148
Containment ponds	834	252	433	30
Aquaculture	2	2	3	2
Trickling filters	2 463	6 345	107	408
Activated biofilter	8	21	5	8
Rotating biological contactors	347	940	276	433
Activated sludge	5 690	27 302	2 585	2 713
Oxidation ditch	741	500	474	131
Biological removal				
Nitrification	860	6 303	1 533	2 533
Denitrification	40	226	42	373
Phosphorus removal	18	222	9	55
High-purity oxygen activated sludge	240	5 800	20	1 500

[a] mgd × 3 785 = m^3/d.

Source: WEF (1998)

Table V.2.18 Municipal wastewater treatment processes in Japan (31 March 1997)

Process		Daily maximum flow (x 1000 m³/day)						
		<5	5-10	10-50	50-100	100-500	500≦	Total
Primary	Sedimentation	1		1				2
Secondary	Activated Sludge							
	Conventional	54	54	278	117	145	17	665
	Step aeration		1	11	14	10	1	37
	Pure oxygen	1	1	3	1	3		9
	Extended aeration	11	1	4				16
	Oxidation ditch	227	45	26				298
	Contact stabilization	1						1
	Sequencing batch reactor	47	4	2				53
	Rapid aerated sedimentation			5		1		6
	Rotating biological contactor	12	6	5	1			24
	Roughing trickling filter	1	1	2				4
	Contact aeration	14						14
	Aerobic filter	10						10
	Others	7		1			1	9
Advanced	Circulating nitrification - denitrification		1	1	1	1		4
	Nitrification – endogenous denitrification	3		1				4
	Anaerobic – Anoxic - Aerobic			3		2		5
	Anaerobic – Aerobic	11		9	1	7		28
Total		400	114	347	352	169	19	1,189

Source: MOC, Japan (1998)

Process descriptions

1. Activated sludge processes

Wastewater and biological solids (microorganisms, other suspended and colloidal matter) are combined, mixed and aerated in a reactor for microorganisms to absorb and assimilate mainly organize matter of wastewater. The above mixture (mixed liquor) is typically transferred to a separate setting basic or clarifier to allow gravity separation of solids from treated wastewater. Settled solids (mixed liquor suspended solids: MLSS) are then recycled to the reactor to maintain concentrated microbial population for degradation of wastewater.

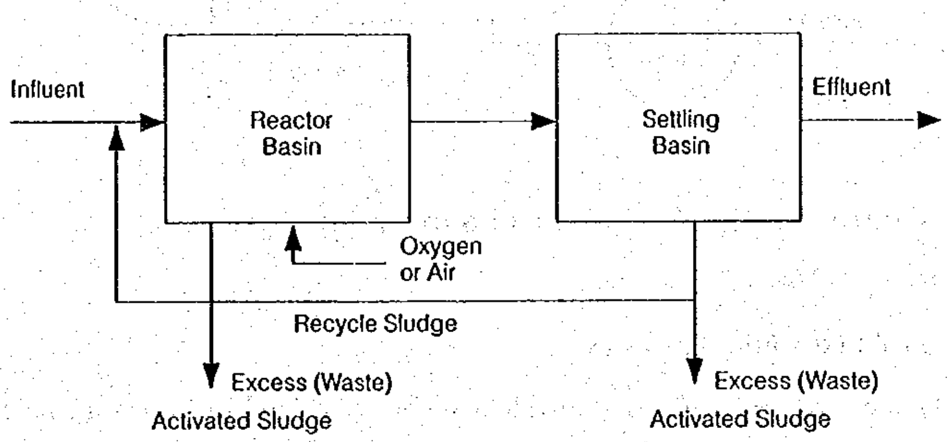


Figure V.2.12 Schematic diagram of a typical activated-sludge process

Source: WEF (1998)

Activated sludge processes have been designed in a large number of different configurations, such as conventional (plug flow), step feed, extended aeration, oxidation ditch and sequencing batch reactor.

Conventional activated sludge process

Plug flow reactor basins, length-to-width ratio more than 10:1, are used for this process. It has a relatively high organic loading at the influent end of the basin. Loading is reduced over the length of the basin as organic material in wastewater is assimilated. This process is susceptible to shock loads.

Oxidation ditch (*Figure V.2.13*)

Wastewater and mixed liquor are pumped around the looped reactor by rotors or other mechanical aeration devices at one or more locations in the ditch. The dissolved oxygen concentration is highest at the points of aeration and subsequently decrease because of oxygen uptake by the biomass as mixed liquor moves around the ditch. Oxidation ditch can achieve nitrification and denitrification. The influent typically enters the reactor near the aerator and the efficient exits the tank upstream of the entrance.

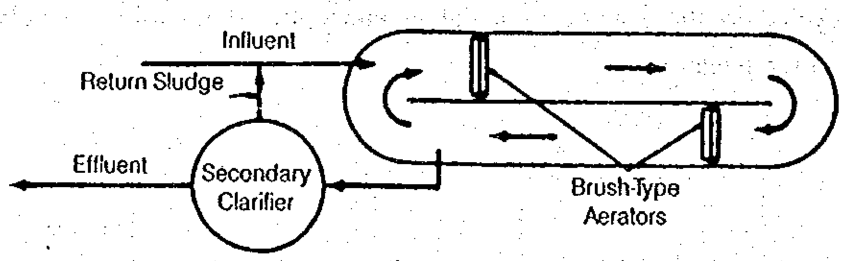


Figure V.2.13 Schematic of a oxidation ditch reactor

Source: WEF (1998)

2. Biological Fixed Film Processes

In this type of processes, reactors provide a surface (medium) on which the microbial layer can grow and expose this surface repeatedly to wastewater for adsorption of organic material and to the atmosphere for oxygen. There are two types of processes, trickling filters and rotating biological contactors.

Trickling filter

Settled primary treated or screened wastewater is applied to the filter medium through which the flow percolates. The surface of the medium quickly becomes coated with a viscous, jellylike, slimy substance containing bacteria and other biota. The biota removes organics by adsorption and assimilation of soluble and suspended constituents. For aerobic metabolism, oxygen is supplied from the natural or forced circulation of air in the filter medium. Oxygen transfer may be direct or by diffusion through the liquid films. Unlike activated sludge processes, recycling of settled biomass is typically not required.

Rotating Biological Contactors

Rotating biological contactors use a fixed film biomass on rotating media. The rotating medium provides a surface on which organisms grow and contact organic wastewater constituents and oxygen from the air. The rotating reactor carries a film of wastewater into the air, which trickles down the surfaces of the contractor and absorbs oxygen from the air. Organisms in the biomass remove organic material from the wastewater film.

3. Natural systems

Natural systems for wastewater treatment include soil absorption, lagoons (ponds), land treatment, floating aquatic plants and constructed wetlands. These natural systems can often be the most cost-effective option for both construction and operation where sufficient land of suitable character is available.

Facultative Lagoon

Facultative lagoons are typically 1.5 to 2.5 m deep, with detention times more than 25 days. Surface layers of the lagoons are aerobic with an anaerobic layer near the bottom. Oxygen is supplied by surface aeration and photosynthetic algae. Facultative lagoons are normally designed in series with a minimum of three cells to reduce short-circuiting. The primary problem with facultative lagoons is the production of algae that remains in the effluent. Facultative lagoons can be followed by constructed wetlands for suspended solids (algae) removal.

Aerated Lagoon

Aerated lagoons or ponds can be either partially mixed or completely mixed. Oxygen is supplied by mechanical floating aerators or diffused aeration. Aerated lagoons are typically 3 to 6 m deep, with detention times ranging from 5 to 30 days. Aerated lagoons accept higher biochemical oxygen demand (BOD) loading than facultative lagoons, are less susceptible to odors, and typically require less land. Aerated lagoons are often followed by a facultative lagoon or a settling lagoon to reduce suspended solids before discharge.

Constructed wetland

Constructed wetlands are designed to treat wastewater using emerging plants such as cattails, reeds and rushes. Three types of constructed wetlands are identified:

- Free water surface (FWS) wetlands
- Subsurface flow (SSF) wetlands
- Vertical flow (VF) wetlands

In FWS wetlands, the majority of wastewater flows over the soil surface. FWS wetland removes BOD using bacteria attached to the plants and vegetative litter. Suspended solids are removed by entrapment in vegetation and sedimentation.

For SSF wetlands, wastewater is treated as it flows horizontally through the root zone and the medium, such as sand and coarse gravel. Filtration is a primary mechanism for suspended solids removal in this process.

In VF wetlands, wastewater application is either by spray or surface flooding and the flow path is vertical through the medium and out through the underdrains.

Process characteristics

Characteristics of treatment processes are shown in *Table* V.2.19. Activated sludge processes have highest nutrient removal efficiency and lowest land requirement with high construction and O&M costs, while natural systems required large area but can be operated at minimum O&M cost.

Nitrogen and Phosphorus removal

Nitrogen removes is mostly achieved by biological process while phosphorus removal is done by both chemical and biological processes. Activated sludge processes, such as oxidation ditch, can be designed to remove nitrogen. Trickling filters will require methanol addition for nitrogen removal. Biological phosphorus removal uses the excess phosphorus uptake by activated sludge. Anaerobic zone without presence of dissolved oxygen and nitrate is required in the process. Phosphorus removal by chemical addition is known for its simplicity of operation and ease of implementation. Phosphorus is removed through chemical coagulation and sedimentation process. Aluminum and iron salts such as alum and ferric chloride are often used for phosphorus removal.

Table V.2.19 Comparison of wastewater treatment processes

Treatment Process		BOD removal fficiency (%)	Nitrogen removal	Phosphorus removal	Construc-tion cost (Million US$)*1	O&M Cost (Million US$/year)*1	Land*1 requirements (ha)	Resistance to shock load	Stability for water temperature change	Ease of O&M	Odour	Skill requirement for O&M	Sludge generation	Maturity of technology
Activated Sludge	Conven-tional Activated Sludge	85-95	low	low	24	0.8	3	low	medium	low	low	high	high	high
	Oxidation Ditch	85-95	high	low to medium	20	0.55	5	medium	medium	high	low	medium	high	high
Biological film	Trickling filter	65-80	low	low	18	0.4	3.5	high	low	high	high	low	low	high
	Rotating biological contractor	80-85	high	low	25	0.7	3	high	low	medium	high	low	low	low
Natural system	Facultative lagoon	60-80	medium	low to medium	3	0.1	35	high	medium	high	medium	low	medium	medium
	Aerated lagoon	60-80	medium	low	10	0.3	15	high	medium	high	low to medium	low	high	medium
	Constructed wetland	60-80	low	low	4	0.1	24	high	medium	high	medium	low	low	medium

2.3.2 ALTERNATIVE PLANS

Three alternative plans for wastewater treatment and disposal processes, which includes ones proposed by PRONAP and INADE-PELT, are discussed below.

Alternative I

Alternative I, one proposed by PRONAP, utilizes the existing Espinar stabilization lagoon to minimize the construction cost of wastewater treatment plant while treated wastewater is discharged to the interior bay of Puno. The treatment process uses a combination of aerated lagoons and facultative lagoons. A SSF constructed wetland polishes treated water from the facultative lagoons. The process flow is shown in *Figure V.2.14*.

Treated water quality for T-N and T-P is less than 10mg/l and 3mg/l respectively. Treated water is at first discharged into the interior bay. Lake water quality will be observed for the next two year to evaluate the requirement of conveyance and disposal of treated water to the outer bay. Alternative I includes outer-bay disposal of treated wastewater while Alternative I-A is same as Alternative I without the outer-bay disposal.

Alternative II

Alternative II, one proposed by INADE-PELT, pumps wastewater to outside of the catchment area of the interior bay of Puno to minimize pollution loads into the interior bay. The process is comprised of conduction, primary treatment and water reuse for forest irrigation. *Figure V.2.14* illustrates the wastewater flow of the system.

The existing Espinar stabilization lagoon will be reserved as wastewater pond for emergency.

Alternative III

This alternative aims to accommodate full tourist development of the area around the Espinar Island while maximizing nutrient removal of wastewater treatment. The following conditions are applied for this alternative.

① Treated water to be discharged to the interior bay of Puno

② High-level nutrient (organic matter, nitrogen, phosphorus) removal is required to improve the trophic condition of the interior bay

③ The existing Espinar stabilization lagoon will be removed and the area is used for tourism development as proposed by INADUR and PELT

④ Land area, less than 10 ha, is available in the flooding area in front of Chejona

An appropriate treatment process was selected out of the processes shown in *Table V.2.19*. The following criteria were used for the selection.

- A process or a combination of processes is capable of high-level removal of nutrients, such as nitrogen and phosphorus

- a process is flexible for change of conditions (temperature, pollution loads etc)

- a process is easy to be operated and maintained

- a treatment technology is well established and abundant operational information is readily available

- a process does not release much offensive odour, which can be a nuisance to surrounding population and an obstacle for the tourism development

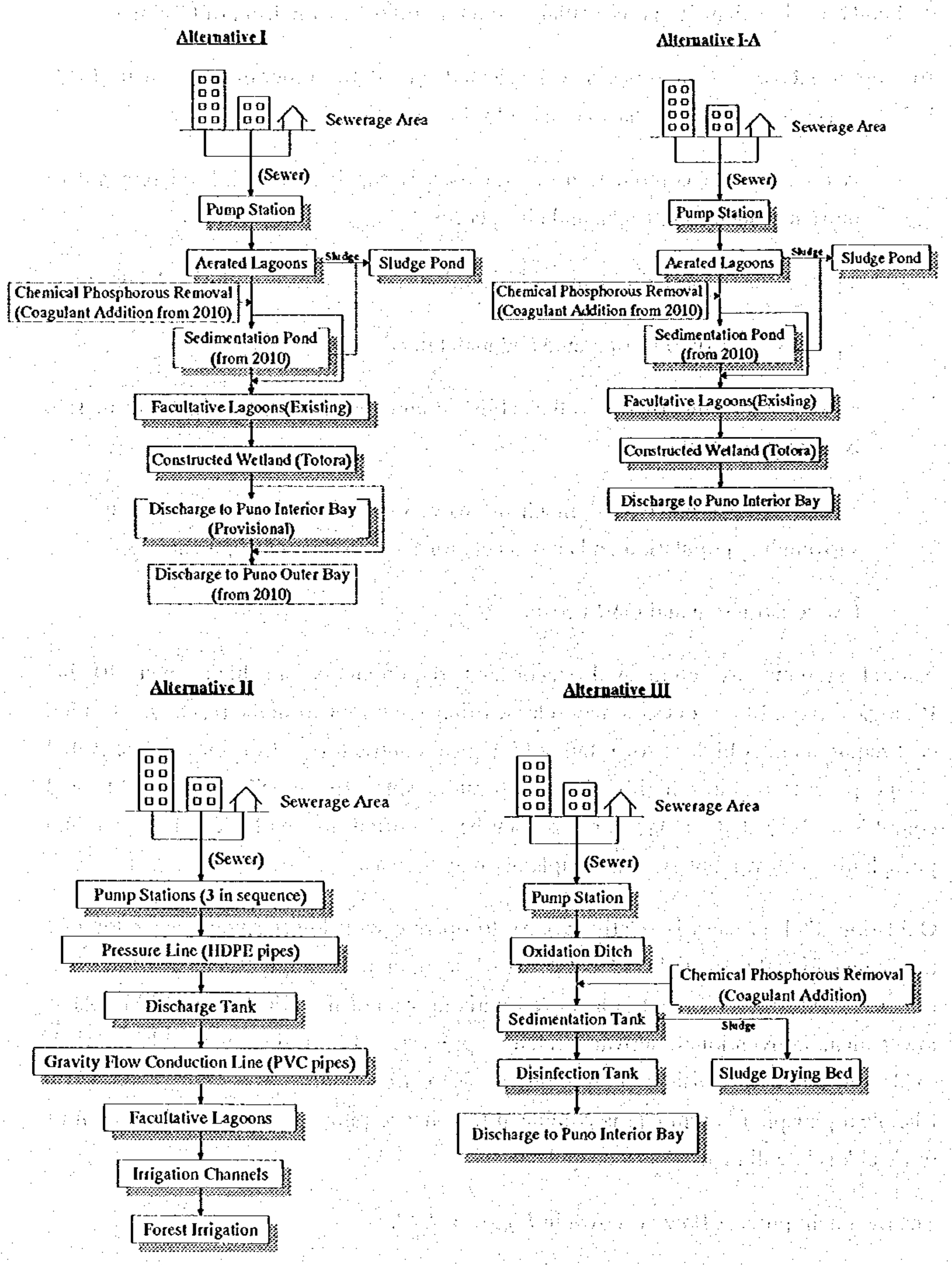
- low construction and O&M costs

Natural systems are eliminated since land requirements are high, over 10 ha. Biological fixed film processes may release offensive odour from the reactors. Capital cost requirement is highest for rotating biological contractors. Conventional activated sludge process requires highly skilled operators since the process is inflexible and complex. Activated sludge process can be modified for biological nitrogen and phosphorus removal, but system complexity may increase.

Oxidation ditch process is relatively easy to operate with lower sludge generator rate than conventional activated sludge process while maintaining high efficiency of nutrient removal. Nitrogen removal is achieved without system modification. O&M cost is lower than conventional activated sludge process. From the above observation, oxidation ditch is considered appropriate as a treatment process for Puno City. Chemical phosphorus removal is combined to enhance phosphorus removal. Alum or ferric chloride will be used as a coagulant.

The treatment process flow is shown in *Figure V.2.14*.

Figure V.2.14 Schematic of wastewater treatment process



2.3.3 PRELIMINARY DESIGNS FOR ALTERNATIVE PLANS

The preliminary designs for the wastewater treatment plants were prepared with the following capacities.

Name	Capacity at Year 2025
Alternative I	20,400 m^3/day (Average Daily Wastewater Flow)
Alternative I-A	20,400 m^3/day (Average Daily Wastewater Flow)
Alternative II	36,600 m^3/day (Hourly Maximum Wastewater Flow)
Alternative III	24,400 m^3/day (Maximum Daily Wastewater Flow)

a) Layout

Tentative layouts for the above alternatives are shown in *Figures V.2.15, 16, 17* respectively.

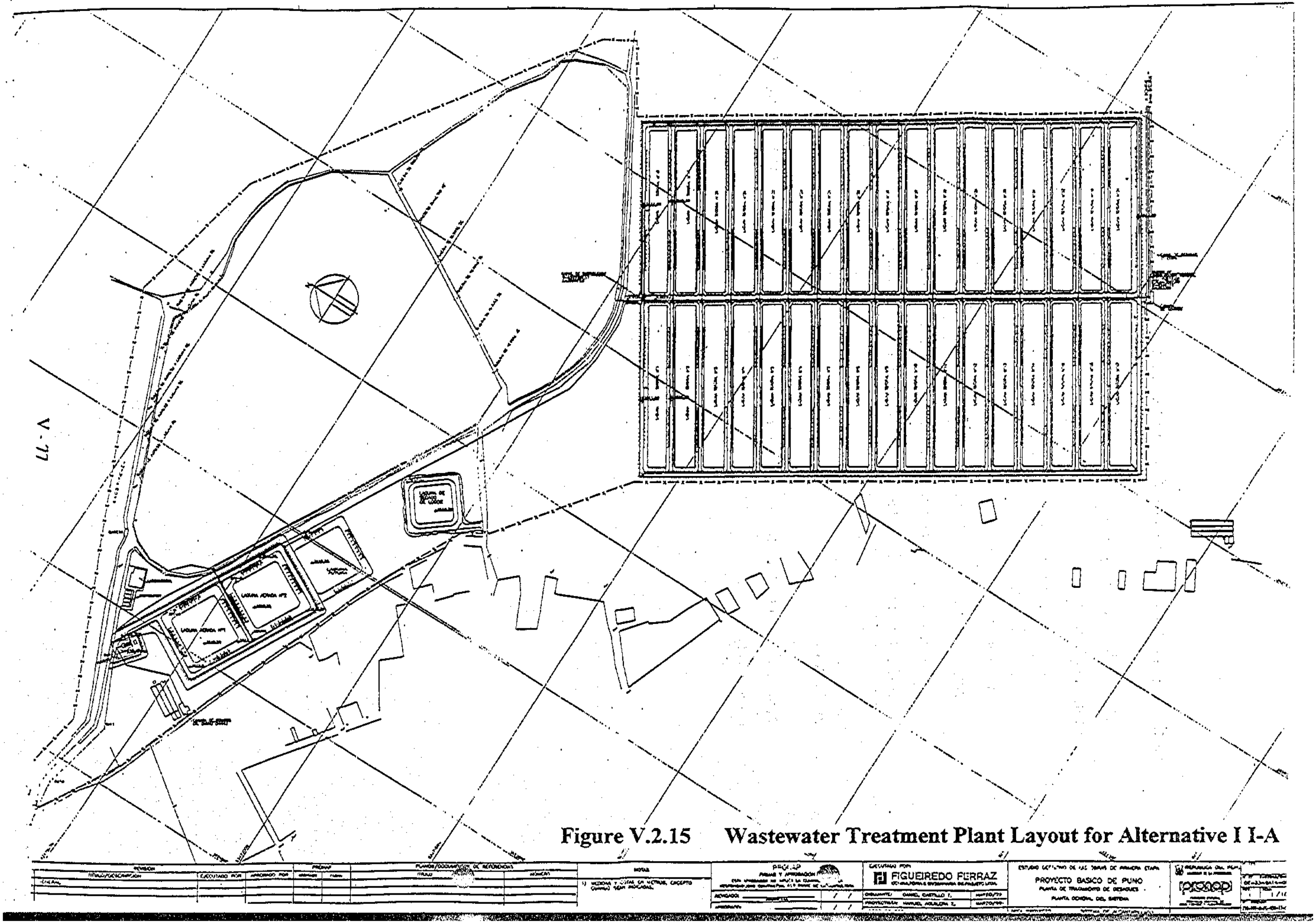
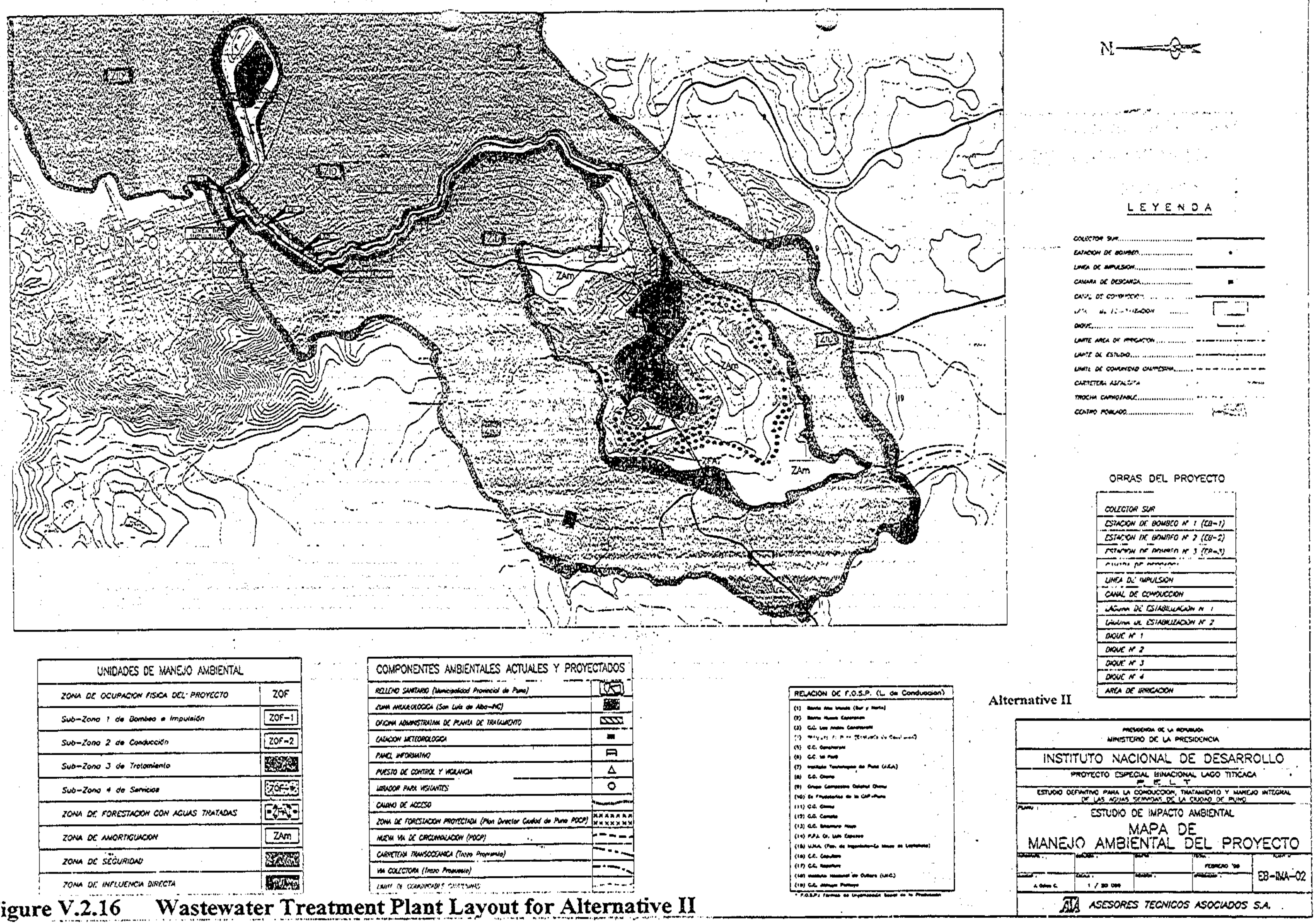


Figure V.2.15 Wastewater Treatment Plant Layout for Alternative I I-A



Alternative II

Figure V.2.16 Wastewater Treatment Plant Layout for Alternative II

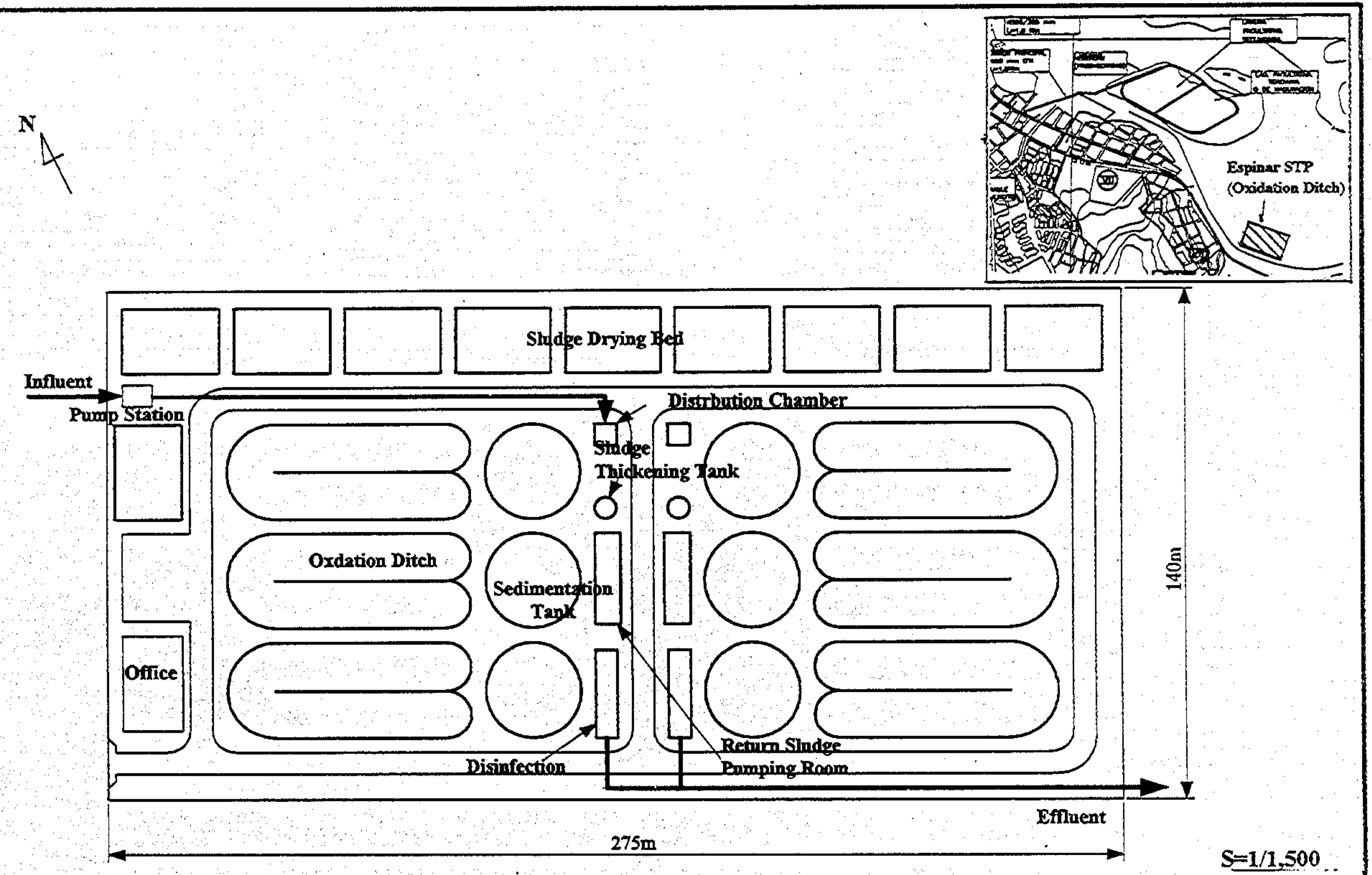


Figure V.2.17 Wastewater Treatment Plant Layout for Alternative III (Oxidation Ditch)

b) **Specifications of facilities**

Specifications for each facility of the wastewater treatment plant together with numbers, dimensions and design parameters are shown in the following tables.

Table V.2.20 Specifications of Wastewater Treatment Plant (Alternative I, I-A)

Facilities	Specifications
1.Pump Station	
EB Puno	Submersible Pump, 200 l/s, 8.6 m, 30 kW, 2 sets(+1)
2. Aerated Lagoon	3 basins
Type	Rectangular Type
Dimension	64.0 m W x 80.0 m L x 4.0 m D
Aeration Power Level	22.35 kW (4 per Basin)
Retention Time	2.43 days
3. Existing Primary Lagoon	1 basins
Type	Facultative lagoon
Area	13.4 ha
Depth Average	1.5 m
Volume	204,600 m3
4. Existing Secondary Lagoon	1 basins
Type	Facultative lagoon
Area	7.9 ha
Depth Average	1.5 m
Volume	118,350 m3
5. Constructed Wetland	34 basins
Type	Sub-surface flow
Dimension	23.0 m W x 203.0 m L
Depth Average	0.3 - 0.5 m
6. Sludge Pond	2 basins
Type	Rectangular Type
Dimension	46.0 m W x 54.0 m L
Retention Time	3.07 days
7. Sedimentation Basin	1 basins
Type	Circular Type
Dimension	30.0 m Dia. x 3.0 m D
8.Pump Station (for I)	
E.B. PRINCIPAL	Submersible Pump, 95 l/s, 41 m, 80 kW, 2 sets(+1)
9.Pressure line (for I)	
Diameter	ϕ400 mm
Pipe Material	Ductile iron pipes
Length	6,839 m
10.Underwater line (for I)	
Diameter	ϕ500 mm
Pipe Material	Ductile iron pipes
Length	7,455 m

Table V.2.21 Specifications of Wastewater Treatment Plant (Alternative II)

Facilities	Specifications
1.Pump Station (EB-1)	
EB-1	Vertical Type Pump(Single Suction), 141 l/s, 82 m, 187.5 kW, 3 sets
2.Pump Station (EB-2)	
EB-2	Vertical Type Pump(Single Suction), 141 l/s, 82 m, 187.5 kW, 3 sets
3.Pump Station (EB-3)	
EB-3	Vertical Type Pump(Single Suction), 141 l/s, 82 m, 187.5 kW, 3 sets
4.Pressure Line	
Diameter	ϕ 550 mm
Pipe Material	Polyethylene (HDPE)
Length	1,553 m
5.Conduction line	
Diameter	ϕ 750 mm
Pipe Material	PVC
Length	5,874 m
6.Facultative lagoon	2 basins
Area	55 ha (35 ha + 20 ha)
Depth Average	3.0 m
Volume	1,617,500 m^3
Retention time	75 days
7.Pump Station	
E.B. EL PUERTO	Submersible Pump, 5.25 l/s, 8.6 m, 1.2kW, 2 sets(+1)

Table V.2.22 Specifications of Wastewater Treatment Plant (Alternative III)

Facilities	Specifications
1. Grit Chamber and Screen	3 basins (including 1 stand-by)
Type	Grit Pit Type
Dimension	0.7 m W x8.0 m L x 0.5 m D
Average Velocity	0.32 m/sec
2.Pump Station	
EB Puno	Submersible Pump, 200 l/s,10.0 m, 13.85 kW, 2 sets(+1)
3. Oxidation Ditch	6 basins
Type	Horse shoe-shape Type
Dimension	6.0 m W x 225 m L x 3.0 m D
Aeration Power Level	270 kW
Retention Time	24.0 hours
4. Sedimentation Basin	6 basins
Type	Circular Type
Dimension	25.5 m Dia. x 3.0 m D
Water Surface Load	7.9 m3/m2/day
Retention Time	3.4 hours
5. Disinfection Tank	2 basins
Type	Rectangular Type
Dimension	2.0 m W x 21.5 m L x 1.5 m D
Required Chlorine	2.02 kg/hour
Retention Time	15.3 min.
6. Sludge Thickening Tank	2 basins
Type	Circular Type
Dimension	6.0 m Dia.x 4.0 m D
Solid Load	64.2 kg/m2/day
7. Sludge Drying Bed	10 basins
Type	Rectangular Type
Dimension	15.0 m W x 27.0 m L x 0.3 m D
Retention Time	10.0 days

c) Cost estimation

Basic conditions

Components of project cost are shown below:

Project cost

- Construction Costs
  - Direct Cost
    - Civil Work
    - Mech./Elec. Work
  - (Site Expenses)
  - (Packing/Transportation Cost)
  - (Import Tax)
  - (Administration Cost, partial)
- Equipment Procurement
  - Equipment
  - (Packing/Transportation Cost)
  - (Import Tax)
  - (Administration Cost, partial)
- Engineering Services
  - Detailed Design
  - Construction Supervision
- Common Costs
  - General/Administration Expenses
  - Land Acquisition
- Contingencies
- IGV (18 %)

The project cost is estimated based on the preliminary design for the Master Plan facilities. Unit prices and lump sum prices were determined considering local conditions, sub-contractors, equipment, available construction equipment and materials as well as suitability of the proposed construction method.

Assumptions and conditions used for the cost estimate are as follows:

Price level:	as of December 1998
Foreign exchange rate:	Peruvian S/. 1.00 = Japanese ¥ 37.00

Unit cost

Typical unit costs are as follows:

Concrete	: 270 S/. /m^3
Form Work	: 25 S/. /m^2
Reinforcement	: 1.5 S/. /kg
Pipe (ϕ200 PVC)	: 66.43 S/./m
Pipe (ϕ200 RC)	: 20.52 S/./m
Electricity	: 0.20 S/. /kWh

Project cost

Total costs for the alternative plans are estimated in Peruvian Soles as follows:

Alternative I

Unit: Thousand S/.

	Phase 1 (1998-2008)		Phase 2 (2009-2015)		Phase 3 (2016-2025)	
(1) Construction Cost		23,440		17,703		18,844
(2) Procurement of Maintenance Equipment		234		114		188
(3) Engineering Cost						
1) Detailed Design	1,406		1,062		1,131	
2) Construction Supervision	938		708		754	
Sub-Total		2,344		1,770		1,884
(4) Common Expenses						
1) General/Administration Expenses	200		200		200	
2) Land Acquisition						
Sub-Total		200		200		200
(5) Contingency		3,903		2,938		3,138
(6) GST 18%		5,386		4,055		4,330
Total		35,506		26,780		28,584
				Grand Total		90,870

Alternative I-A

Unit: Thousand S/.

	Phase 1 (1998-2008)		Phase 2 (2009-2015)		Phase 3 (2016-2025)	
(1) Construction Cost		23,440		11,438		18,844
(2) Procurement of Maintenance Equipment		234		114		188
(3) Engineering Cost						
1) Detailed Design	1,406		686		1,131	
2) Construction Supervision	938		458		754	
Sub-Total		2,344		1,144		1,884
(4) Common Expenses						
1) General/Administration Expenses	200		200		200	
2) Land Acquisition	0		0		0	
Sub-Total		200		200		200
(5) Contingency		3,903		1,904		3,138
(6) GST 18%		5,386		2,628		4,330
Total		35,506		17,428		28,584
				Grand Total		81,519

Alternative II

Unit: Thousand S/.

	Phase 1 (1998-2008)		Phase 2 (2009-2015)		Phase 3 (2016-2025)	
(1) Construction Cost		25,339		10,127		21,076
(2) Procurement of Maintenance Equipment		253		101		211
(3) Engineering Cost						
1) Detailed Design	1,520		608		1,265	
2) Construction Supervision	1,014		405		843	
Sub-Total		2,534		1,013		2,108
(4) Common Expenses						
1) General/Administration Expenses	200		100		100	
2) Land Acquisition	100				67	
Sub-Total		300		100		167
(5) Contingency		4,219		1,686		3,509
(6) GST 18%		5,822		2,327		4,843
Total		38,467		15,354		31,913
				Grand Total		85,734

Alternative III

Unit: Thousand S/.

	Phase 1 (1998-2008)		Phase 2 (2009-2015)		Phase 3 (2016-2025)	
(1) Construction Cost		42,452		17,690		23,286
(2) Procurement of Maintenance Equipment		425		177		233
(3) Engineering Cost						
1) Detailed Design	2,547		1,061		1,397	
2) Construction Supervision	1,698		708		931	
Sub-Total		4,245		1,769		2,329
(4) Common Expenses						
1) General/Administration Expenses	200		200		200	
2) Land Acquisition	0		0		0	
Sub-Total		200		200		200
(5) Contingency		7,068		2,945		3,877
(6) GST 18%		9,754		4,065		5,350
Total		64,145		26,847		35,275
				Grand Total		126,266

d) Implementation plan

In connection with the target years set for this Study (2008, 2015 and 2025), the study period is divided into three phases. Phase 1 (Year 1998 to 2008) contains an urgent and priority project, whose construction is to be completed by the end of 2002. Implementations of the alternative plans for all three phases are scheduled as follows.

Phase 1 (Year 1998 to 2008) - Priority Project

-1997	Preparation of project
1998 - 2000	Detailed design and bidding
2000 - 2002	Construction
2003	Commencement of operation

Table V.2.23 Detail of Phase 1 Construction

Facilities	Sewer Pipe	Pump Station	Wastewater Treatment Plant
Year	2000-2002	2000-2002	2000-2002
Alternative I (I-A)	ϕ150-900, L =25,223m	EB EL PUERTO	EB Puno Aerated Lagoon×2 Constructed Wetland×34 Sludge Pond×1
Alternative II	ϕ150-900, L =25,223m ϕ550 Pressure Line L=1,553m	EB-1 EB-2 EB-3	Conduction line L=5,874 m Discharge Tank×1
Alternative III	ϕ150-900, L =25,223m	EB EL PUERTO	EB Puno Oxidation Ditch×4 Sedimentation Tank×4 Disinfection Tank×1 Sludge Thickening Tank×1 Sludge Drying Bed×6

Phase 2 (Year 2009 to 2015)

(1) Alternative I

- 2008	Preparation of project
2009	Detailed design and bidding
	Construction (Wastewater treatment plant, outer-bay disposal of treated wastewater)
2010	Commencement of operation
- 2015	Construction (Sewer Pipe)

(Alternative I-A: without outer-bay disposal of treated wastewater)

(2) Alternative II

2009 - 2015 Construction (Sewer Pipe)

(3) Alternative III

- 2008 Preparation of project
2009 - 2010 Detailed design and bidding
2010 - 2012 Construction (Wastewater Treatment Plant)
2013 Commencement of operation
- 2015 Construction (Sewer Pipe)

Table V.2.24 Detail of Phase 2 Construction

Facilities	Sewer Pipe	Pump Station	Wastewater Treatment Plant
Year	2009-2015	-	As follows
Alternative I (I-A)	ϕ150-300, L = 46,832m	-	<2009> Sedimentation Basin×1
Alternative II	ϕ150-300, L = 46,832m	-	-
Alternative III	ϕ150-300, L = 46,832m	-	<2010-2012> Oxidation Ditch×1 Sedimentation Tank×1 Disinfection Tank×1 Sludge Thickening Tank×1 Sludge Drying Bed×2

Phase 3 (Year 2016 to 2025)

(1) Alternative I

- 2015 Preparation of project
2016 Detailed design and bidding
2016 - 2017 Construction (Wastewater Treatment Plant, Pump Station)
2018 Commencement of operation
- 2025 Construction (Sewer Pipe)

(2) Alternative II

- 2015 Preparation of project
2016 Detailed design and bidding
2017 - 2018 Construction (Pump Station, facultative lagoon)
2019 Commencement of operation
- 2025 Construction (Sewer Pipe)

(3) Alternative Ⅲ

	- 2015	Preparation of project
2016	- 2017	Detailed design and bidding
2017	- 2018	Construction (Wastewater Treatment Plant, Pump Station)
2019		Commencement of operation
	- 2025	Construction (Sewer Pipe)

Table V.2.25 Detail of Phase 3 construction

Facilities	Sewer Pipe	Pump Station	Wastewater Treatment Plant
Year	2016-2025	As follows	As follows
Alternative I	ϕ150-300, L = 66,007m	<2017> EB EL PUERTO (Pump equipment renewal)	<2016-2017> EB Puno (Pump equipment renewal) Aerated Lagoon×1 Sludge Pond×1
Alternative II	ϕ150-300, L = 66,007m	<2016> EB-1 EB-2 EB-3 (Pump equipment renewal)	<2017-2018> Facultative lagoon×1
Alternative III	ϕ150-300, L = 66,007m	<2018> EB EL PUERTO (Pump equipment renewal)	<2017-2018> EB Puno (Pump equipment renewal) Oxidation Ditch×1 Sedimentation Tank×1 Sludge Drying Bed×2

The project implementation and disbursement schedule with estimated annual disbursements of project cost is presented in *Table V.2.26, 2.27, 2.28* and *2.29.*

Table V.2.26 Implementation and Disbursement Schedule (Alternative I)

Item		Phase 1											Phase 2							Phase 3									
Year		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Implementation Schedule																													
1. Preparation of Project																													
2. Pre-Construction Stage		▬	▬	▬									▬							▬									
2.1 Detailed Design		▬	▬										▬							▬									
2.2 Bidding				▬									▬							▬									
3. Construction																													
3.1 Collection System				▬	▬	▬							▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	
3.2 Sewage Treatment Plant				▬	▬								▬								▬								
- Civil Work				▬	▬								▬								▬								
- Mechanical/Electrical Work					▬																▬								
4. Procurement of Maintenance Equipment						▬							▬								▬								
5. Test Operation						▬							▬									▬							
Disbursement Schedule	**Total Cost** (Thousand S/.)	Fase 1 35,506											Fase 2 26,780							Fase 3 28,584									
1. Land Acquisition	0																												
2. Administration	600			22	22	22	22	22	22	22	22	22	29	29	29	29	29	29	29	20	20	20	20	20	20	20	20	20	20
3. Construction Work	59,987																												
(1) Sewer - civil works	31,639			2,586	2,586	2,586							1,447	1,447	1,447	1,447	1,447	1,447	1,447	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375
- mechanical/electorical	0																												
(2) Pump Station - civil works	5,099				34								5,065																
- mechanical/electorical	1,562				181								1,199								181								
(2) Sewage Treatment Plant -civil works	7,819				6,978								494								347								
- mechanical/electorical	13,868				8,489								817								4,562								
4. Maintenance Equipment	536					234							114									188							
5. Engineering Service	5,999		1,406		938								1,062		708					1,131		754							
6. Contingency	9,978		211	388	2,881	423	0	0	0	0	0	0	1,530	217	323	217	217	217	217	376	970	348	206	206	206	206	206	206	206
7. IGV (18 %) (for 3, 4, 5, 6)	13,770		291	535	3,976	584	0	0	0	0	0	0	2,111	299	446	299	299	299	299	519	1,338	480	285	285	285	285	285	285	285
Total Project Cost	90,870		1,908	3,531	26,085	3,849	22	22	22	22	22	22	13,868	1,992	2,953	1,992	1,992	1,992	1,992	3,421	8,794	3,164	1,886	1,886	1,886	1,886	1,886	1,886	1,886
8. Equip. Renewal (with IGV & conting.)	28,566			20			235	512						20		11,765	235	512					2,736	20		11,765	235	512	
9. Maintenance (with IGV)	27,640					550	574	599	623	659	696	735	778	1,096	1,135	1,174	1,215	1,255	1,297	1,338	1,379	1,418	1,464	1,507	1,547	1,588	1,629	1,670	1,713
Total Disbursement	147,077		1,908	3,552	26,085	4,399	831	1,133	646	681	718	757	14,646	3,108	4,088	14,931	3,441	3,759	3,289	4,758	10,172	4,583	6,086	3,414	3,434	15,239	3,750	4,068	3,599

Table V.2.27 Implementation and Disbursement Schedule (Alternative I -A)

Item \ Phase / Year		Phase 1											Phase 2							Phase 3									
Item		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Implementation Schedule																													
1. Preparation of Project																													
2. Pre-Construction Stage																													
2.1 Detailed Design																													
2.2 Bidding																													
3. Construction																													
3.1 Collection System																													
3.2 Sewage Treatment Plant																													
- Civil Work																													
- Mechanical/Electrical Work																													
4. Procurement of Maintenance Equipment																													
5. Test Operation																													
Disbursement Schedule	**Total Cost** (Thousand S/.)	Phase 1 35,506											Phase 2 17,428							Phase 3 28,584									
1. Land Acquisition	0																												
2. Administration	600			22	22	22	22	22	22	22	22	22	29	29	29	29	29	29	29	20	20	20	20	20	20	20	20	20	20
3. Construction Work	53,722																												
(1) Sewer - civil works	31,639			2,586	2,586	2,586							1,447	1,447	1,447	1,447	1,447	1,447	1,447	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375
- mechanical/electorical	0																												
(2) Pump Station - civil works	34				34																								
- mechanical/electorical	363				181																181								
(2) Sewage Treatment Plant -civil w	7,819				6,978								494								347								
- mechanical/electorical	13,868				8,489								817								4,562								
4. Maintenance Equipment	536					234							114									188							
5. Engineering Service	5,372		1,406		938								686		458					1,131		754							
6. Contingency	8,945		211	388	2,881	423	0	0	0	0	0	0	534	217	286	217	217	217	217	376	970	348	206	206	206	206	206	206	206
7. IGV (18 %) (for 3, 4, 5, 6)	12,344		291	535	3,976	584	0	0	0	0	0	0	736	299	394	299	299	299	299	519	1,338	480	285	285	285	285	285	285	285
Total Project Cost	81,519		1,908	3,531	26,085	3,849	22	22	22	22	22	22	4,856	1,992	2,613	1,992	1,992	1,992	1,992	3,421	8,794	3,164	1,886	1,886	1,886	1,886	1,886	1,886	1,886
8. Equip. Renewal (with IGV & conting.)	26,939			20			235	512						20		11,765	235	512					1,109	20		11,765	235	512	
9. Maintenance (with IGV)	23,896					550	574	599	623	659	696	735	778	913	945	978	1,012	1,046	1,081	1,114	1,149	1,181	1,219	1,256	1,289	1,322	1,357	1,391	1,427
Total Disbursement	132,354		1,908	3,552	26,085	4,399	831	1,133	646	681	718	757	5,635	2,925	3,558	14,735	3,238	3,549	3,072	4,535	9,942	4,346	4,214	3,163	3,175	14,974	3,478	3,790	3,313

Table V.2.28 Implementation and Disbursement Schedule (Alternative Ⅱ)

Item / Phase		Phase 1											Phase 2							Phase 3									
Year		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Implementation Schedule																													
1. Preparation of Project																													
2. Pre-Construction Stage																													
2.1 Detailed Design																													
2.2 Bidding																													
3. Construction																													
3.1 Collection System																													
3.2 Sewage Treatment Plant																													
- Civil Work																													
- Mechanical/Electrical Work																													
4. Procurement of Maintenance Equipment																													
5. Test Operation																													
Disbursement Schedule	**Total Cost** (Thousand S/.)	Phase 1 38,467											Phase 2 15,354							Phase 3 31,913									
1. Land Acquisition	167			100																67									
2. Administration	400			22	22	22	22	22	22	22	22	22	14	14	14	14	14	14	14	10	10	10	10	10	10	10	10	10	10
3. Construction Work	56,542																												
(1) Sewer - civil works	31,639			2,586	2,586	2,586							1,447	1,447	1,447	1,447	1,447	1,447	1,447	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375
- mechanical/electorical	0																												
(2) Pump Station - civil works	1,805				1,805																								
- mechanical/electorical	4,618				3,931															687									
(2) Treatment Plant + Pipe lines -civil	18,480				11,846															6,635									
- mechanical/electorical	0																												
4. Maintenance Equipment	565				253								101							211									
5. Engineering Service	5,655		1,520		1,014								608		405					1,265		843							
6. Contingency	9,414		228	388	3,215	388	0	0	0	0	0	0	323	217	278	217	217	217	217	1,526	206	333	206	206	206	206	206	206	206
7. IGV (18 %) (for 3, 4, 5, 6)	12,992		315	535	4,437	535	0	0	0	0	0	0	446	299	383	299	299	299	299	2,106	285	459	285	285	285	285	285	285	285
Total Project Cost	85,734		2,063	3,631	29,108	3,531	22	22	22	22	22	22	2,939	1,978	2,527	1,978	1,978	1,978	1,978	13,881	1,876	3,020	1,876	1,876	1,876	1,876	1,876	1,876	1,876
8. Equip. Renewal (with IGV & conting.)	12,969			20			235	512						20		5,334	235	512						20		5,334	235	512	
9. Maintenance (with IGV)	40,597					1,013	1,057	1,102	1,147	1,213	1,281	1,352	1,432	1,515	1,569	1,623	1,679	1,736	1,793	1,849	1,906	1,961	2,024	2,084	2,139	2,195	2,251	2,309	2,368
Total Disbursement	139,300		2,063	3,651	29,108	4,544	1,314	1,635	1,169	1,235	1,303	1,374	4,371	3,513	4,096	8,935	3,891	4,225	3,771	15,730	3,783	4,981	3,900	3,981	4,015	9,405	4,363	4,697	4,244

Table V.2.29 Implementation and Disbursement Schedule (Alternative III)

Aspecto / Phase / Año		Phase 1											Phase 2							Phase 3									
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Cronograma de Implementación																													
1. Preparación del proyecto																													
2. Etapa de pre-construcción																													
2.1 Diseño detallado																													
2.2 Licitación																													
3. Construcción																													
3.1 Sistema de recolección																													
3.2 Planta de tratamiento de aguas servidas																													
- Obras Civiles																													
- Obras Eléctricas/Mecánicas																													
4. Equipamiento																													
5. Operación de prueba																													
Cronograma de Desembolsos	**Costo total** (Miles S/.)	Phase 1 64,145											Phase 2 26,847							Phase 3 35,275									
1. Adquisición de terreno	0																												
2. Administración	600			22	22	22	22	22	22	22	22	22	29	29	29	29	29	29	29	20	20	20	20	20	20	20	20	20	20
3. Construcción	83,428																												
(1) Colector	31,639			2,586	2,586	2,586							1,447	1,447	1,447	1,447	1,447	1,447	1,447	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375
- Obras Eléctricas/Mecánicas	0																												
(2) Est. Bombeo - Obras Civiles	2,041				34										2,008														
- Obras Eléctricas/Mecánicas	5,918				181										5,555						181								
(3) Planta de tratamiento - Civiles	12,639				10,893																1,747								
- Obras Eléctricas/Mecánicas	31,190				23,587																	7,603							
4. Equipamiento	835					425										177						233							
5. Servicio de Ingeniería	8,343		2,547		1,698								1,061		708					1,397		931							
6. Imprevistos	13,891		382	388	5,847	452	0	0	0	0	0	0	376	217	1,458	244	217	217	217	416	496	1,521	206	206	206	206	206	206	206
7. IGV (18 %) (for 3, 4, 5, 6)	19,169		527	535	8,069	623	0	0	0	0	0	0	519	299	2,012	336	299	299	299	574	684	2,100	285	285	285	285	285	285	285
Total	126,266		3,456	3,531	52,916	4,108	22	22	22	22	22	22	3,432	1,992	13,215	2,232	1,992	1,992	1,992	3,782	4,503	13,784	1,886	1,886	1,886	1,886	1,886	1,886	1,886
8. Renovación de equipo (incluye IGV y cont.)	72,044															32,253									7,538	32,253			
9. Operación & Mantenimiento	31,323					781	815	850	885	936	988	1,043	1,105	1,169	1,211	1,253	1,295	1,339	1,384	1,427	1,471	1,513	1,561	1,608	1,650	1,693	1,737	1,782	1,827
Total General de Desembolsos	229,633		3,456	3,531	52,916	4,889	837	872	907	958	1,011	1,065	4,537	3,161	14,426	35,738	3,287	3,331	3,375	5,209	5,974	15,297	3,448	3,494	11,075	35,833	3,624	3,668	3,714

e) Organization for operation and maintenance

Required numbers of staff directly involved in the sewerage system operation for each alternatives are shown in *Table* V.2.30 - 32. Temporarily hired workers might be required for the operation such as sludge removal and totora cutting.

Table V.2.30 Required number of staff for O&M of sewerage system (Alternative I, I-A)

(Unit: persons)

Field & Position		Phase 1	Phase 2	Phase 3	Duty
Manager		1	1	1	Responsible for wastewater system
Sewer and Pumping Station					
Sewer	Engineer	-	-	-	Responsible for cleaning of sewers
	Foreman	-	-	-	Responsible for site works
	Worker	2	4	6	2 workers/team
	Driver	(1)	(1)	(1)	2 workers/team
					*Vehicle maintenance shall be done by EMSAPUNO
Wastewater Treatment Plant					
Operation	Engineer	1	1	1	Responsible for technical matters
	Foreman	1	1	1	Responsible for operation of each shift
	Operator	1	1	2	1 (2) operator/shift
Maintenance	Technician	1	1	1	Responsible for site works
	Worker	-	-	-	Cleaning
W. Quality Analysis	Chemist	(1)	(1)	1	Water quality control
Total		7	9	14	

Table V.2.31 Required number of staff for O&M of sewerage system (Alternative II)

(Unit: persons)

Field & Position		Phase 1	Phase 2	Phase 3	Duty
Manager		1	1	1	Responsible for wastewater system
Sewer					
Sewer	Engineer	-	-	-	Responsible for cleaning of sewers
	Foreman	-	-	-	Responsible for site works
	Worker	2	4	6	2 workers/team
	Driver	(1)	(1)	(1)	2 workers/team
					*Vehicle maintenance shall be done by EMSAPUNO
Pump Station					
Operation	Engineer	1	1	1	Responsible for technical matters
	Foreman	-			Responsible for operation of each shift
	Operator	1	1	1	1 (2) operator/shift
Maintenance	Technician	1	1	1	Responsible for site works
	Worker	1	1	1	Cleaning
W. Quality Analysis	Chemist	-	-	-	Water quality control
Total		7	9	11	

Table V.2.32 Required number of staff for O&M of sewerage system (Alternative III)

(Unit: persons)

Field & Position		Phase 1	Phase 2	Phase 3	Duty
Manager		1	1	1	Responsible for wastewater system
Sewer and Pumping Station					
Sewer	Engineer	-	-	-	Responsible for cleaning of sewers
	Foreman	-	-	-	Responsible for site works
	Worker	2	4	6	2 workers/team
	Driver	(1)	(1)	(1)	2 workers/team
					*Vehicle maintenance shall be done by EMSAPUNO
Wastewater Treatment Plant					
Operation	Engineer	1	1	1	Responsible for technical matters
	Foreman	1	2	3	Responsible for operation of each shift
	Operator	3	4	5	1 (2) operator/shift
Maintenance	Technician	1	1	1	Responsible for site works
	Worker	1	2	2	Cleaning
W. Quality Analysis	Chemist	1	1	1	Water quality control
Total		11	16	20	

f) Operation and maintenance cost

Operation and maintenance costs for each alternative are shown below.

Table V.2.33 Operation and Maintenance Cost (Alternative I)

(Unit: S/. /year)

Year	2008	2015	2025
- Personnel Expenses	167,802	222,641	294,000
- Electricity Cost	475,114	846,995	1,118,466
- Chlorine Cost	-	-	-
- Coagulant Cost	-	105,894	139,834
- Totora Cutting	3,853	5,112	6,750
- Repair Cost	87,818	116,518	153,863
Total	734,587	1,297,160	1,712,913

* Figures include IGV.

Table V.2.34 Operation and Maintenance Cost (Alternative I-A)

(Unit: S/. /year)

Year	2008	2015	2025
- Personnel Expenses	167,802	222,641	294,000
- Electricity Cost	475,114	630,388	832,434
- Chlorine Cost	-	-	-
- Coagulant Cost	-	105,894	139,834
- Totora Cutting	3,853	5,112	6,750

* Figures include IGV.

Table V.2.35 Operation and Maintenance Cost (Alternative II)

(Unit: S/. /year)

Year	2008	2015	2025
- Personnel Expenses	130,132	172,661	228,000
- Electricity Cost	1,170,906	1,553,573	2,051,509
- Chlorine Cost	-	-	-
- Coagulant Cost	-	-	-
- Repair Cost	50,512	67,020	88,500
Total	1,351,550	1,793,254	2,368,009

* Figures include IGV.

Table V.2.36 Operation and Maintenance Cost (Alternative III)

(Unit: S/. /year)

Year	2008	2015	2025
- Personnel Expenses	232,867	308,971	408,000
- Electricity Cost	477,401	633,421	836,439
- Chlorine Cost	16,191	21,483	28,368
- Coagulant Cost	74,732	99,155	130,935
- Repair Cost	241,601	320,559	423,301
Total	1,042,792	1,383,589	1,827,043

* Figures include IGV.

2.3.4 EVALUATION OF ALTERNATIVE PLANS

(1) Environmental evaluation

a) Contribution for environmental improvement

Improvement of water quality of the Puno interior bay of Titicaca lake is one of the main objectives of sewerage system development in Puno City. Magnitudes of pollution load reduction to the inner Puno bay by each alternative are calculated using the following conditions.

Table V.2.37 Treated wastewater quality discharged to the inner bay

	Year	BOD_5 mg/l	Nitrogen (T-N) mg/l	Phosphorus (T-P) mg/l
Alternative I*1	2008 2015 2025	12.7 no discharge no discharge	8.5 no discharge no discharge	2.9 no discharge no discharge
Alternative I-A*1	2008 2015 2025	12.7 18.7 26.1	8.5 8.7 9.1	2.9 2.9 2.9
Alternative II		no discharge		
Alternative III*2	All period	20	10	1

*1 According to PRONAP calculation
*2 Design values

Per capita pollution load is divided into sullage (grey water: non-toilet household wastewater) and black water (excreta)

Table V.2.38 Breakdown of per capita pollution load

	BOD_5 g/capita/day	Nitrogen (T-N) g/capita/day	Phosphorus (T-P) g/capita/day
Black water (excreta)	16.2	8.25	0.6
Grey water (sullage)	28.8	2.75	0.65
Total	45	11	1.25

On-site treatment facilities only treat black water. Sullage from houses without a sewer connection is discharged to the ground, streets and drainage ways. From the observation of the present condition of Puno City, the following portion of nutrients contained in sullage is estimated to reach the inner lake.

Table V.2.39 Run-off rate of sullage nutrients

	BOD_5	Nitrogen (T-N)	Phosphorus (T-P)
Run-off rate*	60%	60%	100%

*This rate is only applied for houses without sewer connections.

The results of total pollution load reduction to the inner bay are shown is *Table V.2.43.*

Table V.2.40 Pollution load reduction by proposed measures in year 2025

	BOD_5		T-N		T-P	
	With Project	Reduction (%)	With Project	Reduction (%)	With Project	Reduction (%)
Without Project	2,541.2	0 %	1,292.0	0 %	155.1	0%
Alternative I	331.5	87 %	31.7	98 %	11.9	92 %
Alternative I-A	814.9	68 %	206.9	84 %	67.7	56 %
Alternative II	331.5	87 %	31.7	98 %	11.9	92 %
Alternative III	716.6	72 %	224.3	83 %	31.2	80 %

Phosphorus reduction by Alternatives I-A and II is biggest at 92% while that of Alternative I-A is lowest at 56%. For nitrogen reduction, Alternatives I-A and III have similar removal rate while Alternatives I and II are at 98 %.

b) Initial environmental evaluation (IEE)

The results of IEE are summarized in *Table V.2.41.*

Table V.2.41 Initial Environmental Evaluation (IEE)

Environmental concern	Alternative I	Alternative I-A	Alternative II	Alternative III
Lake water pollution				
Inner bay	B	B	D	B
Outer bay*1	B	D	D	D
Sludge disposal	C	C	C	C
Ground water pollution	C	C	B	D
Offensive odor generation	B	B	B	C
Change of landscape	B	B	B	C

A: serious impact is expected
B: minor impact is expected
C: extent of impact is unknown
D: no impact
* Possible drinking water source contamination

Alternative I may have some impact on drinking water source quality as treated wastewater discharged to the outer bay. Alternative II has minimum impact on the lake water quality of the Puno inner bay but may pollute ground water at the proposed facultative lagoons.

(2) Technical evaluation

The evaluation of technical aspect is summarized in *Table V.2.42*.

Table V.2.42 Technical evaluation of alternative plans

	Alternative			
	I	I-A	II	III
Previous operation experiences in Peru	○	○	△*1	×*2
Appropriateness of technology used	○	◎	○	○
Ease of O&M	○	◎	△	△
Effective implementation schedule for maximum results	○	○	○	○
Ability to respond to new technology	○	○	○	◎

*1 large scale wastewater pumping
*2 oxidation ditch

Oxidation ditch has never been constructed for municipal wastewater treatment in Peru. But the process uses relatively simple mechanical and electrical equipment, which can be maintained by local technicians.

All three alternatives are technically feasible for implementation in Puno City.

(3) Financial evaluation

For the evaluation of alternative plans, the detail cash flow and P/L estimations are prepared. It is required to set up some assumptions for preparing cash flow and P/L estimations for alternatives. The assumptions are as follows:

Revenue and Donation

a) Revenue from sewerage service increases according to the increase of population and service ratio. Also the sewerage charge will be revised every 3 years from 2000 fiscal year (FY) and 5% increase is expected. Tariff collection rate will be improved by 1% annually. In 1998, the rate was 76%.

b) Donation from KFW --- DM 12 million (S/. 21,180,000) will be used for payment of construction cost. The construction cost over S/. 21,180 thousand will be paid by loan (with 5% interest). Inter bank loan rate is now about 5 % per annum.

Depreciation

a) Depreciation for civil structures & mechanical/electrical equipment --- civil structures will be depreciated for 40 years under the straight-line method, while mechanical/electrical equipment will be depreciated for 10 years under the straight-line method.

b) The existing EMSAPUNO's fixed assets were divided into sewerage business (34%) and water supply business (66%). Estimated present fixed assets' depreciation for sewerage facilities is estimated to be 34% of the 1998 FY total depreciation.

Expenses

a) 34 % of General expense (except depreciation) of EMSAPUNO will be allocated to sewerage business and amounts to be S/. 787,000 annually.

b) Non construction expense will be financed by local fund – Puno municipality/Peru government without interest, if needed.

c) Interest expense of loan from FONAVI is excluded, as the settlement of legal negotiation is not yet clear.

d) Income tax of sewerage business is not considered, because EMSAPUNO has been handling sewerage business and water supply business jointly and the total result of profit and loss is not clear.

Cash flow and P/L estimation for alternative plans

The results of Cash flow and P/L calculations are shown in *Table* V.2.43, 2.44, 2.45 and 2.46 for each alternative plan. From the resulted figures, Internal Return Rate (IRR) and Net Present Value (NPV) are calculated as follows.