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**Effluent Permit**

The following treated effluent concentrations were permitted (as yearly averages):

	Yearly limit not exceeding		3 month target# not exceeding	
BOD <sub>7</sub>	10	gO <sub>2</sub> /m <sup>3</sup>		
Total phosphorus#	0.4	gP/m <sup>3</sup>	0.4*	gP/m <sup>3</sup>
Total nitrogen	10*	gN/m <sup>3</sup>		

\* Target value that, if exceeded, results in an obligation to take measures so that the value is not exceeded.

# 3 month target value (Mar-May, Jun-Aug) applied since July 2006.

Gryaab received provisional effluent limits during 2007. Total phosphorus not exceeding 0.4 g/m<sup>3</sup> as target value\* (March-May and June-August as 3 month averages and as yearly average) as well as BOD as target became effective June 2007. From 2011 the effluent limits on total phosphorus will be 0.3 g/m<sup>3</sup> as target value\* (yearly average and March-May and June-August averages) and 0.4 g/m<sup>3</sup> as emission limit value (yearly average).

**General Statistics**

Population connected 2008 640 303  
 Population equivalents incl. industry (based on water consumption) 832 003  
 Dimensioned flow, Q<sub>dim</sub> 4 m<sup>3</sup>/s  
 Average flow during 1980's, 1990's and 2000's varied between 3.2 - 4.5 m<sup>3</sup>/s

Normally flows up to 10 m<sup>3</sup>/s receive full biological/chemical treatment. Flows exceeding the biological/chemical treatment capacity receive only direct precipitation and/or primary treatment.

**Gryaab: General Statistics 2008**

Wastewater pumped to plant (ave 4.32 m <sup>3</sup> /s) (includes internal recirculation)	136.6	Mm <sup>3</sup>
- domestic wastewater	39.3	Mm <sup>3</sup>
- industrial wastewater	11.7	Mm <sup>3</sup>
- recirculated water	0.30	Mm <sup>3</sup>
- stormwater and infiltration	81.4	Mm <sup>3</sup>
Bypass after primary sedimentation	0.71	Mm <sup>3</sup>
Bypass after direct precipitation	8.58	Mm <sup>3</sup>
Peak daily wet weather flow, October 26	12.1	m <sup>3</sup> /s
Minimum daily dry weather flow, July 27	2.3	m <sup>3</sup> /s
Precipitation	819	mm
External organic wastes	501	tons DS
Electrical energy consumption (total)	33.7	GWh
Heat energy consumption (total)	14.2	GWh
Drinking water consumption, Rya plant	196 049	m <sup>3</sup>
Drinking water consumption, Syrhåla plant	262	m <sup>3</sup>
Iron sulphate consumption	5 426	t
Polyaluminium chloride (PAC) consumption	989	t
Sodium hypochlorite consumption	29	t
Polymer consumption in water treatment	45.5	t
Polymer consumption in sludge treatment	162	t
External carbon source (primarily ethanol)	1059	t
Sludge production after digestion (DS)	14 773	t
Dewatered sludge, Rya plant (29.3 % DS)	47 147	t
Dewatered sludge, Syrhåla (- % DS)	0	t
Total sludge delivery	54 351	t
to disposal in Syrhåla cavern	0	t
to agriculture	0	t
to composting	54 351	t
to landscaping	0	t
to research	0	t
Bar screenings	1 054	t
Sand and floatables	94	t
Sediment from tunnels	0	t

Biogas production	57.4	GWh
Heat production (Göteborg Energi heat pump plant)	282	GWh
net production	193	GWh

## Gryaab: Economy 2008

	MSEK	%
Turnover	241.7	
Interest	-32.0	
Depreciation (ordinary)	-39.0	
Total operation costs	-166.3	
Result	4.4	
<b>Distribution of Operation Costs by Post</b>		
Administration, investigations, common costs	28.8	17.3
Properties, buildings, grounds	33.9	20.4
Operation and maintenance, plants	81.7	49.1
Operation and maintenance, tunnels	4.9	3.0
Sludge disposal incl. transport	17.0	10.2
Investment in treatment plants and tunnels	1 474	
Book value	656	
Estimated replacement value	~6 000-8 000	

Net operation costs, excl. sludge disposal	
SEK/m <sup>3</sup> wastewater	1.13
Total treatment costs:	
SEK/m <sup>3</sup> wastewater	1.48
SEK/m <sup>3</sup> drinking water consumed	3.84

## Gryaab: Effluent Water Quality 1992 – 2008

Treatment results: Total effluent conc. and percent removals (incl. internal recirc.)

Year	Bypassed#	BOD <sub>7</sub>		Total phosphorus		Total nitrogen	
		%	g/m <sup>3</sup>	%	g/m <sup>3</sup>	%	g/m <sup>3</sup>
1992	3.8	8	94	0.34	94	19	28
1993	5.6	10	94	0.38	93	22	26
1994*	18.1	17	85	0.75	81	17	24
1995*	23.2	19	81	0.79	79	19	26
1996*	9.6	22	87	0.77	86	24	23
1997*	12.7	15	90	0.65	87	19	35
1998	5.6	7	95	0.48	91	12.7	53
1999	9.1	6	92	0.45	87	11.4	41
2000	8.4	9	93	0.49	87	9.9	51
2001	1.7	7.4	95	0.41	90	10.6	54
2002	8.2	7.7	93	0.49	89	11.9	54
2003	3.3	8	94	0.4	90	10	61
2004	2.7	8	93	0.4	91	10	60
2005	2.3	7	93	0.4	91	11	64
2006	14.1	10	91	0.4/0.5^	87	10	58
2007	9.6	10	92	0.4	89	12	53
2008	6.8	10	92	0.4	90	12	49

\* reduced capacity due to construction during plant upgrade

# majority of bypassed wastewater receives direct precipitation (since 2005)

^ result dependant on calculation method

## Gryaab: Sludge Quality 2008

Product certificate for biosolids since 1999-08-26

			Dewatered Sludge*	SNV criteria (from 1999)
Lead	Pb	mg/kg DS	32	100
Cadmium	Cd	mg/kg DS	0.8	2
Copper	Cu	mg/kg DS	395	600
Chrome	Cr	mg/kg DS	33	100
Mercury	Hg	mg/kg DS	1,0	2.5
Nickel	Ni	mg/kg DS	21	50
Zinc	Zn	mg/kg DS	650	800
Phosphorus	P	g/kg DS	26	-
Nitrogen	N	g/kg DS	36	-

# Gryaab: Unit Processes

## 1 General Treatment Description

**Tunnel System:** Total length approx. 124 km, cross sectional area 6-24 m<sup>2</sup>, slope 0.07-0.1%, 27 access tunnels for inspection and maintenance, transport time at dry weather flow 16-20 h, time of concentration at dry weather flow 0-30 h.

**Water:** Coarse screening, pumping, sand trap, fine screening, primary sedimentation, pumping, activated sludge with pre-denitrification and simultaneous precipitation, secondary sedimentation, post-nitrification in trickling filter. Total retention time approx. 8 h at average flow of 3.8 m<sup>3</sup>/s.

**Sludge:** Belt gravity thickening, anaerobic digestion, dewatering with centrifuges or filter belt presses. Sludge not reused is disposed of in a rock cavern at the Syrånå dewatering facility.

## 2 Wastewater Treatment

### Physical Treatment

4 mechanically cleaned coarse bar screens. Bar openings 20 mm, width 2.5 m.

4 screenings presses.

3 variable capacity wastewater lift pumps, vertical propeller type with variable pitch blades, capacity 1.2-6.0 m<sup>3</sup>/s each, 1 800 kW each, lift height 19 m.

1 variable capacity wastewater lift pump, vertical propeller type with variable pitch blades, capacity 1.2-4.7 m<sup>3</sup>/s, 1 300 kW, lift height 19 m.

Influent canal with aerators, length 280 m, width 3.0 m, volume 2 800 m<sup>3</sup>, retention time 12 min @ Q<sub>dim</sub>.

Sand trap (1300 m<sup>3</sup>), sand wash (cap 25 l/s).

12 fine bar screens (step type). Bar openings 2 mm, width 1.7 m.

2 screenings presses.

12 rectangular primary settlers (59.9 m x 8.0 m x 4.0 m ave. depth) with chain and flight sludge scrapers (21 flights / basin), total volume 22 800 m<sup>3</sup>, total area 5 800 m<sup>2</sup>, retention time 1 h 40 min @ Q<sub>dim</sub>, surface loading 2.4 m<sup>3</sup>/m<sup>2</sup>/h @ Q<sub>dim</sub>. Direct precipitation possible in 4 or 6 of settlers using polyaluminium chloride (PAC) and polymer.

6 variable speed primary sludge pumps, each serving 2 basins, capacity 10.8 – 108 m<sup>3</sup>/h.

Canal after primary sedimentation, length 230 m, width 3.0 m, total volume 3 200 m<sup>3</sup>, retention time 14 min @ Q<sub>dim</sub>.

Intermediate pumping station, 5 variable speed pumps with max 2.1 m<sup>3</sup>/s capacity each, lift height 5.5 m.

### Facilities for Iron Sulphate Addition

Holding tank for 375 tons of iron sulphate i.e. 2.5 weeks consumption at a dosage rate of 10 gFe/m<sup>3</sup> (equivalent to 1.1 mol Fe / mol P). Iron sulphate is 17.5% Fe.

### Activated Sludge

Canal leading to aeration basins, length 175 m, width 3.0 m, volume 1 500 m<sup>3</sup>, retention

time 7 min @ Q<sub>dim</sub>.

3 activated sludge basins, total volume 51 000 m<sup>3</sup>, retention time 3 h 33 min @ Q<sub>dim</sub>, synthetic rubber, tube membrane aerators, 40-60% aerated volume, denitrification in anoxic zones with mixers.

3 turbo compressors with variable capacity deliver air according to oxygen demand in the aerators, capacity 14 000 Nm<sup>3</sup>/h each, average total air flow approx 15 000 Nm<sup>3</sup>/h.

Canal after aeration basins, total length 225 m, width 3.0 - 6.24 m, volume 3 330 m<sup>3</sup>, retention time 11 min @ Q<sub>dim</sub>.

Polymer addition after aeration, 1 continuous mixing tank volume 12 m<sup>3</sup>. Variable speed dosing pump. Concentrated solution diluted with treated effluent before dosing.

### Secondary Settlers

24 two-tray rectangular secondary settlers (59.5 m x 7.8 m x 3.25 m ave. depth each tray) with cable drawn sludge scrapers (5 blades/basin) in upper and lower trays, total volume 72 200 m<sup>3</sup>, total area 21 100 m<sup>2</sup>, retention time 5 h 1 min @ Q<sub>dim</sub>, surface loading 1.7 m<sup>3</sup>/m<sup>2</sup>/h @ Q<sub>dim</sub> (including 6.0 m<sup>3</sup>/s recycle to trickling filters).

24 variable speed recycle sludge pumps, total capacity 3.5 m<sup>3</sup>/s, normal flow 1.6-3.2 m<sup>3</sup>/s.

Canals after settlers, length 2 x 165 m + 400 m, width 3.0 m, total volume 6 380 m<sup>3</sup>, retention time 19 min @ Q<sub>dim</sub>.

### Nitrifying Trickling filters

2 rectangular nitrifying trickling filters (59.5 m x 19.5 m) with a total of 6 circular distribution arms complemented with fixed corner nozzles, crossflow plastic media 240 m<sup>2</sup>/m<sup>3</sup>, total volume 16 500 m<sup>3</sup>, filter depth 7.2 m, total area 2 360 m<sup>2</sup>, surface loading 9 m<sup>3</sup>/m<sup>2</sup>/h @ Q<sub>dim</sub>, trickling time 5-10 min.

4 variable speed and 2 constant speed inlet pumps, total capacity 6 m<sup>3</sup>/s, lift height 6 m.

8 variable speed outlet pumps, total capacity 6 m<sup>3</sup>/s, lift height 7 m.

### Transport to Heat Pumps

Treated effluent is pumped 400 m to the Rya Heat Pump Works (operated by Göteborg Energy AB) where waste heat is recovered to supply about 10% of the heat to the City of Göteborg's district heating system, net annual production approx. 200 GWh.

3 transfer pumps and filters, capacity 3 x 1.75 m<sup>3</sup>/s @ 34 m head.

The diverted water is returned to the Rya WWTP outfall tunnel for discharge.

### Outfall

Treated wastewater transported through a rock tunnel and a double pipeline to an outfall point at Rya Nabbe at a depth of 4 m, approx. 900 m west of the Ålvsborg Bridge.

Tunnel length 825 m and volume 8 200 m<sup>3</sup>, pipeline length 2 x 195 m and  $\phi$  2.0 m.

### 3 Sludge Treatment

Approx. 5 000 m<sup>3</sup> of sludge with a dry solids content (DS) of 0.7 % are removed from the process daily at the Rya plant. After thickening approx. 1 600 m<sup>3</sup>/d (6% DS) remain. Organic food wastes (approx 5% DS) can be pumped directly to the anaerobic digesters. After anaerobic digestion the DS content drops to approx. 3.5%. After dewatering in centrifuges it is increased to 27-33% DS and the resulting quantity of sludge is approx. 130 t/d. Sludge can be dewatered at the main Rya plant or at the Syrhåla dewatering facility. To reach the Syrhåla facility, the digested sludge is pumped through a 7 km pipeline. The dewatered sludge can be disposed in a large rock cavern at the site or stockpiled. The reject filtrate water is led back to the main Rya plant. Digester gas (biogas) is sold to Göteborg Energy AB. Biosolids are further treated (composting) and distributed by Ragn-Sells Avfallsbehandling AB.

#### Pre-treatment of mixed primary/waste sludge and thickening

4 belt gravity thickeners, belt width 2.6 m, capacity approx. 100 m<sup>3</sup>/h of 2% DS sludge each. Polymer addition, 2 continuous mixing tanks, volume 12 m<sup>3</sup>, max capacity 12 m<sup>3</sup>/h, variable speed dosing pumps, polymer solution 0.23%, dosage approx. 3-4 kg/t DS.  
1 thickened sludge silo,  $\phi$  18.0 m, total volume 550 m<sup>3</sup>.

#### Organic food waste receiving station

2 centrifugal pumps with cutting knives, capacity 60 m<sup>3</sup>/h (unloading).  
2 storage tanks, 30 m<sup>3</sup> each.  
2 shredders, capacity 60 m<sup>3</sup>/h each.  
2 sludge pumps (progressive cavity), capacity 60 m<sup>3</sup>/h (to digesters).  
Hot water rinse system.

#### Anaerobic digestion

2 anaerobic digesters (mesophilic), height 29.4 m,  $\phi$  23.5 m, volume 11 375 m<sup>3</sup> each, retention time approx. 20 d.  
Mechanical stirring, 10 rpm, 1 W/m<sup>3</sup>, axle length 23.5 m, propeller diameter 6 m.  
2 sludge-sludge heat exchangers, surface area 128 m<sup>2</sup> each.  
2 water-sludge heat exchangers, surface area 85 m<sup>2</sup> each.  
1 sludge storage silo, height 19.9 m,  $\phi$  18.0 m, total volume 4 513 m<sup>3</sup>, approx. 3 d storage.

#### Dewatering at Rya plant

2 centrifuges, capacity approx. 30 m<sup>3</sup>/h of 3.5% DS sludge, dewatered sludge 25-32% DS.  
2 centrifuges, capacity approx. 50 m<sup>3</sup>/h of 3.5% DS sludge, dewatered sludge 25-32% DS.  
Polymer addition, 1 mixing tank volume 15 m<sup>3</sup>, 1 storage tank for concentrated solution volume 18 m<sup>3</sup>, variable speed dosing pumps, concentrated solution diluted with treated effluent before dosing, polymer solution 0.23%, dosage approx. 6-8 kg/t DS.

Storage area for treated sludge approx. 2 000 m<sup>2</sup>, max. storable volume approx. 12 000 m<sup>3</sup>, equivalent to approx. 3 month's production.

2009-05-04

#### Biogas

Biogas is sold to Göteborg Energi AB where it is upgraded to vehicle fuel quality.

#### Sludge transport to Syrhåla plant

3 variable speed eccentric screw pumps, capacity 50 m<sup>3</sup>/h each @ 1 MPa.  
Ductile iron sludge pipeline, length 6 866 m,  $\phi$  250 mm.  
Ductile iron, reject water pipeline, length 2 337 m,  $\phi$  250 mm.

#### Dewatering and deposition at Syrhåla plant

1 sludge buffer silo, volume 183 m<sup>3</sup>.  
2 pre-dewaterers, belt width 1 700 mm, hydraulically operated, capacity approx. 60 m<sup>3</sup>/h each with 3.5 % DS sludge, pre-dewatered sludge approx. 10-12 % DS.  
2 belt filter presses, belt width 2 200 mm. Dewatered sludge approx 26% DS.  
2 polymer mixing tanks, 3 m<sup>3</sup> each, 1 polymer holding tank, 15 m<sup>3</sup>.  
2 piston pumps for dewatered sludge, hydraulically operated, capacity 0-33 m<sup>3</sup>/h.  
Pipeline to cavern, length 247 m,  $\phi$  200 mm, max. operating pressure 10 MPa.  
Cavern, total volume 600 000 m<sup>3</sup> comprised of 2 tunnels, total length 1 000 m, 20 m wide, 30 m high. Nominal capacity 10 years sludge production (approx. 78 000 tons disposed after 14 years of operation). Storage area for dewatered sludge, volume approx. 1 500 m<sup>3</sup>.

### 4 Heating

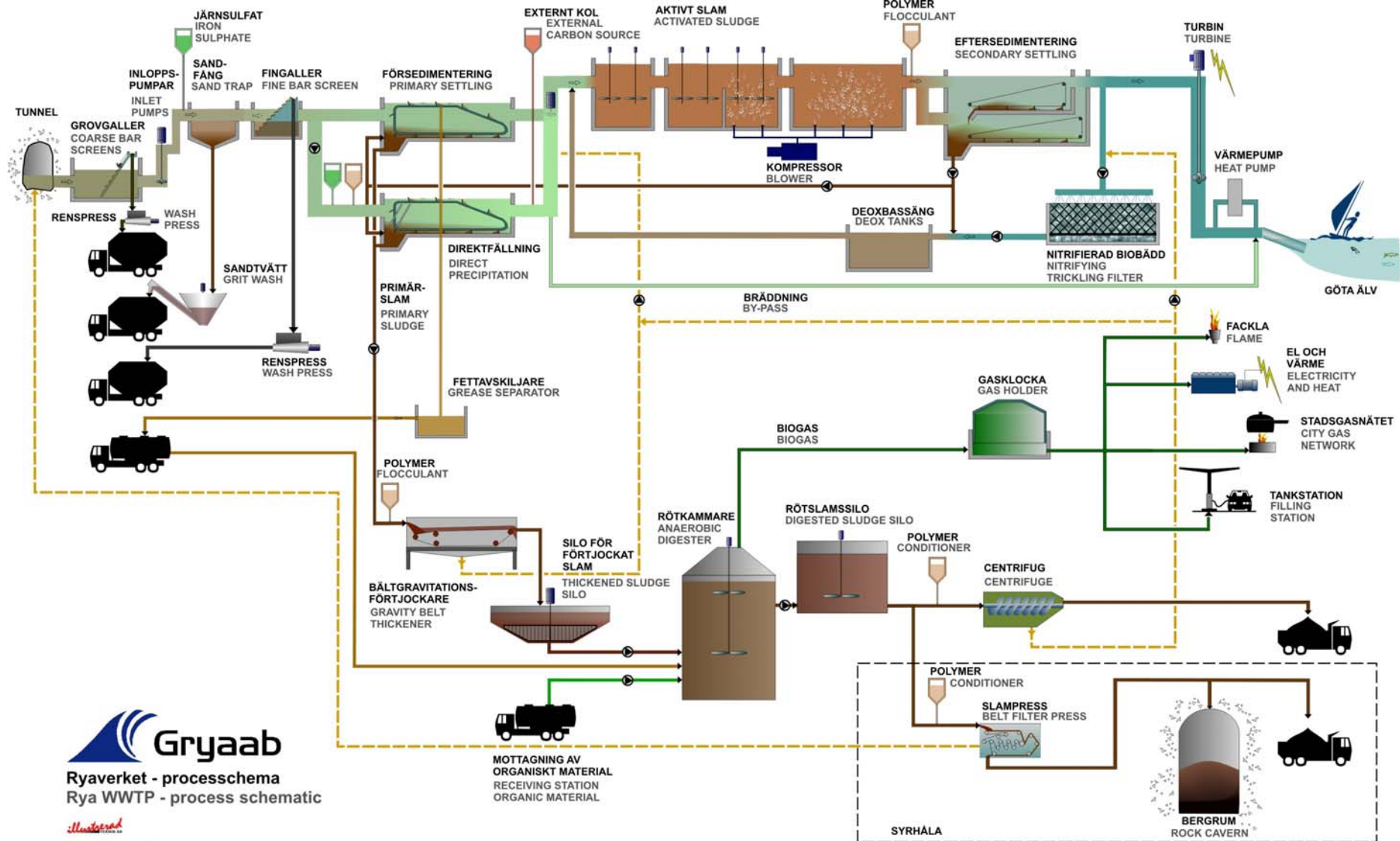
District heating supplied by Göteborg Energi AB, total heat exchanger capacity 9.35 MW.

### 5 Reserve Energy Production

Reserve power: 1 diesel generator, power 630 kVA, current 867 A, voltage 400 V.  
UPS - Rya plant: 25 kVA + 15 kVA + 8 kVA + 2 kVA. Syrhåla plant: 5 kVA.  
3 Caterpillar gas powered co-generation units for emergency standby electricity production, max. output 770 kW electricity/unit.

### 6 IT systems

Process automation: Emerson Process Management DeltaV PlantWeb DCS. 6 central servers. 33 redundant fibre optic LAN connected controllers. 2 100 analogue I/O, 6 000 digital I/O, 12 500 alarms. 17 operator terminals.  
LIMS software: Software Point Wilab.  
Asset management: Bentley Plant XM, IFS Plant Design, IFS Maintenance.  
Electrical design: cadett ELSA.  
Data analysis software: eWASTE (under development).  
Process simulator: Hydromantis GPS-X.  
Catchment simulator: Internally developed on-line simulator.



**Gryaab**  
 Ryaverket - processchema  
 Rya WWTP - process schematic

*Illustrerad*  
 Jan 2006-B2