Performance Evaluation of the Scrayingham Waste Stabilization Pond System, North Yorkshire

by

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Note: this pdf file contains only Chapters 6- 9 of Martin Long's dissertation which relate directly to the Scrayingham ponds.

6. The Study Site

6.1 The Scrayingham Wastewater Treatment Works

The village of Scrayingham is situated in North Yorkshire, approximately 35 miles North East of Leeds as shown in Figure 6.1. The population of the village is estimated to be 82, based on 30 properties each housing an average population of 2.7. Planning consent has been granted for a further 10 dwellings, which will accommodate an estimated additional population of 27. The wastewater treatment works has been designed for a p.e of 109 each producing a hydraulic load of 240 L/hd.d and an organic load of 60 g BOD/hd.d. The surface area loading rate used for the design is 80 kg BOD/ha as recommended by Abis and Mara (2005).

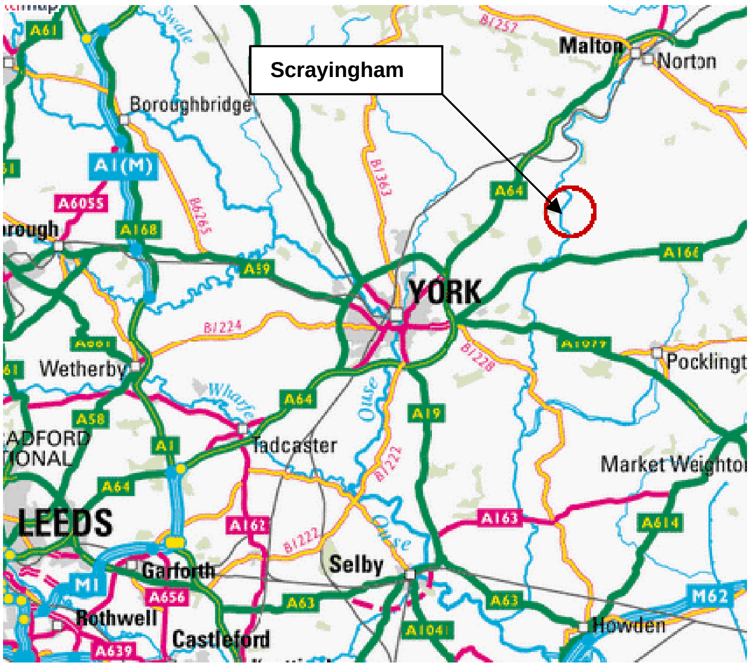

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Figure 6.1 Location of Scrayingham village, North Yorkshire

Wastewater from the village of Scrayingham was formerly treated by way of private septic tanks attached to individual houses. Effluents from the septic tanks discharged into a sewer which in turn discharged to a goit which drained into the River Derwent. The EA does not consider septic tanks an 'appropriate treatment' under the EC Urban Wastewater Directive, and so an additional treatment method was required.

Traditionally Yorkshire Water would have opted to install a small package plant to treat the village's wastewater. However, local landowner George Winn-Darley was not prepared to release any of his land for such a plant, and so an alternative treatment method was sought. Following a visit to the Botton Village WSP by Mr Winn-Darley and discussions with Yorkshire Water, a feasibility study was commissioned to investigate three possible sites for a WSP system at Scrayingham.

Iris Water and Design carried out the study and concluded that two of the sites at Bridge End Farm and Village Farm were not suitable for a wastewater treatment works due to their close proximity to residential properties. A third site 250 m to the south of the village was considered suitable, and a WSP system was subsequently built there.

The site has a natural slope from the road to the goit which receives the final effluent. The average fall is around 25 cm per 10 m run, making the site ideal for a gravity-fed treatment system requiring no energy. The Scrayingham pond system is the first of its kind in the UK to receive a combined effluent from foul drains and surface water. The project was completed in May 2004 and began operating shortly afterwards.

6.2 Preliminary Treatment

The wastewater from Scrayingham first flows through individual septic tanks attached to properties in the village before entering the sewer network. The sewage is screened through a Hydrok Static 6 mm × 6 mm screens before being pumped into the ponds through 80 mm pipes via two pumping stations. The pumping stations are situated in the north of the village outside Rectory Farm and in the centre of the village opposite South Farm.

6.3 Pumping Stations

Wastewater flows from the sewer into a pump well. A cross-section and plan view of the pumping station can be viewed in Appendix B**.** Once the water level within the well reaches a depth of 0.65 m pumping begins at a rate of 5 L/s until the water level reduces to 0.4 m. The pumping station at Rectory Farm pumps the sewage to pumping station at South Farm, and South Farm pumps the wastewater to the WSP.

The pumps run intermittently to average out the flow. Not having the pumps running continuously also reduces wear and tear, thus reducing maintenance costs. During periods of heavy flow the pumps are preset to run on a cycle of 35 seconds pumping and 231 seconds stopped. If the water level within the pump well reaches a depth of 1.75 m a warning is transmitted to Yorkshire Water indicating that the system is experiencing a storm which may cause it to overflow.

6.4 Waste Stabilization Ponds

Iris Water designed a WSP system comprising one facultative pond followed by one maturation pond; this is then separated into five smaller ponds by rock filters as shown in Appendix A. A large final pond has also been built, to be stocked with fish for local anglers at some point in the future. The fish pond has not been included in this study, and will not be discussed further. Full details of the Iris Water design procedure are given in Appendix B.

The wastewater enters the facultative pond through an 80-mm pipe approximately 0.5 m below the pond's surface. The pond can be considered a secondary facultative pond because the raw sewage has previously been screened and settled in private septic tanks.

The facultative pond, shown in Figure 6.2**,** has a maximum depth of 1.5 m and a surface area of 1443 m^2. Taking account of the slope of the embankment, the pond has an estimated volume of 1731 m^3. At a predicted average flow of 42 m^3/day the pond has a HRT time of 41 days. The effluent is filtered through a 100-mm rock filter 4 m in length (Figure 6.3). This filter is planted with substantial amounts of true bull rush (*Scirpus lacustria*) to maintain hydraulic pathways and help maintain aerobic conditions. The effluent exits the pond through a V-notch weir (Figure 6.4), which regulates the flow to the rest of the system during periods of high rainfall.

Once the wastewater has exited the facultative pond it passes through the series of five maturation ponds shown in Figure 6.5. The liquid enters the first pond below the water surface and flows through five ponds of equal size. Each pond is separated by a 3-m length of rock filter consisting of 40-mm gravel to prevent algae being washed out of the system.

The five maturation ponds each have a maximum depth of 0.5 m and a surface area of 87 m^2. Taking account of the slope of the embankment, the ponds have an estimated volume of 34

Figure 6.2 Facultative pond

Figure 6.3 Facultative pond rock filter

Figure 6.4 V-notch weir

Figure 6.5 Maturation ponds

m^3. At the predicted average flow of 42 m^3/day it takes 0.8 days for the water to pass through each of the five ponds, giving a total retention time of 4 days for the maturation ponds. The water exits the fifth pond via a V-notch weir similar to that of the facultative pond (Figure 6.4).

All of the ponds are lined with 0.75-mm butyl rubber liners, protected by Fibertex F32M geo-textile under- and over-liners. The facultative pond base also has a 50-mm concrete base over laying the liner to prevent damage during desludging. It is anticipated that desludging should be required once every 10 years.

The site at Scrayingham consists of one facultative pond, five maturation ponds, one fish pond, tracks for vehicle access and a car park. The site and pond embankments are planted with many types of plants and wild flowers to encourage wildlife habitats to form. The overall area of the site has a width of 44 m and a length of 132.5 m, giving a total plan area of 5764 m^2. The facultative pond has a surface area of 13.2 m^2/hd and the maturation ponds have a surface area of 4.0 m^2/hd. The total surface area per head for the works is 17.2 m^2 (not including the fish pond), which is 70% larger than ponds which have been operating successfully in France and Germany for over 20 years.

6.5 Effluent Requirements

The discharge consent for the Wastewater Treatment Works at Scrayingham derives from it serving an agglomeration with a p.e <2000 which discharges to a freshwater watercourse. The Environment Agency discharge consent requires that the volume of discharge cannot exceed 149 m^3/day, with a dry weather flow discharge not exceeding 22 m^3/day. The maximum permissible BOD is 40 mg/L and SS 60 mg/L. There is no discharge requirement for ammonia.

7. Experimental Work

7.1 Pond Evaluation

The monitoring of a pond effluent provides information on whether the system is under loaded or overloaded, and whether it is complying with discharge standards. The information can be used to determine whether the loading on the ponds can be increased as a community expands, or whether more ponds will be required. It can also be used to improve the design of future ponds to take account of local conditions.

Table 7.1 displays the guidelines provided by Mara and Pearson (1998) for evaluation the performance of waste stabilization ponds which are failing to meet their discharge consent. Determining these parameters for each pond in the system will give a good indication of how the whole system is functioning.

Table 7.1 Guidelines for monitoring pond performance (adapted from Pearson *et al.,* 1987)

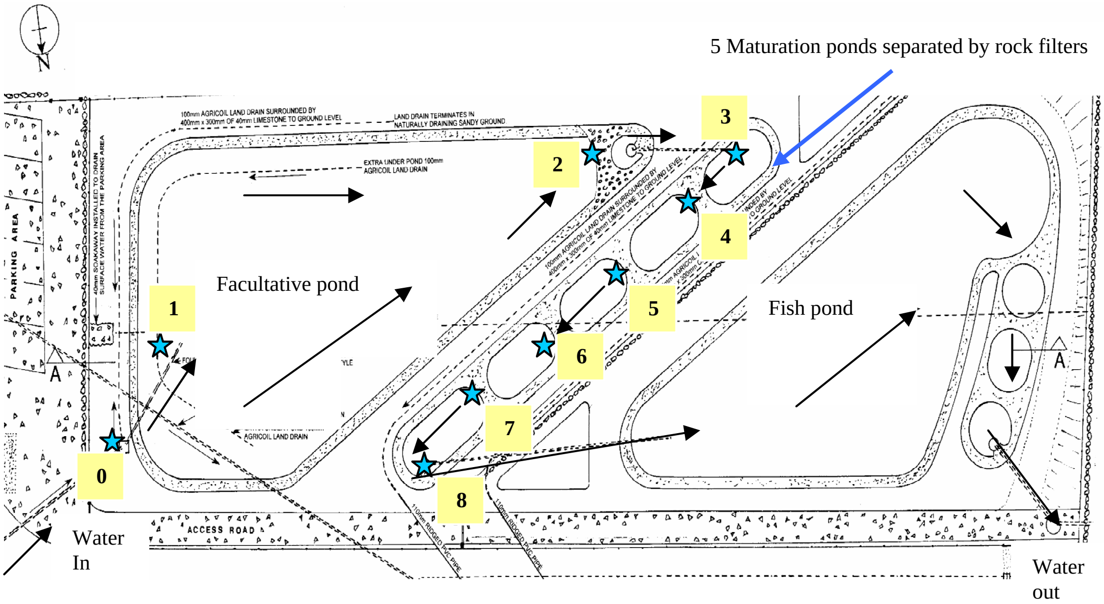
Parameter	Sampling Method	Comments
Flow	-	Raw wastewater & effluent flows
BOD	C	Filtered & unfiltered samples
COD	C	Filtered & unfiltered samples
SS	C	
Ammonia	C	
FC	G	Sample between 08:00 & 10:00
pH & Temperature	G	Take 2 samples: one at 08:00- 10:00 and the other at 14:00–16:00

C = 24 hour flow-weighted composite sample; G = Grab sample

7.2 Sampling Technique

Eight samples were collected from the pond system at Scrayingham on a weekly basis between 15 February and 26 April 2006. The samples were collected between 10.30 am and 11.30 am each week to maintain consistency throughout the study period.

Two of the eight samples were collected from the facultative pond; one was collected from each of the five maturation ponds; and one was collected from the final effluent. The sampling points 0 – 8 are shown in Figure 7.1.



Sample 0: inlet observation chamber
1: facultative inlet
2: facultative outlet
3: maturation pond 1
4: maturation pond 2
5: maturation pond 3
6: maturation pond 4
7: maturation pond 5
8: final effluent.

Figure 7.1 Sampling points at Scrayingham wastewater treatment works

Samples collected on 15 February included a grab sample taken from the work's inlet pipe (sample 0). Analysis of these samples found that the concentration of NH_3 was 8.1 mg N/L from the inlet pipe, and 21.8 mg N/L from the facultative pond effluent. Such a large increase in NH_3 concentration in the facultative pond indicated that a grab sample taken from the inlet pipe was not representative of the daily flow to the works. Based on this finding it was decided to take subsequent influent samples from the facultative pond, as close to the point where the raw wastewater entered the pond as possible (sample 1).

Attempts were made to collect column samples from each of the ponds as shown in Figure 7.2. However, the large amount of plant life within the ponds combined with the shallow depth of the maturation ponds (approximately 40 cm), and the shallow gradient of the facultative pond embankment (Figure 7.3) made it impossible to collect column samples from the pond's edge without contaminating them with sediment (Figure 7.4). Consequently grab samples were taken from the top 30 cm of the ponds using a 35-cm diameter bucket as shown in Figure 7.5**.**

Due to the local conditions and time constraints, this study has been limited to analysing grab samples for BOD_5, suspended solids, faecal coliforms, chlorophyll-*a*, pH and ammonia-N between 15 February and 26 April 2006. All laboratory procedures followed *Standard Methods*, except for chlorophyll-*a* for which the Methanol Extraction Method outlined by Pearson *et al.* (1987) was used.

Figure 7.2 Taking a column sampling

Figure 7.3 Facultative pond embankment

Figure 7.4 Sediment contaminated sample

Figure 7.5 Taking a grab sample

8. Results and Discussion

8.1 General Observations

The weather conditions and other observations for each of the nine sampling visits are given in Table 8.1. The average air temperatures are the average weekly temperatures recorded at the site. The wet conditions do not necessarily mean it was raining, but are observations of the ground conditions on the site, the road and surrounding fields.

It was noted that after the prolonged wet conditions between 15 March and 5 April, the level of the River Derwent rose until it was no longer within its natural channel. This seemed to coincide with a bloom of filamentous algae occurring in the final maturation pond (Figure 8.1). At its peak on 5 April, the algae were so dense that the pond surface was almost entirely occupied by floating mats of algae. The bloom never occurred on the surface of any other pond, although there was evidence of material growing below the surface of the other maturation ponds (Figure 8.2). When samples were collected from these ponds, great care was taken to avoid the filamentous algae and vegetation, and to collect only the liquid.

Although the algal bloom did not occur in the other waste stabilization ponds, it did occur in the fishpond, which the final maturation pond discharges into (Figure 8.3). The bloom remained in the fishpond after it had disappeared from the final maturation pond and was still there after this study was completed on 26 April. Arthur (1983) states that filamentous algae can occur in pond systems which are underloaded.

Birds were observed on the ponds from 8 March onwards. By the beginning of April, many plants began to emerge around the pond embankments, and the true bull rush began to grow in the facultative pond rock filter. By 12 June the site and embankments were overgrown.

8.2 *Daphnia*

Daphnia were observed in different ponds on different occasions (Table 8.2). They were never observed in maturation pond 2, and on 26 April they had a red colouration. Red *Daphnia* can be a sign of low oxygen levels within the pond. When *Daphnia* are exposed to hypoxic (low oxygen) conditions, they increase their production of haemoglobin. When its haemoglobin production increases, its clear outer carapace make them appear red (Deken, 2005).

Submerged vegetation has been observed in the maturation ponds at Scrayingham. This vegetation will encourage the development of large *Daphnia* populations, since the vegetation can provide the *Daphnia* with breeding sites and refuge from predation (Pearson *et al*., 1987). These daphnia can inhibit the performance of a pond system, because at a low organic load *Daphnia* can destroy the algae within a pond system (Abis, 2002).

Table 8.1 Site Observations on Sampling Days

	15th Feb	22nd Feb	8th Mar	15th Mar	29th Mar
Wet/dry	Damp	Wet	Wet	Wet	Dry
Wind	Breeze	Breeze	Calm	Calm	Breeze
Brightness	Cloudy	Cloudy	Cloudy	Cloudy	Clear
Ave Air ^{0}C	3.8	3.2	3.4	3.8	7.6
River level	Normal	Normal	High	Flooded	Flooded
Bloom	No	No	Begins	Thickens	Thick

	5th Apr	12th Apr	19th Apr	26th Apr
Wet/dry	Dry	Dry	Wet	Dry
Wind	Breeze	Windy	Breeze	Breeze
Brightness	Clear	Patchy	Cloudy	Cloudy
Ave air ^{0}C	5.2	9.3	9.5	-
River level	Flooded	High	Normal	Normal
Bloom	Peak	Receding	No	No

Key: Bloom: filamentous algal bloom in final maturation pond

River level: Observations of the River Derwent, which the Scrayingham ponds discharge into.

Figure 8.1 Filamentous algal bloom

Figure 8.2 Vegetation at the base of the maturation ponds

Figure 8.3 Fishpond Algal Bloom

Table 8.2 The Presence of Daphnia

Date	Fac	Mat 1	Mat 2	Mat 3	Mat 4	Mat 5
15th Feb	Yes	Yes		Yes	Yes	Yes
22nd Feb						
8th Mar						
15th Mar						
29th Mar		Yes			Yes	Yes
5th Apr		Yes				Yes
12th Apr	Yes	Yes				Yes
19th Apr	Yes	Yes		Yes	Yes	Yes
26th Apr	Yes	Yes		Yes	Yes	Yes

Fac: facultative pond, Mat: maturation pond.

8.3 Temperature

Temperature measurements were recorded at three locations on the site; the air temperature in the shade, at a 30 cm depth of the facultative pond (there was no access to a point where the mid-depth temperature could be recorded), and the mid-depth of the final maturation pond. A measurement was taken at each location once every hour, and the mean temperature for each week was calculated. From Figure 8.4 it can be seen that the in-pond temperature was always higher than the air temperature. Ponds are designed based on the minimum average monthly air temperature because the rate of bacterial activity, and thus pond efficiency, is lower at colder temperatures. Designing a pond system based on the local air temperature will therefore be appropriate, as it is always colder than the in-pond temperature.

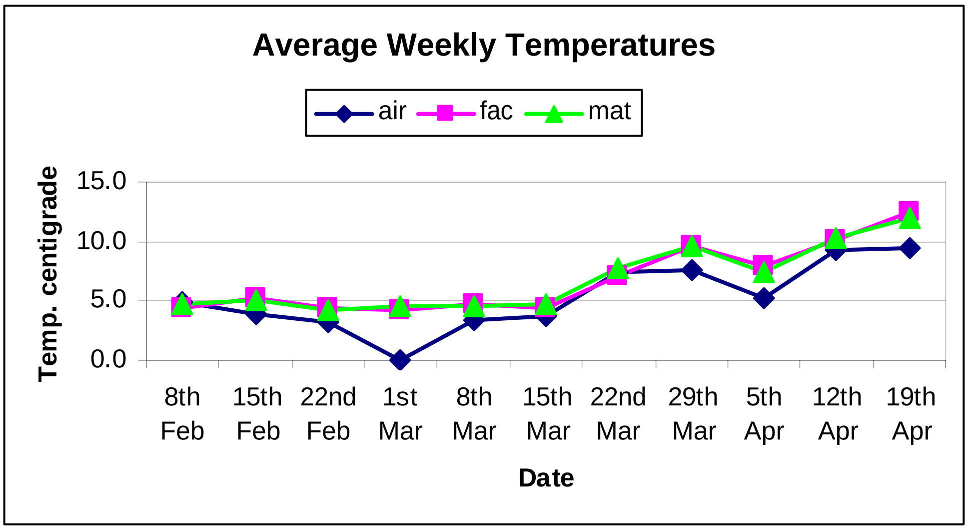


Figure 8.4 Average Weekly Temperatures

8.4 Flow conditions

It has not been possible to ascertain the influent flow to the facultative pond due to the intermittent nature of the pumping stations. Whilst taking a sample from the influent inspection chamber on 15 February, the flow increased from virtually zero to the inlet pipe becoming half full within a few seconds. It then reduced significantly within the following two minutes. It was decided that any attempt to record the flow rate would lead to misleading results, as it would depend upon the moment the water had been pumped. The effluent flow from the facultative and final maturation ponds could have been monitored to give an indication of the flow the works was receiving. However, this was not done and is one of the limitations of this study.

It has been observed that the effluent passed freely from the facultative pond throughout the study period. The effluent from the final maturation pond discharged freely up until 15 March. At this point in time, the filamentous algae became trapped in the effluent take off v-notch weir. The effluent was still discharging freely however, due to the wet weather increasing the pond's depth, and consequently the height at which the effluent left the pond. By 12 April the maturation pond was discharging virtually no effluent due the dryer weather lowering the water level and the filamentous algae obstructing the effluent take-off point. The blockage was cleared the following week to allow the effluent to flow once more.

On 12 June the depth of the maturation ponds were measured. They were found to be 35 cm deep, 5 cm below the effluent take-off weir. No effluent was discharging from either the facultative or the final maturation pond. The facultative pond had reduced in depth by approximately 30 cm. This suggests that during early June 2006, the rate of evaporation from the facultative pond was significantly greater than the rate of wastewater inflow. The reason for the drop in pond depth is likely to be due to the lack of rain: June 2006 was particularly dry month, with the north of England experiencing only 53 mm of rain, which is just 39% of the average rainfall for June 1961 – 1990 (Met. Office, 2006).

8.5 BOD Removal

The results obtained for BOD removal throughout the pond series are shown in Table 8.4, and are illustrated graphically in Figure 8.5. The results show that the final effluent quality is always well below the EA's discharge requirement of 40 mg/L. The maximum unfiltered BOD discharge was found to be 15.2 mg/L on 8 March, and <10 mg/L on all other occasions. The influent BOD was only sampled on one day, 15 February. The concentration was found to be very low at 25 mg/L. The discharge from the final maturation pond was 8.7 mg/L on this day, which amounts to a total BOD reduction of 64% throughout the pond series. The

Table 8.3 BOD Removal

Sample	15th Feb		22nd Feb		8th Mar	
	Unfiltered (mg/L)	Filtered (mg/L)	Unfiltered (mg/L)	Filtered (mg/L)	Unfiltered (mg/L)	Filtered (mg/L)
0	25.0	20.0	10.7	6.5	18.8	7.7
2	12.8	8.5	8.9	4.8	16.3	5.2
3	12.1	7.3	7.3	4.4	11.7	2.3
4	9.0	5.2	7.5	4.0	12.9	2.6
5	7.0	4.5	14.4	3.4	15.0	2.5
6	6.8	3.5	11.3	2.8	10.4	3.2
7	7.8	4.9	8.1	1.9	14.6	2.0
8	8.7	4.3	6.5	2.1	15.2	1.6

Sample	15th Mar		5th Apr		12th Apr	
	Unfiltered (mg/L)	Filtered (mg/L)	Unfiltered (mg/L)	Filtered (mg/L)	Unfiltered (mg/L)	Filtered (mg/L)
1	14.6	11.3	15.3	7.3	10.5	5.8
2	9.3	8.1	13.7	4.8	10.0	4.9
3	9.6	4.7	16.5	4.4	4.9	2.4
4	9.1	3.1	11.3	3.2	2.9	1.3
5	9.3	2.5	8.2	3.4	2.8	1.7
6	8.5	1.5	6.3	3.1	2.3	0.9
7	5.7	1.2	6.3	2.9	3.0	0.8
8	9.8	3.3	7.6	2.6	4.0	1.5

Sample	19th Apr		26th Apr	
	Unfiltered (mg/L)	Filtered (mg/L)	Unfiltered (mg/L)	Filtered (mg/L)
1	15.9	6.2	17.9	4.8
2	13.5	6.3	11.8	3.9
3	13.9	4.3	7.6	3.0
4	9.1	4.8	3.4	2.8
5	8.3	3.4	3.8	2.0
6	6.5	2.4	6.0	2.0
7	5.4	2.6	3.0	2.3
8	5.0	2.2	3.8	1.8

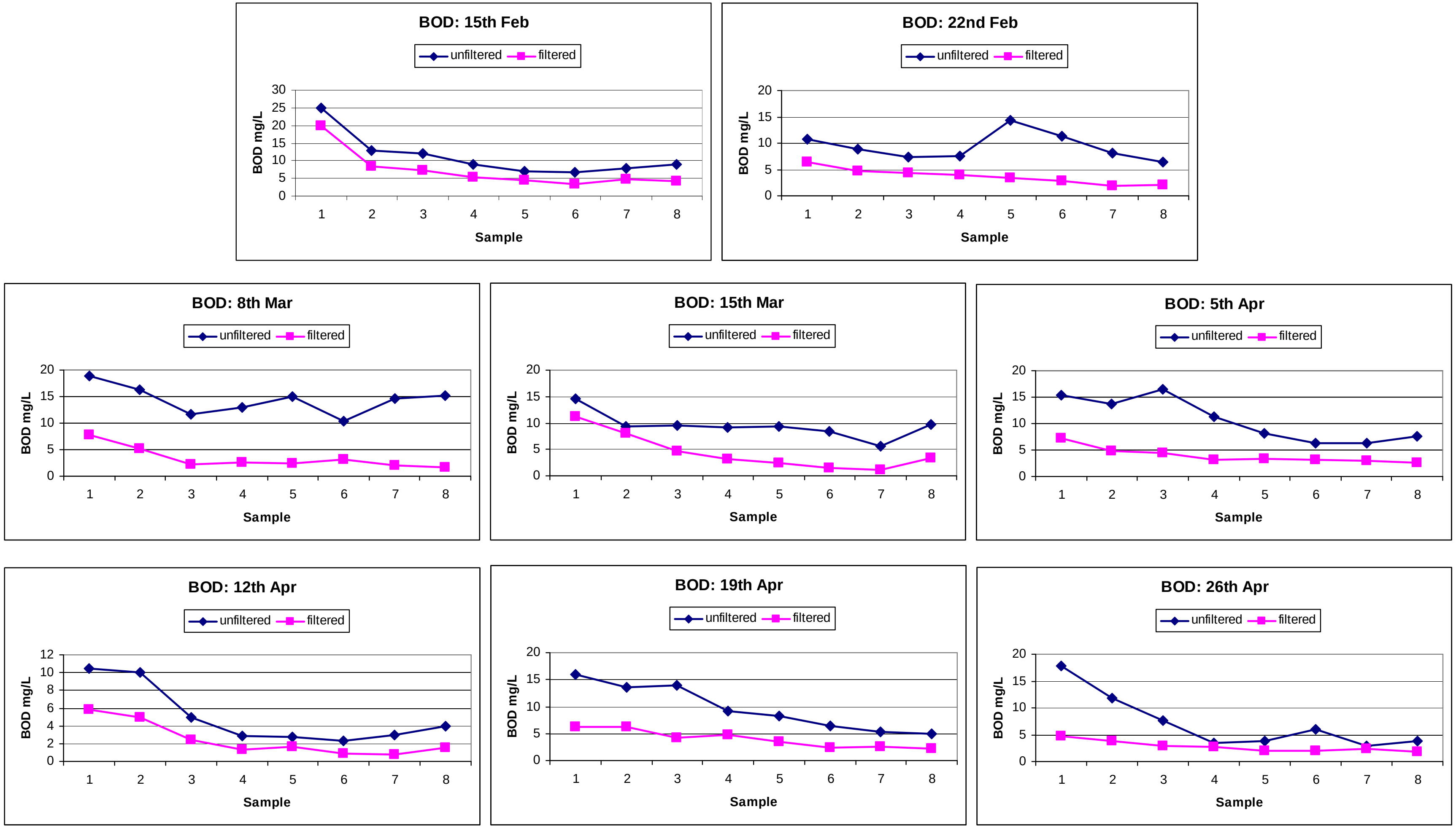


Figure 8.5 Filtered and Unfiltered BOD Removal

minimum BOD on this day was actually found in sample 6 which had a concentration of 6.8 mg/L, which amounts to a BOD removal of 73%.

Any further analysis of the BOD concentrations must be treated with caution due to inadequate sampling technique. Pearson *et al* (1987) recommend that column samples should be used to analyse the BOD of a pond. However, during this study a grab sample containing only the surface 30cm of each pond was used due to there not being an appropriate location to take a column sample from. The samples collected are unreliable because the influent, and therefore organic mater, enters the pond and disperses throughout the depth of the water column.

Due to the maturation ponds having a depth of <50cm (usually around 45cm), a 30cm surface sample can give reasonably reliable results, however the two samples taken from the facultative pond give no indication of that pond's BOD. Viewing the data from just the maturation ponds, it can be seen that the concentration of BOD sometimes increases through the pond series, particularly in the final maturation pond. This can be attributed to the decomposing algal bloom exerting an oxygen demand, faecal matter from birds often observed on the ponds, or experimental errors in the laboratory.

The maximum concentration of unfiltered BOD in the first maturation pond is 16.5mg/L. This is far below the EA's discharge consent of 40mg/L BOD. This shows that the facultative pond removes more than enough BOD and that the maturation ponds are not required for BOD removal.

8.6 Chlorophyll-*a*, pH and Suspended solids

As surface samples have been taken from the ponds, it is expected that the solids attributed to BOD would have settled beyond the depth of the sample, and the solids present in the water's surface may be due to motile algae rising to the ponds surface for photosynthesis. The concentrations of chlorophyll *a* and suspended solids have been compared to see if this is the case. Chlorophyll *a* and pH have also been compared because it is known that rapid photosynthesis causes a rise in pH.

As with the BOD test, the test for chlorophyll-*a* should be performed on a well mixed column sample due to the vertical distribution of algae in the water column. Due to motile algae dominating in facultative ponds, it is likely that on cloudy days without wind the majority of the algae will be close to the ponds surface. Therefore, whilst a grab sample of the top 30cm of the facultative pond is not ideal it should give a reasonable indication of the pond's condition during these weather conditions. Out of the nine sampling days only two were clear, 29 March and 5 April.

A comparison of chlorophyll *a*, pH and suspended solids is displayed in Table 8.5. A graphical representation of the relationship between chlorophyll *a* and pH can be seen in Figure 8.6, and the relationship between chlorophyll-*a* and suspended solids in Figure 8.7.

Figure 8.6 shows an apparent relationship between pH and chlorophyll *a*. The two sets of data were correlated to give an R value of 0.84. This shows that there is a good relationship between pH and chlorophyll *a*. Looking at Table 8.5 it appears that when there is little or no algae in the sample the natural pH of the liquid is around 7.4–7.5. The maximum pH value recorded was 8.8 on 15 March in the facultative pond when the concentration of chlorophyll *a* was 500 µg/L. A pH value of 8.8 was also recorded on 5 April when the pond had a chlorophyll *a* concentration of just 350 µg/L. However, on this day the weather was clear and it is likely that a significant proportion of the algae were at a depth beyond where the sample was taken from.

The pH values found in the ponds on 29 March seem high, but this was a clear day when a significant proportion of algae may not have been contained within the facultative pond sample. The pH values for the ponds may be higher when a surface grab sample is taken than if a column sample had been taken. This is because of the different rates of algal photosynthesis occurring at different depths of the pond, causing a vertical variation in pH (Konig *et al*., 1987). In a column sample these different values would be mixed together to give an average. As the majority of algal photosynthesis occurs towards the top of the pond it is likely that the pH values found in surface grab samples should be larger than those expected from a column sample.

From viewing Figure 8.7 it appears that the concentration of suspended solids change when the concentration of chlorophyll *a* changes. Correlating the two sets of data gave an R value of 0.82. A correlation of 0.82 indicates that there is a good relationship between the concentration of chlorophyll *a* and suspended solids in top 30 cm of each pond. This implies that the majority of the suspended solids which leave in the final effluent are algal solids, and not the more harmful BOD solids.

The concentration of suspended solids in the final effluent never failed the EA’s discharge consent of 60 mg/L. The solids concentration in the final effluent was always <10 mg/L, apart from on 8 and 15 March shortly after the filamentous algal bloom began establishing itself. On these two occasions the concentration of chlorophyll *a* was higher in the effluent discharge than it was at the entrance to the final maturation pond. It is possible that these higher suspended solids concentrations of 31 mg/L and 19 mg/L are due to filamentous algae being washed out of the pond.

A healthy facultative pond should usually have a concentration of chlorophyll-*a* in the range of 500- 2000µg/L. By viewing Table 8.5 it can be seen that all but one of the recorded concentrations of chlorophyll-*a* are below 500 µg/L. Apart from the clear days on 29 March and 5 April, it is expected that the concentration of chlorophyll *a* should be much higher in the surface 30 cm of a healthy facultative pond.

Table 8.5 shows that the maximum concentration of chlorophyll *a* across the study period was 500 µg/L on 15 March. This was a cloudy, calm day when *Daphnia* had not been observed in the ponds for a month. This maximum recorded value is at the low end of what would be expected for a properly functioning pond. The low concentration of algae may be due to low BOD loading, a combination of pH >8 and NH_3 >10mg/L, or the presence of *Daphnia* found in the pond on 15 February and from 12 April onwards.

Table 8.4 Chlorophyll-a, pH and Suspended Solids

Sample	15th Feb			22nd Feb		
	pH	Chl-a (µg/L)	SS (mg/L)	pH	Chl-a (µg/L)	SS (mg/L)
1	7.5	-	-	7.5	21	18
2	7.5	11	-	7.6	29	16
3	7.5	9	-	7.5	28	11
4	7.5	33	-	7.6	31	9
5	7.6	25	-	7.6	36	11
6	7.7	7	-	7.6	25	10
7	7.6	10	-	7.5	19	4
8	7.6	7	-	7.5	17	5

Sample	8th Mar			15th Mar		
	pH	Chl-a (µg/L)	SS (mg/L)	pH	Chl-a (µg/L)	SS (mg/L)
1	7.8	132	22	8.8	502	40
2	7.9	166	27	8.7	445	35
3	7.8	126	20	8.8	379	26
4	7.7	129	21	8.3	224	15
5	7.6	149	23	8.2	152	11
6	7.6	76	17	8.2	46	5
7	7.6	82	29	8.2	59	8
8	7.6	124	31	8.3	136	19

Sample	29th Mar			5th Apr		
	pH	Chl-a (µg/L)	SS (mg/L)	pH	Chl-a (µg/L)	SS (mg/L)
1	8.5	191	31	8.8	349	31
2	8.5	200	31	8.8	404	33
3	8.2	75	10	8.5	449	33
4	8.0	55	8	7.9	321	19
5	7.9	39	8	7.8	176	11
6	7.9	55	7	7.7	112	8
7	7.9	70	8	7.9	213	14
8	8.0	51	7	7.8	101	6

Sample	12th Apr			19th Apr			26th Apr		
	pH	Chl-a (µg/L)	SS (mg/L)	pH	Chl-a (µg/L)	SS (mg/L)	pH	Chl-a (µg/L)	SS (mg/L)
1	8.2	245	25	7.9	74	16	8.4	408	27
2	8.2	246	25	7.9	62	17	8.5	362	27
3	7.9	60	9	7.7	27	5	8.1	88	8
4	7.6	28	5	7.4	12	6	7.6	30	4
5	7.6	23	4	7.4	14	8	7.5	21	6
6	7.5	23	4	7.4	13	12	7.4	19	8
7	7.6	58	6	7.5	14	9	7.4	5	3
8	7.7	109	9	7.5	15	7	7.4	10	4

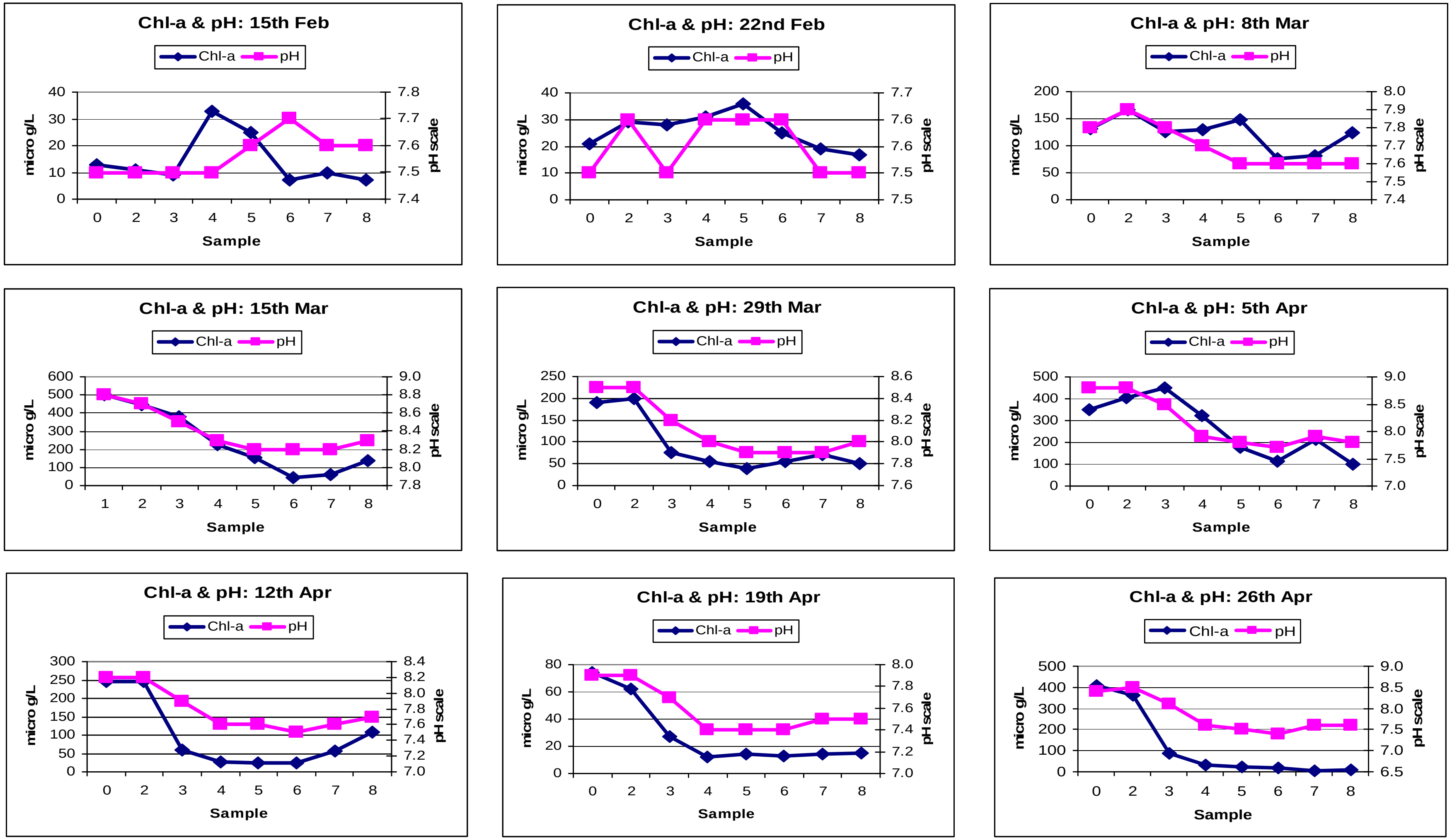


Figure 8.6 Chlorophyll *a* vs. pH

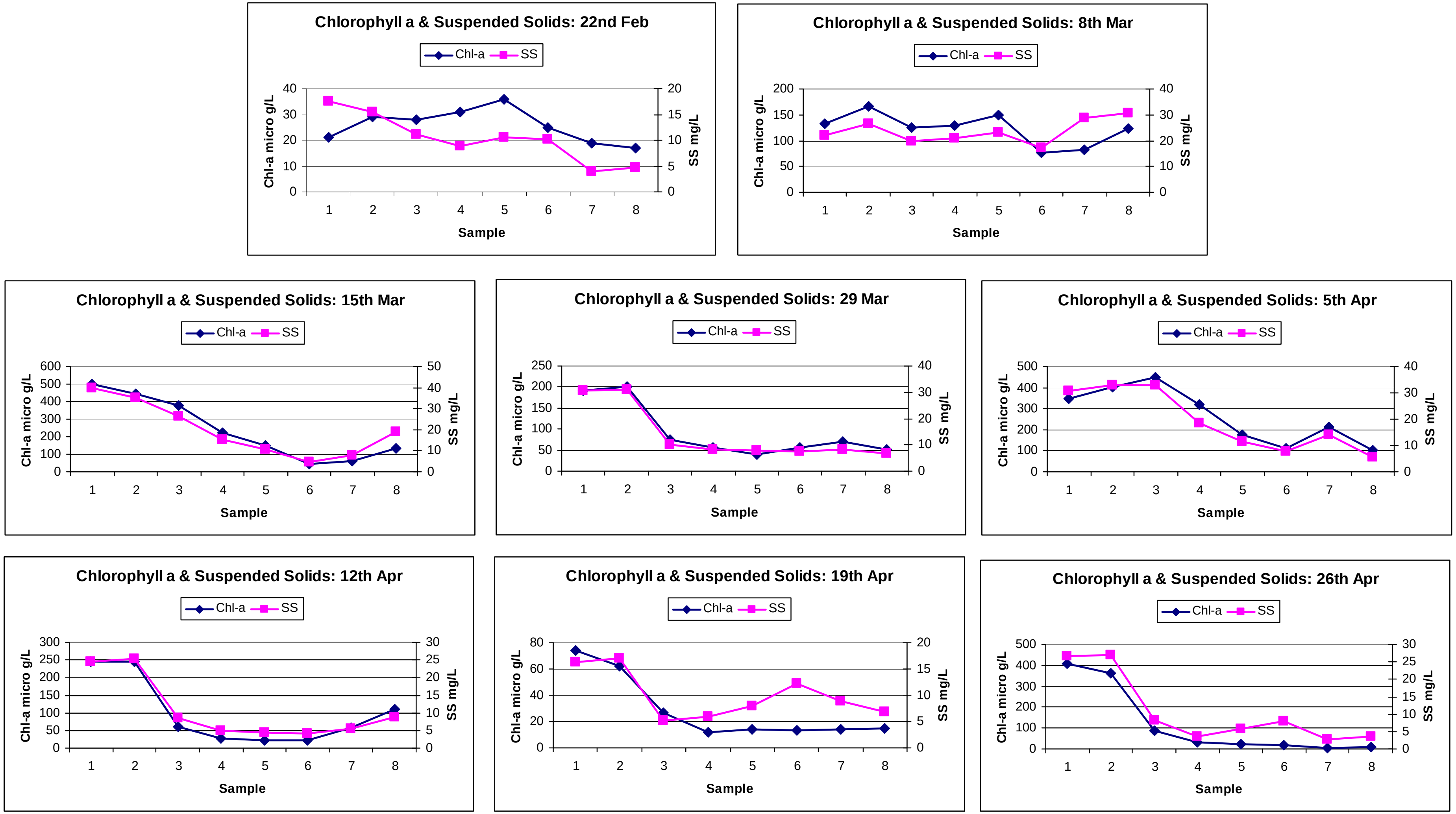


Figure 8.7 Chlorophyll *a* vs. Suspended Solids

8.7 Faecal Coliform Removal

The WHO guidelines on the safe use of wastewater for unrestricted irrigation state that a wastewater should have <1000 FC per 100 ml (WHO, 1989). The final effluent of the pond system at Scrayingham consistently produced FC counts of <100 colonies per 100 ml. The results of the testing can be seen in Table 8.6 and a graphic illustration of the FC removal is shown in Figure 8.8.

The FC count at the influent end of the facultative pond ranged from 9×10^4 to 2.3×10^5 colonies per 100 ml. A typical domestic wastewater would be expected to contain approximately 5×10^7 colonies per 100 ml. The wastewater sampled from the influent end of the maturation pond is <1% of that entering a typical sewage treatment works. This indicates that the organic load to the system may be extremely weak.

Table 8.5 Faecal Coliform results and cumulative % removal from each pond

Sample	22nd Feb		15th Mar		5th Apr		12th Apr	
	Coliforms per 100 ml	Removal (%)	Coliforms per 100 ml	Removal (%)	Coliforms per 100 ml	Removal (%)	Coliforms per 100 ml	Removal (%)
1	9000	-	8300	-	15500	-	22500	-
2	4850	46.11	3550	57.23	9000	41.94	12000	46.67
3	3100	65.56	1250	84.94	3600	76.77	6100	72.89
4	1100	87.78	350	95.78	3200	79.35	1300	94.22
5	650	92.78	225	97.29	2150	86.13	170	99.24
6	400	95.56	25	99.70	585	96.23	5	99.98
7	100	98.89	25	99.70	225	98.55	3	99.99
8	100	98.89	25	99.70	35	99.77	5	99.98

Table 8.6 Average % removal of Faecal Coliforms

Pond	Fac in	Fac out	Mat 1	Mat 2	Mat 3	Mat 4	Mat 5	Final effluent
Ave No. coliforms	13,825	7,350	3,513	1,488	799	254	87	41
Ave % Removal	-	47.99	75.04	89.28	93.86	97.86	99.30	99.58

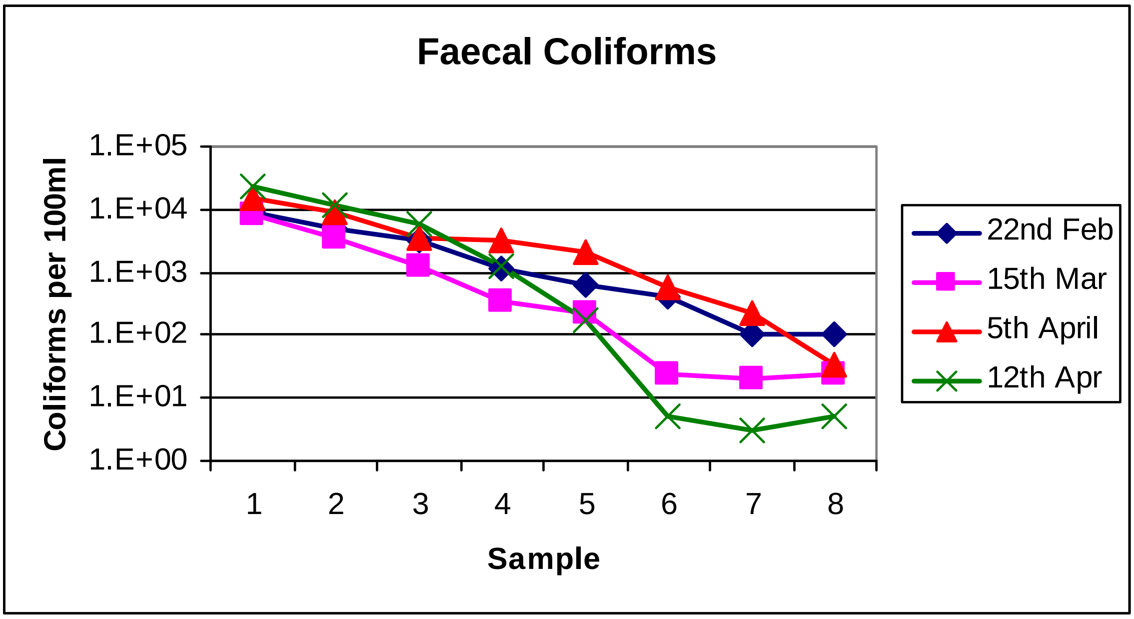


Figure 8.8 Faecal Coliform Removal

From Table 8.7 it can be seen that the facultative pond reduces the number of FCs by an average of 48%. By the time the effluent reaches the inlet to the 3rd maturation pond, the average FC count is <1000 per 100 ml. Only on 5 April was the number of colonies higher, but even then the number was reduced <1000 per 100 ml once the effluent reached the inlet to the 4th maturation pond.

The primary function of a maturation pond is the removal of FCs, so it appears that a safe effluent can be produced without the need for the 3rd, 4th and 5th maturation ponds.

8.8 Ammonia Removal

The ammonia concentrations found in each pond are shown in Table 8.8 and illustrated graphically in Figure 8.9. On 15 February a sample was collected from the inlet inspection chamber. The concentration of ammonia in this sample was significantly less than the facultative pond sample. Based on this finding, it was assumed that the influent sample was not representative of the ammonia entering the pond. Consequently it was decided to collect subsequent influent samples from the influent end of the facultative pond.

The ammonia results 8 March were calculated using a different laboratory technique to the other weeks. These results have been left in the report because they show that similar concentrations of ammonia have been found using two separate experimental methods. However, these results have been left out of the analysis to maintain consistency.

By viewing the average ammonia removal rates in Table 8.9 it can be seen that the ammonia concentration has a slight increase of 2% during its passage through the facultative pond. The ammonia is only reduced as the effluent passes through the series of maturation ponds. It is expected that the low concentrations of algae in the facultative pond will result in only a small fraction of the ammonia being utilised for algal growth. This small reduction is likely to be balanced by the hydrolysis of organic nitrogen raising the concentration of NH_3 to above its original level.

The facultative pond outlet is separated from the inlet to the first maturation pond by a rock filter. The 4% reduction of ammonia between these two points occurred from 5 April onwards after reeds began to grow in the filter. It is likely that this small reduction in ammonia is due to the nitrification-denitrification process occurring around the roots of the plants and on the exposed surfaces of this filter.

Table 8.7 Ammonia results and cumulative % removal from each pond

Sample	15th Feb		22nd Feb		8th Mar	
	NH_3 (mg/l)	Removal (%)	NH_3 (mg/l)	Removal (%)	NH_3 (mg/l)	Removal (%)
1	8.1	-	19.6	-	22.9	-
2	21.8	-	20.2	-3	20.9	9
3	21.3	2	20.2	-3	20.0	13
4	19.9	9	19.9	-1	17.8	22
5	18.2	17	19.6	0	15.8	31
6	17.4	20	18.8	4	13.2	42
7	15.7	28	17.6	11	10.0	56
8	14.6	33	17.6	11	10.7	53

Sample	15th Mar		29th Mar		5th Apr	
	NH_3 (mg/l)	Removal (%)	NH_3 (mg/l)	Removal (%)	NH_3 (mg/l)	Removal (%)
1	14.8	-	9.8	-	3.9	-
2	14.6	1	10.1	-3	4.2	-8
3	14.6	1	10.1	-3	3.9	0
4	13.4	9	9.5	3	3.6	8
5	11.5	22	9.2	6	3.1	21
6	9.8	34	8.7	11	2.5	36
7	7.3	51	8.1	17	2.5	36
8	8.1	45	7.8	20	2.5	36

Sample	12th Apr		19th Apr		26th Apr	
	NH_3 (mg/l)	Removal (%)	NH_3 (mg/l)	Removal (%)	NH_3 (mg/l)	Removal (%)
1	3.6	-	3.9	-	3.9	-
2	3.6	0	3.9	0	3.9	0
3	3.4	6	3.9	0	2.8	28
4	2.5	31	3.4	13	2.5	36
5	2.2	39	2.8	28	2.2	44
6	1.7	53	2.2	44	2.2	44
7	1.7	53	2.0	49	2.0	49
8	1.7	53	2.0	49	2.0	49

Table 8.8 Average % removal rates of ammonia at the influent of each pond

Pond	Fac	Mat 1	Mat 2	Mat 3	Mat 4	Mat 5	Final effluent
Ave % removal	-2	4	13	22	31	37	37

(Note: excludes the results obtained on 8 March. Fac = facultative pond; mat = Maturation pond

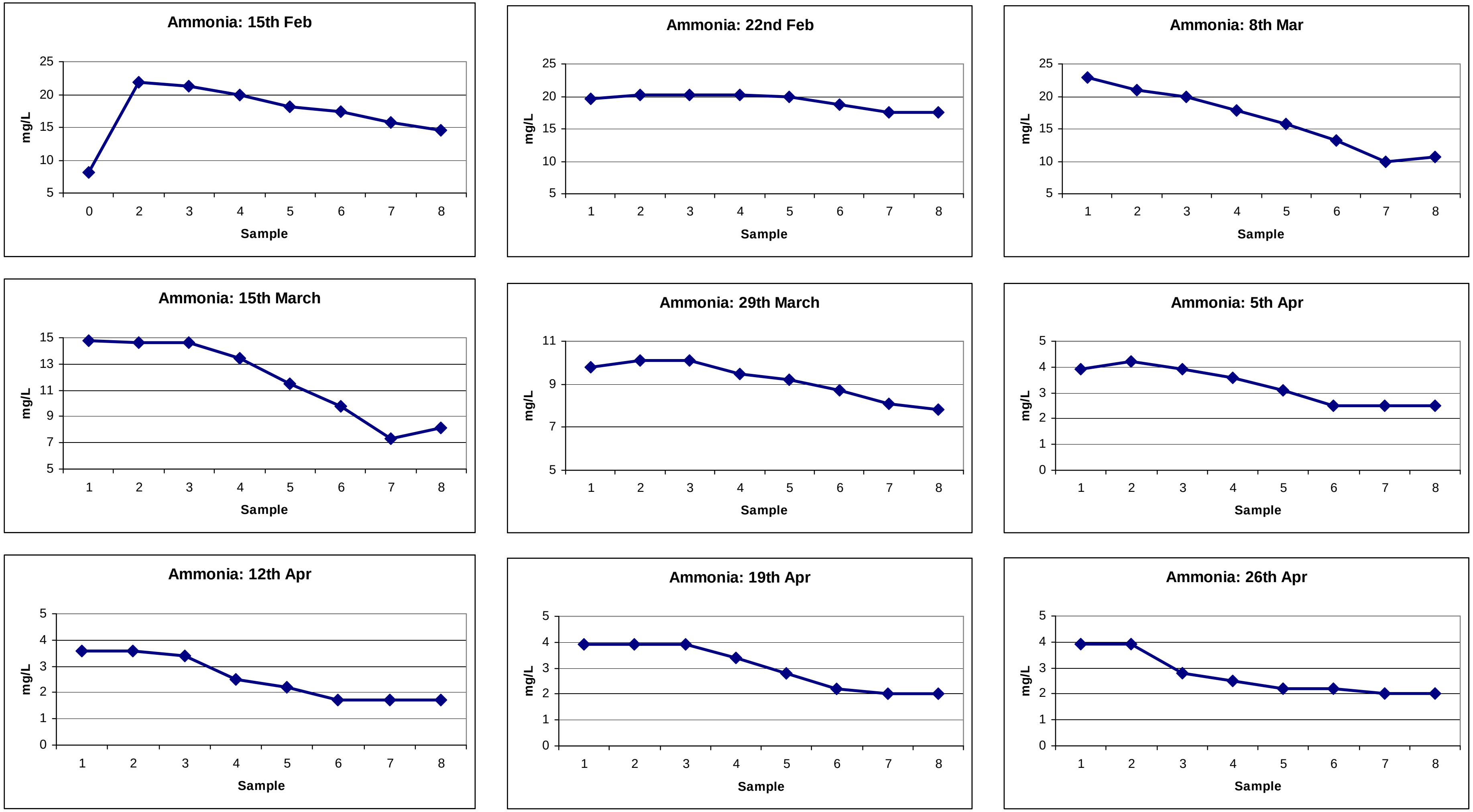


Figure 8.9 Ammonia Removal

The series of five maturation ponds remove on average 37% of the ammonia found in the facultative pond. The removal rate through each of the first four ponds is approximately 9% per pond, with none occurring in the final pond. The reduction may be attributed to the uptake of ammonia by vegetation growing at the base of the ponds. However, the filamentous algal bloom in the final maturation pond may cause the ammonia levels to increase when the material decomposes resulting in no net reduction.

The concentration of ammonia is much higher in the pond system at the beginning of the study period than it is at the end. By viewing Table 8.8 it can be seen that from 15 February to 8 March, there was approximately 20 mg/L NH_3 in the facultative pond. The levels fell throughout March, until they levelled out at 3.5–4.0 mg/L throughout April.

The increased levels of ammonia at the beginning of the study period caused a filamentous algal bloom to occur in the final maturation pond. Microscopic analysis of the algae revealed the presence of *Spirogyra* (Figure 8.10).

Figure 8.10 *Spirogyra*

Spirogyra forms dense, bright green mats in shallow slow-moving waters. It is found in nutrient-rich waters (Bellinger, 1992; Microscopy UK, 2006), and its presence in large amounts can indicate excess phosphorus and nitrate from fertilization of farmland (Microscopy UK, 2006). These excess nutrients can contaminate storm-water run-off, which finds its way into the sewer network via surface drains.

Comparing the data in Figure 8.11 with the data in Table 8.10 it can be seen that the high concentrations of ammonia within the pond system coincides with wet weather. This wet weather causes the River Derwent to flood for several weeks, indicating that the water table may have been higher than normal. The concentration of ammonia within the ponds drops once the weather is dry and as the floodwaters recede.

The village of Scrayingham is situated in a rural location surrounded by agricultural land. It seems plausible that the high levels of ammonia can be attributed to surface water run-off from this land and the infiltration of groundwater into the sewer network. The source of the ammonia is unknown, but it possible that it could arise from urea contained within the urine of grazing animals or fertilizer applied to crops in the area. Wikramanayake *et al* (2003) found that 52% of total nitrogen applied to land was lost as NO_3 and NH_3 in surface run-off during periods of heavy rainfall.

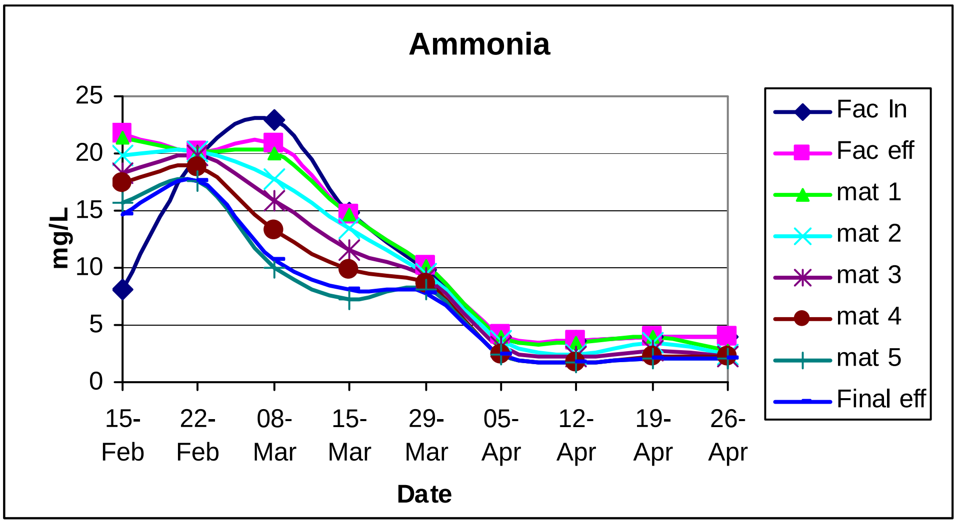


Figure 8.11 Ammonia concentrations throughout the study period

Table 8.9 Ground Conditions During Algal Bloom

	15th Feb	22nd Feb	8th Mar	15th Mar	29th Mar	5th Apr	12th Apr	19th Apr	26th Apr
Weather	Damp	Wet	Wet	Wet	Dry	Dry	Dry	Wet	Dry
River	Norm	Norm	High	Flood	Flood	Flood	High	Norm	Norm
Bloom	No	No	Begin	Yes	Yes	Peak	Reduce	No	No

The concentrations of ammonia found in the final effluent between 15 February and 29 March ranged from 7 mg/L to 18 mg/L. From 5 April until the end of the study period on 26 April, the effluent ammonia concentration fell to <2.5 mg/L. The EA has not set an ammonia consent for the pond system at Scrayingham, and therefore no breach has ever occurred. However, the fact that a fishpond has been constructed at the site suggests that the intention is to keep freshwater fish there at some point in the future. Randall and Tsui (2002) found that acute toxicity of 32 freshwater fish species occurred at ammonia concentrations of 2.8 mg/L. This value is well below the concentration which was discharged to the fishpond during February and March 2006.

It is possible that the situation will be repeated next year as the weather in February 2006 was not extreme. During this month the north of England received 93% of the average February rainfall during 1961–1990. March was very wet, however, receiving 138% of the March average over the same period (Met. Office, 2006). The results of the research have highlighted that the pond system is ineffective at removing significant quantities of ammonia to a suitable level.

9. Conclusions

This study has shown that the waste stabilization pond system at Scrayingham has consistently produced an effluent quality well below the EA's discharge consent, even when the mean air temperature is <4.0°C. The highest concentration of BOD discharged between February and April 2006 was 15\mg/L (consent 40 mg/L), whilst the highest solids concentration was 31 mg/L (consent 60 mg/L), the majority of which are likely to be algal solids.

The system is very effective at removing faecal coliforms from the liquid, with the numbers reduced to <1000 colonies per 100 ml by the time the liquid reaches the 3rd maturation pond.

The influent to the facultative pond was found to contain low concentration of chlorophyll *a* and faecal coliforms, indicating that the system is receiving a low organic load. The one sample collected from the inlet chamber confirms this suspicion by containing a BOD concentration of just 25 mg/L.

The significantly reduced pond depths witnessed during June 2006 when there was only 39% of average rainfall led to no effluent being discharged from the ponds. This indicates that the ponds receive a low hydraulic load during dry weather. Due to there being no effluent discharged at this time, it can be concluded that flow into the system from domestic sources is lower than the rate of evaporation from the ponds. This can lead to increased salinity which will affect the development of aquatic micro-organisms within the pond.

The system was found to reduce ammonia by 37% throughout the system, with no removal occurring in the facultative pond. The concentration of ammonia within the system was found to vary with the weather conditions. Wet weather between 15 February and 15 March 2006 coincided with the facultative pond ammonia concentration ranging from 15 mg/L to 22 mg/L. Final effluent concentrations of ammonia during this period were in the range 8–17 mg/L. During dry weather from 5 April 2006 onwards, the ammonia concentration in the facultative pond reduced to <4 mg/L, with the final effluent in the range 1.5–2.5 mg/L.

The high concentrations of ammonia during the wet weather led to the development of a filamentous algal bloom in the final maturation pond and the fishpond. These filamentous algae became trapped in the effluent take-off weir, restricting the effluent flowing from the system. It has been hypothesised that the filamentous algal bloom and increased ammonia concentrations are due to farm activity in the local area. The source of the increased ammonia is unknown, although it is likely to have originated from either urea produced by grazing animals or fertilizer applied to crops contaminating the stormwater entering the sewer network.

Waste stabilization pond systems in northern France and Germany are designed and operated successfully using a pond surface area of 10–11m^2/hd. The system at

Scrayingham has a surface area of 17.2 m^2/hd. The findings of this study indicate that the ponds are probably underloaded and have thus been overdesigned, but a further study of flow rates and influent BOD concentrations will be required to confirm this. Underloaded ponds limit the production of algae which seriously inhibits the ponds ability to remove nutrients. Nutrient removal has been found to be ineffective within the system, making the fishpond an unsafe environment for fish stock.

In general the ponds are producing an excellent quality effluent in terms of BOD, suspended solids and faecal coliforms.

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Appendix A: Treatment Works Plan View

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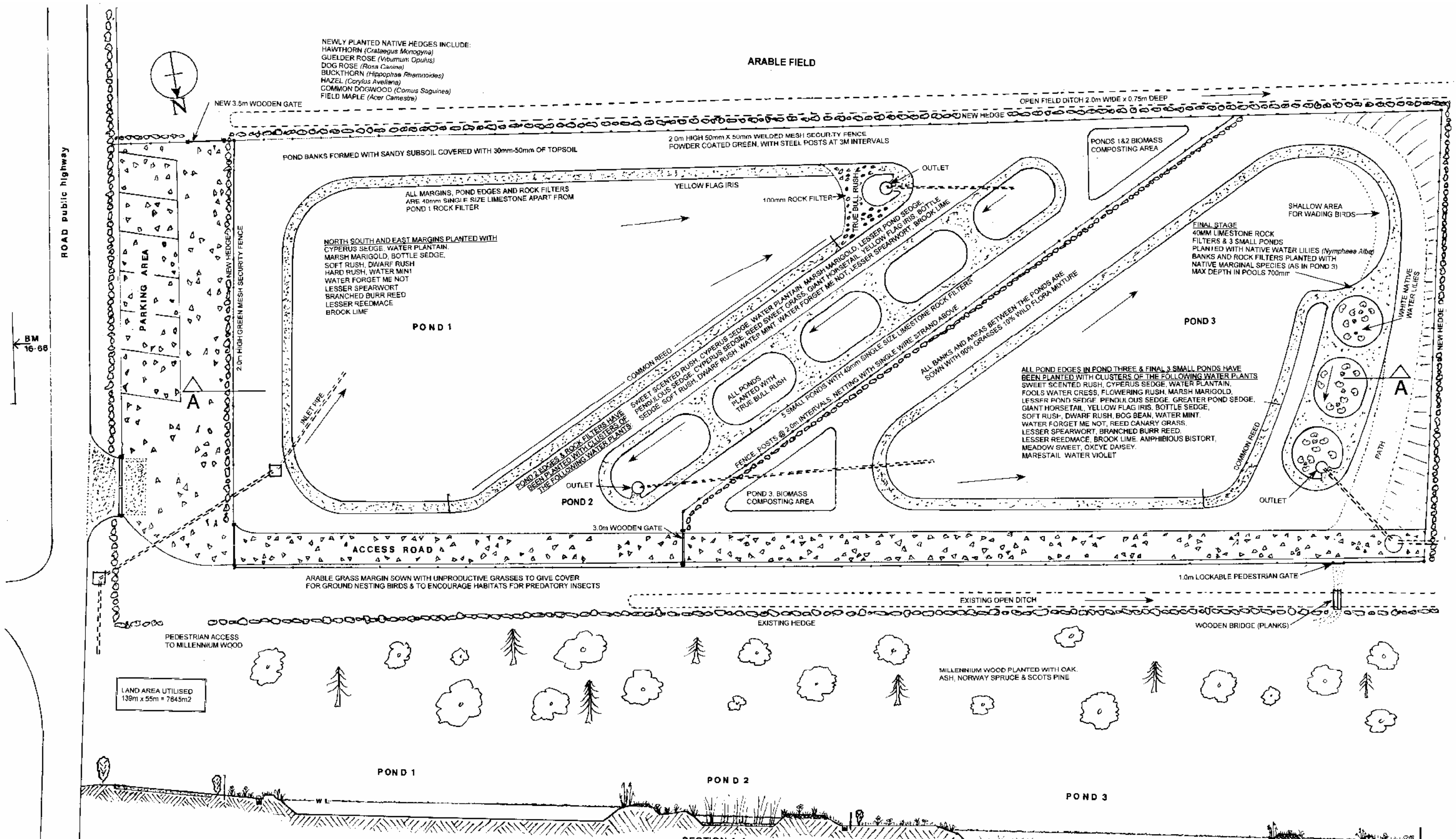

SECTION A-A

WATER PLANT LIST

Plant Name (Latin)	Plant (Com. Name)	Pond 1	Pond 2	Pond 3
Marginal Plants				
Acorus Calamus	Sweet Scented Rush		5	10
Alisma Plantago	Water Plantain	5	5	5
Apium Nodiflorum	Fools Water Cress			5
Botomus Umbelatus	Flowering Rush			10
Caltha Palustris	Marsh Marigold	7	10	10
Carex Acutiformis	Lesser Pond Sedge		5	5
Carex Pendula	Pendulous Sedge		5	5
Carex Pseudocyperus	Cyperus Sedge	6	5	6
Carex Riparia	Greater Pond Sedge			6
Carex Rostrata	Bottle Sedge	6		5
Equisetum Japonicum	Giant Horsetail		5	5
Glyceria Maxima	Reed Sweet Grass		5	
Iris Pseudacorus	Yellow Flag Iris	30	10	20
Juncus Effusus	Soft Rush	6	6	7
Juncus Ensifolius	Dwarf Rush	6	6	7
Juncus Inflexus	Hard Rush	5		
Mentha Aquatica	Water Mint	18	10	10
Menyanthes Trifoliata	Bog Bean			6
Marginal Plants. Cont.				
Myosotis Palustris	Water Forget-me-Not	5	5	5
Phalaris Arundinacea	Reed Canary Grass			5
Phragmites Austra is	Common Reed	140		20
Ranunculus Flammula	Lesser Spearwort	6	6	6
Scirpus Lacustris	True Bull Rush		250	20
Sparganium Erectum	Branched Burr Reed	8		7
Typha Angustifolia	Lesser Reedmace	10		10
Veronica Beccabunga	Brook Lime	5	10	10
Deep Marginal Plants				
Poligonium Amphibium	Amphibious Bistort			10
Bog Area Plants				
Filipendula Ulmaria	Meadow Sweet			5
Leucanthemum Vulgara	Ox-eye Daisy			5
Oxygenating Plants				
Hippuris Vulgaris	Marestail			10
Hottonia Palustris	Water Violet			10
Water Lilies				
Nymphaea Alba	White Native Lily			10

GRASS & WILD FLORA MIXTURE

Grasses	Wild Flora Mixture cont.
Common Bent	Catsear
Crested Dogstail	Field Scabious
Strong Creeping Red Fescue	Oxeye Daisy
Wild Flora Mixture	Birdsfoot Trefoil
Yarrow	Corn Poppy
Kidney Vetch	Selfheal
Common Knapweed	Bulbous Buttercup
Corn Marigold	Yellow Rattle
Wild Carrot	Common Sorrel
Foxglove	Red Campion
Lady's Bedstraw	Tufted Vetch

Iris Water & Design Langburn Bank Castleton Whitby YO21 2EU Tel: 01287 660002 Fax: 01287 660004 E-mail: info@iriswater.co.uk	*Project:*	**SCRAYINGHAM ECOLOGICAL WASTE WATER TREATMENT SYSTEM**
	Title:	**LANDSCAPE PLAN / SECTION A-A. AS BUILT**
	Scale: 1:250	**Date: 18/11/04** — **Drg. No: 03B** — **© IW&D 11/04**

Appendix B: Scrayingham Design Calculations

Iris Water's Design Calculations

The following formula was used by Iris Water to calculate the mid-depth areas of the ponds:

Pond area = (10 × BOD × average daily flow) / (surface area loading)

The pond system was designed to serve 109 p.e. To calculate the average daily dry weather flow Iris Water assumed an organic load of 60g BOD/hd/day, and a hydraulic load of 140 litres/hd/day plus 100 litres/hd/day for groundwater infiltration.

Design Loads

p.e	Hydraulic Load (L/d)	Groundwater Load (L/d)	**Hydraulic Total Load (m^3/d)**	Organic Load g BOD/hd.d	**Organic Total Load kg BOD/d**
109	140	100	**26.2**	60	**6.54**

Design Criteria

The ponds were designed using the following data:

Total Dwellings……………………………….…...40
Total Population.……………………………….….109
Organic load…………………………………….…6.54 kg BOD/day
Dry Weather Flow (DWF) in foul drain...………...26.2 m^3/day
Formula A maximum flow………………………...178.8 m^3/day
Average Daily Flow (DWF × 1.6)………………...42 m^3/day
Design BOD……………………………………….250 mg/L
Surface Area Loading……………………………...80 kg BOD/ha day

Facultative Pond

Pond Area = (10 × 250 × 42) / 80 = 1312 m^2 + 10% buffer = 1443 m^2
Max Depth 1.5 m
Volume 1731 m^3 (accounting for embankment slope)
Retention Time 41 days
Area per head 13.2 m^2/hd

Maturation Pond

BOD assumed to have been reduced by 70% in facultative pond.

BOD = 250 × 0.3 = 75 mg/l
Pond Area = (10 × 75 × 42) / 80 = 394 m^2 + 10% buffer = 433 m^2
Max Depth 0.5 m
Volume 173 m^3 (accounting for embankment slope)
Retention Time 4.1 days
Individual Pond Area 87 m^2 (including rock filters)
Area per head 4.0 m^2/hd