Institute of Freshwater Ecology

THERMAL STABILITY AND WATER QUALITY OF THE PROPOSED SWINDEN QUARRY, REHABILITATION SCHEME - PART 2

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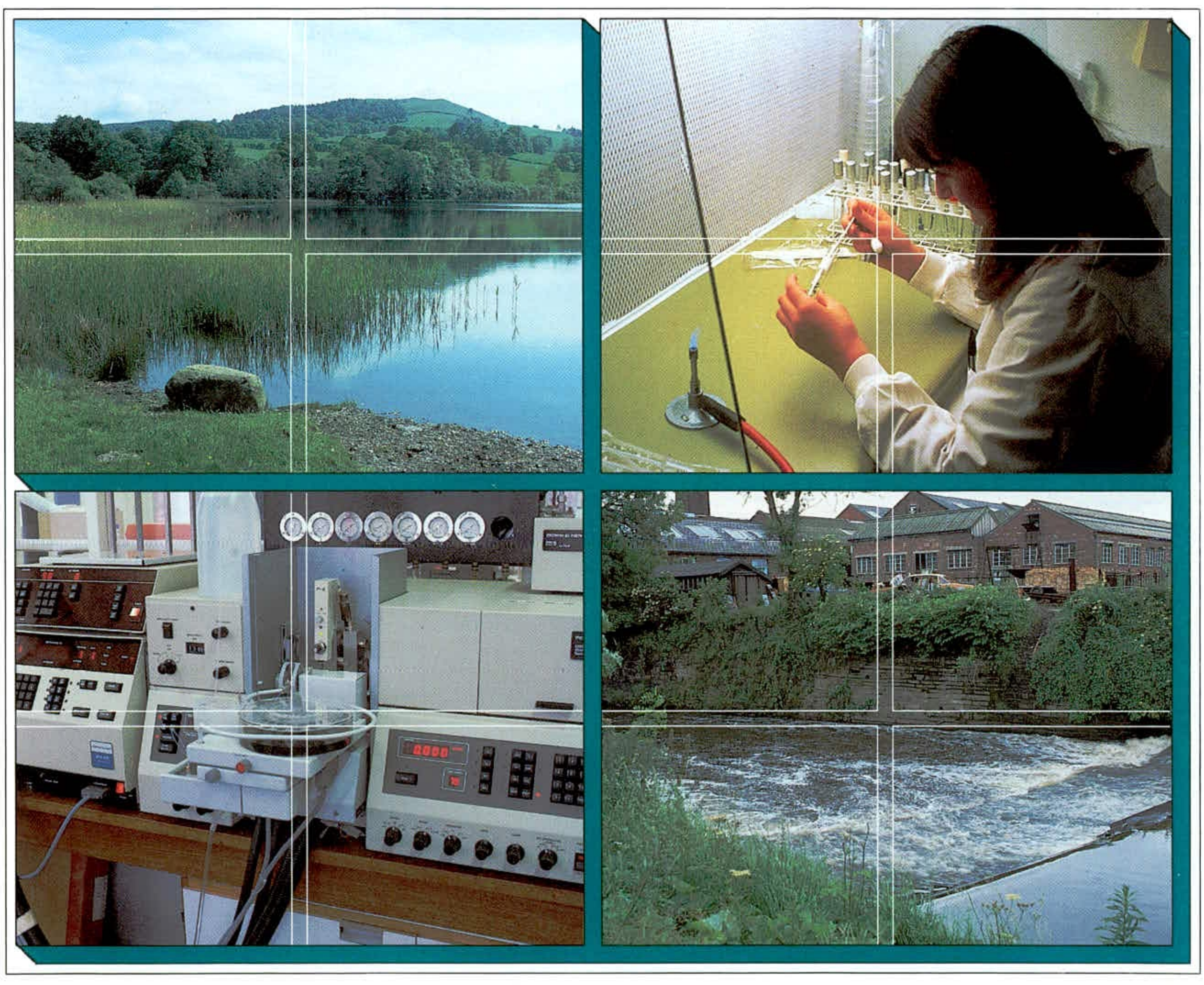
Report To: Gibb Environmental
Project No: T04050U7
IFE Report Ref.No: RL/T04050U7/2



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This report makes its recommendations from a state of the art understanding of the way in which aquatic systems work and is considered to represent the best advice available at the present time. However it should be borne in mind that changes in the physical and chemical properties of water are driven by a complex interaction of biological, chemical and physical processes which are still not entirely predictable and the Institute cannot guarantee that changes will occur exactly as predicted.

Executive summary.

A further study has been made of the likely physical and chemical behaviour of the lake created by the, proposed, rehabilitation of the Swinden quarry. New calculations were made for two new filling scenarios in which the lake fills with ground water over a period of either 24 years or 50 years.

Results from the heat balance models show that, irrespective of the rate of filling, the lake is likely to stratify during the summer and be completely mixed in the winter. Only during the very early stages of filling (first few metres) will the lake be completely mixed all year.

A number of different models of predicting algal productivity have been used to assess the likely trophic status of the proposed lake. Irrespective of the rate of filling, the phosphorus concentrations will limit the growth of algae. In the stratified system summer mean chlorophyll concentrations will be around 15 mg/m^3 with maximum summer levels approaching 55 mg/m^3. Blue green algae are unlikely to dominate.

The water quality of the proposed lake is likely to be good with relatively small algal blooms and insignificant deoxygenation of the bottom water.

Contents.

1. Introduction.

1.1 Sir Alexander Gibb and partners have been commissioned to assess the feasibility of rehabilitating a former limestone quarry at Swinden, Yorkshire. The proposal is to allow the quarry to fill with water from local sources. The IFE presented a report in May 1995, giving estimates for three scenarios, of the likelihood of stratification of the new water body and the likely water quality in the new lake should the rehabilitation occur.

1.2 This IFE study, commenced in October 1995, and will report on the likely stratification behaviour of the lake and the likely levels of selected water quality parameters, mainly nutrients and algal biomass for two alternative filling scenarios.

2. Basic data.

2.1 Earlier calculations assumed that the quarry would take ten (10) years to fill, using either ground-water or local streams. After this the level would be maintained by rainfall alone. The new scenarios are based on assumptions, that filling will result from ground-water alone and will take either twenty four (24) or fifty (50) years. As a result of the differential ground-water head, the rate of fill is faster towards the beginning of filling as follows:

	fill time = 24y.		fill time = 50y	
Filling stage	Average inflow (m^3/d)	time (days)	Average inflow (m^3/d)	time (days)
Lower 20m	2556	1139	1228	2370
20 - 40 m	2222	1310	1062	2740
40 - 60m	1894	1537	886	3285
60 - 80m	1704	1708	839	3470
upper 20m	1421	3066	682	6385

3. Stratification.

3.1 A simple description of the processes driving the thermal stratification of lakes is given in an earlier report (Hilton, May 1995). At the very bottom of the quarry the steep sides will shelter the lake and tend to reduce the wind speed experienced by the parts of water surface, compared to the speeds experienced at normal, local ground level. Although it is possible to estimate the wind speed in this sort of sheltered system when the topography is relatively flat, any local variation in topography (hills) will increase the variability on these estimates to such an extent that only the most sophisticated of models is likely to make remotely realistic estimates of the wind speed in the depths of the quarry. However, the wind speed is not the only factor controlling mixing and stratification. The density differential which can develop between the top and bottom waters is a major factor controlling the development of stratification. In the absence of saline inflows with a very different density to other water sources, the density difference results from temperature differences induced by climatic change throughout the year. As a result, at some point in the year the temperature of the surface water (assuming stratification has occurred) will cool down and approach the temperature of the bottom water, so that the density differential is very small making the system unstable. Hence, once the water depth is large enough to allow stable stratification to develop then the lake will overturn in the autumn, irrespective of the wind speed. Even if we assume from expérience that the wind speed at the bottom of the quarry is about half that at the quarry top, the only effect will be to extend the period of stratification slightly, not to allow the development of continuous stratification.

3.2 Below about 3 m depth, the lake will be too shallow to stratify and will remain mixed all year round. Up to about 15 metres deep it will stratify for a few days at a time before re-mixing. These estimates will hold irrespective of the filling period.

4. Effects of algal growth on water quality.

4.1 Estimates of the likely water quality changes in the quarry for two filling scenarios and one full scenario were given in a previous report (Hilton, May, 1995). A number of possible empirical equations for the estimation of chlorophyll levels were discussed. Since, during the filling stage no water will exit the lake, retention times will approach infinity. Under these circumstances not all the available equations are soluble and only those estimators using the lake nutrient concentration as the predictor are useable. Physical and chemical data used for the estimation of likely water quality are given in table 1.

Table 1 Physical, chemical and hydrological properties of Swinden Quarry.

Location Grid ref. = 3980E 4615N Latitude = 54.054 N; Longitude = 2.000 W
Final lake level = 193 m AOD

	Volume (m^3)	Area (m^2)	Length (m)	Width (m)	Mean depth (m)
Bottom to 80m :	11 644 000	145 550	510	285	80
each bottom 20m:	2 911 000	145 550	510	285	20
top 20m :	4 356 000	270 000	900	300	20
total volume	16 000 000	270 000	900	300	59.25

Section	flow rate (1000 x m^3/a)		Diss. P mg/m^3	NO_3-N mg/m^3	NH_4-N mg/m^3	Tot-N mg/m^3
fill time (y)	= 24y	=50y				
lower 20m	933	448	40	1300	450	1750
second 20m	811	388	40	1300	450	1750
third 20m	691	323	40	1300	450	1750
fourth 20m	622	306	40	1300	450	1750
final stage	519	249	40	1300	450	1750

4.2 Since, in both the new scenarios (24y and 50y filling times) only a single inflow (ground-water) is envisaged, the predicted biomass will be the same for all five stages of filling for both scenarios. The results are the same as for the 10y ground-water filling scenario. The predicted summer mean biomass levels with P-limitation = 15 mg/m^3 and with N-limitation = 112 mg/m^3. Maximum annual biomass levels with P-limitation = 55 mg/m^3 and with the light limitation range between , 269 and 395 mg/m^3.

4.3 On the basis of these predictions is it possible to say that the summer mean concentrations of chlorophyll a will be about 15 mg/m^3 with maximum levels of approximately 55 mg/m^3.And that nitrogen fixing blue - green algae are unlikely to dominate the flora.

5.Conclusions.

5.1 Except for the first few metres of filling, the lake will stratify thermally from about May to September, both during its filling stages, irrespective of the filling time (10, 24 or 50 years) and when full.

5.2 Phosphorus concentrations in the lake will determine the maximum algal populations which occur during filling.

5.3 Neither light nor nitrogen will growth limiting during filling.

5.4 During filling with ground water,summer mean chlorophyll levels will be about 15 mg/m^3 with maximum summer levels up to 55 mg/m^3.

5.5 Nitrogen fixing blue green algae will not be a problem during filling with ground-water alone.

5.6 Algal populations are likely to be over-estimates as phosphorus concentrations in the inflows were only reported as being <40 mg/m^3.

5.7 The thermal stability of the lake will be the same irrespective of the length of time of filling and the choice of the available water sources.

5.8 The water quality in the lake is independent of the time of filling and only depends on he source of water.

5.9 Because chlorophyll levels will be low and the hypolimnion (bottom water) volume will be large, oxygen levels in the bottom water will remain high.

6. Recommendations.

6.1 The client should not be concerned about large uncertainty in the estimation of filling times, since the rate of filling of the lake affects neither the stratification behaviour nor the water quality,

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