Proceedings of the 13th Annual British Columbia Mine Reclamation Symposium in Vernon, BC, 1989.
The Technical and Research Committee on Reclamation

PRACTICAL SEDIMENT POND DESIGN WITH THE USE OF FLOCCULANTS

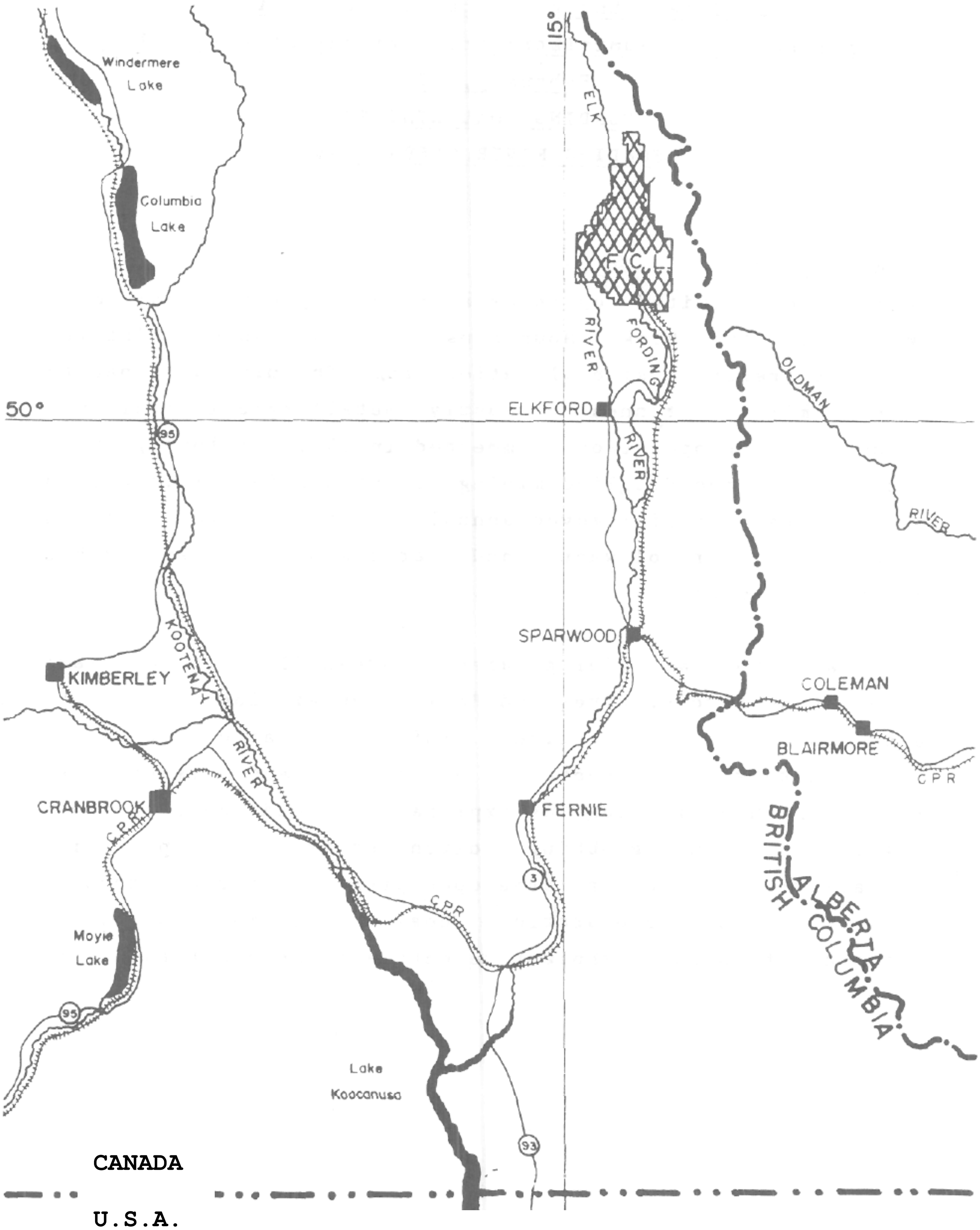
Ron Jones, Environmental Control Officer
Roger Berdusco, Administrator, Environmental & Geology
February, 1989
FORDING COAL LIMITED
FORDING RIVER OPERATIONS

INTRODUCTION

Fording *Coal* Limited operates a large, open pit coal mine located in the Rocky Mountains of southeastern British Columbia (refer to site location map). The mine's capacity is 6.0 million tonnes of mostly metallurgical coal per annum. Mining operations commenced in 1972, employing both truck/shovel and dragline mining techniques in multiple seam pits. Total material moved annually is forty-eight million bank cubic meters of waste and over six million bank cubic meters of raw coal.

There are two main mining areas: Greenhills on the west side of the Fording River and Eagle Mountain located on the east side. The active mining operation occupies approximately 2,300 hectares of land. Land disturbances include such activities as exploration, road construction, logging, clearing, grubbing, ditch construction, powerline installation, mining in large open pits, waste rock dumping or spoiling, coal preparation, coal stockpiling, and waste disposal of coarse washplant rejects and washplant tailings.

FORDING RIVER OPERATIONS
AREA LOCATION MAP



This large land disturbance has the potential to cause erosion and elevated sediment discharge into the Fording River. To minimize sediment discharge into the Fording River, Fording Coal Limited operates six large settling ponds, several smaller catch basins, and twelve kilometres of diversion ditches.

This paper discusses Fording Coal Limited's approach to manage suspended solids discharge from the mining area. The theoretical aspects of sediment settling rates, results of laboratory testing on minesite sediment samples, and the application of both theory and laboratory tests to develop practical sediment pond designs, are reviewed.

SEDIMENT PARTICLE SIZE & THEORETICAL SETTLING RATE CHARACTERISTICS

Settling ponds and smaller catch basins are used to remove suspended solids in contaminated water. The ponds retain the water for a sufficient period of time called "detention time" so that the sediment particles can be removed by gravity settling. A particle that has a specific gravity greater than water will accelerate downward until it reaches a constant velocity. This settling rate velocity is dependent on factors such as the particle's size, shape, and mass, and water temperature, turbulence, and viscosity.

Based on the Canadian Soil Survey Committee (C.S.S.C.) classification, a sand particle size is 0.05 to 2.0 millimeter (mm). Particles in this size range should require less than ten minutes to settle one meter. Usually silt particles in the size range of 0.01 to 0.05mm require approximately 1 to 1 1/2 hours to settle. Fine silt particles in the size range of greater than 0.002 to 0.02mm require up to 24 hours. Coarse clay particles in the size range of 1 to 2 microns may require greater than 36 hours for settling. Fine clay or colloidal size particles of less than 1 micron may remain in suspension indefinitely.

THE PROBLEM OF "FINE SEDIMENT TREATMENT"

Silt size sediment particles of greater than 0.01mm can be treated in a settling pond by plain sedimentation or gravity type settling. This can be accomplished by constructing a reasonably sized 6-10 hour detention time settling pond at moderate capital cost. However, sediment particles that are "fine",(less than 0.01 to 0.001mm in size), require treatment in 36 hours or greater detention time settling ponds. These large structures have a usable water volume 3-6 times larger than a 6-10 hour pond, and can require a capital outlay 6 times greater. The problem of cost effective treatment of this fine sediment size fraction prompted Fording Coal to investigate the use of flocculants and develop a "Practical Sediment Pond Design,"

MINESITE HYDROLOGY

The 30 year normal precipitation average is *725mm per* year at the Fording River minesite. A majority of this precipitation, over 400mm, is in the form of snowfall. This is probably due to the high elevation of 1,700 meters in the Fording Valley and up to 2,300 meters in the Eagle Mountain mining area. This snowfall usually accumulates in the Fording Valley from November to early March. Snowfall accumulates in the mountains from October to April.

Erosion and subsequent sediment problems at the minesite occur during the spring runoff from April to June. The runoff is dominated by snowmelt with the peak flows usually occurring near the end of May, as illustrated in the 1981 hydrograph of the upper Fording River in Figure 1. Although the spring runoff can peak well over one hundred times greater than base flows in winter, the duration is a relatively short period, usually 2 weeks to a maximum of 6 weeks. Maximum sediment loading in creeks usually occurs during this peak runoff period.

PROVINCIAL GOVERNMENT REQUIREMENTS

The British Columbia Ministry of Environment (M.O.E.) requires settling pond discharge contain less than 50 milligrams per liter (mg/1) or 50 parts per million (ppm) of total suspended solids (TSS). The design flow for removal of TSS in settling ponds should be the 10 year, 24 hour flood flow.

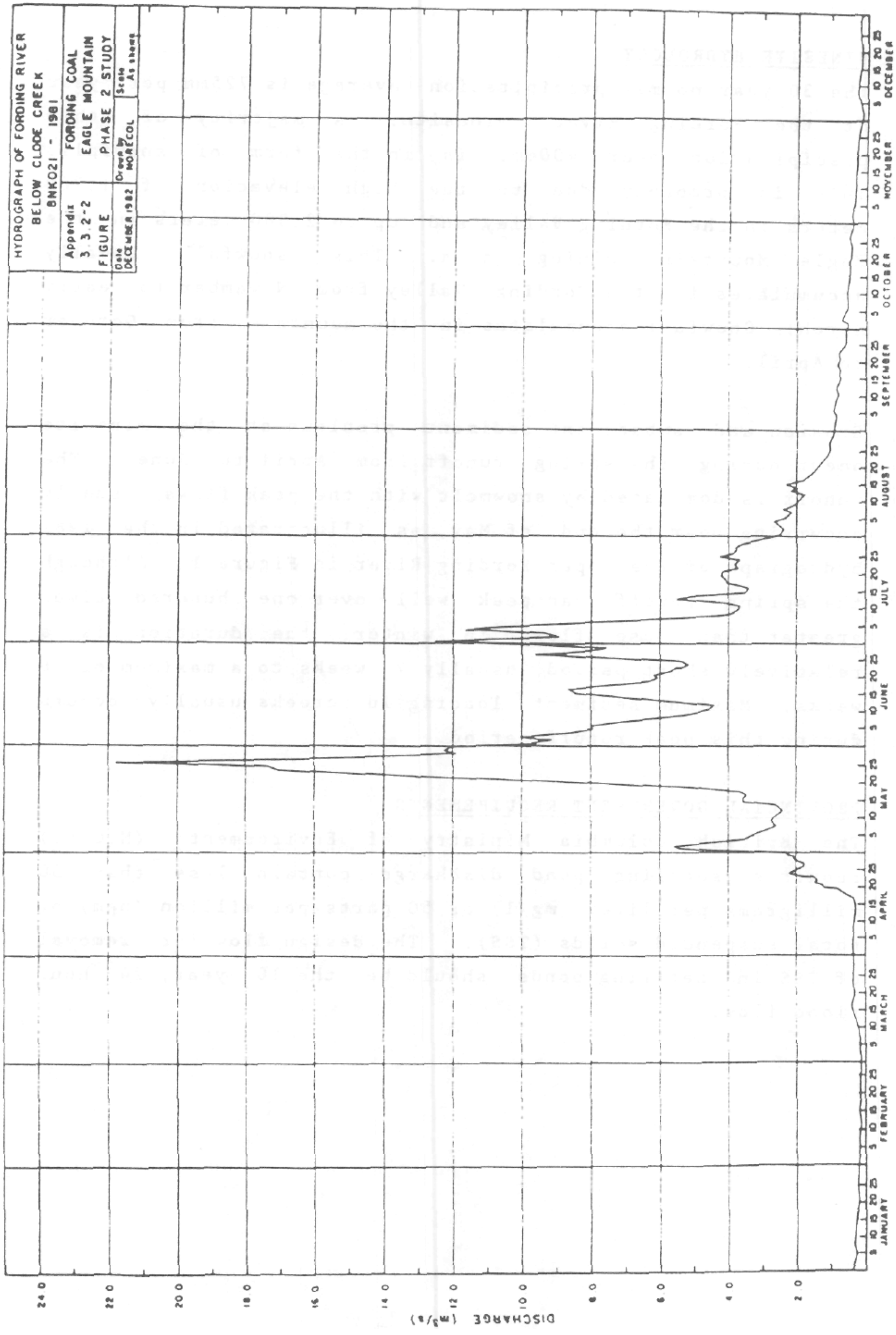

HYDROGRAPH OF FORDING RIVER
BELOW CLODE CREEK
8NK021 - 1981
Appendix
3.3.2-2
FIGURE
FORDING COAL
EAGLE MOUNTAIN
PHASE 2 STUDY
Date
DECEMBER 1982
Drawn by
NORECOL
Scale
As shown
DISCHARGE (m3/s)
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

FIGURE 1

In the late 1970's and 1980-1981, Fording Coal Limited had difficulty meeting the B.C. Ministry of Environment 50 mg/1 TSS objective during peak spring runoff at several settling ponds. In addition, many of the large settling ponds were beginning to fill up with sediment and maintenance clean-outs costs were found to be prohibitive.

LAB SEDIMENT SETTLING RATE STUDY

A study was initiated in 1980-1981 to find ways to improve existing settling pond trap efficiency (sediment removal) combined with a method or design to lower maintenance clean-out costs. This study involved sampling twelve different creeks and testing sediment settling rates using imoff cones in a laboratory situation. A "modified pipette" with a large size tip opening was used to minimize turbulence and flocculant breakage which are important factors in achieving good lab test results. Ideal settling rate tests were also carried out on sediment samples with various flocculants at different dosage rates or concentrations. The flocculants that worked best at the Fording River minesite were Cynamid magnifloc cation 587-C and anion 1849-A. The cation 587-C flocculant is added first to "coagulate" or destabilize the electrostatic charges on the individual sediment particle. Then the heavy molecular weight anion 1849-A flocculant is added to "flocculate" or agglomerate the small individual particles to form a large particle mass that settles quickly.

Proceedings of the 13th Annual British Columbia Mine Reclamation Symposium in Vernon, BC, 1989.
The Technical and Research Committee on Reclamation

OPTIMUM FLOCCULANT DOSAGE

The optimum dosage or concentration for each flocculant was determined by carrying out sediment settling rate tests in the Environmental Service's laboratory. Magnifiée 587-C optimum dosage rate in terms of quantity used/cost effectiveness is 3.0 ppm, as shown in Figure 2. Magnifloc 1849-A optimum dosage rate was also 3.0 ppm as shown in Figure 3.

IDEAL SETTLING RATES WITH AND WITHOUT FLOCCULANTS The ideal settling rate tests indicated that the majority (80 percent of the total) of incoming sediment was coarse and could be removed effectively by gravity settling in a 1-2 hour detention time, without the addition of flocculants, as illustrated in Figure 4.

Typical samples from settling pond inlets that contained high sediment concentrations were found to require very high flocculant addition rates to meet the Ministry of Environment's objective. It was observed that these large dosages did not change the coarse fraction settling rate time significantly, thereby wasting the use of flocculants (illustrated in Figure 5). However, for the fine sediment fraction that would not settle readily by gravity in 24 hours time, flocculants were proven to be effective in meeting the B.C. Ministry of Environment 50 mg/1 objective, as shown in Figures 6 and 7. Ideal settling time was reduced for the fine fraction from an excess of 24 hours to less than 2 hours with cost effective rates of flocculant addition.

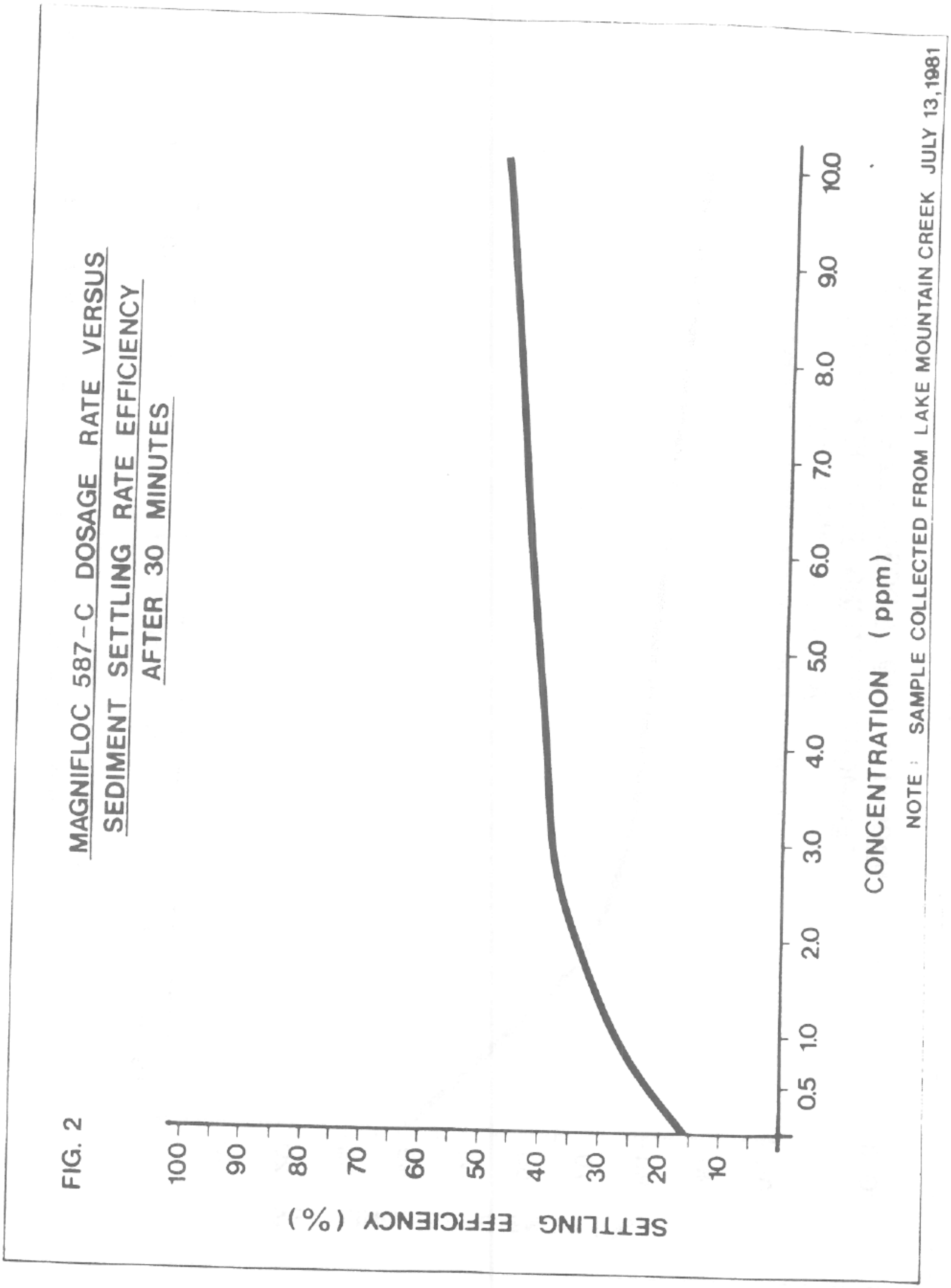
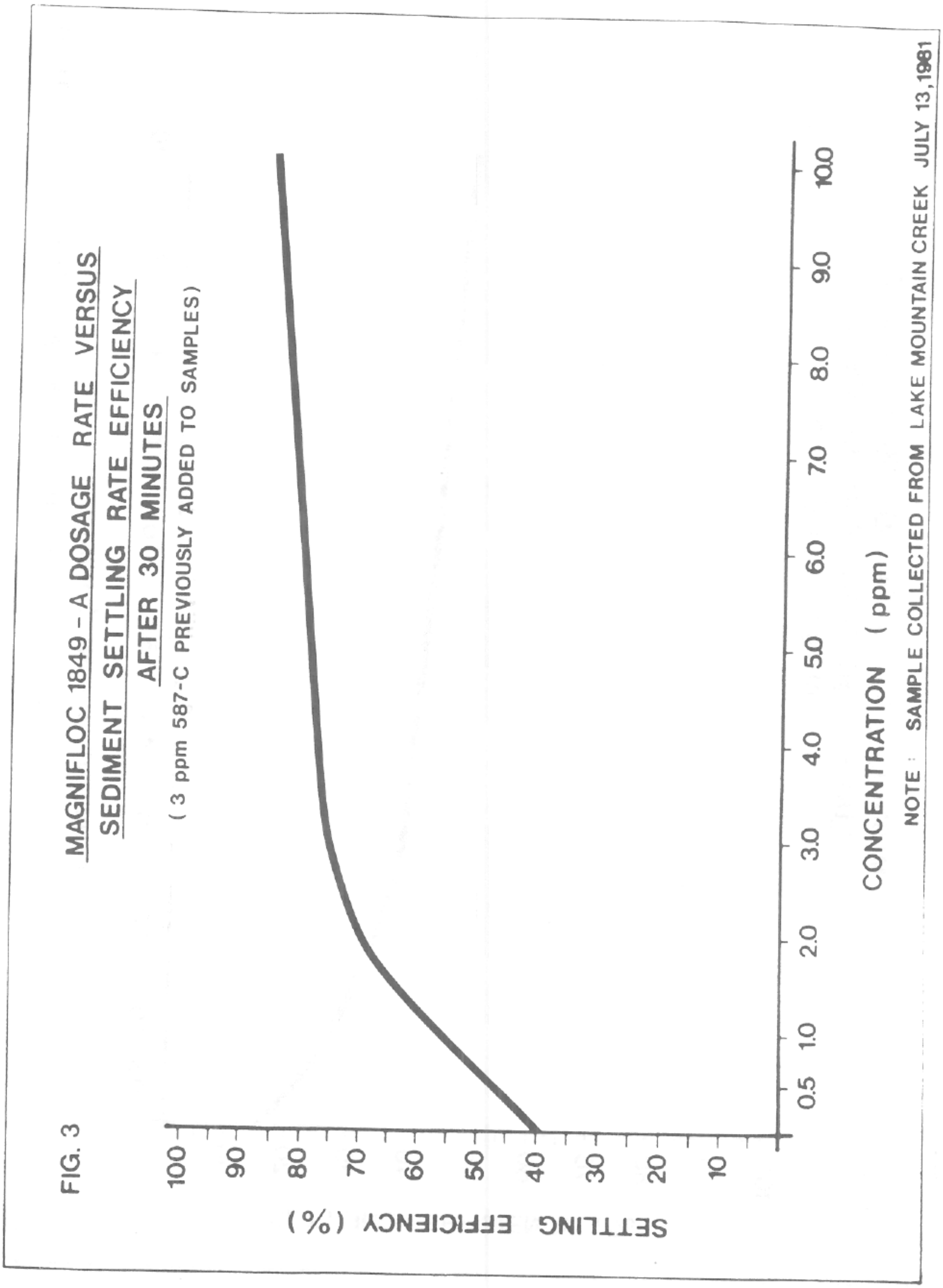


FIG. 2

MAGNIFLOC 587-C DOSAGE RATE VERSUS SEDIMENT SETTLING RATE EFFICIENCY AFTER 30 MINUTES


MAGNIFLOC 1849 - A DOSAGE RATE VERSUS
SEDIMENT SETTLING RATE EFFICIENCY
AFTER 30 MINUTES
(3 ppm 587-C PREVIOUSLY ADDED TO SAMPLES)
SETTLING EFFICIENCY (%)
100
90
80
70
60
50
40
30
20
10
0.5
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
CONCENTRATION (ppm)
NOTE : SAMPLE COLLECTED FROM LAKE MOUNTAIN CREEK JULY 13, 1981
FIG. 3

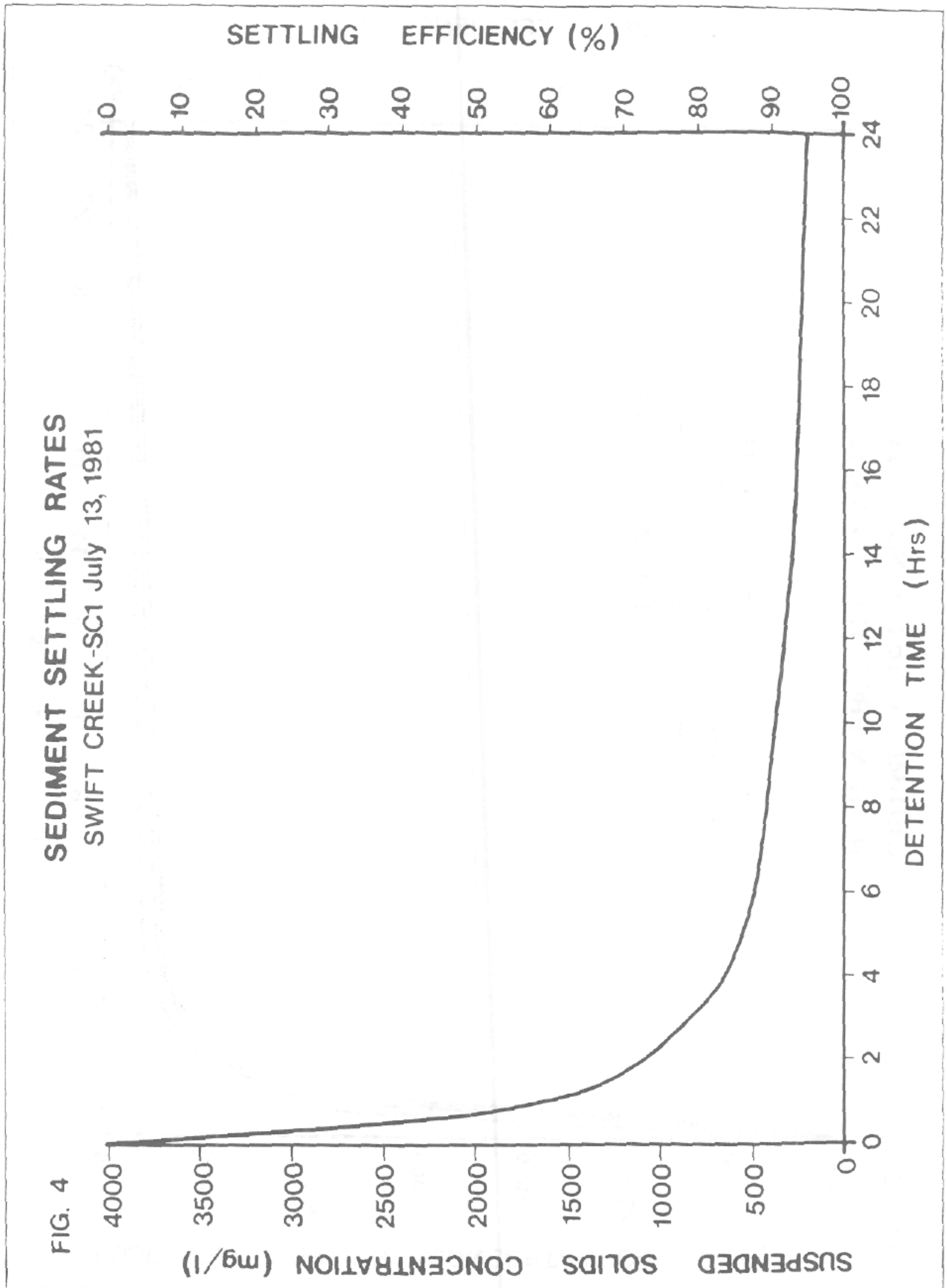

SEDIMENT SETTLING RATES
SWIFT CREEK-SC1 July 13, 1981
SETTLING EFFICIENCY (%)
0 10 20 30 40 50 60 70 80 90 100
DETENTION TIME (Hrs)
0 2 4 6 8 10 12 14 16 18 20 22 24
SUSPENDED SOLIDS CONCENTRATION (mg/l)
4000 3500 3000 2500 2000 1500 1000 500 0

FIG. 4

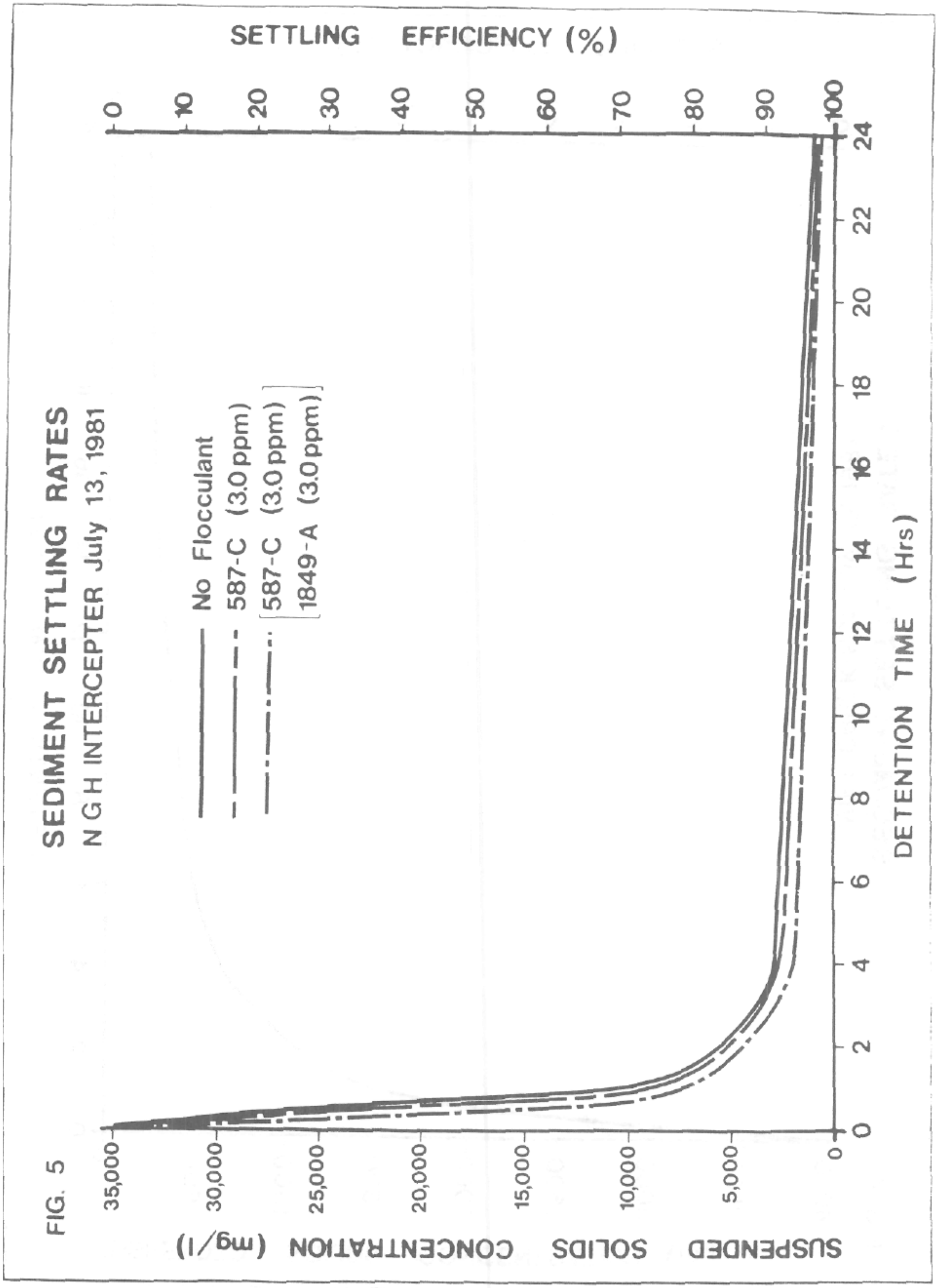

SEDIMENT SETTLING RATES
N G H INTERCEPTER July 13, 1981
No Flocculant
587-C (3.0 ppm)
587-C (3.0 ppm)
1849-A (3.0 ppm)
SETTLING EFFICIENCY (%)
0
10
20
30
40
50
60
70
80
90
100
SUSPENDED SOLIDS CONCENTRATION (mg/l)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
DETENTION TIME (Hrs)
0
2
4
6
8
10
12
14
16
18
20
22
24

FIG. 5

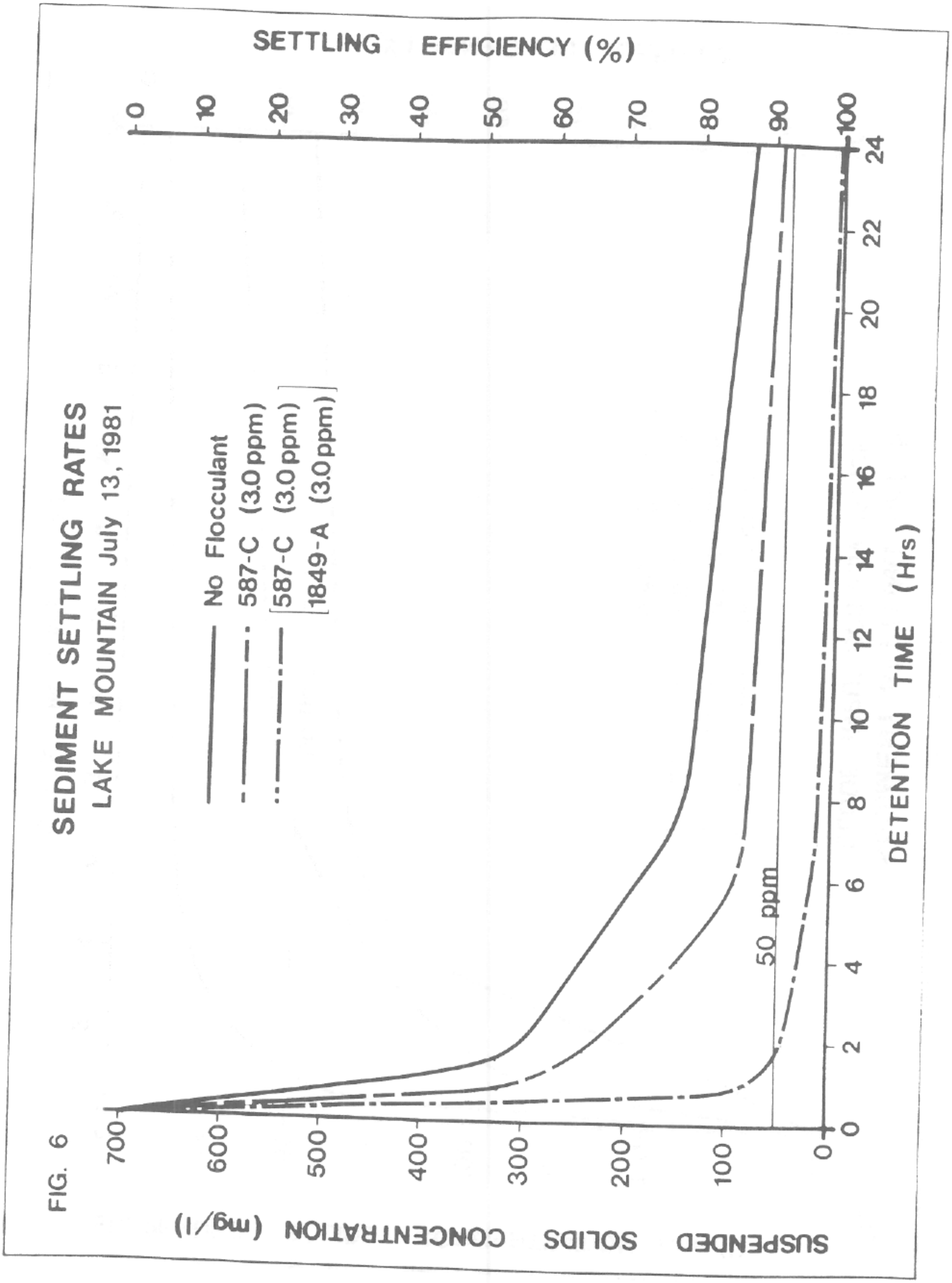

SEDIMENT SETTLING RATES
LAKE MOUNTAIN July 13, 1981
No Flocculant
587-C (3.0 ppm)
587-C (3.0 ppm)
1849-A (3.0 ppm)
SETTLING EFFICIENCY (%)
0
10
20
30
40
50
60
70
80
90
100
SUSPENDED SOLIDS CONCENTRATION (mg/l)
700
600
500
400
300
200
100
0
50 ppm
DETENTION TIME (Hrs)
0
2
4
6
8
10
12
14
16
18
20
22
24

FIG. 6

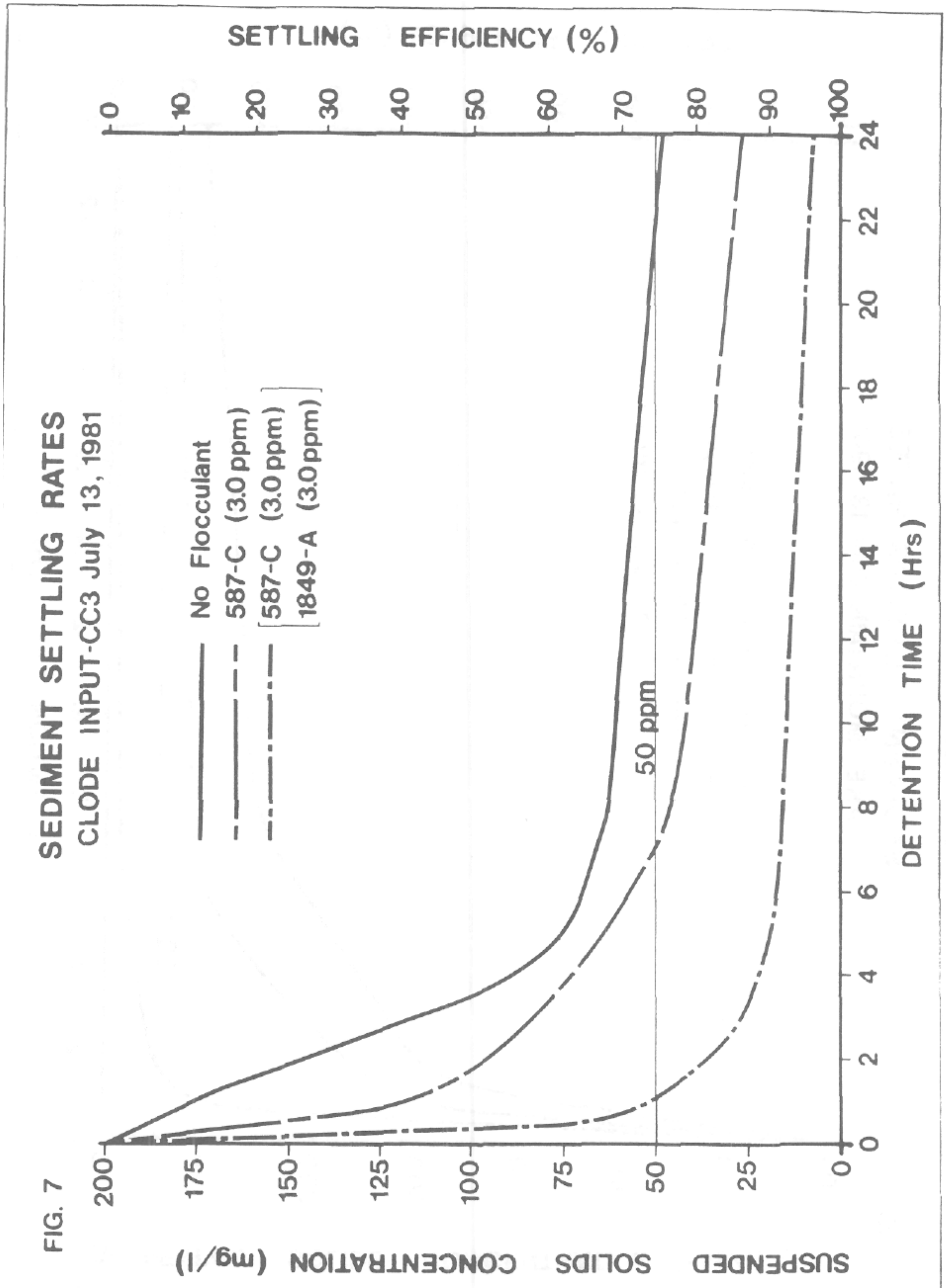

SEDIMENT SETTLING RATES
CLODE INPUT-CC3 July 13, 1981
No Flocculant
587-C (3.0 ppm)
587-C (3.0 ppm)
1849-A (3.0 ppm)
SETTLING EFFICIENCY (%)
0 10 20 30 40 50 60 70 80 90 100
SUSPENDED SOLIDS CONCENTRATION (mg/l)
200 175 150 125 100 75 50 25 0
DETENTION TIME (Hrs)
0 2 4 6 8 10 12 14 16 18 20 22 24
50 ppm

FIG. 7

NON-IDEAL SETTLING RATES IN SEDIMENT PONDS

The settling time for treatment of the "fine fraction" with flocculants is 2 hours, as determined in the laboratory under ideal conditions. But what is this 2 hour ideal settling time equivalent to in a non-ideal situation such as an actual settling pond?

B.C. Ministry of Environment recommend in their "Draft Guidelines for the Design and Operation of Settling Ponds Used for Sediment Control in Mining Operations", 1980, that a multiplier of 1.2 be applied to allow for non-ideal settling in actual pond design. A further correction factor of 1.25 should be applied at the Fording River Operation's minesite sediment ponds to correct for the colder pond water temperature of 5-10 C versus lab temperature of 20-22 C. Thus a practical correction factor for the settling rate tests conducted in the lab and then applied to actual Fording Coal Limited settling ponds is:

1,2 x 1.25 -= 1.5 к 2 hours - 3 hour detention time with flocculants

FORDING COAL LIMITED'S SEDIMENT POND DESIGN

The basic design of Fording Coal Limited's settling pond consists of the following, as illustrated in Figure 8.

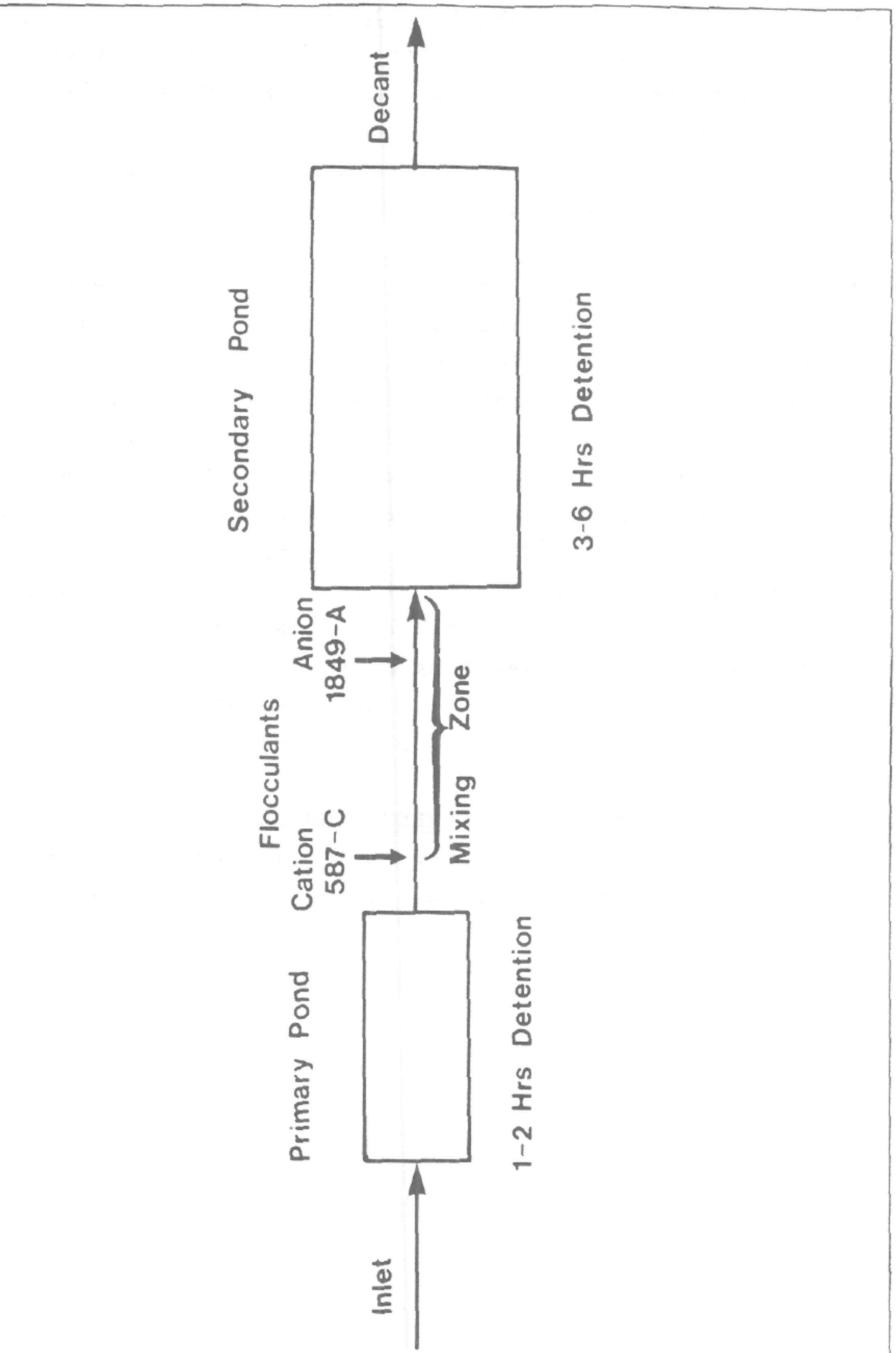


FIG. 8 FORDING COAL SEDIMENT POND DESIGN

1. Primary Pond

The first pond is small in size, with approximately 1-2 hours detention time and is used to trap the incoming coarse fraction (silt and sand size range > 0.01mm) *of* sediment. An average of 80-90% of the total inlet sediment load is removed by the primary pond without the use of flocculants. This pond is specifically designed to be dewatered and cleaned out at a low cost. This may be accommodated by providing access for equipment to remove sediment and providing alternate routes for incoming water during maintenance. The discharge from this pond contains only the fine suspended sediment fraction.

2. Mixing Zone

The length of channel that connects the primary pond with the secondary pond is considered the Mixing Zone for flocculants. First the cation and then the anion are added to enhance settling of the fine fraction carried over from the primary pond. Tests indicate a 2-5 percent grade range is ideal for mixing flocculants. Excessive grades may overshear the flocculants, resulting in lower settling rates. Lab mixing tests also indicate that a time of 30 seconds to 3 minutes appears adequate for mixing the 587-C and 1849-A flocculants at moderate speed. There is a slight improvement in settling efficiency with the longer mixing time period of 3 minutes versus the 30 second mixing time, especially for the heavy molecular weight anion 1849-A polymer.

3 . Secondary Pond

The second pond is large in size, with an approximate 3-6 hour detention time. It is used to trap the fine fraction consisting of fine silt down to clay (0.01 to 0.001mm) with the use of flocculants. Pond length to width ratios should be a minimum of 2:1 and ideally 5:1 to avoid short circuiting and dead space problems.

Fording Coal Limited's existing settling ponds have been upgraded to the primary/secondary pond system, and newly constructed ponds are also designed with two ponds and flocculant addition. The settling ponds very seldom exceed the B.C. Ministry of Environment T.S.S. 50 mg/1 objective and maintenance costs for clean-out of the sediment are much reduced.

Fording Coal Limited's more recent settling pond design includes provision for infiltration and/or exfiltration through in-situ alluvial sand-gravels beneath the pond dike. This design is more effective in removing the fine fraction of sediment and also reduces the capital costs of settling ponds by subsequent downsizing.

February, 1989

:pp

REFERENCES

1. Cheremisinoff, P.N. and Young, R.A. - "Pollution Engineering Practice Handbook", Ann Arbor Science Publishers, 1976.

2. Chow, V.T., "Handbook of Applied Hydrology", McGraw Hill Inc . , 1964.

3. Ettinger, P.E., "Development of Methods to Improve Performance of Surface Mine Sediment Basins Phase *I*", Skelly and Lay Consultants on behalf of United States Environmental Protection Agency, 1980.

4. Gibbs, R.J. and Konevar, L.N., "Effect of Pipetting on Mineral Floes", Environ. Sci. Technology Vol. 16, No. 1, 1982.

5. Goldman, S.J. et al, "Erosion & Sediment Control Handbook", McGraw Hill Inc., 1986.

6. Howie, H.J., "Draft Guidelines for the Design and Operation of Settling Ponds Used for Sediment Control in Mining Operations", Province of British Columbia, Ministry of Environment, 1980.

7. Jones, R.G., "Erosion & Sedimentation Control Strategy", Fording Coal Limited, 1980.

8. Kyca, K.P., "An Evaluation of Flocculant Dosages Applied Suspended Solids in Water", 1981. Fording Coal Limited.

9. McKeague, J.A., "Manual on Soil Sampling & Method of Analysis", Second Edition, 1978. Canadian Society of Soil Science.

10. Merritt, F.S,, "Standard Handbook for Civil Engineers", McGraw Hill Inc . , 1976.

11. Syme, D.T., "The Optimum Mining Speeds & Mixing Times for Magniflocs 587-C & 1849-A", 1982. Fording Coal Limited.