SURFACE MINE RECLAMATION

AS AN ABATEMENT PROCEDURE

The practice of backfilling abandoned strip mines has a dual effect. The most obvious effect is that surface runoff is prevented, from entering the underground mine pools; an ancillary effect is that contaminated tributaries are diluted by the new influx of uncontaminated surface runoff,

The method used to study and quantify the effect of backfilling select strip mines in the study area follows.

The study area was subdivided into 17 drainage sectors; and these drainage sectors were, in turn, agglomerated into 5 drainage basins. Those drainage basins that were relevant to. the study area were the Lower Rausch Basin upstream of M, p. 8 and downstream of M. S. 8, and the Lorberry Basin.

The benefits derived from backfilling, that is, increased amounts of surface runoff and decreased volumes disc charging from mine pools were summarized to predict the impact of the abatement procedures on the stream system's chemistry.

Finally, the costs of backfilling strip mines were compared with the benefits to determine feasibility; and a comparison with the Neutralization Impoundment Scheme was conducted, assuming a 25-year life for both schemes,

Although backfilling strip mines is a permanent solution with no annual operating costs, it will be seen that its effectiveness, in terms of abatement, is only marginal compared to a treatment scheme which has similar cost.

METHOD OF CALCULATION OF BENEFITS FROM STRIP MINE RECLAMATION

RUNOFF VOLUMES INFILTRATING MINE POOLS THROUGH INTERCEPTION BY STRIP MINES

The rational runoff equation……

$$Q = C\,i\,A$$

was used to estimate these volumes. The parameters were determined by the following techniques:

A = area of "entrapped" watershed, that is, if, strip mines, having a total area of 5 acres, surround 50 acres of watershed, the "entrapped" area is 50 acres. Entrapped watershed areas are designated by colored borders on the Strip Mine Location Map.

i = total rainfall from June, 1970 through May, 1971. The total annual rainfall was used because little is known about the time of concentration in the underground mine pools. Therefore, all rate parameters were based upon a calendar year.

C = interception coefficient = 0.45

losses - 0.45 - loss to evaporation and transpiration

0.10 - runoff coefficient

METHOD OF CALCULATION OF BENEFITS PROM STRIP MINE RECLAMATION

RUNOFF VOLUMES AUGMENTING EXISTING RUNOFF SUBSEQUENT TO STRIP MINE RESTORATION

The equation and parameters used to evaluate the intercepted volumes was also used to determine the augmented volumes; one exception being the determination of "C”:

C = additional runoff.coefficient= 0.55
ambient runoff coefficient = 0.10
loss to evapotranspiration = 0.35

The difference in the loss values for evaporation and transpiration is a result of decreased evaporation resulting from increased surface vegetation (part of the restoration procedure). It is assumed that transpiration losses will not increase significantly due to the type of vegetation used (coniferous trees) for restoration.

CALCULATION LIMITATIONS

The method of determining which of the 17 drainage sectors contribute their intercepted waters to a particular mine pool is limited due to inadequate and antiquated information concerning the extent of underground mining operations. Barrier pillars, which formerly isolated the mine pools, now have numerous breaches.

For these reasons, the destination of the surface waters that infiltrate underground mine pools via strip mines can only be crudely determined, and the credibility of the calculated results can be questioned.

Surface runoff augmentation, on the other hand, has a ready solution. The interruption of surface runoff can be studied using topographic-maps and the calculated results bear the same credibility acquired using any rational runoff technique.

In the Lorberry Basin, an estimated 30.5 million gals./yr. are presently entering mine pools. The predicted volume of runoff after restoration of strip pits is 50 million gals./year. This indicates an unaccounted balance of 19.5 million gals./yr. of runoff. The destination of these volumes is as follows: 9.1 million gals./yr. is lost to evaporation. Decreased evaporation is expected with the elimination of surface pooling and the vegetating of barren areas.

Runoff from the area North of Panther Head to the Stumps Run area (95 acres approx.) is entering strip mines and percolating through the porous glacial material into the surrounding water table. The eventual destination of these waters is the Lorberry Creek. Estimated volumes lost to these strip mines are approximately 6.7 million gals./yr.

Runoff entering two parallel strip mines located at the summit of Panther Head gravitates to a small isolated mine pool of undetermined volume. The runoff intercepted from this area (approx. 50 acres) is approximately 3.7 million gals./year.

SUMMARY

BASIN: LORBERRY

AREA OF STRIP MINES: Approx. 52.55 acres

ENTRAPPED AREA: Approx. 600 acres (Plate II - red area)

VOLUMES PRESENTLY ENTERING MINE POOLS:

IN THIS BASIN..

Volumes (approx.)	Percent
16 million gals./yr.	0.8%

IN OTHER BASINS....(Lower Rausch Basin-downstream of Measuring Station #8)

Volumes (approx.)	Percent
14.5 million gals./yr.	0.5%

VOLUMES SUPPLIED AFTER RESTORATION:

Volumes (approx.)	Percent
50 million gals./yr.	2.46%

TOTAL RESTORATION COSTS: $361.000

INCREASE IN TOTAL BASIN DISCHARGE: 1.66%

DECREASE IN CHEMICAL CONCENTRATION: 2.03%

In the Lower Rausch Creek Basin. in the area upstream of Measuring Station #8. 64 million gals./yr. are presently entering mine pools The predicted volumes of runoff after restoration of strip-pits are 88 million gals./year. The balance to be accounted for is 24 million gals./year.

Decreased evaporation will allow an additional runoff volume of 16 million gals./year. 8 million gals./yr.. resulting from 290 acres of "entrapped watershed" located immediately north of the Study Area's north boundary. is intercepted by a series of strip mines parallel to. and south of. the Reading Railroad Co. track bed. These pits are numbered 278. 279, 280. 281. 293. 294. 380. 381. 382. This area was included in the analysis. because the runoff is impounded in these pits and "scavenged" by a coal processing operation which discharges its excess waters within the Lower Rausch Creek Basin. Restoration would redirect these waters to the Good Spring Basin.

SUMMARY

BASIN: LOWER RAUSCH - UPSTREAM OF MEASURING STATION #8

AREA OF STRIP MINES: 100.35 acres (approx.)

ENTRAPPED AREA: 1200 acres (approx.) (Plate II - pink area)

VOLUMES PRESENTLY ENTERING MINE POOLS:

IN THE BASIN....

	VOLUMES (approx.)	PERCENT
	22 million gals./yr.	4%

IN OTHER BASINS.... (Lower Rausch Basin-downstream of M.S.#8)

	VOLUMES (approx.)	PERCENT
	42 million gals./yr.	1.5%

VOLUMES SUPPLIED AFTER RESTORATION:

	VOLUMES (approx.)	PERCENT
	88 million gals./yr.	16.5%

TOTAL RESTORATION COST: $974.000.

INCREASE IN TOTAL BASIN DISCHARGE: 11.5%

DECREASE IN CHEMICAL CONCENTRATION:

12.2%

SUMMARY

BASIN: LOWER RAUSCH - DOWNSTREAM OF MEASURING STATION #8

AREA OF STRIP MINES: 111.87 acres (approx.)

ENTRAPPED AREA: 890 acres (approx.) (Plate II - orange area)

VOLUMES PRESENTLY ENTERING MINE POOLS:

IN THE BASIN....

	VOLUMES (approx.)	PERCENT
	24 million gals./yr.	.86%

IN OTHER BASINS.... LORBERRY BASIN

	VOLUMES (approx.)	PERCENT
	38 million gals./yr.	1.865%

VOLUMES SUPPLIED AFTER RESTORATION:

	VOLUMES (approx.)	PERCENT
	76 million gals./yr.*	2.70%

TOTAL RESTORATION COST: $740.000.

INCREASE IN TOTAL BASIN DISCHARGE: 1.35%

DECREASE IN CHEMICAL CONCENTRATION: 2.21%

* includes gain due to decreased evaporation 14 million gals./yr.

CONCLUSIONS

After a thorough study of both the costs and benefits of restoring strip-mines in the area. it was decided that this method of abatement is not economically justifiable. For the sake of comparison. the costs and the benefits of the strip-mine reclamation proposal will be compared with those costs and benefits associated with the Lagoon Neutralization Scheme.

LORBERRY BASIN

Strip-Mine Reclamation

TOTAL COSTS:	$ 361,000	
Annual Cost (amortized at 7% for 25 years):	$ 30,977	
Total Annual Cost	$ 30,977	
Percent Treatment:	2.03%	

Neutralization-Impoundment

Total Cost:	$ 171,000	-Operating Cost: $ 21.300/year
Annual Cost (amortized at 7% for 25 years)	$ 14,673	
Annual Operating Cost	$ 21,300	
Total Annual Cost	$ 35.973	
Percent Treatment	100.0%	

LOWER RAUSCH CREEK BASIN - UPSTREAM OF MEASURING STATION no. 8

STRIP-MINE RECLAMATION

TOTAL COSTS : $ 974.000.

Annual Cost (amortized at 7% for 25 years) $ 83,580

TOTAL ANNUAL COST $ 83,580

Percent Treatment: 13.2%

NEUTRALIZATION - IMPOUNDMENT

TOTAL COST : $ 104.500 Operating Cost: $ 8,800./near

Annual Cost (amortized at 7 % for 25 years) $ 8,970

Annual Operating Cost $ 8,800

TOTAL ANNUAL COST $17,770

Percent Treatment: 100%

LOWER RAUSCH CREEK BASIN - DOWNSTREAM OF MEASURING STATION #8

STRIP-MINE RECLAMATION

TOTAL COSTS: $740.000.

Annual Cost (amortized at 7% for 25 years) $ 63,499.

TOTAL ANNUAL COST: $ 63,499. Percent Treatment: 2.71%

NEUTRALIZATION IMPOUNDMENT

TOTAL COSTS: $190,380. Operating Cost: $ 15,900/yr.

Annual Cost (amortized at 7% for 25 years)	$ 16,340.
Annual Operating Cost	$15,900.
TOTAL ANNUAL COST:	$ 32,240.

Percent Treatment: 100%

TREATMENT ALTERNATIVES

(for Lorberry and Lower Rausch Creeks)

Abstract:

After extensive investigation of the nature of the waters of Lorberry and Lower Rausch Creeks, recommendations have been made for treating the acidic mine waters and preventing fresh waters from entering the deep mines via strip mines or "crop falls".

The recommendations include neutralization, impoundments, and diversions by means of lined and unlined swales to restore the acidic waters to their uncontaminated state. Complete treatment methods have been discounted mainly because of unsuitable topography at any potential location. Furthermore, due to the varying nature of the waters, complete treatment is not conducive to optimum pollutant removal.

When contemplating these recommendations, the following criteria were carefully considered:

a) first, the physical nature of the streams. This section of study covers the flow characteristics of the waters, the condition of the streambed, and the character of the terrain in the immediate vicinity of the stream.

b) second, the chemical nature of the stream. Assessment of the four (4) major. contaminants in acid mine water with their respective effects on the biota and plant life provided conclusive information as to the size and type of treatment facilities.

c) third, the water usage within the basins.. This information is necessary to provide treatment where it will be the most beneficial to all concerned.

LORBERRY CREEK

Physical Nature:

Lorberry Creek is characterized by rapids at frequent intervals from its headwaters at Rowe Tunnel to the south where it joins Lower Rausch Creek. These rapids have abetted in natural aeration of the stream and subsequent deposition of "Yellow Boy" - an orange-yellow slime containing predominantly ferric hydroxide ($Fe(OH)_3$) and ferric sulfate ($Fe(S04)_3$) - on the rubble-strewn stream bottom. From Panther Head, an anticlinal nose of Sharp Mountain, to its confluence with Lower Rausch Creek, the stream flow is mildly turbulent, effecting slight scouring activity at some locations wherever the flow is constricted or accelerated due to either natural or artificial appurtenances.

The terrain adjacent to the stream ranges from that of high relief to that of a flood-plain. From its headwaters at Rowe Tunnel to a distance of approximately 150 yards downstream, the terrain is rather level east-. ward to L.R. 53029, and rather rugged and steep to the west and north. From this point southward, the stream is bounded on the east by L.R. 53029 and ;mountainous areas on the west. From the south of Panther Head to the stone bridge carrying L.R. 53029 over Lorberry Greek, the terrain is rather flat with the area 100 yards upstream from the bridge being the site of an abandoned colliery. Downstream from the bridge to the box culvert under relocated L.R. 53029 the terrain is gently sloping and the area is sparsely populated. Further to the south, to the confluence with Lower Rausch Creek, the, lands are within the right-of-way of Interstate Highway Route 81, except for minor areas.

Chemical Nature:

The chemical nature of Lorberry Creek was studied from four aspects: suspended solids, iron, sulfate, and acidity.

Suspended Solids - When a large charge of putrescible material is discharged into a clean stream, the waters become opaque, and the green plants, which by the process of photosynthesis, remove carbon dioxide from the water and release oxygen to it, are forced to die. Scavenging organisms remain, which increase until their demand reaches the available oxygen supply. Decomposition occurs and a change from biological to chemical degradation occurs. The higher forms of aquatic life (game fish) are very sensitive to these changes and frequent "shocks of this variety make these streams uninhabitable. Lorberry Creek has two sources that "slug" the stream with suspended materials. Both sources are active mining operations, S-342 and S-343. (For locations, see Plate I Base Map)

Iron The amount of dissolved iron present in the stream waters is dependent on the amount of oxygen contained, as well as the pH of the water. When ferrous iron (Fe++) is changed to ferric iron (Fe+++) through aeration, a precipitate is formed. Iron in the ferrous state represents C.O.D. (Chemical Oxygen Demand), robbing oxygen from other organisms. Ferric iron (Fe+++) is found as an insoluble salt, harmless to biota unless sufficient quantites arise so as to produce the same effect as that found with suspended solids. In Lorberry Creek there are significant amounts of ferrous iron (Fe++) being changed to ferric iron (Fe+++) by natural aeration caused by the rubble-strewn stream bottom. This action, however, has caused large amounts of the insoluble iron salt to be deposited upon the stream bottom. The amount of iron removal through the process of natural aeration and adsorption in Lorberry Creek is approximately 66 percent.

Acidity - the acidity of a stream is related to the pH of its waters. As noted previously, iron transformation from soluble ferrous to insoluble ferric compounds is dependent upon both aeration and pH. However, pH is the prime determinant; a unit increase in pH increases many times the rate of reaction of the transformation of ferrous iron to ferric iron. Neutralization acquires a significant role in iron removal and subsequent reduction of C.O.D.

Lorberry Creek's alkaline demand (acidity) ranges from 15 to 45 ppm of $CaCO_3$ (measured at is confluence with Lower Rausch Creek. The volume of acid waters flowing from Rowe Tunnel (measuring Station #4,constitutes 60% of the total flow of Lorberry Creek), contains a range of 50 to 10Q ppm acidity (measured as $CaCO_3$). These waters are partially diluted by the unmarked stream (measuring Station #9) whose waters originate in the State Game Lands. Notable additions to the acidity of Lorberry Creek are sources S-61 and S-62 (for location see Plate I - Base Map). Sources S-61 discharges less than 0.5% of the total flow of Lorberry Creek, but has an acidity approaching 1000 ppm.

Source S-62 discharges sporadically from deep mining operations and has an average acidity of 350 ppm.

Sulfates - The effects of sulfates on aquatic life are not as marked as those of iron. In sufficient quantities, sulfates will produce turbidity, thus making the water opaque and preventing photosynthesis. The undesirable nature of sulfate-laden water affects the highest organisms of the life chain. rather than the lowest. Man finds the odor and taste of sulfate-laden water objectionable when the sulfate level exceeds 250 ppm.

The sulfate level of 250 ppm is exceeded at only one location in Lorberry Creek.. That location is at Source S-61, which contains 350 ppm, but dilution immediately reduces this content to an acceptable load. Rowe Tunnel discharges waters having a peak load of 140 ppm, and the peak sulfate load at the box culvert (measuring Station #2) beneath relocated L.R. 53029 are 20% of the maximum 250 ppm.

Neutralization of these waters will increase the sulfates present, but should the level exceed 250 ppm, the cost of treatment versus the benefit derived does not justify the expenditure.

LORBERRY CREEK

Water Use:

The sole of supply of potable water for the inhabitants of the hamlet of Lorberry Junction is drawn from wells that reach into an aquifer located approximately 100 feet below the surface. The springs in the area are contaminated by the strip mines in the area north of the hamlet. Lorberry Creek itself is not a source of waters for industrial, municipal or domestic uses. The stream and its tributaries-only serve to carry acidic mine waters from active and abandoned mining operations. The headwaters of Lorberry Creek are at Rowe Tunnel.

This tunnel drains the abandoned Lincoln Colliery workings, and, presently, receives acid mine waters from two active operators, Sources 342 and 343. Immediately downstream from the mouth of Rowe Tunnel, several drainage swales carry the sporadic flows pumped from Source S-62.

At Panther Head, source S-61 flows continually from the drift portal via gravity. There are three "clean" tributaries to Lorberry Creek; two are sporadic the other is continuous. At the intersection of the two roads, L.R. 53029 and T-430, a corrugated metal pipe carries the waters from the first tributary. It is spring fed and flows along road T-430.

The second tributary located west of Station 92 + 98 on L.R.53029 is known as Stumps Run Creek. At periods of low flow, the stream is fed by ground water, and, at periods of high flow, the stream is fed by springs. The stream then flows south and west to its junction with Lorberry Creek. This stream is bordered on both banks by crop falls and strip mines and there is evidence of seepage into these depressions. The third tributary is one of continuous flow and serves as drainage for the State Game Lands. Its junction with Lorberry Creek is located approximately 200 yards southwest of the hamlet of Lorberry Junction. It is spring fed and flows north and east to its junction with Lorberry Creek. Its flow record is that of measuring Station #9.

TREATMENT PROPOSALS FOR LORBERRY CREEK

NOTE: For orientation purposes, the locations of the following treatment and rehabilitation facilities can be found on Plate III, Treatment Rehabilitation Scheme.

A. Complete Treatment Proposal:

This type of facility is infeasible due to the following for all proposed sites except one:

1) lack of suitable topography

2) proposed location would necessitate the complete removal of small existing developed areas.

3) rights-of-way of Interstate Highway No. 81 is in the immediate area.

The one area that would be suitable for a complete treatment facility is east from Panther Head to the stone bridge on L.R. 53029. The area is more than ample, but complete treatment is unnecessary at this location for the following reasons:

1) a typical installation provides neutralizaion, aeration, and facilities for the precipitation of solids. the streambed provides for more than sufficient natural aeration and other combinations of alternatives should be considered it would be treating unpolluted waters, (i.e., run-off, "clean" waters from measuring Station #9 from the State Game Lands, and the other two sporadic tributaries which which are also "clean" waters.)

B. Neutralization Proposal:

This proposal, along with the following impoundment proposal, provides for treatment of the waters of Lorberry Creek.

The proposed location of Neutralization Plant No. 1 for optimum utilization of the stream's natural aeration is at Rowe Tunnel. The topography of the area is conducive to a facility of this type, but provisions would have to be made downstream for the placement of impounding lagoons as the streambed is already saturated with ferric hydroxide precipitation and one cannot rely upon further adsorption of the iron salts produced by neutralization processes. The operation of the plant would have to be of a continuous nature. The waters leaving the plant would be over-neutralized to compensate for the minor acid sources entering farther downstream.

C. Impoundment Lagoons:

Lagoon Complex No. 1 is proposed for a site directly upstream from the stone bridge on L.R. 53029. The area available consists of ten (10) acres. These proposed lagoons are necessary to allow for the settlement of suspended materials and insoluble iron salts. A twolagoon scheme is proposed to allow for alternate operation.; sludge could be removed from one lagoon while the other lagoon would be in operation.

Sludge removal could be accomplished by either the use of hopper-tank trucks or by pumping methods. Disposal could be made in selected strip-mine pits approximately one-half mile north of Lorberry Junction.

These pits have an estimated capacity of forty million gallons. Hauling of the sludge does have certain disadvantages, namely:

1) the access roads in the area are too steep - thus making hauling a problem.

2) the roads are unsurfaced and subject to erosion, thus requiring perpetual maintenance.

3) the increased activity of motor trucks in the area would be detrimental to the wild life, as well as being a nuisance to the few inhabitants of Lorberry Junction and its surroundings.

The pipeline proposal includes a permanent trunk line and a branch type flexible distribution system. The trunk line would extend 2,600 feet and rise 400 feet from the Lagoon to the distribution point. The distribution system would radiate in either a "star" or "branch" pattern and consist of either excavated swales or portable open conduit.

The disposal site has few other uses since backfilling of the area is practically impossible due to the surrounding topography.

The consequences of dumping sludge into these strip-mines are not directly ascertainable. Due to the dip of the coal seams in the area, one could reasonably expect the material to permeate underground and exude at either source S-61 or S-340. If the discharge from these two sources would exhibit a significant increase due to the dumping of sludge and re-circulation, it would still not contaminate the waters south of Lorberry Junction mainly because, of the arrangement of the lagoon complex and disposal site.

PREVENTIVE PROPOSALS FOR LORBERRY CREEK

A. Flow Diversion and Re-channeling

Rehabilitation of Stumps Run Basin

1) construct levees (or embankments) on the high walls of strip-mine pits, nos. 311, 312,313,314,315,316,322,323 and 324. (these pit locations can be found on Plate 2, - Stripping Pit Locations).

2) realign and rechannel streambed for a distance of 300 yards upstream from its junction with Lorberry Greek.

3) the purpose of these actions would be to supply sufficient flow for dilution of sulfates expected with institution of sludge filling of abandoned strip mines.

4)The yield of this activity would be an additional 290 acres of watershed collection that would otherwise gravitate to the Lincoln Pool and exude at Rowe (measuring Station No. 4)

5) the reason for the modification is that the area extending 400 yards upstream of the junction with Lorberry Creek is composed of glacial till. The predominance of sandy, gravelly material and large boulders is conducive to ground water flow. When the volumes of water draining from the Watershed are low, the flow becomes submerged and comes in contact with pyritic-bearing materials. Rechanneling will cause these flows to be intercepted and realignment will reduce the runoff time, thereby diminishing the amount received by the ground water and the time that the water is in contact with the pyritic-bearing materials.

SUPPLEMENT TO NATURAL AERATION AND MIXING AT NEUTRALIZATION PLANT NO. I

In order to insure proper mixing and prompt aeration, at a point immediately following the injection of the neutralization agent (sodium hydroxide, quick lime, or pebble lime) a gravity aerator of any type should be emplaced to insure sufficient mixing and aeration. Two of the more common designs are the cascade and the inclined apron studded with riffle plates. The cascade type is such that the available fall is subdivided into a series of steps and the inclined planes type is usually studded with riffle plates set into the planes in herring bone fashion and breaking up the sheet of water that would otherwise form.

LOWER RAUSCH CREEK

Physical Nature:

The construction of Interstate Highway 81 (L.R. 1005) has left few sections of the original streambed of Lower Rausch Creek intact. The relocation procedures have left the stream banks barren and have destroyed any natural pools where game fish might have spawned.

From its source at the former Westwood Colliery Area to the box culvert beneath U.S. Route No. 209, to its intersection with Interstate Highway No. 81, the streambed has been altered by stripping operations to prevent influx of the waters into the pits. The terrain in this area is gently sloping and strewn with breaker debris. From the box culvert under U.S. Route No. 209 to the box culvert directly upstream from Measuring Station No. 12, the stream meanders through box culverts from the east to the west side of Interstate Highway No. 81. This area is mountainous and for the most part, inaccessible.

This problem is compounded by the large cut and fill banks constructed for Interstate Highway No. 81. Downstream the terrain varies, from one of being flat and then rising sharply, then of one of mild relief.

This type of terrain is typical to its point of confluence with Lorberry Creek. The flow can be considered mildly turbulent throughout, with some small rapids at frequent intervals. The stream bed is of a sandy nature and coated with "Yellow Boy" deposition.

Chemical Nature:

As mentioned previously, the chemical characteristics described can be grouped into four categories: suspended solids, iron, acidity, and sulfates.

Suspended Solids - There are two major contributors to the volumes of suspended solids content of Rausch Creek. Both are located upstream from the New Lincoln Drainage Tunnel (Measuring Station No. 8). The Madenford Dredging Operation at Westwood Mines being an active contributor, and the old Westwood Refuse Bank being its passive counterpart. During high rainfall periods, the waters carry off large amounts of material and deposit them in the creek. This bank covers 120 acres and contains seven million cubic yards of refuse material. Efforts are presently being made to stabilize the slopes to prevent future erosion.

Iron - This stream experiences some natural iron removal as evidenced by the deposition of the iron salts on the stream bottom, but there is no net decrease in iron from source to confluence with Lorberry Creek as is found in the Lorberry Basin. This is directly attributable to the interruption of ground water by Interstate Highway 81 construction which, together with runoff from stripped areas contribute over 50% of the total iron load to Lower Rausch Creek during peak flow periods. Furthermore, several mine openings were sealed with concrete slabs during the construction of the highway. During high rainfall periods, the level of the underground mine pools rise and mine water seeps under the concrete caps and permeates through the fill material, exuding along the stream banks.

There are five continuous sources that discharge iron-bearing waters constituting the remaining fifty percent of the total iron load for Lower Rausch Creek All of these operations are abandoned and are recorded as Measuring Stations 5, 6, 7, 8, and 12. M.S. 7 is the greatest contributor and M.S. 12 the least.

Sulfates - Although three of the five recorded sources exceed the maximum 250 mg/l (M.S. 6, 7 and 12), the peak sulfates at a point immediately upstream from the confluence does not exceed 200 mg/l.

Acidity - As noted before, the acidity of a stream is related to the pH of its waters. Iron transformation of soluble ferrous to insoluble ferric compounds is dependent on both aeration and pH. However, pH is the prime determinant; a unit increase in pH increases the rate of reaction of ferrous iron to ferric iron. Neutralization acquires a significant role in iron removal and subsequent reduction of C.O.D.

Lower Rausch Creek's alkaline demand (acidity) ranges from 10 ppm to 50 ppm of CaCO3 at the confluence with Lorberry Creek. The volume of acid, mine waters flowing from Measuring Station #7, which constitutes 25% of the total flow of Lower Rausch Creek, contain from112 ppm to 213 ppm of acidity. This source is the largest contributor; the next largest being from Measuring Station #11. This contributes a greater flow, (by about 2%), but the acidity ranges from 34 ppm to 75 ppm. The other contributing sources are Measuring Stations 5, 6, 8 and 12, where flows are much less in volume.

There are no alkaline sources contributing to the waters of this stream

LOWER RAUSCH CREEK

Water Usage:

There is no domestic, industrial or municipal usage of the waters of the Lower Rausch Creek Basin. The basin serves only to carry surface runoff, fresh water outfalls, and acidic mine waters.

In the Joliett-Westwood area there are three (3) fresh water dams whose overflow water is intercepted by "crop falls" or strip mines. Two (2) of these dams are spring-fed, and the third dam is a combination of being spring- and well-fed. The waters that are intercepted gravitate to the Westwood Pool. The Westwood Pool is the water supply for the Madenford Dredging Co. operation via the Westwood Deep Well Pump (Source 327). The waters used in this operation are partially recycled, with some waters being discharged into Lower Rausch Creek.
These waters are the headwaters of Lower Rausch Creek.

TREATMENT PROPOSALS FOR LOWER RAUSCH CREEK

(These treatment and rehabilitation sites are located on Plate III, Treatment & Rehabilitation Scheme)

A. Complete Treatment Proposal:

The major deterrent to a complete treatment facility is the absence of suitable area of land. Furthermore, a facility of this type cannot offer the flexibility required for the type of application necessary.

B. Neutralization Proposal:

In this basin, due to the number of frequency of pollution sources, a two-plant scheme is proposed, consisting of Neutralization Plants II and III, as depicted on Plate III.

Neutralization Plant II is to be located at the site of Measuring Station #8 to neutralize the waters from the Westwood-Joliett area and the New Lincoln Tunnel. During peak flow periods, this plant would "overneutralize" to compensate for the acidity of water flows from Measuring Station #7. At low flow, the plant's operation would be either curtailed or suspended. Neutralization Plant III is proposed to be located at the confluence of the waters of Measuring Station #12 and Lower Rausch Creek. This plant would operate continuously and treat all waters from the Creek.

This scheme, combined with the following impoundment proposal, produces clean waters at a point that is on the perimeter of the last workable coal measure. As a result, all waters flowing by this point would be treated and the unmined lands to the south of this perimeter would be restored to their original uncontaminated state.

Furthermore, the operating schedule of these plants could be varied to produce optimum pollutant removal at any rate of flow.

C. Impoundment Proposal:

Lagoon Complex II is proposed to be located 300 yards south of U.S. Route No. 209, on the east side of the northbound lane of Interstate Highway 81.

This area was formerly stripped and some backfilling has taken place. The area available for construction of the lagoons is approximately 7 acres. A two-lagoon scheme is again proposed to facilitate sludge removal. The bottom elevation of the lagoons is proposed at 1100'+ and their location close to the box culvert at Station 532+00 (under the northbound lane). This procedure of construction, in reducing the hydrostatic head, reduces the risk of damage to the box culvert and the road embankment.

Sludge Removal and Disposal could be accomplished by proposed pipeline methods, simply because the lagoon complex as proposed is inaccessible. The pipeline would extend 800 feet and rise 200 feet to its discharge into pit numbers 358, 359, 360, 361 and 362. These pits have an approximate capacity of 440 million gallons. These waters would then gravitate to Rausch Creek and New Lincoln Pools, exuding at Measuring Station 7 and 8.

Lagoon Complex III is proposed at a site approximately 100 yards south of the location of proposed Neutralization Plant III. There are approximately 15 acres available for construction of the two lagoon scheme.

It is recommended that the lagoons be placed north of the confluence of the two sporadic springs previously mentioned in the Water Usage Section. Bottom elevation of the lagoons is proposed to be 890+ to prevent any risk of damage to the embankment of Interstate Highway 81 should the lagoons seep or break. Sludge Removal would be possible with the use of trucks or pipeline, or a combination of both.

a) the trucks could haul the sludge from Lagoon Complex III along Township Road T-412 to a distribution point 500 feet south of Pa. Route 209. A gravity swale would carry the sludge from this distribution point to pit numbers 357, 358, 359, 360, 361 and 362. The capacity of these pits is approximately 440 million gallons, These sludge waters would then gravitate to the Rausch Creek Pool, exuding at Measuring Stations 7 and 8.

proposal statistics:

road T-412	light-duty, paved
hauling distance	7,000 feet

length of conduit	1,000 feet
type of conduit	open swale, gravity flow

b) using trucks alone, - the sludge would be hauled from the lagoon, along Township Road T-412, to the strip-mines via existing haul roads used during stripmine operations.

proposal statistics:

road T-412	light duty, paved
access road	rather poor, but stable having steep grades
hauling distance	approximately one mile

c) by pipeline "A" the sludge would be pumped from the lagoon to pit numbers 341, 342, 343, 344 and 345. These pits have an estimated capacity of 100 million gallons. Hauling is not practical or possible in this area due to the topography. The water from these pits gravitates to the Lincoln Pool and possible adverse effects might arise due to the presence of active operations in the area who dewater their operations. This procedure would implant additional burdens upon the pumping requirements of the active operators.

proposal statistics:

length of pipeline	3,600 feet
pumping head	400 feet

d) by pipeline "B"; by this pipeline, the sludge would be pumped to pit numbers 441, 442, 443, 444 and 446. These pits have an estimated capacity of 200 million gallons. The water gravitates from these pits to the Rausch Creek - East Franklin Pool, which excludes

Measuring Stations 5, 6 and 7. proposal statistics:

length of pipeline	3,500 feet
pumping head	300 feet

e) by pipeline "C"; by this pipeline, sludge would be pumped from Lagoon Complex III to Lagoon Complex II and then be disposed of by the method of disposal proposed for Lagoon Complex II. This system utilizes the "activated sludge method". The sludge pumped from Lagoon Complex III is used to "seed" the waters of Lagoon Complex II to promote flocculation of the suspended particles proposal statistics:

length of pipeline	6,500 feet
pumping head	200 feet

PREVENTIVE PROPOSALS FOR LOWER RAUSCH CREEK

A. Flow Diversion and Rechanneling:

Case I - A swale, preferably of a protected nature, extending from the "hook" in L.R. 53029, approximately 3,300 feet south of Joliett, to the drainage swale for the south-bound lane of Interstate Highway Route 81, would transport the waters from the south flank of the eastern nose of the Joliett Anticline. This swale would prevent the rain waters that would fall upon 270 acres from entering the heavily strip-mined area south of township road, T-625. The swale would have an approximate length of 4,800 feet.

Case II - At Westwood Mines, a swale cut around the base of the Westwood Spoil Bank would prevent theme culm and silt-bearing waters from discharging onto the surrounding countryside. The flow of waters could be diverted into Lower Rausch Creek and then be treated at proposed Neutralization Plant II and Lagoon ComplexII.

Case III - A network of swales is needed at Joliett to intercept the outfalls from the three (3) major water bodies and the numerous springs in that area.

All swales in the proposed network should be protected due to the sandy character of the soil and the abundance of "crop falls" in the area.

Special attention should be paid to Parkson StripMine, (Source 348), where many sporadic springs flow into the pit and flow to its eastern end, then fall into an unsealed abandoned drift. The water then flows to the Westwood Pool, to be pumped to the surface at Source 327.

A protected drainage swale should be constructed along the southern bank of the strip-mine (of Parkson) with the excavated material also used to construct a levee along this same edge. Furthermore, sealing of this drift is also recommended to prevent entrance of oxygen into the abandoned workings, as well as removing this safety hazard to the inhabitants of the area.

The benefits to be derived from enactment of this proposal would be as follows:

a) water prevented from entering the Westwood Mine Pool

1) from springs:

Source 165	36,000 gpd
Source 166	21,600 gpd
Source 321	21,600 gpd

2) from fresh-water outfalls:

Source 320	7,200 gpd
Source 322	28,800 gpd
Source 348	11,000 gpd
TOTAL	126,200 gpd

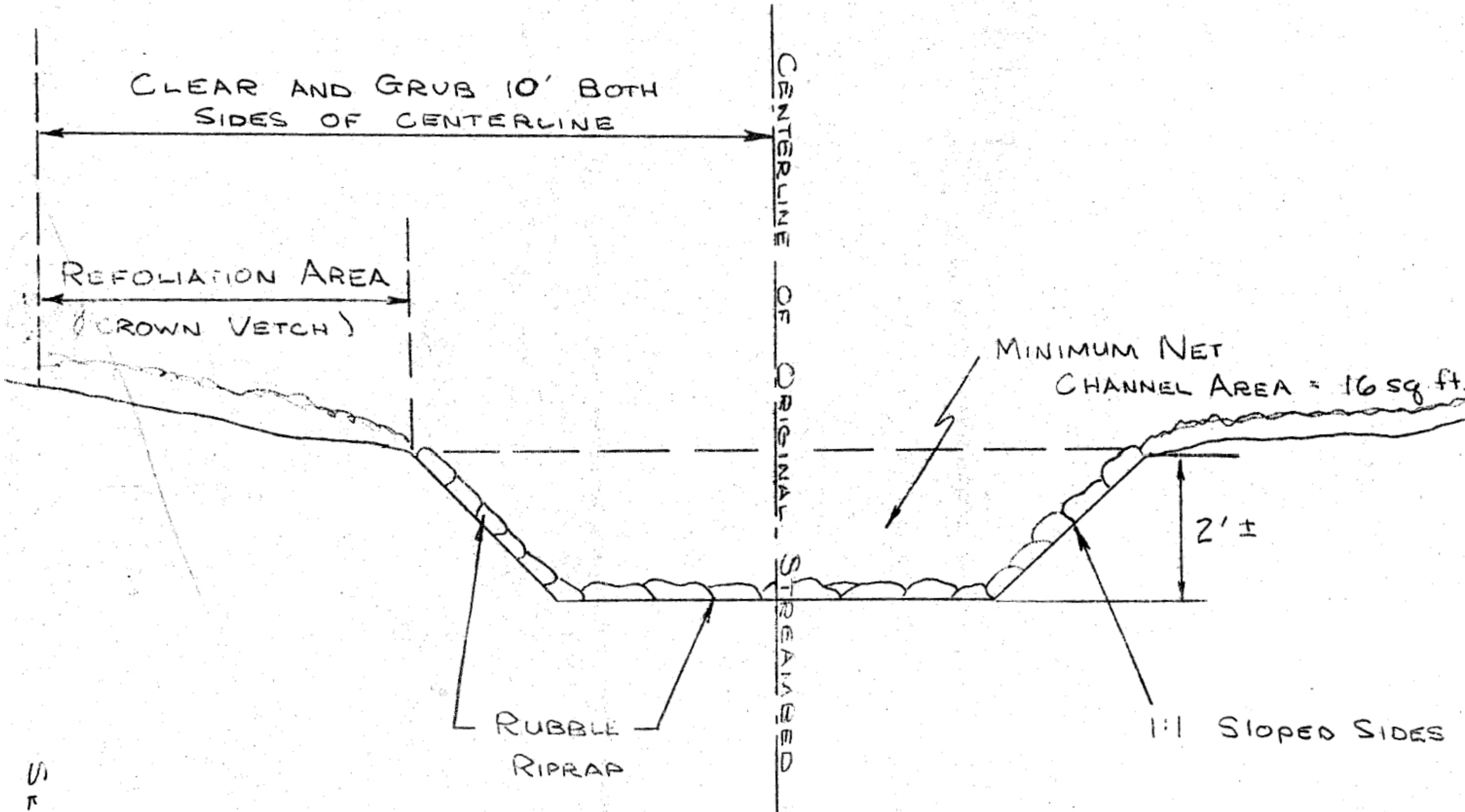
The sealing of the drift at Source 348 would reduce the iron content and acidity of the waters of Westwood Pool.

The "branch" type swale network would extend approximately 5,400 feet from the Joliett Fresh Water Dam north to Lower Rausch Creek, entering immediately downstream from the former scale house for the Westwood Colliery.

SUPPLEMENT TO NATURAL AERATION AND MIXING

The same procedure recommended at Neutralization Plant I in the Lorberry basin is recommended in the basin for Neutralization Plants II and III.

That is, a gravity aerator, of any type be emplaced to insure sufficient mixing and aeration.

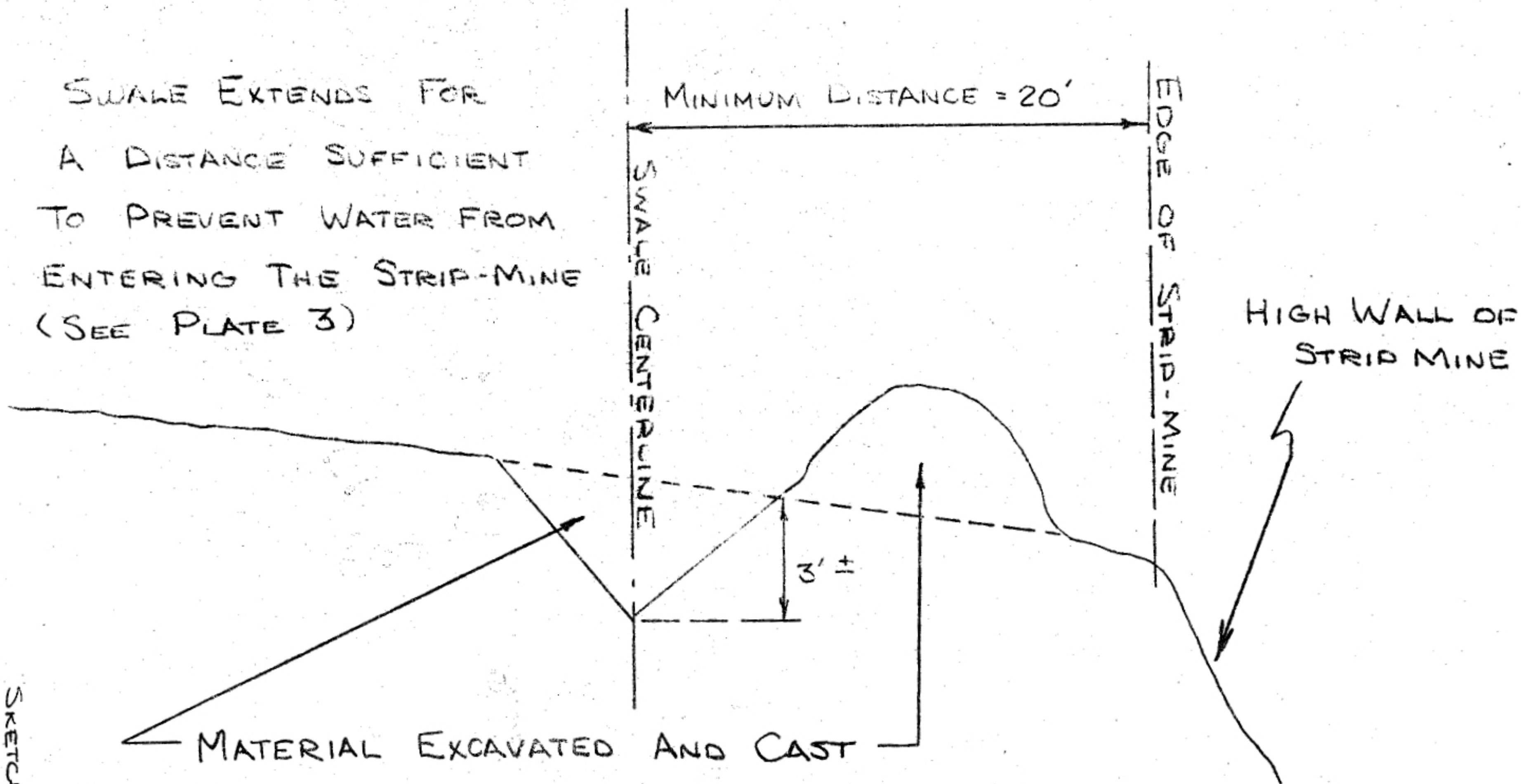


SKETCH 1

STREAM RECHANNELING

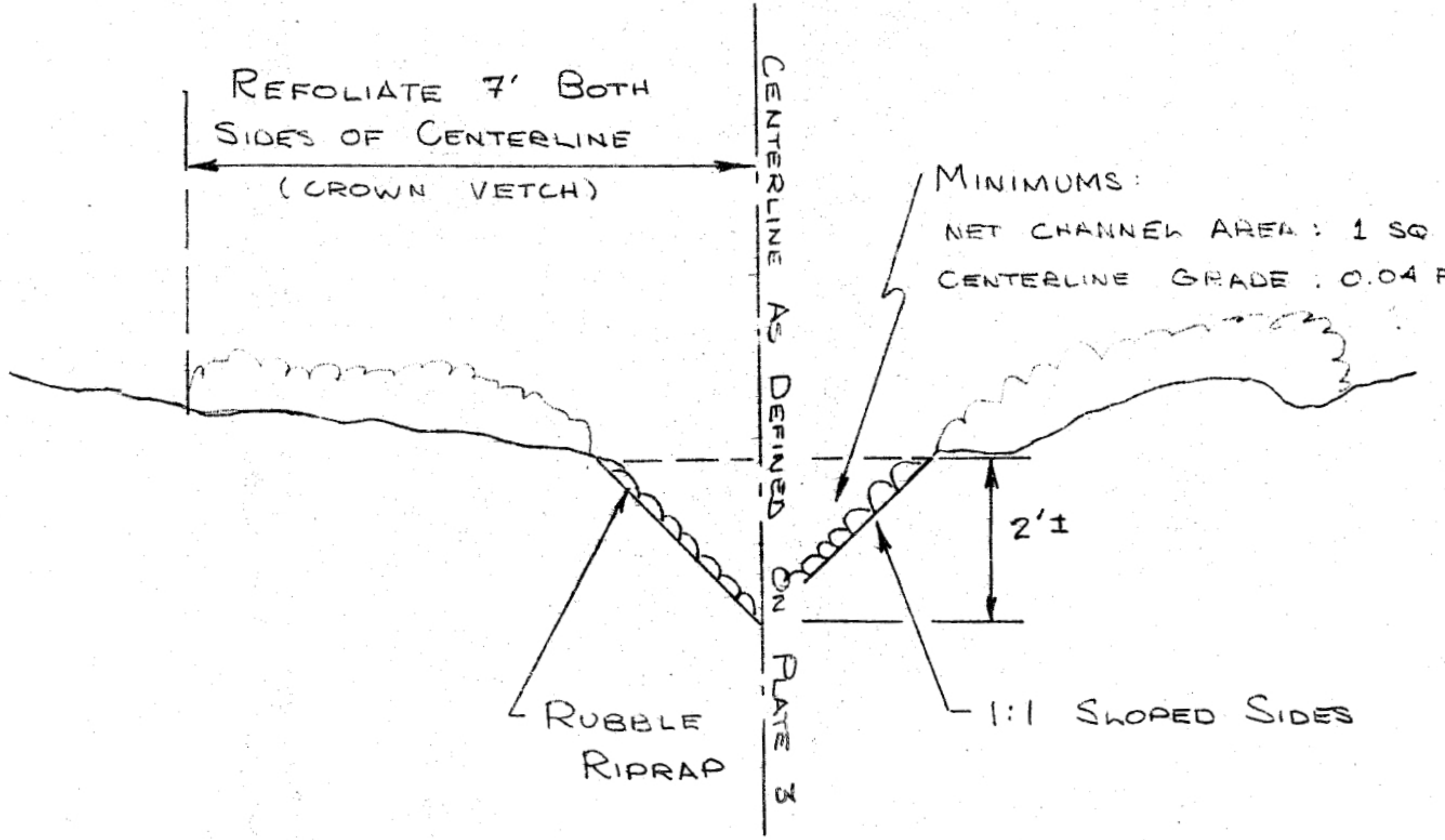
STUMPS RUN REHABILITAT

Sketch 2



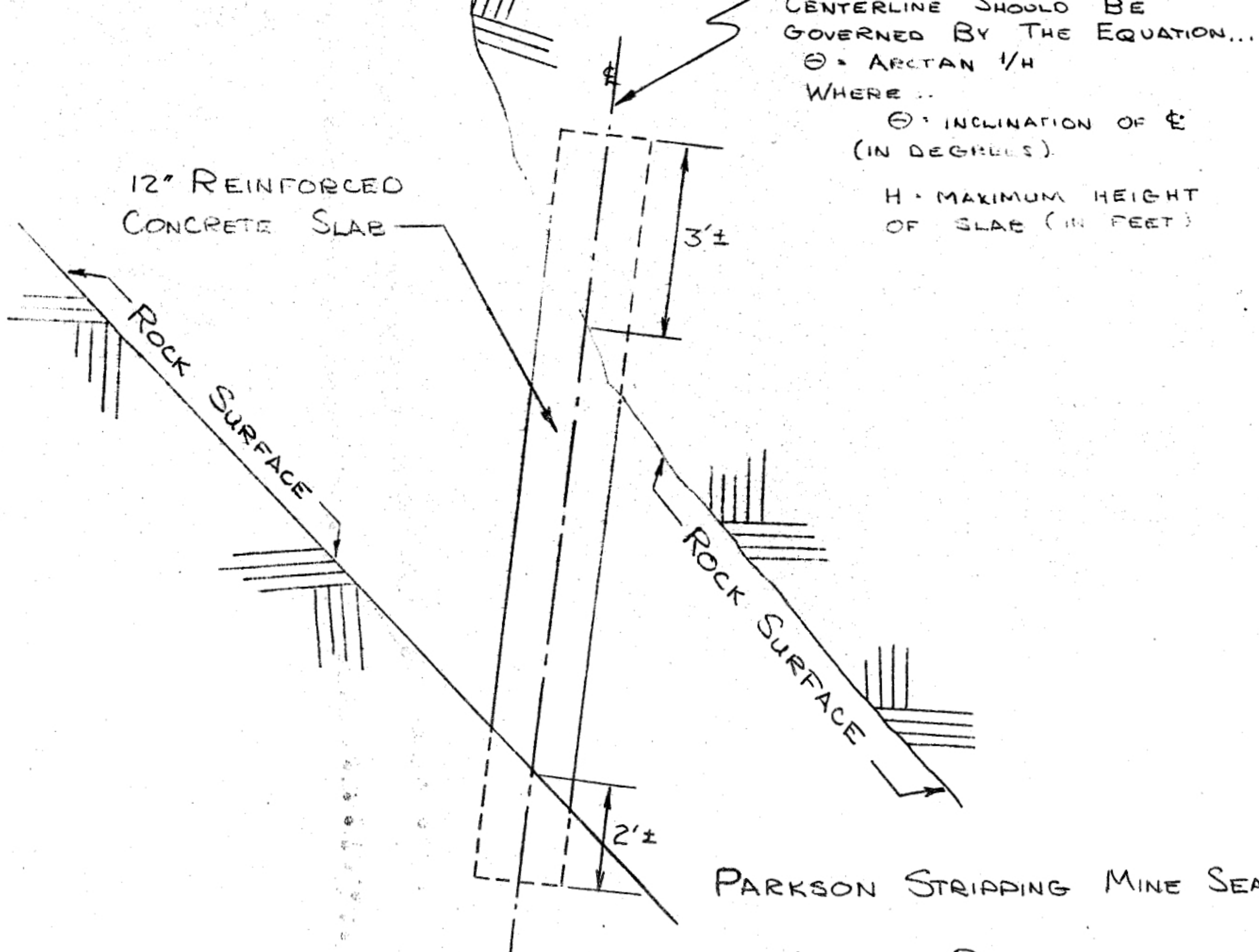
Levee Construction

<u>Stumps</u> <u>Run</u> <u>Rehabilit</u>



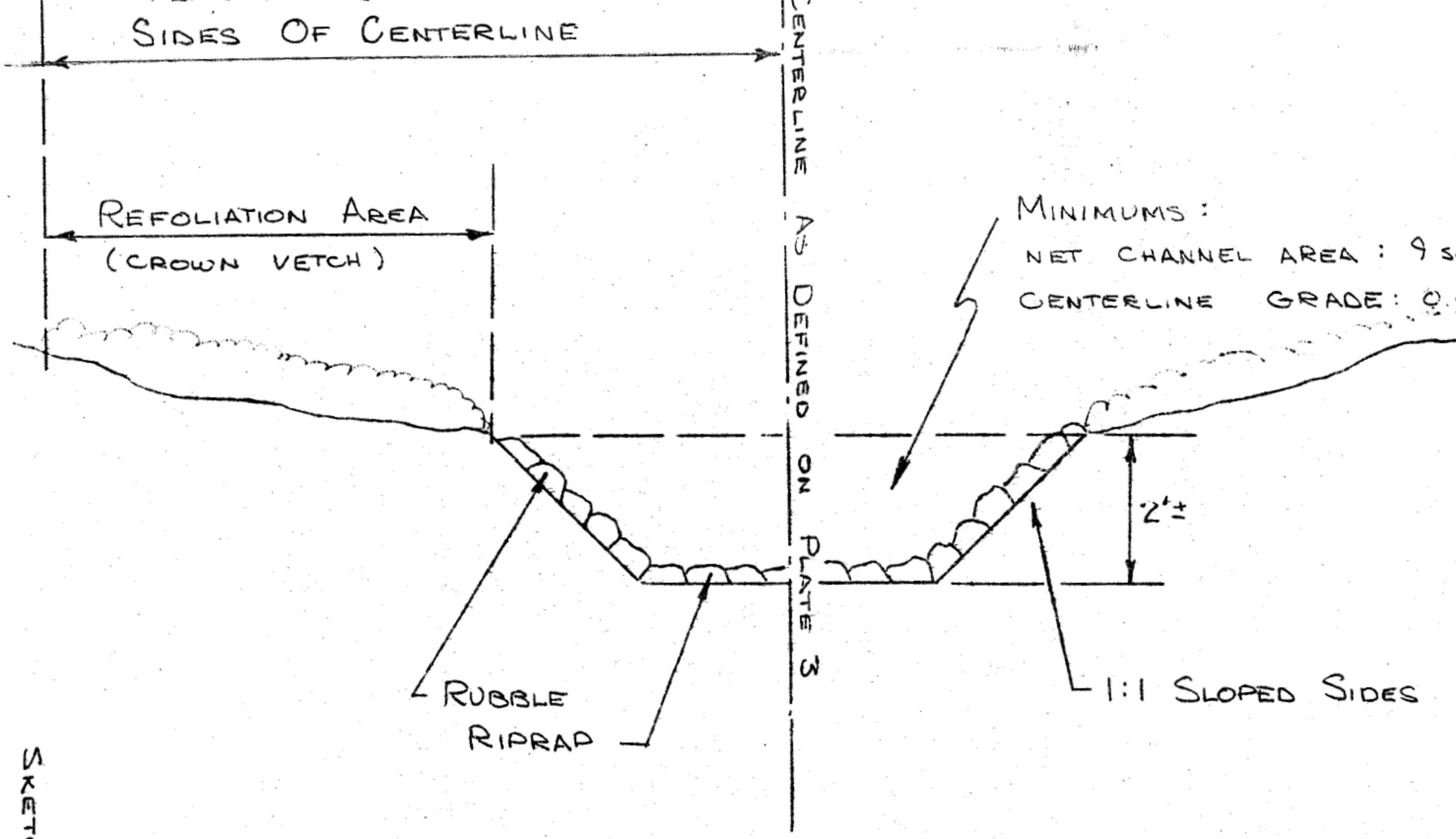
SKETCH 3

WESTWOOD AND
JOLIETT AREA REHABILITATIO



JOLIETT AREA REHABILITATION

SKETCH 4



Sketch 5

"L.R. 53029" Rehabilitation

DESIGN DATA

The design for the treatment facilities was based upon the flows recorded during the hydrologic year from June 1970 to August 1971. The results of this record were used to compute the annual average flow, the peak monthly average flow, And the peak and low flows for each basin.

The average annual flow is termed to be the highest flow during Low Flow Periods, the Normal Flow Period occurs between the annual average flow and the peak monthly average flow, the Flood Flow Period occurs between the peak monthly flow average and the peak flow for the year.

The Neutralization Plants have no flow limit because their operation does not require confining or impounding the flows.

The Lagoon Complexes are designed for two rates of flow, During Normal Flow Periods the lagoons have a retention time of 48 hours. This retention time is needed to precipitate the solids normally found in the waters. During Flood Flow Periods when dilution reduces the solids concentration in the waters, a 24-hour retention time is used.

As a safety factor, to prevent "overtapping" of the lagoons, the outlet works are designed for flows twice the peak yearly flow.

OPERATION MODES

Neutralization Plants

Continuous 24-hour/day operation. Lime feed accomplished using vibratory bins matched with screw feeders.

Inlet and Diversion Works

Designed to Supplant Aeration and Mixing using "cascade steps". Diverts all discharge up to annual average flow into First Order Lagoon; all discharges in excess of the annual average flow up to the maximum monthly average into the Second Order Lagoon (Normal Flows). All flows in excess of the maximum monthly average are considered to be Flood Flows and are proportionately discharged into each lagoon.

Lagoons

A) During Low Flow Periods (defined to be annual average flows) the First Order Lagoons can be drained for cleaning, with the Second Order Lagoon accommodating the flows from the First Order Lagoon.
B) During Normal Flow Periods (defined as the maximum monthly average flow). The First Order Lagoon will carry those flows up to the annual average, and the Second Order Lagoon will carry those in excess of the annual average up to the maximum monthly average (48-hour retention). C) During Flood Flow Periods both lagoons operate on a 24-hour retention basis to accommodate flows beyond the maximum monthly average.

Outlet Works - The outlet works have a movable crest spillway capable of completely stopping the flow or completely draining the lagoon. The capacity of the spillway works is governed by a conduit carrying the waters from the spillway under the dam. At all times during operation this conduit does not flow under pressure.

Sludge Removal - The entire quantity of the sludge material is to be removed during a period not exceeding one (1) month.

FACILITY		Supplied (48-hr. retention time)	STORAGE CAPACITY				SLUDGE REMOVAL	
NEUTRALIZATION PLANT NO. 1		Acid Mine Waters (in million gallons)	Acid Mine Waters Normal Flow (in million gallons)	Retention Time (hours)	Acid Mine Waters Flood Flow (in million gallons)	Retention Time (hours)	Weight of Dried Sludge (tons/year)	Volume of Slurry Mixture (gallons/year)
LAGOON COMPLEX NO. 1	First Order Lagoons	16	16	48	32	24		
	Second Order Lagoons	24	24	48	48	24		
	TOTAL	40	40	48	80	24		
	Sludge Removal						1,216	1,646,936

	FACILITY NEUTRALIZATION PLANT NO. 2	Supplied (48-hr. retention time) Acid Mine Waters (in million gallons)	STORAGE CAPACITY Acid Mine Waters Normal Flow (in million gallons)	Retention Time (hours)	Acid Mine Waters Flood Flow (in million gallons)	Retention Time (hours)	SLUDGE REMOVAL Weight of Dried Sludge (tons/year)	Volume of Slurry Mixture (gallons/year)
LAGOON COMPLEX NO. 2	First Order Lagoons	8	4	48	8	24		
	Second Order Lagoons	8	4	48	8	24		
	TOTAL	16	8	48	16	24		
	Sludge Removal						304	411,734

FACILITY		STORAGE CAPACITY					SLUDGE REMOVAL	
		Supplied (48-hr. retention time)						
NEUTRALIZATION PLANT NO. 3		Acid Mine Waters (in million gallons)	Acid Mine Waters Normal Flow (in million gallons)	Retention Time (hours)	Acid Mine Waters Flood Flow (in million gallons)	Retention Time (hours)	Weight of Dried Sludge (tons/year)	Volume of Slurry Mixture (gallons/year)
LAGOON COMPLEX NO. 3	First Order Lagoons	12	12	48	24	24		
	Second Order Lagoons	23	23	48	46	24		
	TOTAL	35	35	48	70	24		
	Sludge Removal						912	1,235,202

FLOW RATES

			SUPPLIED				REQUIRED			
			LIME FEED		ACID MINE WATER FLOW		LIME FEED		ACID MINE WATER FLOW	
			Maximum	Minimum	Normal	Flood	Maximum	Minimum	Normal	Flood
			lbs./day		million gals./day		lbs./day		million gals./day	
NEUTRALIZATION PLANT NO. 1			32,016	3,202	no limit	no limit	11,602	476	8	15
LAGOON COMPLEX I	INLET WORKS	Without bypass			8	16				
		with bypass			12	24				
		TOTAL			20	40			20	35
	LAGOONS	1st order			8	16				
		2nd order			12	24				
		TOTAL			20	40			20	35
	OUTLET WORKS	1st order Lagoons			16	32				
		2nd order Lagoons			24	48				
		TOTAL			40	80			20	35

FLOW RATES

			SUPPLIED				REQUIRED			
			LIME FEED		ACID MINE WATER FLOW		LIME FEED		ACID MINE WATER FLOW	
			Maximum	Minimum	Normal	Flood	Maximum	Minimum	Normal	Flood
			lbs./day		million gals./day		lbs./day		million gals./day	
NEUTRALIZATION PLANT NO. 2			32,016	3,202	no limit	no limit	530	20	4	8
LAGOON COMPLEX II	INLET WORKS	without bypass			4	8				
		with bypass			4	8				
		TOTAL			8	16			4	8
	LAGOONS	1st order			4	8				
		2nd order			4	8				
		TOTAL			8	16			4	8
	OUTLET WORKS	1st order lagoons			4	8				
		2nd order lagoons			4	8				
		TOTAL			8	16			4	8

FLOW RATES

			SUPPLIED				REQUIRED			
			LIME FEED		ACID MINE WATER FLOW		LIME FEED		ACID MINE WATER FLOW	
			Maximum	Minimum	Normal	Flood	Maximum	Minimum	Normal	Flood
			lbs./day		million gals./day		lbs./day		million gals./day	
NEUTRALIZATION PLANT NO. 3			32,016	3,202			2,750	690	17.5	28
LAGOON COMPLEX III	INLET WORKS	without bypass			8	16				
		with bypass			12	24				
		TOTAL			20	40			17.5	28
	LAGOONS	1st order			6	12				
		2nd order			11.5	23				
		TOTAL			17.5	35			17.5	28
	OUTLET WORKS	1st order lagoons			16	32				
		2nd order lagoons			24	48				
		TOTAL			40	80			17.5	28

COST ESTIMATES

In the treatment proposal, three neutralization plants matched with three settling lagoon facilities comprised the only feasible method of water treatment that could offer good effluent quality while not imposing any serious financial hardships on the active mine operators in the area. The costs associated with the construction and operation of these facilities Are presented on the following pages. The design of these facilities has been oriented toward maintenance - free operation; however, if maintenance problems arise, allowances have been made to provide for these in the contingencies. The capital costs of these operations has been itemized for each major unit operation as proposed in the treatment alternatives.

A separate cost breakdown has been [I] presented for the largest single cost for a unit operation, that of lagoon construction and sludge removal. Included in the cost breakdown are operating expenses for the sludge removal alternatives. If alternatives for sludge removal exist, the determining consideration is the operating cost. The lowest operating cost, in turn, determines the capital cost of the type of sludge removal recommended. This capital cost, then, is added to the cost of the lagoons. The operating cost for sludge removal is the operating cost for the lagoons, lagoon facilities and sludge removal facilities.

These cost estimates have been based on the prevailing- unit prices for materials and wage rates found in this locale.

PRO-RATED COSTS

Pro-rated assessments for active and abandoned operations are computed upon the acid load discharged from that particular operation. The operations are first classed according to each treatment facility into which they discharge; then, the operator's share of that facility's initial cost. and operation is determined by this acid load percentage of that facility's total acid load.

SUMMARY

Pro-rated Costs at Individual Lagoon Complexes

	Pollution Source No.	Percent Contribution	Initial Capital Cost	Annual Cost
Lagoon Complex I:-				
abandoned	S-58	79.87	$136,660.	$ 17,010.
active	S-61	11.71	20,035.	2,495.
active	S-62	0.20	340.	45.
active	S-342	4.27	7,305.	910.
active	S-343	3.86	6,605.	820.
active	S-345	0.09	155.	20.
	TOTAL	100.00	$171,100.	$ 21,300.
Lagoon Complex II:-				
abandoned	S-77	9.95	$ 10,400.	$ 875.
abandoned	S-320	0.17	180.	15.
abandoned	S-327	88.85	92,840.	7,820.
active	S-231	1.03	1,080.	90.
	TOTAL	100.00	$104,500.	$ 8,800.
Lagoon Complex III:-				
abandoned	S-72	92.55	$176,200.	$ 3,380.
abandoned	S-73	0.26	495.	10.
abandoned	S-75	0.13	245.	5.
abandoned	S-332	3.57	6,800.	130.
abandoned	S-335	0.88	1,675.	30.
active	S-121	2.16	4,110.	80.
active	S-336	0.45	885.	15.
	TOTAL	100.00	$190,380.	$ 3,650.

ESTIMATED TOTAL COSTS AS DIVIDED INTO

FOLLOWING ABATEMENT AREAS

(1) LORBERRY BASIN

(2) LOWER RAUSCH BASIN - Upstream of Measuring Station #8

(3) LOWER RAUSCH BASIN - Downstream of Measuring Station #8

LORBERRY BASIN

Treatment Proposal	% Abatement	Capital Cost	Operating Cost Per Year
Lagoon Complex I and Sludge Removal (1)	74.1%	$149,450	$ 7,550
Neutralization Plant	24.7%	$ 10,600	$ 8,300 (Lime) 5,250 (Power)
Contingencies		$ 8,150	$ 200
TOTAL - Treatment	98.8%	$168,200	$21,300
Prevention Proposal			
Stump's Run Rehabilitation			
Rechanneling	0.8%	$ 550	
Levees	0.4%	$ 2,350	
TOTAL - Prevention	1.2%	$ 2,900	
GRAND TOTAL	100 %	$171,100	$21,300

LOWER RAUSCH BASIN - Upstream of Measuring Station #8

Treatment Proposal	% Abatement	Capital Cost	Operating Cost Per Year
Lagoon Complex II and Sludge Removal (2)	71.0%	$ 85,100	$ 2,000 "A"*
Neutralization Plant	23.7%	$ 10,600	$ 5,250 (Lime) 1,150 (Power)
Contingencies		$ 5,000	400
TOTAL - Treatment	94.7%	$100,700	$ 8,800.

Prevention Proposal			
Case III Joliett Rehabilitation	4.3%	$ 2,250	
Case II Westwood Rehabilitation	1 %	$ 1,550	
TOTAL - Prevention	5.3%	$ 3,800	
GRAND TOTAL	100 %	$104,500	$ 8,800.

*"A" refers to the pumping schedule to be enacted at Lagoon Complex II only if Alternative B for sludge disposal is not selected for Lagoon Complex III; in this case, Pumping Schedule "B" is applicable.

LOWER RAUSCH BASIN - Downstream of Measuring Station #8

Treatment Proposal	% Abatement	Capital Cost	Operating Cost Per Year
Lagoon Complex III and Sludge Removal (3)	74.6%	$168,030	$ 3,650
Neutralization Plant	24.9%	$ 10,600	$ 5,250 (Lime) 6,250 (Power)
Contingencies		$ 9,050	$ 750
TOTAL - Treatment	99.5%	$187,680	$15,900
Prevention Proposal			
Case I - "LR 53029" Reclamation	0.5%	$ 2,500	
GRAND TOTAL	100 %	$190,180	$15,900

(1) Lagoon Complex I includes acid contributions from active operations S-342, S-343, S-345 and S-62 and abandoned operations S-61 and S-58.

(2) Lagoon Complex II includes acid contributions from active operation S-231 and abandoned operations S-77, S-320 and S-327.

(3) Lagoon Complex III includes acid contributions from active operations S-121 and S-336 and abandoned operations S-72, S-73, S-75, S-332 and S-335.

COST SUMMARY - Construction of Lagoons, Lagoon Facilities and Sludge Removal

Lagoon Complex I - Lorberry Creek

1.	Excavation	$ 66,000.
2.	Rip-rap	4,500.
3.	Clearing & Grubbing	12,900.
4.	Planting - Erosion Control	700.
5.	Fencing	10,500.
6.	Inlet Works	18,600.
7.	Spillway 2 @ $6,500.	13,000.
8.	Outlet Works	
	25 cfs capacity	14,100.
	37 cfs capacity	15,100.
9.	Sludge Removal - Capital Costs	7,050.
10.	Sludge Removal - Operating Costs/Year	7,550.
	TOTAL COSTS*	$149,450.

*includes all items except #7 and #10

Lagoon Complex II - Lower Rausch Creek

1.	Excavation	$ 30,900.	
2.	Rip-rap	3,000.	
3.	Clearing & Grubbing	5,200.	
4.	Planting - Erosion Control	200.	
5.	Fencing	7,100.	
6.	Inlet Works	18,600.	
7.	Spillway	13,100.	
	or		
8.	Outlet Works		
	2 @ 6 cfs capacity @ $8,300.	16,600.	
9.	Sludge Removal - Capital Costs	3,500.	
10.	Sludge Removal - Operating Costs		
	Operating Costs/Year	2,000.	Schedule A
		6,000.	Schedule B
	TOTAL COSTS*	$85,100.	

*includes all items except #7 and #10

Lagoon Complex III - Lower Rausch Creek

1.	Excavation		$ 67,100.
2.	Rip-rap		6,300.
3.	Clearing & Grubbing		15,800.
4.	Planting - Erosion Control		800.
5.	Fencing		14,500.
6.	Inlet Works		18,600.
7.	Spillway 2 @ $6,500.		13,000
	or		
8.	Outlet Works		
	25 cfs capacity	$14,100.	
	37 cfs capacity	15,100.	
			29,200.
9.	Sludge Removal - Capital Costs		
	a) $2,930. d) $8,600.		
	b) $ 0 e) $14,600.		
	c) $9,000.		2,930.
10.	Sludge Removal - Operating Costs/Year		
	a) $3,650. d) $5,550.		
	b) $4,150. e) $5,550.		
	c) $4,850.		3,650.
	TOTAL COSTS*		$168,230.

*includes Items 1, 2, 3, 4, 5, 6, 8, 9a

WATER QUALITY

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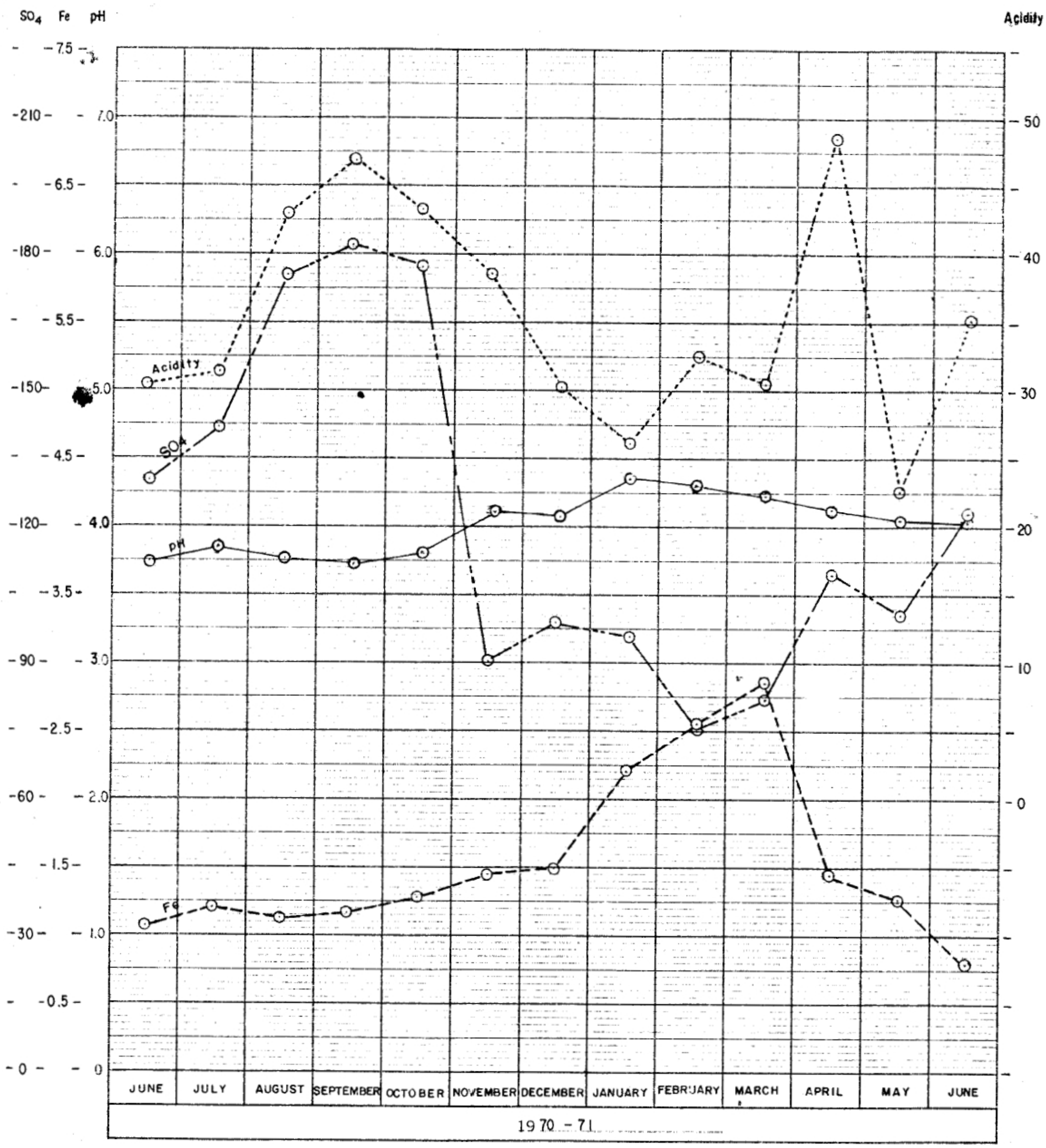

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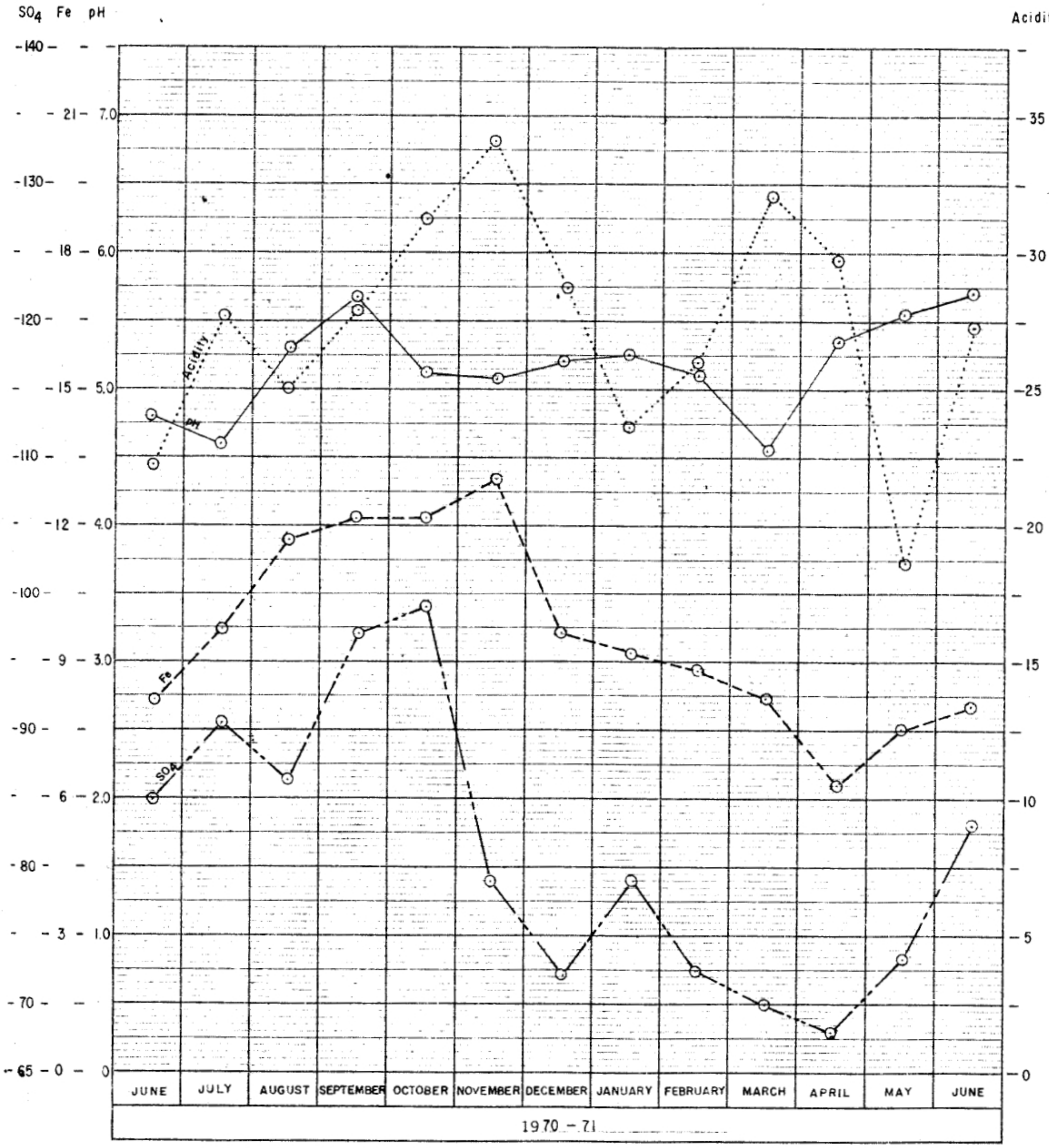

K&E 1 YEAR BY MONTHS X 150 DIVISIONS 359-170 KEUFFEL & ESSER CO.

WATER QUALITY

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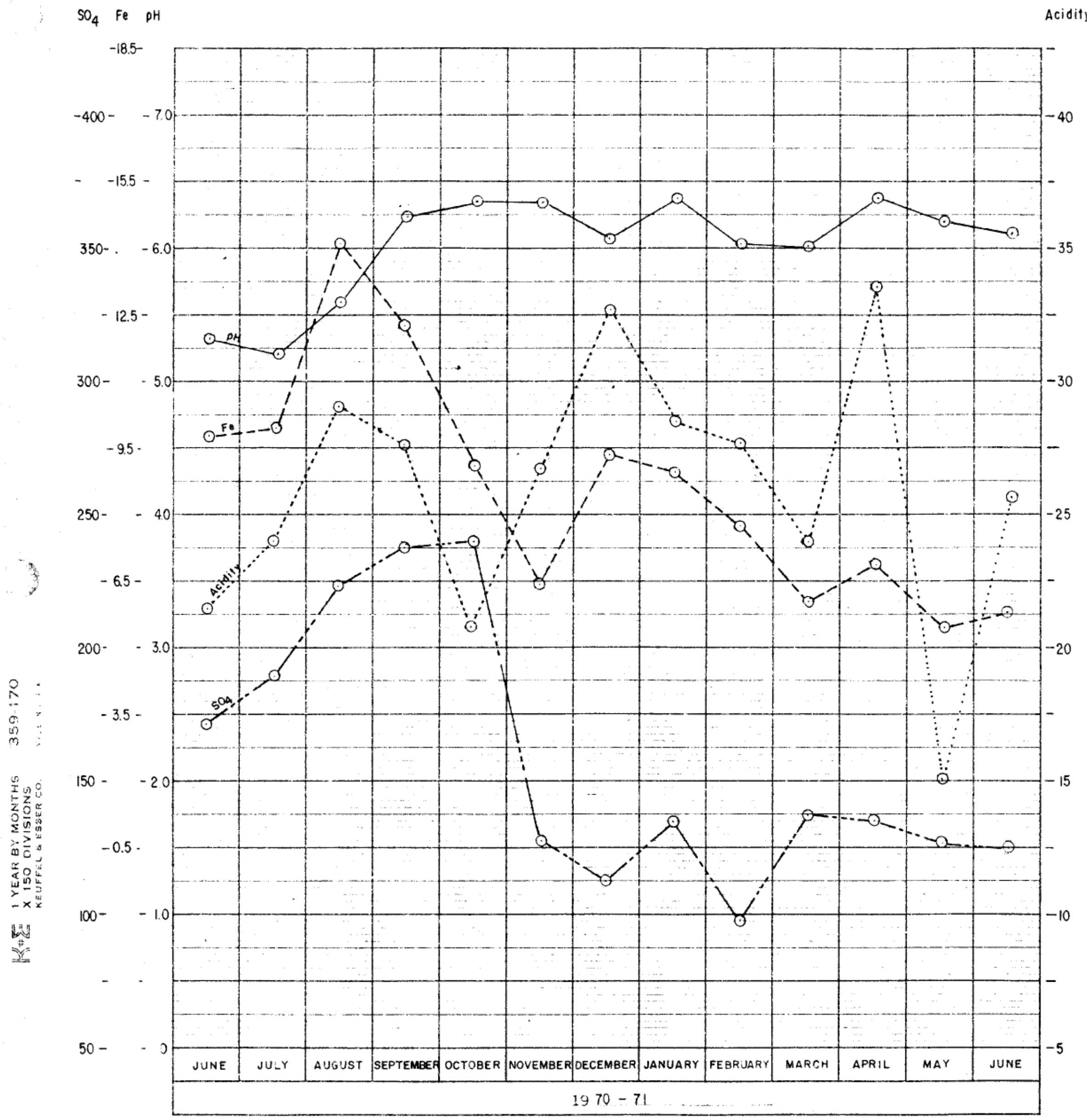

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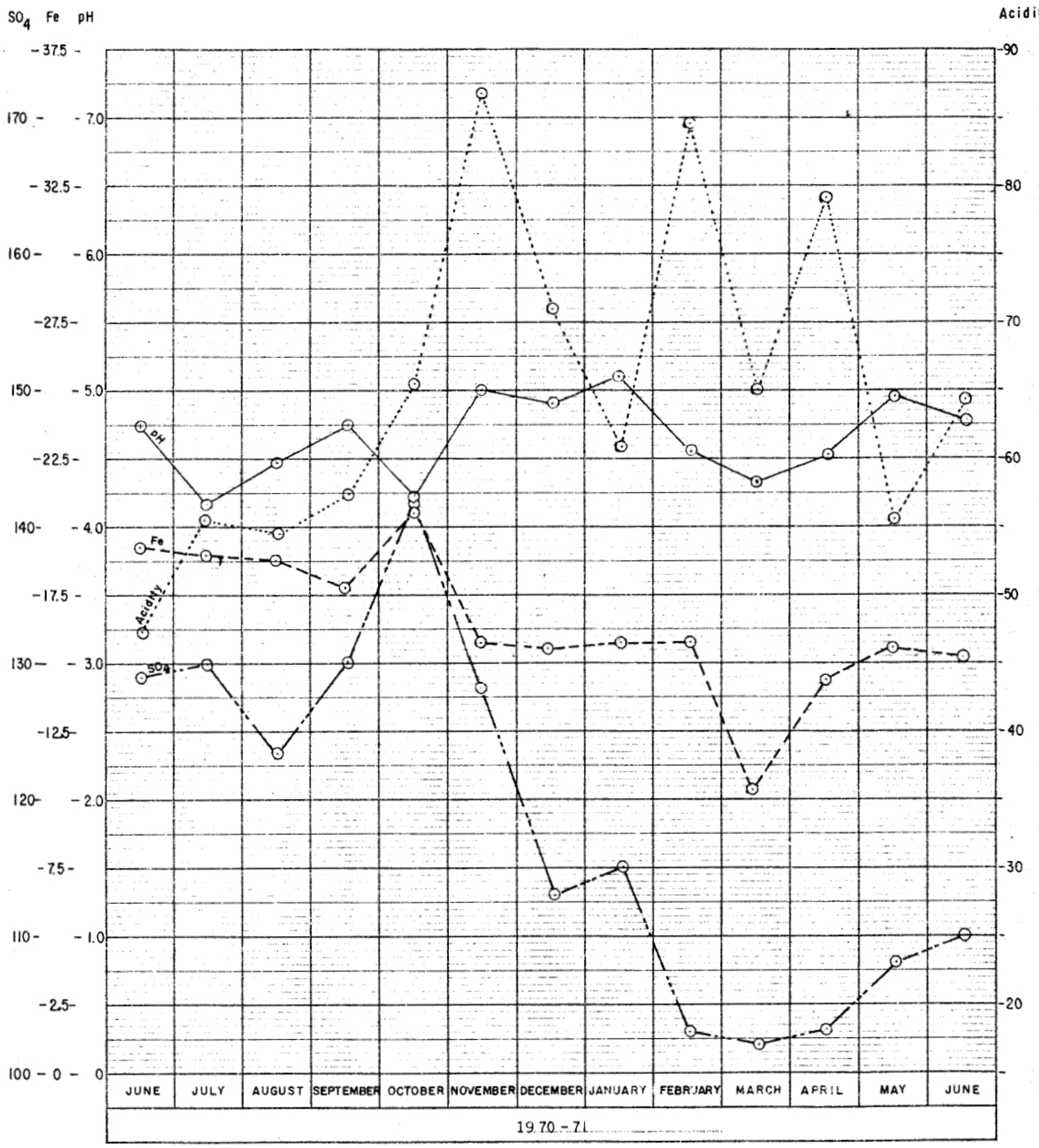

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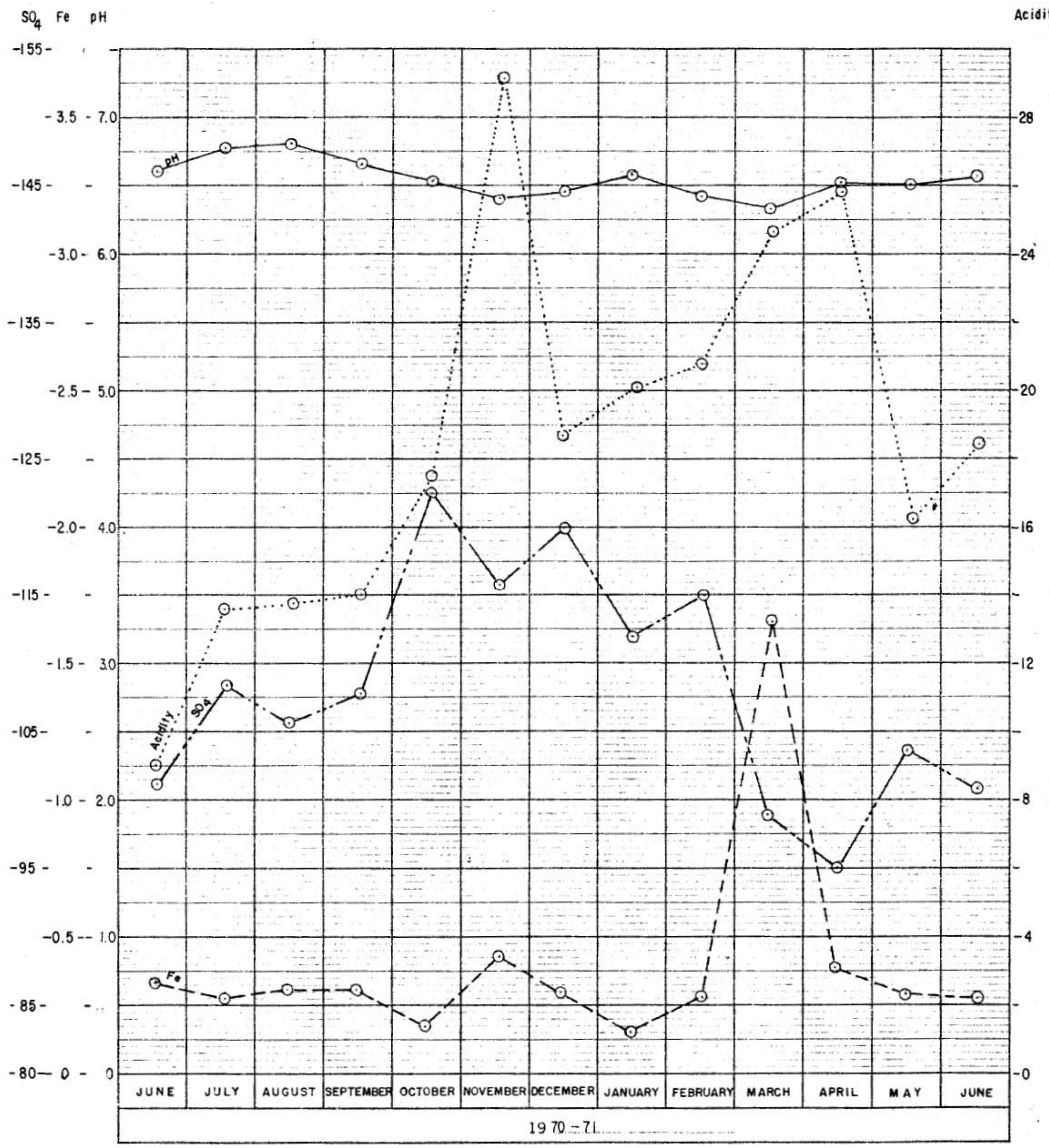

WATER QUALITY.

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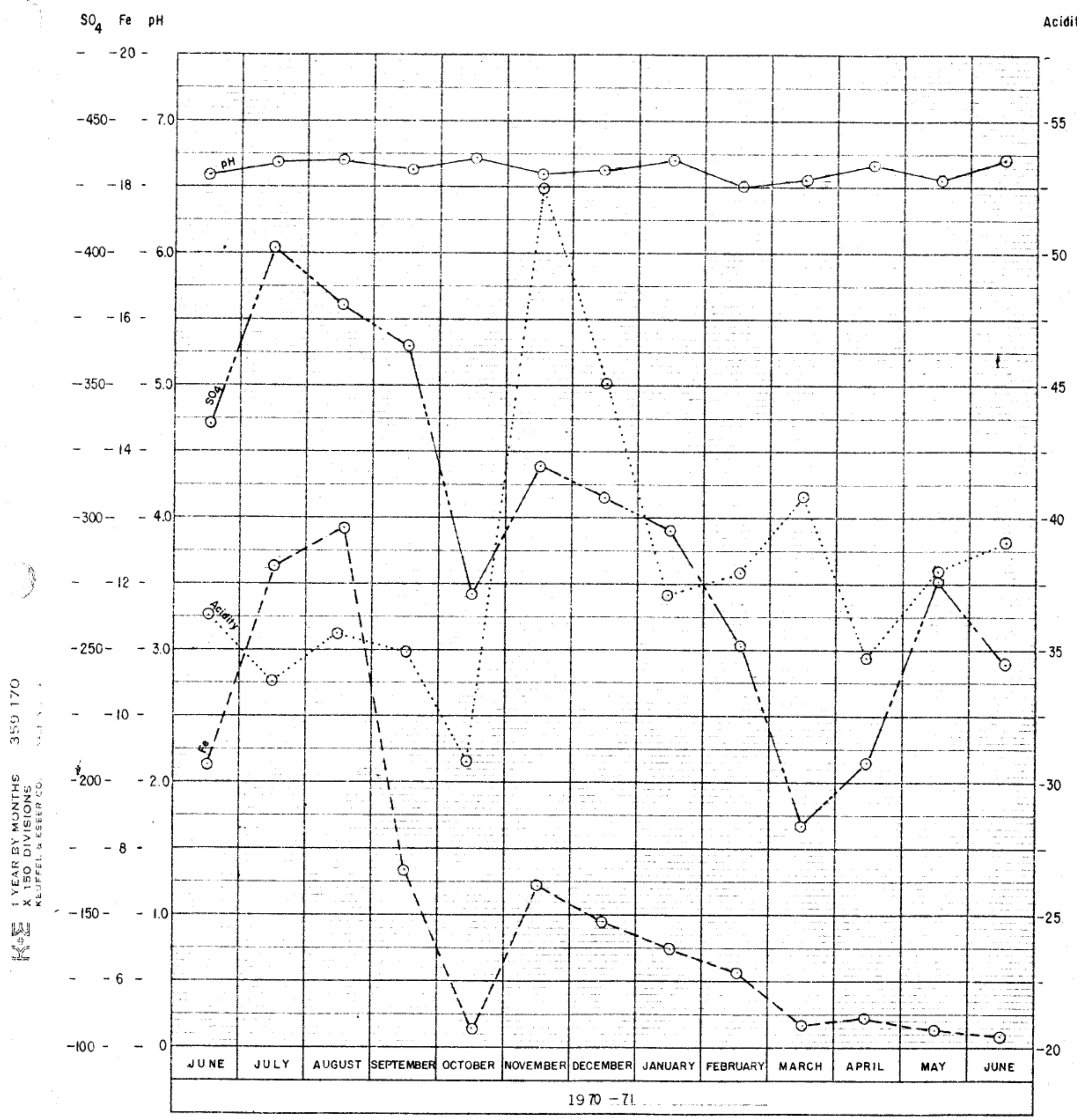

WATER QUALITY

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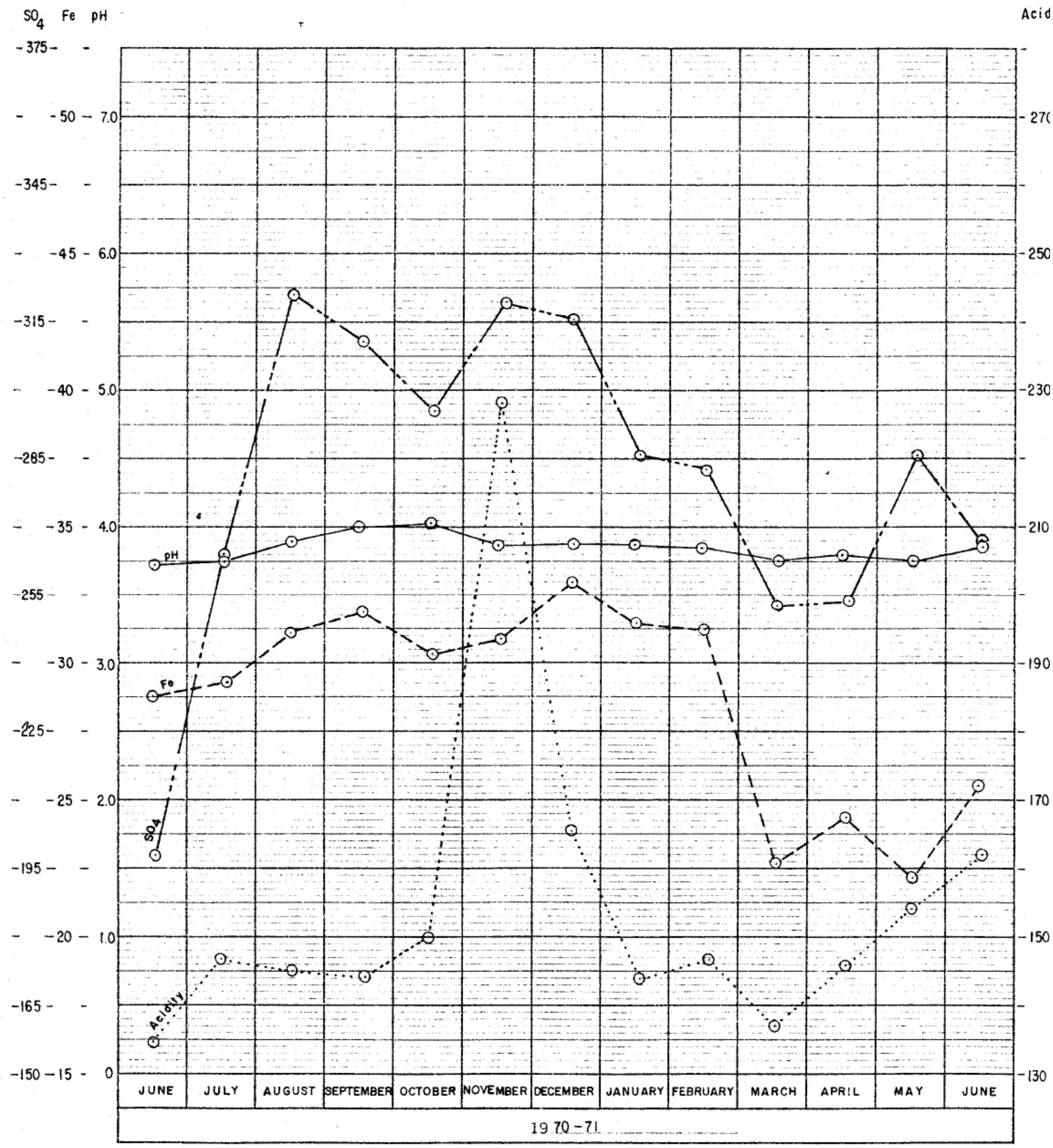

WATER QUALITY

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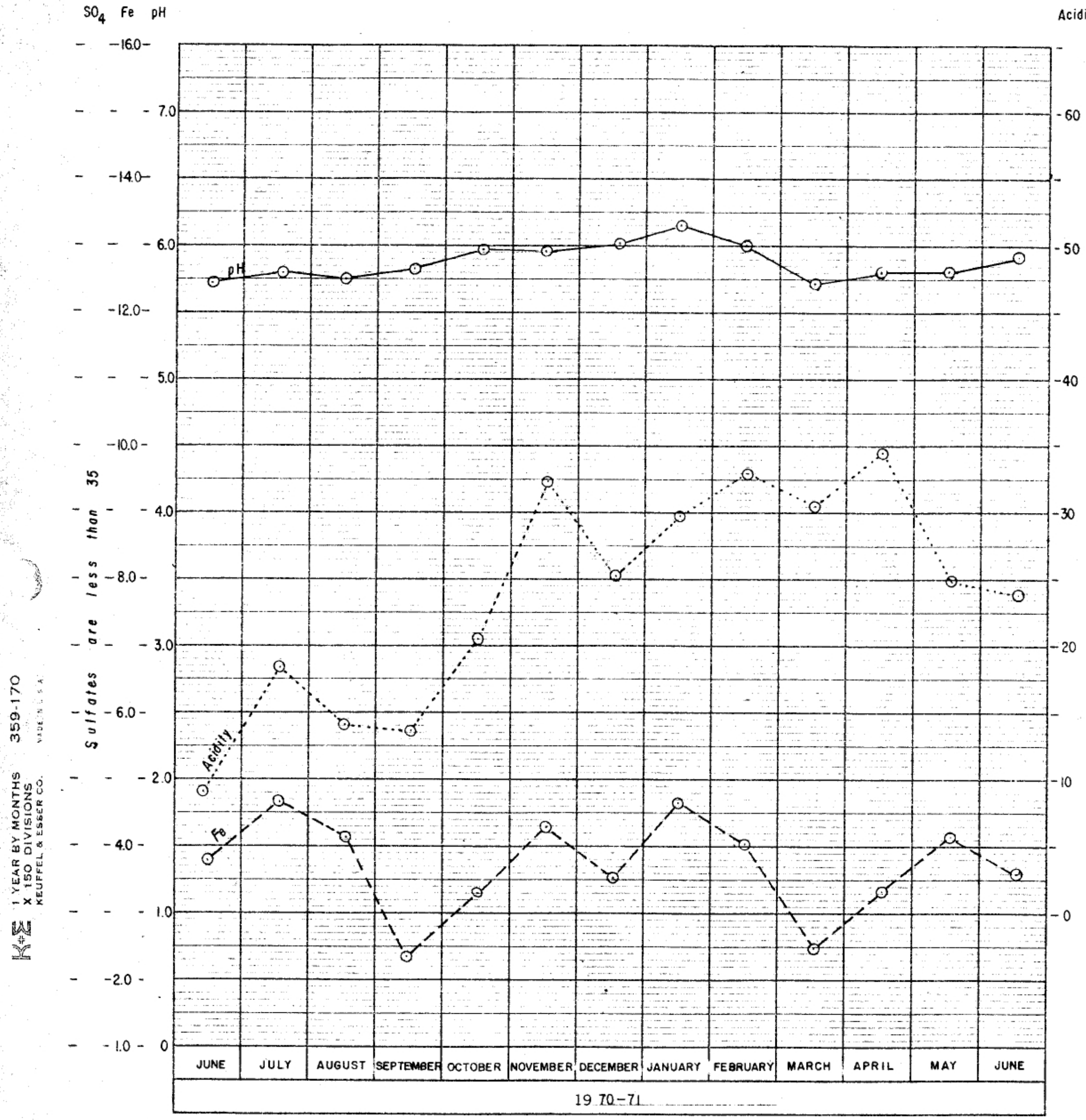
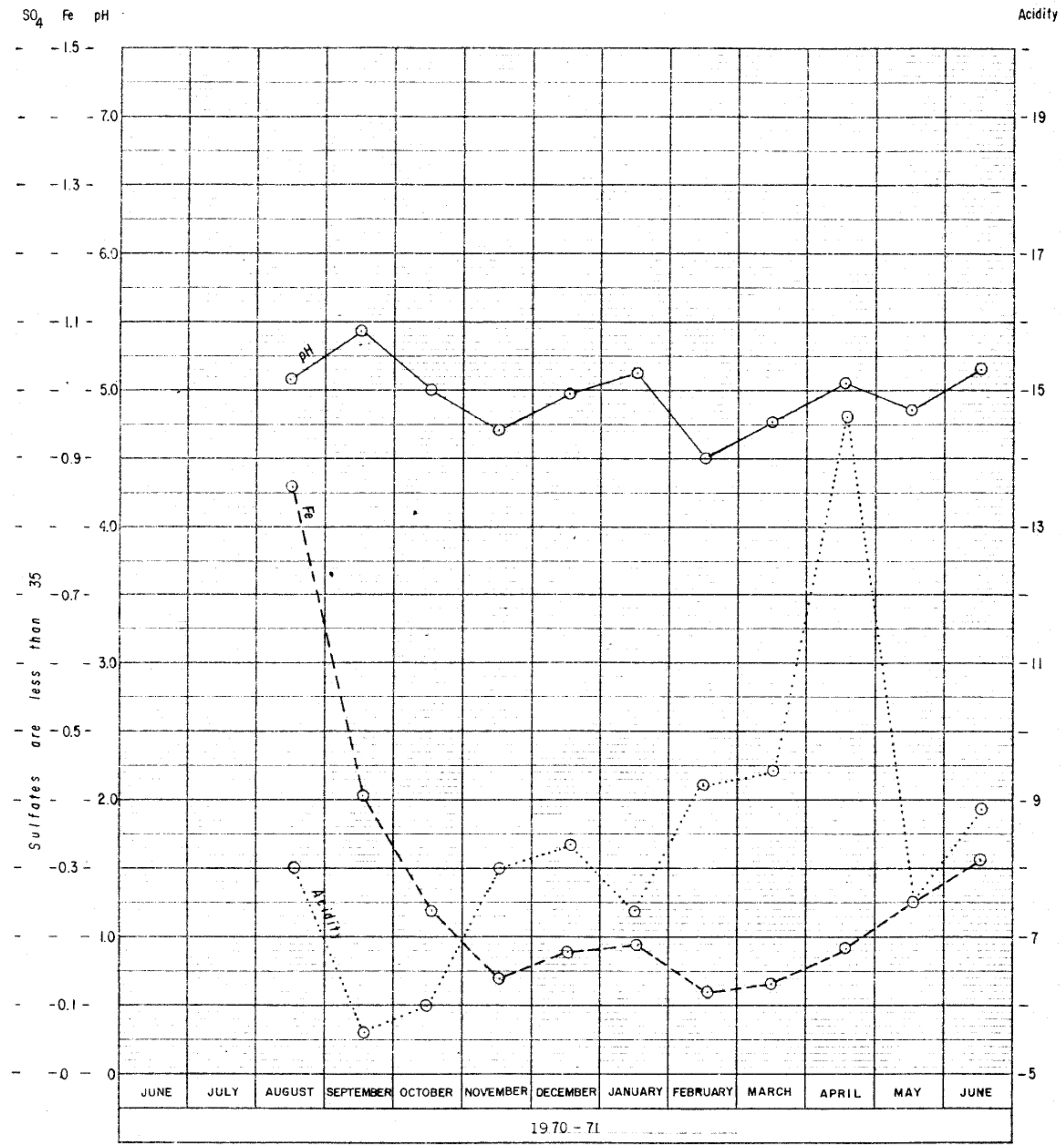


WATER QUALITY

SOURCE 9



WATER QUALITY

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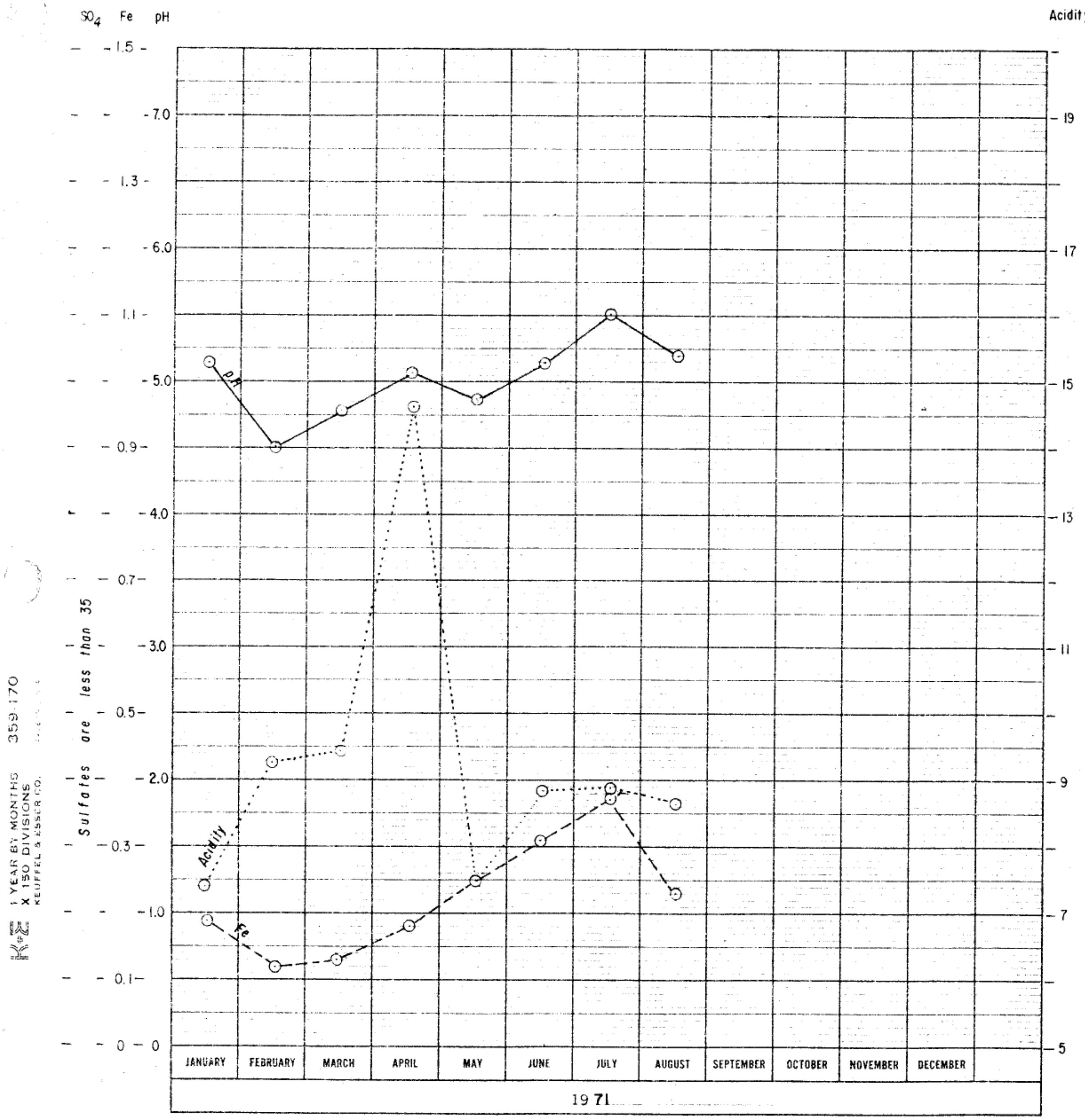

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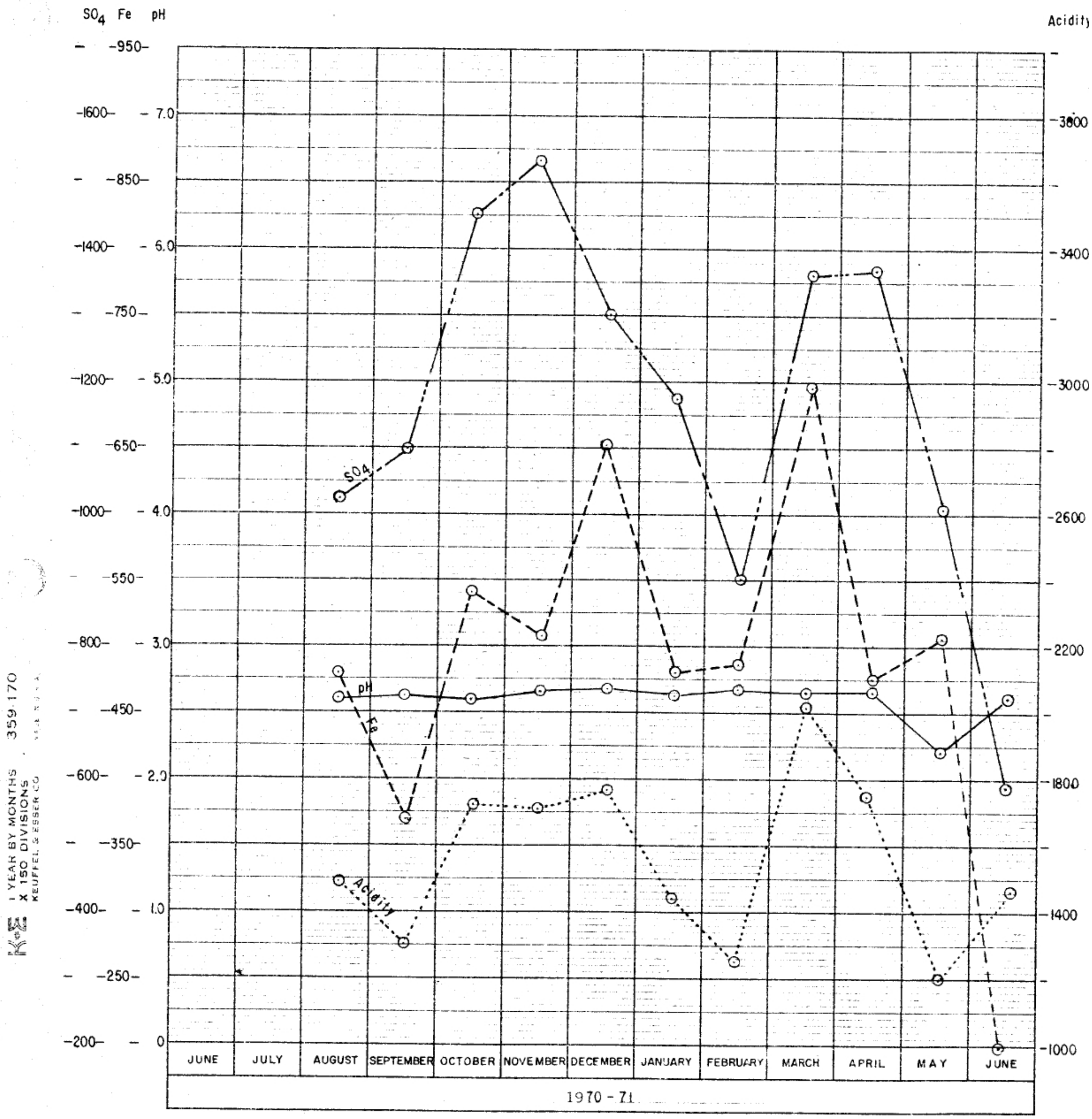

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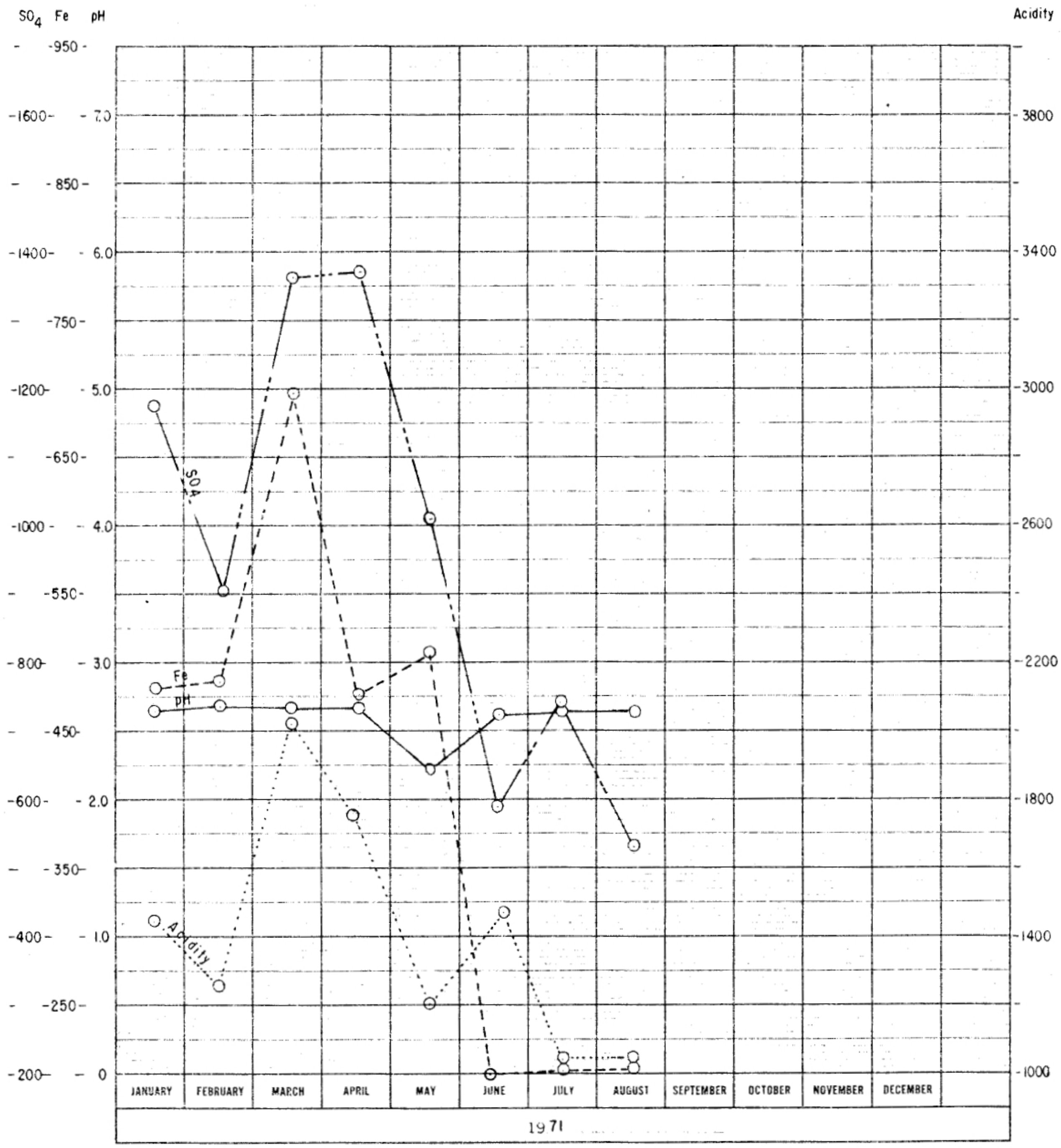

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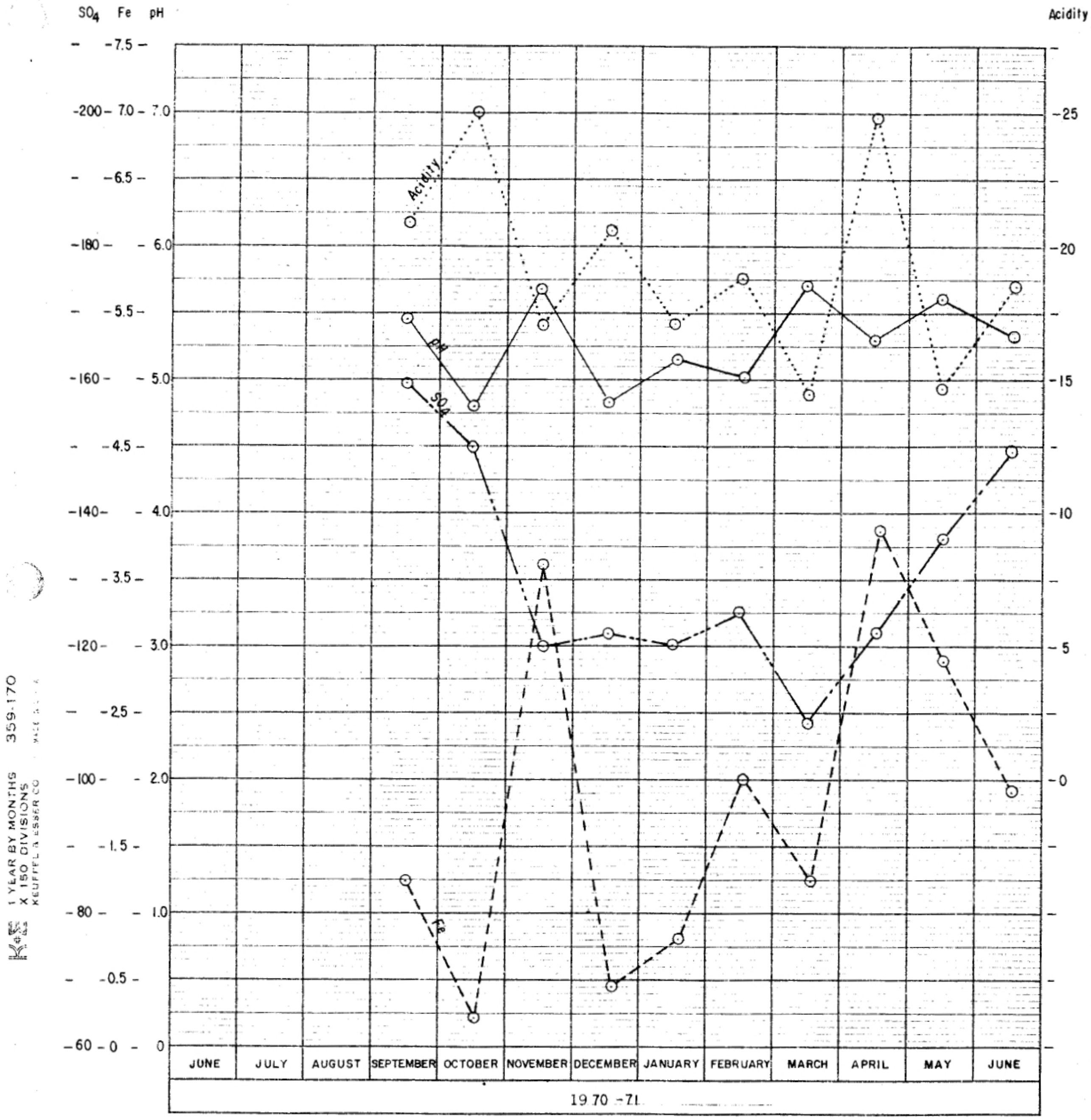

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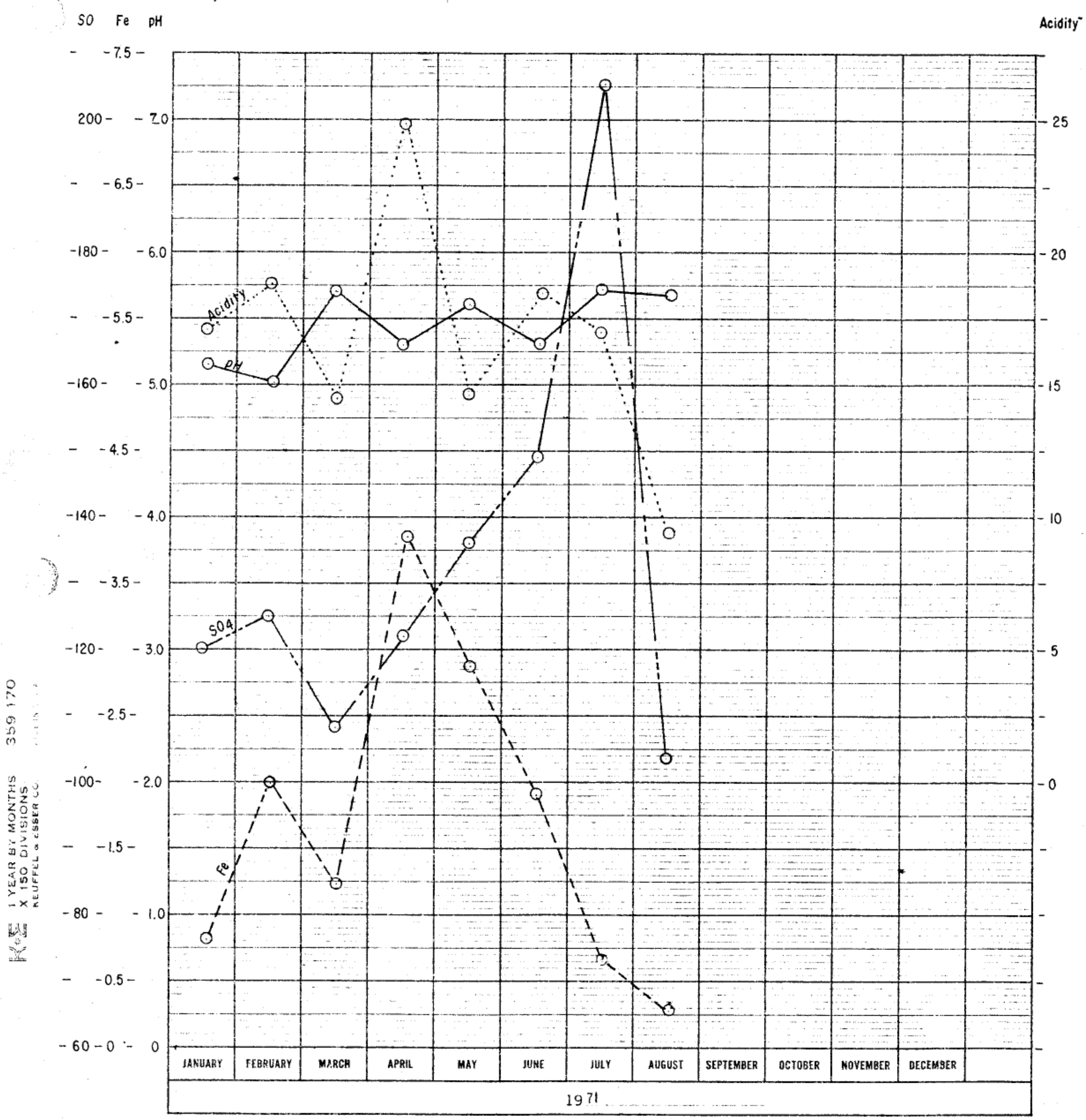

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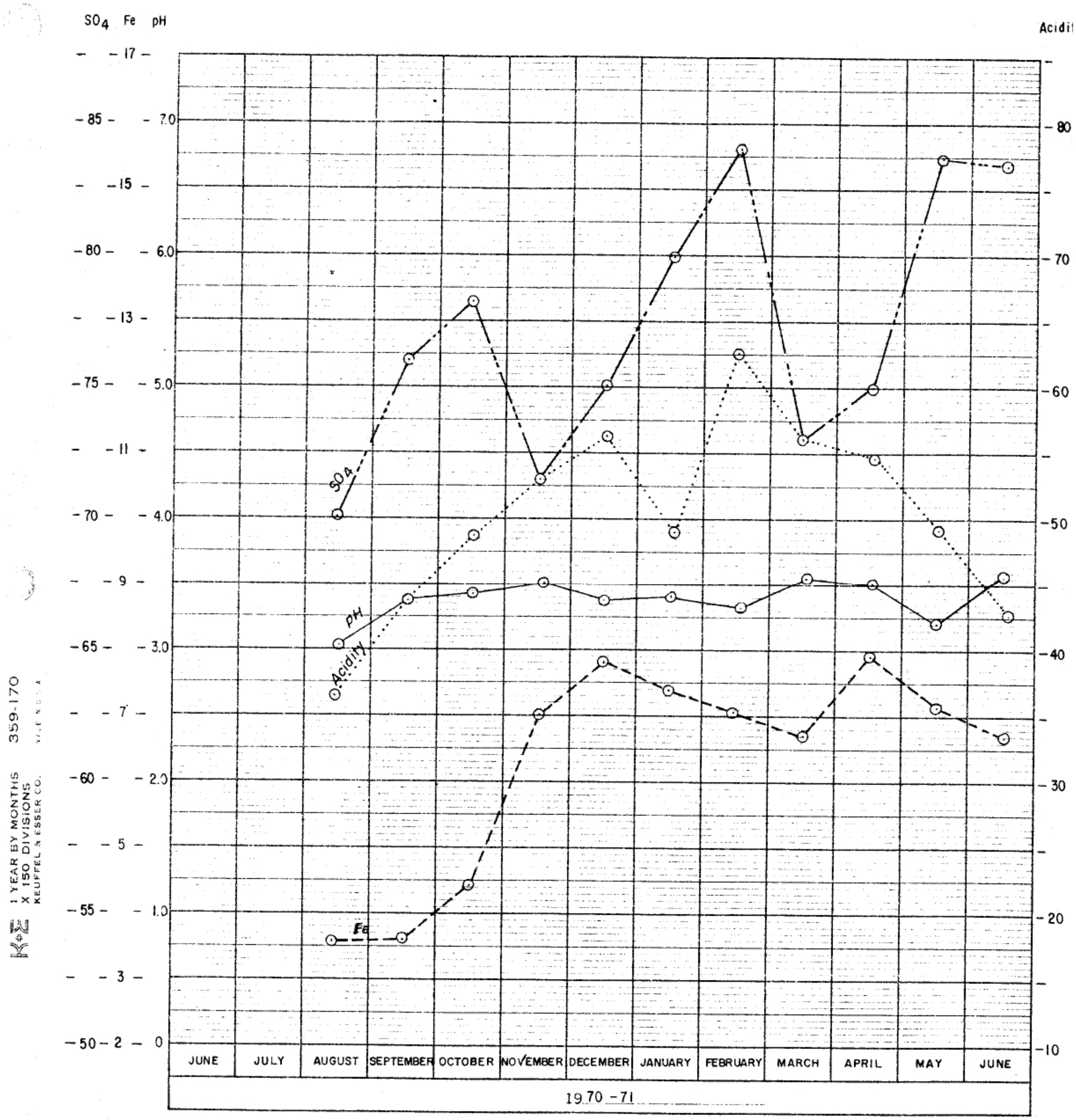

WATER QUALITY

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