HESS LAKE
ENGINEERING FEASIBILITY REPORT

JUNE, 1982

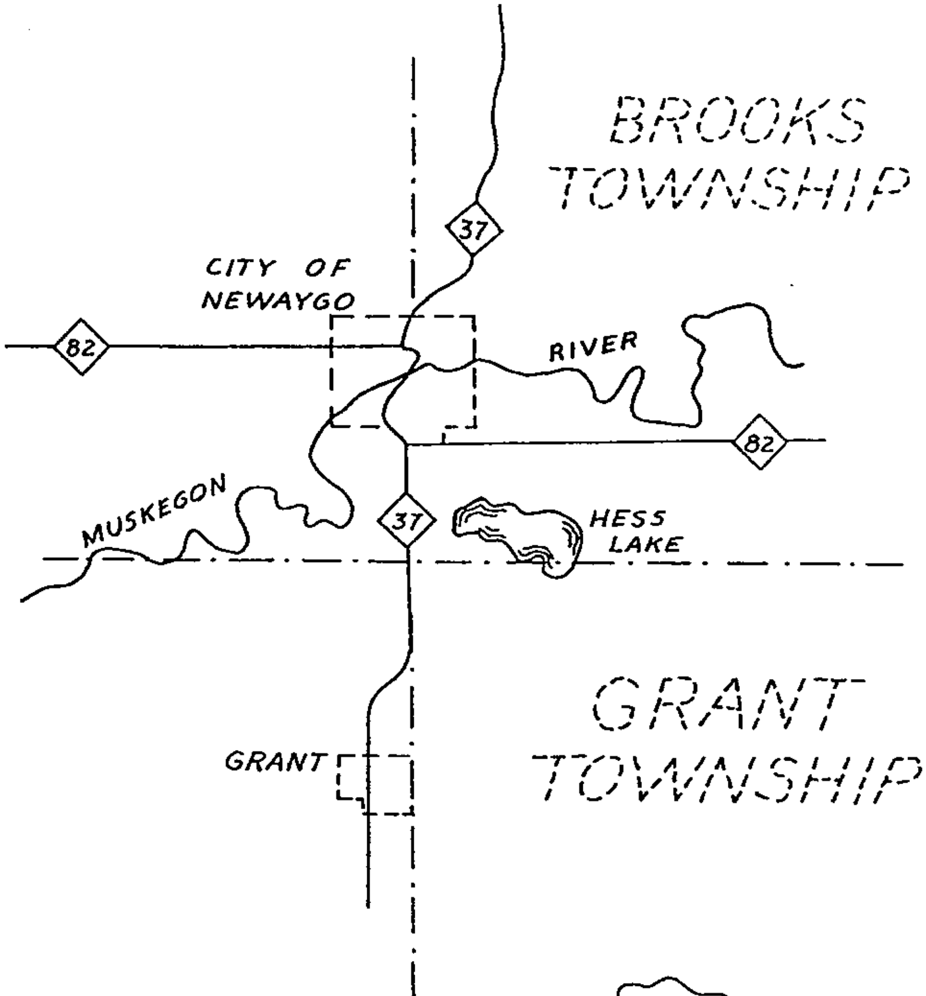
COMPLETED UNDER THE AUTHORITY OF:

THE HESS LAKE BOARD
AS INCORPORATED UNDER
MICHIGAN ACT 345 OF 1966

PREPARED BY:

EDMANDS ENGINEERING, INC.
1501 WEST THOMAS STREET
P. O. BOX 580
BAY CITY, MICHIGAN 48707

HESS LAKE VICINITY

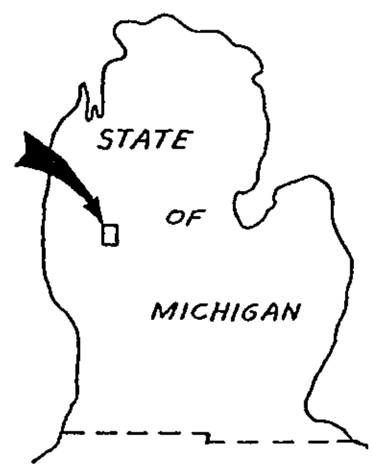


HESS LAKE

BROOKS AND GRANT TOWNSHIPS

NEWAYGO COUNTY

MICHIGAN



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HESS LAKE

ENGINEERING FEASIBILITY REPORT

SUMMARY

1. Hess Lake is a highly eutrophic lake with very low water clarity, oxygen depletion in the deeper water during the summer, thick organic sediments, and excessive rooted weed growth. These water quality problems are caused by excessive phosphorus entering the lake.

2. The excessive phosphorus input is causing a rapid rate of sediment buildup. The sediment buildup is expected to make the Lake unusable in less than 50 years with continually diminishing water quality until that time.

3. The major source of phosphorus to Hess Lake is the Wheeler Drain. This agricultural drain contributes about 55% of the total annual input.

4. To protect and improve the water quality and usefulness of Hess Lake, the phosphorus input must be reduced by about 800 kg per year and the Lake must be dredged to a greater depth.

5. Phosphorus reduction should be accomplished by by-passing its high phosphorus water around the Lake as described in Alternative No. 5, Page 17.

6. Dredging should deepen about 30% of the Lake to a depth of 15 feet or more.

7. No algacides (copper containing compounds) should be used in the Lake as these may cause a greater and more persistant rooted weed problem in the future.

HESS LAKE

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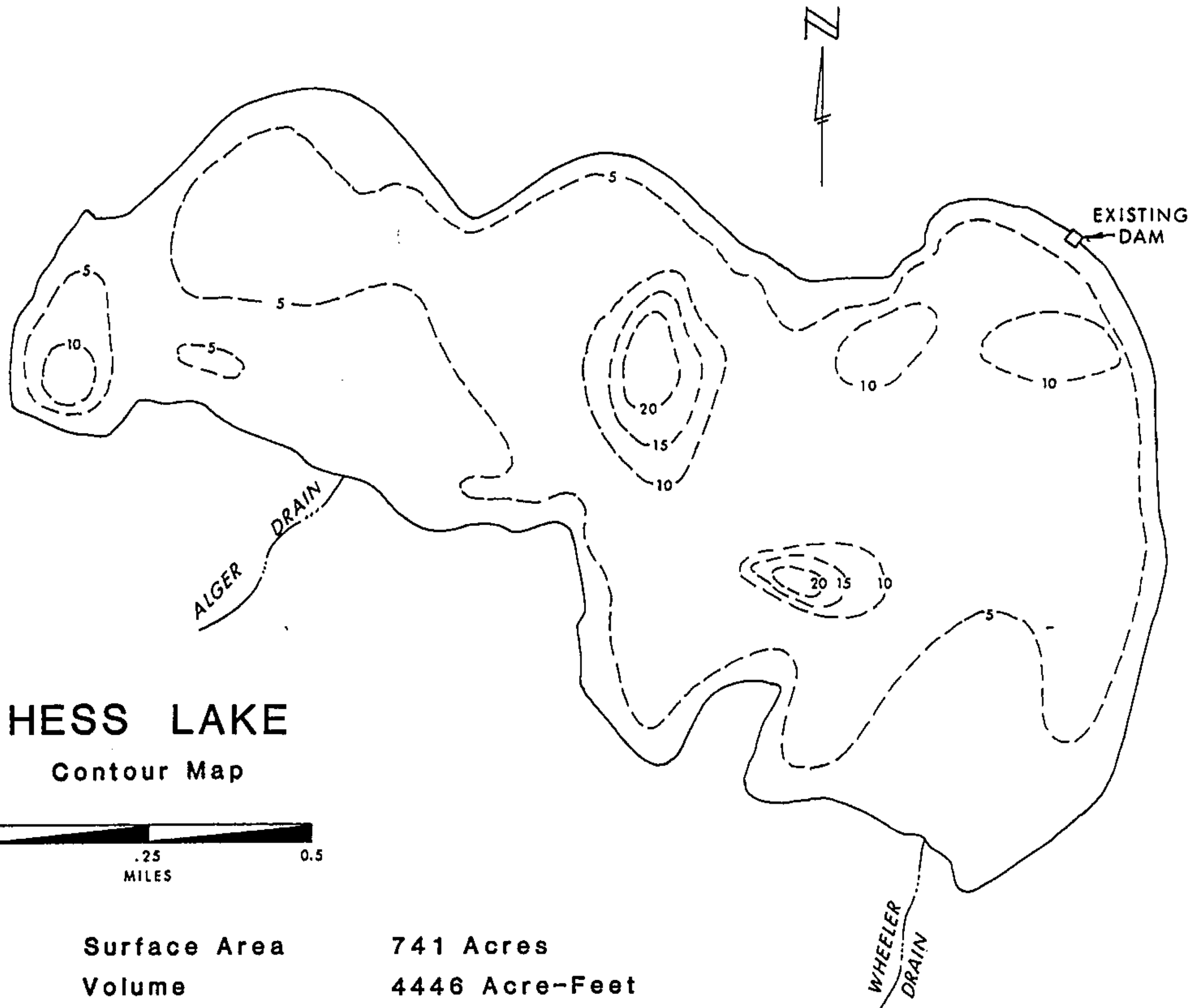
INTRODUCTION

Excessive turbidity and large areas of problem weed growth has limited the recreational and aesthetic value of Hess Lake for more than 10 years.[5] In a concerned effort to bring about beneficial changes in the Lake environment, the Hess Lake Board has authorized this Feasibility Study. The Study identifies the existing water quality problems, the sources of the problem causing nutrient, and the most feasible improvement alternatives. The following report, together with the referenced material, will fulfill the requirements of Section 10 of Public Act 345 of 1966.

EXISTING CONDITIONS AND PROBLEMS

Hess Lake is an inland lake 741 acres in surface area. The Lake has three relatively deep areas (Figure 1) but, as a whole, the Lake has little overall depth. The average depth of the Lake is 6 feet. The volume of Hess Lake (4,446 acre-feet or 5,520,000 m^3) is not great for a lake of its surface area and again reflects its shallow nature. Only about 5% of the Lake's volume lies below the 10 foot level. Figure 2 shows a cross section from east to west through the center of the Lake and illustrates the shallowness.

The drainage basin for Hess Lake (Figure 3) covers 15 square miles or 13 times the area of the Lake. As Figure 3 shows, most of the drainage area lies to the south of the Lake and farming is the most prevalent land use in most of the area (Figure 4).

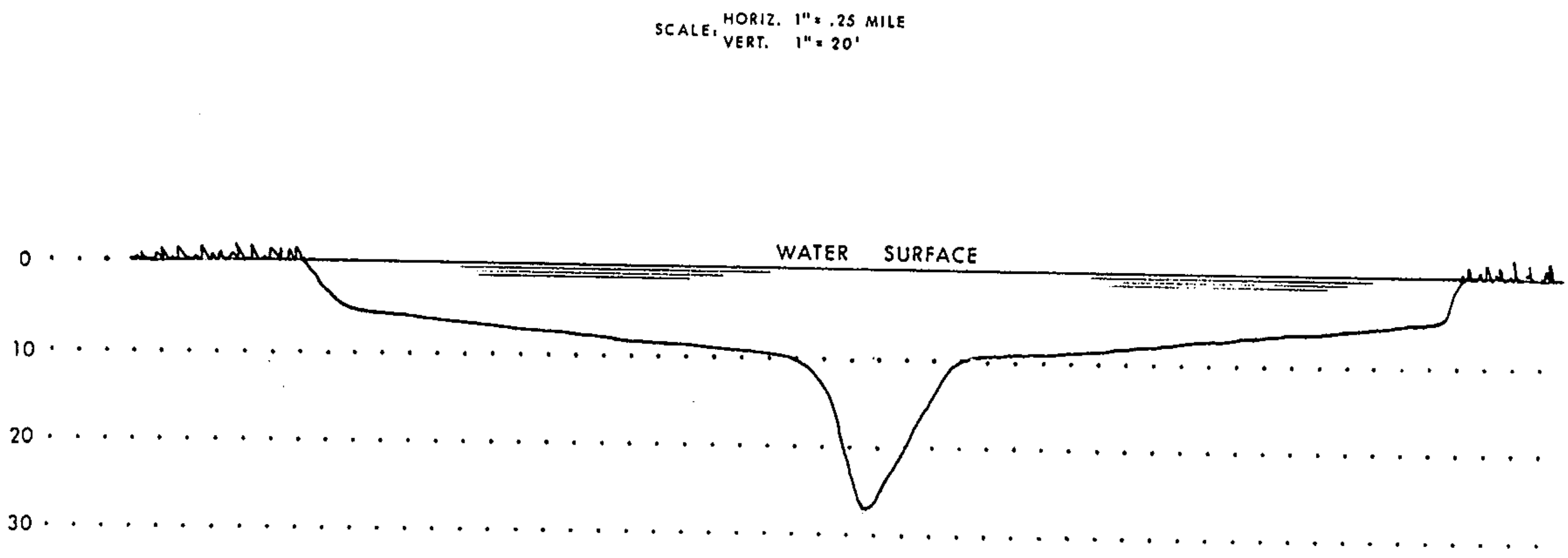


HESS LAKE

Contour Map

Surface Area	741 Acres
Volume	4446 Acre-Feet
Mean Depth	6 Feet

Figure 1

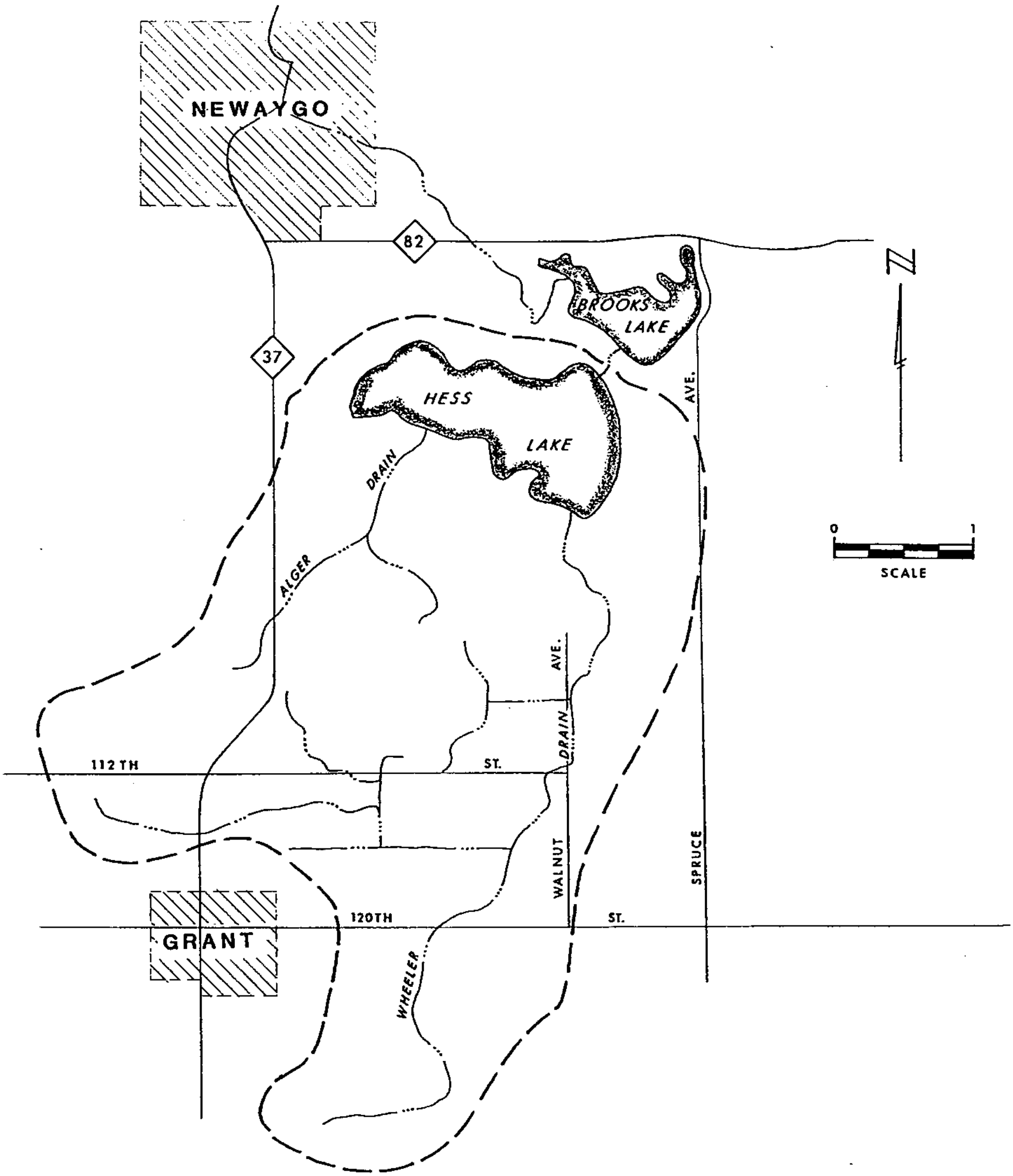


HESS LAKE

East-West Lake Profile Map

(Depth in Feet)

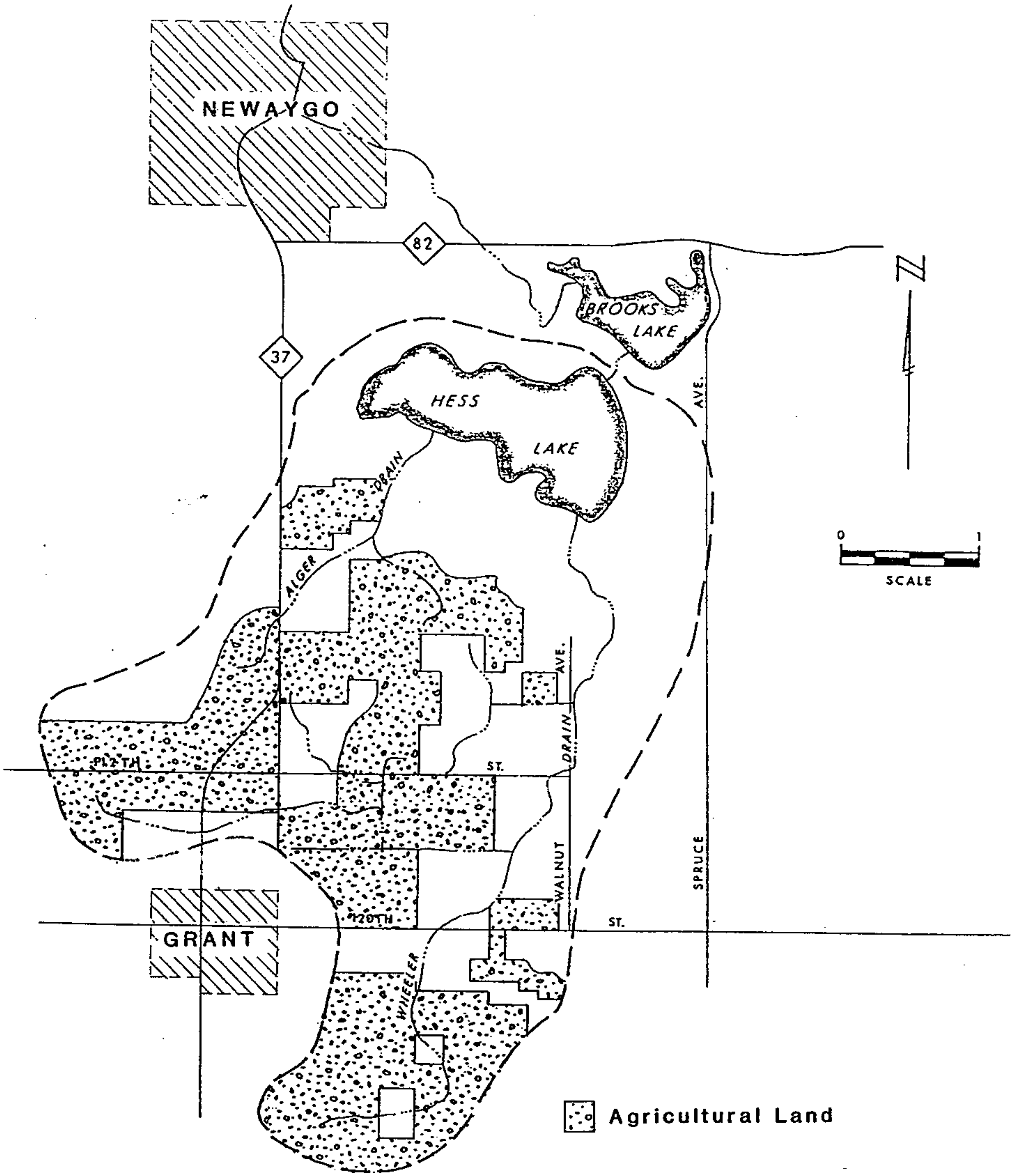
Figure 2



HESS LAKE DRAINAGE BASIN

Area 15 Square Miles

Figure 3



HESS LAKE DRAINAGE BASIN

Figure 4

According to the Lake use study completed in 1972,[5] there are 384 lakeside dwellings with varying degrees of use. Twenty-nine percent of the residences use their dwellings year round, 46% use them 1-8 months of the year, and 25% of the residences use them only on weekends. All of the dwellings are served by individual wells and on-site wastewater disposal systems. A study by the County Health Department in 1978 showed that about 40% of the lakeside on-site disposal systems were within 100 feet of the Lake. The same study showed elevated nitrate levels in 43% of the water wells. This information indicates that the dissolved materials in the wastewater is filtering through the sand and reaching the ground water and probably the surface waters of the Lake. This addition of dissolved materials is adding to the problems of Hess Lake. The phosphorus inputs by this source are quantified in the section on Phosphorus Inputs beginning on Page 7.

TURBIDITY

The major problem to the use and ecology of Hess Lake is its high turbidity. Most good water quality lakes in Michigan have secchi disk reading (water transparency) of 12 feet or more. Even poor quality lakes measure in the 6 foot range. Hess Lake's secchi disk reading seldom exceeded 2.6 feet during the summer of 1981.

This very high water turbidity causes problems for recreation and for the biology of the Lake. Recreation is hampered because turbid water is dangerous and unpleasant to swim in, navigation is more difficult, fish are less likely to see the fisherman's lure, and turbid water is aesthetically displeasing.

High turbidity also upsets the natural biology of the Lake. Low light penetration limits most plant and animal life to the upper few feet of the Lake where the light is strong enough for production. High turbidity causes problems for fish in finding their prey. Turbidity gives an environmental advantage to the noxious plants and animals that thrive under these low light conditions and low light levels can increase the severity of low dissolved oxygen levels in the Lake.

There are two causes of the high turbidity in Hess Lake.

Algae are microscopic plants that start the food chain in the Lake by producing food for larger species. A certain amount of algae is necessary for a healthy lake but in concentrations above about 2,000 cells per milliliter they cause an unattractive and often fowl smelling condition to the water. Concentrations were always in excess of 2,000 cells/ml in Hess Lake during the summer of 1981 and reached over 10,000 cells/ml in early July, 1981. These concentrations were more than enough to cause the green cast, fishy smell, and low turbidty observed during the study period.

The other cause of turbidity is the resuspension of sediment material from the bottom of the Lake. As the algae and other plant materials die and partially decompose they sink to the bottom forming a mostly organic muck that is only slightly heavier than water. It takes very little disturbance to push this material back into the upper waters. Because the Lake is shallow, even moderately strong winds have a large effect on resuspending this fine particulate matter. Studies on Hess[5] and other lakes have also shown that boat usage effects the resuspension of sediment material, particularly the large power boats.

SHALLOWNESS

The shallowness of Hess Lake is also a major problem. The Lake as originally formed by the receeding glaciers about 10,000 years ago was moderately deep and of good water quality. As the plants and animals in the Lake died, sank and only partially decomposed, they began to form a soft organic muck that now covers the Lake bottom in the areas that are more than 4 feet deep. As Figure 5 shows, the rate of sedimentation was very slow for most of the past 10,000 years. Within the last 100 years, however, the rate of sedimentation increased greatly and the Lake lost even more of its depth. Now about 20 feet of muck covers most of the Lake bottom.

The sediment (muck) is not the result of directly washed in materials but rather the remains of plants and animals which grow in the Lake. However, the amount of growth in the Lake is dependent on the amount of dissolved materials such as carbon, nitrogen and phosphorus which find their way into the Lake.

In ancient times and under natural forest conditions, most of the plant stimulating nutrients were held on the land. Only minor amounts of nutrient minerals were washed into the Lake and only minor amounts of algae and weeds grew in the Lake. As modern man stripped the land for agricultural and residential use, more nutrients were washed into the Lake causing increased weed and algae growth which caused increased turbidity and increased sedimentation. Figure 5 illustrates this sudden increase in sedimentation rate during the last century.

SEDIMENT ACCUMULATION

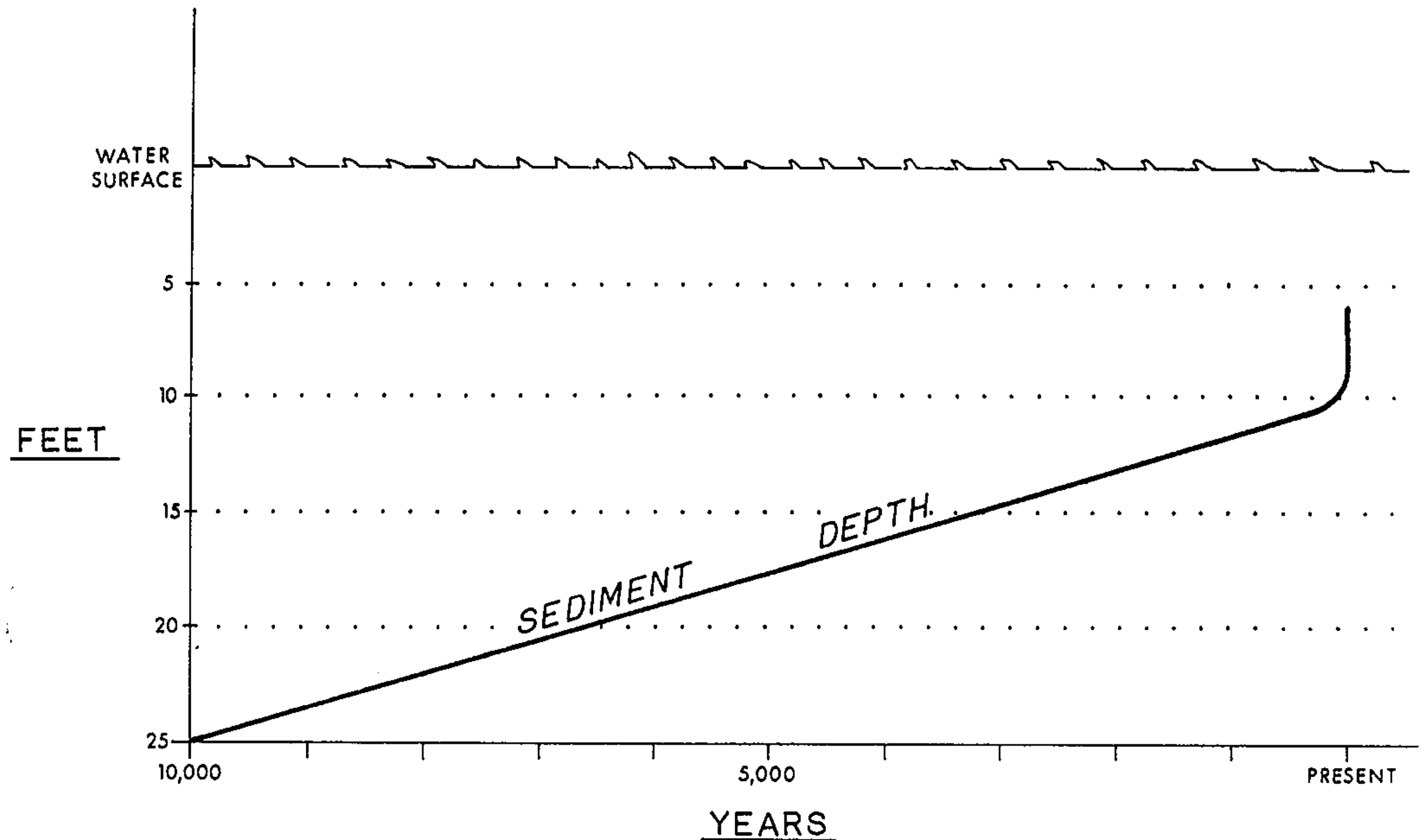


Figure 5

Evidence of this change is found in the geologic record. Several sediment samples were taken with a vertical coring device during the winter of 1981-82. The deep sediments and therefore the oldest sediments were found to be composed almost entirely of unidentifiable organic matter and pine pollen. This was true of the sediments from about 5 feet deep down to at least 20 feet into the sediments.

This composition indicates that pine and spruce dominated the forests surrounding Hess Lake during most of the last 10,000 years and that the Lake was probably of good quality producing only the easily decomposed green algae and few rooted weeds. The upper 5 feet of sediment is much different in composition with less pine pollen and a large amount of diatom algae remains. This shows a change in the surrounding forests and shows an enriched and more productive condition in the Lake during recent times. Since the pine forests were removed and intensive farming began in the area about at the turn of the century, the 5 feet of sedimentation translates to about one inch of sedimentation per year.

In summary of the above, Hess Lake is very turbid because of the excessive algae growth and resuspension of sediment materials by wind and boats. The Lake is very shallow having lost over 20 feet of its depth during the last 10,000 years. About 5 feet of depth has been lost within the last 100 years.

The lack of depth in Hess Lake also has a profound effect on water quality. It has been shown that lakes with little depth experience more water quality problems than do lakes that have large areas of deep water.[4] The reason for this is that nutrient material in shallow water remains in the system much longer.

As algae and other aquatic organisms die they sink to the bottom, decompose and become part of the sediment. In deep water, 15 feet or greater, decomposition is slower and more nutrients are trapped in the sediments and deep water. This deep water "sink" serves to remove nutrients from the upper waters during the summer recreational period and thereby maintaining good water quality.

Hess Lake has very little deep area to remove nutrients from the water. Nearly all the nutrients remain in shallow water and in contact with the upper productive water. This encourages maximum algae and weed growth and its associated recreational problems.

Hess Lake now has about 3% of its area in water deeper than 15 feet. To help maintain good water quality, about 30% or more of the Lake area should be deeper than 15 feet. From a water quality standpoint, it is better to have a relatively small area very deep than it is to have a large area only moderately deep. In the case of Hess Lake, it would be better to deepen 30% of the Lake to 20 feet deep than to deepen the entire Lake only 10 feet deep even though the same amount of material might be removed.

PHOSPHORUS

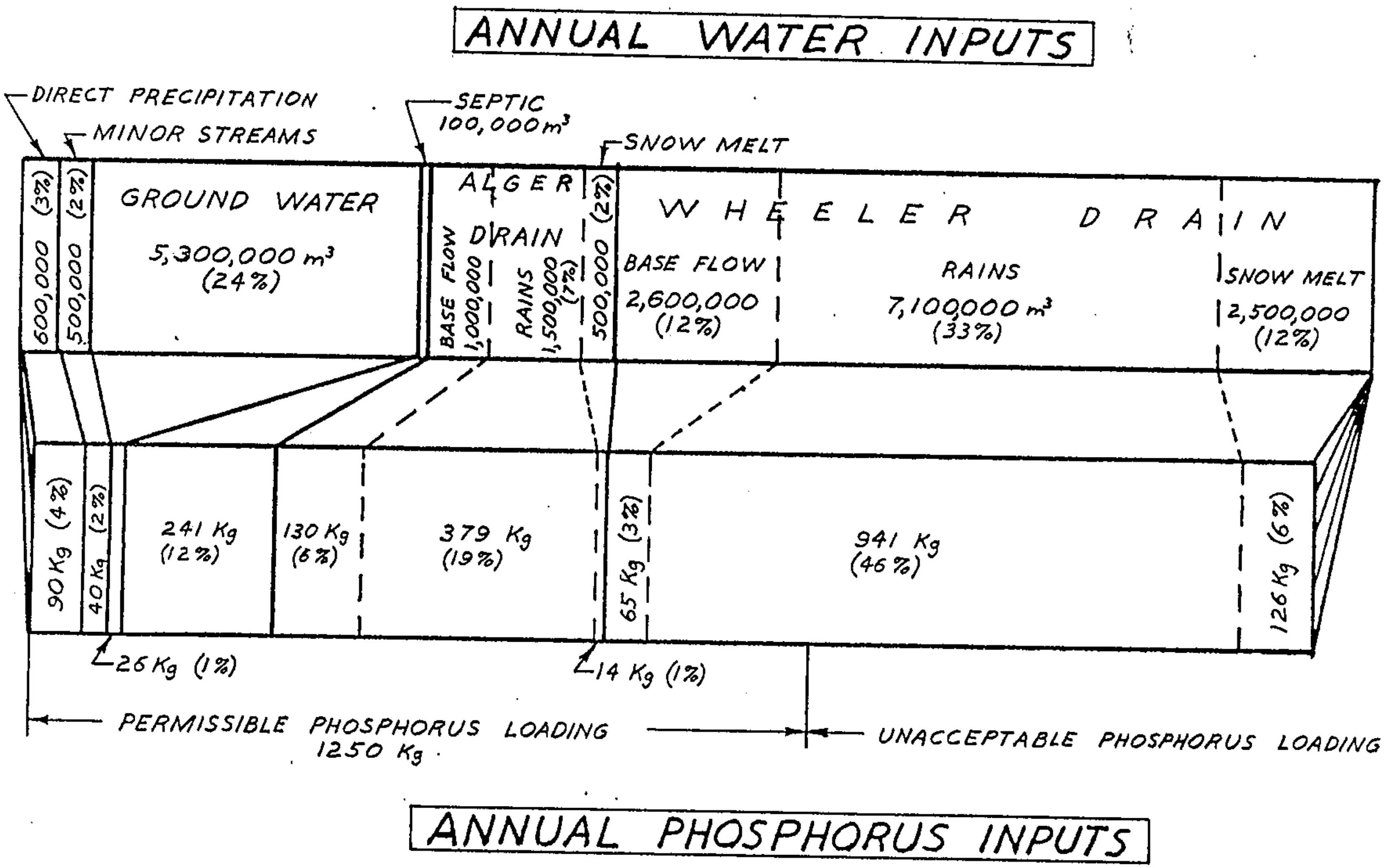
Hess Lake has lost much of its depth due to the accumulation of in-lake generated sediments. The nutrients that enter the Lake stimulate the growth of the sediment producing material. The nutrient of concern is phosphorus.

Phosphorus is necessary for all plant and animal life. Aquatic plants take the phosphorus directly from the water or from the sediments. Very small amounts will produce a large amount of growth as plants only need about 20 parts per million phosphorus (wet weight) for good growth. And, in general, the more phosphorus that is added to a lake the more plant life it will produce. The object, then, is to reduce the amount of phosphorus entering the Lake so that the plant life and the resulting sediments are reduced.

Every lake can tolerate a certain amount of phosphorus input. Hess Lake can tolerate up to about 2,750 pounds (1250 kg) per year with only minor water quality problems. Additions above this "permissible loading limit" result in excessive plant growth and obvious water quality problems. Hess Lake is currently receiving an excess of 1,770 pounds (800 kg) of phosphorus per year. This large excess is the major problem to the Lake causing high nutrient concentrations in the water (30 μg/l P) high concentrations of blue-green algae ($\geq$ 2,000 cells/ml), excessive sedimentation rates and large areas of rooted weed growth.

An historical perspective is also worthy of note. Based on values of other lakes in similar settings, the amount of phosphorus entering Hess Lake before the arrival of modern man was calculated. Under undistrubed conditions, say 200 years ago, the phosphorus input from all sources was probably about 1,500 pounds (680 kg) per year. The measured inputs for 1981 amount to 4,500 pounds (2,050 kg), 3 times the amount that once flowed into the Lake.

FIGURE 6
HESS LAKE ANNUAL WATER & PHOSPHORUS INPUTS

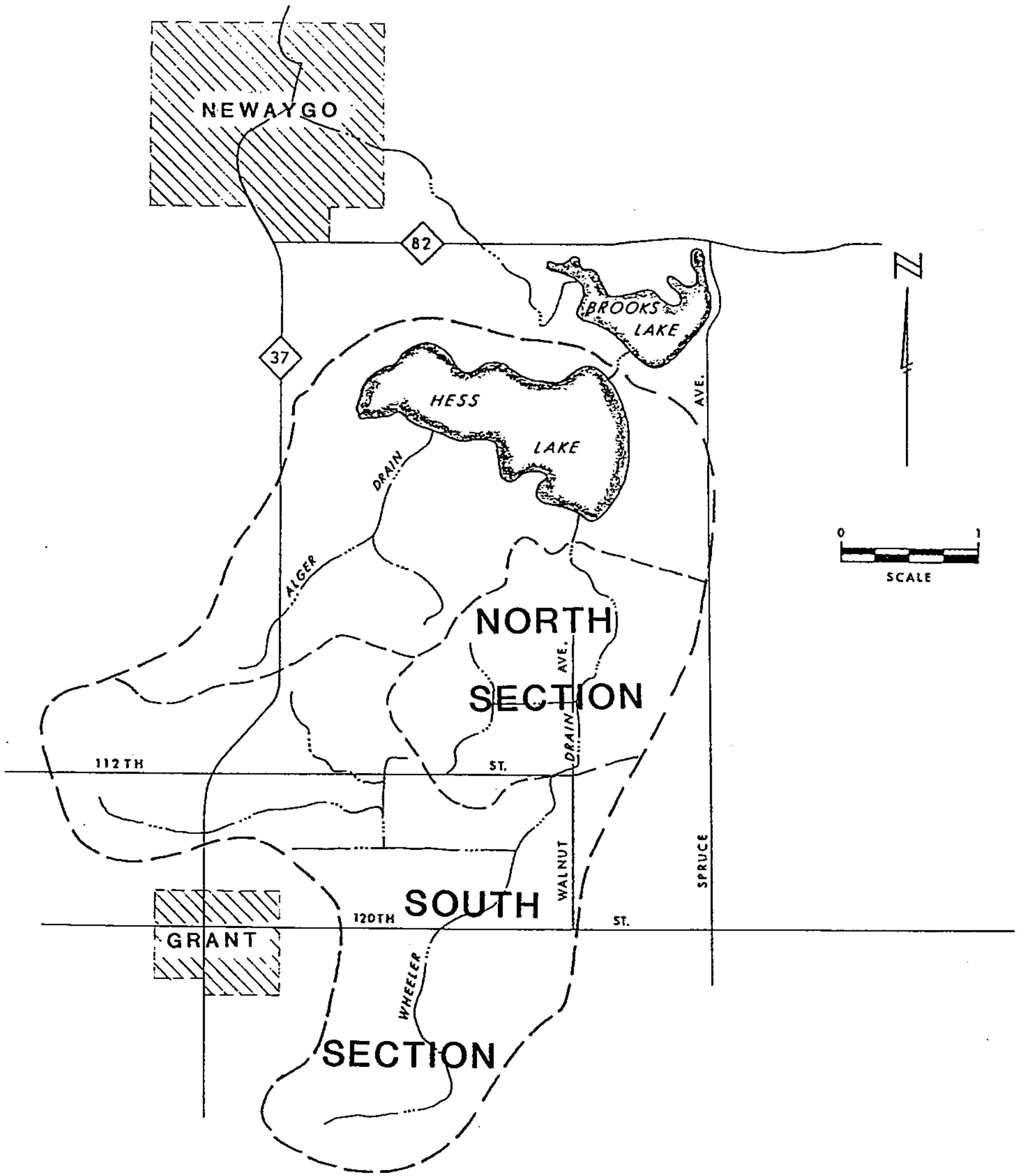


Another measure of water quality showing recent changes is the Trophic State Index scale, abbreviated TSI. The scale is based on certain measured water quality data and reduces the information to a 0 to 100 scale. The higher the number the poorer the water quality. The TSI value for Hess Lake was 54 in 1972, 56 in 1974 and 58 in 1981. This trend clearly shows the diminishing water quality in Hess Lake due to the excessive incoming phosphorus.

PHOSPHORUS INPUTS

Phosphorus is carried into Hess Lake with its water inputs. These water inputs are detailed in Figure 6. Upon study of Figure 6, it is obvious that most of the water entering the Lake is from the Wheeler Drain. It is not surprising that this agriculture based drain also contributes the major portion of the phosphorus to the Lake. Agricultural land commonly looses large amounts of phosphorus because it is barren much of the year, is fertilized more heavily than other ground and it drains quickly through artifical drainage.

Most of the water and phosphorus input through the Wheeler Drain is dependent on rainfall. As the rains fall, particularly the heavier rains, they wash particle and dissolved material into the Wheeler Drain system and cause a tempoary rise in flow. It is during these wet weather flow "pulses" that most of the phosphorus enters the Lake through the Wheeler Drain.



HESS LAKE DRAINAGE SYSTEMS

Figure 7

The high flows through the Wheeler Drain create a physical problem as well as a chemical problem. The high flows carry particulate matter into the channel and Lake depositing it there as the flow velocity diminishes. Based on samples taken following the September 30, 1981 storm, about 185 cubic yards of sediment entered the Lake during the 24 hour period following the rain. It is easy to see why the channel requires periodic dredging to remain serviceable.

Although the channel helps settle out the particulate matter, settling has little effect on reducing phosphorus input. Samples of Wheeler Drain water analyzed before and after settling show 25% down to zero reduction in phosphorus after settling. Apparently the phosphorus is not bound to the coarser particulate matter (sand) and settling has little effect on reducing phosphorus input.

To further illustrate the effect of the Wheeler Drain, the Drain was separated into two sections, north and south (Figure 7). The south section's watershed is comprised of 7.3 square miles, most of which is farm land. The grade of the Drain is 20 feet of drop over a 3 mile distance (Figure 8). This south section produces about 52% of the water that flows through the Drain and about 60% of the phosphorus. About one third of the entire phosphorus input to the Lake originates in this section of the Drain. It is also important to note that the flows from the south section are very erratic in nature occurring after rains and during spring runoff. During dry periods the south section has almost no flow. The soils in the south contain large areas of organic mucks.

The north section of the Drain resembles a natural northern Michigan stream not unlike the many trout streams in the area. It meanders through a densely forested area of sandy soils. It has a continuous ground water feed base flow of about five cubic meters per minute even during dry periods. Its waters are cool, of good quality and generally low in phosphorus content. The stream drains about 2.4 square miles and contributes about 48% of the Drain's water and about 40% of the Drain's phosphorus. The north section has a steeper grade of about 36 feet in 2 miles (Figure 8).

The good quality of the north section was demonstrated during collection dates during July and August, 1981 when phosphorus concentrations were .02 mg/l and .03 mg/l respectfully. No flow was coming from the south section at these times. When runoff flows from the south section were dominant, the phosphorus concentrations ranged from .08 to .42 mg/l.

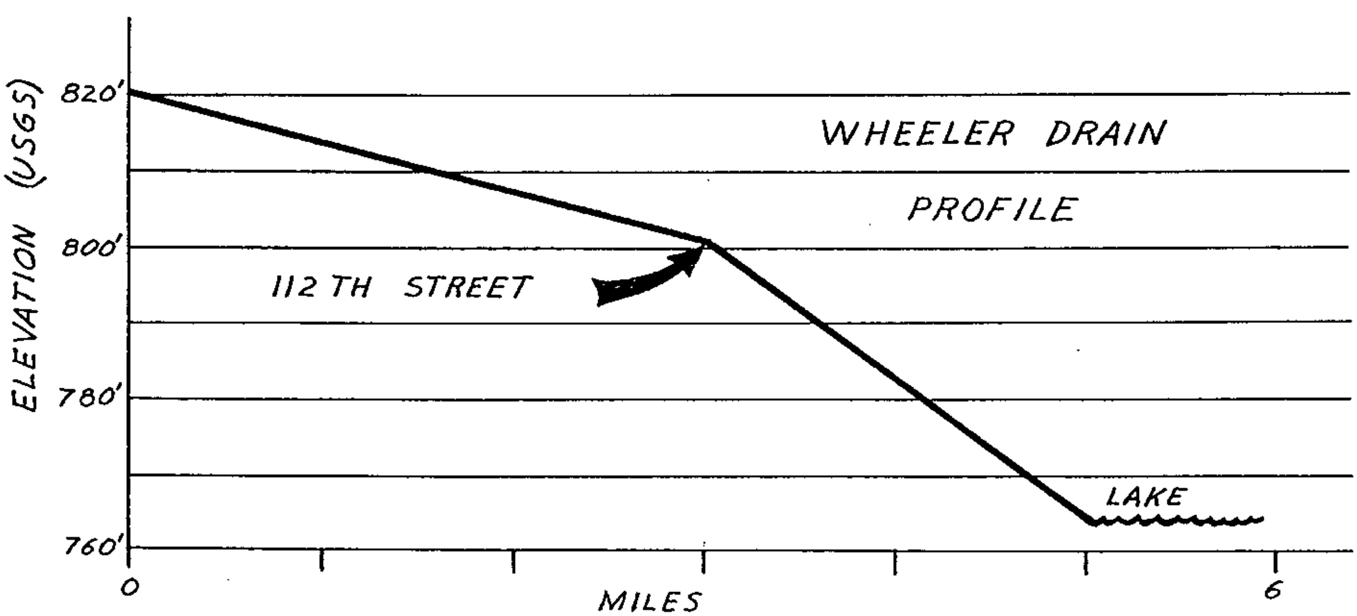


FIGURE 8

The Alger Drain also contributes a substantial amount of phosphorus to Hess Lake. Most of the input comes during rainfall periods indicating a fast "flush" of runoff from the drainage area land. Major portions of the Alger Drain watershed are also in agricultural production.

Septic input from the surrounding homes has an additive effect to water quality problems in Hess Lake but the phosphorus input by this source is relatively small compared to the other present inputs. Phosphorus enters a septic tank at a rate of about 1.1 pounds (0.51 kg) per person per year in areas with a detergent phosphorus ban such as Michigan. The amount that travels from the septic system to the Lake is a function of soil type, nearness to the ground water table and direction of ground water flow and proximity to the Lake.

The soils in the Hess Lake vicinity are almost entirely a coarse rubicon sand which does little to restrict the movement of water and nutrients that are injected beneath the surface. The direction of ground water flow appears to be toward the Lake except perhaps near the outlet and for a short stretch along the north edge of the Lake. In some areas the homes are built in low areas where the septic systems are near the ground water table. This facilitates the movement of phosphorus into the Lake.

The natural ground water inputs to the Lake are substantial but this water typically carries very little phosphorus. The ground water input is calculated at 5.3 million cubic meters but its phosphorus input is only about 26 kilograms or one percent of the total.

Hess Lake has two small continuous flow tributary streams and some intermittent drainages. These contribute only minor amounts of water and phosphorus to the Lake, about 2% of the water and phosphorus. Precipitation directly on the Lake is also a minor contributor of water and nutrients.

GOALS

The following are considered realistic goals for the protection and enhancement of the water quality of Hess Lake.

1) The in-lake sedimentation rate must be reduced. The present sedimentation rate is estimated at about one inch per year. The average depth of the Lake is only 6 feet. Given these two factors, the life the Lake is probably only a few more decades as the rate of fill-in will increase as the Lake becomes increasingly shallow. Dredging would help alleviate the sedimentation problem. Reduced sedimentation rates would improve the longevity of the dredging. Also, techniques to reduce sedimentation are generally less costly than dredging.

2) Turbidity should be reduced. The algae growth portion of the turbidity should be reduced so that secchi disk readings increase to about 4.5 feet during the summer season. This reduction in turbidity is necessary to restore the biological balance of the Lake and decrease the rate of sedimentation. Rooted weed growth would be expected at greater depths and greater density in certain areas, but dredging would limit the areas of growth.

3) The phosphorus input to the Lake should be about 1,250 kg per year under present hydraulic conditions. If hydraulic conditions change, including additional depth, the new loading limit should be calculated according to the formula.

$$L = 200 \, (\bar{z} \, p)^{0.5} \times 3 \text{ where:}$$

$\bar{z}$ = mean depth (volume ÷ area) in meters

p flushing rate (outflow volume ÷ lake volume)

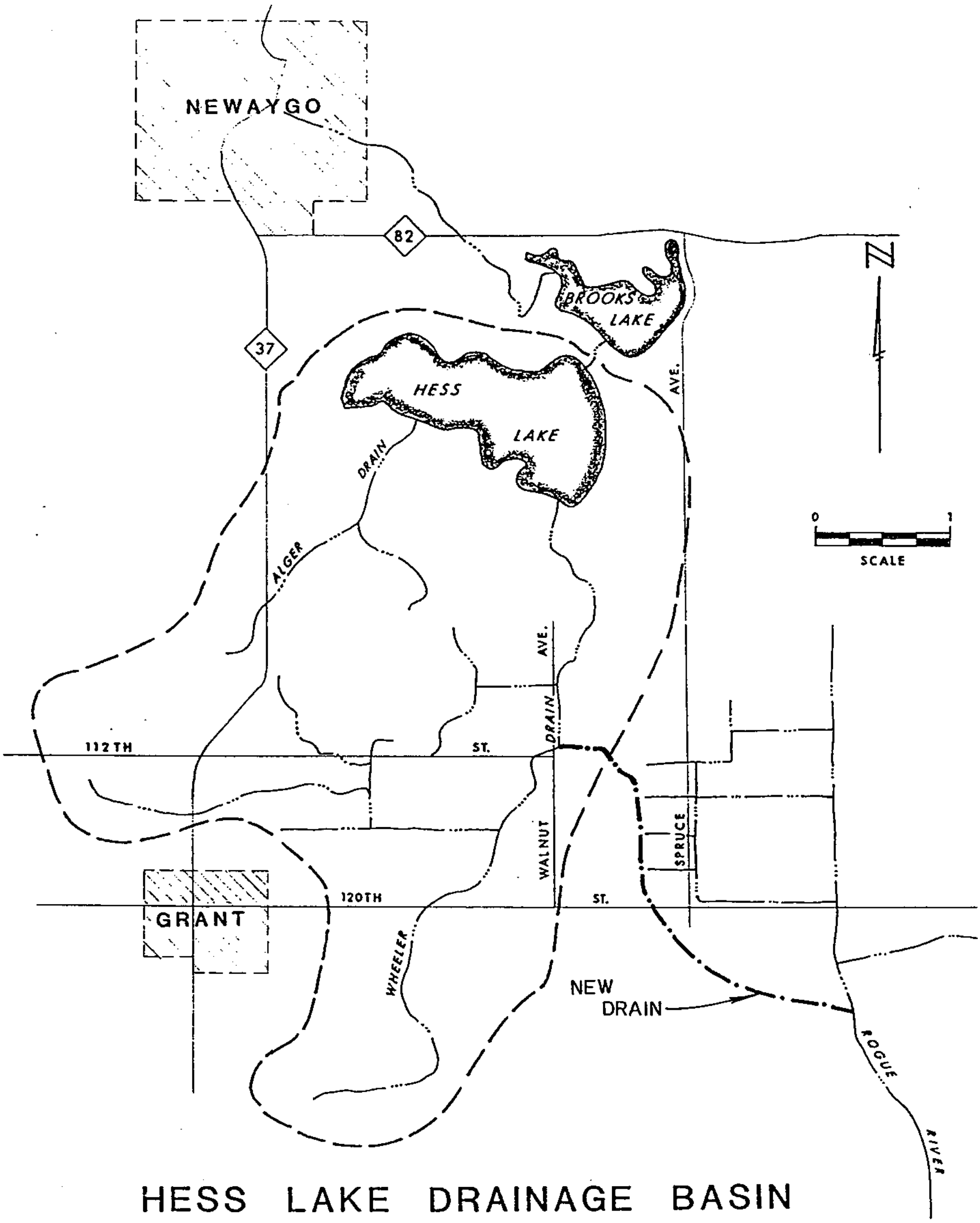
Goals #1 and #2 above would be attained if the loading is reduced to 1,250 kg/year from the present 2,050 kg/year, or according to the formula.

4) Dredging must take place. Hess Lake needs greater depth to maintain an ecological balance and maintain its use as a community resource. Greater depth would increase the Lake's fishery, decrease rooted weed growth, decrease the amount of nutrients recirculated within the Lake and reduce the turbidity due to resuspended materials.

5) To help maintain good fishing potential in Hess Lake, 5-10% of the Lake should remain in rooted weed growth throughout the summer.

CORRECTION ALTERNATIVES

To correct the problems in Hess Lake, two things must be accomplished, reduce the phosphorus input and increase the depth in the Lake. Doing only one will not bring about the desired changes to improve and protect the Lake for future years.



HESS LAKE DRAINAGE BASIN

Area 15 Square Miles

ALTERNATIVE # 1

Figure 9

Because of technical and financial constraints, the implementation of the phosphorus reduction and the Lake deepening may have to be accomplished in stages. In this case, priority should be given to implementing the phosphorus reduction portion of the project as this is the most time critical portion of the Lake improvement. Dredging can be done with somewhat more delay and still benefit the Lake to an equal amount.

PHOSPHORUS REDUCTION ALTERNATIVES

Phosphorus reduction can be accomplished by several techniques which are described as Alternates 1 through 5.

1) Diversion of Wheeler Drain into the Rogue River. This alternative would consist of a new drain connecting the Wheeler Drain at 112th Street to the Rogue River in the vicinity of 128th Street (Figure 9). The connection would be downstream from the last dewatering pump station. The ditch would be about 3 miles long and would divert the entire south section of the Drain away from the Lake. This would remove about 6.4 million cubic meters of water from the Lake per year and reduce the phosphorus loading about 680 kg/year. The phosphorus loading to the Lake would then be about 1,370 kg/year and the desired changes could be expected to take place. The water diverted from the Lake should not cause any serious problems for Lake level maintenance or flow-through as there would still be enough water to flush the Lake about 1.7 times/year as opposed to the present 2.4/year.

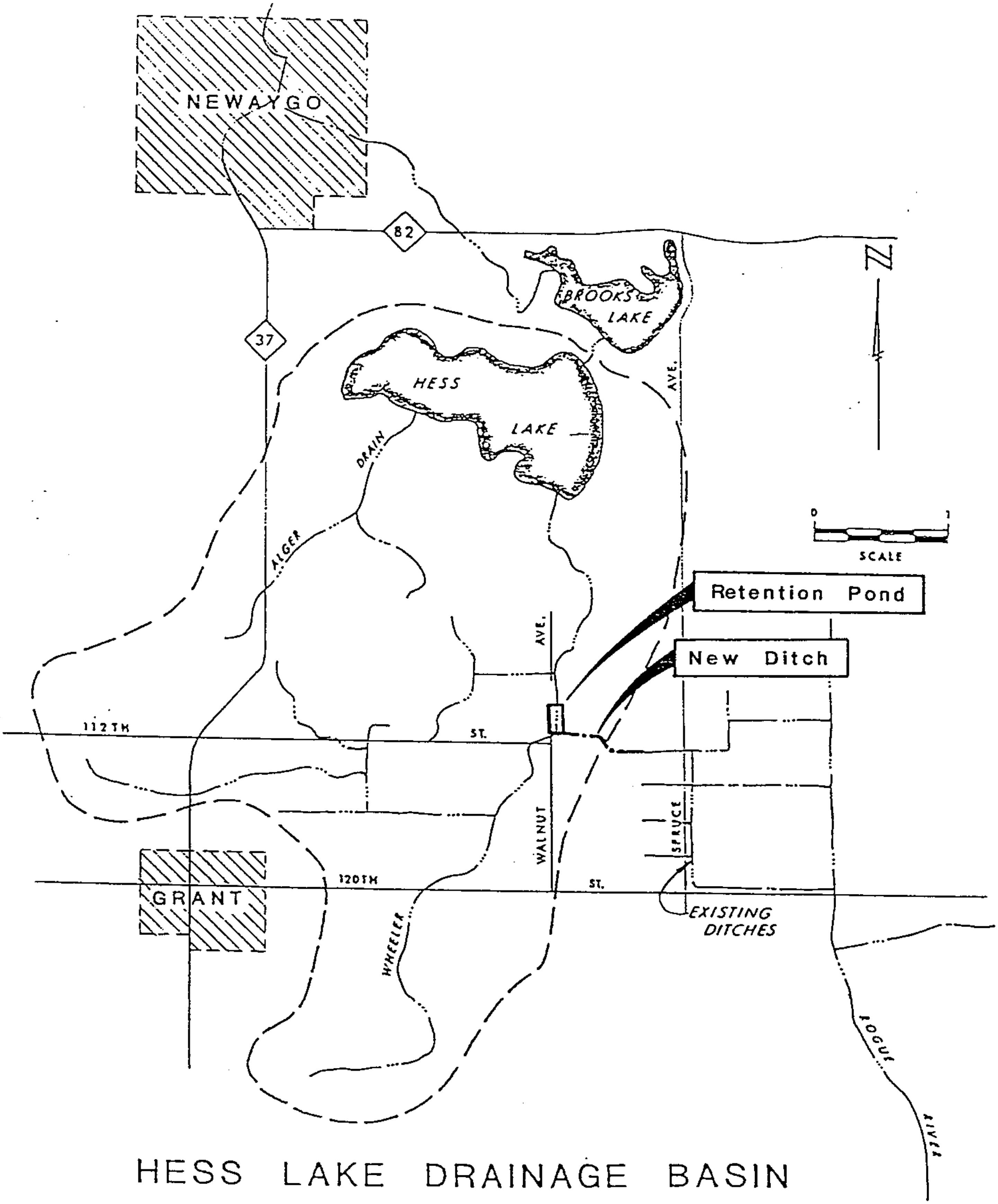
The potential problems with this altnerative are several. There appears to be enough fall to produce sufficient flow but this should be accurately surveyed to insure its technical feasibility. Legal and administrative problems could also be expected as the current drain construction procedures are based on benefit to the land owners adjacent to the ditch. In this case there is little or no benefit to the land owners in the Rogue River district and approvals may be very difficult to obtain even with the Hess Lake residents paying for the work. Flooding and water quality problems downstream would also have to be considered.

The cost of constructing the diversion ditch with its necessary culverts, seeding, land and right-of-way acquisition, etc. is estimated at $400,000 - $500,000, which assumes the Rogue River can handle this additional flow. Based on 700 kg phosphorus removed per year over the next 20 years that amounts to an efficiency of $32 per kg of phosphorus prevented from entering the Lake. There may be additional cost in further studies to determine the effect of the diversion on the Rogue River hydraulic capacity and water quality.

2) Partial Diversion to the Rogue River System. In this alternative the waters from the south portion of the Wheeler Drain would be diverted into the existing drains in the Rogue River system (see Figure 10). Even though the receiving drains would be improved to accept the additional flow, not all of the high flows could be accommodated. Therefore, a retention basin of 35 acres would be built in the 112th Street vicinity to retain the high storm generated flows so that they could be released gradually in the days following the rain. If the flows exceeded the capacity of the retention basin, the excess would be spilled into the north section of the Wheeler Drain and Hess Lake. This alternative would prevent about 690 kg of phosphorus from entering the Lake and would bring about most of the desired changes.

The difficulties with this alternative include additional pumping of the diverted water and obtaining approvals for the diversion. Downstream water quality effects on the Rogue River would have to be addressed and the phosphorus retention and diverting efficiency would be largely dependent on the magnitude and frequency of the rains.

The cost of the partial diversion alternative is estimated at \$1,500,000 - \$2,000,000. This includes the cost of the land, clearing and grading, control structures, and two miles of drain improvement including culvert replacment. Based on removal of 690 kg of phosphorus the cost efficiency of this system would be about \$120/kg phosphorus removed or diverted.



HESS LAKE DRAINAGE BASIN

Area 15 Square Miles

ALTERNATIVE # 2

Figure 10

3) Chemically Remove Phosphorus from the Wheeler Drain. The addition of chemicals, such as alum, to water precipitates the phosphorus which then forms a flock settling to bottom forming a sludge or sediment. This process is widely used in wastewater treatment plants where phosphorus concentrations are high. This alternative would require a 30 acre retention pond to capture the high flows, two precipitation ponds for settling of the flock and chemical feed equipment. The efficiency of chemical phosphorus removal is not 100% and an estimated over all removal is 700 kg/year.

This alternative would require continuous operation and maintenance including periodic removal of the precipitated phosphorus sludge. Acidity residual in the discharged water can also be a problem and could have a detrimental effect on the Lake unless corrected.

The cost of building the chemical treatment facility would be in the range of $1,500,000 plus operation and maintenance of $40,000/year. Based on the cost over 20 years this alternative would cost about $158/kg of phosphorus removed.

4) Phosphorus Removal Lake on Wheeler Drain. This alternative would use a man made lake located in the 108th Street area to remove phosphorus. The new lake would remove phosphorus through natural processes of plant uptake and sedimentation. A large lake (200 acres) would be necessary to achieve adequate removal. The lake would need a permanent water level and 15 to 20 feet of depth in 30% of its area. Some operation and maintenance would be necessary for maximum phosphorus removal and safety.

Some problems may be encountered in procuring enough land for a lake of this size. The new lake would be an added resource to the area although its water quality would be poor.

The cost of the new lake, including the necessary land and rights-of-way, is estimated to be about $5,800,000 plus a yearly operation cost of $20,000. The cost of removal would be about $368/kg of phosphorus removed.

5) By-Pass System for Wheeler Drain. In this alternative a dam would be built just upstream from Hess Lake on the Wheeler Drain. A large diameter pipe would be connected from the pond, through the Lake, to a discharge point downstream from Brooks Lake (Figure 11). The Wheeler Drain water would be forced through the pipe by the pressure buildup in the pond and thus the Lake would be by-passed by the Wheeler Drain. Not all of the heavy flows could be put through the pipe but most of the high nutrient flows would be by-passed. About 845 kg of phosphorus per year would be by-passed thereby reducing the loading to Hess Lake to about 1,200 kg/year.

The by-pass alternative would have good flexability in operation allowing low nutrient flows to be put into the Lake while by-passing high nutrient flows. This would allow about 30% of the Wheeler Drain water to be spilled into the Lake while removing about 70% of its phosphorus and meeting the Hess Lake loading requirements. The legal aspects of installing a pipe across the bottom lands of the Lake would have to be resolved and accurate survey work along the proposed route would be necessary before finalizing plans. Some manual operation control of the new Wheeler Drain dam may also be necessary for maximum efficiency.

The cost of the by-pass system is estimated at $650,000 to $700,000. The dollar efficiency of such a system would be about $40/kg phosphorus by-passed.

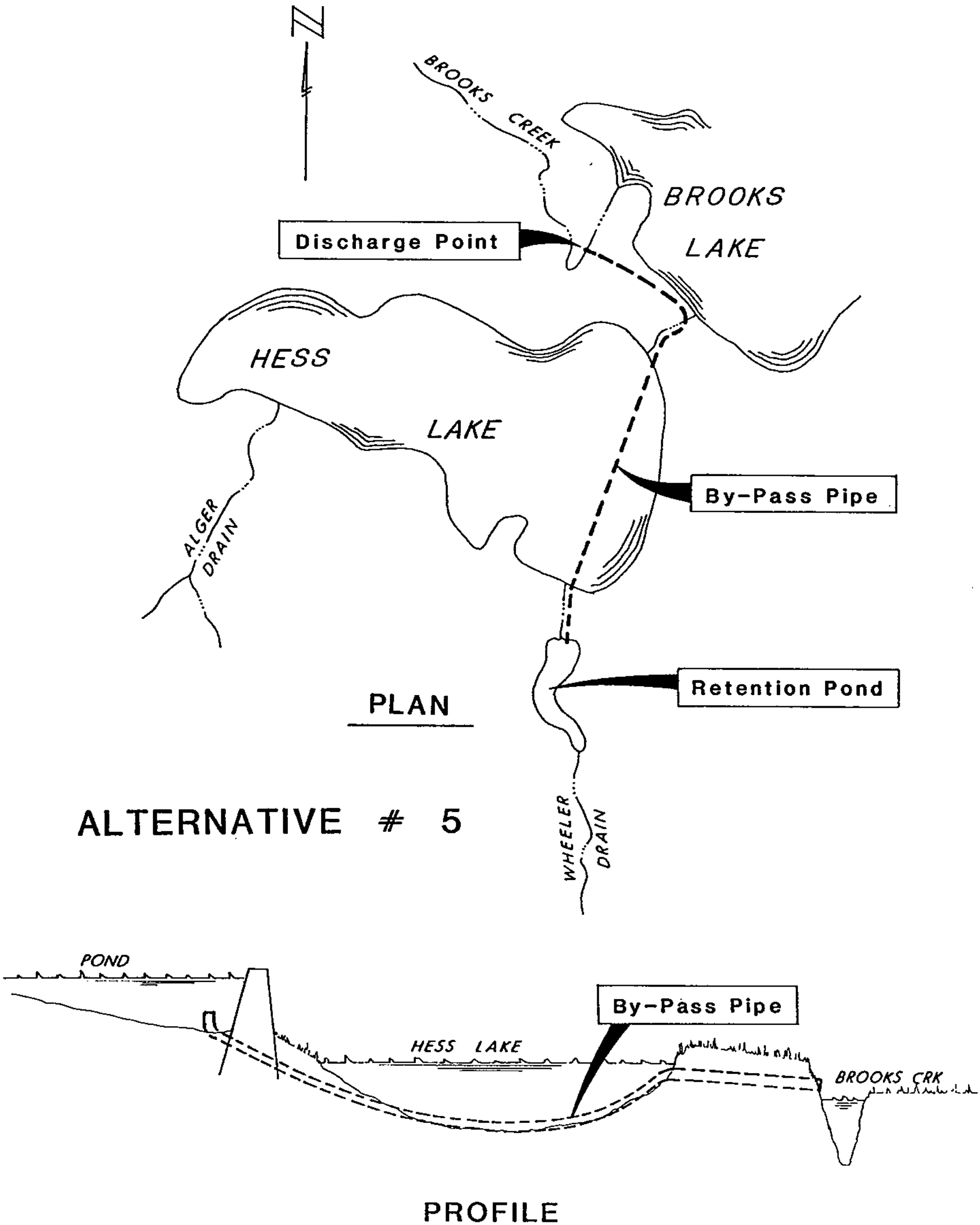

N
BROOKS CREEK
BROOKS LAKE
Discharge Point
HESS LAKE
By-Pass Pipe
ALGER DRAIN
Retention Pond
PLAN
ALTERNATIVE # 5
WHEELER DRAIN
POND
By-Pass Pipe
HESS LAKE
BROOKS CRK
PROFILE

Figure 11

LAKE DEEPENING ALTERNATIVES

Two methods of accomplishing the Lake deepening portion of the Lake improvement project are discussed in Items 6 and 7:

6) Lake Dredging. Dredging to remove the accumulated sediments and to deepen the Lake is necessary to restore the ecological balance of Hess Lake. About 30% of the Lake should be dredged to a depth of 15 feet or more plus some sediment removal in shallow, weed infested areas. About 3.5 million cubic yards of material would be removed. A disposal site of 225 acres would be needed for the dredged material. The dredging would take 3 or more years to complete.

   The problems with dredging are usually in finding a suitable disposal site and in the large manpower and energy demand. The benefits to the Lake are almost immediate with each yard of material removed; weed growth diminishes, volume increases, nutrients stored in the sediments are removed, and fish habitat improves. It appears that most of the material to be removed is organic sediments. This material is roughly equivalent to animal waste in its fertilizer content and soil conditioning properties. It may have use in the community as a soil building material.

   The cost of dredging the Lake is estimated at 6 to 7 million dollars at 1982 prices and depending somewhat on how the operation is administered and contracted. A phosphorus removal cost relationship is not appropriate here as the benefits go far beyond simple nutrient removal. The cost estimate includes land for spoils disposal and assumes 2 - 3 sites will be available close to the Lake.

7) Lake Drawdown. Lowering the level of a lake has been shown to compact sediments and reduce weed growth. Hess Lake would have to be lowered 5 to 6 feet to realize these beneficial effects. Because of the large volume, large ground water input, large surface water inputs during normal drawdown times, small elevation differences between the Lake and the discharge point and limited capacity of the discharge stream, this alternative is not considered technically feasible.

OTHER CONSIDERED ALTERNATES

8) Watershed Management. This alternative would use modifications of farming and development practices upstream on the Wheeler and Alger Drains to reduce nutrient input. Conservation tillage, cover crops, individually tailored fertilizing programs, contour plowing, greenbelts, grassed waterways, retention ponds, natural wetlands, etc., would be used to control runoff and nutrient export from the land. A wide ranging program such as this over 15 square miles would be difficult to administer and its practical implementation would be largely dependent on its benefit to the grower or land owner. There is also some doubt if such programs have any long term effect once the land reaches a new equilibrium.[8] At best the results would be questionable and highly changeable depending on the cooperation of the land owner and the physical aspects of the land. No substantial reduction of the sediment buildup at the mouth of the Wheeler Drain would be expected. Proper erosion control practices should be used, of course, but the renovation of Hess Lake should not be dependant on upstream modifications.

9) Weed Harvesting. Machinery is now available that can cut, load and transport to shore several thousand pounds of weeds per hour. Although harvesting is generally preferable to chemical treatment, it is also slow and expensive. Some nutrients are removed with each cutting but the removal is generally low. In Hess Lake one cutting of 100 acres would remove 100 to 200 kg of phosphorus (5% to 10% of the total input). It is obvious that weed harvesting alone would not bring about the desired changes in Hess Lake although in combination with other techniques it may have considerable benefit.

10) Aeration/Circulation. These systems generally add oxygen and circulate the deep, oxygen poor waters with the surface waters. This action can benefit fish and other organisms and can reduce algae problems. Hess Lake is already well oxygenated throughout most of its depth and is well mixed by the prevaling winds. No benefit would be expected from an aeration/circulation system.

11) Bottom Discharge. The discharge of deep water rather than surface water is often possible with minor modifications to the outlet structure of a lake. This action increases nutrient output as the deep water is generally highest in nutrients. Hess Lake has little deep water volume and little elevation change at its outlet. These factors would make a bottom discharge system difficult to implement and largely ineffective under the present conditions. This alternative should be re-evaluated once the Lake has been dredged and nutrient inputs reduced.

PHYSICAL SEDIMENTATION

The Wheeler Drain carries large coarse particulate matter (mostly sand) in its high flows as well as dissolved nutrients. The particulate matter falls out of the water column soon after reaching the Lake producing a physical sedimentation problem in the area of the Drain's entrance point. This sedimentation problem can be solved by reducing the high flows in the Drain, by trapping the sediment before it reaches the Lake, or by controlling the energy of the high flows using a series of dams. Stabilizing the Drain banks may also help. Alternatives considered most useful in controlling the washed-in sediment problem are Alternates #5, #4 and #1, in their order of effectiveness. All the Alternatives except #5 should include sediment trapping and control in the downstream area.

LOCAL FUNDING

Special assessments are generally used to raise local funds for Lake projects. In an attempt to attain approximate individual home owner costs, a count of the riparian owners was made. There are approximately 389 lakeside parcels under single ownership. There are also 130 backlot parcels, one tier removed from the Lake and under one parcel number.

There are numerous ways to assess benefit to property including front footage, lot size and single ownership. For illustration only, the following formula was used to approximate a typical assessment to a home owner:

$$\text{Lake side owner assessment} = \frac{C}{N_L + (B \times N_B)}$$

C	=	Total Project Cost (including interest)
N_L	=	Total Number of Lake Side Owners
B	=	Benefit Factor for Backlots (if less than lake side Ownership)
N_B	=	Total Number of Backlot Owners

There are also numerous ways to finance the project. Generally the Lake property owners absorb the majority of the cost but local units of government commonly contribute up to 40% of the project costs. The Federal Lake Improvement Program, under Section 314 of the Clean Water Act, can also contribute up to 50% of the cost for certain lake improvement programs. At present the Federal program is not being funded. Low interest government loans are another possibility that would help keep individual assessments to a minimum.

The following are two examples of possible funding methods. They are probably at the maximum extreme of individual assessment costs as they contain no allocation for government participation, low interest loans, staging of bond issues, and staging of the dredging portion of the project.

1) Two bond issues - One 10 year bond issue started immediately to pay for the By-Pass System. Once the By-Pass System is in place and the Lake is ready for dredging (2-3 years) another bond issue (20 year) to pay for the dredging and disposal land would be initiated. The time interval (2-3 years) between the two issues would have an advantage in lower interest rates, if that should occur.

   The cost of the first 10 year $700,000 bond issue would be about $124,000 principal and interest retirement payment per year. According to the formula (assuming the backlots would pay one half a full assessment):

   $$\frac{\$124,000}{389 + (0.5 \times 130)} =$$ \$273/year/lake front property for 10 years and \$137/year/back lot property for 10 years

   The second bond issue would pay for the dredging and the payments would extend over 20 years. The 6.9 million dollar bond issue would require a yearly principal and interest payment of about $923,800 according to the formula:

$$\frac{\$923,800}{389 + (0.5 \times 130)} =$$ \$2,035/year/lake front property for 20 years and \$1,018/year/back lot property for 20 years

Double payments would be necessary for several years to pay off both bond issues.

The payment and work schedule might then proceed as follows:

Year	Lake Front Property Payment/Year	Work Accomplished
1 - 3	\$ 273	By-Pass System designed and installed
4 - 7	\$2,308	Dredging of Lake
8 - 10	\$2,308	Double payment continues
11 - 20	\$2,035	Single Payment

The total of each individual assessment could also be paid in one lump sum saving the interest charges. The lump sum payment for the first bond issue would be about \$1,540 per lake front property, and for the second bond issue, \$15,200 per lake front property. Staging of the dredging bond issues or reinvesting the money available between start up and completion would also reduce the payment.

2) "Pay-as-you-go" Plan - This method of finance would have a yearly assessment of about \$770/lake front property for 13 years and the project would proceed as the funds become available. It would take about twice as long (13-14 years) to complete the project by this method.

Enough money would be raised to build the by-pass system during the second year of assessments. There would then be an eight year lag in work while the funds accumulated so that dredging costs could be paid. The dredging would then be completed three years later and the project and assessments would end in year thirteen.

The above financial plans illustrate that any number of financial arrangements are possible. Other combinations of borrowing and paying are possible as well as modifications to the project, i.e., dredging in stages, dredging to a lesser depth, etc. It is cautioned, however, that the benefits from a modified project may be less than desirable. Any modifications should be evaluated for their effect.

Also, federal funds for Lake renovation are not currently available but the program is still in existance and could receive funding in the future.

VALUE OF SPOILS

Most of dredged material would probably be organic matter and may have use as a soil building material. If the soils could be sold for even a small amount per cubic yard much of the project could be paid for by the returning funds. The nutrient value, soil building characteristcis, and potential markets of the spoils should be further investigated.

RECOMMENDATIONS

The recommendations of this report are as follows, given in their order of importance.

1) Control the phosphorus input to Hess Lake by implementing Alternative No. 5, the By-Pass System for the Wheeler Drain,.

2) Dredge approximately 30% of the Lake to a depth of 15, or more, feet. Additional core samples should be taken, but it is believed 15 feet of depth would remove only organic sediments. This is desirable and no sand or other inorganic material should be removed except in shallow areas and not to a depth greater than 6 feet deep. Removal of inorganic material could change the ground water characteristics and influence the Lake level, either up or down.

3) The use of chemical herbicides may be necessary before and during the implementation of the lake improvement systems. Because the Lake is shallow and the sediments are rich, the Lake is very susceptable to rooted weed growth. The high turbidity caused by the microscopic algae growth is presently limiting the rooted weed growth. This process should be allowed to continue since algae growth is much less harmful to lake use than rooted weed growth. Therefore, no algacides (copper containing compounds) should be used. The rooted weeds may be killed as necessary.

4) To fund and administer the recommended programs the Lake Board should continue its special assessment approach to raising funds.

   The Federal Clean Lakes Grant Program could be used to offset part of the cost of the recommended improvements if the Federal funds again become available. The Hess Lake Board should make application under this program if the funds are again available.

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METHOD OF DATA COLLECTION

The Lake was observed and samples taken periodically between June, 1981 and May, 1982. Samples for physical, chemical and biological testing were gathered from the tributary streams, the outlet, and the Lake itself depending on the information required. Field measurements were taken using standard limnological equipment and methods. Phosphorus samples were preserved and analyzed according to Stardard Methods using the ascorbic acid method by a State approved laboratory.

Benthic samples were taken using a ponar grab dredge with a 225 cm^2 opening. Core samples were taken with a 2.5 cm diameter steel tube with a one way check valve. Quantitative algae samples were taken 0.6 m below the surface with a 2 l kemmerer sampler and preserved in 5% formalin solution. The drop count method of algae analysis was used for quantitative analysis. This analysis procedure normally carried a precision of $\pm$ 30% at the 95% confidence level.

Flow measurements were made using the measured velocity of a confirned flow in a known cross section. Velocity was measured using a pigmey type current meter. Ground water input was calculated using Darey's flow net method assuming a one meter deep band of input along the south portion of the Lake. Tributary flows were lineraly correlated with rainfall magnitude. A rainfall magnitude and frequency histogram was then constructed based on several years of weather bureau records. The stream flows were then calculated based on the amount of flow produced by a specific rainfall magnitude and the number of times per year that amount of rain is expected to fall. This process gave the volume of flow for each rainfall throughout the year. These volumes were then multiplied by the measured or correlated total phosphorus concentration to yeild the total amount of input at that sample point.

Winter and snow melt flows were measured independently of rainfall along with their corresponding phosphorus concentrations.

Fifteen years of flow records by the U.S. Geological Survey were also used to correlate the flow data. Replicate flow measurements showed a precision of ± 37% at the 95% confidence level. Direct precipitation inputs were calculated based on 30 inches of precipitation contributing .3 kg/hd/yr. of phosphorus to the Lake.

Septic inflow was calculated based on usage of the lakeside dwellings from the 1972 Lake Use Study. Domestic water use was assumed to be the widely accepted 100 gal./person/day. Phosphorus input was based on an average input of 0.5 kg P/person/year to the septic system. Assuming the coarse sands retain at least some of the phosphorus, a 35% soil retention factor was used. The phosphorus input was calculated as the total input to the system (.5 kg/person/year) minus 35% soil retention multiplied by the number of people using the dwellings for the percentage of the year they are in use.

TABLE 1

HESS LAKE

WATER QUALITY SUMMARY

PARAMETER	MEAN VALUE
pH	8.9 units
Conductivity	297 μmhos s=21
Total Phosphorus	31 μg/l s=15
Diss. Phosphorus	12 μg/l s=7
Secchi Transparancy	4.1-2.7 feet
Hardness	155 mg/l
Chlorophyl a	7.1-17.0 mg/l
Total Inorganic Nitrogen	.414 mg/l
Total Organic Nitrogen	1.000 mg/l
Nitrogen: Phosphorus Ratio	46:1
Chloride	12.0 mg/l
Dissolved Oxygen (surface waters)	9.2 mg/l
Dissolved Oxygen (15 feet)	0.8 mg/l

TABLE 2

BENTHOS SAMPLES

STATION H-10

8-20-81 SAMPLES

SPECIES	NUMBER/m^3	
Culex	14	Shannon-Weaver
HIRUDINEA	30	Diversity Index = 1.84
Procladius	59	
Harnischia	30	
Total	133	

1-21-82 SAMPLES

Procladius	87	Shannon-Weaver
Chironomus	42	Diversity Index = .92
Total	129	

HESS LAKE
SAMPLE SITES

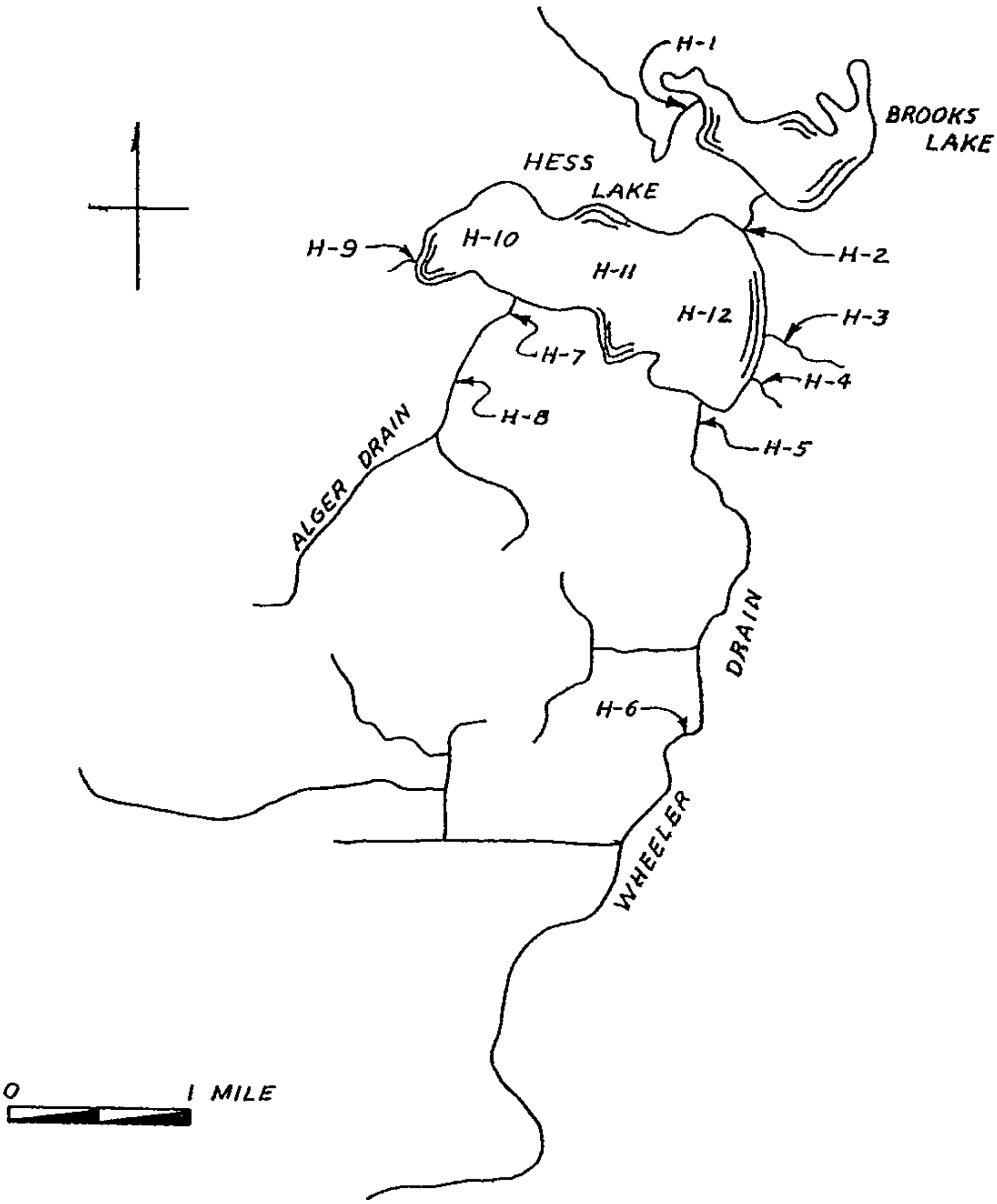

FIGURE 12

FIGURE 13
HESS LAKE ALGAL CELL CONCENTRATIONS

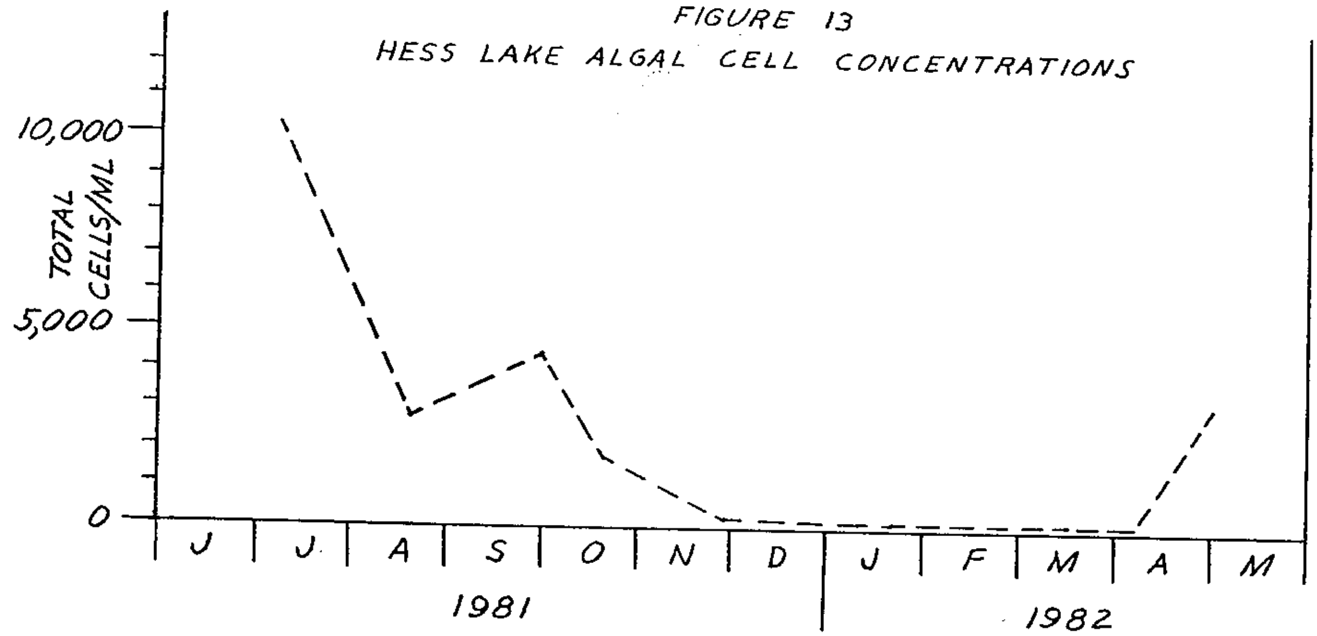

FIGURE 14
HESS LAKE ALGAL SPECIES COMPOSITION