THE FLUOR CORPORATION LTD.
CONSTRUCTORS AND ENGINEERS
GENERAL OFFICES AND WORKS
LOS ANGELES
22

P. O. ADDRESS
BOX 7030
EAST L.A. BRANCH

June 1, 1951

Corps of Engineers, U. S. Army
Office of District Engineer
Alaska District
Anchorage, Alaska

Re: POL Pipeline
Seaboard to Interior Alaska
Contract DA-95-507-ENG-95
Your File NPAGD-A
Fluor Contract No. 5160

Gentlemen:

We are presenting herewith a Preliminary Engineering Study of the POL Pipeline, Seaboard to Interior Alaska for your consideration.

Yours very truly

THE FLUOR CORPORATION, LTD.

C. M. Hawke
Project Manager

CMH:am

PRELIMINARY ENGINEERING

POL PIPELINE

HAINES, ALASKA, TO FAIRBANKS, ALASKA

Volume I

Table of Contents

B

Preliminary Engineering

POL Pipeline

Table of Contents, Continued

C

INTRODUCTION

In Accordance with Design Directive No. Alaska General T-50-1, dated March 21, 1950 and Memorandum outlining Definitive Criteria dated July 10, 1950 as received from the Office of the District Engineer, Alaska District, we are including herewith the report of the preliminary study covering the selection of the route and design of a POL Pipeline system from Haines, Alaska to Fairbanks, Alaska.

The system includes terminal tank farms, pumping stations, dock facilities for tanker unloading and all other appurtenances necessary for the transportation and handling of refined petroleum products in quantities sufficient to satisfy both normal and emergency demands.

An eight (8) inch line was originally indicated and studies made on this basis called for three normally operating pump stations with two emergency stations. Conferences held in Seattle on March 5, 6, and 7, 1951 with the Corps of Engineer's representatives from the office of the Chief Engineer, Portland Division, and Alaska District, representatives from Headquarters, USARAL, Alaska and Mr. S. S. Smith, special consultant, from the Shell Oil Company resulted in the acceptance of a six (6) inch pipeline to obtain better operating characteristics at normal throughput. This decision, however, was based on the utilization of the existing 3" Canol Pipeline extending from Haines Junction, Yukon Territory, Canada and the laying of additional 3" pipeline to connect between Haines Junction and Haines.

This system as now designed in a preliminary stage requires four (4) normally operating pump stations and six (6) emergency operating pump stations; each station to have complete pumping facilities for both the 3" and the 6" pipelines combined in a common pump house.

Considerable reconnaissance has been performed in the field and studies made in the office to select the best route for the pipeline. Alternate routes out of Haines have been explored and are herein reported upon.

The estimates which are included are based on Seattle costs and reflect the best guesses of material and equipment suppliers. A special effort has been made to obtain more accurate prices on major pieces of equipment which together with the pipe make up a major portion of the entire construction cost. Quantitative takeoffs of minor materials have been made and prices have been inserted for their supply and installation based on Fluor's experience.

It is believed that the costs are factual within a plus or minus 10 percent of actual costs.

Following our preparation of the major portion of the design work based upon the above premises there has been received a revised criteria which introduces a much higher ultimate capacity. Effort has been made to provide for this unexpected increase in capacity by added pumping facilities. For economic and operational reasons explained herein an expanded system of this character, in our opinion, fails to pass the qualifications of sound engineering judgement which influenced the original selection of the six inch line size.

E-2

OFFICE OF THE DISTRICT ENGINEER
ALASKA DISTRICT
CORPS OF ENGINEERS
Anchorage, Alaska

Definitive Review Conference covering POL pipeline, Haines to Interior Alaska, took place Monday, 5 March 1951, in conference room of Seattle Branch of Alaska District, attended by:

Hqtrs, USARAL Alaska	Maj. A. F. Moffitt Jr. Mr. F. A. Wolff
Hqtrs, AAC Anchorage, Alaska	Mr. O. C. Riggs
Office, Chief of Engineers Washington, D.C.	Mr. L. J. Fegan Mr. R. K. Ost
North Pacific Division Portland, Oregon	Lt. Col. T. H. Lipscomb Mr. G. H. Kelleway Mr. R. J. Davis Mr. H. N. Walker
Architect-Engineer	Mr. R. L. Merrick Mr. H. J. Gearin Mr. C. M. Hawke Mr. G. D. Bachemin
Shell Oil Company	Mr. S. S. Smith (Special consultant on pipeline work for the Shell Oil Company on loan to the United States Government)
Alaska District Anchorage, Alaska	Mr. Warren George Mr. E. W. Digges Mr. Edwin J. Kreitlow

The meeting began at 9 a.m. with an introduction of persons attending, a short statement covering purpose of meeting, followed by a general review by the Fluor Corporation covering their approach to the problem, during which period questions were invited from the members attending for any further explanation or clarification on points bearing on the Fluor Corporation's presentation. After the District's program had been explained, a discussion of specific points connected with the design took place; and these discussions in turn were resolved into the conclusions and recommendations that follow.

The text of the conference followed was a compilation in brochure form, prepared by the Fluor Corporation especially for subject conference, copies of which were given to all conference members, entitled "POL Pipeline, Seaboard to Fairbanks, Alaska," dated 5 and 6 March 1951. Contained in subject brochure was a copy of data previously issued by the Fluor Corporation to all offices concerned, for their information and prestudy for use in subject conference. Submitted along with the brochure were a number of drawings as listed on pages 1 and 2 of brochure.

There follows a summary of major points discussed, on which the conferees based the conclusions and recommendations as subsequently shown.

Incl 1

A profile based on an 8-inch line, contained in the brochure, was discussed, and it was stated that operating at 1350 pounds, 5 pump stations would be required. Of these, 3 stations would be permanent construction; 2 stations of stand-by construction. The stand-by stations would go on the line when through-puts in excess of 12,000 barrels per day were required. Stations 3 and 5 were identified as stand-by stations. Stations 1, 2 and 4 would be required to attain normal through-put requirements.

It was pointed out that low flow range of operation of the 8-inch line would cause excessive intermingling of the product. However, it was indicated that if the flow be kept in the turbulent range for all products, this would be controlled. However, this would result in a shutdown of the pipeline the major portion of the year under normal conditions.

Comment on location of pipeline with respect to existing highway indicated that maximum distance of line from the highway would be about 1½ miles and that, in general, pipeline would follow road. Hydraulics were figured on the basis of a line of approximately 650 miles, expect final design to shorten this mileage somewhat.

Comments were made on how surge pressures might affect the operation of the line, and it was felt that due to the build-up that would result at Fairbanks, for example, with static head from Pump Station 4, would result in excess of pressure; and indicate preferred selection of pipe having a wall thickness of .322 inches instead of wall thickness of .277. In general, it was desirable to have few stations and to pump at relatively high pressures. The statement was made that pipe should definitely be of an uniform wall thickness throughout the system except at river crossings and under-water crossings and lakes. However, at lake and river crossings, pipe of special fabrication would be desirable so that the wall thickness could be increased. However, the increase should be on the outside diameter. The inside diameter of the line throughout the system should be uniform. The thinking favoring the .322 line thickness was because of anticipated shock pressures that would occur. However, statement was made that if a .277 wall thickness pipe was used, it would result in a saving of approximately 15 tons of steel per mile over a .322 wall thickness.

Pressures discussed appeared to be within range of commercial installations. Further feeling was indicated that pressure reducing stations should be avoided for reasons of maintenance and complicated operation. Open lines were preferred.

Carbon content of the pipe discussed was from .15 to .22% carbon. 32,000 to 34,000 pounds yield-point seamless pipe was preferred. Electric welded pipe is only to be used as a last resort, as shock at low temperatures is apt to open it.

The Architect-Engineer favored no preservative outside coatings or steel on unburied pipeline. Exception was taken to use of moss where available for coverin the line for reasons of corrosion and doubtful benefit.

Water separation and filtration were discussed, and the Architect-Engineer favored mechanical separation of the water by use of degumed excelsior pack type water separators and sumps in tanks. The use of activated alumina and similar dehydrating agents were discussed. Chemical dehydration appeared to present objectionable effects upon quality of product and might alter fuel specifications. Statement was made that dehydration is used on stateside lines to control interior corrosion. No example is known in the states where dehydration was used to remove water to prevent freezing of the lines.

Information was presented indicating that, especially on Canol and commercial lines, at low temperatures internal corrosion was at a minimum.

On 8-inch line, positive displacement pumps with low speed Diesel engines were suggested. On the two emergency stand-by stations, moderate speed Diesel engines driving centrifugal pumps were suggested as the most desirable.

Housing at the two emergency stand-by stations was to consist of a single one-family quarters, and the Architect-Engineer suggested that additional housing be added to provide for transient pipeline crews. The criteria had been developed based upon the operating personnel's family being evacuated in an emergency, and the subject housing used for additional operating personnel.

Discussion was held on whether to support pipeline on bridges located convenient to the line, or whether military considerations would point to a need for under-water crossings, even at a higher cost.

Pipeline suspensions were also discussed and appeared to have less merit than under-river crossings. However, costs were to be considered in selection of bridge crossings versus under-water crossings. Kluane Lake crossing was discussed, and it was pointed out that the under-water section of the line should have the same inside diameter as the land line. The advantages and disadvantages of crossing both the streams and the lake were fully explored.

A discussion of tankage brought out that in commercial practice, terminal storage should provide for at least 150% for cycle storage. However, consideration of a number of products and the cycle time was the determining factor in the selection of quantity of tanks at the terminals. It was strongly recommended by the Architect-Engineer that in normal operations, motor gasoline and aviation fuels should be transported through the line in the winter; and Diesel oil should preferably be kept out during cold weather periods. Under this plan, storage should be provided at inland terminal for Diesel to carry over during anticipated cold weather periods. The originally proposed dispersed tankage at the booster stations was covered. From a pipe line operator's viewpoint, it would be preferred that the tankage be concentrated, as close as other considerations would allow, at the ultimate terminal.

The Army representative reviewed military policy as regards duplication and dispersal of tankage, which was the basis for the original tankage location. Terminal tankage at Haines must take into consideration possible delay in delivery time with adequate tankage provided, based upon a two weeks' cycle supply.

It was indicated that based on proposed normal through-put requirements and emergency through-put requirements, the 8-inch line under normal conditions would be shut down periodically.

The use of coils for heating tanks at Haines terminal was generally discussed.

At this point, the matter of relocation of the Canol pipeline to provide for pumping from Haines instead of the present tank farm at Skagway, was entered into. To attain 3,000 barrels per day through the Canol pipeline, it was indicated that 14 stations would be required. It also was pointed out by the Army representative that it was proposed to reactivate four stations on the Canol pipeline in the summer of 1951 to increase through-put of Diesel to 1,580 barrels per day from present through-put of approximately 1,000 barrels, and that funds to accomplish this are already available.

The required through-puts for the emergency condition, previously furnished to the Architect-Engineer in the design criteria, covered through-put in the new pipeline only, and these figures took into consideration that the Canol pipeline would be operating at 1,530 barrels per day.

Representatives from OCE pointed out to the conferees that in a recent conference in Washington, the staff had agreed that the total emergency requirement that would be transported through pipeline or pipelines to the Fairbanks area would be 16,324 barrels per day. The premise on which these decisions are based are that these capacities will not need to be exceeded in emergency conditions.

In the discussions covering flow and pipeline size, the representative of the USARAL stated that he felt that all elements in Alaska favored the 8-inch line over the 6-inch line but that based on firmness of figures and disadvantages in operation of the 8-inch line, the 6-inch line is preferable.

The reactivation program planned on reactivation of Canol pipeline Stations C, G,L and N, between Whitehorse and Fairbanks on No. 4 line.

Strategic considerations prevented tankage reserves from being considered as an influence in reducing through-put capacity.

A general discussion was held on the advantage of operating a 6-inch and the 3-inch lines simultaneously or separately under normal through-put requirements.

It was estimated roughly by the consultants that the decrease in cost of a 6-inch line with 10 stations over an 8-inch line with 5 stations was in the order of one million dollars.

In a general discussion wherein a small pipeline with large inland terminal storage was weighed against a pipeline having a large capacity and small inland storage, the point was made by the consultant that it was objectionable to store aviation gasoline any longer than the minimum possible time in storage, that in commercial practice the storage of aviation fuel and Diesel oil for more than a year was not desirable for the reason that it affected the specifications of the fuels. In the case of AVGAS, it increased the gum content. From an overall operating standpoint, it was pointed out that a 6-inch line operated at higher pressures was preferable to an 8-inch pipeline in that it provided for more rapid transportation of any given batch of product from marine terminal to inland tankage.

In discussion of pipeline operation, it was pointed out that some Diesel cuts over into gasoline might be tolerated in certain localities, but would not be acceptable in the Arctic where low octane ratings are not permissible.

It was suggested by the consultant that kerosene buffer plug should be used between the Diesel and any other product. The use of a buffer would require the erection of a small additional tank at Haines and any other transfer point for kerosene.

A general discussion was entered into as regards rehabilitation of the 3-inch Canol system, beyond the rehabilitation by the Command planned for 1951. In the ultimate operation of a 6-inch and a 3-inch pipeline common stations would be used, each using its separate equipment.

The advantages and disadvantages of stand-by equipment, positive displacement pumps versus centrifugal type - and where centrifugal types are used, the advantages of ability to operate either in pairs or as units - were fully explored.

A rough outline was made, subject to further study, of the cost of paralleling the 6-inch line with a 3-inch line from Haines to the junction of the Haines Cut-off to the Alcan Highway was in the neighborhood of one and one-half million dollars.

Similarly, as the wall thicknesses of an 8-inch line had been previously discussed, the 6-inch line and its wall thicknesses were covered.

The consultant felt that he could guarantee successful operation of the 6-inch line on all products at a flow rate of 3,600 barrels per day minimum. This was later qualified by him in a statement that it would be based on through-put figures for gasoline products, exclusive of Diesel, and that this figure probably would not be acceptable during winter operation because of the higher viscosity of Diesel oil as compared to the viscosity of the gasoline.

The experience gained by the consultant indicated that in a packed pipeline, intermingling of fuels of different gravities was not excessive during shutdown periods for the reason that any low point in the line effectively prevented action beyond that point.

The Army representative pointed out that the Alaska Communications System Offices would design and prepare cost estimates for communication facilities, which the Architect-Engineer is to recommend as being necessary for proper operational control of the pipeline. Funds can then later be allocated from the pipeline project to the Office of the Chief, Signal Corps for coordination of the Signal facilities with the Canadian Government and for construction of the facilities.

A teletype system was indicated as necessary for the reason that it provided a written record of all orders on dispatching of product, in addition to other means of communication, which would serve other purposes.

The relative location of the POL dock versus dry cargo dock and tank farm location at Haines were discussed.

Conferees discussed the placing of tanks at the Haines terminal and other points in complete protective revetments, together with optimum spacing of tanks. The building of tanks was fully discussed, with advantages of conserving vapor loss of fuel versus strategic considerations involved.

The ability to shift station locations slightly and still stay within hydraulic considerations was covered, and an allowance of 2½ to 3 miles was indicated.

CONCLUSIONS

1. Based on finalized through-put figures approved in Washington, disadvantages of operating 8-inch line at normal through-put rate, increase advantages of operating 6-inch line at normal through-put rate, plus increased speed of delivery of product from seaboard to interior, plus the inability to consider as a factor in operation, tankage capacities in emergency conditions at terminal points, resulted in the decision to use a 6-inch pipe throughout, along with a new 3-inch pipeline from Haines to the junction of the Haines Cut-off with the Alcan Highway, at which point it will connect with the existing 3-inch Canol pipeline, were the choices for pipe sizes.

2. 6-inch pipe to be .28 inches in wall thickness on land and .312 inches under lakes and streams, and to be of low carbon content, seamless steel with inside diameter of pipe uniform throughout.

3. The Architect-Engineer was directed to study the relative advantages and come up with a cost engineering study on fixed displacement pumps versus centrifugal type pumps.

4. Stand-by pumping would be provided in all stations to be used for normal operation, with no stand-bys for those stations set up for emergency operation.

5. Mechanically controlled water separation to be provided to the extent of sump in tanks and treated excelsior water separators. No chemical dehydrating agents to be used.

6. No corrosion inhibitors to be used pending operational showing of need.

7. Pumps for 3-inch and 6-inch line would be in same operation buildings, but separate pumps to be installed for each system.

8. Pumps for 3-inch line would be indicated as preferably of the triplex or quintuplex type.

9. The Army will provide the pumps needed in four of the ultimate stations to service the 3-inch lines.

10. Architect-Engineer to provide for the pumps needed for the additional installations.

11. Closed system operation to be used on both pipelines as ultimately developed between terminals.

12. The use of kerosene plugs to be provided for with the installation of the required tankage at the Haines terminal and other transfer points.

13. The dispersal of tanks at Haines to be maximum obtainable in the order of 500 to 600 feet center to center of tanks.

14. Estimates to be made by Architect-Engineer on use of tanks 24 feet in height with full revetment protection, against tanks of optimum heights with normal fire walls.

15. All tankage above that at Haines necessary for operation of pipeline to be located at station closest to Tok Junction.

16. Tanks to be painted an olive drab color.

17. Pipeline above ground not to be painted.

18. Pipeline above ground not to be moss-covered.

19. Pipeline at river crossings to be submerged and no closer to bridges than 300 yards.

20. Pipeline to be buried in stream bottoms.

21. Pipeline to cross Kluane Lake, both 6-inch and new 3-inch.

22. Steel for tanks to preferably be ASTM 201 with A-7 acceptable as second choice.

23. Accurate metering of products to be provided.

24. Pressures in excess of 1600 lbs. per square inch should be avoided.

E-3

Design Analysis

Capacities

Capacities used in the design of the system are as contained in the Criteria furnished by the Corps of Engineers and made a part of this report under Section E-1. The most efficient balance between allowable line pressure and the pump station locations has been made on the basis of emergency capacities.

This presentation is based on decisions reached at the Definitive Review Conference covering POL Pipeline, Haines to Interior Alaska, held in Seattle, Washington on March 5, 6, and 7, 1951. (A report of the Minutes of this meeting is included herein under Section E-2.)

The recommended use of a six inch line and utilization of the present three inch Canol No. 4 line in the system was the decision reached at the conference and was based on the agreement that capacities in excess of emergency rate, namely 16,324 barrels per day, would not be required of the system. Other considerations prompting the decision reached was to provide a "Safe Operations" line by using the three inch line for transportation of Diesel fuel during extreme cold conditions, and the ability to maintain fairly high stream velocities in the six inch line. The dual system also provides a more rapid operating system with less line displacement. two features which are of value at times when operations are not within the normal schedule.

The principle disadvantage to use of the proposed lines is that the system is stationed at the upper capacity limit with ten stations. Any further increase in capacity requires the installation of a great number of stations and thus capital investment as well as operating costs rise very rapidly. The capacity which may be obtained by use of the three inch is extremely low and its eventual expansion is much more limited than that of the six inch line.

Design Temperatures

Design temperatures are based on climatological data from five weather stations along the pipe line route and available date resulting from operations of the Canol No. 4 line. The minimum low temperature is placed at -20°F. and the average high fluid temperature is placed at a plus 55°F. Plotted temperature data incorporated in this section show this temperature range to be applicable to design, however, the records reveal that the low temperature is reached a very few days of the year. Hence, basing design on -20°F. provides an excess capacity at higher temperatures.

Design Fluid Characteristics

Viscosity and specific gravity characteristics used were those supplied by the criteria. Accuracy checks were made with available data and found in very close agreement with the data supplied.

Hydraulics

Friction loss curves for three and six inch pipe for the various products to be handled are included herein. These curves are corrected for viscosity and specific gravity at the temperature shown and hence read direct. The friction factor curve used in preparing these curves is also included and is the result of industry wide research over a period of years; it is considered the most reliable data available.

Stations are located on the profile to provide a station near Tok Junction and to provide emergency flow rates without exceeding the maximum allowable stress of the pipe. This pressure is 1610 pounds per square inch and provides a safety factor of 2.1 including an allowance of 50 times average emergency velocity for maximum instantaneous surge pressure. Without surge allowance the safety factor of 2.5 and is within industry practice. Stations required for normal pumpings are provided with housing for sufficient personnel to operate on a full time schedule and to house line maintenance personnel.

Stations required for emergency rates are provided with facilities for a resident operator-custodian, and sufficient bunking quarters for a full time operating staff for comparative long durations.

<u>Comingling of Product Interfaces</u>

Selection of a pipe size and a sufficient operating rate such that turbulent flow will be maintained at all times is the foremost fundamental principle of design observed herein. As long as flow remains well within the turbulent range comingling will be held to a minimum. Reference to the included plot of pumping rate vs. Reynolds number will give the relation that exists for the three types of products to be handled. Operating data on the Canol No. 4 line indicates fairly conclusively that safe turbulent flow of Arctic "C" Diesel fuel is maintained only by holding the Reynolds number in excess of ten thousand at temperate ranges below 0°F. The chart referenced above shows that maintaining a high Reynolds number on jet fuel and gasoline is no problem but does become a problem when handling Diesel fuel at low temperatures.

Hence, the ability to obtain a safe operating system in the combination six and three inch lines is considered of great value. It will be necessary to operate equipment at booster stations along the line if it becomes necessary to handle batches of Diesel fuel in the six inch line in periods of extreme cold conditions.

Continuous twenty-four operation of the line for periods of time necessary to handle sizable batch quantities of products is based on maintaining the minimum quantity of product comingling and the desire to have sufficient available trained operating personnel to place the line in full time normal operation. This is the reason for our insistance on such an operating schedule.

Other design features incorporated in the system with a view to reduction of comingling are as follows:

1. The system is designed for "closed line" or "tight line" operation with one station pumping directly into the suction of upstream station. No over and short tanks are to be provided at intermediate stations.

2. Station lines are as streamlined as possible with no dead pockets or

blind spots to collect and spread fluids. Ample drain facilities to the sump are provided at locations such as pumps, scraper traps, and proving meter runs.

3. Adequate sump facilities are provided so that drainage can be collected and held until time to place the fluid collected back into the contaminated plug between products, or place it back into a clean fluid at times when prover runs are made on meters.

4. Provisions are supplied to place a kerosene buffer between products easily contaminated (mainly for use when handling batches of Diesel fuel in the large line.)

5. Provisions are made at the Tok tank farm to take "heart" cuts from the mainline stream or to make "heart" deliveries back into the main line stream, thereby allowing a minimum of interfaces to move to the end of the line for disposal or blending.

6. Adequate positive displacement and flow type meters, continuous gravitometers, and other recording type instrumentation is being supplied in order that continuous record can be made available to personnel operating the system. This naturally provides a system by which mistakes in dispatching can be detected before ultimate deliveries are made. It also makes any line leaks readily apparent and assists in location of the trouble.

7. The system is designed for a single line. Loops are contamination spreaders unless extremely well operated, and shall never be considered as a means of providing additional capacity to this system.

It has become apparent that the problem of providing "as safe an operating line as is possible" has taken precedent over the other considerations usually entering pipeline design. This feature is considered paramount to all others due to the consequences which can arise by the inability to deliver products to meet full specifications or to the costs involved in having to destroy large quantities of products failing to do so. Other problems peculiar to the system which have prompted design of "safe basis" are:

1. Extreme range of capacities expected of the system.

2. Extreme range of temperatures which cause the change in fluid characteristics.

3. Possibility of infiltration of personnel lacking experience at periods of expanded operation.

Station Design

It is proposed to install positive displacement pumping equipment at the normal operating stations and centrifugal equipment at the emergency station. This selection was based on economic as well as operating features of one unit over the other. While it is true that large capacity centrifugal pumps offer sizeable first cost savings over equal capacity plunger equipment the range narrows as capacity is reduced and reaches a point where the opposite becomes true. The loss in operating efficiency and added first cost of centrifugal units in the capacity range of this system makes the centrifugal units more costly than plunger units by several thousand dollars.

First Cost Centrifugal per Unit - -	$37,720.00
First Cost Plunger Units - - - - - -	34,220.00
Additional Cost for Centrifugal	$ 3,500.00

The above figure is a result of the cost of additional horsepower to drive the unit and the more expensive higher ratio speed-increaser required for the higher rotative speeds of the centrifugal pumps. Actual cost of the centrifugal pump without associated equipment is about one thousand dollars less than a comparative plunger pump.

Reference to the pump unit selection sheet for the six inch line included herein shows that the three plunger units for normal operating stations are sized to meet all pumping requirements of the system. Standby pumping capacity can be provided during emergency operations by operating the other two units at slightly higher speeds which can be accomplished without exceeding the power rating of the engines. The additional cost per station to equip the normal stations with centrifugal units would run about $11,000.00.

The reason for the recommendation of plunger type pumping equipment at the normal operating stations is to operate at higher efficiencies. The centrifugal pumps available to fit the capacities and heads of this system have peak operating efficiencies between 72 and 75 percent. These units must be sized to produce emergency flow pumping conditions and when reduced flow is effected (normal pumping conditions) a further reduction of about 25 percent of efficiency occurs. The only way to avoid this efficiency loss would be to change impellor size in each pump or to have a combination parallel series arrangement of pumps, either of which would be extremely objectionable.

Plunger pumps have a peak operating efficiency of 85 to 90 percent and are sized such that they maintain this peak efficiency at normal pumping rates. Thus, an increased efficiency of approximately 45 percent is realized by use of the plunger equipment for normal pumping rates. At normal operating conditions this increased efficiency will provide savings in the fuel consumption of the system as follows:

<u>System Horsepower Required at 100 Percent Efficiency</u>

$$\text{H.P.} = \frac{410 \text{ B/H} \times 6500 \text{ psi}}{2450} = 1100$$

<u>System Horsepower Using Plunger Equipment</u>

@

$$@\ 90\%\ \text{Efficiency} = \frac{1100}{90\%} = 1220$$

<u>System Horsepower Using Centrifugal Units</u>

$$@\ 55\%\ \text{Efficiency} = \frac{1100}{55\%} = 2000$$

This provides a saving of 780 horsepower, The power thus saved can be calculated in value of fuel oil saved as 0.42 pounds of fuel per horsepower hour at seven cents per gallon.

780 x 0.42 = 328 Pounds per Hour
328/7.2 = 455.5 x 24 = 1670 Gallons per Day
1670 x 7 cents = $74.90 per Day

The change in flow to emergency conditions means that it will be possible to operate centrifugal units at their peak efficiencies. This improved efficency combined with the operational advantages of centrifugal pumps as booster station pumping equipment and probability of short operating time requirements at emergency rates makes their choice for the emergency stations apparent.

Very little comparative data is available on relative maintenance costs of the two types of pumping equipment. It is our opinion that very little cost difference would be discernable. Certainly the saving in fuel obtained by the use of plunger units at the normal stations would make whatever difference which may exist of little consequence.

Other Design features worthy of note are:

1. Pressurized engine room and office which will prevent entry of vapors into these spaces and is a safety measure.

2. Location of the majority of the operating manifolding, metering and prover equipment within the pump room. This is for the protection to the equipment against extreme cold weather conditions and for the comfort of operating personnel

3. Automatic safety devises and alarm signals on all operating equipment.

Design Calculations

Basic design calculations are reproduced and follow in this section.

E-4

Route Selection

The overall route of the pipeline has been established by studies made from aerial photographs and by field inspection trips. The principle objectives followed in the route selected were:

1. Protection of the line from physical damage by avoiding slide areas and maintaining distance from highways.

2. Minimum overall length of line.

3. Accessibility from existing highways to line location for construction and maintenance purposes.

4. Minimum construction obstructions, hence less overall cost.

Maps of the established route are herewith presented in Volume II. Still further minor route changes will be made in the final field survey and line staking operation. However, these will have little effect on the overall line route as established. There is included herewith a tabulation of highway distances and the length of pipeline route involved for each sheet of mapping. The highway route involved is 660 miles and the pipeline route is 606.3 miles. We have added an arbitrary figure of 2½% to the pipeline route (14.7 miles) to make the total pipeline route 621 miles. This is considered a safe quantity to provide for sufficient line slack in over or under bends, and to provide for minor variations in final route selection work. A total reduction in excess of 52 miles has been accomplished by route selection work. Little or no attention was paid to the present location of the Canol Line in the new route selection. There does exist places, however, where the two routes parallel each other for short distances. We recommend a safe clearance between the two lines of a minimum distance of at least 50 feet at these locations.

The majority of the line will be surface laid and will more or less follow the Haines Cutoff Road and the Alcan Highway. Where the line parallels the highway it will as a general rule be located a minimum of 290 feet from the centerline of the highway or at the outer edge of the customary right-of-way. This is of utmost importance since it affords protection from:

1. Damage due to mechanized highway work equipment such as tractors, etc. yet provides space for further borrow pits and for clearing homesites along the highway without the eventual need to either relocate the line or to bury it in the future.

2. Vehicular accidents resulting from highway traffic.

The sections of the line from Haines to Station No. 2 and from the south side of Big Delta townsite to the terminus of the line will be buried. Also along the route any major or minor highways or used trail crossings or any inhabited areas will be likewise treated. Proper casing pipe will be installed in all highways or railroad crossings of which there will be approximately 54 crossings.

Muskeg, swamp, and tundra areas in general have been avoided but where there exists no alternate, the line through these areas will be supported by one of the following methods; a carefully constructed timber corduroy surface, fill made over the area, use of timber piling bents across the area. The most feasible means employed must of necessity depend on the location of the individual area and the availability of material used to form a suitable support. The final length involved and more detailed method of support over such areas will be presented in the final engineering stage of the project.

Stream Crossings

The following list of stream crossings comprise the total length which is presently considered major and minor streams and which will be crossed by buried pipe.

The streams which require valves are those considered major streams. The Lake Kluane crossing is not made a part of stream crossings.

Map Sheet No.	Name	Length Buried Pipe	Valves
1	Chena	500 Ft.	Yes
3	Chena Slough	1,100	No
4	Chena Slough	400	No
7	Tanana	600	Yes
15	Tanana	1,650	Yes
22	Big Gerstle	2,200	Yes
23	Little Gerstle	300	No
24	Johnson River	1,500	Yes
30	Robertson River	2,650	Yes
32	Yerrick Creek	300	No
37	Tok River	300	No
37	Tok Overflow	200	No
38	Tanana River	500	Yes
59	White River	15,000	Yes
65	Donjek River	7,500	Yes
69	Burwash Creek	500	No
70	Duke River	5,200	Yes
83	Dezdeash River	300	No
84	Quill Creek	500	No
85	Kathleen River	500	No
90	Unahini River	3,000	No

92	Takhanne River	400	No
94	Stanley River	500	No
97	Nadahini River	4,000	No
98	Clear Creek	1,400	No
102	Big Boulder Creek	700	Yes
104	Chilkat River	1,000	Yes
	Total Length	52,700 Ft.	Stream Crossings

All stream crossings will be made by burying pipe in the stream bed to a depth of at least seven feet below the lowest portion of the river bottom. Pipe in stream crossings is to be of heavy wall with no protective coating applied. The major crossings which have valves are to have insulating gaskets installed on each side. All streams will be crossed a minimum of at least three hundred feet from the bridge locations along the highways.

Creeks, Sloughs and Ravines

Creeks and sloughs of which there are approximately 101 are to be crossed by the most appropriate method. This in general will be by the construction of "H" type bents to support the pipe. Only in cases where indications of extreme flash flooding is apparent will pipe be buried. Several crossings of deep ravines will be made in which it will be necessary to use the pipe as the compression member of the crossing, with support supplied by tension lines. Further work on all types of line support will be developed after field surveys are completed.

Other Criteria

Other criteria as established for this project and contained in the Design Criteria latest revision, March 20, 1951, Pages 9 through 15 inclusive is now considered fully acceptable and is made a part of this criteria.

PLANS

FOR

P.O.L. PIPE LINE

HAINES, ALASKA TO FAIRBANKS, ALASKA

THE FLUOR CORPORORATION LTD.

CONSTRUCTORS AND ENGINEERS

LOS ANGELES, CALIFORNIA

NO. P.O. 00001-5160

PRELIMINARY LOCATION

AERIAL PHOTOGRAPHY AND MAPPING

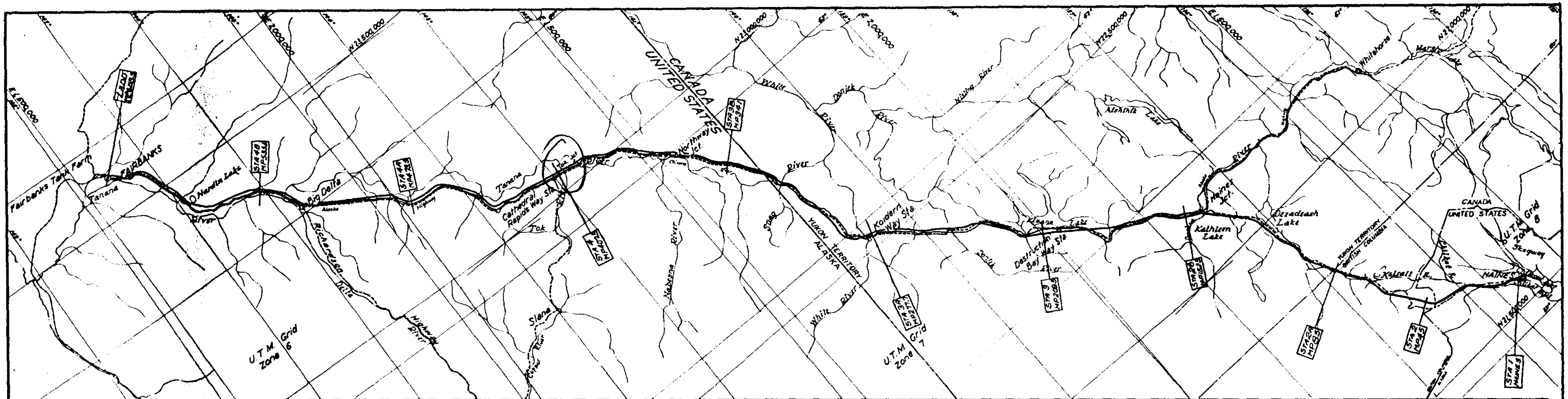
BY

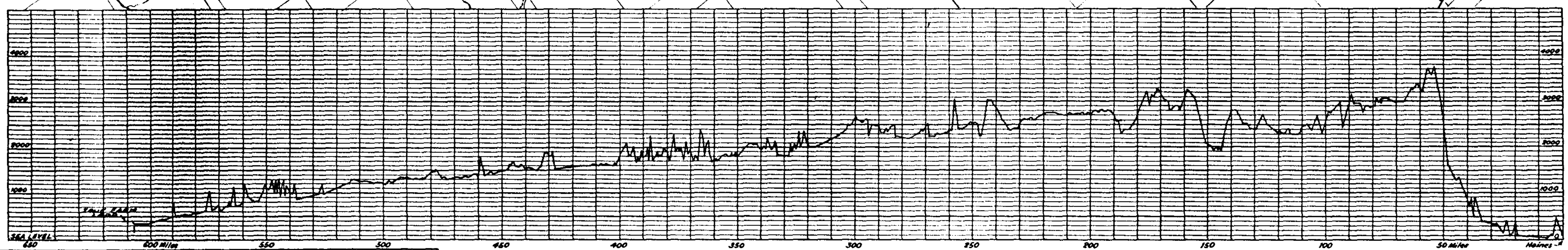
RYALL ENGINEERING COMPANY

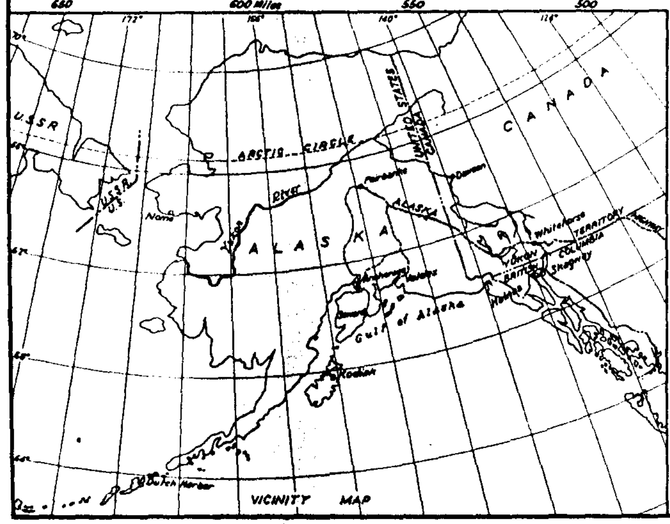
LITTLE ROCK, ARKANSAS

MARCH 1951

5160-LA-206 SH. 1A







• L E G E N D •

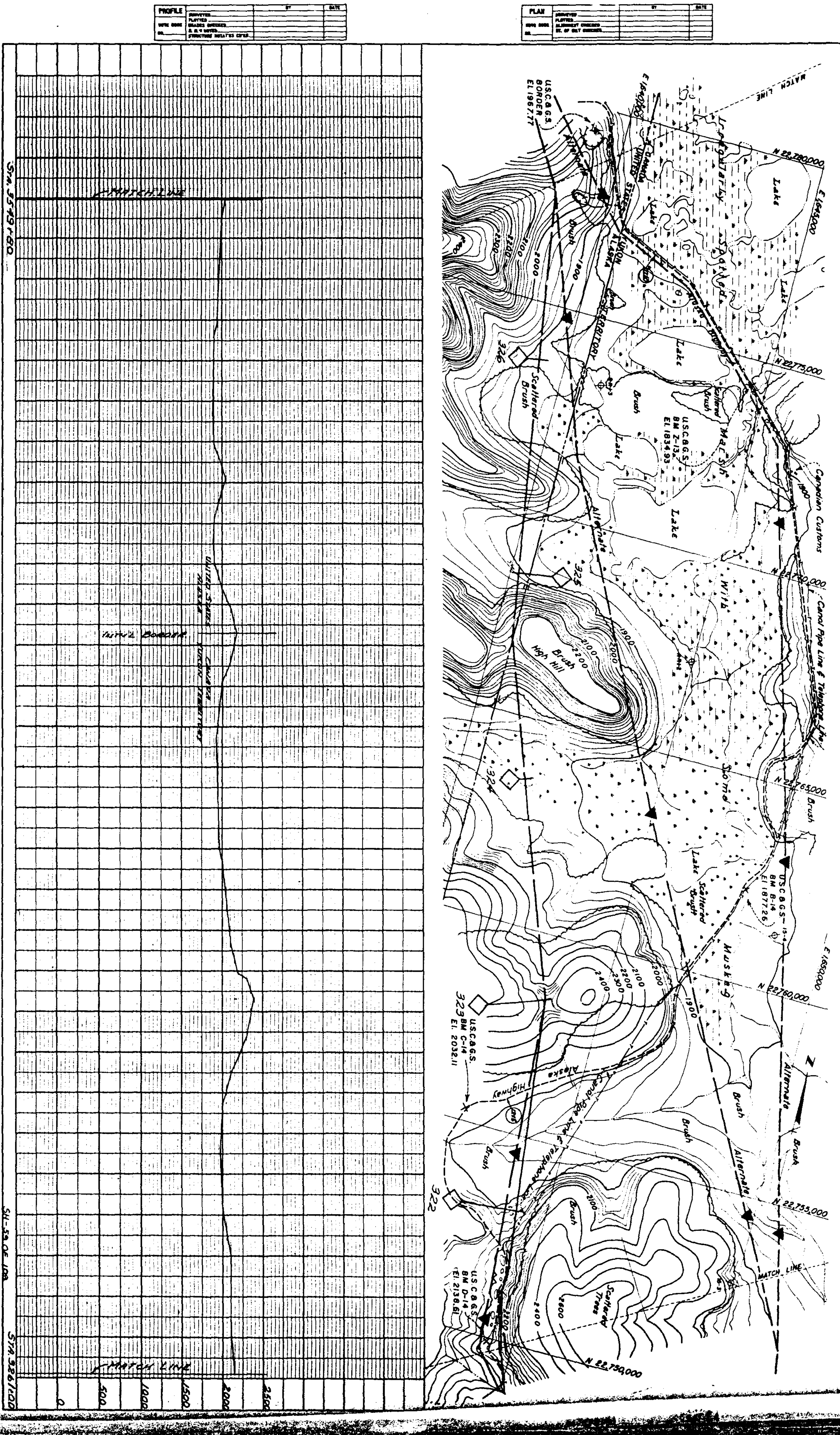
P.O.L. Line	Unidentified Line
Alternate Route	• U.T.M. Grid Line
Elevations Along P.O.L. Line	Triangulation Point
Highways or Road	Center of Photograph
Railroad	Bench Mark
Railroad Survey	Highway Mile Post
Canol Pipe Line	Timber or Brush
Telephone Line	Swamp or Muskeg
G.L.O. Section Line	Borrow Pit
Property Line	Top Bank
Abandoned Route	

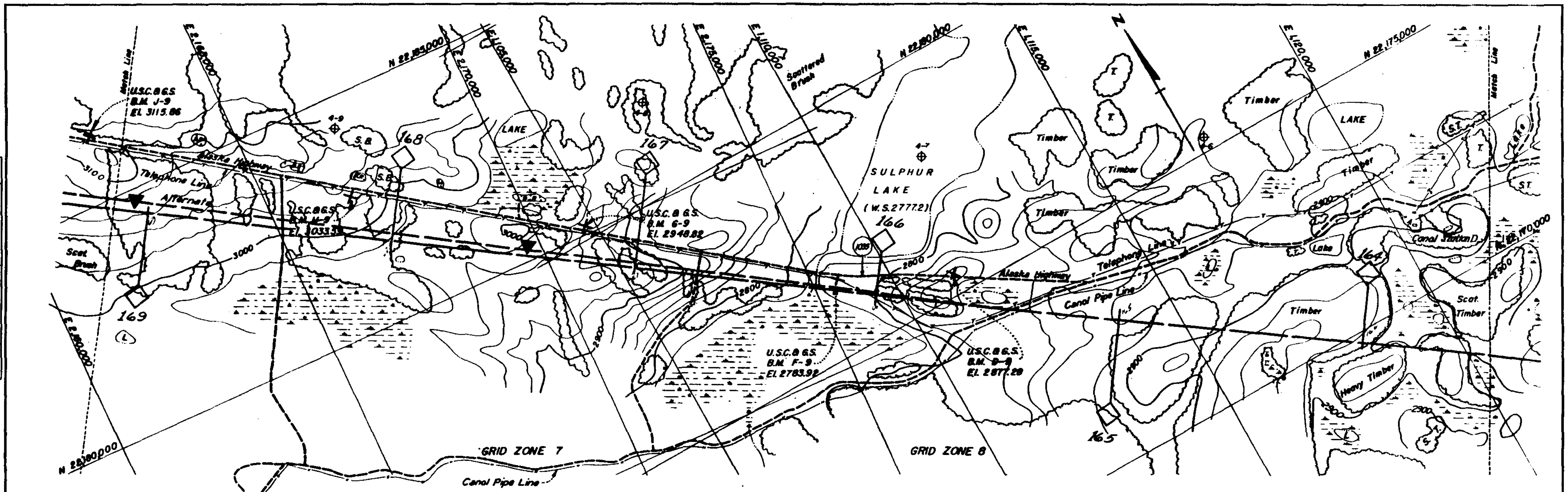
• Universal Transverse Mercator (U.T.M.) 5000' Grid Line Zones 6, 7 or 8.

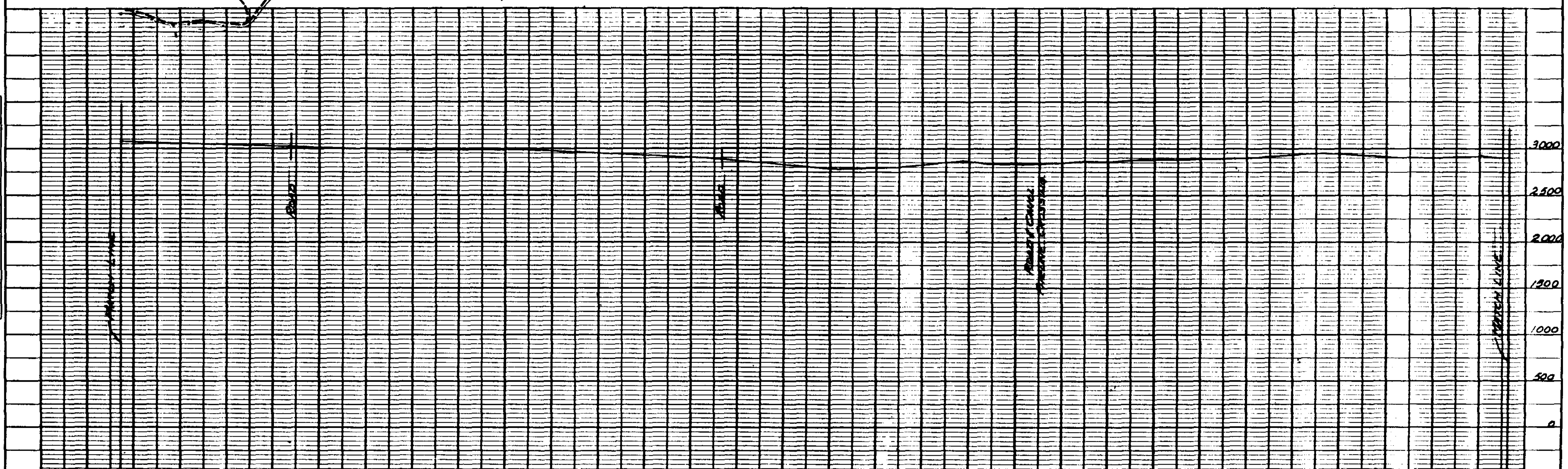
Horizontal Control by U.S. Coast and Geodetic Survey verticle control from U.S.C. & G.S. and Geodetic Survey of Canada bench marks along route. Datum is mean sea level, August 1950 Adj.

Topography and Preliminary Location of P.O.L. Line by Ryall Engineering Co. by Stereo-photogrammetric methods from aerial photography of October 1950.

516C 206


PROFILE
PLAN
MATCH LINE
INT'L BORDER
UNITED STATES
ALASKA
CANADA
YUKON TERRITORY
U.S.C.&G.S. BORDER El. 1967.77
U.S.C.&G.S. BM Z-13 El. 1834.93
U.S.C.&G.S. BM B-14 El. 1877.26
U.S.C.&G.S. BM C-14 El. 2032.11
U.S.C.&G.S. BM D-14 El. 2138.61
N 22,780,000
N 22,775,000
N 22,770,000
N 22,765,000
N 22,760,000
N 22,755,000
N 22,750,000
E 1,645,000
E 1,650,000
Lake
Marsh
Muskeg
Brush
Scattered Brush
Scattered Trees
High Hill
Canadian Customs
Canol Pipe Line & Telephone Line
Alaska Highway
Alternate
326
325
324
323
322
0
500
1000
1500
2000
2500

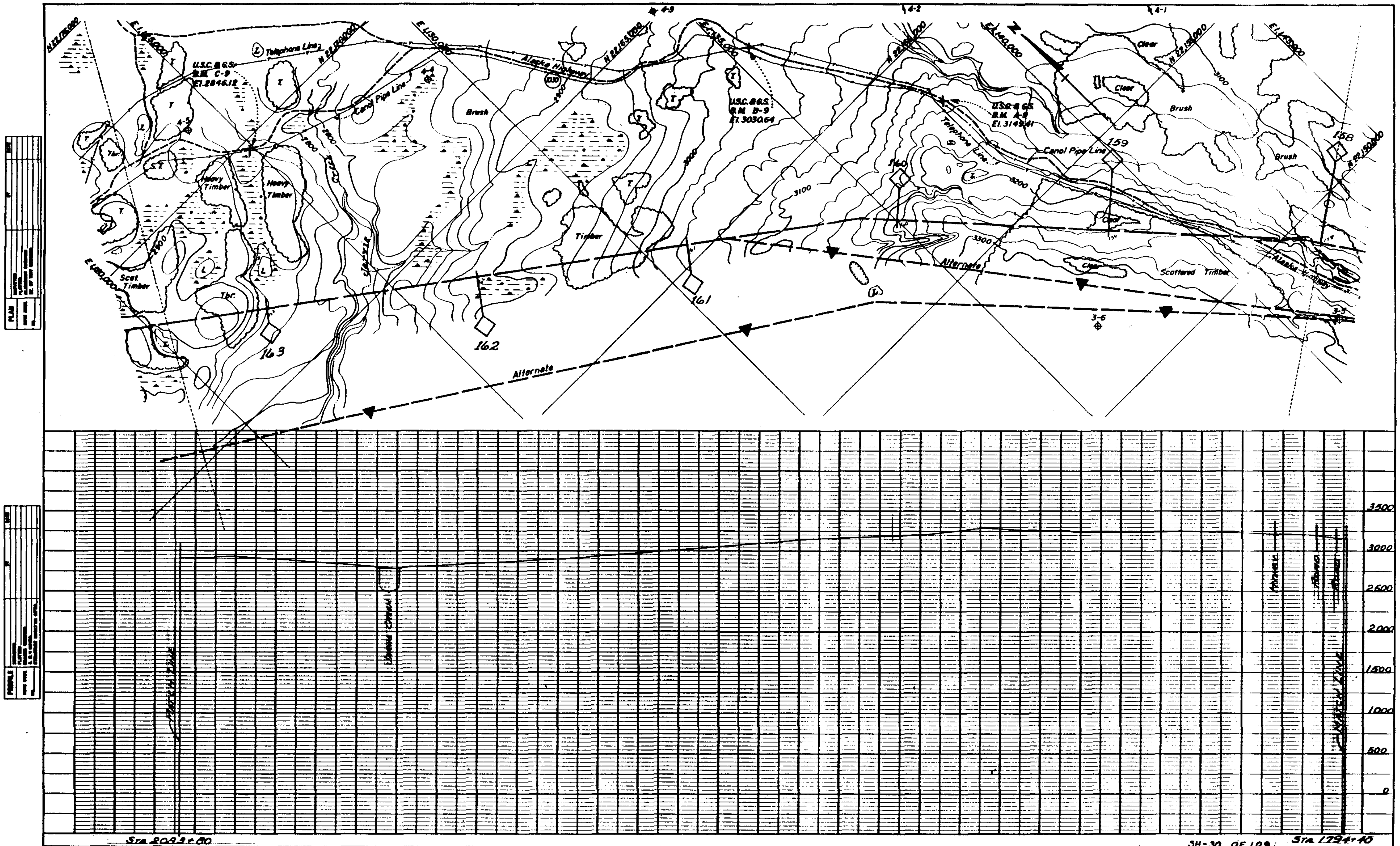


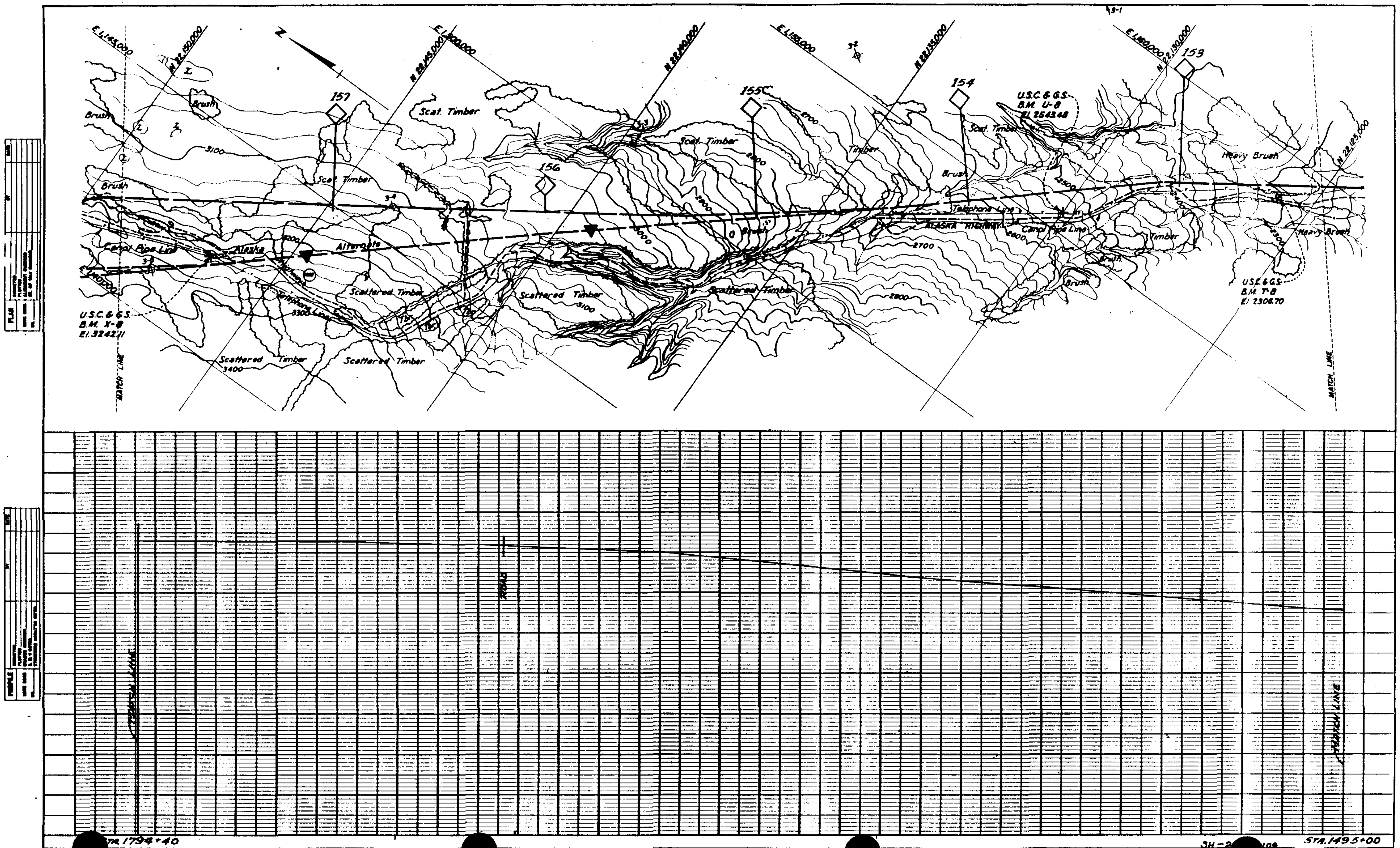


STA. 2382+80

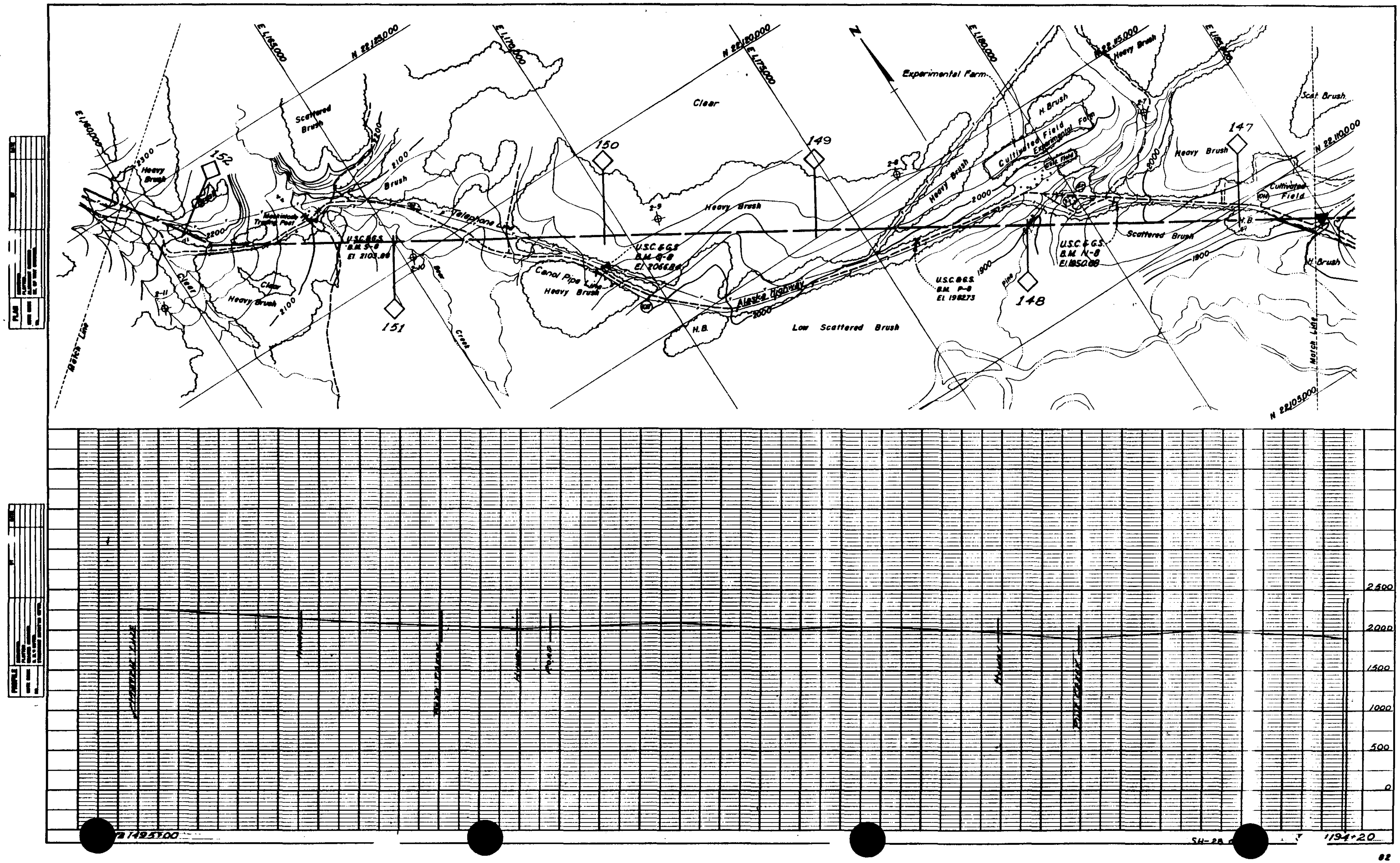
3H-31 OF

STA. 2083+80

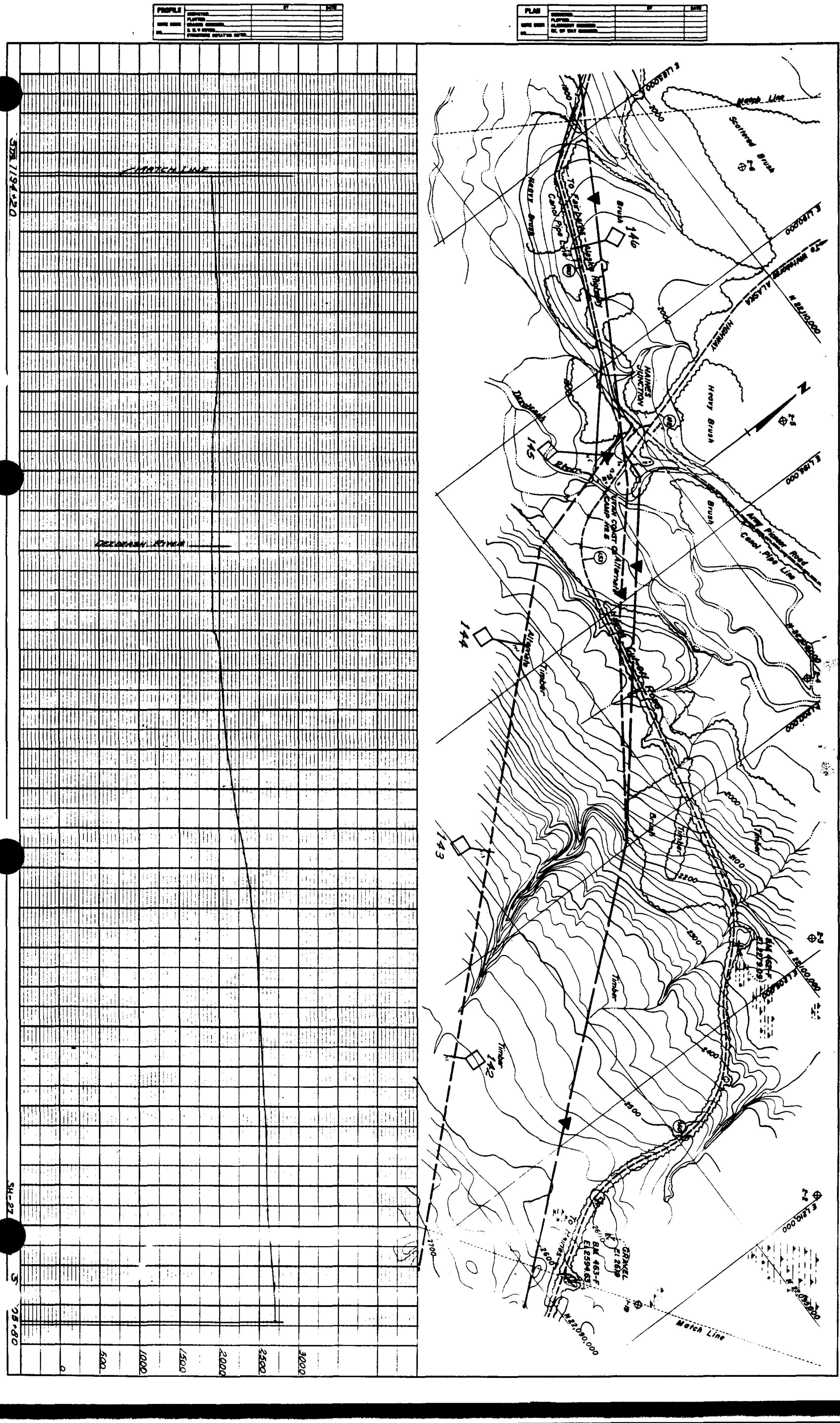

Alaska Highway
Telephone Line
Canol Pipe Line
U.S.C.&G.S. B.M. C-9 El. 2846.12
U.S.C.&G.S. B.M. B-9 El. 3030.64
U.S.C.&G.S. B.M. A-9 El. 3149.41
Heavy Timber
Heavy Timber
Scat. Timber
Brush
Timber
Clear
Scattered Timber
Jarvis Creek
Alternate
Alternate
163
162
161
160
159
158
2800
2900
3000
3100
3200
3300
Match Line
Jarvis Creek
Hiway
Road
Road
Match Line
0
500
1000
1500
2000
2500
3000
3500
Sta 2083+80
SH-30 OF 109
STA 1794+40


MATCH LINE
E 1,145,000
N 22,150,000
N 22,145,000
E 1,150,000
N 22,140,000
N 22,135,000
E 1,155,000
E 1,160,000
N 22,130,000
N 22,125,000
N
157
156
155
154
153
Brush
Scat. Timber
Scattered Timber
Timber
Heavy Brush
3100
3200
3300
3400
3000
2900
2800
2700
2600
2500
2300
Canol Pipe Line
Alaska
Alternate
Telephone Line
ALASKA HIGHWAY
U.S.C.& G.S.
B.M. X-8
El. 3242.11
U.S.C.& G.S.
B.M. U-8
El. 2543.48
U.S.C.& G.S.
B.M. T-8
El. 2306.70
ROAD
STA. 1794+40
STA. 1495+00
MATCH LINE

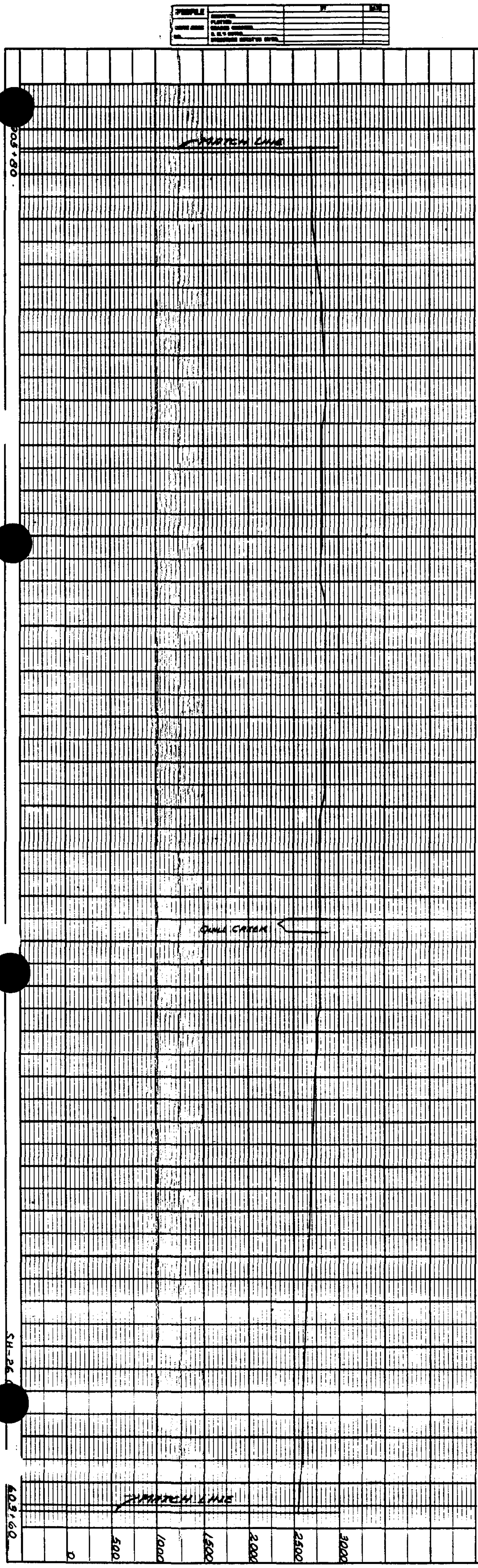
81

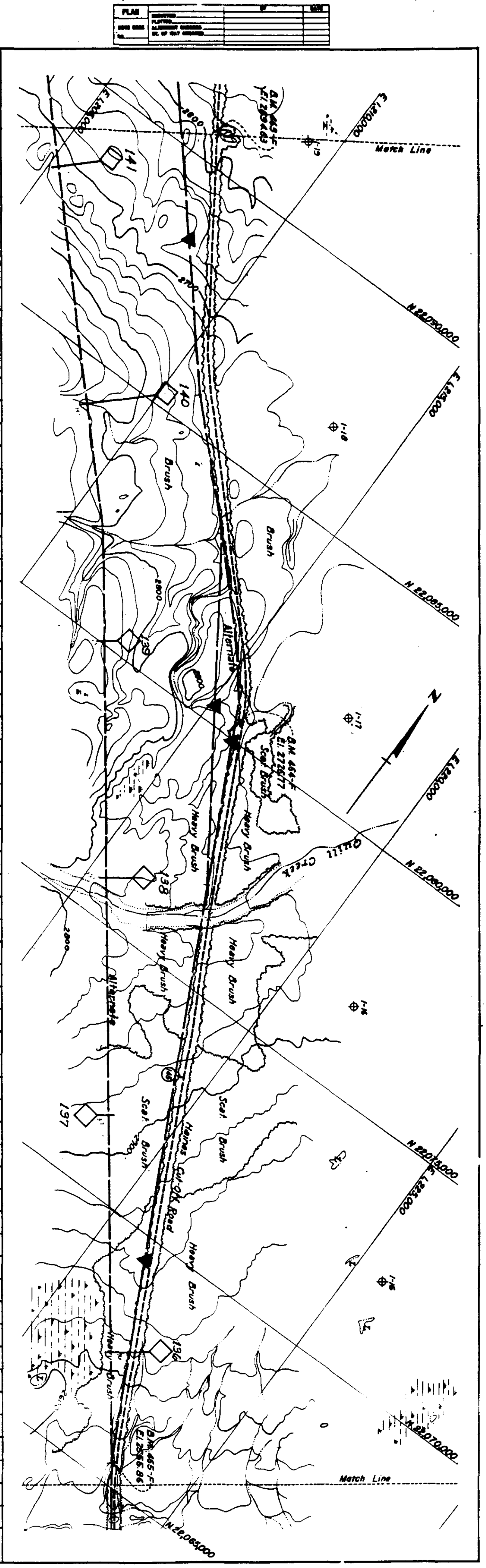


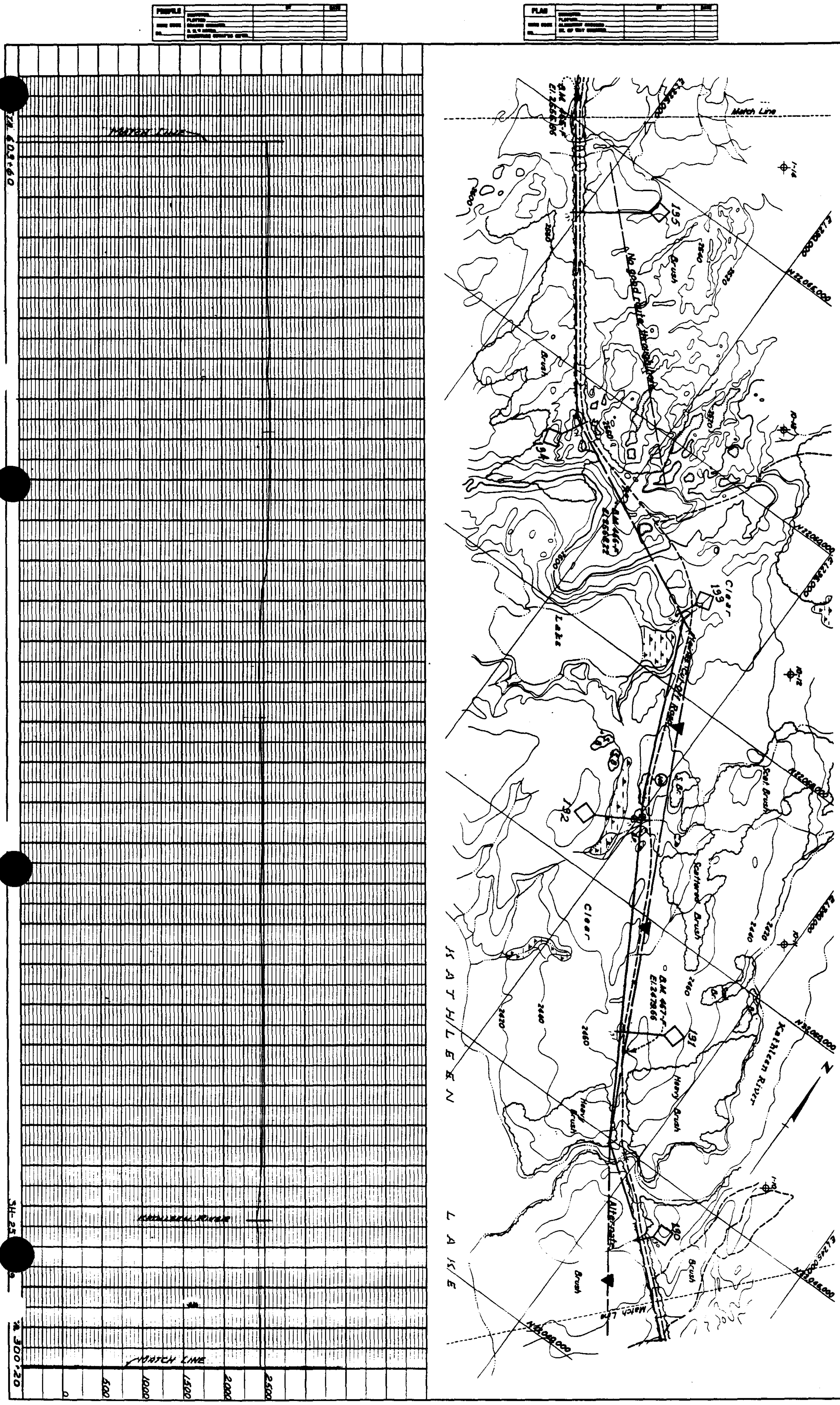
PLAN
PROFILE
Match Line
E 1,160,000
E 1,165,000
E 1,170,000
E 1,175,000
E 1,180,000
E 1,185,000
N 22,125,000
N 22,120,000
N 22,115,000
N 22,110,000
N 22,105,000
N
Experimental Farm
152
151
150
149
148
147
Heavy Brush
Scattered Brush
Brush
Clear
Telephone Line
U.S.C.&G.S. B.M. S-8 El 2103.86
U.S.C.&G.S. B.M. Q-8 El 2066.86
U.S.C.&G.S. B.M. P-8 El 1982.73
U.S.C.&G.S. B.M. N-8 El 1850.88
Canal Pipe Line
Alaska Highway
Low Scattered Brush
H.B.
H. Brush
Cultivated Field
Experimental Farm
Cultivated Field
Scat. Brush
Creek
Pipe
2300
2200
2100
2000
1900
2500
1500
1000
500
0
1194+20
82



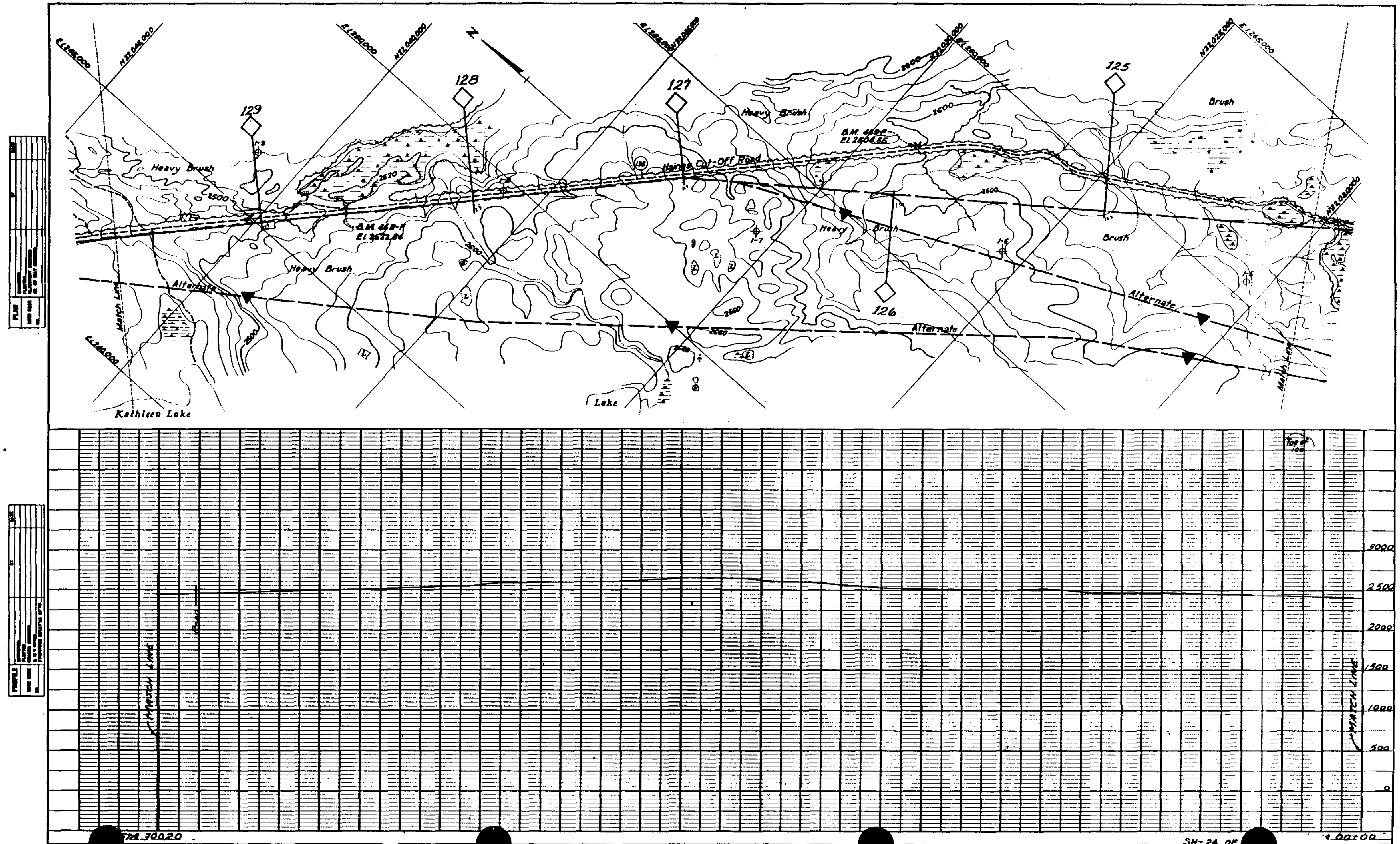
PROFILE
PLAN
MATCH LINE
DEZADEASH RIVER
STA 194+20
STA 205+80
SH-27
0
500
1000
1500
2000
2500
3000
Match Line
Scattered Brush
Heavy Brush
Brush
HAINES JUNCTION
ALASKA HIGHWAY
To Whitehorse
Canol Pipe Line
Army Pioneer Road
Timber
GRAVEL
N 22,090,000

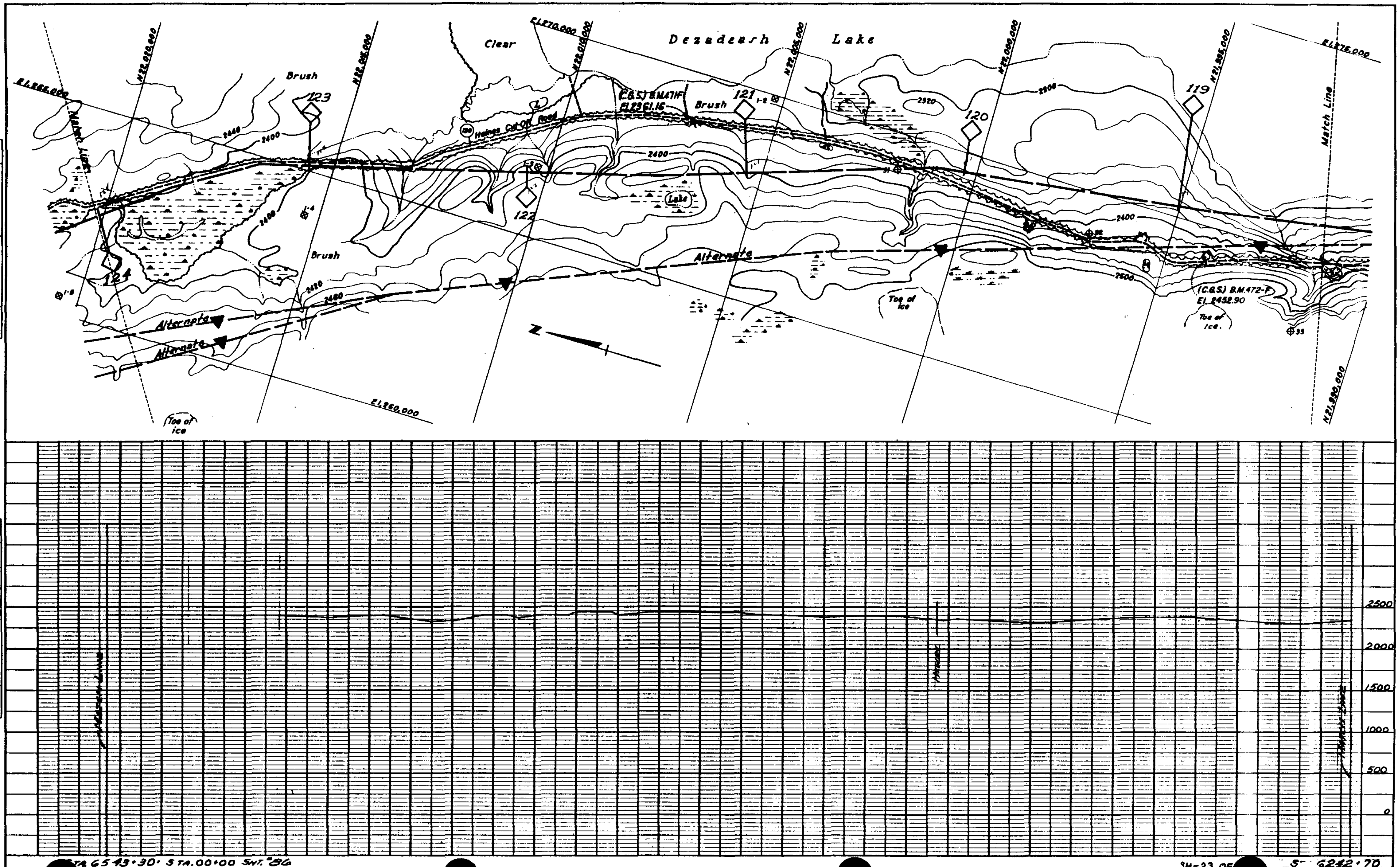

PROFILE
MATCH LINE
QUILL CREEK
MATCH LINE
0
500
1000
1500
2000
2500
3000
SH-26


PLAN
Match Line
N 22,090,000
N 22,085,000
N 22,080,000
N 22,075,000
N 22,070,000
N 22,065,000
141
140
139
138
137
136
Brush
Heavy Brush
Scat. Brush
Alternate
Quill Creek
Haines Cut-Off Road
B.M. 466-F
El. 2720.77
B.M. 465-F
El. 2566.86
2800
2700
N
Match Line



MATCH LINE
KATHLEEN RIVER
0
500
1000
1500
2000
2500
Match Line
Brush
Clear
Lake
Scattered Brush
Heavy Brush
Kathleen River
KATHLEEN LAKE

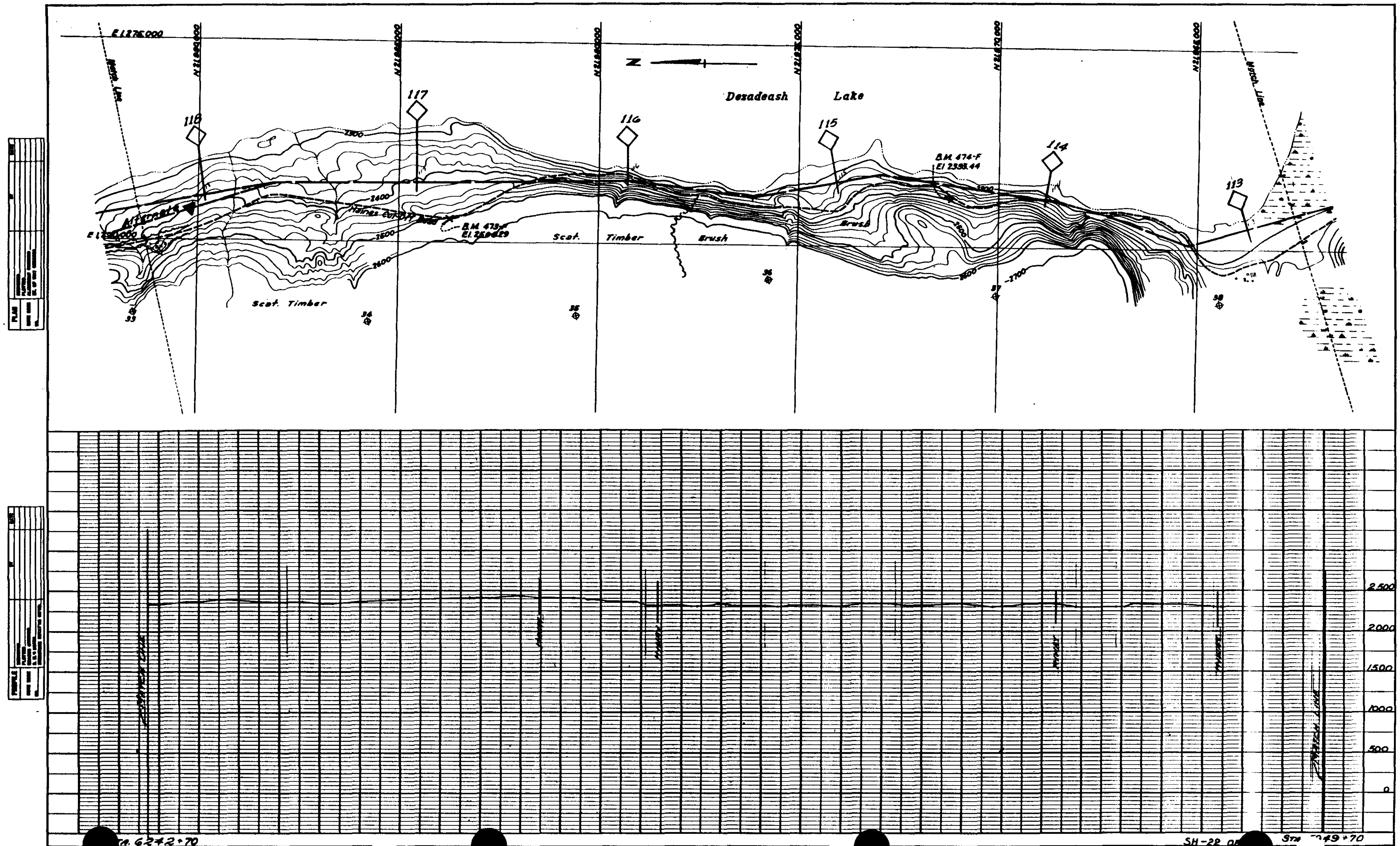

PLAN
PROFILE
129
128
127
126
125
Heavy Brush
Brush
B.M. 468-F
El. 2622.84
B.M. 468-E
El. 2604.65
Haines Cut-Off Road
Alternate
Match Line
Kathleen Lake
Lake
2500
2600
MATCH LINE
Road
3000
2500
2000
1500
1000
500
0
SH-24 OF



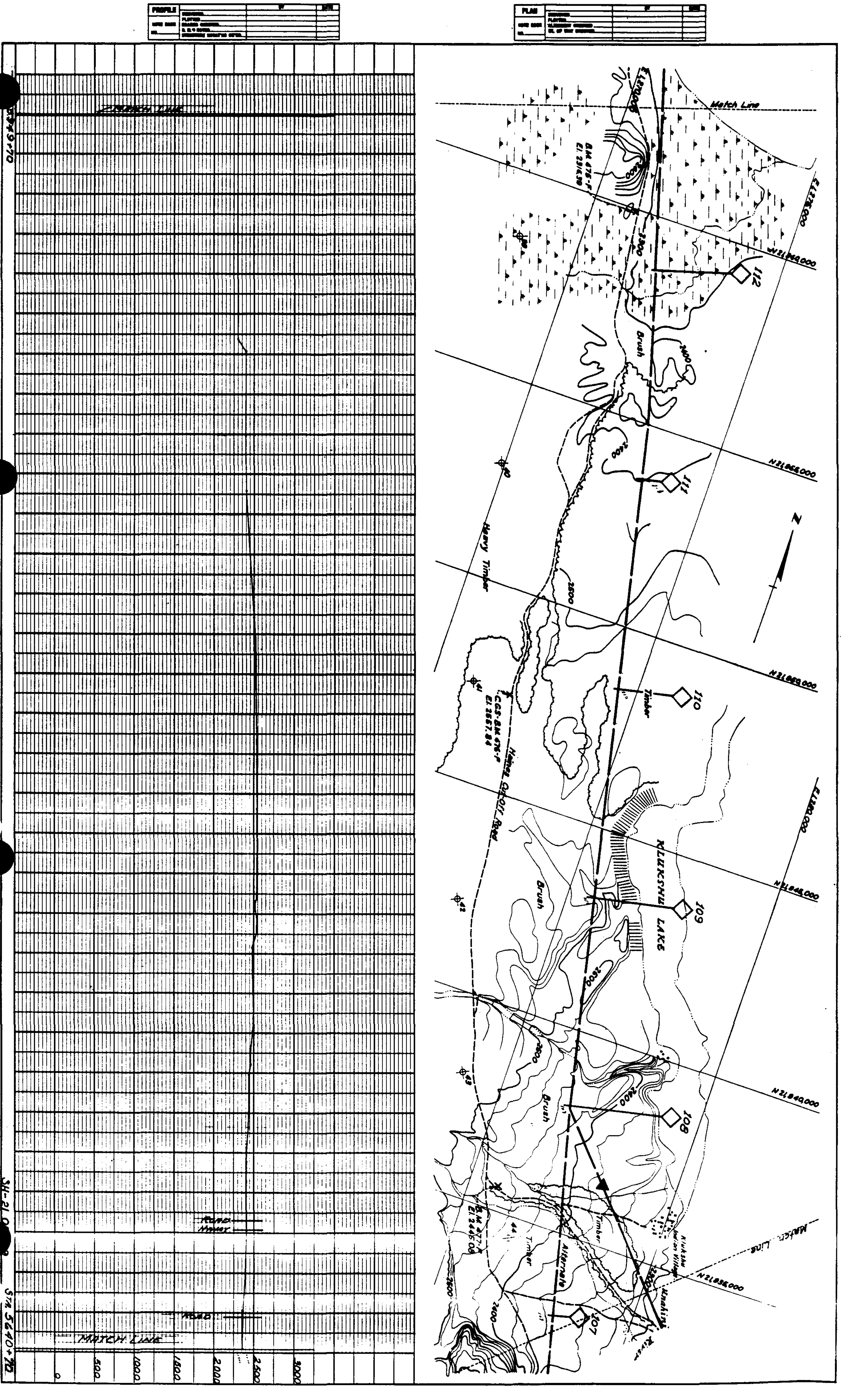
STA 6543+30: STA.00+00 SHT. 86

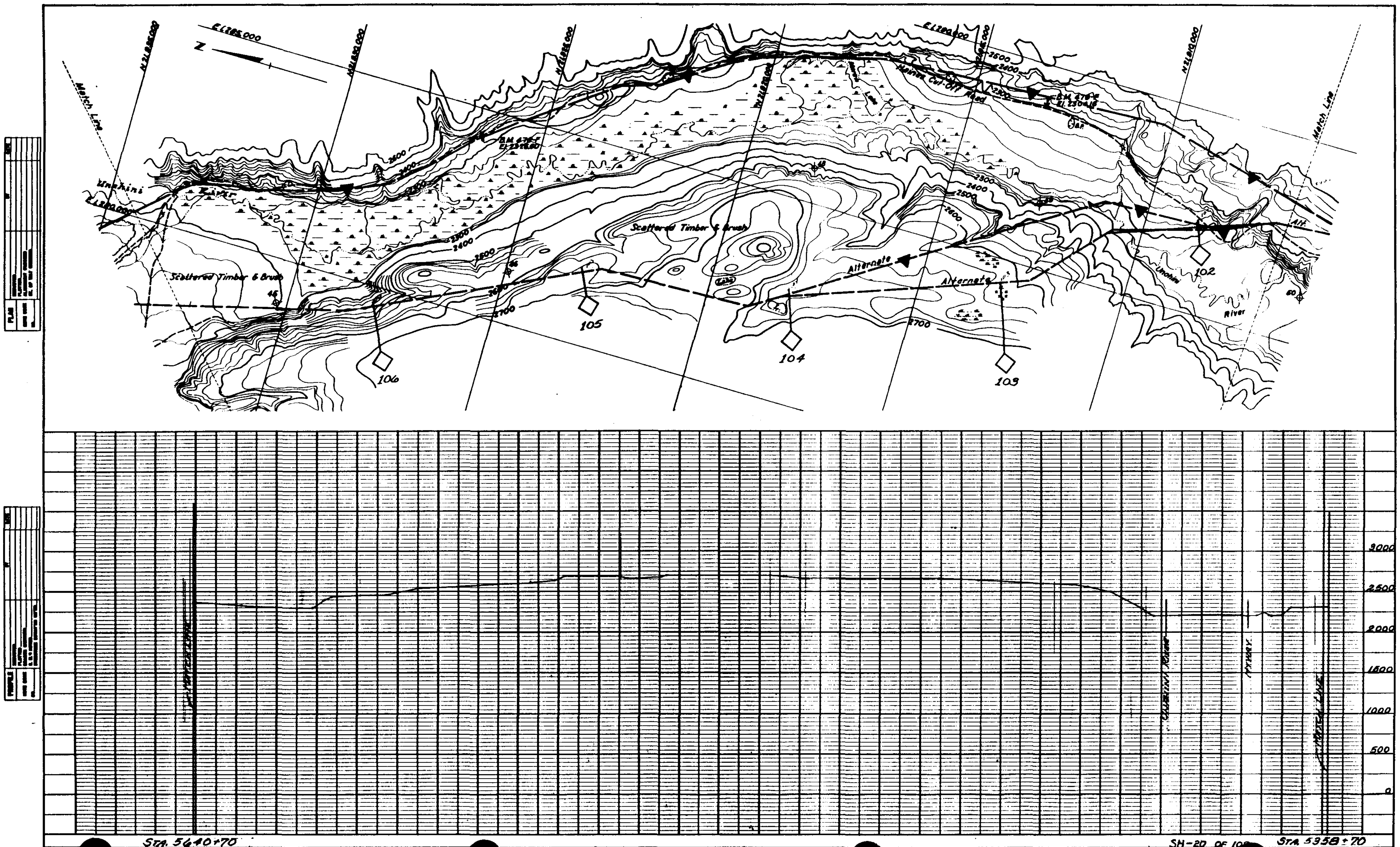
SH-23 OF

S- 6242+70

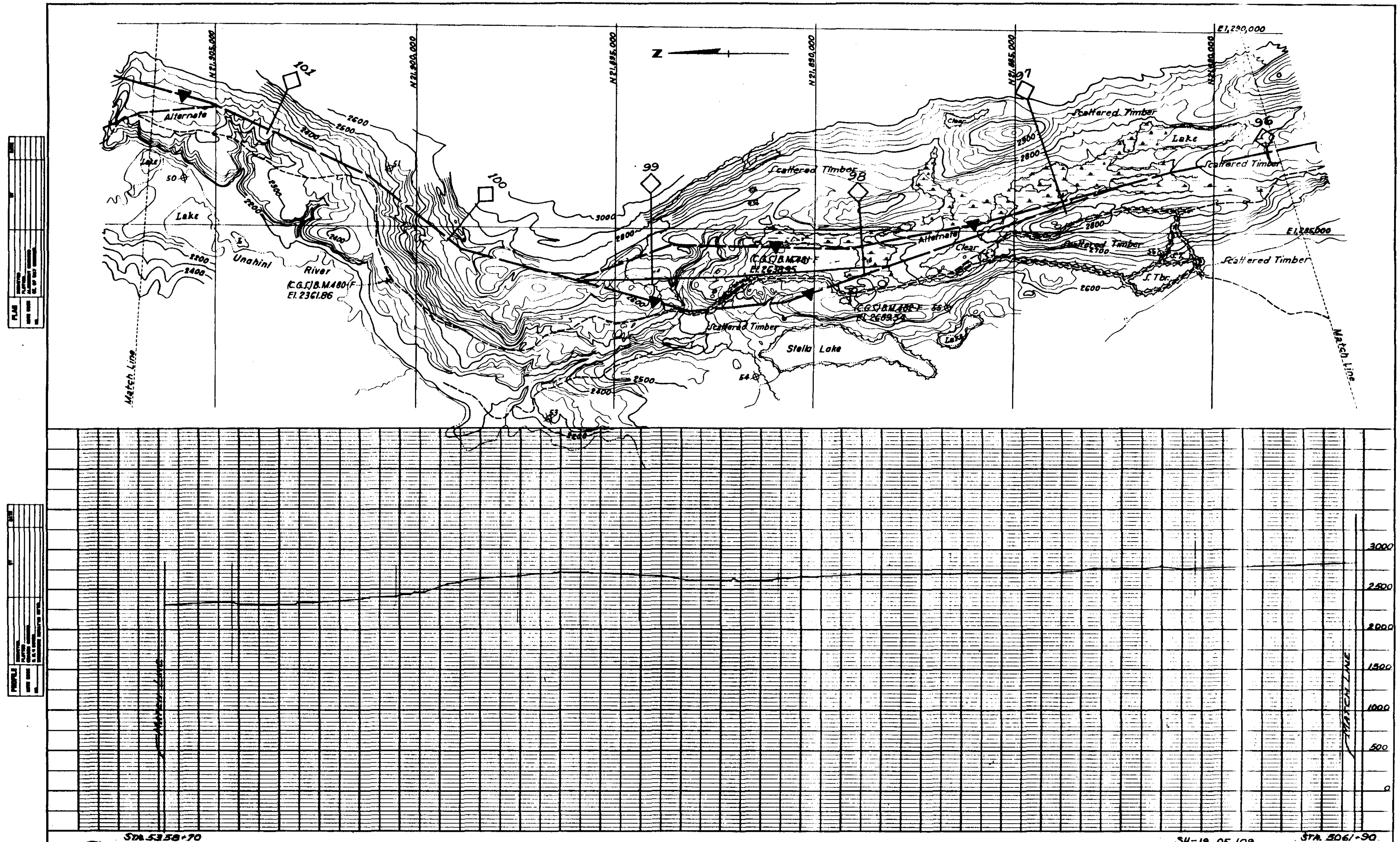


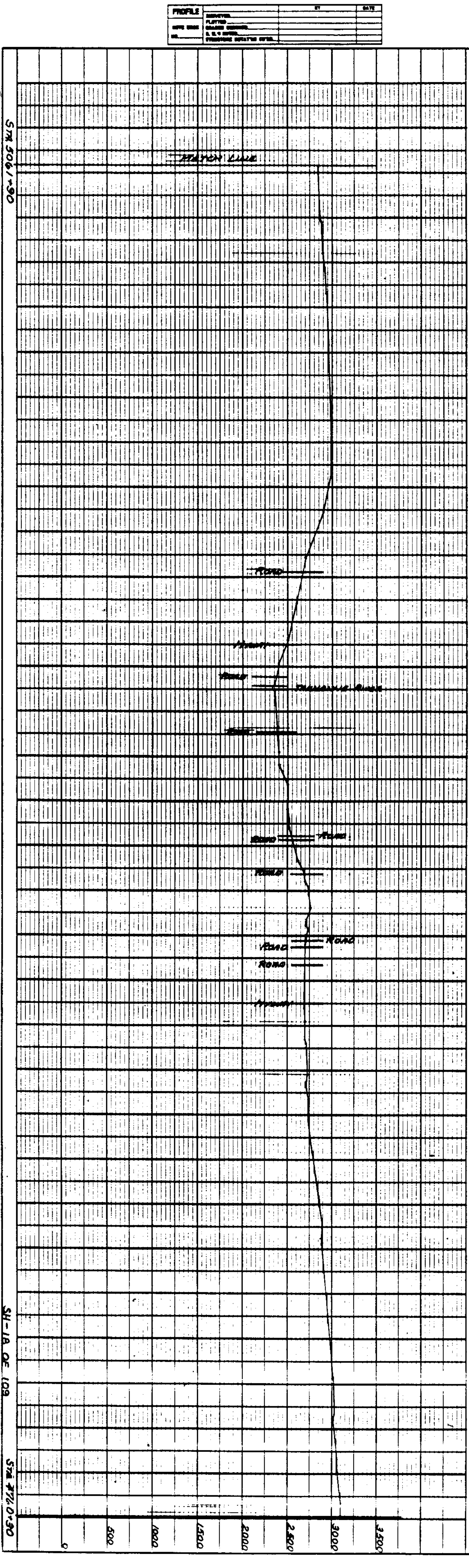
E1276000
N21880000
N21885000
N21880000
N21875000
N21870000
N21865000
Match Line
Dezadeash Lake
118
117
116
115
114
113
Alternate
Haines Cut-off Road
B.M. 473-F
El. 2508.29
B.M. 474-F
El 2393.44
Scat. Timber
Brush
2400
2500
2600
2700
33
34
35
36
37
38
MATCH LINE
2500
2000
1500
1000
500
0
STA. 6242+70
SH-22 OF
STA 6049+70

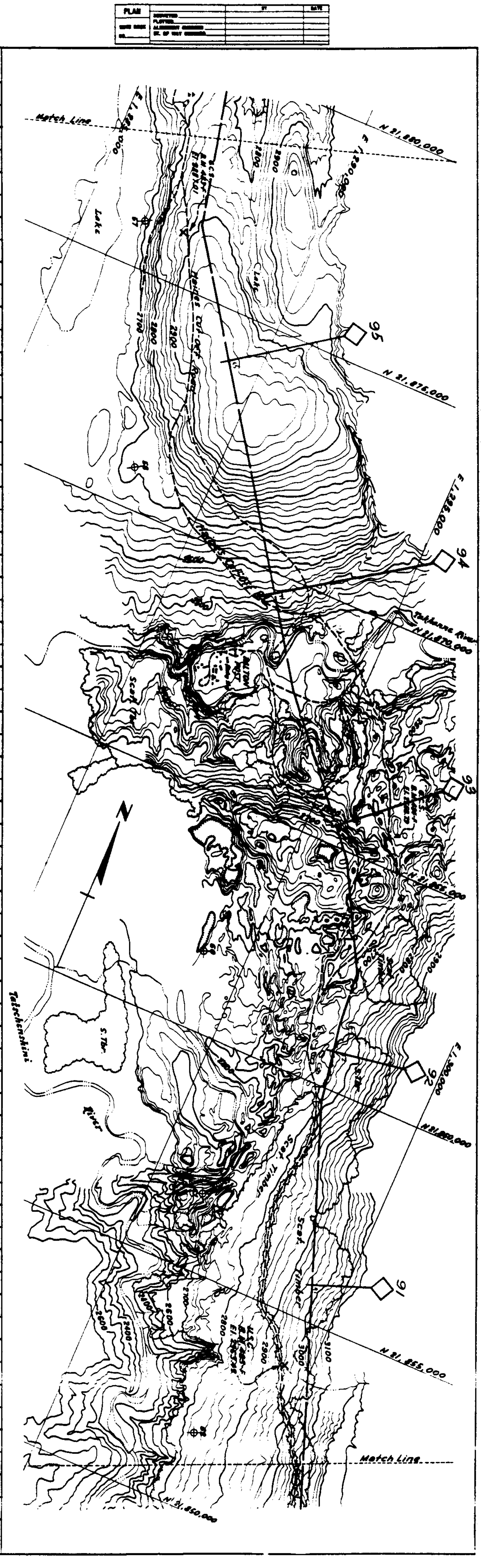

PROFILE
PLAN
MATCH LINE
Match Line
Road
Brush
Heavy Timber
Timber
Haines Cut-Off Road
KLUKSHU LAKE
Alternate
Klukshu Indian Village
N21,868,000
N21,860,000
N21,848,000
N21,840,000
N21,836,000
112
111
110
109
108
107
0
500
1000
1500
2000
2500
3000

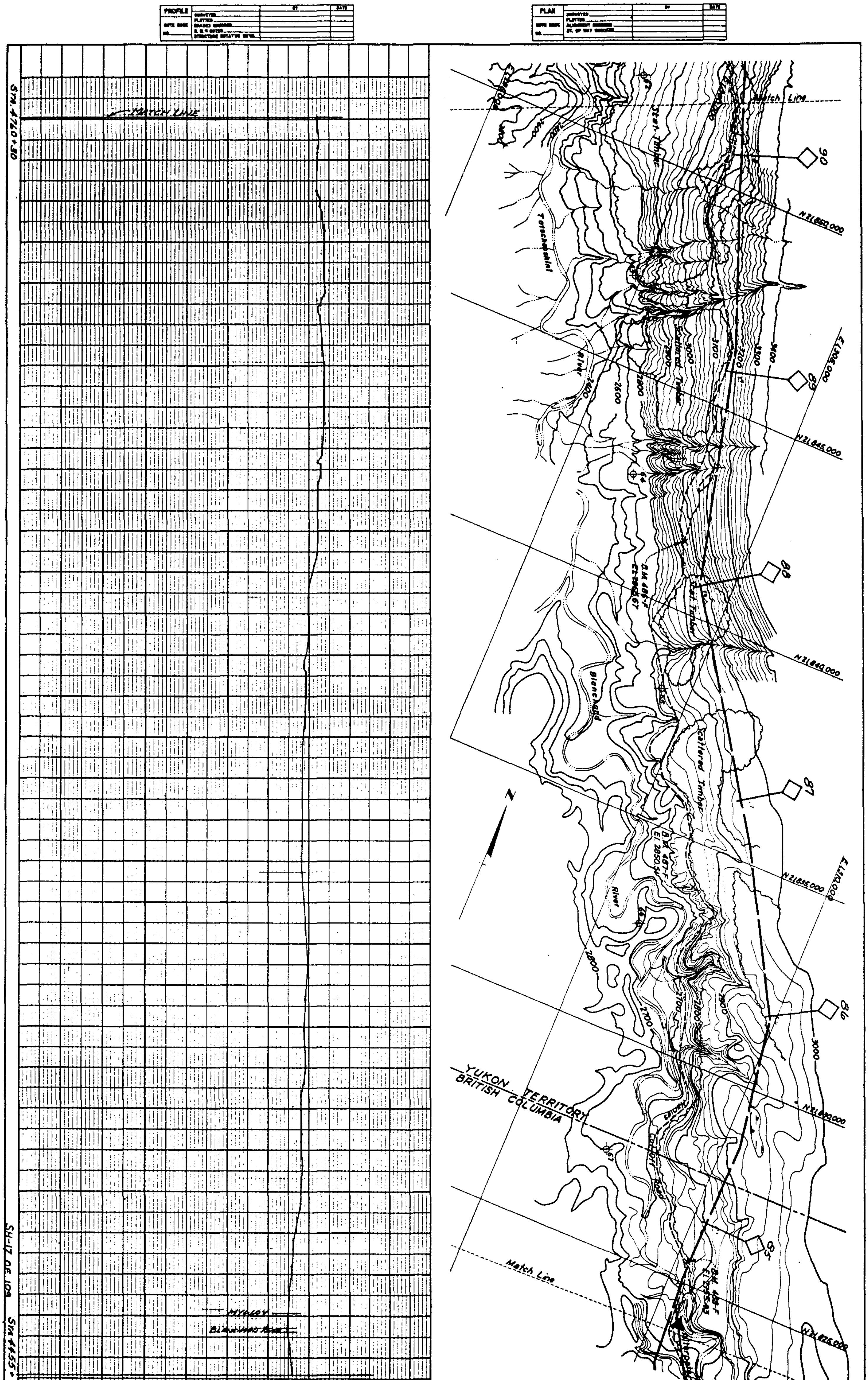


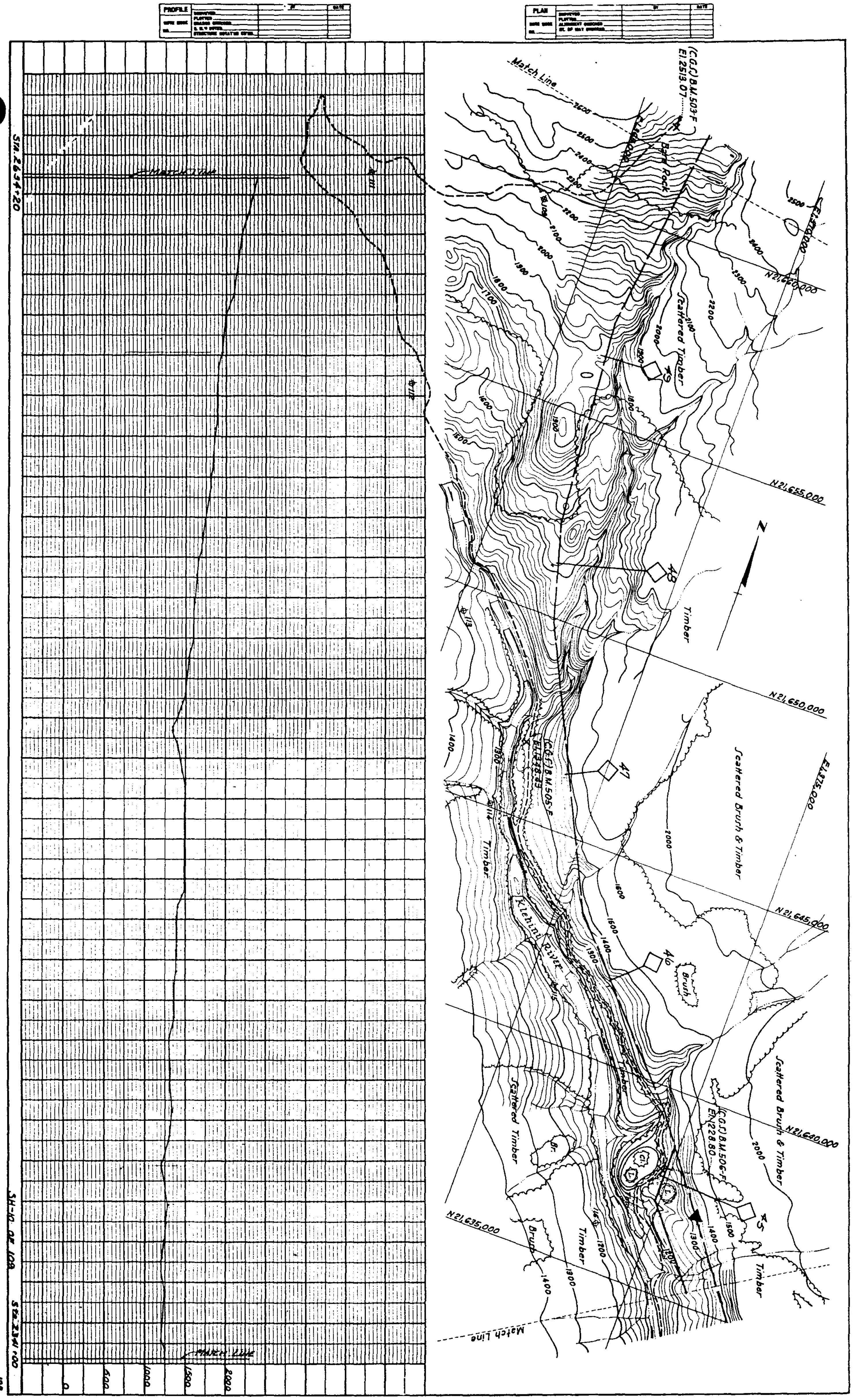
PLAN
PROFILE
Match Line
Scattered Timber & Brush
Alternate
River
106
105
104
103
102
2400
2500
2600
2700
3000
2500
2000
1500
1000
500
0
HYWAY
MATCH LINE
STA. 5640+70
STA. 5358+70

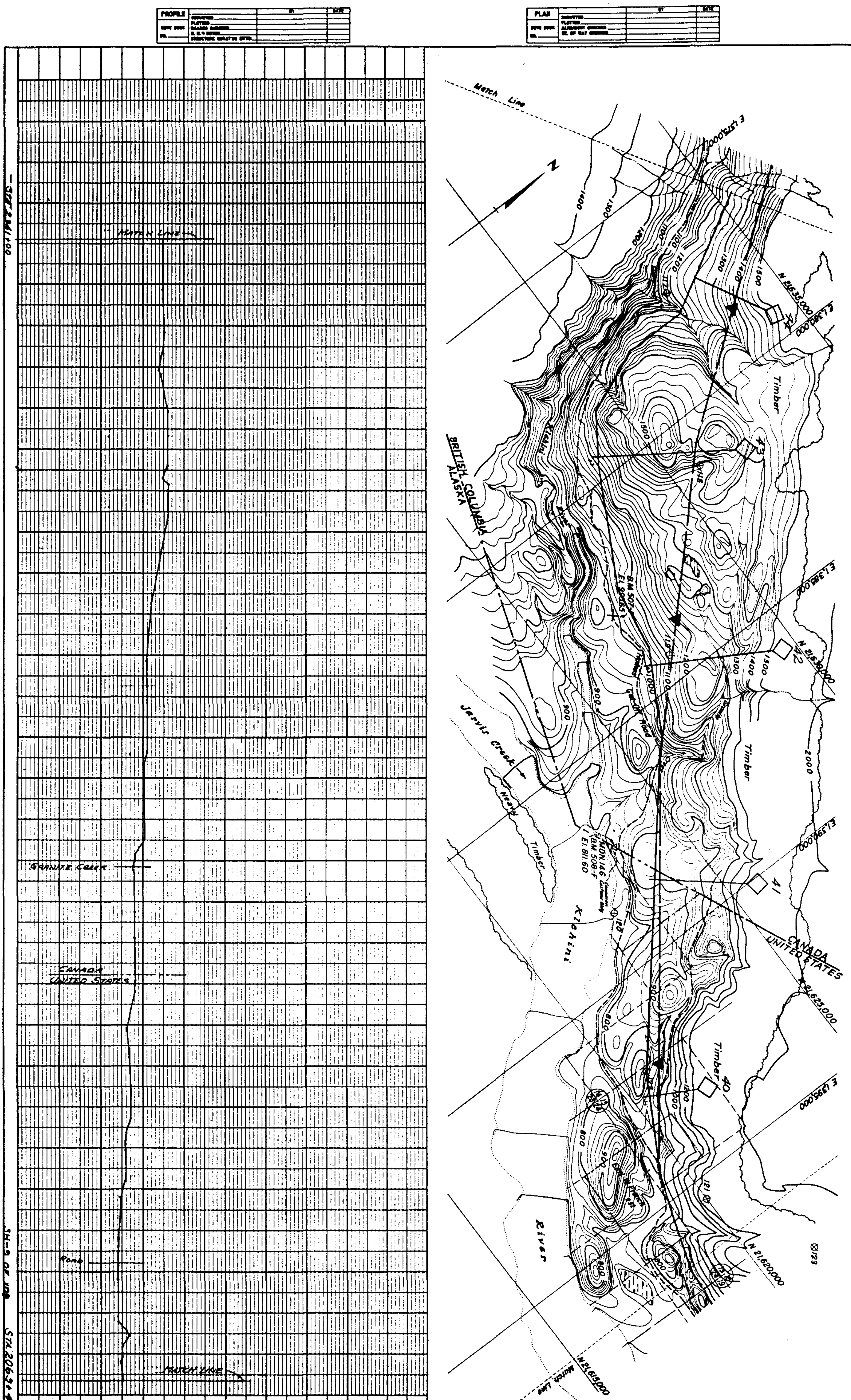

Match Line
Alternate
Lake
50
Lake
2200
2400
Unahini
River
(C.G.S.) B.M. 480-F
El. 2361.86
101
2600
2500
2400
2300
2200
51
100
N21,905,000
N21,900,000
N21,895,000
N21,890,000
N21,885,000
N21,880,000
Z
99
3000
2800
2600
2500
2400
53
Scattered Timber
98
Stella Lake
54
Scattered Timber
(C.G.S.) B.M. 480-F
El. 2683.74
55
Lake
97
Clear
2900
2800
Scattered Timber
Alternate
Clear
2700
Scattered Timber
96
Lake
Scattered Timber
Scattered Timber
S. Tbr.
2600
E1,290,000
E1,285,000
Match Line
Match Line
3000
2500
2000
1500
1000
500
0
STA. 5358+70
SH-19 OF 109
STA. 5061+90


PROFILE
STA 506+90
MATCH LINE
Road
SH-1A OF 109
0
500
1000
1500
2000
2500
3000
3500


PLAN
Match Line
N 21,880,000
N 21,875,000
Takhanne River
N 21,870,000
N 21,865,000
N 21,860,000
N 21,855,000
N 21,850,000
95
94
93
92
91
Lake
Scat. Timber
River
Match Line


PROFILE
PLAN
MATCH LINE
STA. 4760+30
SH-17 OF 109 STA 4455+70
0
500
1000
1500
2000
2500
3000
3500
Match Line
Scattered Timber
River
Blanchard
YUKON TERRITORY
BRITISH COLUMBIA
N21,860,000
N21,845,000
N21,840,000
N21,835,000
N21,830,000
N21,825,000
90
89
88
87
86
85
N


PROFILE
PLAN
Match Line
Bare Rock
Scattered Timber
Timber
Scattered Brush & Timber
Klehini River
Brush
N21,660,000
N21,655,000
N21,650,000
N21,645,000
N21,640,000
N21,635,000
49
48
47
46
45
Match Line


PROFILE
PLAN
Match Line
MATCH LINE
GRANITE CREEK
CANADA
UNITED STATES
ROAD
N
BRITISH COLUMBIA
ALASKA
Timber
Jarvis Creek
Klehini
River
E 1,360,000
E 1,355,000
N 21,625,000
N 21,620,000
N 21,615,000
43
42
41
40
1500
1400
1300
1200
900
800
2000

101