TUKTOYAKTUK WATER RESERVOIR

DREDGING CONSTRUCTION OBSERVATIONS

epec consulting western ltd.

TUKTOYAKTUK
WATER RESERVOIR

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September 17, 1982.

File: 6985-003-01-60

Government of the Northwest Territories
Department of Public Works
Engineer Division
Yellowknife, NWT
X1A 2L9

Attention: Mr. Brian Lemax, P. Eng.,
Project Officer

Dear Sir:

Re: Final Report, Dredging and Construction Observations of the Tuktoyaktuk Potable Water Reservoir

We are pleased to submit herewith the final report dealing with the dredging and construction related to the Tuktoyaktuk Reservoir.

The information contained within the report comes from such sources as DPW Engineering, Thurber Consultants, Dome-Canmar, Department of Local Government, Water and Sanitation Section, Niels Jacobsen Consulting, previous EPEC reports and the dredging and construction records of EPEC Consulting.

We would like to thank you very much for you comments and co-operation in preparation of this final report.

Yours truly,

EPEC Consulting Western Ltd.

DP Clark

D.J.P. Clark,
Senior Projects Co-ordinator

DJPC/llb

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A. INTRODUCTION

Tuktoyaktuk is a small community situated on the Arctic coast in Canada's Northwest Territories which serves as the centre of oil and gas exploration activity for the Beaufort Sea. The community has developed along a peninsular gravel bar and development of the community is restricted on three sides by the sea and on the fourth side by small lakes, poorly drained tundra and the community airport. Land suitable for development and the siting of municipal water/ sewer facilities is in very short supply despite the continuing requirement.

The oil and gas industry has provided the impetus for a solution to this land shortage problem. Dredges have been in this area fulfilling contracts to build artificial islands to serve as drilling platforms in the Beaufort Sea. During 1979 a 600 mm cutter suction dredge was used to place 80,000 m^3 of sandy material in a low lying area which had been identified as a potential subdivision location. The completed cost of material in place was extremely economical when compared with placement by conventional methods.

For many years, Tuktoyaktuk has been obtaining potable water from services in the vicinity of the Hamlet that are not considered to be ideal from a water quality standpoint. During the summer months, water is obtained from Ice Lake or New Water Lake and during the winter it is pumped from the upper strata of freshwater in Tuktoyaktuk

Harbour. The water quality problems include algae, insects, dust, silt, turbidity as well as variable salinity.

The requirement for a water reservoir in Tuktoyaktuk during 1981 forced the Government of the NWT to take a very close look at dredging as a method of placing the required fill for construction.

The remaining components of the water supply upgrading program are planned for construction in 1982 and 1983 and generally consist of a portable intake pumping system , supply pipeline to the reservoir, distribution pumphouse at the reservoir, installation of an impermeable reservoir liner and erosion protection measures (against wind and water). The new supply system is expected to be operational by the fall of 1983.

This report encompasses the work which was carried out during the first phase of the water supply upgrading program, namely, construction of the earthen reservoir. It includes a description of the activities that took place during dredging and construction of the reservoir itself. The time frame covered is approximately from June 1981 to September 1981. Discussions are included on design problems, constraints and considerations, timing, dredging and construction problems and techniques as well as an overall synopsis for each phase. The report deals specifically with the construction aspects of reservoir work including the placement of the dredge spoils. Complementary work being carried out by the Department of

Public Works, as the department responsible for construction, and the Department of Local Government as the ultimate client department, is referred to in this report.

A.1 Design Considerations

In September, 1980, EPEC Consulting Western Ltd. was commissioned by the Government of the Northwest Territories to proceed with design work in connection with the potable water reservoir Thurber Consultants Ltd. were selected as subconsultant to provide all geotechnical backup, as well as recommendations on reservoir design and site selection. The G.N.W.T. had previously established that the most efficient water supply system for the Hamlet considering a twenty year design period would be a trucked water distribution system. Water from a new water source (as yet undetermined) would be pumped each summer by means of a portable pump intake through a supply line to a reservoir to be located at some point near or within the Hamlet. A pumphouse located at the reservoir would provide treatment and operate as a truck fill point.

Initially, the objective was to provide an operational system by the fall of 1981, however this was not considered to be practical or desirable from an engineering viewpoint.

Timing was a critical factor during the initial stages of the project since much work was required to establish the preferred reservoir location including design considerations and geotechnical investigations. The reservoir site could be established prior to source identifications as costs associated with supply options were felt to be relatively insensitive to the reservoir location. A great deal of data collection assimilation and evaluation was required prior to establishing the design criteria required for the reservoir construction which had a bearing on the reservoir location. Based on EPEC's Predesign and Design Brief, and 'Water Supply, Sewage and Solid Waste Disposal Study' prepared by M.M. Dillon Ltd., May , 1981, the final design was to be completed to allow for reservoir construction commencing early in the summer of 1981.

A.2 Siting Considerations

Detailed investigations and assessments were carried out during the pre-engineering phase before a firm recommendation could be made with respect to the location of the reservoir. Many variables and constraints affected the site selection. The key items which affected site selection are listed as follows:

- distance from Hamlet
- road and power access
- area requirement for reservoir

- surface and subsurface conditions
- construction costs
- operating and maintenance costs for the water supply system
- conflicts regarding existing land tenure
- proximity to borrow source (where alternatives using dredged material were examined)
- sea water flood elevations during storms
- distance from assumed water resupply source
- anticipated construction schedule
- construction problems

A site reconnaissance was carried out at Tuktoyaktuk between September 16 and 19, 1980 by EPEC, Thurber and DPW. Nine sites were selected for detailed analysis. Two construction methods were considered, namely:

- dredged material in lowland sites with an earthwork contract to form berms.
- dredged material on upland sites followed by earthwork contract.

The use of existing lakes were considered but not examined in detail due to anticipated high construction costs for berming and dredging to remove bottom sediments and probable water quality problems.

Before proper comparisons on costs and construction methods could be made, design criteria for the reservoir had to be established. Due to occasional storms causing high flood levels it was established that the reservoir base be set near the maximum expected 50 year flood elevation to guard against possible ballooning of the liner.

A liner was an assumed requirement in order to prevent excessive seepage losses from the reservoir for all sites and construction methods and to prevent sea water from seeping in during excessively high storm levels.

Two factors were used to establish the dyke height requirement and consequently the cross-sectional configuration. Firstly, the reservoir must be of dimensions that will minimize the volume of water stored as ice during the period of maximum ice thickness. The second factor was construction cost. Plots were made of ice storage vs. construction costs and the configuration was optimized with berm height of roughly 8 m.

Inside dyke slopes were considred to be 3:1 for excavated materials and 4:1 for dredged materials. A one cell reservoir system was chosen rather than 2 cell, primarily due to construction cost consideration.

Other design parameters were assumed such as dyke top width, outside dike slope (3:1), and a square cell configuration for cost comparison purposes.

It should be noted here that a major portion of the actual reservoir design took place during the preliminary engineering phase. As can be seen it was necessary to establish the design interior in order to allow for more accurate cost estimates and comparisons to be made.

Estimated capital costs for reservoir construction were prepared as well as the costs of the remaining works (ie. distribution pumphouse, supply line and portable pumphouse) for each potential reservoir site. Water delivery, road and maintenance costs were also prepared for each site.

A detailed comparison of all sites showed that either the Tare Lagoon or Harbour Flats site were the most attractive mainly from the points of view of capital and operating costs. Also, since both of these sites considered the use of dredged sand materials from the Harbour for construction, the geotechnical constraints were not as serious as for the upland sites using in-situ materials for construction of a facility on permafrost.

The final draft of EPEC's Predesign Report and Design Brief was submitted to the G.N.W.T. on November 13, 1980 recommending that the reservoir be constructed at either the Tare Lagoon or Harbour Flats sites. It was also recommended that geotechnical investigations be carried out at each site to provide a basis for final selection. Other design recommendations were made such as maintaining the reservoir floor above the 1:50 year flood level, using a one-cell configuration and that the design concepts presented be used in final design. Also, a circular configuration was recommended for consideration at this time primarily due to its more efficient shape and subsequent construction cost savings.

The report recommendations were adopted by the Government of the Northwest Territories and in early December, geotechnical investigations were carried out by Thurber Consultants Ltd. at the two alternate reservoir sites. Due to insufficient ice thickness, adequate geotechnical information to make a proper decision regarding the reservoir location was not obtained. It was decided to conduct further site drilling in conjunction with the proposed harbour drilling program for borrow materials later in the winter. Findings of the drilling resulted in a recommendation for use of the Harbour Flats site. The recommendations were approved by both the Government of the Northwest Territories and the Hamlet Council.

Following the adoption of the Predesign Report and Design Brief recommendations, work proceeded towards completion of the design details and preparations of the contract documents, assuming that the Harbour Flats would be the most suitable site for the reservoir.

EPEC prepared and submitted a report comparing square vs circular reservoir configuration along with recommendations. It was found in the predesign calculations when comparing the rectangular and circular configurations, that there were significant differences in volumes of material. These considerations were as follows:

total dredged volumes,
excavation to embankment,
liner area required,
liner sand cover volume, and
fence length required.

It was found, considering the above, that an overall average savings of 14% would be realized if a circular shape was utilized. It is interesting to note that the "total dredged volume" and "excavation to embankment" had savings of 15 and 20 percent respectively.

The circular shape did present greater challenge to survey control, however, this was accomplished with a great degree of success by Underhill & Underhill surveyors, who employed a radial system of layout. It is interesting to note that the circular shape lent itself to construction equipment movement particularly when the dykes narrowed to completion at design elevation. In a square rectangular configuration, the equipment must negotiate right angle turns which is often times difficult as the dyke reaches its final height.

By late December, a decision had been reached to proceed with a circular design.

Numerous discussions and some design meetings took place between DPW, Thurber and EPEC during December and January to tie down design details such as geotechnical considerations due to underlying permafrost, subdrain systems and sand drains. One design aspect which required careful thought was the interior dyke slope.

Thurber obtained the assistance of Northwest Hydraulic Consultants to carry out theoretical investigations on potential erosion of the sand cover material over the liner. The slope factor was particularly significant due to the difference in earth materials required for dyke construction using a 3:1 slope or a 4:1 slope for example. After careful consideration of numerous factors and recommendations from the subconsultant, a 4:1 interior slope was recommended and adopted into the design.

On December 11, 1980 a meeting was held in Yellowknife with Dome/ Canmar to discuss the proposed dredging program using the Aquarius dredge. Although Dome had made previous verbal commitments to the G.N.W.T. regarding the availability of the dredge, serious negotiations and planning for the program began at this time.

In December and January the Harbour drilling program was arranged. The purpose of the geotechnical investigations were to locate a single source of suitable borrow material within Tuk harbour for use in construction of the reservoir. A second objective was to establish the subsurface conditions at each of the two proposed reservoir sites. The investigations were carried out between February 25 and March 8, 1981 by Thurber Consultants. The drilling was conducted by Midnight Sun Drilling out of Whitehorse using a CME 750 all terrain drill.

A geotechnical report (Inf. 3) was submitted by Thurber Consultants on March 28, 1981. A suitable borrow area was identified in the area between the Dew Line Station and Tuk Island.

Investigations at the Harbour Flats site indicated underlying fine grained sand or silty sand. The excessive ice content of the frozen sand was found to be generally less than 5%. The stratigraphy of the Tare Lagoon site was found to be similar to the Harbour Flats site except that a 2 m clay layer overlies the sand. If the latter site were to be used as a reservoir site, vertical drains would likely be required to prevent buildup of water pressure with thaw degradation. This added construction feature combined with the need for further drilling at the site (if selected) led to the recommendations of Harbour Flats site as the preferred reservoir location.

Draft specifications and drawings for reservoir construction were submitted to the G.N.W.T. on January 30, 1981 and the finalized documents were completed for tender on February 20, 1981. The contract included the following:

- earthworks required for reservoir construction as well as an access road and pad for the future distribution pumphouse using previously dredged materials on site.
- installation of a subdrain system consisting of perforated HDPE pipe covered with filter cloth, laid beneath the floor of the reservoir.
- installation of a gravity drain system including manholes and gravity drain exists. (See as-built construction drawings) (Inf. 2) (Appendix A).

The earthworks portion of the contract was set up to allow the contractor to insert his estimated operating hours and unit rate/hr. for each piece of equipment he felt would be required to complete the project. The subdrain and gravity drain portion of the tender were presented in a price per unit of measurement basis.

The contract was advertised on February 24, 1981, with a closing date of March 19, 1981.

Three tenders for the earthworks were received and after careful evaluation, Dekay Construction from Ontario was selected based on expected contract cost, experience and equipment.

On April 1, 1981, a meeting was held at the Dome/Canmar offices in Calgary to discuss and finalize the dredging program that was to be carried out under Domes direction. Final agreements between Dome/Canmar and G.N.W.T. were proposed at this time.

A preconstruction meeting on the earthworks portion of the project was held in Yellowknife on April 30 between DPW, EPEC and Dekay. Following this, Dekay Construction proceeded with arrangements for equipment, manpower and other contract matters. Mr. Dekay travelled to Tuktoyaktuk May 2 - 4 and met with EPEC in Whitehorse on May 5, for discussions and further arrangements.

B. DREDGING OPERATION

B.1 Mobilization

Dome/Canmar initiated their mobilization (Inf. 5) on or about the 11th of May 1981 with the hauling of sand for a temporary access road which was utilized to haul land line for transport of dredged materials. Preparation for the dredging operation was carried out intermittently until the 18th of June. (See Fig. 1 - Activity Flow Schedule)

Staff of D.P.W., G.N.W.T. and EPEC Consulting mobilized on the 15th of June and all parties were on site by 1100 hrs. on June 17.

B.2 Pre-Dredging Surveys

The pre-dredging survey of the reservoir site was initiated by 3 DPW staff members on the 16th of June, and together with 2 EPEC staff members, the preliminary survey was completed @ 1700 hrs on the 18th of June.

The intent of the preliminary survey was to document original ground elevations prior to dredging in order that accurate volumes of dredged material could be calculated through subsequent quantity surveys.

A grid pattern was set out,utilizing a baseline running N.N.W. - S.S.E. immediately adjacent to the landfill site and approximately parallel to an access road which borders the general landfill area.

As the site was free from ice and snow, the survey was carried out

PRELIMINARY DREDGING

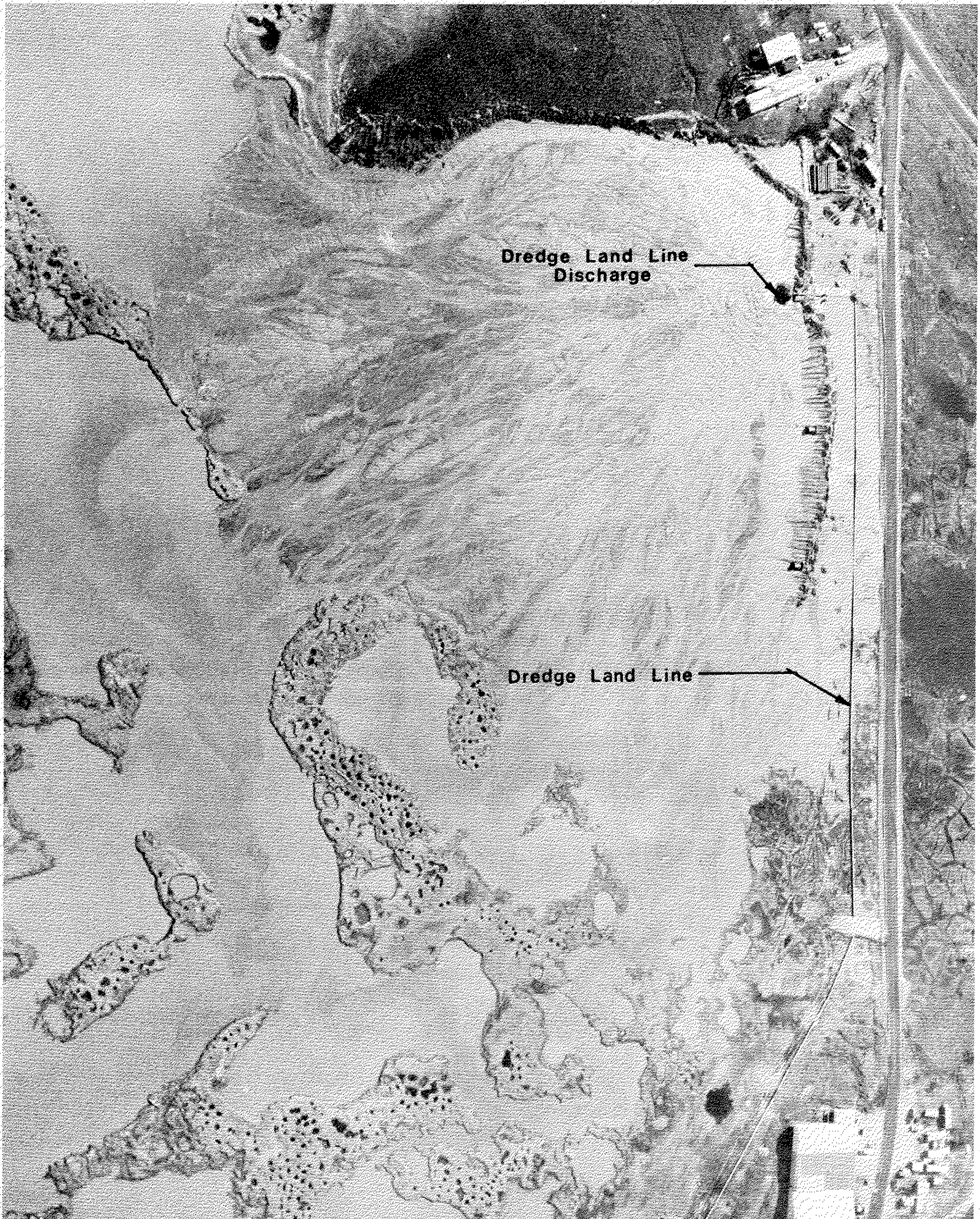

PHOTO 1

using transit, level and chain and the crew employed hip waders where necessary in order that water-filled depressions and the outer limits of the grid could be included.

Six ground targets, each consisting of two 1.2 X 1.2 m. sheets of plywood painted white were placed at key points on the base line and the grid. These targets were employed for rough control and points of identification during examination of low level oblique aerial photography of the site prior to and during the dredging deposition. (See Photo No. 1)

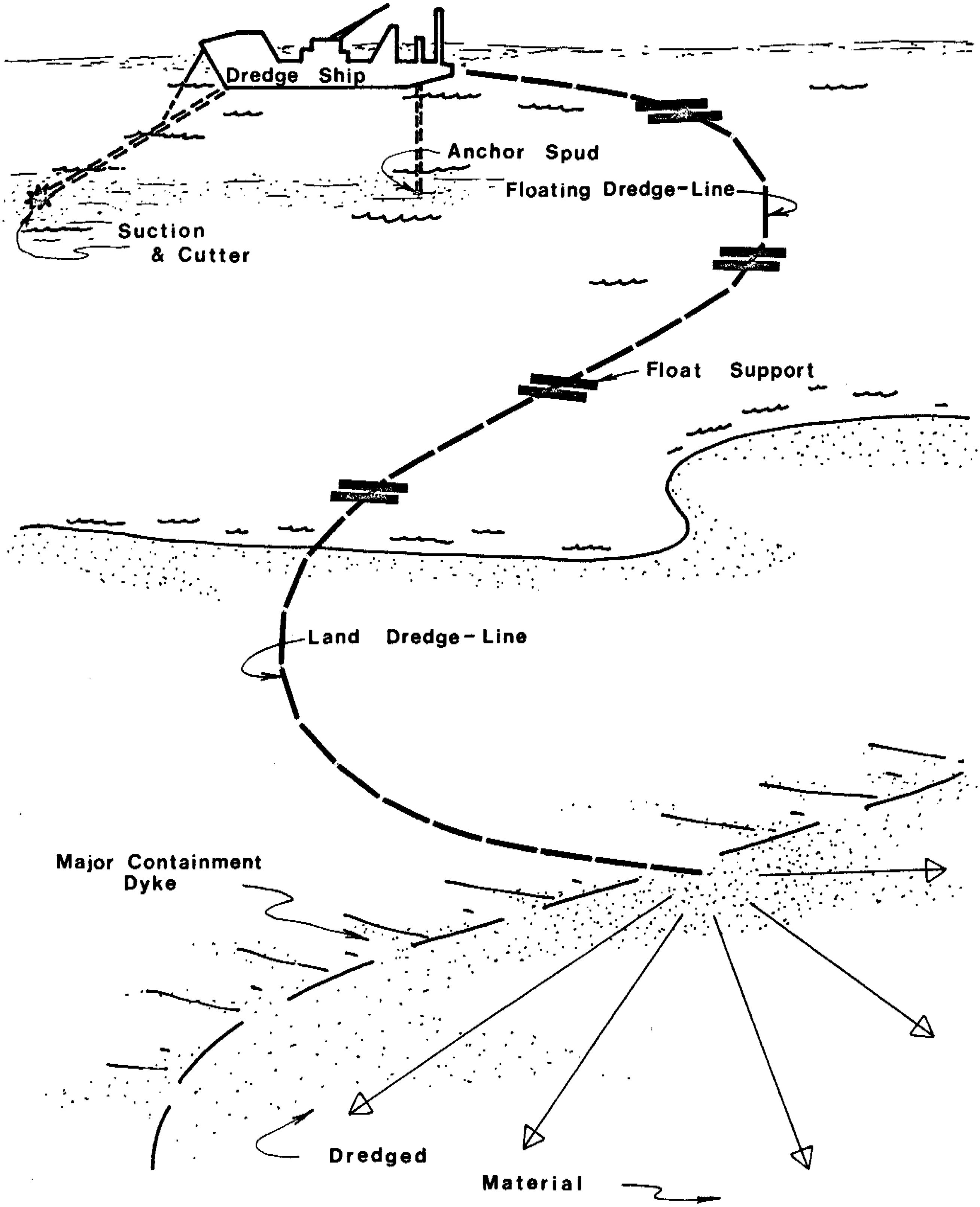
Dredge Ship
Anchor Spud
Floating Dredge-Line
Suction
& Cutter
Float Support
Land Dredge-Line
Major Containment
Dyke
Dredged
Material

FIGURE 3-A

B.3 Dredge Vessel

The dredging operation was carried out using a cutter-suction dredge and a 0.91 m diameter pipeline to transport the dredged materials. A cutter-suction dredger is equipped at the forward end with a ladder, which terminates in a cutterhead as the excavating tool. The ladder structure accomodates the cutter drive, and generally, a submerged dredge pump(s). The ladder can be raised or lowered to the desired dredging depth. The vessel has two spuds at the stern; one of these is lowered to provide a pivot about which the dredger is swung with the aid of cables, anchors and winches.

The most important components of a cutter-suction dredger are the cutter and the dredge pump(s). A revolving cutter situated immediately forward of the suction inlet dislodges the soil and presents it to the suction pipe, incorporated in the cutter ladder. The soil is mixed with water, and the mixture is drawn up through a suction pipe with the aid of the dredge pumps to the disposal site; first through a floating pipeline connected to the dredger, and then through a fixed pipeline on the shore.

The dredge employed on this project was the "Aquarius" which is a sea-going ship owned by Zanen Verstoep of Holland and contracted to Dome-Canmar.

Specifications are as follows:

Length	107 m
Width	19 m
Draft	1.5 m (w/full fuel)
Dead Weight	1500 tons
Propulsion	2 variable pitch electric propellors (17000 H.P.)
Cutter Ladder	650 tons w/64 tooth cutterhead
Cutter Head Drive	2700 H.P.
Pumping Capacity(water)	200 m^3/min.
Cutter pump (submerged)	- 3000 H.P.
Cutter pump (surface)	- 2 (at 5000 H.P each.)
Spuds	- 2 (each 110 tons and 37 m. long.)
Accomodation on board	- 24 persons.

B.4 Dredging Duration

The dredge Aquarius started dredging from the assigned borrow area in Tuk Harbour at 1730 hrs. on the 18th of June. On the 19th of June the vessel experienced problems with the cutter shaft bearings and ceased operation at 0930 that same day.

For the next seven days the Zanen Verstoep personnel tried several adjustments and refits to the cutter shaft and bearings. At 2245 hrs. on the 25th of June dredging recommenced.

Dredging continued intermittently for the next 11 days until 2345 hrs. on the 6th of July. The Aquarius dredge was scheduled to move to Tarsuit on the 5th of July, however, Dome agreed to remain on site an extra day. On the 6th of July a cable on the auxilliary spud broke and the dredging operation was terminated.

B.5 Materials Transport

The dredged materials were transported through a 0.91 meter diameter pipe which consisted of approximately 935 m. of floating line, 285 m. of submerged line and 700 m. of land line (Dome/Canmar - Inf 7). The floating pipeline was routed from the Aquarius to a point of land approximately 700 m N.N.E. from the center of the land fill site where it was anchored in place. The submerged pipe was located from the above described point of land being approx. 285 m. in a southerly direction to where it continued as a "landline" in a S.S.E. route for approximatelv 700 m until it entered the dredging deposition area. (Photo 1 & 2)

DREDGING 50% COMPLETE

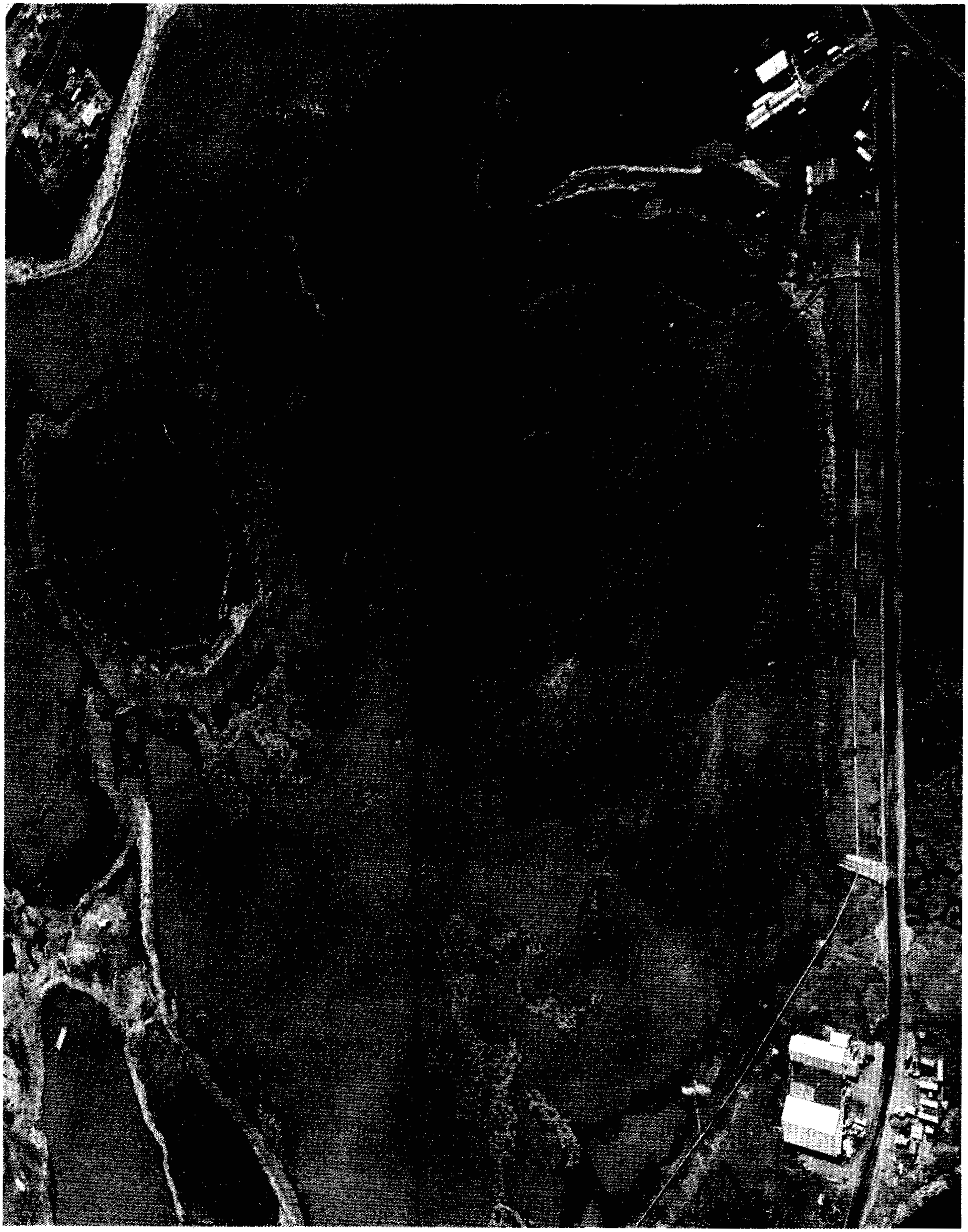

PHOTO 2

B.6 Landfill Site Operations (Fig. 1, 2 & 3)

The landfill operation was controlled and directed by Dome-Canmar personnel while observations, cost control and quantity surveys were the responsibility of the Department of Public Works Engineer and the EPEC staff. Dome/Canmar employed a superintendent and two landfill foremen, of which one was constantly present during dredging.

A typical shift was composed of the following personnel:

1. - Landfill foreman
2. - Two heavy equipment operators (dozer)
3. - Three labourers
4. - One loader operator
5. - EPEC representative

Men and equipment were supplied by Dome-Canmar, Beau-Tuk Marine Services and Grueben Construction. The landfill crew was responsible for inspection and repair of the land line, construction, maintenance and repair of control dikes, control and regulation of the outfall pipes and manipulation of the dredged material with the use of bulldozers.

For the most part two D-6 wide track Cat dozers were used to "train" the fill where possible and to erect control dikes. A D-7 Cat was also used on the site, however use of the heavier machine was restricted to areas which had or were draining well.

CHANNELS OF COMMUNICATION
TUK RESERVOIR - DREDGING TO LANDFILL

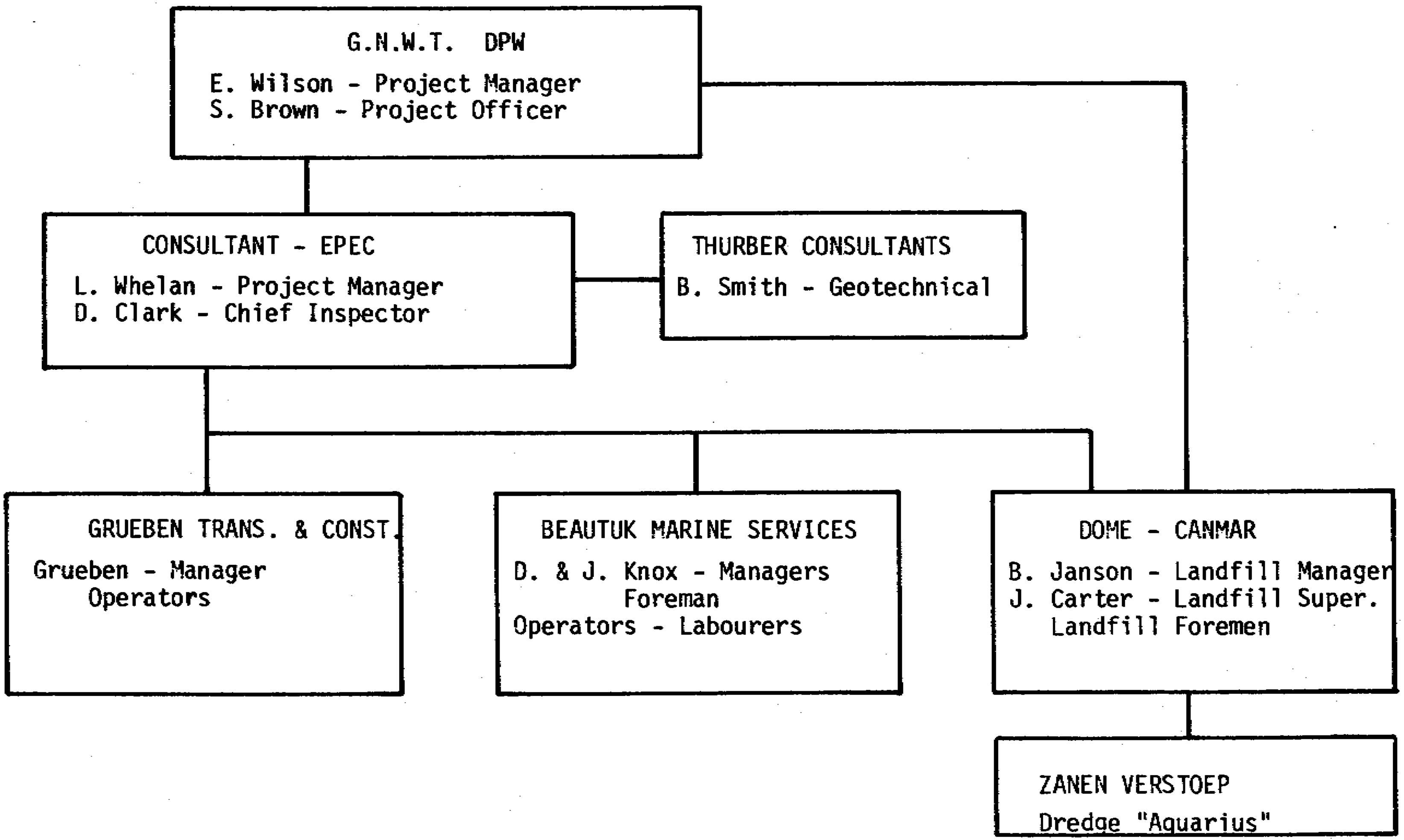

FIGURE 2

epec consulting western ltd.

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DATE
PROJECT No.
DRAWING No.

CHANNELS OF COMMUNICATION

epec consulting western ltd.

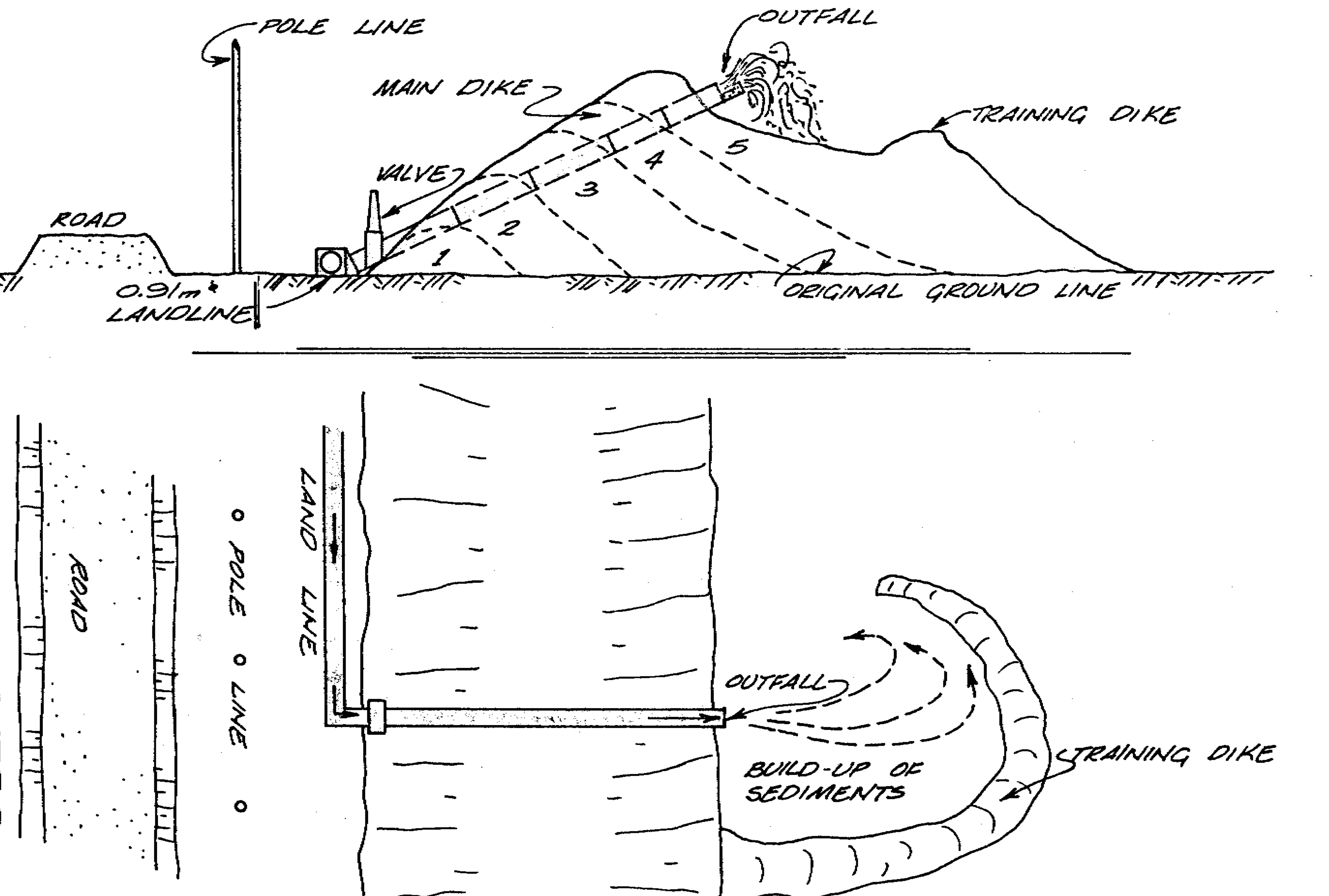

FIGURE 3

TUK. RESERVOIR/DREDGING OPERATION

LANDFILL DIKE SCHEMATIC

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Due to the pervious nature of the dredged material,most dikes were constructed with dozers and then lined with heavy plastic sheeting. Whenever possible the plastic sheeting was covered with dredged material. The main dike which ran parallel to and inside the dredge "land line",was constructed initially to protect the pipe, survey base line and road from inundation by dredged materials. This dike also provided a means by which to control the flow of liquids and to eventually build the deposition as high as possible. (Fig. 3) (Photo 2) It was originally intended that the deposition should occur within an area measuring 300 meters x 500 meters with depths of fill to a maximum of 4 meters with elevations roughly equal throughout. On-site discussions with the landfill foremen indicated that the deposition might possibly be manipulated to a greater extent than was realized previously. D.P.W./EPEC requested that the landfill deposition be biased as much as possible to the south-west corner of the landfill site.

It seemed that greater volumes of material deposited in the specific location of the proposed reservoir would substantially reduce equipment cycle times during construction of the reservoir. The main dike was eventually constructed to an elevation of 7 - 8 meters and the advantages of relatively greater volumes present in the south west corner of the site became quite evident during the reservoir earth-works construction. The minor or "training" dikes were constructed in the same fashion as the main dike and were generally constructed so as to change the direction of flow from the outfall, causing eddies with an accompanying energy loss and a greater rate of sedimentation. (Fig. 3) (Photo No. 3)

B.7 Dredged Materials

The dredged materials were taken from a borrow area defined in drawing No. 15 - 22 - 16 - 4 Thurber (Appendix B), located approximately 1400 meters north of the S.W. corner of the landfill site. (Inf. 3)

The materials are composed of a fine grained-sand with minimal inclusion of silts and clays. Random sampling & testing by the Dome-Canmar inspector on the Aquarius indicate an average fine sand content of 94% and 6% silt content. Very few samples contained gravel and where these sizes were present they represented an average of 0.27%. This sampling was done throughout the landfill each day during operation shut down time & crew changes. (Inf. 7)

Often, due to the nature of the dredged material and its saturation, it was difficult at best to move machinery into certain areas in order to construct dikes. With the absence of dikes it was often impossible to induce the required sedimentation and build up of the find sand. Consequently some dredged material was washed out to beyond the outer limits and below sea level where it is unrecoverable by land based machinery or common methods of excavation.

In photo No. 2 it can be seen that the outflow is cutting into the dredged fill and carrying it beyond the intended perimeter and into the shallow bay to the S.E. of the landfill site. This situation most often occurred when the cutter head entered an area containing silty material. The silts remained in solution and the water flows would cut a trench 2 - 3 meters deep and occasionally as much as 10 meters wide.

On three occasions during the dredging operation the D-6 bulldozers became mired,in the saturated sands over top of the tracks. Fine sand and water entered the final drives of the machines and one dozer was down for several days before replacement parts were recieved and repairs completed.

An interesting phenomenon was observed during and after the dredging deposition in the landfill area. For lack of a better description the writer will call the objects observed "piping cones". These cones were thousands in number and had minimum diameters of 20 mm while an occasional specimen would have a diameter of 350 mm, a height of 200 mm., and an opening at the top of 26 mm (See photo No. 4). These cones were created by "piping" or a release of hydrostatic pressure through a least line of resistance,in this case to the surface where the vertical flow of water carried with it fine sands and silts which formed a cone. During the first few days of reservoir construction the writer observed some of these cones to have water exiting the ground surface with a column of water up to 175 mm above the pinnacle of the cone. The release of hydrostatic pressure from the dredged material was induced by natural consolidation and vibration imparted to the soils by men and equipment.

It is interesting to note that the entire landfill site, where the soils have not been manipulated by machinery, assumes much of the nature and shape of a braided alluvial fan. (Photo No. 2)

DREDGING COMPLETED

NOTE: MAJOR CONTAINMENT DIKE ON WEST SIDE – SEE DIKE SCHEMATIC

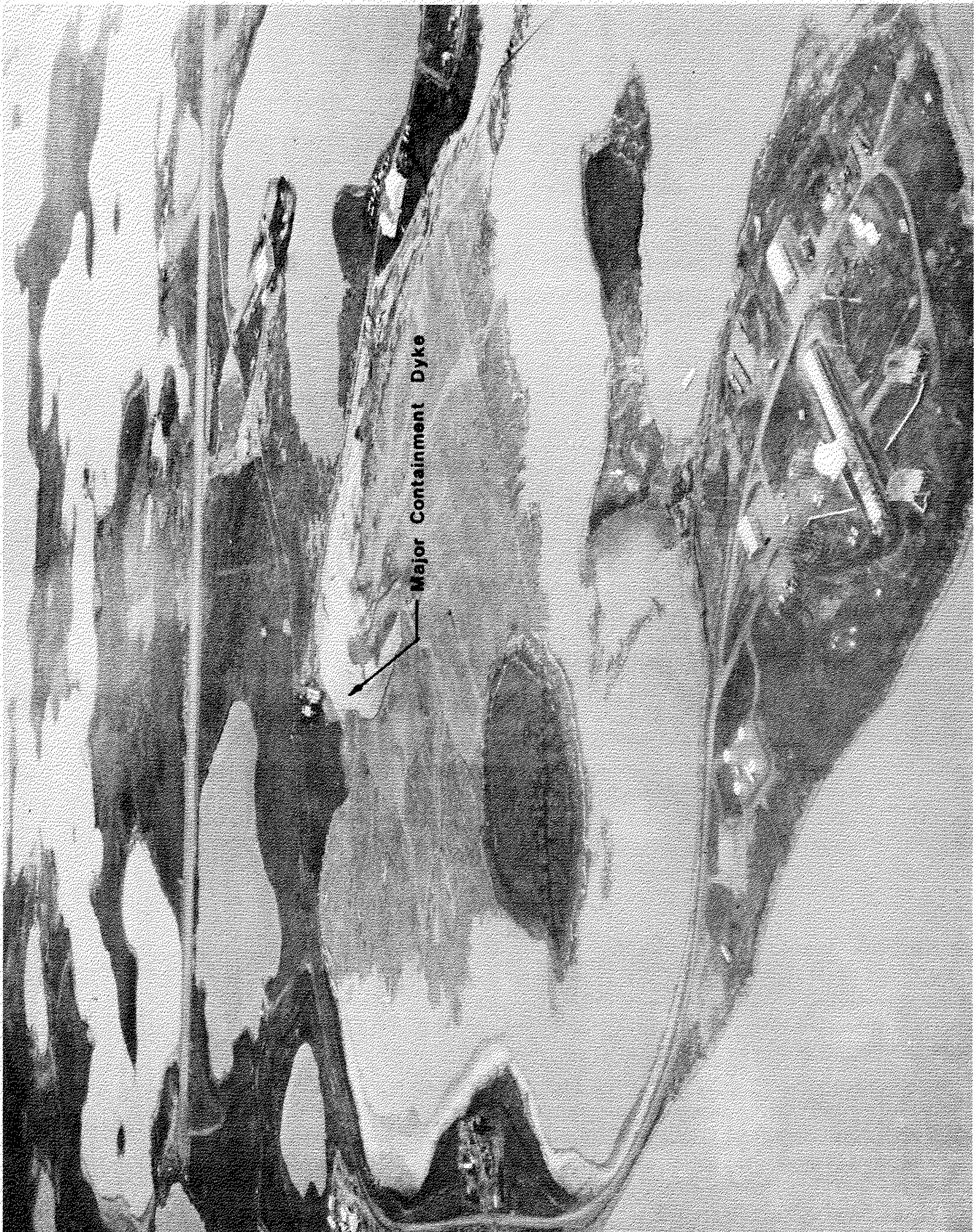


PHOTO 3

PIPING CONES

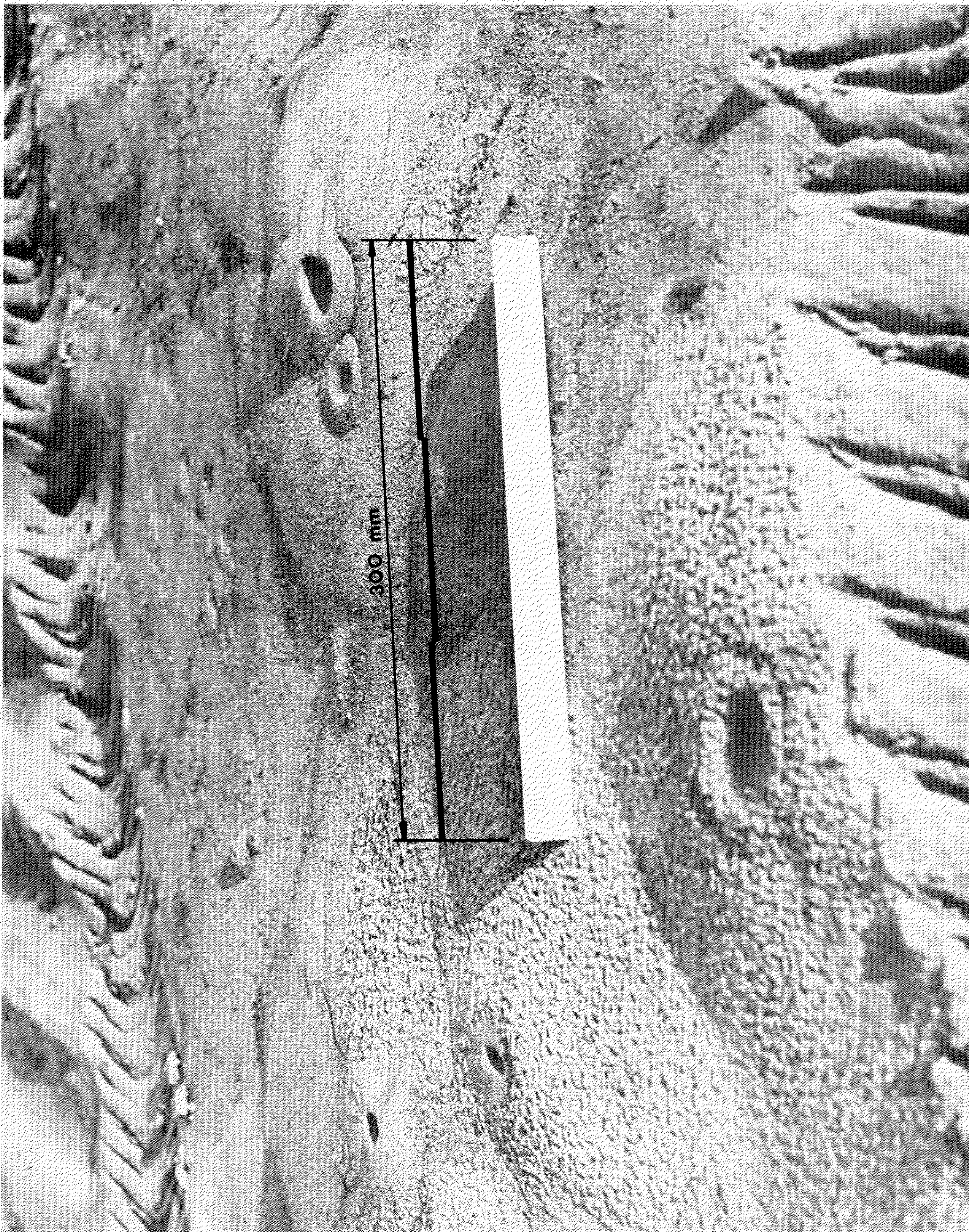


PHOTO 4

B.8 Dredging Surveys

Dredged volume surveys were carried out on June 30, July 1, 4, 5, 6 and 16. These surveys were executed employing the same methods as the pre-dredging survey. The grid system was re-established in each case with elevations on grid points and grade breaks on the topography being noted.

Total volumes were calculated for each survey as listed below.

- June 30	262,000 m^3
- July 01	284,000 m^3
- July 04	438,908 m^3
- July 05	503,194 m^3
- July 06	49,912 m^3 (Calculation for material below sea level)
- July 16 (Final)	582,000 m^3

The dredging surveys were arduous ventures due to the characteristics of the materials at the periphery of the landfill site and occasionally well within the deposition boundaries. Members of both D.P.W. and EPEC staff often found themselves floundering up to the waist in the super saturated fine sands. The extrication process was extremely humorous if one witnessed it from high and dry ground at the time.

Aerial photography was considered an integral part of the dredging surveys. The aerial photography was carried out using a Bronica 4.5 cm X 6 cm format camera through the open window of a Cessna 185 aircraft. Most runs on the dredging photography were low level (steep oblique) frames taken at 915 meters A.S.L. The reference baseline for the majority of photo flight paths was the access road immediately adjacent to the landfill site, consequently most survey frames should be observed with the access road at the bottom of each photograph.

Most ground targets were washed away or buried in the first three days of dredging. The photography was extremely useful in ascertaining the extent of deposition, the direction and character of drainage, relative water content and general progress.

B. 9 Volumes of Dredged Material

- Dredged:

Dome (from Aquarius Log: Educated Guess)	739,943 m^3
EPEC (measured volumes above sea level)	582,000
EPEC (measured volumes below sea level)	50,000
Measured total usable	582,000 m^3

- Used or to be used in construction:

Volume to date in reservoir construction	354,000 m^3
Volume required for liner cover	16,000
Total volume req'd for reservoir	370,000 m^3

- Other materials used:

Land assembly construction (approx.)	10,000 m^3
Used by residents of Tuk (estimated)	15,000

- Total estimated usage to date 395,000 ,^{3}

*- Total estimated available volume for other usage 187,000 m^3

*Note: This total does not include "overspill" which deposited dredged material south and S.E. of the reservoir area. The above described site was not surveyed prior to dredging for it was not previously included in the landfill site nor was it surveyed for quantities after dredging due to the super saturation of the material. It is estimated that this area could contain 15 - 20,000 m^3 of dredged material. This material may be available if it drains sufficiently to support the weight of excavation equipment.

B. 10 Summary and Discussion

The Aquarius dredging log records a total of 191.7 hrs. of dredge operation with an estimated total of 739,943 m^3 removed from the Tuk Harbour floor in the assigned borrow area.

The dredging operation took a total of 13 days which represented two periods. The first term was from 1730 hrs on June 18 until 0930 hrs on June 19, a duration of 16 hrs, when a bearing on the cutter shaft overheated and the operation was shut down. The second term began at 2245 hrs, June 25 and operations terminated at 2345 hrs July 6.

As mentioned in "Dredged Materials" the cutter would occasionally enter a zone of high silt content. With most of the silt remaining in suspension the flow from the outfall would cut a deep swath through the "built up" fine sands and would find it's own, often erratic path, through the sands downslope to the sea. Often a 4 - 5 hour build up of sandfill would be washed away in ½ hour under these conditions.

A constant vigilance was kept by the EPEC and Canmar landfill supervisory staff and when high silt contents were observed exiting the outfall, the Zanen Verstoep operators aboard the Aquarius were informed of the situation by radio within minutes. Crew of the dredge were also often aware of the materials being engaged by the cutter before their exit from the outfall. The dredge operator, when it was suspected that the silt zone was extensive, would "search" with the cutter or realign the dredge. When siltateous fluid was cutting through the sands it was often difficult or impossible for the bulldozer equipment to control wasting of the sand fill unless a control or "training" dike provided means of access to a point(s) close to the flow in order to manipulate it's course

The dredge was shut down for several periods during the landfill operation in order to make repairs, perform regular maintenance, or rerig and change anchor location. Some of these occurrences are as follows:

- Replace cutter teeth on regular basis.
- Regular maintenance on cutter suction pump.
- Regular maintenance on cutter shaft and bearings.
- Inspection of cutter - suction ladder.
- Change anchor locations and realign dredge.
- Repair or replace section of floating line.
- Repairs to land line.
- Remove rocks from pump

The landfill site crew often used the duration of shutdown to repair the landline,and to repair, add to and construct new "training" dikes. With out these breaks in pumping it would have been most difficult to construct effective diking.

Photograph No. 3 shows a dike which has origins in the extreme southwest corner of the landfill site and extends in an easterly direction, thence in a northerly direction in a short spur. This dike took three and one half days to construct due to constant pumping and problems associated with engagement of a silt zone. Greater experience with landfill operations may have resulted in the using of some material from the point of high ground which constitutes a spur south of the landfill in construction of "training" dykes prior to initiation pf dredging to landfill. It is worth noting that in future operations of such character and magnitude that consideration be given to the construction of preliminary dyking with material at hand. In some operations it may be considered expedient (relative to cost) to cease dredging for a day or two in the initial effort in order to construct sufficient areas of lined (plastic sheeting) catchment. When areas of fine sand are associated with large silt zones the above described may often be cost productive.

The dredging operation was carried out within a fixed Budget and accordingly the DPW/EPEC staff endeavoured to establish a daily expenditure record based on costs associated with the dredge and contractors costs. Daily examination and approval of subcontractor's (BeauTuk, Gruben) invoices were carried out and many visits were made to the Aquarius and Camp 208 to determine the per diem expenditures.

In conclusion it must be said that this endeavour was an experience not soon forgotten and should be considered as valuable reference for any similar projects.

C. RESERVOIR CONSTRUCTION

C.1 Pre-construction preparation of dredged materials

After the landfill operation and prior to construction of the reservoir, the dredged materials within the landfill site were prepared for construction of the reservoir. (Photo 5)

During the dredging to landfill operation it was noted that vibration imparted to the material would induce "surface piping" through the soils and release hydrostatic pressures or at least initiate the process.

On the 8th of July the EPEC field staff requested that Beau-Tuk Marine Services run two D-6 bulldozers with the "blade up" over the landfill site until construction of the reservoir began. The purpose in this case was to accelerate the natural consolidation of the material in order to provide an adequate bearing surface for the excavating equipment which would be used in the construction of the reservoir. The equipment was run back and forth over the fill in the slope direction wherever possible from the 10th to the 15th of July.

NOTE: STRIATIONS ON DREDGED MATERIAL AND MAJOR CONTAINMENT DIKE IN "HOOK" SHAPE

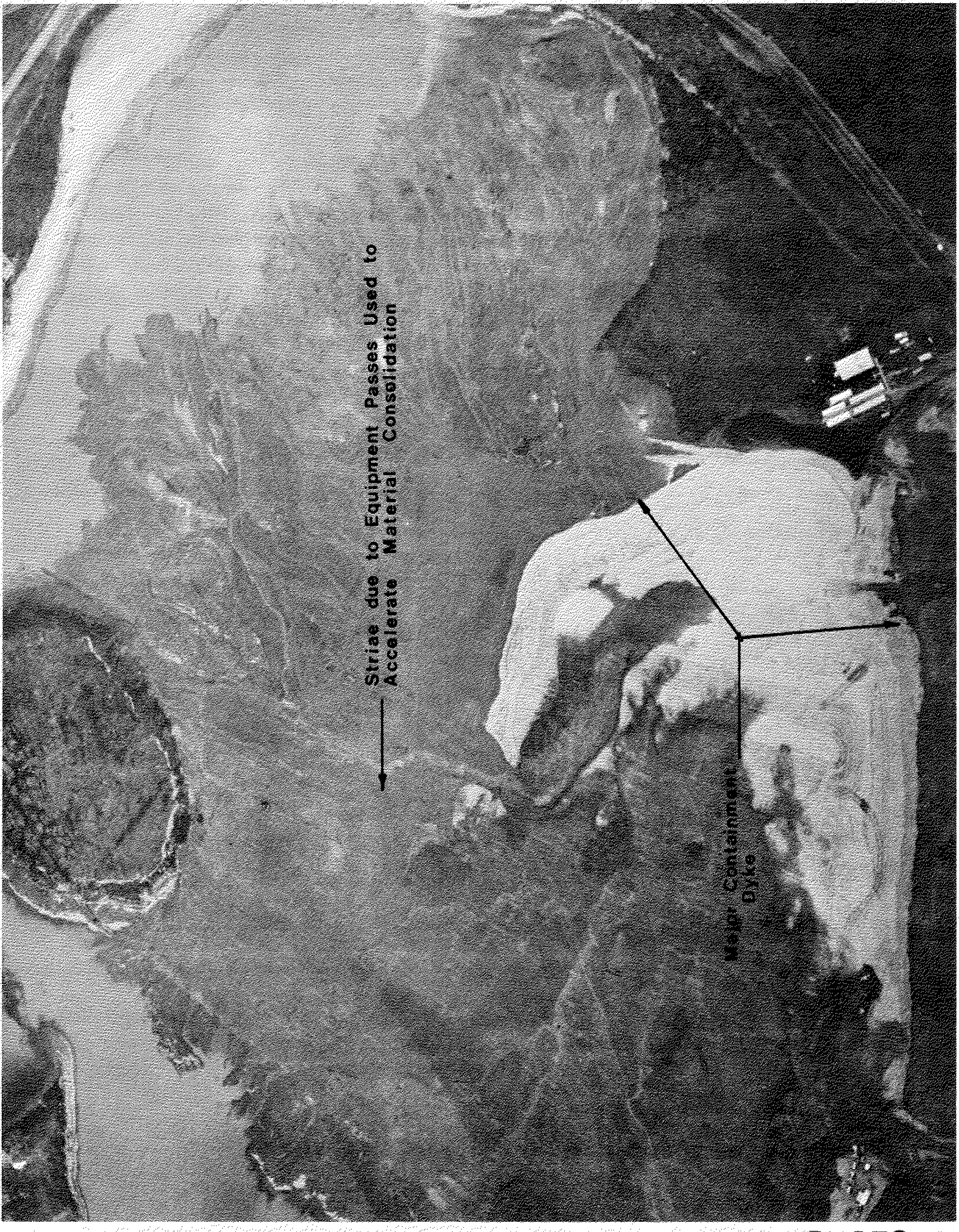


PHOTO 5

This activity constituted one of several field decisions made as a result of observations during the dredging and construction activities. Examination of the landfill site on the 15th of July confirmed that the movement of the equipment during the 5 day term had enhanced the consolidation process and in turn had promoted drainage along the direction of travel.

C.2 Mobilization

The contractor (Dekay Construction - London, Ontario) commenced mobilizing in early June and completed mobilization through delivery of the subdrain pipe in mid July. The contractor moved two tractor scrapers (TS - 14B), spares, accomodation and an Argo all terrain vehicle by rail from Ontario to Hay River where it was barged to Tuktoyaktuk. The bulldozers used in construction were supplied with operator on site by Beau-Tuk Marine Services and Grueben Construction. Both of the latter have offices in Tuktoyaktuk. Mobilization for construction of the reservoir dyke was completed on June 13th.

C.3 Construction Contract

The "form" of the construction contract was a problem.

Two contract types were at first considered, one being the "yardage" (m^3) form,and the second constituting a volume/rental agreement.

To the writer's experience no contract has been so thoroughly discussed prior to tender. Some of the considerations and questions which promoted such thought are as follows:

- What type of equipment will bear up on the surface of the landfill and yet excavate and transport cost-effective volumes?
- What final dimensions will form the finished deposition?
- Will there be ice or snow on the site?
- Dependent on the physical form of the deposition, what will equipment cycle times be?
- After landfill completion what points & how may points may be occupied for survey control?
- If "outside" contractor has winning bid can the equipment be barged down the McKenzie River on time?
- If the landfill deposition is radically different than estimated - how much contingency should be allowed for in the contract?
- If the dredging operation starts early or late relative to the instructions for the assigned contractor how must the potential extra costs be handled?
- A circular configuration for the reservoir has been chosen with an approximate dyke height of 8 m. How will effective construction survey control be established and maintained when higher ground is 1000 m away?
- Which contract agreement will be fairest to all parties involved?
- Which contract agreement will be most easily controlled and administered?
- Which contract agreement will best serve the community for which the reservoir is intended?

In reality 60% of the listed questions could only be answered after completion of the dredging to landfill operation. After much deliberation with DPW it was decided that the contract would not be a bid based on an estimated volume but would in fact be an equipment rental agreement based on the volumes estimated combined with a final completion date.

The tender forms were presented in such a manner that each contractor could estimate equipment hours based on a total in cubic meters volume and enter a separate bid item for MOB - DEMOB costs.

Each tender was received and evaluated according to the specifications. The contract was awarded to DeKay Construction of London, Ontario.

Note - Further reference will be made to contracts in the Summary & Discussion to follow.

C.4 Pre-Construction Surveys

DeKay Construction Ltd. contracted Underhill & Underhill surveyors to carry out construction surveys.

The Underhill survey team and the EPEC staff arrived at the site on the 14th of July. The contractor's surveyors set control points on the A-A axis which was later referenced to known points on surrounding locations of higher elevation.

On the 14th and 16th of June EPEC held meetings with Mr. Carl Friesen, who was DeKay's surveyor, in order to establish an acceptable construction control method.

After meetings with the contractor's surveyor, it became obvious that the ideal method of construction control would be a radial pattern originating from the reservoir centre point. As described in "Pre-Dredging" and "Dredging Surveys" a grid method of control was previously employed in order to obtain the most accurate estimates related to landfill volumes during the dredging to landfill activities. Subsequent to the meetings with the contractor's surveyor the grid established by the DPW/EPEC staff was converted to a radial pattern in order that all further control and construction surveys would be compatible.

On the 16th of June the EPEC staff completed a final "grid" survey to establish final dredged volumes and converted the grid to the construction survey radial.

The contractor's surveyors under Mr. DeKay's instructions laid out the top and bottom of slopes as they existed in the horizontal position relative to the terrain disposition.

Note: Construction surveys will be discussed further in the summation and discussion of "Construction".

C.5 Earthworks

On the 16th of July the contractor began to construct the dyke of the reservoir. Given horizontal "toe" stakes for the floor of the reservoir the contractor elected to excavate the reservoir floor immediately and employ the excavation as dyke on the north-east and south-east sectors using the equipment listed in Table 1.

epec consulting western ltd.

EARTH MOVING EQUIPMENT COST/HRS.

DRAWN BY

DATE

PROJECT No.

DRAWING No.

EQUIPMENT DESCRIPTION	RENTAL/HR.	TOTAL HRS.	TOTAL COST
TS 14B SCRAPER - TERREX	180.00	570.50	102,690.00
TS 14B SCRAPER - TERREX	180.00	562.50	101,250.00
D-6D DOZER - CAT	100.00	617.25	61,725.00
D-8X DOZER - CAT	135.00	557.50	75,262.50
450-C DOZER - J. DEERE	80.00	38.50	3,080.00
HYSTER COMPACTOR	120.00	520.50	62,460.00
D-6C DOZER - CAT	100.00	130.00	13,000.00
		2,996.75	419.467.50

TUK RESERVOIR CONSTRUCTION (EARTHWORKS)
EARTH MOVING EQUIPMENT COST/HRS.

TABLE 1

Within 3 - 4 hours of commencing excavation on the reservoir floor the Terrex excavators could not be self or "push" loaded to more than 30% capacity. At this time it became obvious that a "subcut" or drainage swale was required to alleviate high pore pressures in the surrounding and underlying material.

As a result of a site meeting it was decided to cut a subdrain or swale along the A-A axis which would eventually be graded to the perimeter of the landfill/tidal interface. The subdrain would also be graded slightly lower than the cell (reservoir) floor and would be permitted to flow unobstructed until such time as the dyke was constructed across the A-A axis. At this time field decisions were being made which would affect the overall cost of the earthworks to a great degree.

After the swale or subcut was completed the scrapers commenced with the second attempt at excavating the cell floor. Each scraper was able to self load an approximate 80% of the rated volume for the machine. If the scrapers were "push" loaded by dozers the vibrations imparted by the tracked vehicles would "pump" the water to the surface. Although the scraper might be loaded more heavily in a shorter time span the pumping action of the dredged sand made unassisted travel by the scrapers after loading very slow to impossible, with an accompanying lengthy cycle time.

The dyke on the east and west side continued under construction but due to the drainage swale on the A-A axis each m^3 excavated on the west perimeter and placed on the east dyke carried a cycle time penalty. If the A-A axis berm were completed there was a risk of high pore water pressures building up within the cell floor prior to installation of the subdrain. As the mass of the east and west side dyke increased, with the accompanying vibration imparted by the equipment, the floor of the cell drained increasing quantities of water.

On the 29th of July a situation report was submitted to DPW by EPEC which described in detail what had transpired to date and the proposed future activities. The situation report was the result of a construction meeting attended by the DeKay Construction and the EPEC staff. During this meeting the contractor was informed that expenditure on the earthworks phase was slightly over 50% with a 32% relative earthworks volume completed. (Appendix E).

Subsequent to the construction meeting of July 28 it was decided to lay the north gravity drain on the A-A axis and to build the dyke across the drain as quickly as possible. In general terms the "bridging" of the A-A axis with a dyke would substantially reduce earth movement cycle time and thus satisfy cost versus dyke volume/hr.

The filling of the void in the dyke over the A-A axis coupled with the installation of the gravity drain had its own problem. As described above, the A-A axis was left open to alleviate a very obvious problem of drainage related to the soil structure in general. By leaving a channel open for drainage this area became so saturated that the installation of the gravity drain was extremely difficult.

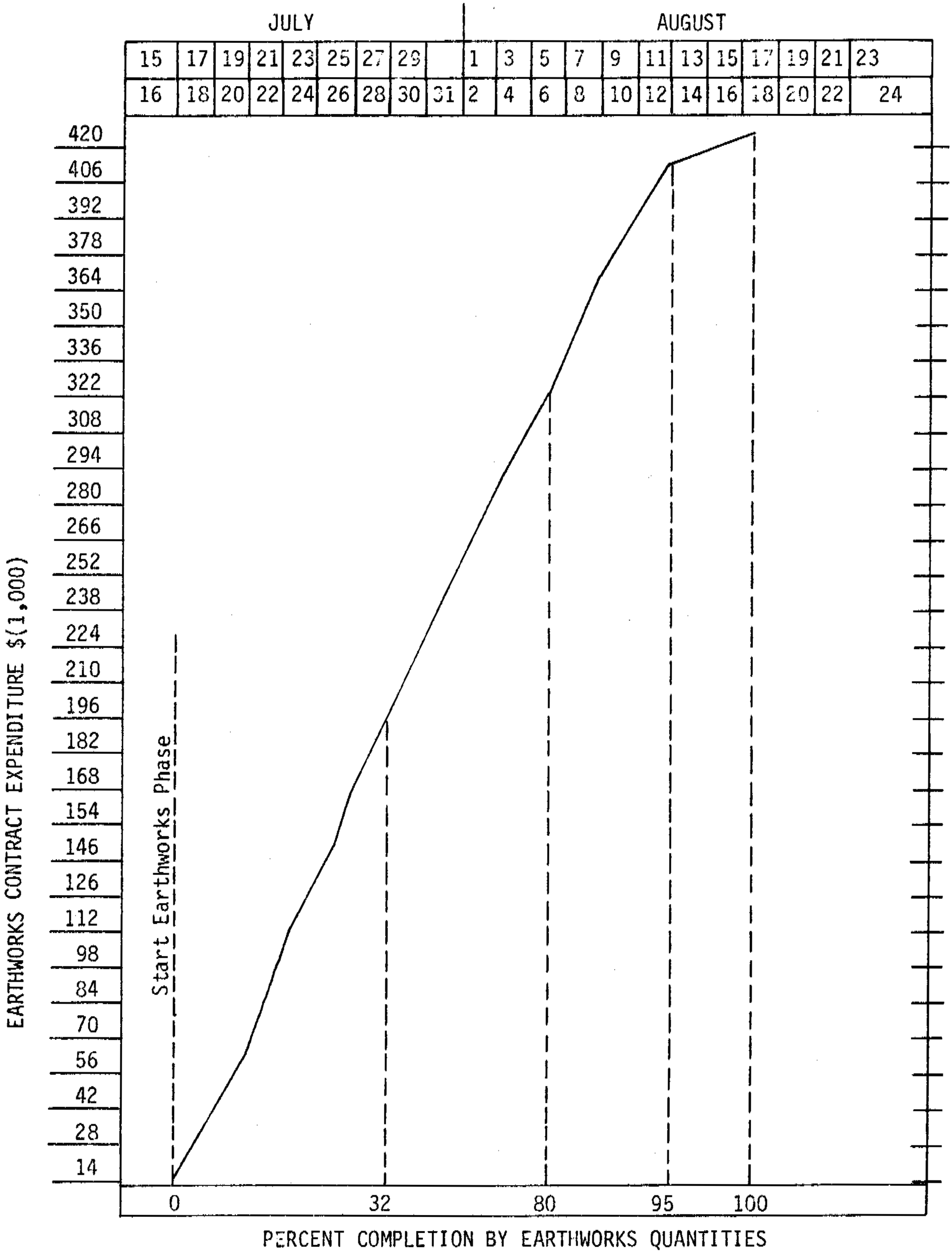


FIGURE 4

epec consulting western ltd.

COST vs. PRODUCTION
OF RESERVOIR EARTHWORKS

DRAWN BY	DATE	PROJECT No.	DRAWING No.

Great care had to be taken to fill the first 2 - 3 meters over the A-A axis centre line and its gravity drain due to the super saturation as a result of its prior usage. Once access had been gained over the A-A axis, all dykes grew in stature, it seemed by the hour. (Fig. 4) The dyke on the A-A axis (south) presented much the same problem, however conditions were not so pronounced due to the general drainage slope, previous alleviation of pore pressures and everyone's tuition being paid, after efforts on the north side.

The original slope of the reservoir ramp road (access from the outer edge to the top of dyke) in initial design was 4:1. Through familiarization with the dredged material on site the EPEC field staff proposed a ramp slope of 8:1 and recieved approval from Mr. Fred Willows of DPW during a site visit on the 25th of July. The ramp road had to be designed and constructed in such a manner as to prevent obstructing the construction or future servicing of any of the subdrain clean-outs which border the east and west berms. Although no specific tests have been carried out it is suspected that the ramp road will require the addition of a proper surface to support axle-borne traffic (single axle) of over 1 ton.

During construction of the reservoir it was noticed that the increasing mass of earthworks and vibration imparted by the machinery resulted in excessive hydrostatic pore pressures within 4 - 7 meters of the outside toe of the dyke slopes. This phenomenon coupled with a high water elevation due to a storm on the 3rd of August, which inundated the downstream manhole of the gravity drain (Photo 6), led to the construction of a drain which presently encompasses the eastern or

HIGH FLOOD WATER AT SEAWARD MANHOLE

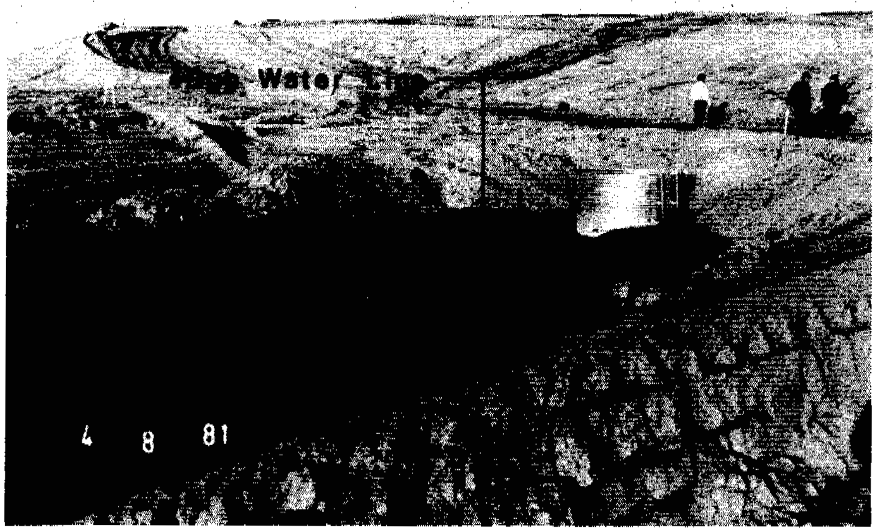


PHOTO 6

NOTE: "DATA BACK" ON CAMERA INDICATES DAY / MONTH / YEAR

seaward half of the reservoir. The construction of this drain lends itself to the original design in that it creates the approximate backslope from the ring road, but also will help to relieve pore pressures from the toe of the outside slope, and will dissipate any action from storm tides. The excavation of the eastern drainage ditch (swale) also provides a substantial area of drained borrow such that material may be removed from the swale's eastern edge to cover the reservoir liner. This will provide drained material for construction, while if done with care will serve to widen the drainage ditch at the downstream north end.

Nine days prior to earthworks completion, the access road and pad was surveyed. It became very apparent at this time that there would be drainage problems with any access across the existing road to the east, into the reservoir or landfill site. "Tare" lagoon which is on the west side of the main access road, drains through the road in an easterly direction then in a north easterly direction to the sea. The landfill site has created a barrier to the previous short fetch, and water drainage must be provide in order that water may travel northward on the east side of the main access road, then flow seaward behind the Beau-Tuk Warehouse or into the drainage swale provided for the reservoir.

The Government of the NWT had considered erosion to be a major consideration prior to the construction of the reservoir. During construction, high winds created great difficulty on 2 - 3 occasions when equipment operators experienced hardship with breathing and could not continue operating the machinery without the aid of goggles in order to retain visual reference in the sand storm.

The reservoir was deliberately left with dozer "wind" rows on the inside and outside slopes in order to minimize wind and runoff erosion.

C.6 Construction Surveys

As described in the "Pre Construction Surveys" the contractor's surveyor and the EPEC staff adopted a radial method of control and construction layout. The contractor (Mr. Bev. DeKay) advocated the exact horizontal displacement of stakes in order to shape the earthworks in a cut or fill situation. Such layout is irregular and most unwieldy in any earth moving situation and this was conveyed to Mr. DeKay during the 1st and 2nd construction meetings. The contractor released his surveyor shortly after start up. Due to irregularities in slope layout and extra time involved in working to the construction stakes the EPEC staff asked that the contractor bring the surveyor to the site on a permanent basis and that the layout be carried out employing a standard slope staking method. After the surveyor's return and the use of regular methods for layout there were no further problems in this regard.

C.7 Gravity Drains

The gravity drain in the A-A axis (north) was installed during the area's use as a relief drain for the cell floor. As explained in the earthworks comments this axis was employed as an outlet for pore water released due to the dyke loadings and equipment vibration.

Due to this condition, the Contractor experienced great difficulty in placing and maintaining grade of the forms associated with concrete pours for the manhole bases. The saturation of the fine sand coupled with surface flow in the area made jointing and laying to grade of the gravity drains a lengthy task.

C.8 Sub Drains

The Contractor laid all pipe in the subdrain with priority given to the main line through the centre of the reservoir in the main or A-A axis. After contructing the main pipe in the A-A axis, the grid pipes on the reservoir floor were layed, followed by the installation of the cleanout pipes up the sides of the reservoir. (Photo 7)

The Contractor experienced some problems in setting grade for the main pipe through the system.

SUBDRAINAGE CONSTRUCTION

NOTE: LATERAL TRENCHING ON RESERVOIR FLOOR FOR SUBDRAINS.

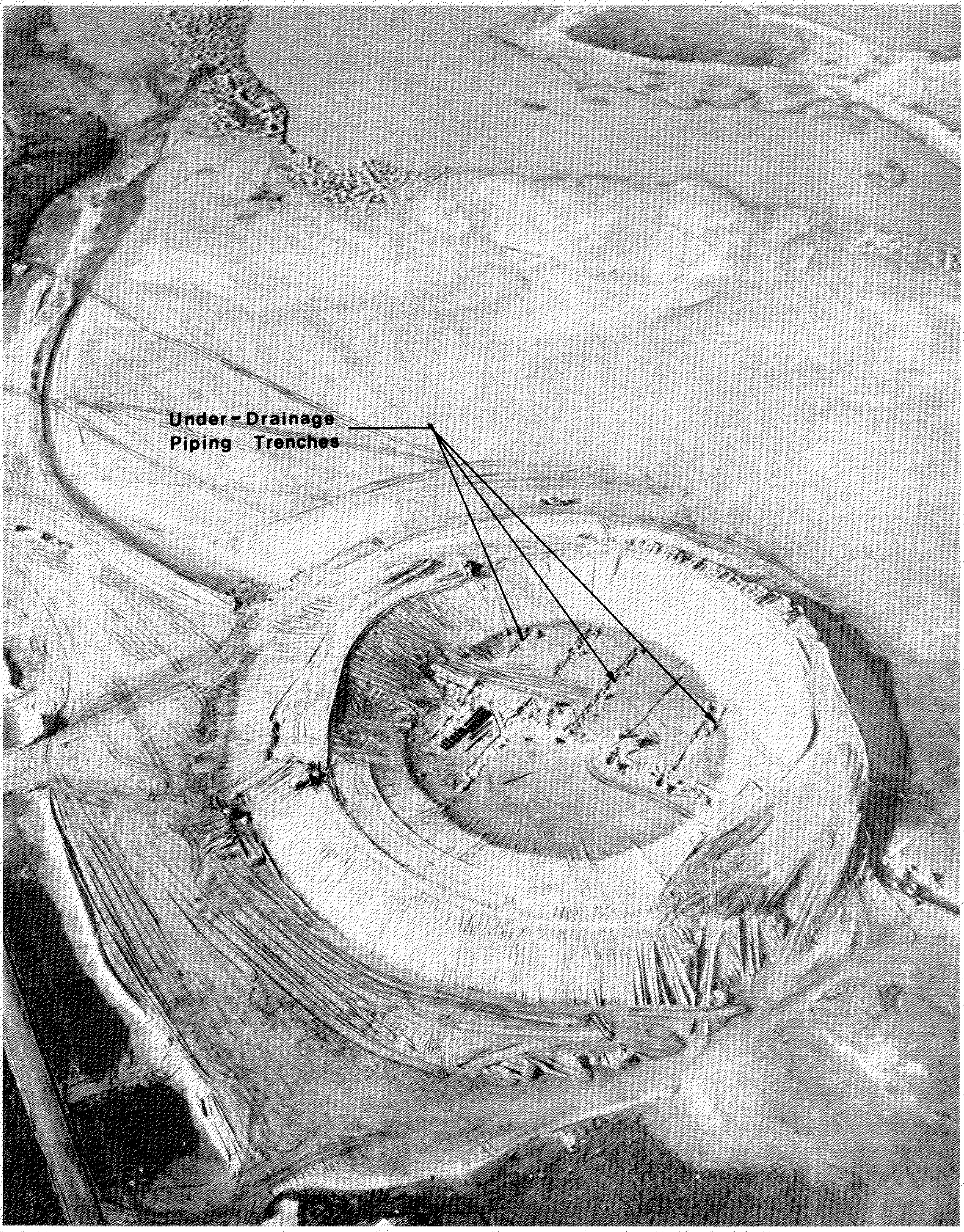


PHOTO 7

RESERVOIR DRAINAGE SWALES

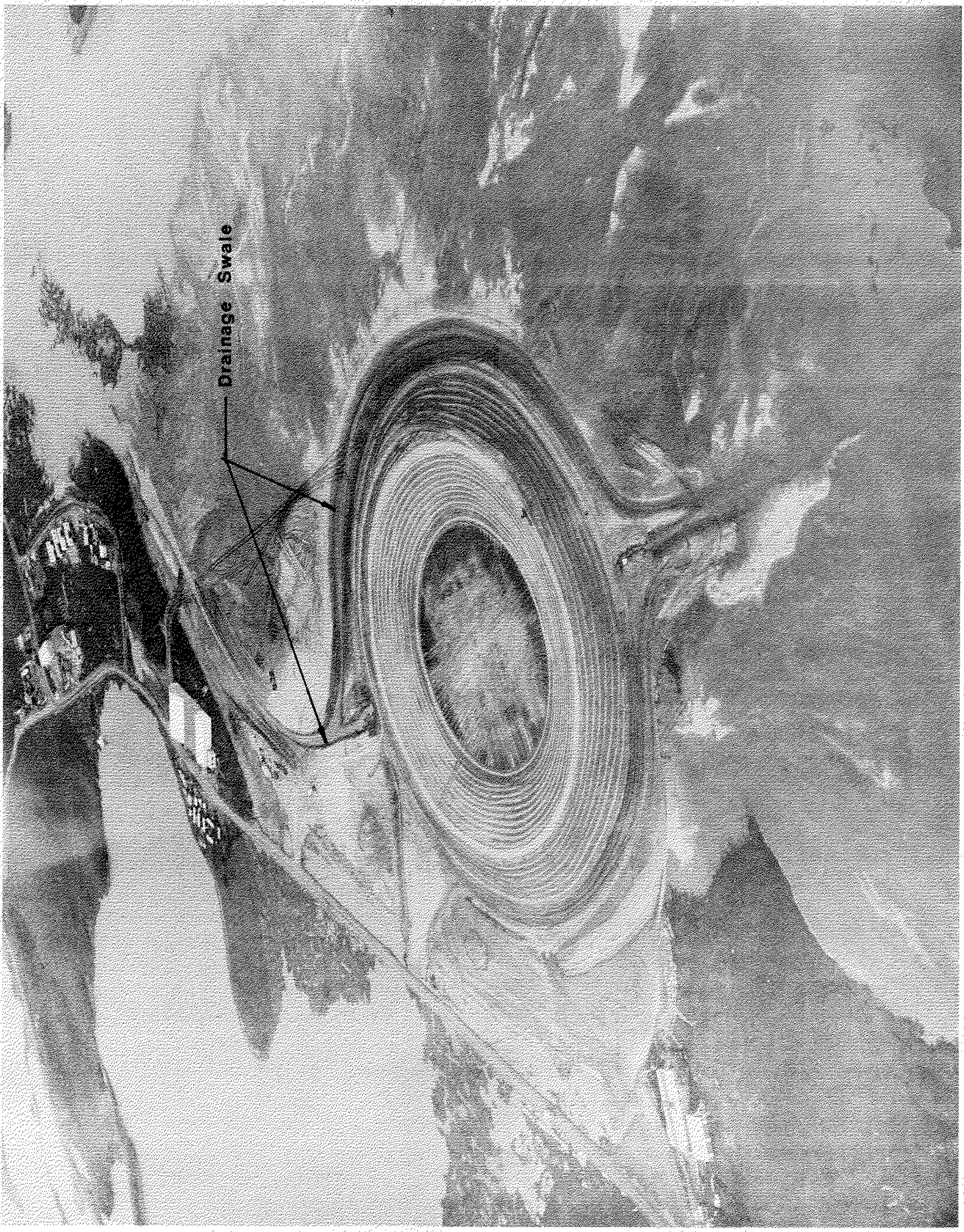


PHOTO 8

C.9 Summary

The Tuk reservoir construction was an interesting and challenging experience for everyone concerned.

As discussed under "Construction Contract" one of the most difficult tasks was to decide what form or type of contract should be used. Due to the many unknowns involved it is felt that the contract which was employed was the best possible choice. It is important to note that this contract may not necessarily be ideal for all landfill projects and that each should have "custom made" specifications to suit site specific requirements.

The contractor (DeKay Construction) on this project was an experienced excavator and carried the contract to its completion in a very professional manner. To have anyone other than an expert contractor on projects of this manner and time frame would be disasterous.

DPW personnel who worked with us on this project were very helpful. The full support of the Government of Northwest Territories and Thurber Consultants was greatly appreciated. One always felt part of a team as the project went from phase to phase. The completion of this portion of the Tuk Reservoir project has given the employees involved from EPEC a real sense of satisfaction.

INFORMATION SOURCES

1. EPEC Consulting Western Ltd. "Predesign Report & Design Brief for Tuktoyaktuk Potable Water Reservoir", November 7, 1980.

2. EPEC Consulting Western Ltd. "Tuktoyaktuk Potable Water Reservoir - Contract Drawings and Specifications", February, 1981.

3. Thurber Consultants Ltd. "Tuktoyaktuk Water Reservoir - Geotechnical Report No. 1, Borrow Source and Site Investigations", March 20, 1981.

4. EPEC Consulting Western Ltd. - Design and Construction files, correspondence, notes, etc., September 1980 - September 1981.

5. George Gevaert - Dome Canmar.- Personal Communication

6. Report by DLG Water & Sanitation Section to Arctic Waters, advisory committee.

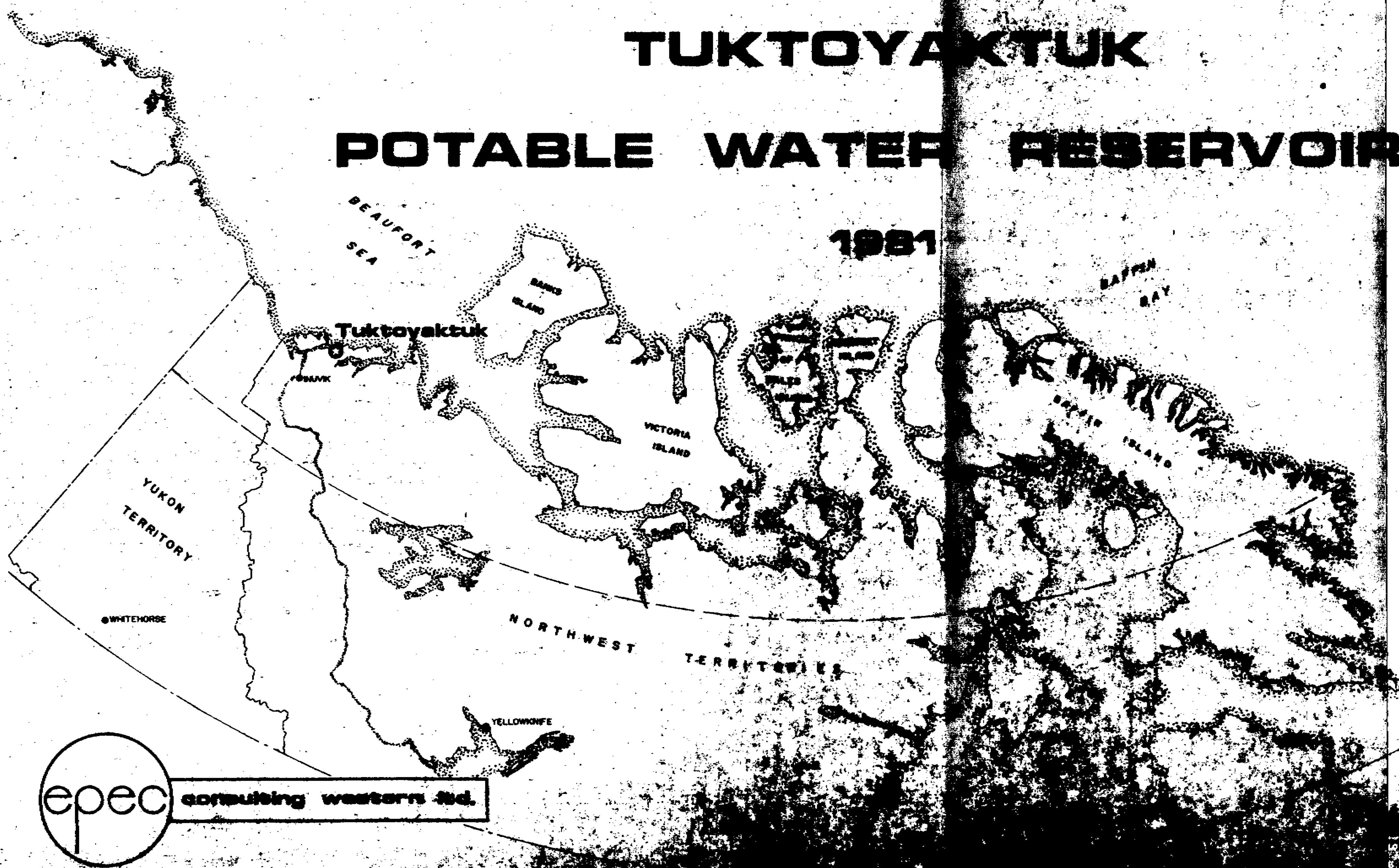
7. Aquarius log and records.

8. Dredging Licence 3608, granted June 1981 to the Government of the Northwest Territories by D.I.A.N.D.

GOVERNMENT OF THE NORTHWEST TERRITORIES
DEPARTMENT OF PUBLIC WORKS

TUKTOYAKTUK
POTABLE WATER RESERVOIR

1981



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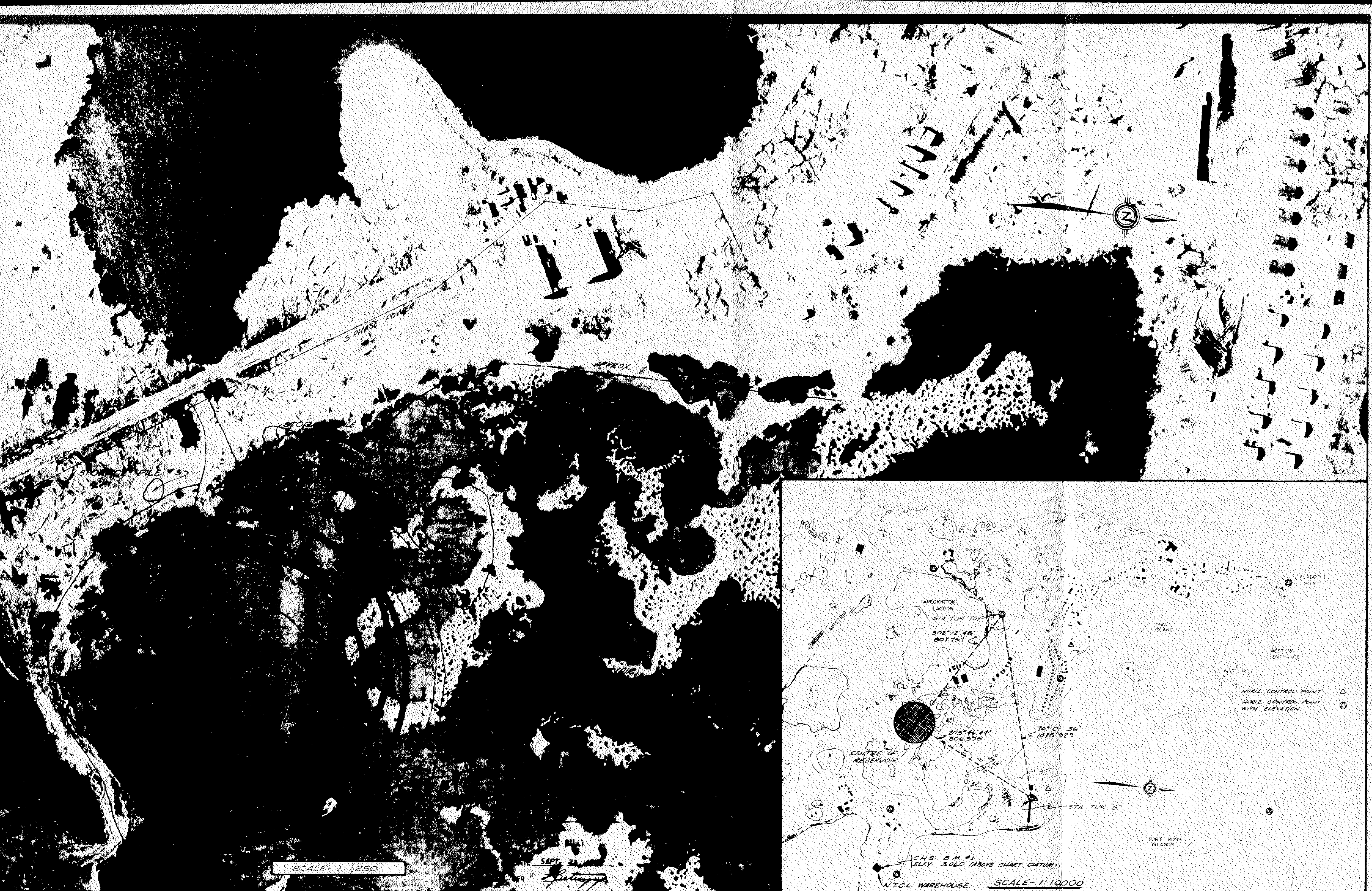
PROJECT NO.



MARK	NATURE OF REVISION	DATE	ENG	DRWN

DEPUTY MINISTER, DPW	DATE
CHIEF ENGINEER, DPW	DATE
APPROVED	DATE

SCALE	DESIGNED BY	DRAWN BY
AS NOTED	NAJ	WHB
DATE	**CHECKED BY**	**PROJECT NUMBER**
JAN. 81	GW	60-6585-003-01-40

TUKTOYAKTUK POTABLE WATER RESERVOIR

GENERAL LOCATION PLAN

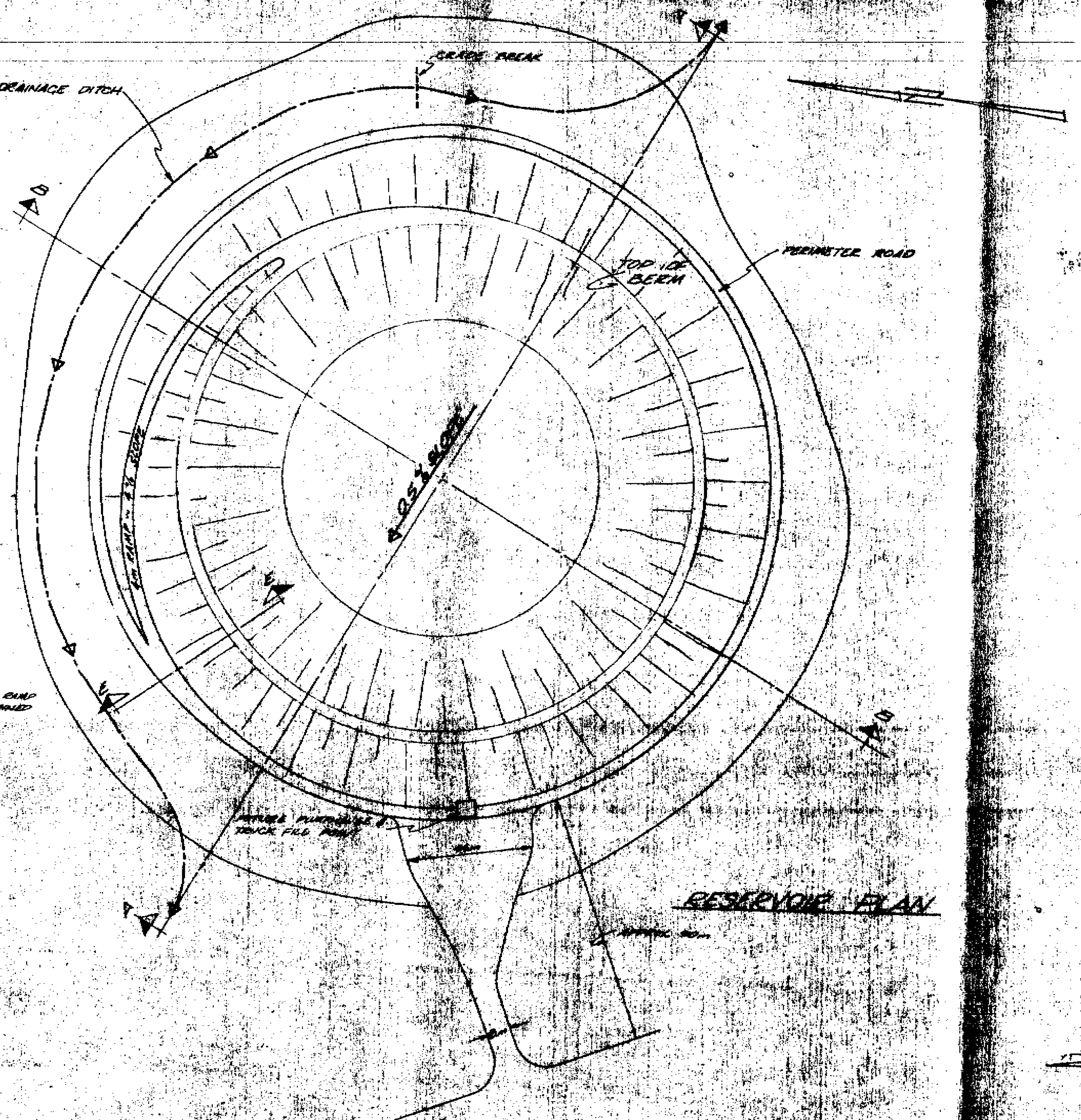
SITE PLAN

Northwest Territories Public Works

80-110

epec consulting western ltd. environmental planning & engineering consultants

SHEET 1 OF 4



NOTE:
EXACT LOCATION OF RAMP TO BE FIELD DETERMINED BY THE ENGINEER

RESERVOIR PLAN

DESIGN PARAMETERS

DESIGN LIFE: 20 YEARS

ACTIVE STORAGE CAPACITY: 90,100 m³
(ONE YEARS STORAGE REQUIREMENT)

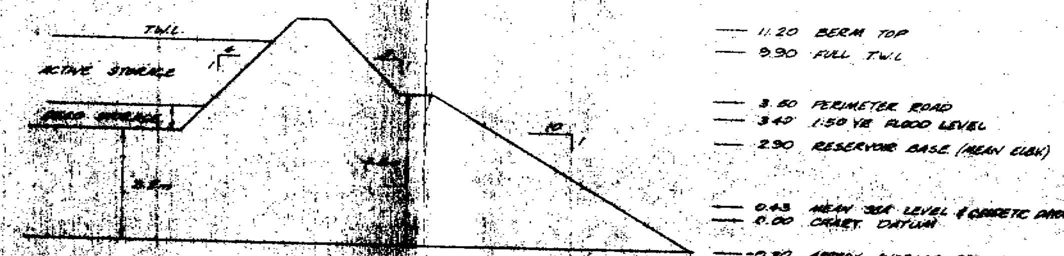
DESIGN POPULATIONS & WATER REQUIREMENTS:
- TUK. HAMLET - 1500 PERSONS @ 121.5 lpcd
- DOME CANMAR CAMP - 400 PERSONS @ 186 lpcd
- OTHER USERS - 2700 m³/yr.

FREEBOARD - 1.3m
ICE - 2.1m
WATER - 4.4m } ACTIVE CAPACITY: 90,100 m³
DEAD STORAGE - 0.5m

RESERVOIR BASE SET AT 2.9m ABOVE CHART DATUM TO AVOID DAMAGE FROM FLOODING.

ESTIMATED MAX. 1:50 YR. FLOOD WATER ELEVATION IS AT 0.5m ABOVE THE RESERVOIR BASE.

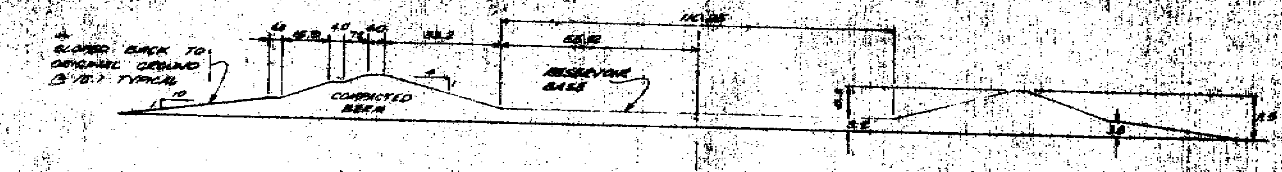
PROPOSED CONSTRUCTION SCHEDULE FOR WATER SUPPLY SYSTEM:
- 1981 DREDGING FROM HARBOUR
- 1981 EARTHWORKS (RESERVOIR, ACCESS RD. AND PAD FOR PUMPHOUSE) AND SUBDRAINAGE SYSTEM
- 1982 LINER INSTALLATION, PUMPHOUSE/TRUCK FILL POINT
- 1982 FILL LINE TO RESERVOIR AND INTAKE/PUMPING FACILITIES AT RESUPPLY SOURCE.



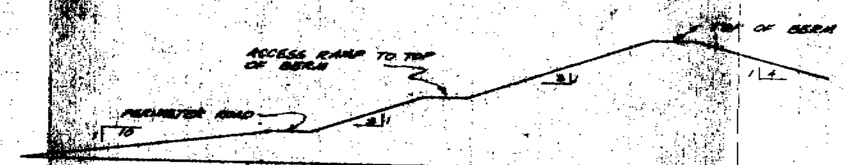
SCHEMATIC X-SECTION
NOT TO SCALE

NOTE:
G.H.S. B.M. #1, ELEV. 3.060 ABOVE CHART DATUM WAS USED AS DATUM REFERENCE POINT. SEE SHEET 1 of 4 FOR LOCATION.

SECTION 'A-A'



SECTION 'B-B'



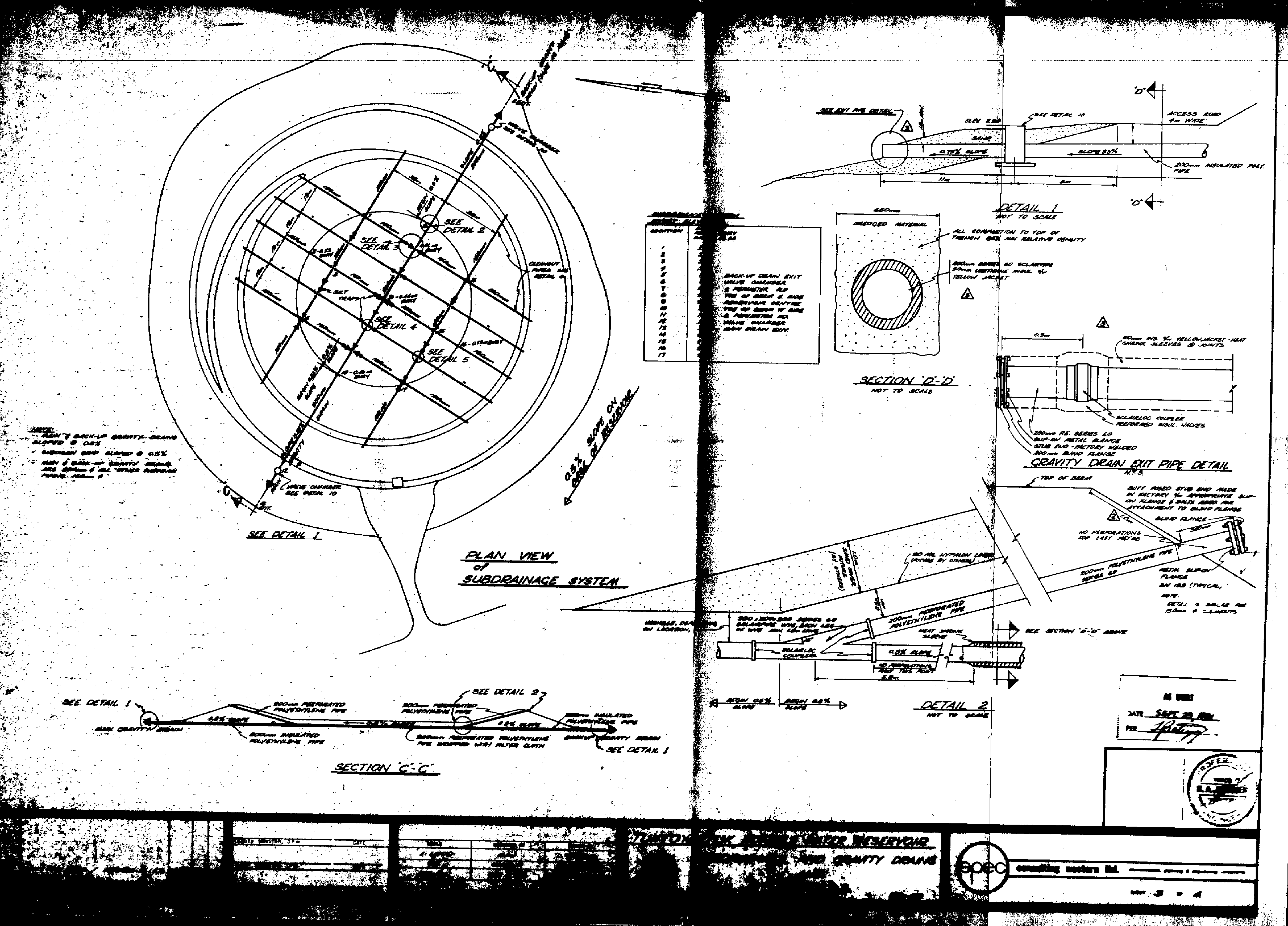
SECTION 'E-E'
NOT TO SCALE

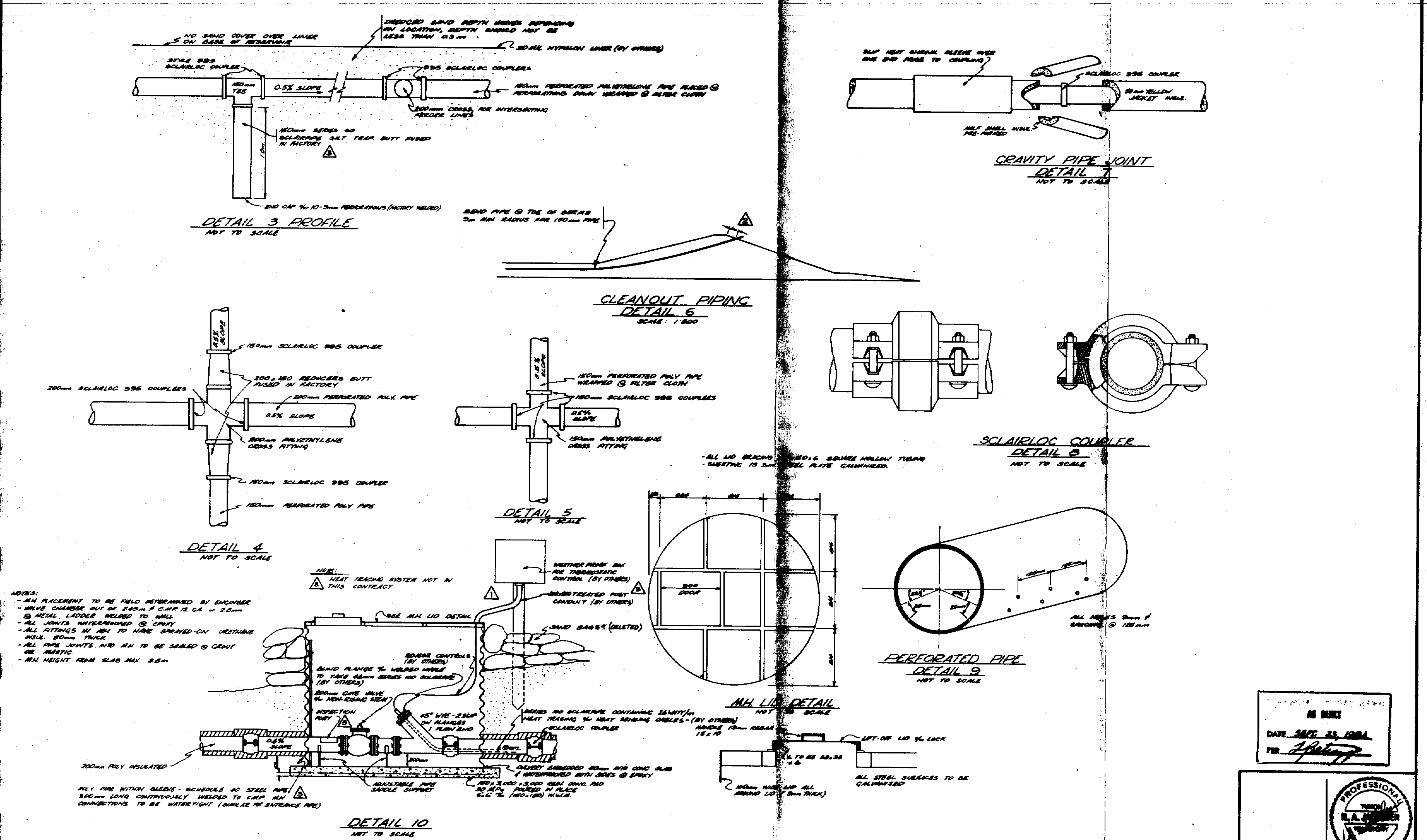
SEPT. 23, 1981

TUKTOYAKTUK POTABLE WATER RESERVOIR

GENERAL PLAN

apec consulting engineers ltd.


PLAN VIEW of SUBDRAINAGE SYSTEM
NOTE:
- MAIN & BACK-UP GRAVITY DRAINS SLOPED @ 0.5%
- SUBDRAIN GRID SLOPED @ 0.5%
- MAIN & BACK-UP GRAVITY DRAINS ARE 200mm ϕ & ALL OTHER SUBDRAIN PIPING 150mm ϕ
SEE DETAIL 2
SEE DETAIL 3
SEE DETAIL 4
SEE DETAIL 5
VALVE CHAMBER SEE DETAIL 10
SEE DETAIL 1
0.5% SLOPE ON FACE OF RESERVOIR
SECTION 'C-C'
MAIN GRAVITY DRAIN
200mm PERFORATED POLYETHYLENE PIPE
200mm INSULATED POLYETHYLENE PIPE
200mm PERFORATED POLYETHYLENE PIPE WRAPPED WITH FILTER CLOTH
BACKUP GRAVITY DRAIN
DETAIL 1
NOT TO SCALE
ACCESS ROAD 4m WIDE
200mm INSULATED POLY. PIPE
0.75% SLOPE
11m
3m
SECTION 'D-D'
NOT TO SCALE
DREDGED MATERIAL
ALL COMPACTION TO TOP OF TRENCH 85% MIN RELATIVE DENSITY
YELLOW JACKET
0.5m
50mm INS. c/w YELLOWJACKET - HEAT SHRINK SLEEVES @ JOINTS
SCLAIRLOC COUPLER
PREFORMED INSUL. HALVES
200mm P.E. SERIES 60
SLIP-ON METAL FLANGE
STUB END - FACTORY WELDED
200mm BLIND FLANGE
GRAVITY DRAIN EXIT PIPE DETAIL
N.T.S.
TOP OF BERM
BLIND FLANGE
NO PERFORATIONS FOR LAST METRE
200mm POLYETHYLENE PIPE SERIES 60
METAL SLIP-ON FLANGE
200mm PERFORATED POLYETHYLENE PIPE
HEAT SHRINK SLEEVE
SCLAIRLOC COUPLERS
0.5% SLOPE
SEE SECTION 'D-D' ABOVE
DETAIL 2
NOT TO SCALE
AS BUILT
GRAVITY DRAINS
consulting western ltd.



3	CHANGES AS PER ADDENDUM 1 & 2		MAJ	WRB
2	DIMENSION ADDED		MAJ	WRB
1	REVISED SENSOR CABLE LOCATION		MAJ	WRB
	NATURE OF REVISION	DATE		

DEPUTY MINISTER, D.P.W. — DATE

CHIEF ENGINEER, D.P.W. — DATE

SCALE	DESIGNED BY	
AS NOTED	M.A.J.	
DATE	CHECKED BY	
	QW & CO.	

TUKTOYAKTUK POTABLE WATER RESERVOIR

DETAILS

TABLE 2

POPULATION PROJECTIONS FOR HAMLET

YEAR	1. NATURAL GROWTH (GNWT PROJECTION)		2. M.M. DILLON SHORT TERM PROJECTION TO 1985 - NATURAL GROWTH BEYOND		3. M.M. DILLON HIGH GROWTH PROJECTION TO 1995 - NATURAL GROWTH BEYOND		4. DECLINE GROWTH CONCEPT AFTER 1985
	Pop	% growth	Pop	% growth	Pop	% growth	Pop
1978	760						
1979	781						
1980	803		800	5.0	800	5.0	800
1981	826		840	4.762	840	4.762	840
1982	850		880	4.545	880	4.545	880
1983	875	2.869	920	4.348	920	4.348	920
1984	900		960	4.167	960	4.167	960
1985	925		1,000		1,000		1,000
1986	952		1,028		1,040		990
1987	978		1,056		1,080		980
1988	1,005	2.762	1,085	2.762	1,120		965
1989	1,032		1,115		1,160		940
1990	1,060		1,146		1,200	3.448	895
1991	1,090		1,175		1,240		850
1992	1,117		1,205		1,280		830
1993	1,144	2.529	1,235	2.529	1,320		810
1994	1,169		1,266		1,360		800
1995	1,201		1,298		1,400		?
1996	1,236		1,330		1,435		
1997	1,261	2.464	1,363		1,470		
1998	1,292		1,396	2.464	1,506	2.464	
1999	1,319		1,431		1,543		
2000	1,356		1,466		1,581		
2001	1,396		1,502		1,620		

NOTE: ALL FIGURES ARE YEAR-END POPULATIONS

Figure 5

POPULATION PROJECTIONS
TUKTOYAKTUK HAMLET

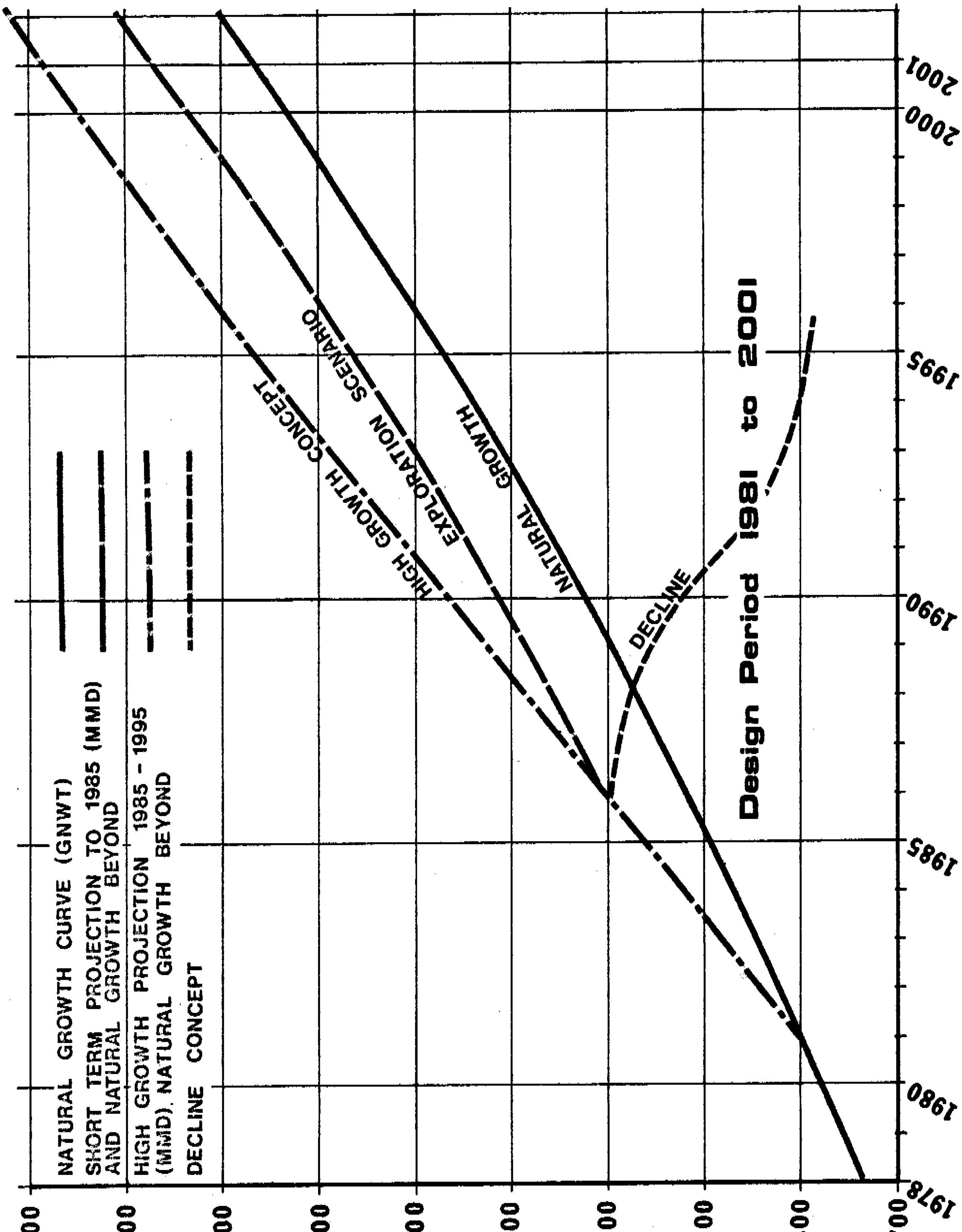


TABLE 3

THEORETICAL YEARLY POTABLE WATER REQUIREMENTS

YEAR	*HAMLET PER CAPITA CONSUMPTION (lpcd)	YEARLY REQUIREMENT (m^3) HAMLET	DOME/CANMAR	OTHER (DEW LINE, NTCL, ETC)	TOTAL
1980	106.8	31,186	20,000	2,700	53,886
1981	107.6	32,990			55,690
1982	108.5	34,850			57,550
1983	109.3	36,703			59,403
1984	110.1	38,579			61,279
1985	111.0	40,515			63,215
1986	111.6	41,875			64,575
1987	112.2	43,246			65,946
1988	112.8	44,672			67,372
1989	113.4	46,151			68,851
1990	114.1	47,727			70,427
1991	114.7	49,192			71,892
1992	115.3	50,712			73,412
1993	115.9	52,245			74,945
1994	116.6	53,880			76,580
1995	117.2	55,526			78,226
1996	117.9	57,235			79,935
1997	118.6	59,003			81,703
1998	119.3	60,788			83,488
1999	120.0	62,678			85,378
2000	120.8	64,478			87,178
2001	121.5	66,521	20,000	2,700	89,221

* Based on formula where Total Per Capita Consumption equals: 90 (lpcd) X (1 + 2.3315 X 10^{-4} X Population)

FIGURE 6

TOTAL YEARLY REQUIREMENT VS YEAR

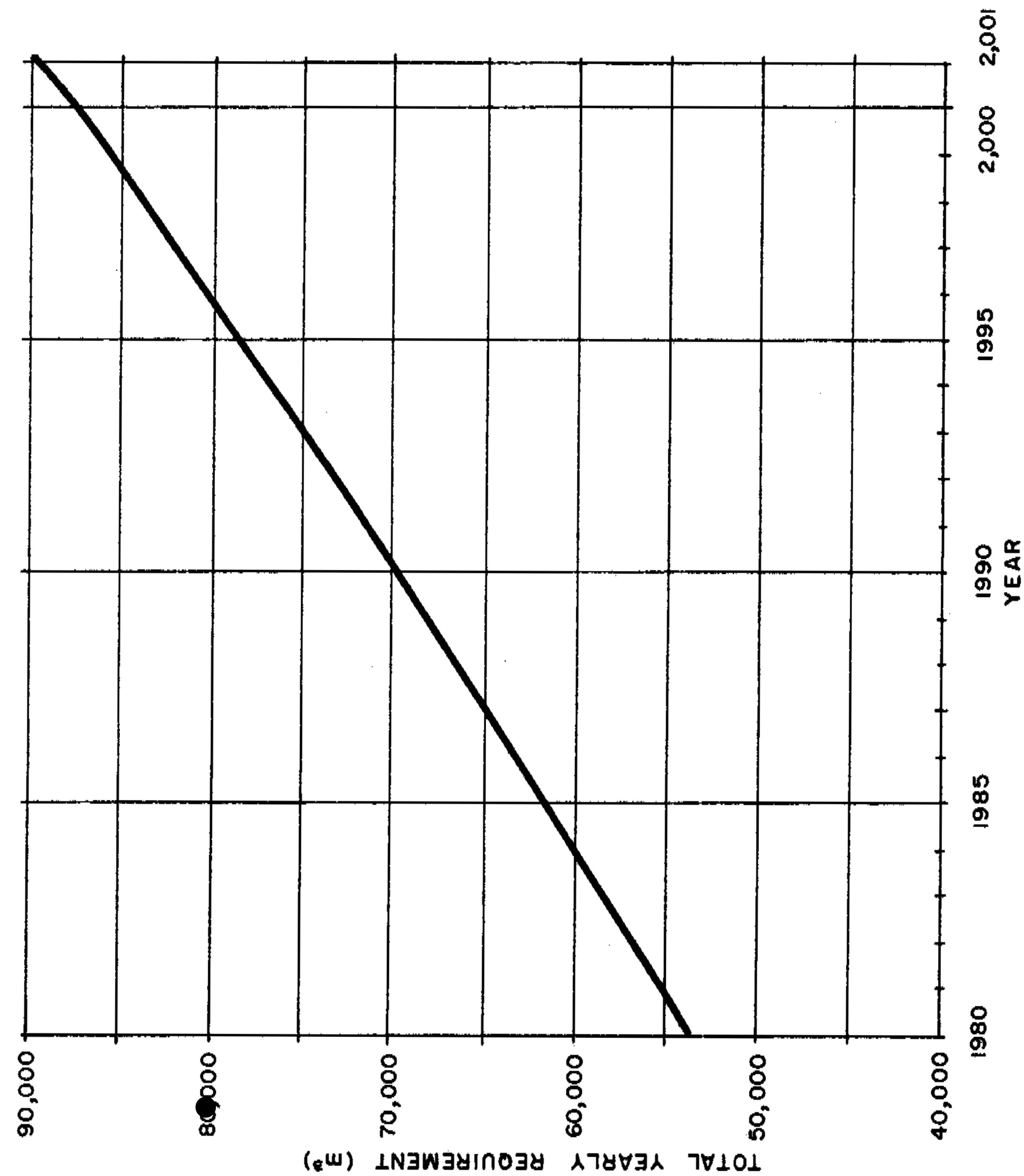


FIGURE 7

GRAPH SHOWING TOTAL VOLUME REMAINING IN RESERVOIR OVER YEARLY CYCLES

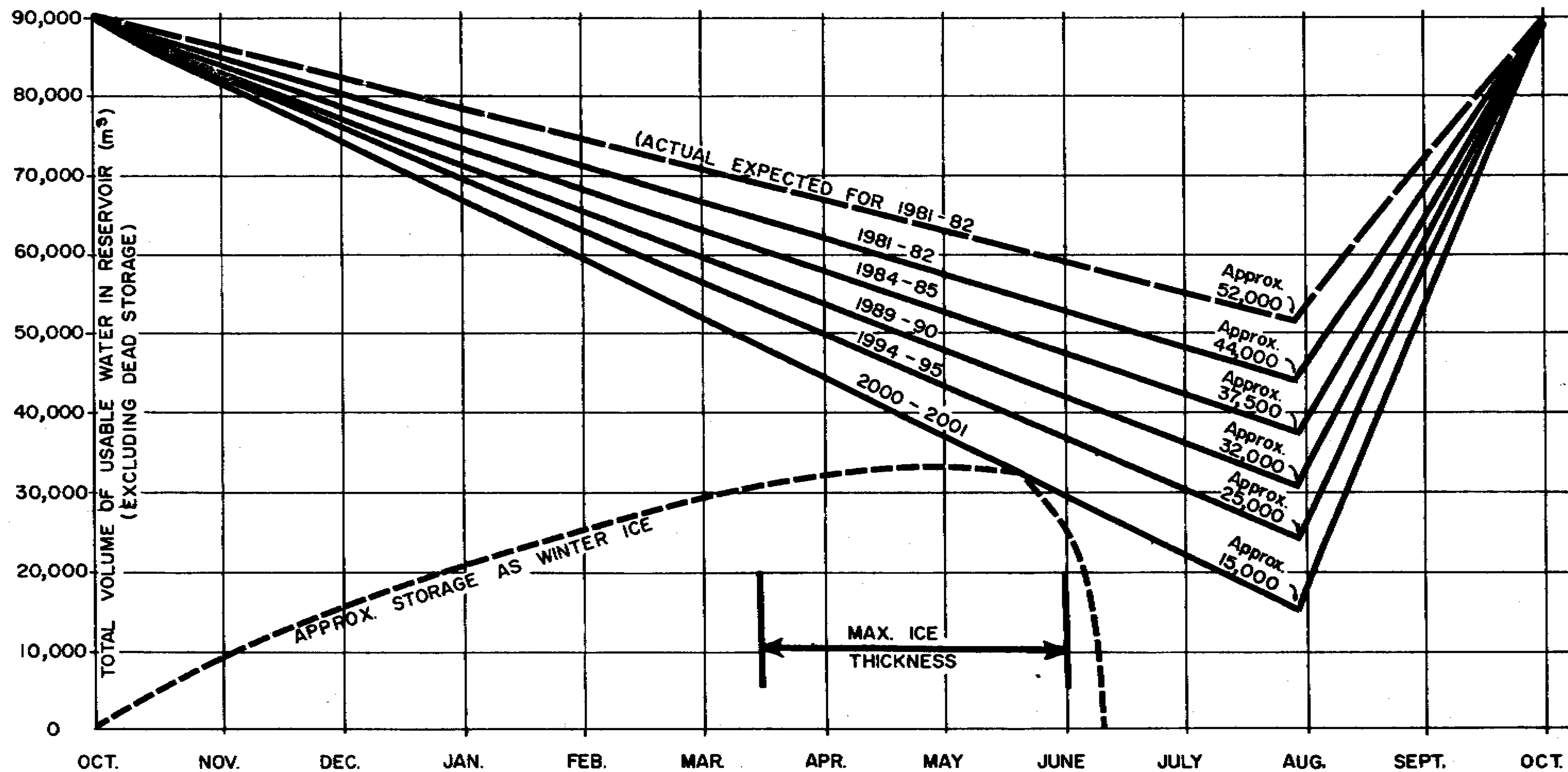
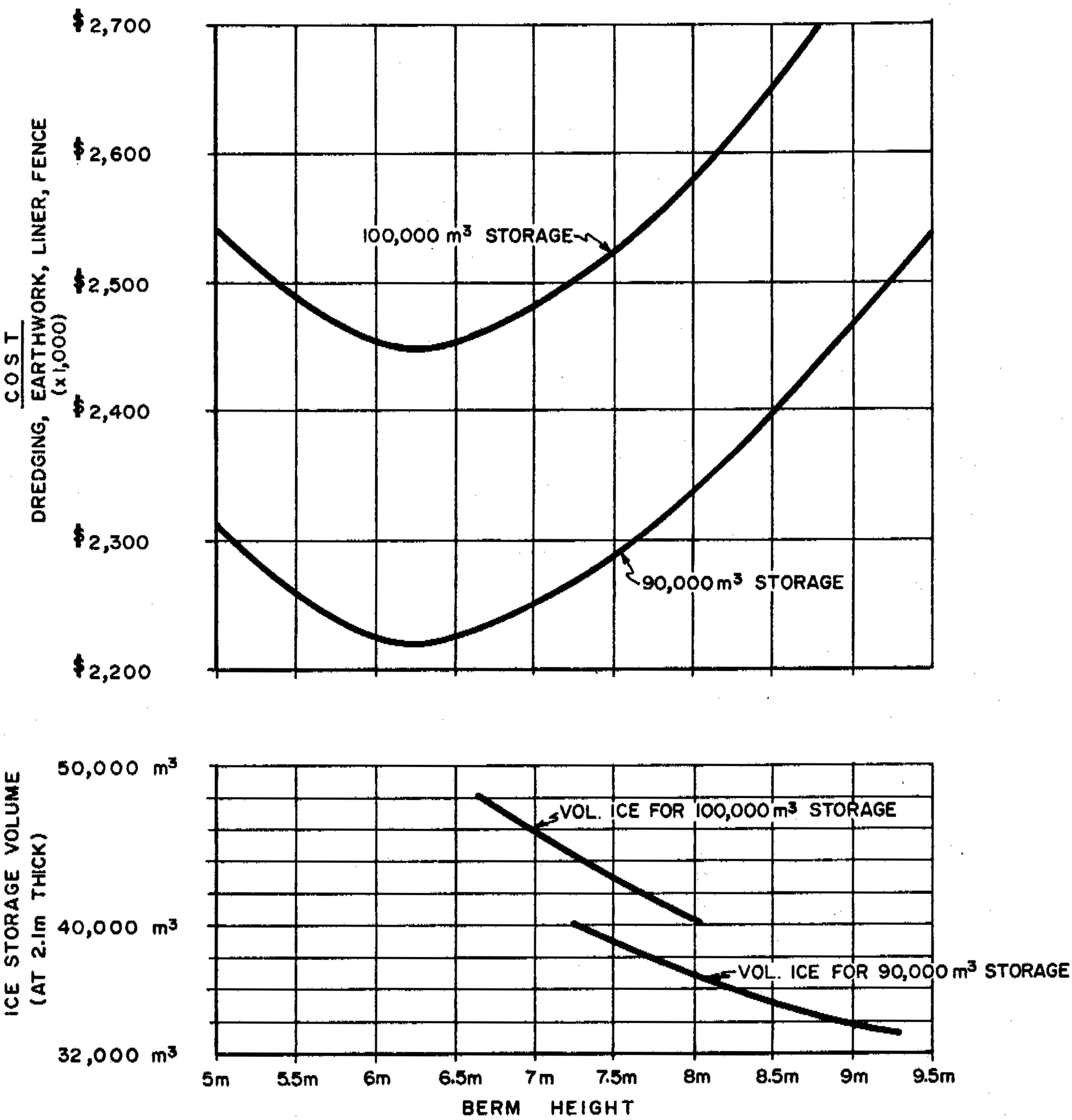
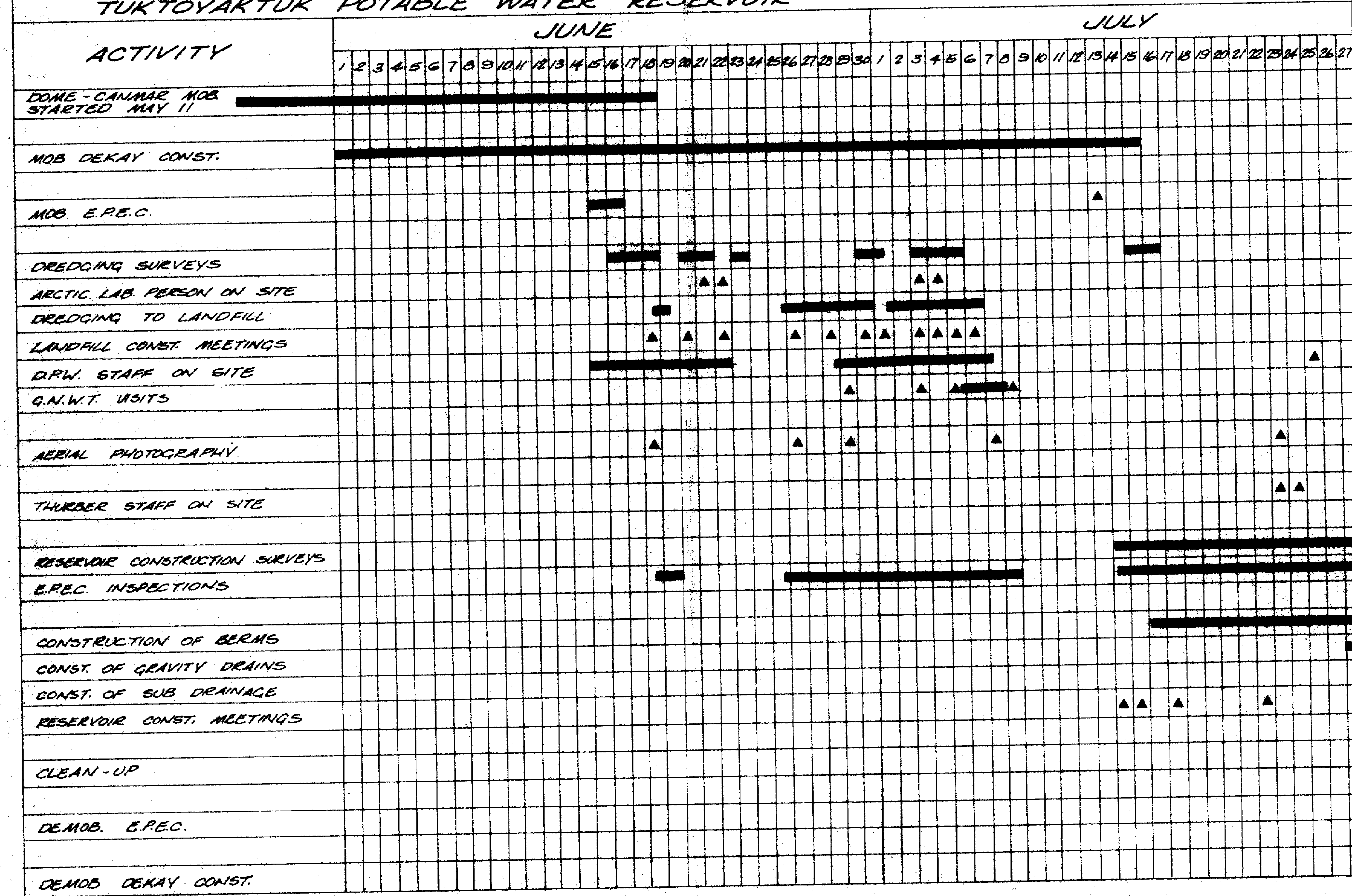


FIGURE 8

ICE STORAGE & COSTS VS BERM HEIGHT



ACTIVITY FLOW SCHEDULE OF DREDGING & CONSTRUCTION PHASES
TUKTOYAKTUK POTABLE WATER RESERVOIR



PRELIMINARY DREDGING

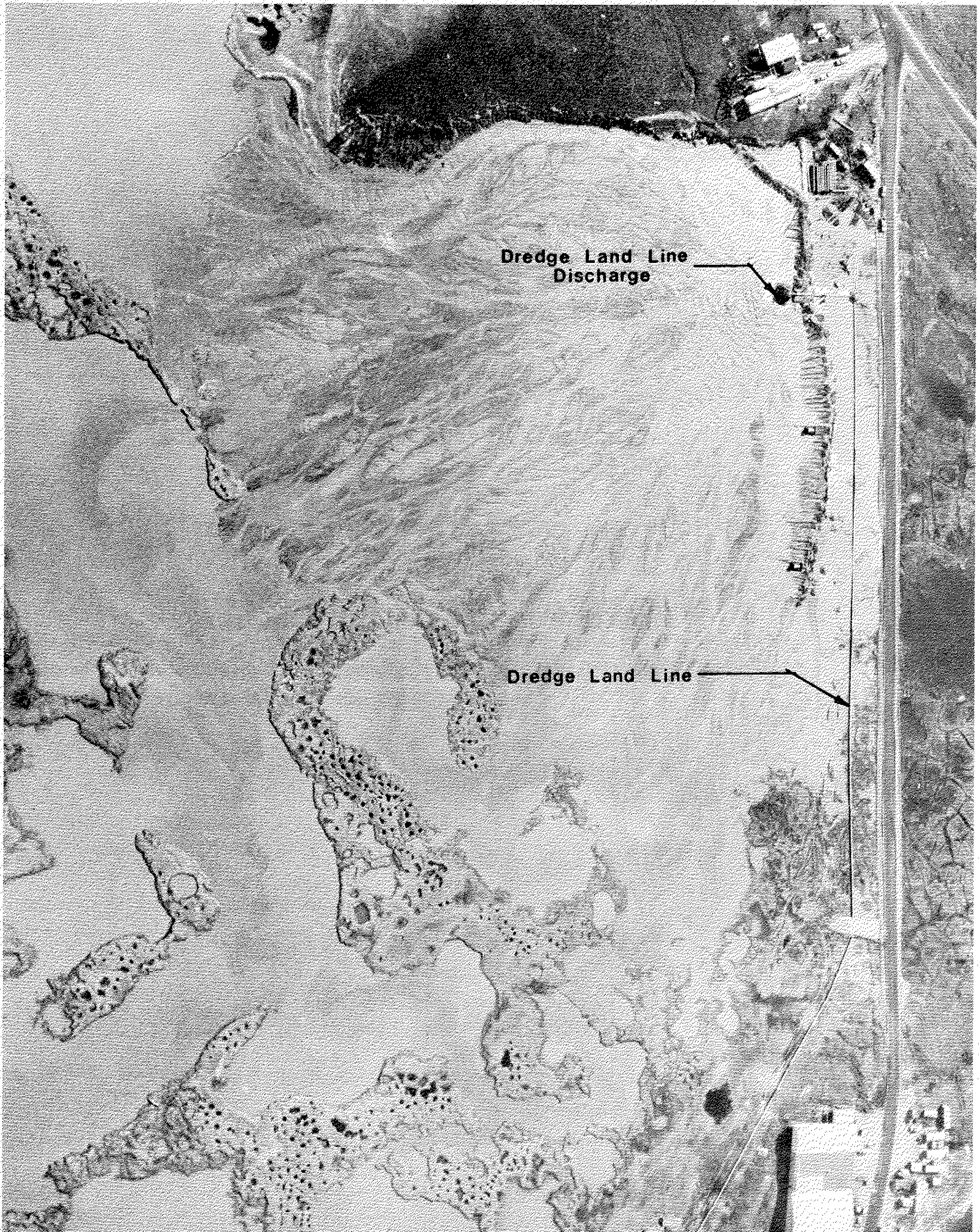
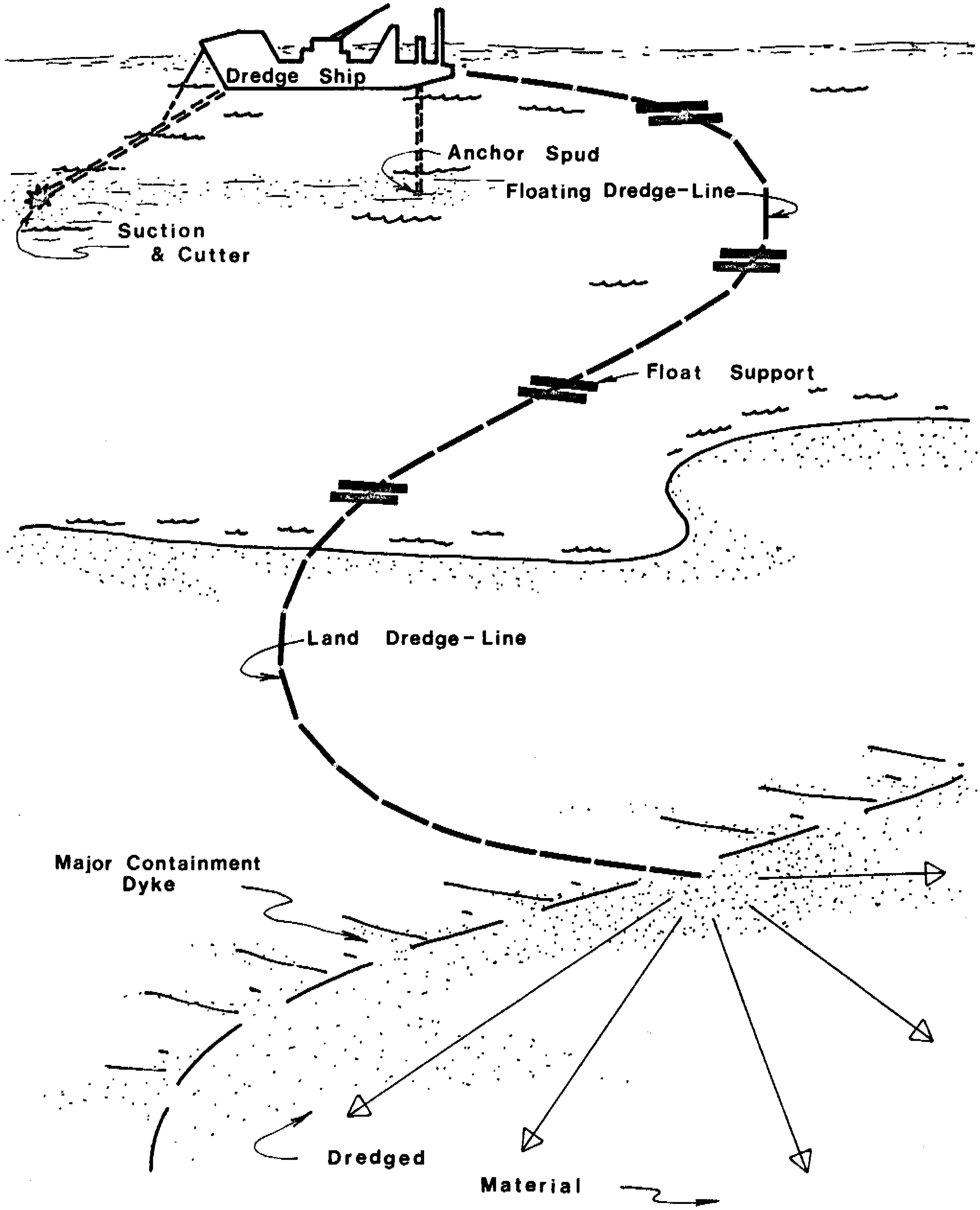


PHOTO 1

using transit, level and chain and the crew employed hip waders where necessary in order that water-filled depressions and the outer limits of the grid could be included.

Six ground targets, each consisting of two 1.2 X 1.2 m. sheets of plywood painted white were placed at key points on the base line and the grid. These targets were employed for rough control and points of identification during examination of low level oblique aerial photography of the site prior to and during the dredging deposition. (See Photo No. 1)



Dredge Ship
Anchor Spud
Floating Dredge-Line
Suction
& Cutter
Float Support
Land Dredge-Line
Major Containment
Dyke
Dredged
Material

FIGURE 3-A

B.3 Dredge Vessel

The dredging operation was carried out using a cutter-suction dredge and a 0.91 m diameter pipeline to transport the dredged materials. A cutter-suction dredger is equipped at the forward end with a ladder, which terminates in a cutterhead as the excavating tool. The ladder structure accomodates the cutter drive, and generally, a submerged dredge pump(s). The ladder can be raised or lowered to the desired dredging depth. The vessel has two spuds at the stern; one of these is lowered to provide a pivot about which the dredger is swung with the aid of cables, anchors and winches.

The most important components of a cutter-suction dredger are the cutter and the dredge pump(s). A revolving cutter situated immediately forward of the suction inlet dislodges the soil and presents it to the suction pipe, incorporated in the cutter ladder. The soil is mixed with water, and the mixture is drawn up through a suction pipe with the aid of the dredge pumps to the disposal site; first through a floating pipeline connected to the dredger, and then through a fixed pipeline on the shore.

The dredge employed on this project was the "Aquarius" which is a sea-going ship owned by Zanen Verstoep of Holland and contracted to Dome-Canmar.

Specifications are as follows:

Length	107 m
Width	19 m
Draft	1.5 m (w/full fuel)
Dead Weight	1500 tons
Propulsion	2 variable pitch electric propellors (17000 H.P.)
Cutter Ladder	650 tons w/64 tooth cutterhead
Cutter Head Drive	2700 H.P.
Pumping Capacity(water)	200 m^3/min.
Cutter pump (submerged)	- 3000 H.P.
Cutter pump (surface)	- 2 (at 5000 H.P each.)
Spuds	- 2 (each 110 tons and 37 m. long.)
Accomodation on board	- 24 persons.

B.4 Dredging Duration

The dredge Aquarius started dredging from the assigned borrow area in Tuk Harbour at 1730 hrs. on the 18th of June. On the 19th of June the vessel experienced problems with the cutter shaft bearings and ceased operation at 0930 that same day.

For the next seven days the Zanen Verstoep personnel tried several adjustments and refits to the cutter shaft and bearings. At 2245 hrs. on the 25th of June dredging recommenced.

Dredging continued intermittently for the next 11 days until 2345 hrs. on the 6th of July. The Aquarius dredge was scheduled to move to Tarsuit on the 5th of July, however, Dome agreed to remain on site an extra day. On the 6th of July a cable on the auxilliary spud broke and the dredging operation was terminated.

B.5 Materials Transport

The dredged materials were transported through a 0.91 meter diameter pipe which consisted of approximately 935 m. of floating line, 285 m. of submerged line and 700 m. of land line (Dome/Canmar - Inf 7). The floating pipeline was routed from the Aquarius to a point of land approximately 700 m N.N.E. from the center of the land fill site where it was anchored in place. The submerged pipe was located from the above described point of land being approx. 285 m. in a southerly direction to where it continued as a "landline" in a S.S.E. route for approximatelv 700 m until it entered the dredging deposition area. (Photo 1 & 2)

B.6 Landfill Site Operations (Fig. 1, 2 & 3)

The landfill operation was controlled and directed by Dome-Canmar personnel while observations, cost control and quantity surveys were the responsibility of the Department of Public Works Engineer and the EPEC staff. Dome/Canmar employed a superintendent and two landfill foremen, of which one was constantly present during dredging.

A typical shift was composed of the following personnel:

1. - Landfill foreman
2. - Two heavy equipment operators (dozer)
3. - Three labourers
4. - One loader operator
5. - EPEC representative

Men and equipment were supplied by Dome-Canmar, Beau-Tuk Marine Services and Grueben Construction. The landfill crew was responsible for inspection and repair of the land line, construction, maintenance and repair of control dikes, control and regulation of the outfall pipes and manipulation of the dredged material with the use of bulldozers.

For the most part two D-6 wide track Cat dozers were used to "train" the fill where possible and to erect control dikes. A D-7 Cat was also used on the site, however use of the heavier machine was restricted to areas which had or were draining well.

CHANNELS OF COMMUNICATION

TUK RESERVOIR - DREDGING TO LANDFILL

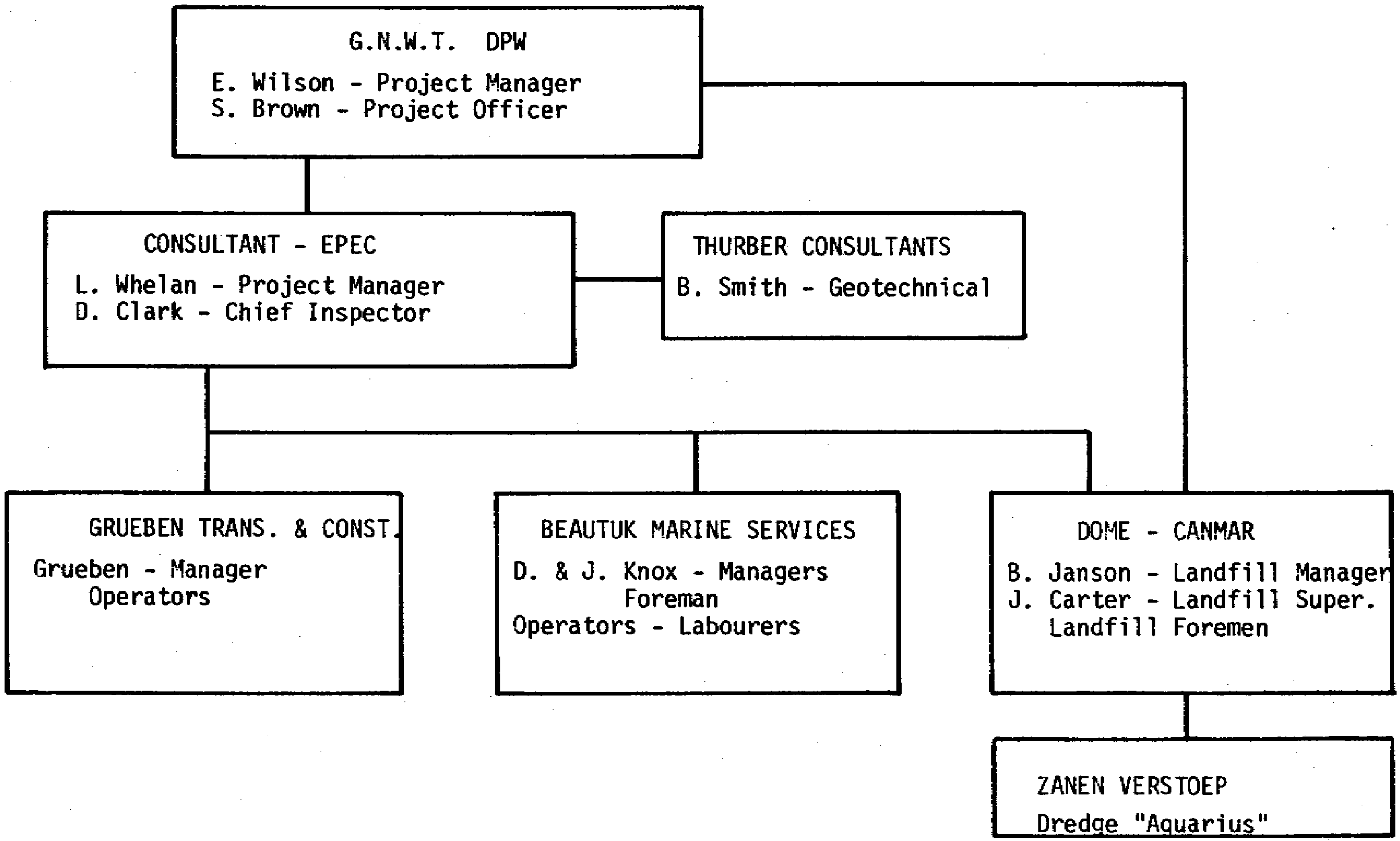


FIGURE 2

epec consulting western ltd.

CHANNELS OF COMMUNICATION

DRAWN BY	DATE	PROJECT No.	DRAWING No.

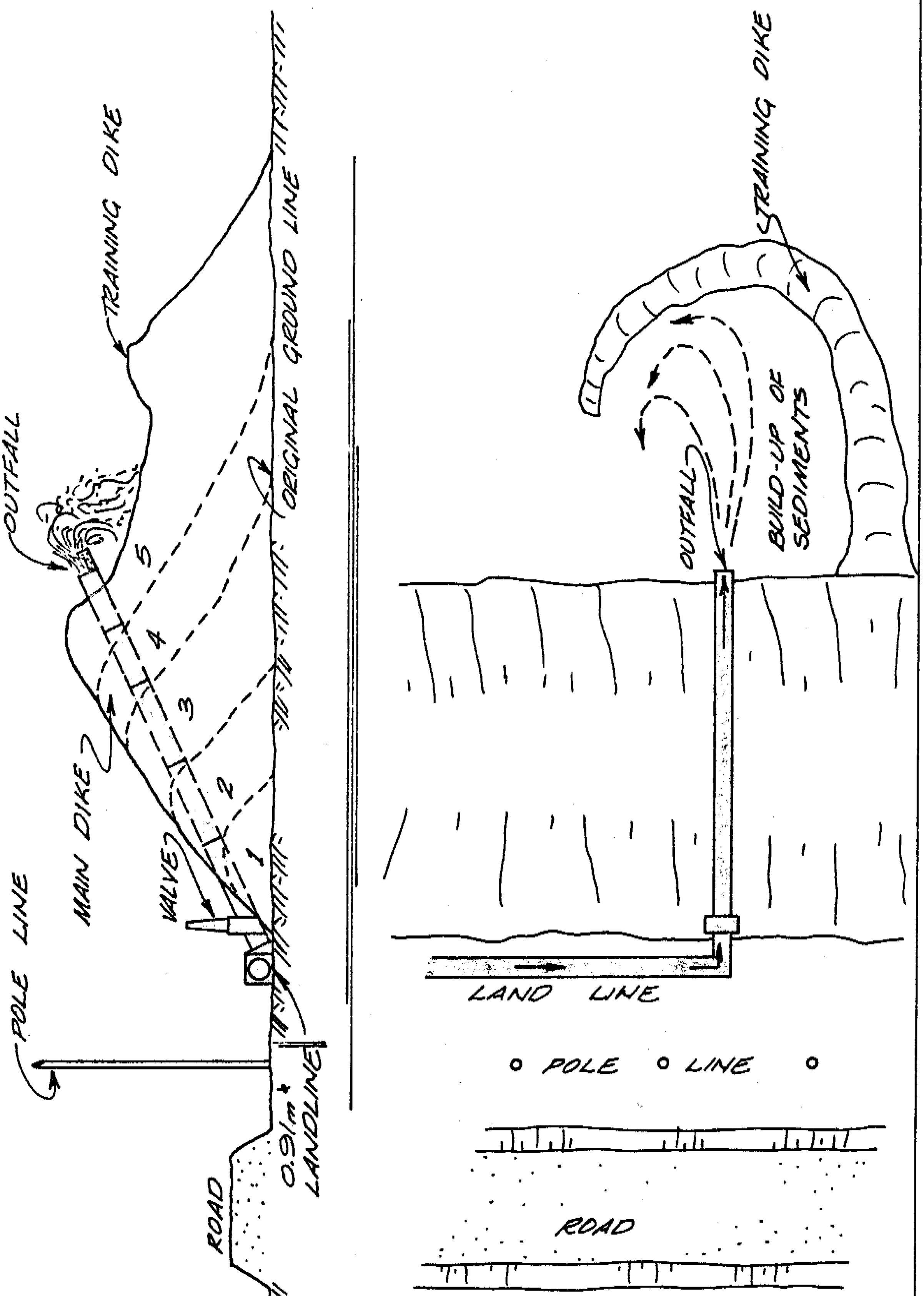


FIGURE 3

epec consulting western ltd.

TUK. RESERVOIR/DREDGING OPERATION

LANDFILL DIKE SCHEMATIC

DRAWN BY	DATE	PROJECT No.	DRAWING No.
WKByggs	Nov/81	6985-005-01-40	

Due to the pervious nature of the dredged material,most dikes were constructed with dozers and then lined with heavy plastic sheeting. Whenever possible the plastic sheeting was covered with dredged material. The main dike which ran parallel to and inside the dredge "land line", was constructed initially to protect the pipe, survey base line and road from inundation by dredged materials. This dike also provided a means by which to control the flow of liquids and to eventually build the deposition as high as possible. (Fig. 3) (Photo 2) It was originally intended that the deposition should occur within an area measuring 300 meters x 500 meters with depths of fill to a maximum of 4 meters with elevations roughly equal throughout. On-site discussions with the landfill foremen indicated that the deposition might possibly be manipulated to a greater extent than was realized previously. D.P.W./EPEC requested that the landfill deposition be biased as much as possible to the south-west corner of the landfill site.

It seemed that greater volumes of material deposited in the specific location of the proposed reservoir would substantially reduce equipment cycle times during construction of the reservoir. The main dike was eventually constructed to an elevation of 7 - 8 meters and the advantages of relatively greater volumes present in the south west corner of the site became quite evident during the reservoir earth-works construction. The minor or "training" dikes were constructed in the same fashion as the main dike and were generally constructed so as to change the direction of flow from the outfall, causing eddies with an accompanying energy loss and a greater rate of sedimentation. (Fig. 3) (Photo No. 3)

B.7 Dredged Materials

The dredged materials were taken from a borrow area defined in drawing No. 15 - 22 - 16 - 4 Thurber (Appendix B), located approximately 1400 meters north of the S.W. corner of the landfill site. (Inf. 3)

The materials are composed of a fine grained-sand with minimal inclusion of silts and clays. Random sampling & testing by the Dome-Canmar inspector on the Aquarius indicate an average fine sand content of 94% and 6% silt content. Very few samples contained gravel and where these sizes were present they represented an average of 0.27%. This sampling was done throughout the landfill each day during operation shut down time & crew changes. (Inf. 7)

Often, due to the nature of the dredged material and its saturation, it was difficult at best to move machinery into certain areas in order to construct dikes. With the absence of dikes it was often impossible to induce the required sedimentation and build up of the find sand. Consequently some dredged material was washed out to beyond the outer limits and below sea level where it is unrecoverable by land based machinery or common methods of excavation.

In photo No. 2 it can be seen that the outflow is cutting into the dredged fill and carrying it beyond the intended perimeter and into the shallow bay to the S.E. of the landfill site. This situation most often occurred when the cutter head entered an area containing silty material. The silts remained in solution and the water flows would cut a trench 2 - 3 meters deep and occasionally as much as 10 meters wide.

On three occasions during the dredging operation the D-6 bulldozers became mired,in the saturated sands over top of the tracks. Fine sand and water entered the final drives of the machines and one dozer was down for several days before replacement parts were recieved and repairs completed.

An interesting phenomenon was observed during and after the dredging deposition in the landfill area. For lack of a better description the writer will call the objects observed "piping cones". These cones were thousands in number and had minimum diameters of 20 mm while an occasional specimen would have a diameter of 350 mm, a height of 200 mm., and an opening at the top of 26 mm (See photo No. 4). These cones were created by "piping" or a release of hydrostatic pressure through a least line of resistance,in this case to the surface where the vertical flow of water carried with it fine sands and silts which formed a cone. During the first few days of reservoir construction the writer observed some of these cones to have water exiting the ground surface with a column of water up to 175 mm above the pinnacle of the cone. The release of hydrostatic pressure from the dredged material was induced by natural consolidation and vibration imparted to the soils by men and equipment.

It is interesting to note that the entire landfill site, where the soils have not been manipulated by machinery, assumes much of the nature and shape of a braided alluvial fan. (Photo No. 2)

DREDGING COMPLETED

NOTE: MAJOR CONTAINMENT DIKE ON WEST SIDE - SEE DIKE SCHEMATIC

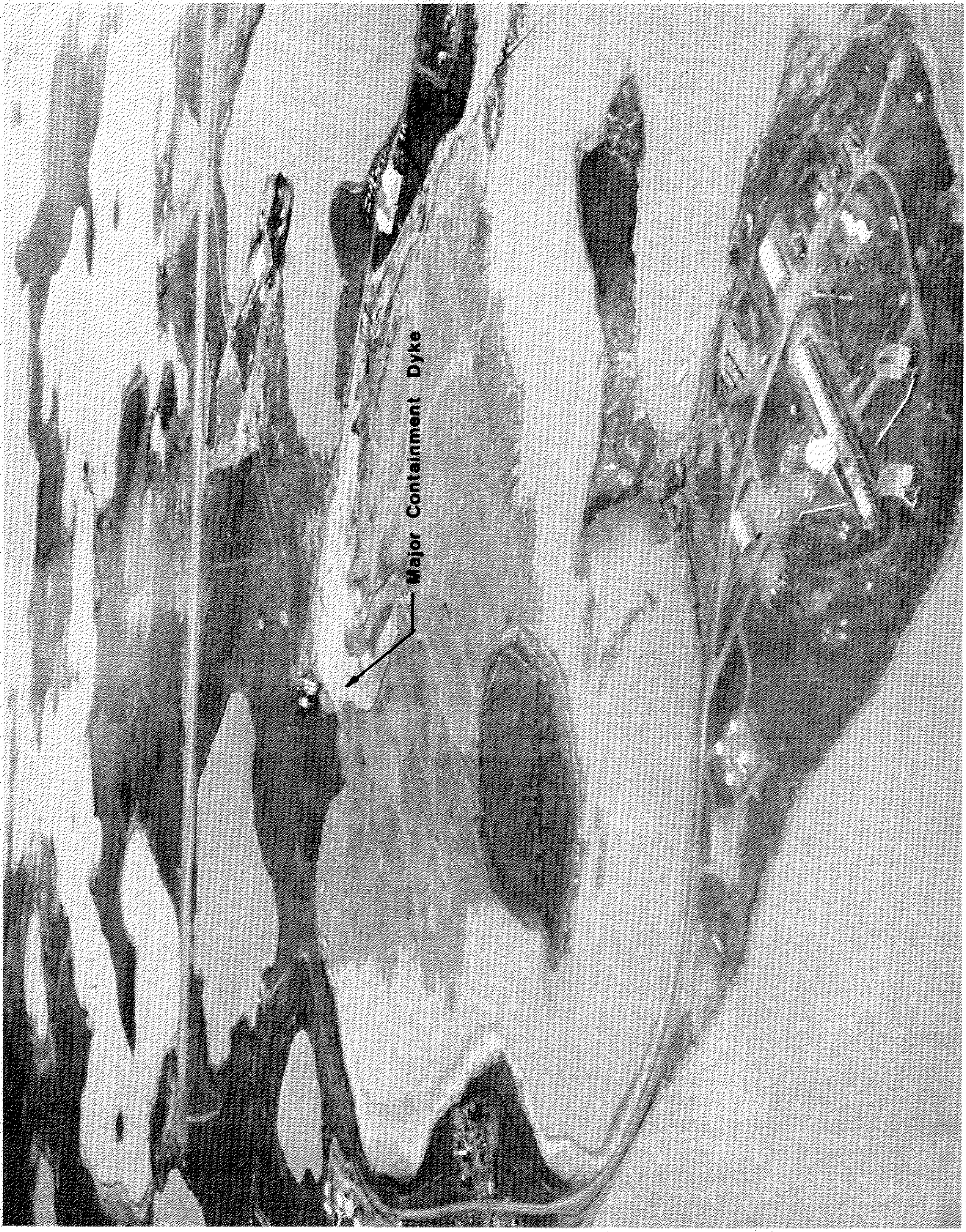


PHOTO 3

PIPING CONES

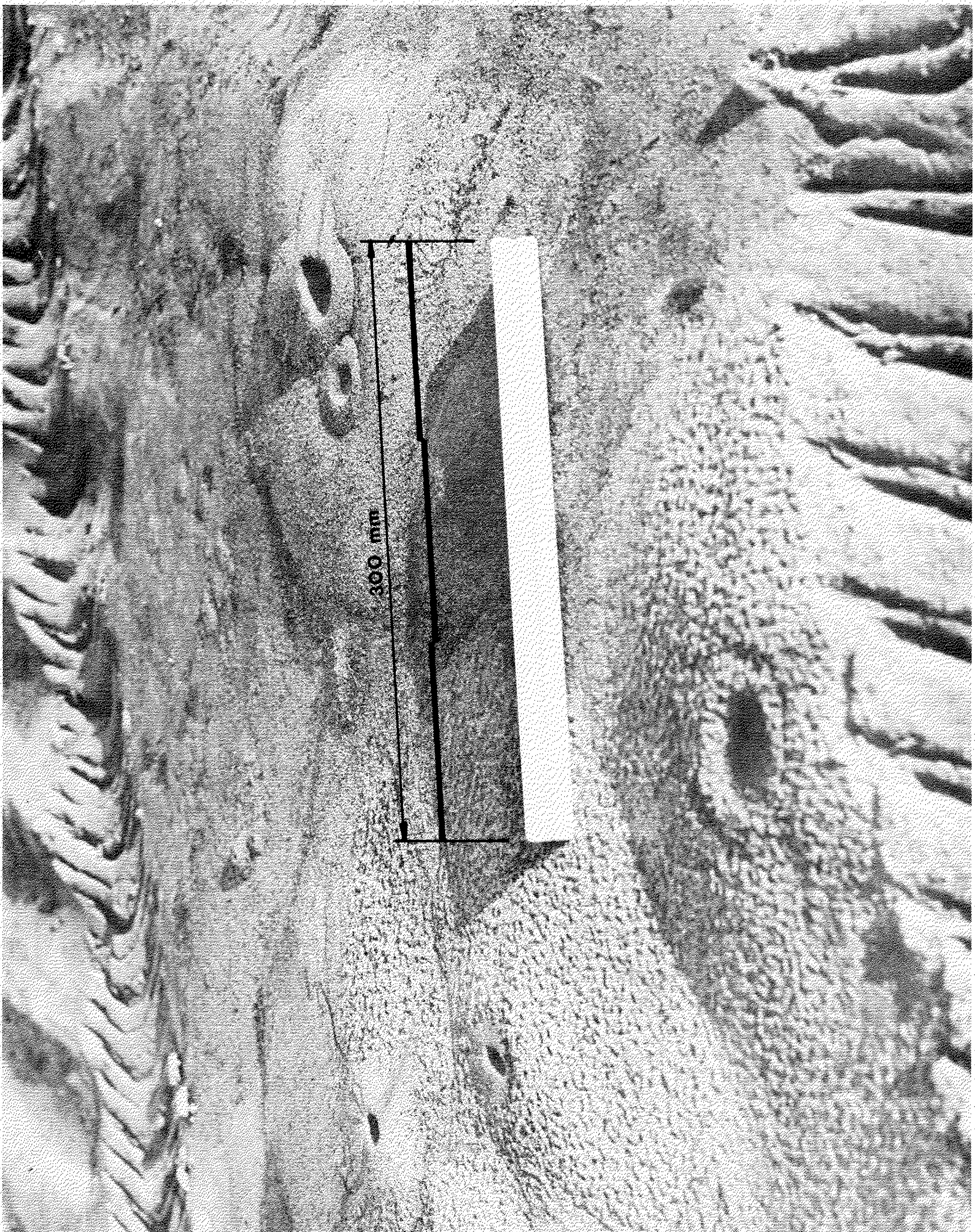


PHOTO 4

B.8 Dredging Surveys

Dredged volume surveys were carried out on June 30, July 1, 4, 5, 6 and 16. These surveys were executed employing the same methods as the pre-dredging survey. The grid system was re-established in each case with elevations on grid points and grade breaks on the topography being noted.

Total volumes were calculated for each survey as listed below.

- June 30	262,000 m^3	
- July 01	284,000 m^3	
- July 04	438,908 m^3	
- July 05	503,194 m^3	
- July 06	49,912 m^3	(Calculation for material below sea level)
- July 16 (Final)	582,000 m^3	

The dredging surveys were arduous ventures due to the characteristics of the materials at the periphery of the landfill site and occasionally well within the deposition boundaries. Members of both D.P.W. and EPEC staff often found themselves floundering up to the waist in the super saturated fine sands. The extrication process was extremely humorous if one witnessed it from high and dry ground at the time.

Aerial photography was considered an integral part of the dredging surveys. The aerial photography was carried out using a Bronica 4.5 cm X 6 cm format camera through the open window of a Cessna 185 aircraft. Most runs on the dredging photography were low level (steep oblique) frames taken at 915 meters A.S.L. The reference baseline for the majority of photo flight paths was the access road immediately adjacent to the landfill site, consequently most survey frames should be observed with the access road at the bottom of each photograph.

Most ground targets were washed away or buried in the first three days of dredging. The photography was extremely useful in ascertaining the extent of deposition, the direction and character of drainage, relative water content and general progress.

B. 9 Volumes of Dredged Material

- Dredged:

Dome (from Aquarius Log: Educated Guess)	739,943 m^3
EPEC (measured volumes above sea level)	582,000
EPEC (measured volumes below sea level)	50,000
Measured total usable	582,000 m^3

- Used or to be used in construction:

Volume to date in reservoir construction	354,000 m^3
Volume required for liner cover	16,000
Total volume req'd for reservoir	370,000 m^3

- Other materials used:

  Land assembly construction (approx.) 10,000 m^3

  Used by residents of Tuk (estimated) 15,000

- Total estimated usage to date 395,000 ,^{3}

*- Total estimated available volume for other usage 187,000 m^3

*Note: This total does not include "overspill" which deposited dredged material south and S.E. of the reservoir area. The above described site was not surveyed prior to dredging for it was not previously included in the landfill site nor was it surveyed for quantities after dredging due to the super saturation of the material. It is estimated that this area could contain 15 - 20,000 m^3 of dredged material. This material may be available if it drains sufficiently to support the weight of excavation equipment.

B. 10 Summary and Discussion

The Aquarius dredging log records a total of 191.7 hrs of dredge operation with an estimated total of 739,943 m^3 removed from the Tuk Harbour floor in the assigned borrow area.

The dredging operation took a total of 13 days which represented two periods. The first term was from 1730 hrs on June 18 until 0930 hrs on June 19, a duration of 16 hrs, when a bearing on the cutter shaft overheated and the operation was shut down. The second term began at 2245 hrs, June 25 and operations terminated at 2345 hrs July 6.

As mentioned in "Dredged Materials" the cutter would occasionally enter a zone of high silt content. With most of the silt remaining in suspension the flow from the outfall would cut a deep swath through the "built up" fine sands and would find it's own, often erratic path, through the sands downslope to the sea. Often a 4 - 5 hour build up of sandfill would be washed away in ½ hour under these conditions.

A constant vigilance was kept by the EPEC and Canmar landfill supervisory staff and when high silt contents were observed exiting the outfall, the Zanen Verstoep operators aboard the Aquarius were informed of the situation by radio within minutes. Crew of the dredge were also often aware of the materials being engaged by the cutter before their exit from the outfall. The dredge operator, when it was suspected that the silt zone was extensive, would "search" with the cutter or realign the dredge. When siltateous fluid was cutting through the sands it was often difficult or impossible for the bulldozer equipment to control wasting of the sand fill unless a control or "training" dike provided means of access to a point(s) close to the flow in order to manipulate it's course

The dredge was shut down for several periods during the landfill operation in order to make repairs, perform regular maintenance, or rerig and change anchor location. Some of these occurrences are as follows:

- Replace cutter teeth on regular basis.
- Regular maintenance on cutter suction pump.
- Regular maintenance on cutter shaft and bearings.
- Inspection of cutter - suction ladder.
- Change anchor locations and realign dredge.
- Repair or replace section of floating line.
- Repairs to land line.
- Remove rocks from pump

The landfill site crew often used the duration of shutdown to repair the landline,and to repair, add to and construct new "training" dikes. With out these breaks in pumping it would have been most difficult to construct effective diking.

Photograph No. 3 shows a dike which has origins in the extreme southwest corner of the landfill site and extends in an easterly direction, thence in a northerly direction in a short spur. This dike took three and one half days to construct due to constant pumping and problems associated with engagement of a silt zone. Greater experience with landfill operations may have resulted in the using of some material from the point of high ground which constitutes a spur south of the landfill in construction of "training" dykes prior to initiation pf dredging to landfill. It is worth noting that in future operations of such character and magnitude that consideration be given to the construction of preliminary dyking with material at hand. In some operations it may be considered expedient (relative to cost) to cease dredging for a day or two in the initial effort in order to construct sufficient areas of lined (plastic sheeting) catchment. When areas of fine sand are associated with large silt zones the above described may often be cost productive.

The dredging operation was carried out within a fixed Budget and accordingly the DPW/EPEC staff endeavoured to establish a daily expenditure record based on costs associated with the dredge and contractors costs. Daily examination and approval of subcontractor's (BeauTuk, Gruben) invoices were carried out and many visits were made to the Aquarius and Camp 208 to determine the per diem expenditures.

In conclusion it must be said that this endeavour was an experience not soon forgotten and should be considered as valuable reference for any similar projects.

C. RESERVOIR CONSTRUCTION

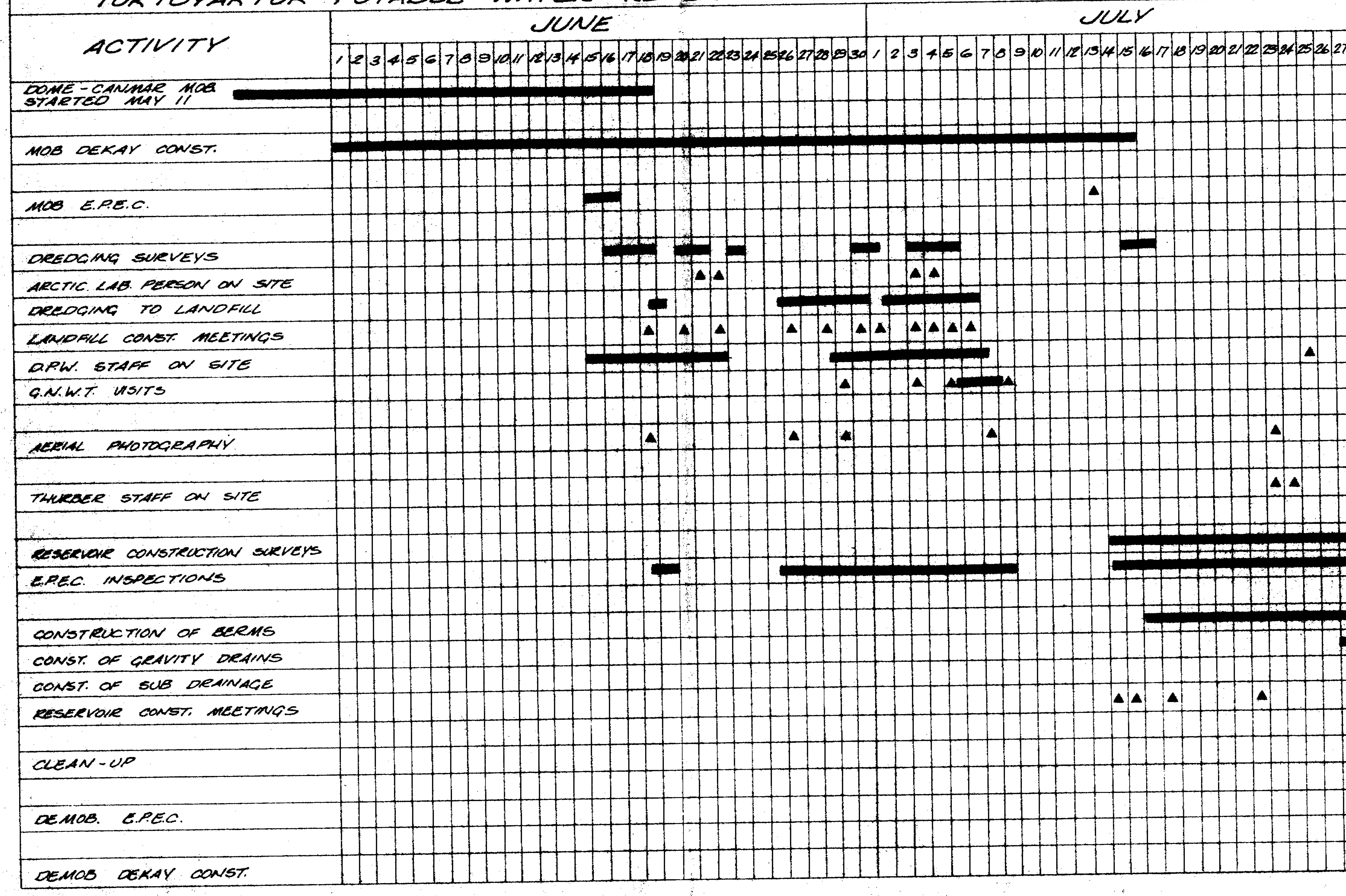
C.1 Pre-construction preparation of dredged materials

After the landfill operation and prior to construction of the reservoir, the dredged materials within the landfill site were prepared for construction of the reservoir. (Photo 5)

During the dredging to landfill operation it was noted that vibration imparted to the material would induce "surface piping" through the soils and release hydrostatic pressures or at least initiate the process.

On the 8th of July the EPEC field staff requested that Beau-Tuk Marine Services run two D-6 bulldozers with the "blade up" over the landfill site until construction of the reservoir began. The purpose in this case was to accelerate the natural consolidation of the material in order to provide an adequate bearing surface for the excavating equipment which would be used in the construction of the reservoir. The equipment was run back and forth over the fill in the slope direction wherever possible from the 10th to the 15th of July.

ACTIVITY FLOW SCHEDULE OF DREDGING & CONSTRUCTION PHASES
TUKTOYAKTUK POTABLE WATER RESERVOIR



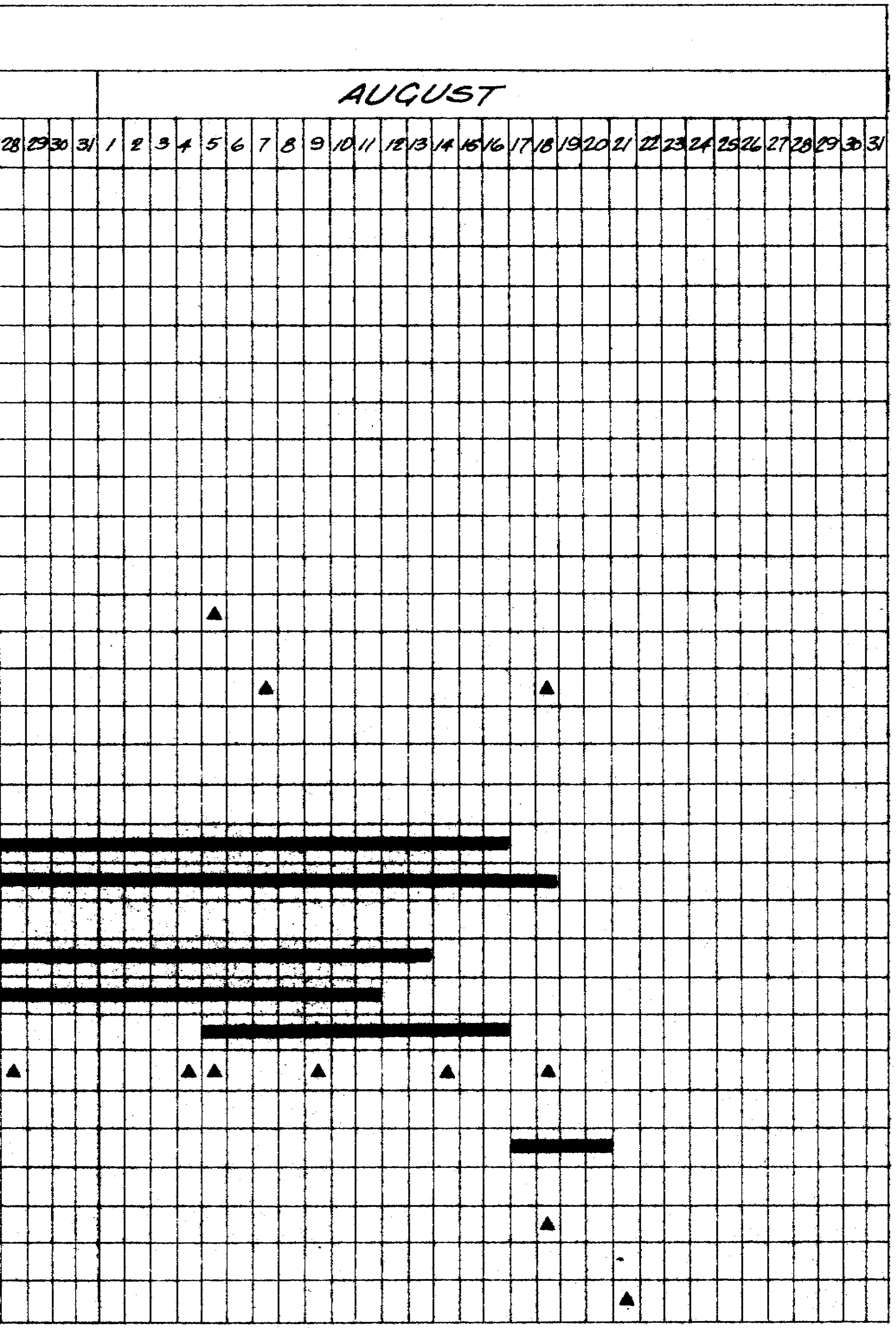

AUGUST
28 29 30 31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

FIGURE 1