OVERVIEW OF
DITCH DEGRADATION PROBLEMS
IN RELATION TO NORTHWEST ALASKAN
PIPELINE CONSTRUCTION

Woodward-Clyde Consultants

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Prepared for

Northwest Alaskan Pipeline Company
P. O. Box 1526
Salt Lake City, Utah 84110

July 27, 1978

Three Embarcadero Center, Suite 700
San Francisco, California 94111
415-956-7070

Woodward-Clyde Consultants

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Northwest Alaskan Pipeline Company
P. O. Box 1526
Salt Lake City, Utah 84110

Attention: Mr. Bob Hauser

Subject: Overview of Ditch Degradation Problems

Gentlemen:

Transmitted herewith are twelve (12) copies of the report on our recently completed overview evaluation of potential ditch degradation problems in construction of Napline.

Conclusions are drawn that ditch degradation can be kept to an acceptable level with proper attention to design and construction details. A table is provided which can be used with mile-by-mile evaluation of geotechnical and scheduling data to identify areas along the alignment where ditch degradation may be intense. Some potential mitigative measures are identified, and some additional studies are recommended.

If there is further effort desired on the problem please let us know.

Sincerely,

William T. Black

William T. Black

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Enclosures

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OVERVIEW OF DITCH DEGRADATION PROBLEMS IN RELATION TO NORTHWEST ALASKAN PIPELINE CONSTRUCTION

1. PURPOSE

The chilled gas pipeline to be constructed by Northwest Alaskan Pipeline Company (Napline), now being planned, will follow the same corridor as that followed by Alyeska Pipeline Service Company (TAPS) in constructing the existing warm oil pipeline from Prudhoe Bay to Delta Junction, Alaska. Much experience was gained in construction of TAPS as to the behavior of ditch walls in soils along the planned alignment and under the varying seasonal conditions. It is the purpose of this broad qualitative study to consolidate the information that can be gained from the TAPS experience with general knowledge of the geotechnical and thermal conditions along the entire Napline route to provide a perspective view of potential ditch degradation problems. Generic problems are to be identified. Potential severity of the degradation is evaluated and possible mitigative actions are briefly examined. Additional studies needed to fully evaluate the ditch degradation problem are identified.

Since the study is an overview, it is not the intent to provide specific answers to specific problems but to provide Napline Management with a starting point from which to plan additional studies and actions needed to resolve the ditch degradation problem in a cost effective manner.

2. SCOPE

The overview is restricted to those problems that confront the construction forces between the time the ditch is excavated and the time the ditch is backfilled. It has to do with the problems of (1) keeping the ditch width and depth to a practical minimum so as to keep the quantity of excavation and backfill to a minimum, (2) reducing ditch cleaning, and (3) increasing the likelihood that the pipe will be placed in a ditch with firm walls and bottom for proper support. It does not address other potentially serious problems in which ditch degradation may play a role. Some of these other problems which must be studied but are not addressed directly herein are (1) general slope stability, (2) long-term thermal conditions, and (3) long-term erosion control.

The study is subjective in nature. Logic is applied to the effects that natural phenomena will have on the construction effort and vice-versa, but no attempt is made to establish and apply governing parameters in an analytical manner to provide quantitative answers.

The study is primarily concerned with Napline in the general case when it parallels another feature such as TAPS. River crossings and crossings of the TAPS line are excluded as these crossings will require site specific studies and/or designs.

3. STUDY METHODOLOGY

Four geotechnical engineers experienced on the TAPS work were asked to evaluate the potential for ditch degradation along the proposed route. They were asked to evaluate the effects of soil types, thermal conditions, ground slopes, water table, depth of burial, construction schedule and configuration of Napline versus various facilities of TAPS. They were also asked to check their conclusions against the degradation events that they had witnessed on TAPS construction. Their evaluations were quite similar and from them a matrix of conditions was developed that highlights the overview of the problem.

Although the study is subjective, it brings to bear available knowledge of the geotechnical, climatic, and thermal conditions that will govern ditch stability. Further, advantage has been taken of the experience that is available to provide the most reliable evaluation of the problem that is possible with the present level of data available.

4. CORRIDOR CHARACTERISTICS

4.1 Alignment

To deliver gas that is recovered in oil production at the Prudhoe Bay Field to U.S. markets Napline is being designed as a chilled gas pipeline to follow established transportation corridors. From Prudhoe Bay to Delta Junction, Alaska it generally follows either the Haul Road built to support the construction of TAPS (soon to be under state control) or the actual TAPS line. From Delta Junction to the Canadian Border Napline will follow the right-of-way of the inoperative Haines Pipeline which in turn generally parallels the Alaska Highway.

Based on present planning Napline will always be located downslope (if there is a cross-slope) from TAPS and will be offset approximately eighty (80) feet. Also based on present planning it will be offset from the Haul Road approximately seventy (70) feet. Offset distance between the Haines Pipeline and the Alaska Highway is usually over one hundred (100) feet.

4.2 Soil Conditions

The Napline will traverse most of the representative soil conditions present in Alaska. These include the ice-rich North Slope coastal plain composed of silts overlying sands or gravels, both frozen and thawed river floodplains consisting of granular soils, mountainous terrain of the Brooks range where exposed bed rock is prevalent, and ice-rich colluvial slopes and valleys of the Yukon-Tanana uplands and Brooks Range foothills which are predominantly silt with sand and rock fragments intermingled.

From Delta Junction to the Canadian border the route follows the valley of the Tanana river. Intermittent permafrost is present and soil types will most likely be varying thicknesses of silt overlying sands and gravels or glacial till. Slopes are generally low in the section of the line, but hilly terrain is encountered near the Canadian border.

4.3 Water Conditions - Because of the snow melt above frozen soils there is substantial surface water and runoff each spring. Much of the route is over land that has little slope and there is indistinct drainage. For this reason it stays marshy the entire summer with surface water available to drain into excavations. This surface water augments the melting of permafrost on the perimeters of excavations. Where the terrain is hilly the melt water concentrates in small ephemeral streams which may flow heavily for short periods of time. Again, if the surface water is permitted to enter ditches, it will augment the melting of permafrost and release more water. Thus, surface water can and does play a strong role in ditch wall instability or degradation.

In flood plains there is usually a high water table if the ground is thawed. The high water table combined with the usually granular soils makes ditch walls unstable unless excavated at relatively flat slopes.

4.4 Structures

Since the Napline will parallel the TAPS or Haul Road for much of the way, major uncontrolled ditch degradation could possibly adversely affect structures along those facilities. These structures include the above-ground and below-ground sections of TAPS and appurtenances such as valve control buildings, the TAPS workpad, the Haul Road embankment, and the gas pipeline which extends from Pump Station #1 to Pump Station #4 on the TAPS.

4.5 Climatic Conditions

Based on present planning no general construction activity is anticipated from late fall to early spring. Ditches may be open in early spring when ambient temperature is still below freezing and the active soil layer (that depth of soil that freezes each winter) is frozen. They may be open in late spring when ambient temperatures are above freezing but the active layer has not fully thawed. In summer and early fall the active layer will be thawed. In late fall ambient temperatures will probably be below freezing and the active layer partially frozen.

Therefore, ditch walls will be subjected to any of the thermal conditions that can occur, but the variety of seasonal conditions offers opportunities for scheduling critical sections of ditch to the most advantageous season.

5. EFFECTS OF DITCH DEGRADATION

For best efficiency and therefore best economy pipelining must proceed in an orderly production line manner. Ditch degradation, if excessive, interferes with the production line and therefore is costly. Since the ditch bottom and sides need to be relatively clean and firm to properly receive the pipe and bedding and padding, loose slough material must be removed. Thus, excess excavation time is required and excess material is required to backfill the ditch. Backfill material may require importing.

In the case of the Napline there is the possibility that ditch degradation, if not kept under control, could adversely affect the parallel structures owned and used by others. These incidents could cause major problems especially if there was interference with the operation of TAPS.

Major ditch degradation could cause unacceptable environmental damage. This would be especially true near important fish streams.

For several reasons then, ditch degradation could have a serious adverse impact on cost of Napline. It becomes necessary to understand the causes of ditch degradation, the locations where it is likely to occur and to investigate and plan possible mitigating actions if the impact of the degradation would be excessive.

6. GENERAL CASE OF DITCH DEGRADATION

In all cross-country pipeline work, soils occur that are not stable if a rectangular or near-rectangular ditch cut is made through them. The walls will ravel or slough under gravity loads. These conditions are made worse if there is a high ground water level. The inflow of water increases the potential for sloughing. Surface water entering the ditch will cause erosion at the shoulder and, if the ditch bottom has a longitudinal slope, will erode and undercut the sidewalls and cause wall caving. These characteristics will be present in certain soil types along the Napline route. Pipeliners are experienced in handling such situations and consequences can normally be limited to an acceptable level.

Special conditions along the Napline, however, increase the potential for the "normal" instabilities mentioned above and introduce new conditions that are not present except in arctic or subarctic climates and soils. The principal condition is the presence of extremely low ambient temperatures for an extended period of time each year. These low temperatures cause deep seasonal frost and preserve all precipitation in the form of snow or ice. In the permafrost soils there is a residual layer of frozen soil at some depth beneath the surface that is not thawed during the summer melt. In both the seasonally frozen material and in the permafrost there is substantial water content locked in as ice which fills the pores of the soil matrix. In certain soils, water has been collected by natural forces and frozen into segregated ice inclusions. Where nature has been most proficient in the segregation process, the proportion of ice volume to soil volume may be high (100% ice for limited profile depths). The frozen soil or ice exists at temperatures near melting or will be brought to these temperatures rapidly by exposure to summer ambient conditions.

These special conditions introduce additional problems to pipelining. In the first instance the surface water problem is greatly increased. As the accumulated snow starts to melt in the spring, the resulting water cannot infiltrate the frozen soil below so it either stands on flat ground or runs downhill. As the thawing continues downward more surface water is developed until thawed soil is reached so that infiltration can begin. In the case of permafrost soils, infiltration will not occur unless a "talik" zone (a non-frozen layer within the permafrost) is reached. Thus, essentially all of the water content of the snow and the excess water in the thawed active soil layer become surface water or are held in the upper few feet of soil. In flat ground these waters become lakes, ponds or very sluggish streams and persist for much of the summer. If a ditch is cut through the terrain it usually fills with water. The water will erode thawed soils, weaken the soil in the ditch walls, and cause sloughing. The water will be warmer than the still frozen soil and will cause thawing which adds to the erosion problem.

The second problem is that the advancing thaw front, whether in seasonal frost or permafrost, may generate excessive pore pressures in fine-grained soils with corresponding reduction in shear strength. It is possible for mass movement of soil to occur on these planes of reduced strength, thus causing relatively large volumes of soil to move into the ditch. The large volumes of soil may disrupt drainage and therefore cause local erosion of work pad or other works.

As can be seen from the discussion above the Napline will certainly suffer the "normal" problems of ditch instabilities and in certain conditions of soil and slopes may encounter much more frequent and severe conditions of ditch degradation.

7. FLAT GROUND CONDITIONS (SLOPES LESS THAN 5%)

There is only one case where wide ditch width is likely to occur on flat ground, with reasonable construction care. This is not really a case of degradation as the action will occur while the excavation is in progress. This is the case of excavation in a thawed granular material where there is a high water table. Because of the agitation of the water in the ditch by the excavation equipment the side walls will slough to a stable slope. Experience on TAPS indicates that the slope that is reasonably stable will be approximately 1 to 1. If loose silts or sands are encountered, a wall slope of 1.5 horizontal to 1 vertical may be developed. Thus the width of the top of the trench, the potential for damage to adjacent structures, and the volume of material to be removed and replaced is largely dependent on the design depth of the trench. For deep excavations large quantities of material will have to be moved. This problem is no different in Alaska than in other places of the world but may occur more frequently.

If the ground is frozen but is subjected to thawing ambient conditions over long periods of time, lesser degradation will occur over extensive lengths of open trench. Ambient conditions and solar radiation will cause thaw. Thawing will cause a flow of water which speeds up the process. If left open long enough, the trench will assume a "U" shape with substantial widening of the top. The seriousness of this type of degradation is that it will occur wherever the soil has excess ice content and is subjected to thawing conditions.

8. SLOPING GROUND CONDITIONS

All the problems that can occur in flat ground trenches can occur in sloping ground but there are several conditions that can change the severity and extent of the ditch degradation. Unfortunately only one of these is positive. It is somewhat uncommon to find as high a water table in sloping ground as in flat ground, although there can be seepage within the active layer, and therefore the potential for extremely wide ditches to occur during excavation is substantially less.

On the other hand the nature of the sloping ground tends to concentrate surface waters, and if these waters break into a ditch a large inflow of sediment may occur. Further, the large volumes of water flowing along the longitudinal slope in the ditch can cause heavy hydraulic erosion and/or thermal erosion. If the longitudinal slope is steep enough, the sediment moves down slope and there is no healing from deposition of sediment.

Also on sloping ground there is likely to be an embankment on the uphill side of the ditch composed of the TAPS work pad plus the extension of the pad by Napline. This embankment will cause higher shear stresses in the soil weakened by excess pore pressure during thawing and increases the likelihood of mass movements of soil into the ditch.

9. CONCLUSIONS

After the systematic evaluation of the conditions that cause degradation and the tentative schedules and modes of Napline construction, it is concluded that there is a low probability that ditch degradation can endanger the support and therefore the integrity of the TAPS oil line. This conclusion is based on the relatively wide planned separation between the two lines and the absence of such extensive lateral ditch degradation during the TAPS work. There appears to be little chance for damage to the Haul Road or the fuel gas line from ditch degradation.

There will be ditch degradation, however, and it can be critical from the standpoint of progress and cost. Severe ditch degradation was encountered in the TAPS work and it must be remembered that the ditch was excavated mostly in "thaw stable" materials. In contrast, Napline will be placed in a ditch through all soils. A matrix has been developed to identify the conditions that will generate the degradation and an evaluation has been made of the effects of potential degradation in a relative manner. This matrix is presented as Table 1.

The numbers 1 to 5 on Table 1 represent a comparison to a "0" case. The "0" case represents a minimum depth ditch excavated in thawed non-saturated but moist silty sand with some apparent cohesion and with side wall slopes of about 4 vertical to 1 horizontal. If such a ditch is excavated and backfilled within 5 days there should be little if any degradation. A rating of 1 on the table indicates a condition that is very little worse than the "0" case; a 5 rating indicates the potential for severe degradation, with the intervening numbers representing intermediary conditions. The rating numbers can be combined for different conditions to give an approximate relative rating. Any singular rating of 4 or 5 or any combined rating of 6 or more should be considered as a red flagged item for attention. Any singular rating of 3 over a lengthy section of line should be red flagged.

TABLE 1

RELATIVE[a] EFFECTS OF SOME CONDITIONS ON DITCH DEGRADATION

Condition[f]	Permafrost[b] Silts[d]	Permafrost[b] Sands[e]	Thawed[c] Silts[d]	Thawed[c] Sands[e]
Early Spring Ditching	0[g]	0	1[h]	1
Summer Ditching	4	4	0	0
Late Fall Ditching	2	2	0	0
Cross Slope >5%	4	3	2	2
Cross Slope >5% Long Slope >10%	5[i]	4	2	2
High Water Table	N/A	N/A	4	4
Five Day Open Ditch	0	0	1	1
Fifteen Day Open Ditch	4	4	2	2
Thirty Day Open Ditch	5	5	3	3
Early Spring Work Pad Construction	1	1	1	1
Summer or fall Work Pad Construction	3	3	0	0
Shallow Burial	0	0	0	0
Deep Burial	2	2	3	3
Low Ice Content Soil	2	2	N/A	N/A
Moderate Ice Content Soil	3	3	N/A	N/A
High Ice Content Soil	4	1	N/A	N/A

[a]As compared to 0-case (see Text).

[b]Soils containing permafrost but may have talik zones.

[c]Non-permafrost soils but may be seasonally frozen.

[d]Includes MH, ML, SM, GM soils.

[e]Includes SW, CW, SP, GP soils.

[f]Conditions are not independent. See text for discussion.

[g]0 denotes no significant increase in degradation over 0-case.

[h]1 denotes slight increase in degradation potential over 0-case.

[i]5 denotes potential for massive or extensive degradation as compared to 0-case.

Application of the matrix on a mile-by-mile basis, after geotechnical and thermal data are collected, will permit identification of site specific problems and an evaluation of the potential severity of the problem.

Review of the matrix also indicates some actions that can be taken to prevent or mitigate the most severe degradation. These are self-explanatory and are merely listed below:

1. Early pad construction prior to breakup would be helpful in permafrost soils provided that snow and ice are removed.
2. Early spring ditching would be helpful in both permafrost and thawed soils. Late fall ditching will be of some help.
3. One of the most positive means of preventing ditch degradation in permafrost soils is to backfill the ditch as fast as possible.
4. Control of surface water will contribute very strongly to ditch stability.
5. Shading of moderate or high ice content soils gives some promise of being helpful.
6. A clean smooth vertical ditch wall will be helpful in preventing permafrost melt as it will present the least surface to the ambient temperature or solar heat. Line blasting of the walls will probably provide the best practical method to obtain the smooth wall.
7. Realignment some 20 to 30 feet further away from the TAPS work pad or Haul Road will be helpful on steep slopes or in granular flood plains with high water table.

Many or all of the mitigating actions listed above will require separate activity and generate costs. No attempt has been made to determine if any of them are cost effective.

9.1 Problem Management Strategy

Several strategies could be developed for handling the problem of ditch degradation. If left to the contractors, most of them would probably adopt the gambling attitude of coping with the degradation as it occurs. Very little planning and design for mitigation would be done. On the other hand the conservative design engineer would probably try to identify and categorize all site specific cases and provide a specific design for each. It would be prudent for Napline Project Management to adopt a course in between these two. This middle course would utilize Table 1, terrain maps, subsurface data and project schedules to categorize the relative severity of the potential problems along the alignment. For those areas with a high rating (singular rating of 4 or 5 or combined rating of 6 or higher) specific designs should be developed to mitigate the effects. For a singular rating of 3 generic solutions might be developed that field forces can apply as needed. For any rating of 1 or 2 or combined rating of 4, 5 or 6 (unless one of the ratings is a 4 or 5) the solutions would be left up to the field forces. In other words no significant preventive measures expenditures would be made for such ratings. This does not imply that corrective costs will not be incurred in some place but the frequency and magnitude of the corrective costs are not likely to be large so do not warrant preventive measures.

10. RECOMMENDATIONS

It will require a mile-by-mile analysis of the pipeline route as well as a detailed analysis of the construction modes and schedule to determine the linear extent of the various critical conditions outlined in the matrix. The study will be required to evaluate where the cost of preventive action will be less than the costs of ditch degradation if no action is taken. It is recommended that a preliminary mile-by-mile analysis be made as soon as sufficient data are available.

Upon determination of the critical areas from the above study, it is recommended that site-specific mitigative plans be developed. These would include passive fixes such as revision of schedules or modes or active fixes such as surface water control designs, shading, clean side wall designs or alignment shifts.

It is believed that one of the most serious potential problems involves steeply sloping ground where the alignment parallels aboveground TAPS construction. The amount of thawing beneath the TAPS pad is not known. Neither is it known how much the advancing thaw will adversely affect the stability of the pad. Therefore, it is recommended that two or three such locations be selected and investigated during the summer of 1978. The investigations should include probing the TAPS work pad and down hill from it to determine top of permafrost. Vane shear tests and peizometer readings should be made at the permafrost surface. If feasible a backhoe should be used to open a trench at the toe of the work pad to observe the action of the embankment. With this information together with the configuration of the work pad, an analytical model can be developed that will help to predict the effects that may occur when the Napline trench is excavated.