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Ditchwall database for the Norman Wells to Zama Oil Pipeline
Volume III:
Summary of Ditchwall database evaluation

Geo-engineering (M.S.T.) Ltd.

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Energy, Mines and
Resources Canada

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Ressources Canada

Canada

INTERPROVINCIAL PIPE LINE COMPANY
NORMAN WELLS
TO
ZAMA OIL PIPELINE

SUMMARY
OF
DITCHWALL DATABASE
EVALUATION

Prepared for:
GEOLOGICAL SURVEY OF CANADA
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1.0 INTRODUCTION

Geo-Engineering (M.S.T.) Ltd. was retained by the Geological Survey of Canada to compile as much of the available geotechnical information as possible from the Daily Ditch Logs for the Norman Wells to Zama oil pipeline, and to create a readily-accessible computerized database. This work has been completed and this report serves to summarize some of the major findings or trends, and demonstrates the potential uses of the database. A separate report, documenting the actual coding and creation of the database, was also prepared as the first phase to the study, and is entitled "Interprovincial Pipeline Company Norman Wells to Zama Oil Pipeline - Ditchwall Database Documentation."

Terms of reference for this component of the task were established in our proposal of March 1991 and are summarized below:

- Comparison of ditchwall information with terrain typing.
- Comparison of ditchwall information with continuous geophysics.
- Comparison of ditchwall information with the available borehole databases.
- Produce statistical summaries of pertinent data with terrain and kilometer post-breakdowns.
- Produce a summary report documenting the above findings, and assigning confidence factors to the data.

Due to difficulties in compiling the geophysical and ditchwall log information, we were unable to compile/compare the borehole information within the scope of this study.

Several sources of information/references were used in compiling and analyzing the ditchwall database. These included the following:

- Daily Ditch Logs - Norman Wells to Zama Pipeline, Interprovincial Pipe Line (NW) Ltd.

- As-Built Alignment Sheets - Norman Wells to Zama Pipeline, Interprovincial Pipe Line (NW) Ltd.

- Permafrost and Terrain Research and Monitoring: Norman Wells Pipeline - Volume I Environmental and Engineering Considerations, Environmental Studies No. 64, Indian & Northern Affairs Program, 1988.

- Permafrost and Terrain Research and Monitoring: Norman Wells Pipeline - Volume II Research and Monitoring Results: 1983-1988, Indian & Northern Affairs Program, 1988.

- Relationships Between Soil Parameters and Wheel Ditch Production Rates in Permafrost - Masters of Engineering Project - R. Saunders, University of Alberta, April 1989.

- Permafrost and Thermal Interfaces from Norman Wells Pipeline Ditchwall Logs, Nixon et al, Canadian Geotechnical Journal, October 1991.

- Norman Wells Project - Delineation of Permafrost Distribution by Geophysical Survey Volumes I to VI, Hardy Associates (1978) Ltd., September 1982.

- Norman Wells Project - Delineation of Permafrost Distribution by Geophysical Survey Spread 5, KP 722.7 to KP 868.3, Hardy Associates (1978) Ltd., August 1981.

Authorization to proceed with the study was received by means of Contract No. 23397-1-0308/01-055 dated May 23, 1991.

2.0 BACKGROUND

The Norman Wells to Zama Oil Pipeline was constructed during the winter months of 1983/84 and 1984/85. During construction, geotechnical and trench conditions were regularly documented by pipeline inspection personnel. This information was summarized on what were referred to as the Interprovincial Pipe Line (NW) Ltd. - Norman Wells to Zama Pipe Line - Daily Ditch Logs.

Prior to construction, a continuous geophysical survey, using electrical conductivity methods, was undertaken along the entire pipeline alignment by Hardy Associates (1978) Ltd. in 1981 and 1982. The variance between electrical conductivities for frozen and unfrozen soil was used to interpret whether terrain was frozen (permafrost) or unfrozen. Details of the interpretation can be found in the original geophysical reports referenced in this report.

The ditchwall logs and the continuous geophysics have now both been entered into databases, so information between them could be compared. This report summarizes some of our findings using the databases, but in no way reflects all the possible information which could be correlated or extracted from them.

3.0 EVALUATION OF DATA

Once the ditchwall database had been compiled, simple selection techniques common to all database programs were used to extract blocks of data, to determine what trends in the data existed, and if the results supported our anticipated expectations. Primary selection criteria, in general, was either by terrain-type or kilometer post.

Some of the more illustrative correlations/findings are presented in the next sections. The first section summarizes information based on dominant terrain unit occurrences. The second section presents similar information but summarized by kilometer post. The third and fourth sections summarize frozen/unfrozen ground distribution, and presents comparisons between the ditchwall database and the continuous geophysics.

3.1 TERRAIN UNIT BREAKDOWNS

Terrain-type serves as a means of grouping clusters of information that we anticipate being similar on the basis of geological origin and, consequently, similar soil type, organic cover, etc. Terrain-typing is normally undertaken by personnel experienced in surficial geology and recent geological processes, combined with skill in air photo interpretation. Areas of similar geological origin are classified as terrain units and are normally identified on an air photo or photomosaic. This makes terrain-typing and air photo interpretation very cost-effective when evaluating a pipeline alignment as opposed to drilling. Therefore, there is a great deal of interest in assessing the "accuracy" of terrain-typing in relation to actual conditions in the field.

Three important parameters have been correlated to terrain-type in this study and include soil type, thickness of peat and cobble frequency. The results of our findings are discussed below.

3.1.1 Dominant Terrain-Type Occurrence

In order to investigate the dominant soil types for the major terrain units, the major terrain units were established from the ditchwall database. As the ditchwall logs occur roughly equally-spaced along the pipeline alignment, the percent occurrences by terrain unit from the actual ditchwall logs was used to determine the dominant terrain unit occurrences. It is our experience this approach is approximately the same as using the continuous terrain occurrence information.

Using this technique, it was discovered, that of the many terrain units encountered on the pipeline alignment, seven of them constitute approximately 85 percent of the route. These terrain units and their percentage breakdowns are shown in Figure 1.

3.1.2 Soil Type by Terrain Unit Breakdown

Each of the seven dominant terrain units were then examined individually, and the breakdown of soil types for each terrain unit determined, as shown in Figure 2.

As can be seen, the thick organic terrain units of OU-MG and OU have the greatest component of peat or organic silt occurrences as expected. In addition, we would anticipate the lacustrine terrain units of LP, LP-MG and OV-LP to have the highest percentages of lacustrine soils (clays/silts and sands). The results in Figure 2 also tend to support this theory. In the case of LP, for example, the percentage of soil types encountered that were lacustrine was 77 percent. This particular correlation with terrain-type is extremely good.

The occurrence of till was also reasonably reflected in the breakdown, being over 65 percent in the terrain unit, MG, and representing over 50 percent of the soil types encountered in OV-MG, LP-MG and OU-MG.

On the basis of this comparison, the terrain-typing appears to correlate quite well with soil logging in the ditchwall database.

3.1.3 Peat Thickness by Terrain Unit Breakdown

The actual thickness of peat was measured at most ditchwall locations. Therefore, an average thickness of peat was computed for the main terrain units for every ditchwall log with a measured peat thickness. These average peat thicknesses are shown in Figure 3. It should be noted that, in the case of thicker organic units, where the thickness of peat was greater than the depth of the ditch (typically 1.2 m), the depth of the ditch was used in the calculation and these averaged thicknesses will not be representative. These thicknesses, therefore, serve more as an indicator of relative peat thickness in terrain units where depth of peat exceeds 1 m.

However, notwithstanding the above limitations, we can see that the average thickness of peat for non-organic terrain units is around 0.3 m (e.g. LP, MG and LP-MG), and around 0.45 m in the case of terrain units with a veneer of organics (e.g. OV-LP and OV-MG). Based on discussions with experienced air photo interpretation personnel in our company, the terrain modifier “veneer” generally refers to thicknesses of organics less than 0.6 m (2 ft.). Peat thicknesses in excess of this are generally classified as OU to reflect blankets, fens, etc. As can be seen in Figure 3, the two thicker organic terrain units of OU-MG and OU do actually reflect thicker peat thickness, varying from 0.9 to 1.0 m.

Based on the above, the ditchwall log information tends to support the terrain-type (air photo interpretation) very well with respect to thicknesses of peat.

3.1.4 Cobble Occurrence by Terrain Unit Breakdown

The occurrence of cobbles in the ditchwall, or base of the trench, was considered a potentially serious problem during construction, which could have lead to point-loading of the pipe when or if settlement occurred. To alleviate this problem, select bedding or sand bags were placed under the pipeline in these areas.

The criteria set for the ditchwall inspector to flag the occurrence of cobbles was when two or more 150 mm diameter or greater cobbles were encountered within 10 m of each other in the trench, and would continue for 50 m past the last occurrence.

The presence of cobbles from a geological standpoint generally would be primarily associated with alluvial, glaciofluvial or moraine deposits. As alluvial and glaciofluvial terrain units are relatively minor in occurrence in relation to the entire pipeline length, the terrain unit, MG (ground moraine) reflects the largest terrain unit where we could expect cobbles. It should be stressed, however, that because a material is till, does not necessarily mean it must have cobbles, but rather if cobbles are present and one is not in an alluvial or fluvial terrain unit, one is likely dealing with a ground moraine.

Figure 4 presents the summary of cobble occurrence by dominant terrain unit. As can be seen, the highest percentage of cobble occurrences are found in the terrain units of MG and LP-MG (32 and 42 percent, respectively). Therefore, cobble occurrence seems to generally support the assumption that more cobbles should be found in moraine than lacustrine or organic terrain units.

3.2 KILOMETER POST BREAKDOWN

As the Norman Wells Pipeline traverses some 869 kilometers, it is reasonable to anticipate soil and permafrost conditions should vary considerably over its length. For the purposes of our summaries, we have broken the pipeline route into 50 kilometer intervals (except for KP 800 to 869.483, which were grouped together). Summaries of soil type, peat thickness and cobble occurrence for this breakdown were also calculated similar to the terrain unit breakdown and the results are presented below.

3.2.1 Terrain Units by Kilometer Post Breakdown

To establish the general variation of surficial geology along the pipeline route, the percentages of occurrence of the previously identified dominant terrain units, were established for each 50 kilometer interval and the results are shown in Figure 5.

As can be seen, lacustrine terrain units LP, LP-MG or OV-LP, dominate the first 350 km of pipeline route. In that same interval, thicker organics are almost non-existent, and till is a minor unit. Between KP 350 and KP 850, moraine terrain units MG and OV-MG become much more dominant, with the exception of around KP 500, where lacustrine terrain dominates. From KP 600 to the end of the route, the thicker organic terrain units of OU and OU-MG, become more significant and dominate around KP 750 to KP 800.

This terrain unit occurrence breakdown will be referred to in the next sections, which relate to soil type, peat thickness and cobble occurrence.

3.2.2 Soil Type by Kilometer Post Breakdown

Soil conditions were grouped in a similar fashion as for the terrain unit breakdown, and the results presented as Figure 6.

As can be seen, lacustrine soil types (clay/silt and sand) tend to dominate the breakdown from KP 100 to KP 350. Till tends to dominate the kilometer post breakdown from KP 400 to the end of the route, except around KP 550 to KP 600, where lacustrine soil types dominate.

The percentages of ditchwall logs with thick organics (i.e. no mineral soil) was variable, but was greatest (approximately 35 percent) between KP 550 and KP 600.

This is generally supported by the terrain-type occurrences in Figure 5, but there are some areas where the correlation is not as strong.

3.2.3 Peat Thickness of Kilometer Post Breakdown

Peat thicknesses for all terrain units were averaged for each 50 kilometer interval along the pipeline route, and the results are summarized in Figure 7. The first 350 km of pipeline route reflects peat thicknesses typically between 0.25 and 0.35 m. From KP 400 to the end of the route, peat thicknesses ranged from 0.58 to 0.83 m.

Comparing Figure 7 with the terrain unit breakdowns in Figure 5, it is apparent that the thicker organics primarily occur in the organic terrain units, which are concentrated in the southern half of the route. It would, therefore, appear that a stronger correlation of peat thickness occurs with terrain-typing, rather than by kilometer post alone.

3.2.4 Cobble Occurrence by Kilometer Post Breakdown

The occurrence of cobbles was identified for each 50 kilometer interval, similar to the terrain unit breakdown and the results are summarized in Figure 8. It appears the frequency of cobbles is higher in the northern half of the pipeline route than in the southern half. This is generally reasonable in the sense that cobbles are less likely to occur in more organic terrain than in other terrain units. However, correlating the cobble frequency with either terrain occurrence or kilometer post is difficult, and only a loose correlation at best can be justified.

It is also possible that the cobble criteria was not adhered to equally along the pipeline alignment, and it is possible it may have been enforced more rigidly in areas where few sections required select bedding, as opposed to portions of the route where select bedding was required more frequently.

3.3 FROZEN GROUND DISTRIBUTION

The ditchwall logs contain information on the thermal condition of the ditch. For the purposes of this summary, only the condition of the ditch bottom was investigated; as a result, any frozen over unfrozen conditions (F/U) were considered unfrozen (U).

The ditchwall log generally will reflect thermal conditions at approximately 1.2 m below existing grade. As this depth is relatively shallow in relation to active layer thicknesses, the validity of the ditchwall database to identify permafrost conditions is somewhat controversial. The recent paper by Nixon et al (1991) outlines the difficulties in using the ditchwall logs for this purpose.

Some of the possible geothermal situations that could prevail adjacent to the ditchwall are illustrated in Fig. 9. In cases A and B shown in this figure, the normal situations for permafrost (i.e. frozen) and seasonal frost (i.e. unfrozen) are outlined. The more difficult situations, where the ditchwall log could be interpreted incorrectly, are illustrated by cases C and D. In case C, the permafrost table could have extended beneath the trench base, and the ditchwall inspector would likely have logged this as an unfrozen situation. However, MacInnes et al (1988) reports that in the first few years following construction, the thickness of active layer along the Norman Wells pipeline route immediately off the cleared rights of way to be generally less than 1.0 m. One could argue that the right of way would not have had time to deepen significantly between clearing, and the subsequent ditching and logging of interest here. Therefore, the depth of ditch possibly would not tend to exceed the depth of the active layer in this case. However, this would only apply to newly-cleared rights of way and would not apply necessarily to previously cleared rights of way. Consequently, the distribution of frozen ground summaries were broken down to reflect different right of way conditions and to explore this further.

Three types of right of way conditions are identified in the ditchwall database; newly-cleared (NEW), CNT cutlines (CNT) and other previously cleared rights of way (OTH). Figures 10 to 12, inclusive, summarize the frozen ground distribution for these right of way conditions, respectively. Figure 13 presents the frozen/unfrozen ground distribution for the entire pipeline right of way, based on the ditchwall logs alone.

As can be seen, the impact of right of way disturbance is not strongly defined by the ditchwall logs; however, the following points can be made:

- the previously cleared R.O.W., other than the CNT, is predominantly unfrozen (which could reflect a deeper active layer),
- the CNT cutline appears predominantly frozen; however, it exists only in the northern half of the pipeline, and
- the greatest extent of unfrozen ground occurs around KP 650 and does not appear to be directly associated with right of way disturbance.

These findings tend to support the validity of using the ditchwall logs as a rough indicator of permafrost conditions. If, for example, the CNT line had indicated high percentages of unfrozen segments, we would have to acknowledge a greater percentage of the ditchwall logs identify deeper active layers rather than unfrozen terrain. However, since the greatest amount of the CNT line was logged as frozen, it suggests the error may not be significant. It would, therefore, be worthwhile, in the future, to check the active layer thicknesses at numerous locations on the CNT portion of the pipeline right of way.

3.4 COMPARISON WITH CONTINUOUS GEOPHYSICS

One of the identified goals of creating the ditchwall database was to compare the results of the frozen/unfrozen ground logging to the results of the continuous geophysics.

To investigate this further, the continuous geophysics was digitized from the original geophysics reports, and a continuous file, summarizing the length of each frozen/unfrozen segment, created. To further make this geophysical database more useful, the old kilometer posts and slack chainages were converted as closely as possible to as-built kilometer posts. This process was quite complicated and involved two steps. The first step was to adjust the slack station chainages from individual points of inflection (P.I.'s) to original kilometer post values. This involved a scaling process to adjust the slack chainages to fit between the P.I.'s. All physical features referenced in the geophysics, such as creek and river crossings, pipeline crossings and road crossings, was compiled, and then a set of correlations or conversion equations was developed, which related these control points from original kilometer posts to as-built kilometer posts. Figure 14 shows the adjustment factor between the original geophysical kilometer posts and as-built kilometer posts established for this study.

We acknowledge this technique is somewhat crude and may be subject to some error, but we feel the accuracy should be better than ± 100 m, and we are unaware of a more accurate available technique.

For purposes of comparison with the continuous geophysics, a continuous file of thermal conditions was created from the ditchwall database. To create this file, the thermal conditions at each ditchwall log were assumed to extend halfway between itself and the next ditchwall log with valid information. Copies of this file and the continuous geophysics file are provided in the report on the database documentation.

Two primary areas were investigated for comparison purposes between the ditchwall database and the continuous geophysics; frozen ground distribution and number of frozen/unfrozen interfaces per kilometer. These aspects are discussed separately below.

3.4.1 Frozen Ground Distribution

The percentage of frozen ground was determined for each data source by construction spread and by 50 km interval breakdowns, and the results are presented in Figures 15 and 16, respectively.

As can be seen, reasonable comparisons or at least similar trends exist between the two data sources for most of the pipeline alignment for frozen ground distribution.

The percentage of frozen ground by construction spread breakdown shown in Figure 15 indicates a very good correlation between the ditchwall database and the continuous geophysics for identifying regional breakdowns of frozen ground distribution. Similar conclusions, based on kilometer post, can also be made; however, locally, there are more areas of discrepancy as can be seen in Figure 16.

3.4.2 Frozen/Unfrozen Interfaces

A key component of pipeline design in permafrost, centres around the existence and frequency of occurrence of thermal interfaces. That is to say, every time the pipeline crosses a frozen/unfrozen interface, there is the potential for differential settlement or frost heave. Therefore, the attractiveness of using continuous geophysics to identify these conditions over drilling boreholes is of extreme interest to pipeline design.

The frequency of frozen/unfrozen interfaces (presented as interfaces per kilometer) for each data source was calculated by construction spread and by 50 km interval breakdowns, and the results are presented in Figures 17 and 18, respectively. As can be seen, large differences exist between the results from the two data sources, with the ditchwall logs tending to underpredict (or the geophysics tending to overpredict) this condition.

4.0 DISCUSSION

In general, the information contained in the ditchwall database tends to support most of our anticipated expectations. Although some of the results may seem intuitively obvious now that the pipeline is constructed, they are important in that they support or validate the general techniques and design methods used to obtain the information (e.g. terrain-typing and continuous geophysics).

Strong to moderate agreement of soil type, thicknesses of peat and cobble occurrence with terrain-typing methods provide us with more confidence in using this technique when evaluating other pipeline projects. Also, the correlation between the ditchwall logs and the continuous geophysics is good when evaluating overall percentages of frozen/unfrozen ground along a pipeline alignment. This supports the use of geophysics to identify regional permafrost quite well.

The value of the continuous geophysics to accurately identify small occurrences of frozen or unfrozen ground, or quick transitions, however, is not fully-supported by the ditchwall logs. As the ditchwall logs were generally recorded every 100 m, one could argue some interfaces were missed, and this is one possible explanation for the differences in a number of interfaces per kilometer post between the ditch logs and the geophysics. On the other hand, the interpretation of the geophysics could be confusing local changes in soil conditions to be thermal changes.

In the extreme southern portions of the route (i.e. Construction Spread #6), the differences between the continuous geophysics and the ditchwall logs is the greatest. However, it also appears that the spacing of ditch logs in Spread #6 is often very close and it seems the ditch inspectors were trying to identify variations in ditch conditions more accurately than in some other construction spreads, where the spacing of the logs is exactly 100 m. If this was the case, one would anticipate that the ditchwall logs should not have missed small occurrences of frozen/unfrozen ground due to wide spacing.

It is unlikely we will be able to completely resolve this issue, as reasonable arguments can be made for both interpretations. In quite likelihood, actual conditions may be somewhere between the two cases.

5.0 FUTURE WORK

Two areas of further study have already been suggested, which could be addressed in future work.

The first suggestion is to convert the ditchwall logs to a more meaningful co-ordinate system, perhaps, the UTM system with Northings and Eastings. This task is considered to be feasible, providing that the Interprovincial Pipe Line Company can provide survey information for major points of inflection along the pipeline route. If this information is available, Northings and Eastings would be calculated from the as-built kilometer chainages and the accuracy is expected to be quite reasonable.

The other suggestion for future work would be to compare the ditchwall database with existing borehole information. Again, we believe this task to be feasible, and would require conversion of all boreholes on the pipeline alignment into as-built kilometer chainages. Similar summary breakdowns could then be made as presented in this report, but compared to borehole information.

There are undoubtedly other uses that could be made of the ditchwall database. Now that it is computerized, tailor-made databases could be constructed to suit a specific end-user's needs. Changes to the database format for other purposes can be readily accommodated.

6.0 CLOSURE

The findings of our evaluation of the ditchwall database information, in most cases, support our expected results. Good correlations were found to exist with terrain-typing and the continuous geophysics, except for the frequency of thermal interfaces.

Respectfully submitted,

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Senior Geotechnical Engineer

RS/jlw

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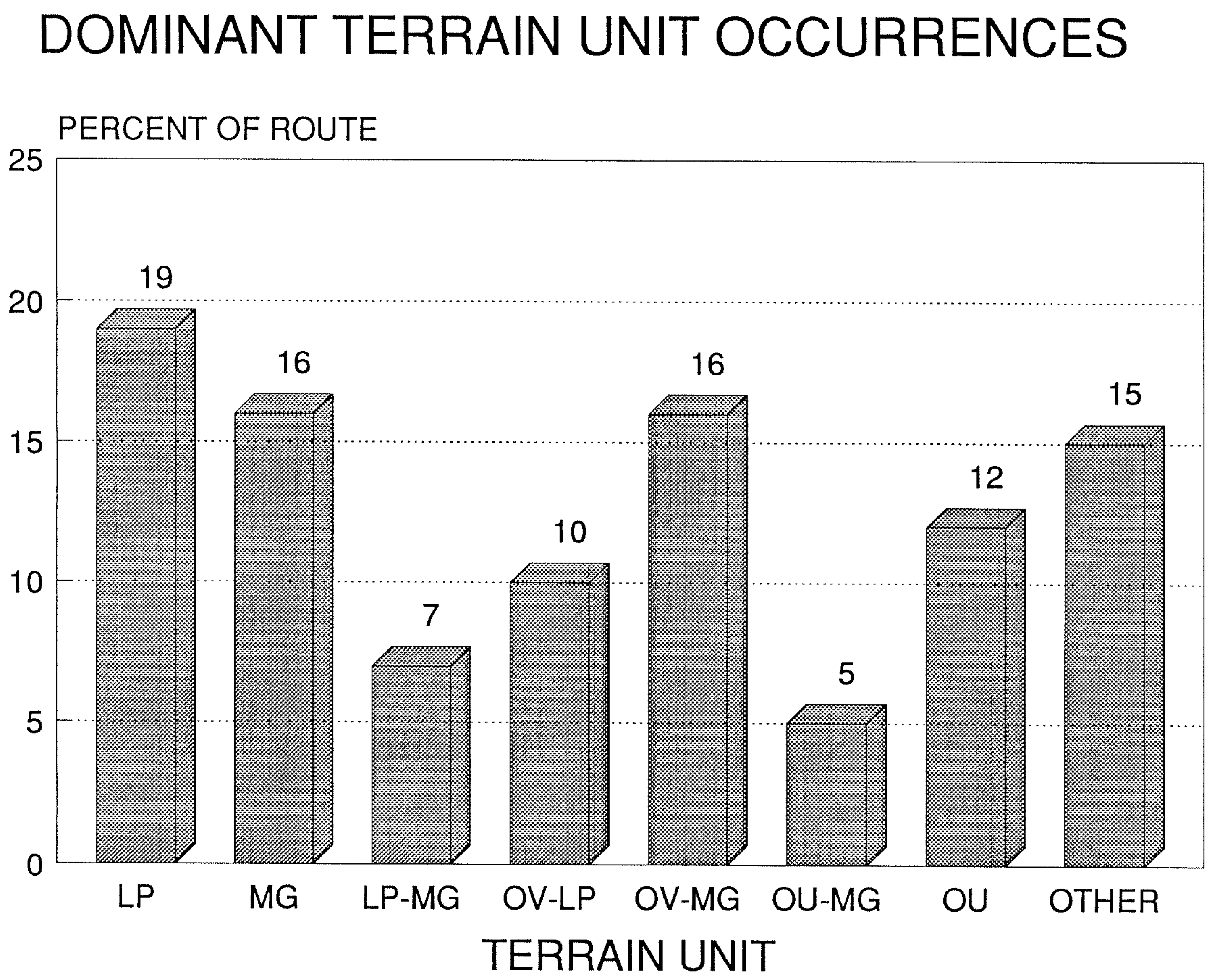
APPENDIX A

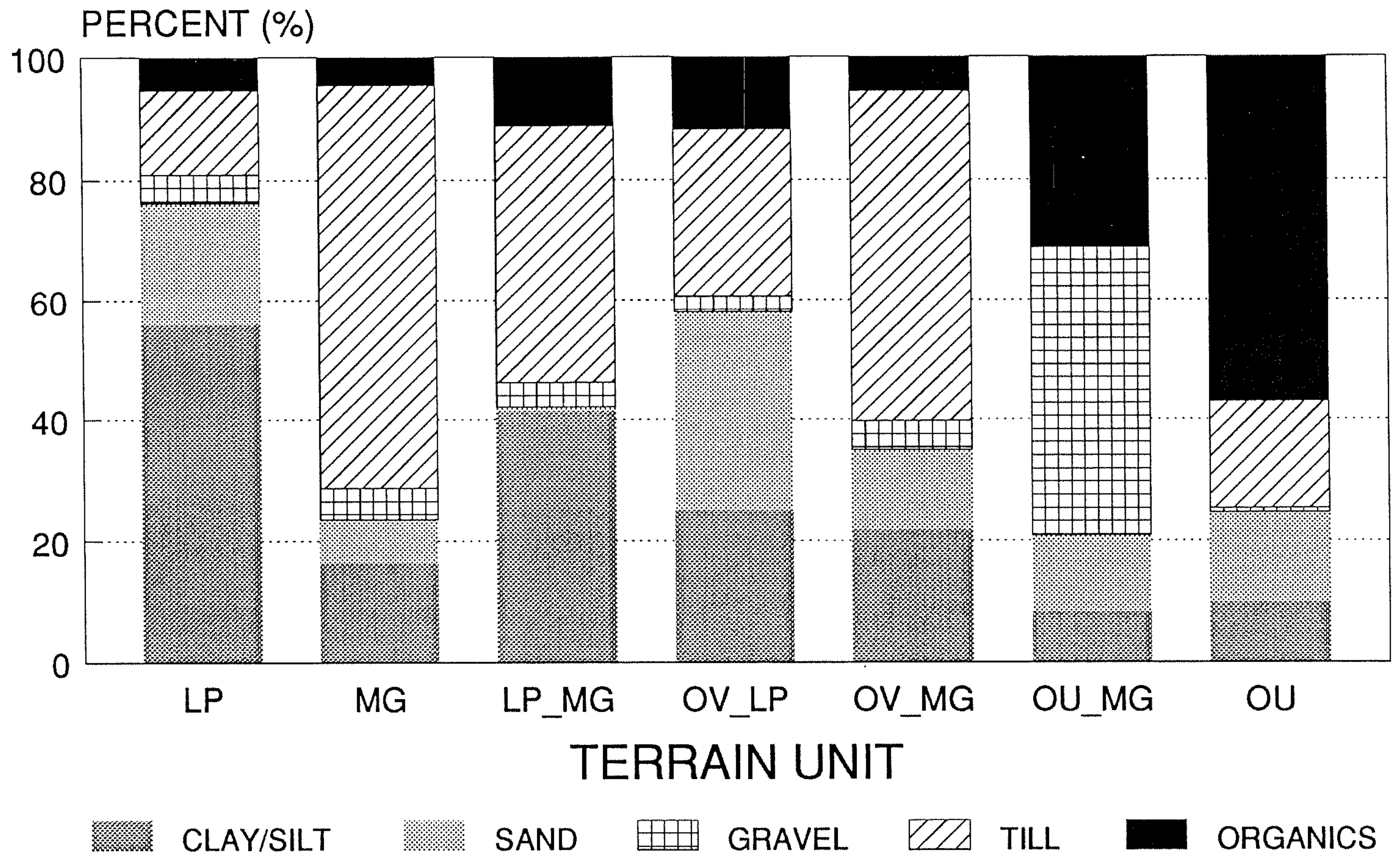
FIGURES



DITCHWALL DATABASE

FIGURE 1

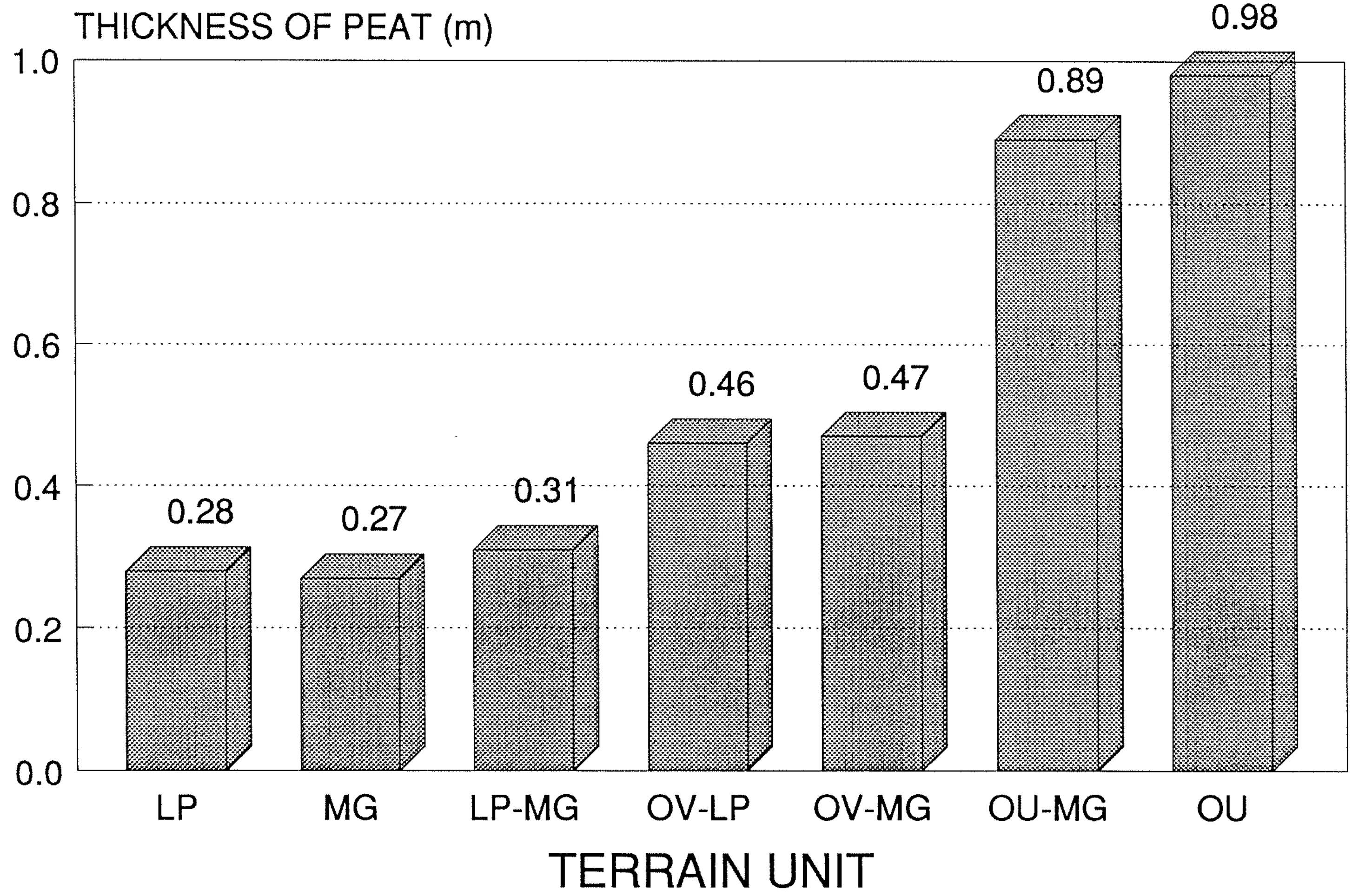
SUMMARY OF MAJOR SOIL GROUPS
TERRAIN UNIT BREAKDOWN



DITCHWALL DATABASE

FIGURE 2

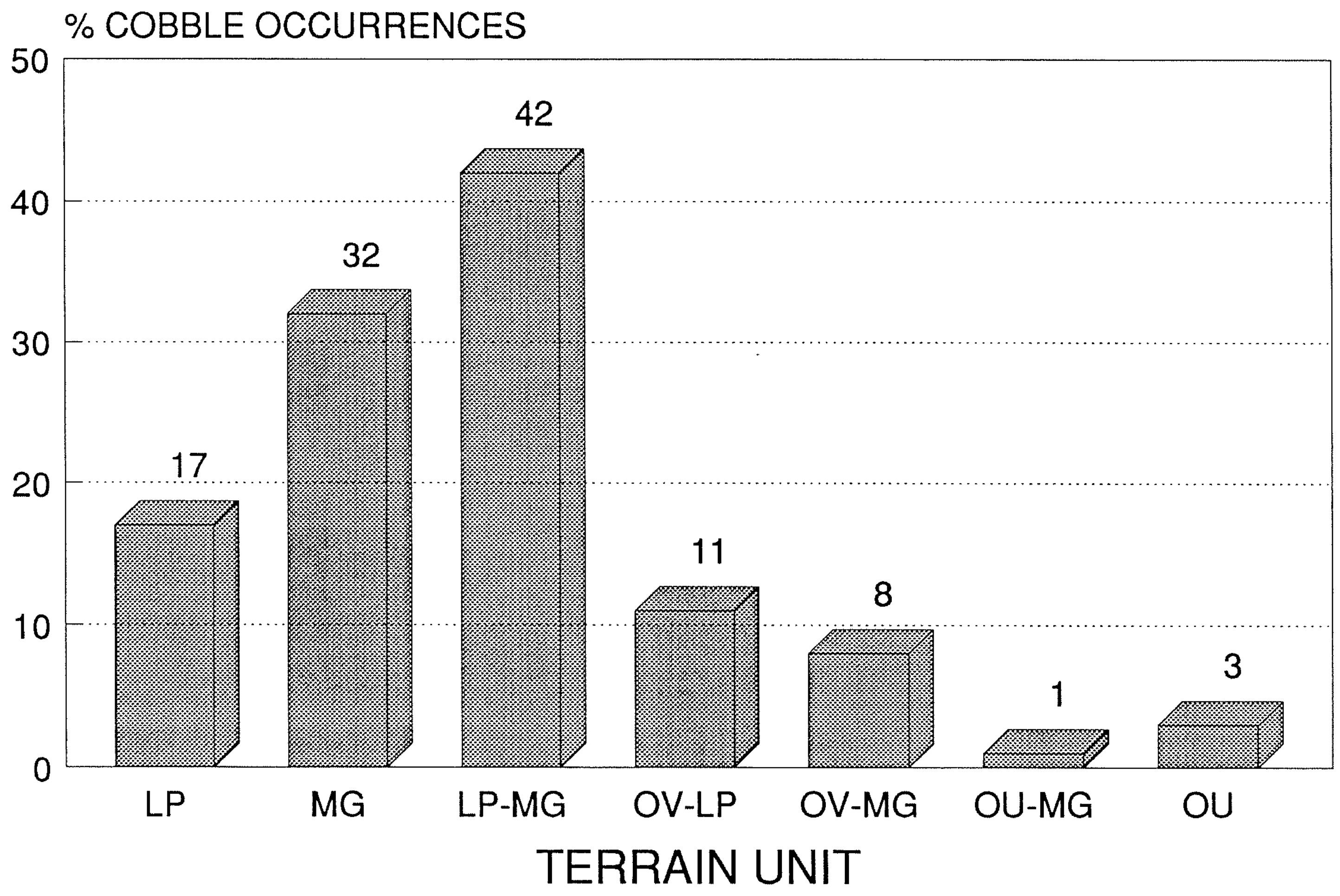
SUMMARY OF PEAT THICKNESS
TERRAIN UNIT BREAKDOWN



DITCHWALL DATABASE

FIGURE 3

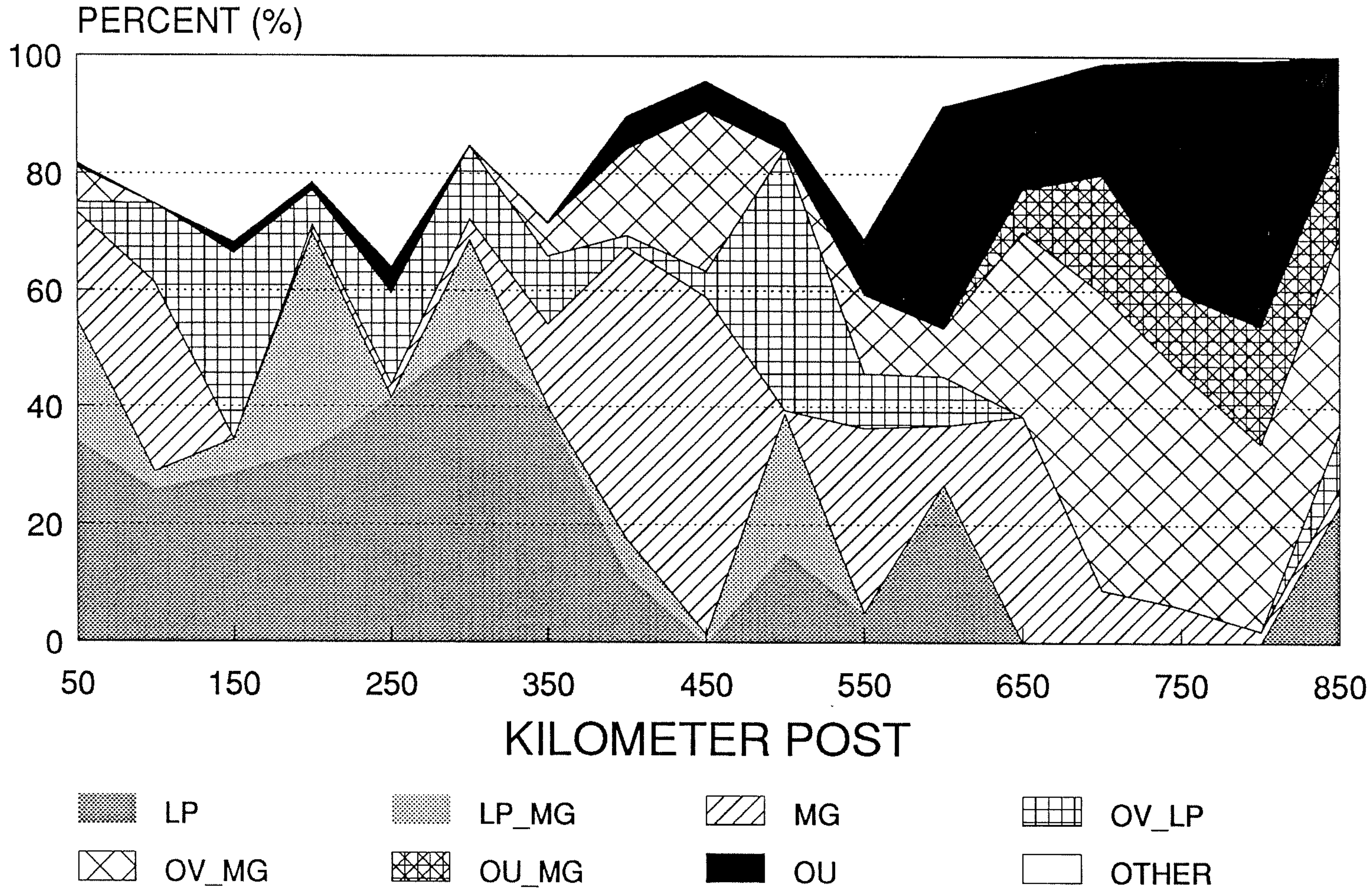
SUMMARY OF COBBLE OCCURRENCE
TERRAIN UNIT BREAKDOWN



DITCHWALL DATABASE

FIGURE 4

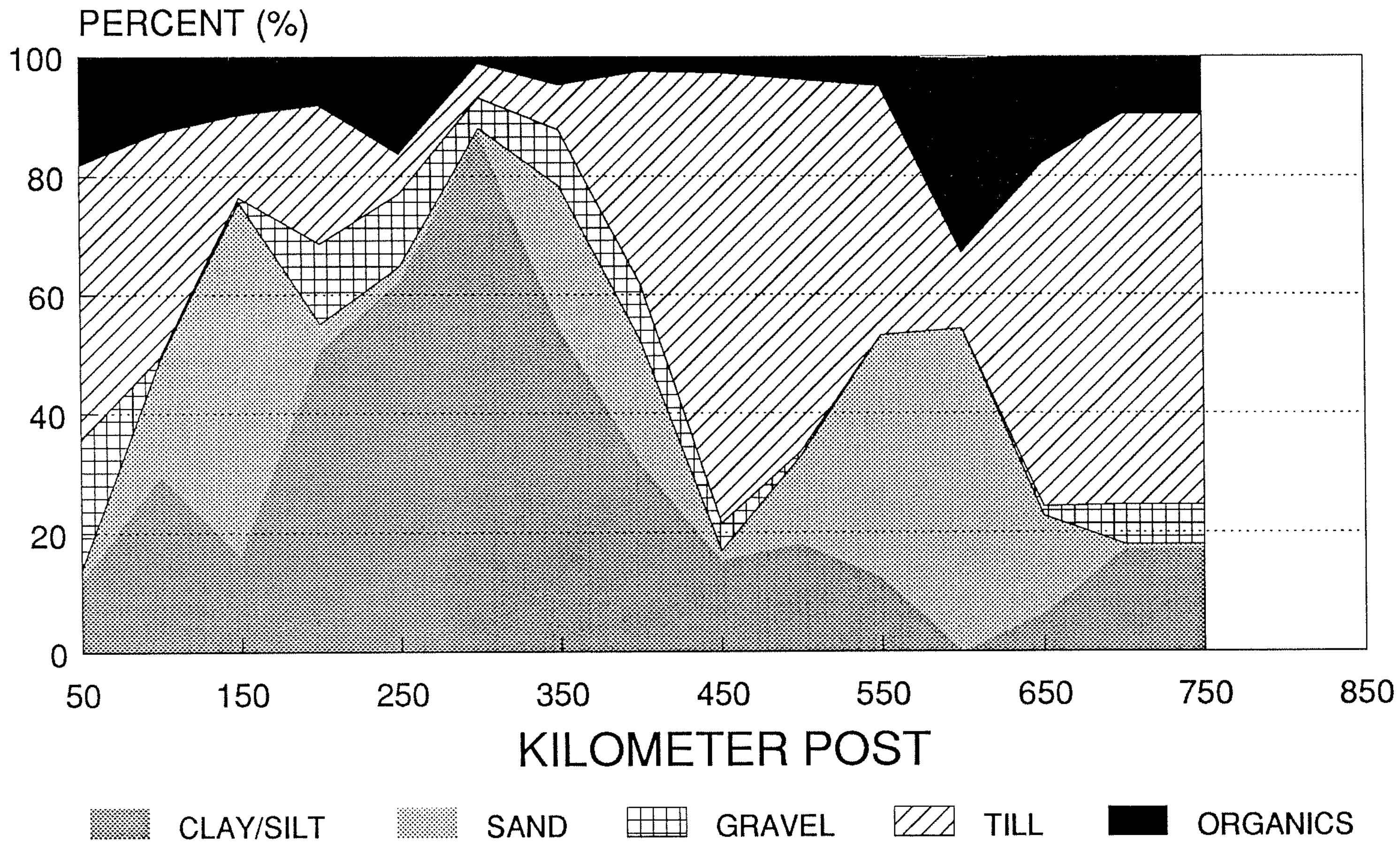
SUMMARY OF MAJOR TERRAIN UNITS
KILOMETER POST BREAKDOWN



DITCHWALL DATABASE

FIGURE 5

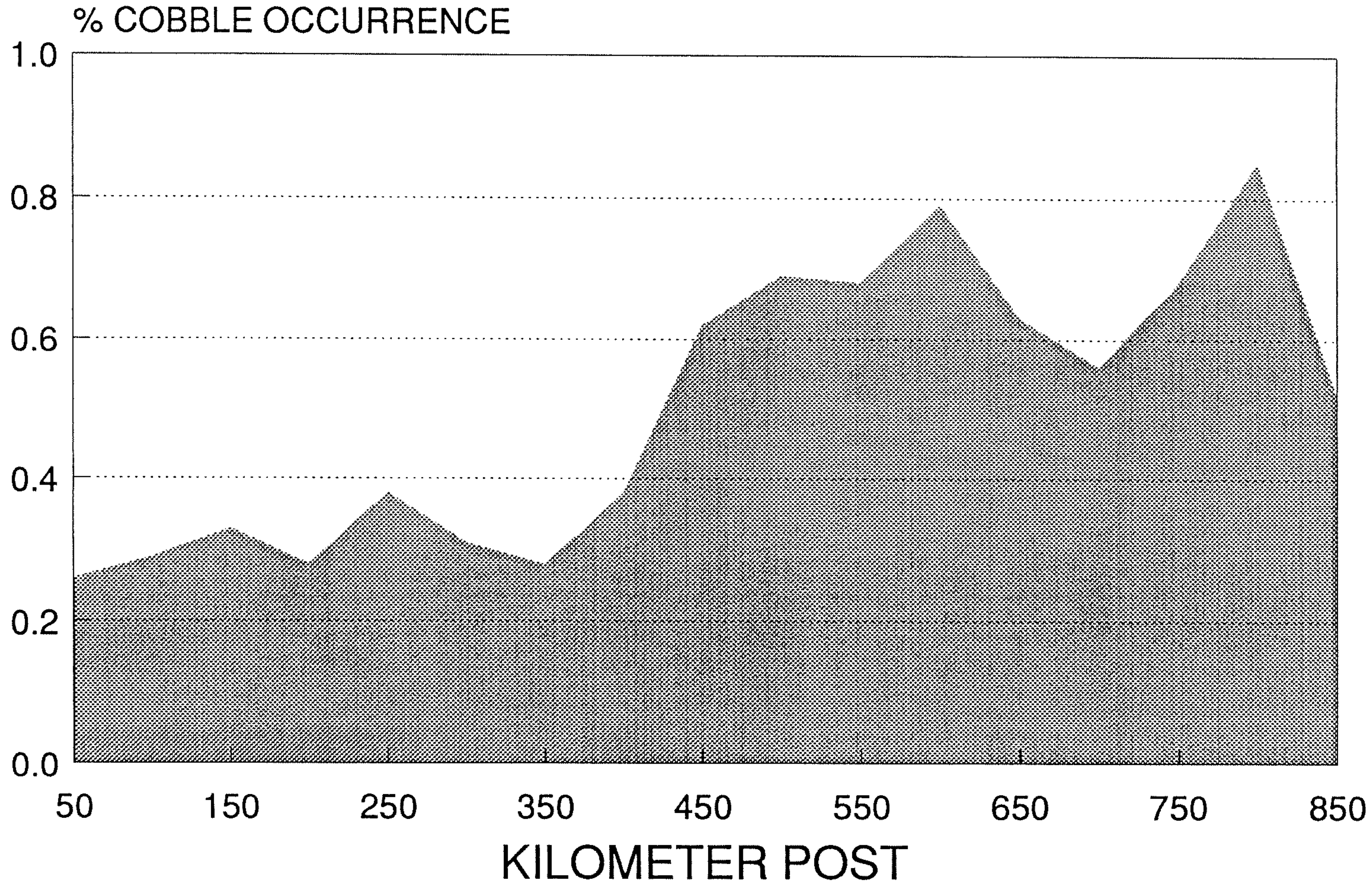
SUMMARY OF MAJOR SOIL GROUPS
KILOMETER POST BREAKDOWN



DITCHWALL DATABASE

FIGURE 6

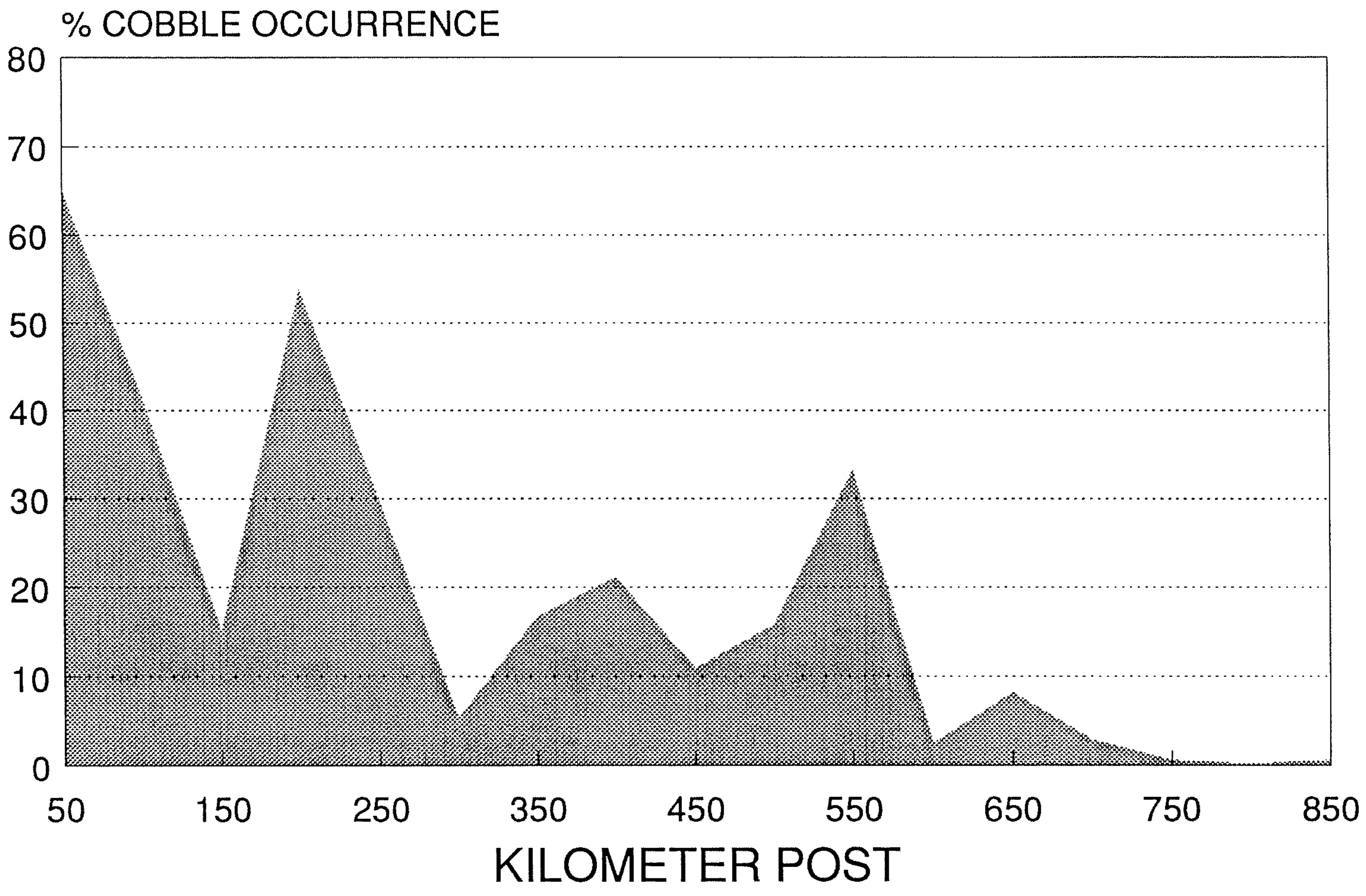
SUMMARY OF PEAT THICKNESS
KILOMETER POST BREAKDOWN



DITCHWALL DATABASE

FIGURE 7

SUMMARY OF COBBLE OCCURRENCE
KILOMETER POST BREAKDOWN



DITCHWALL DATABASE

FIGURE 8

(A) RE-FREEZING ACTIVE LAYER IN PERMAFROST

(B) SEASONAL FROST IN UNFROZEN TERRAIN

(C) RE-FREEZING DEEP ACTIVE LAYER IN PERMAFROST

(D) DEEP SEASONAL FROST IN UNFROZEN TERRAIN

LEGEND

▨ SEASONAL FROST

☐ UNFROZEN

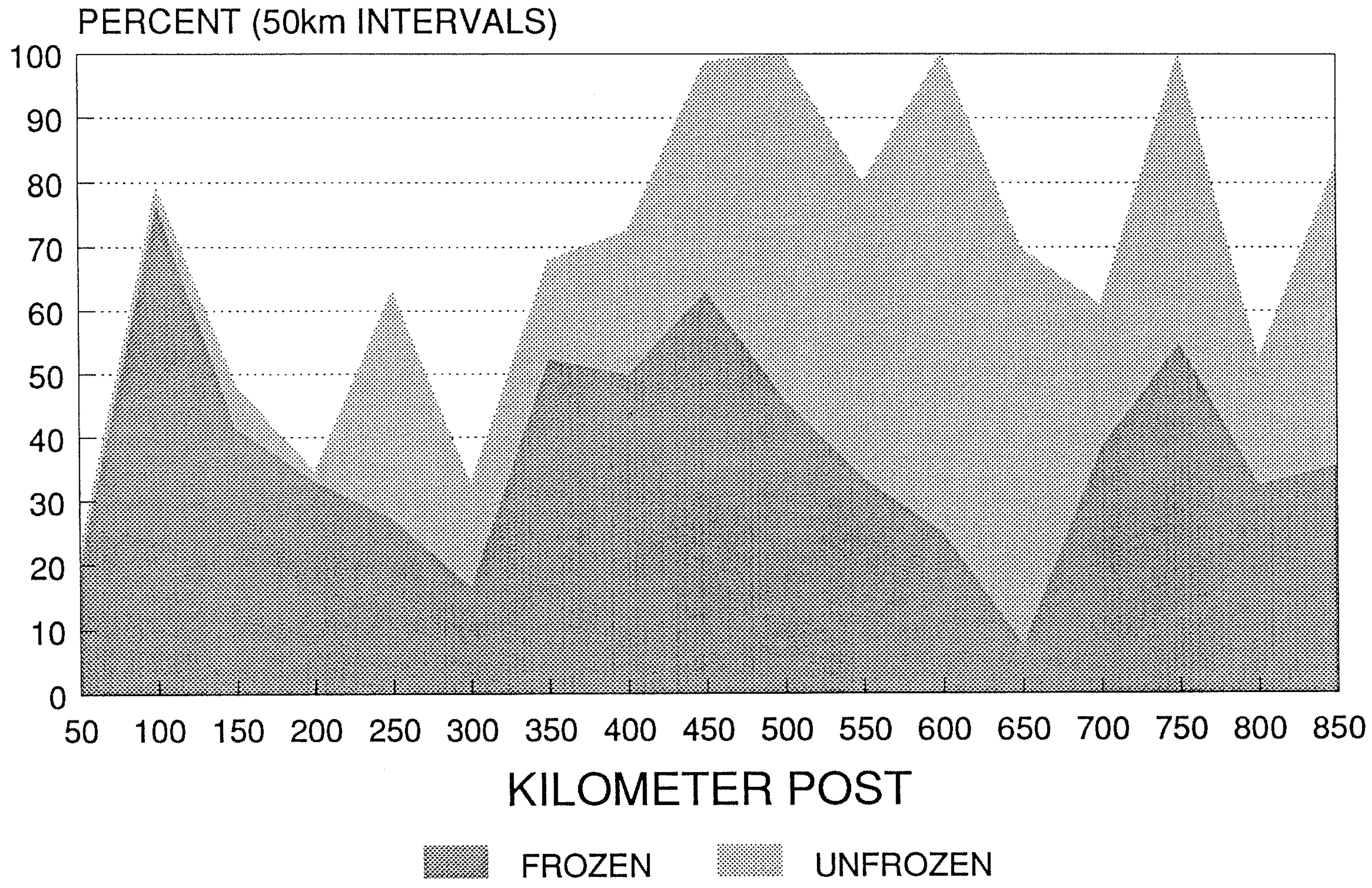
▩ PERMAFROST

DITCHWALL DATABASE

SCHEMATIC OF POSSIBLE DITCH THERMAL CONDITIONS

SCALE: NTS	PROJECT No G379	FIGURE 9

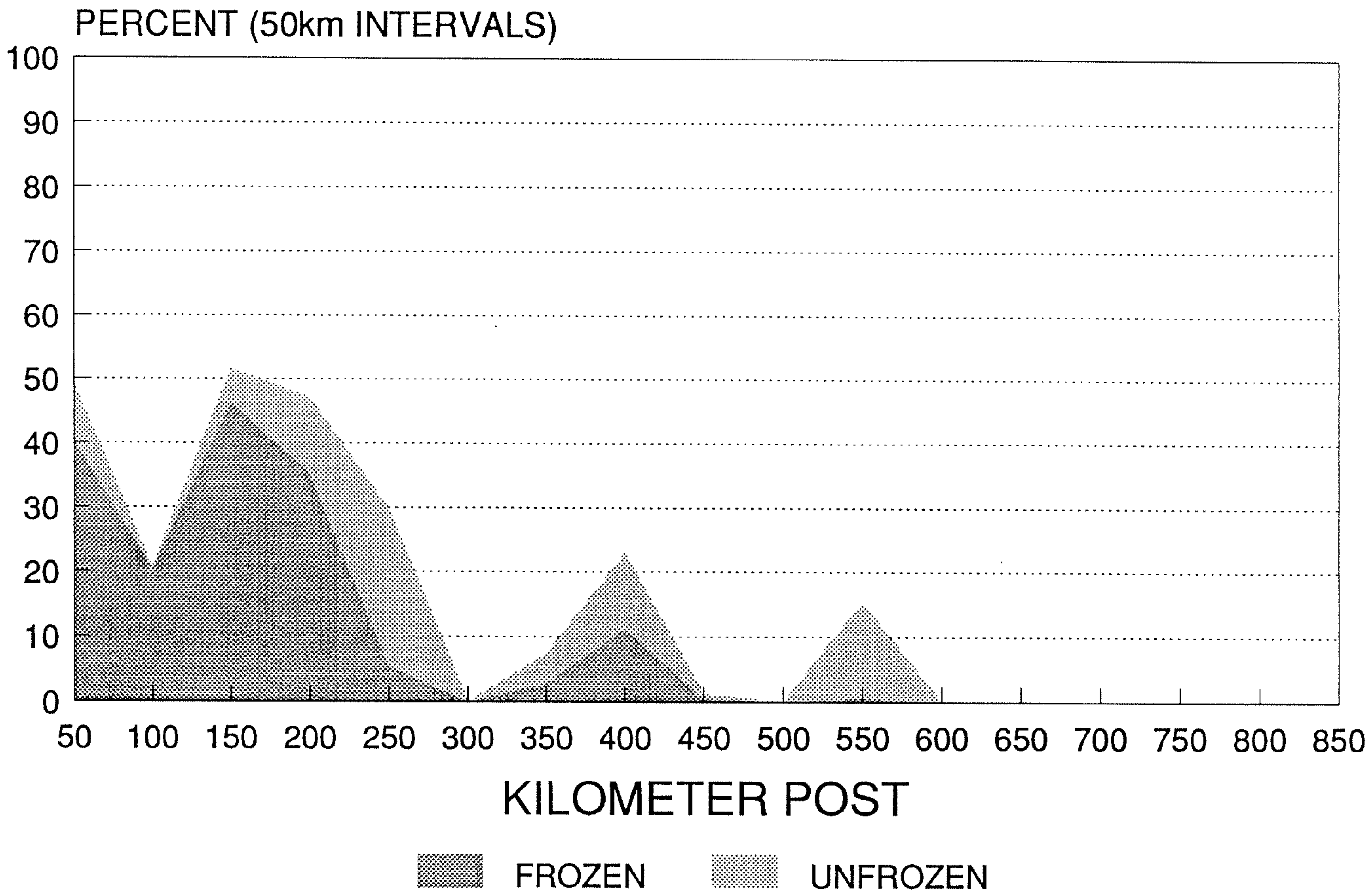
FROZEN GROUND DISTRIBUTION
PREVIOUSLY UNCLEARED R.O.W.



DITCHWALL DATABASE

FIGURE 10

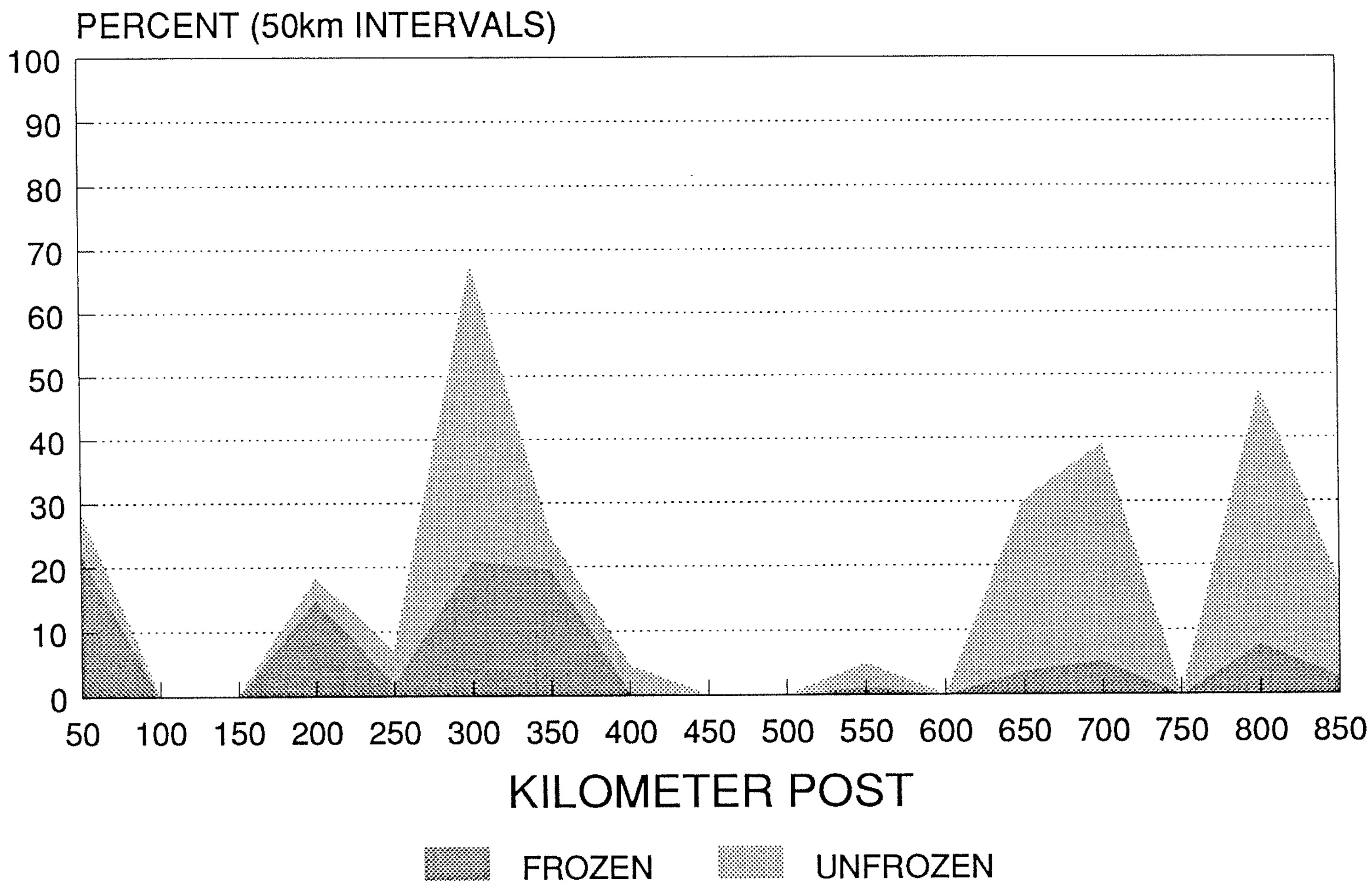
FROZEN GROUND DISTRIBUTION
CNT CUTLINE



DITCHWALL DATABASE

FIGURE 11

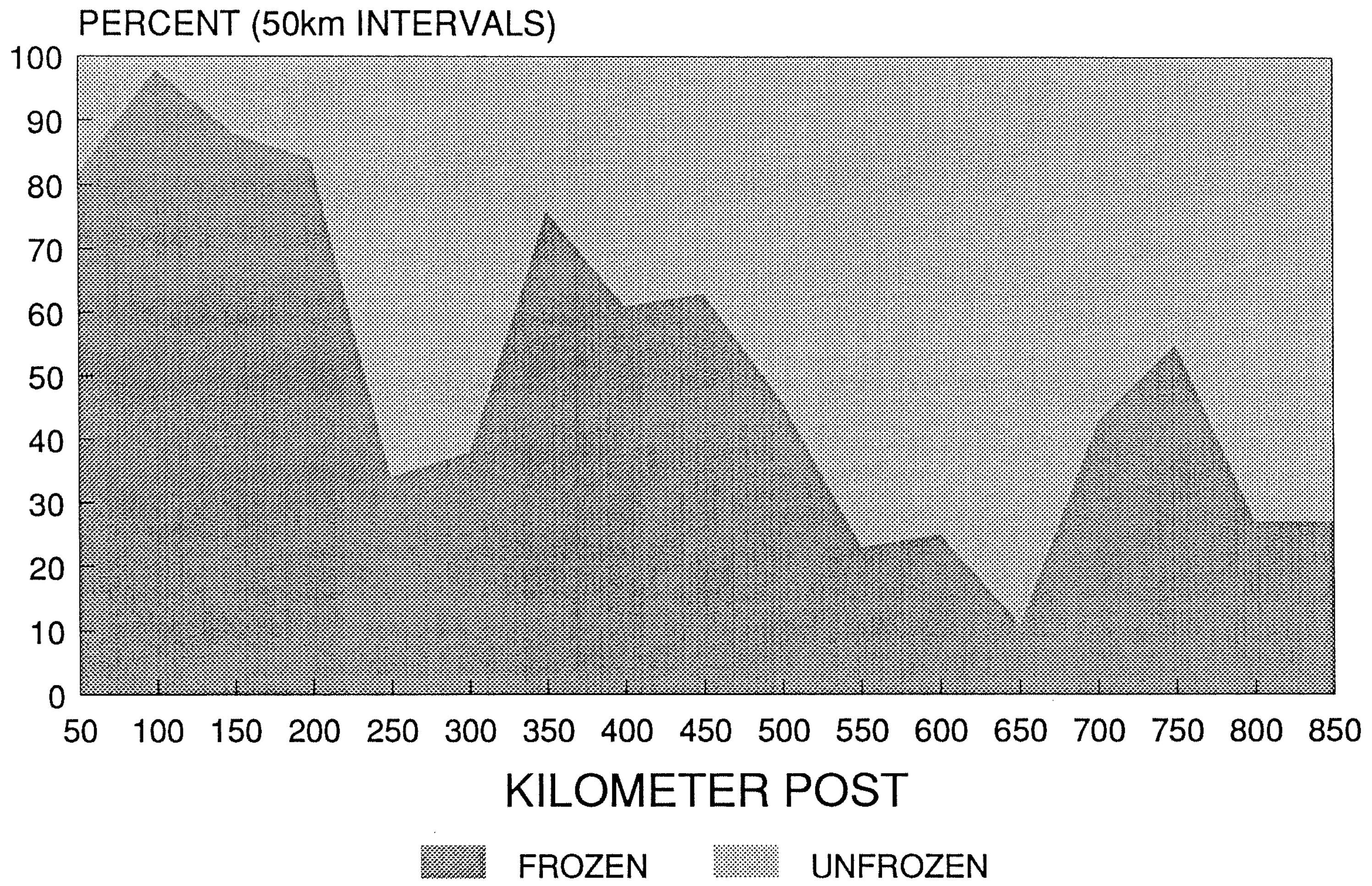
FROZEN GROUND DISTRIBUTION
OTHER PREVIOUSLY CLEARED R.O.W.



DITCHWALL DATABASE

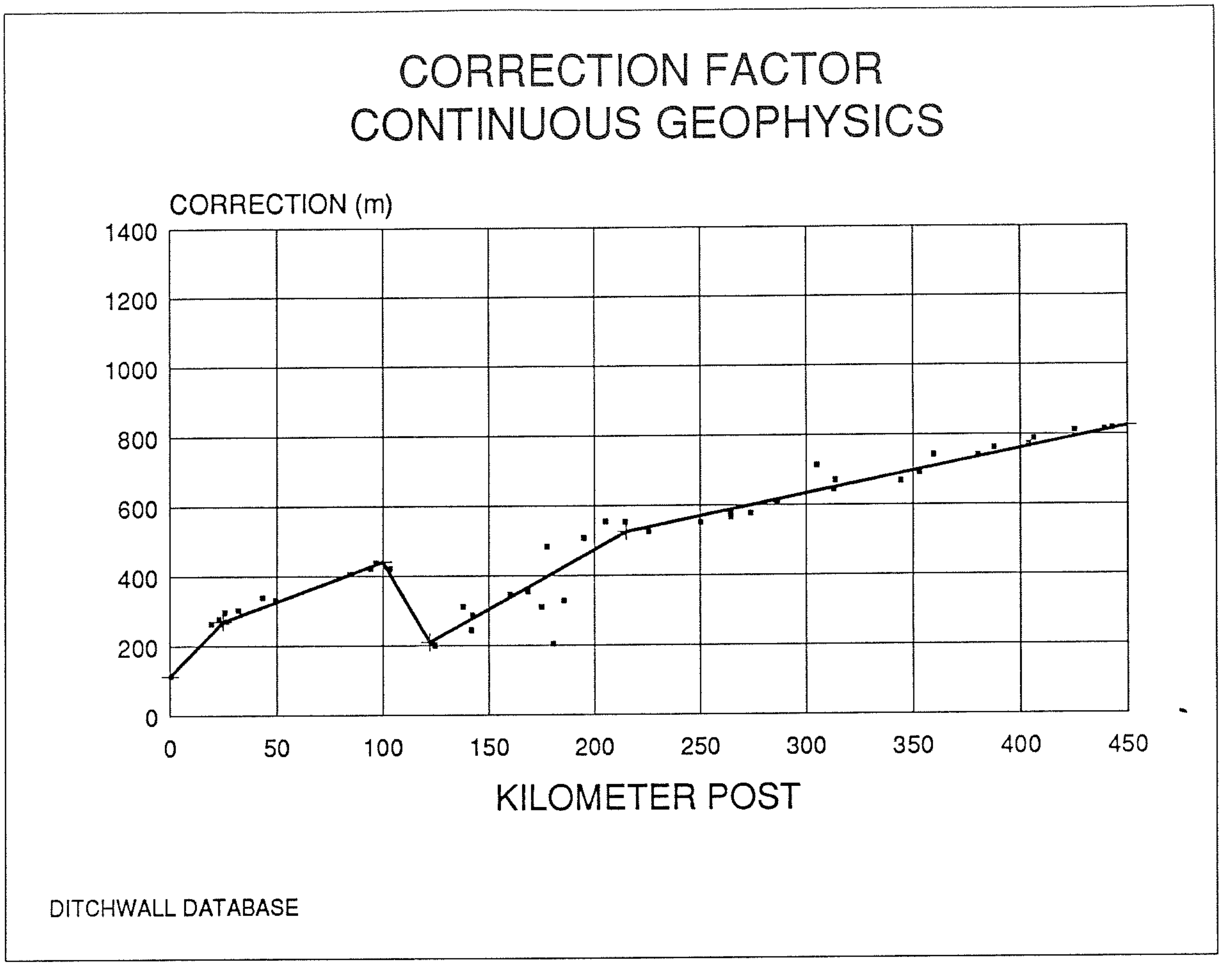
FIGURE 12

FROZEN GROUND DISTRIBUTION
ALL R.O.W.



DITCHWALL DATABASE

FIGURE 13


CORRECTION FACTOR
CONTINUOUS GEOPHYSICS
CORRECTION (m)
1400
1200
1000
800
600
400
200
0
0
50
100
150
200
250
300
350
400
450
KILOMETER POST
DITCHWALL DATABASE

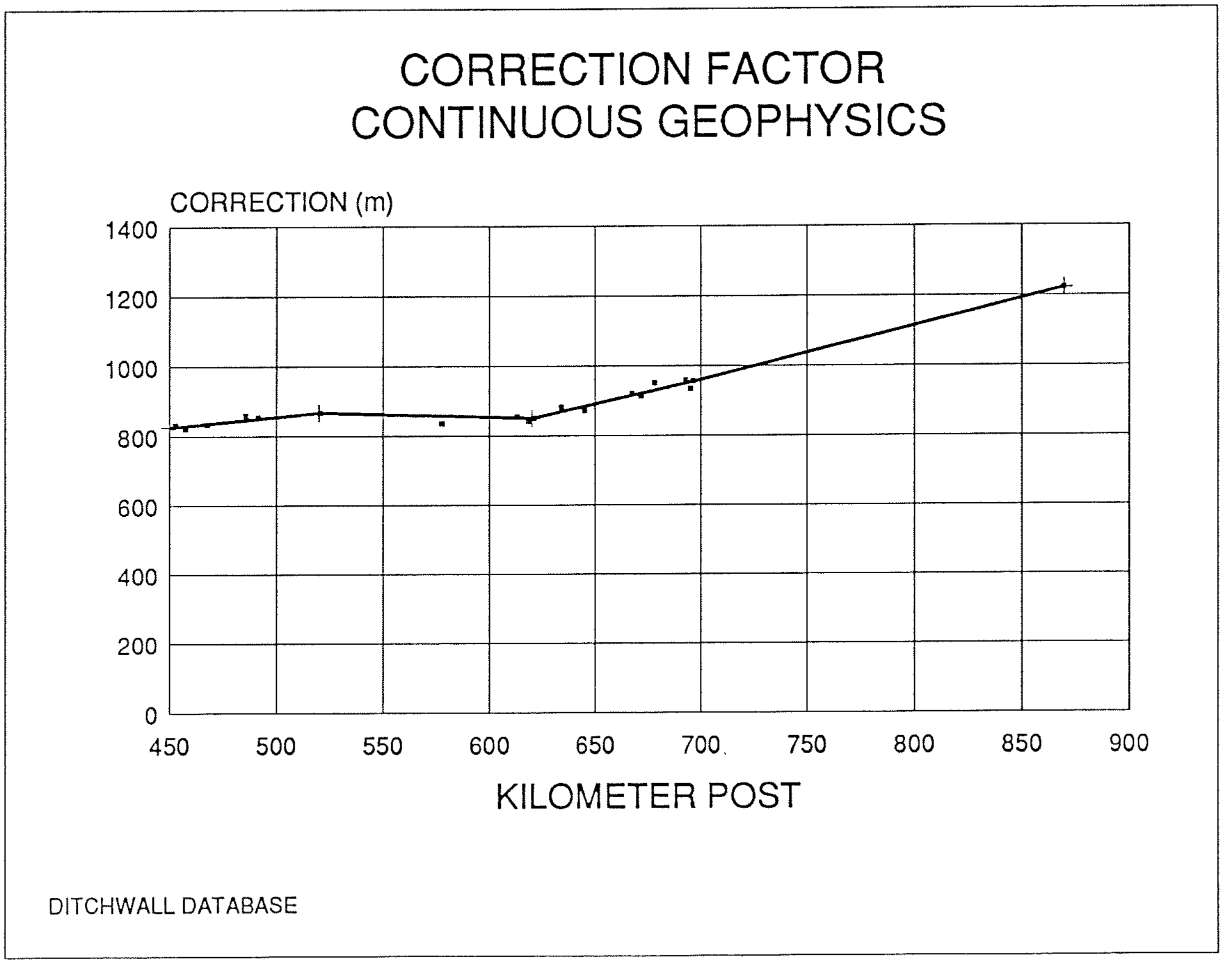
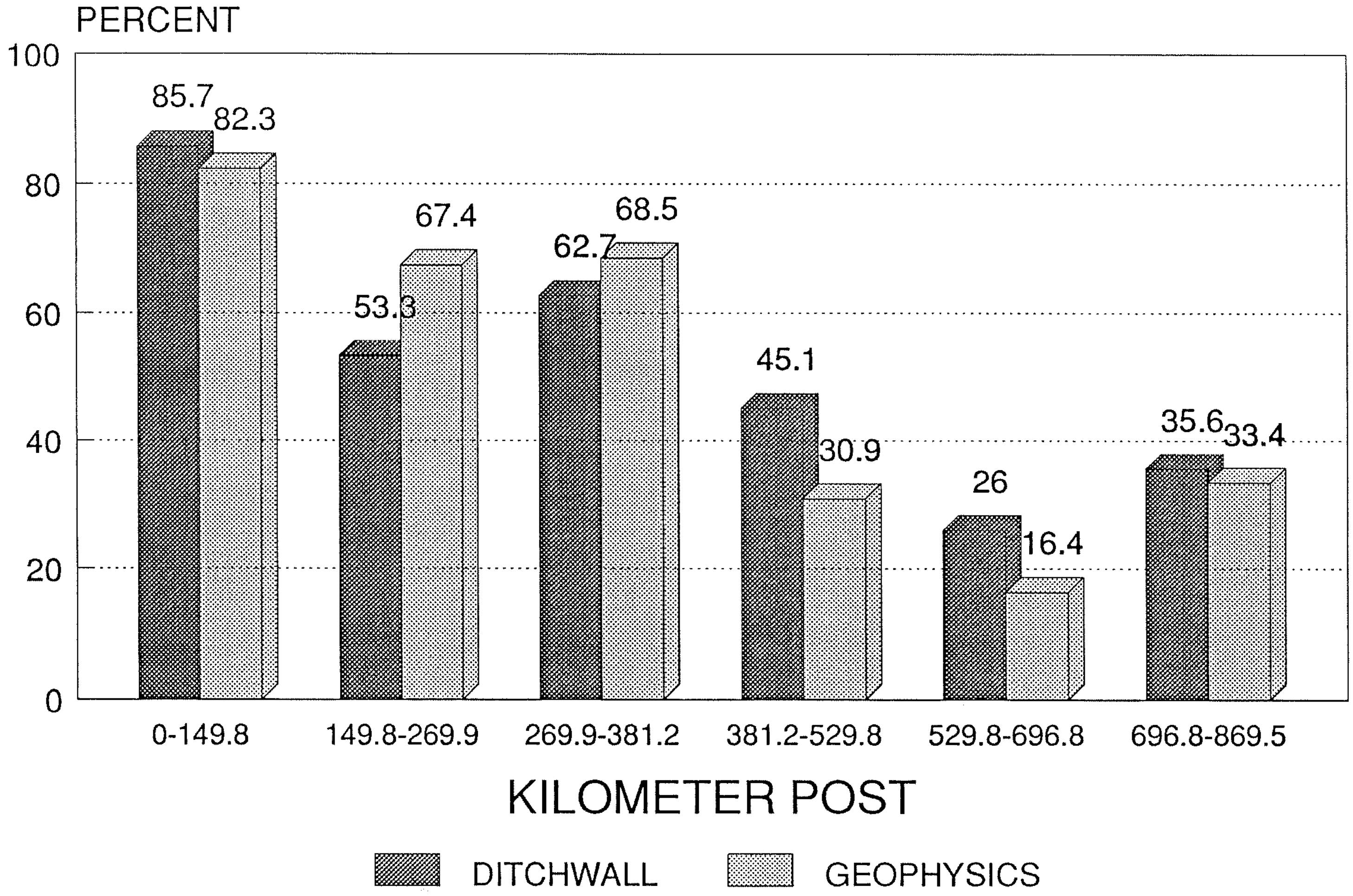

CORRECTION FACTOR
CONTINUOUS GEOPHYSICS
CORRECTION (m)
1400
1200
1000
800
600
400
200
0
450
500
550
600
650
700
750
800
850
900
KILOMETER POST
DITCHWALL DATABASE

FIGURE 14

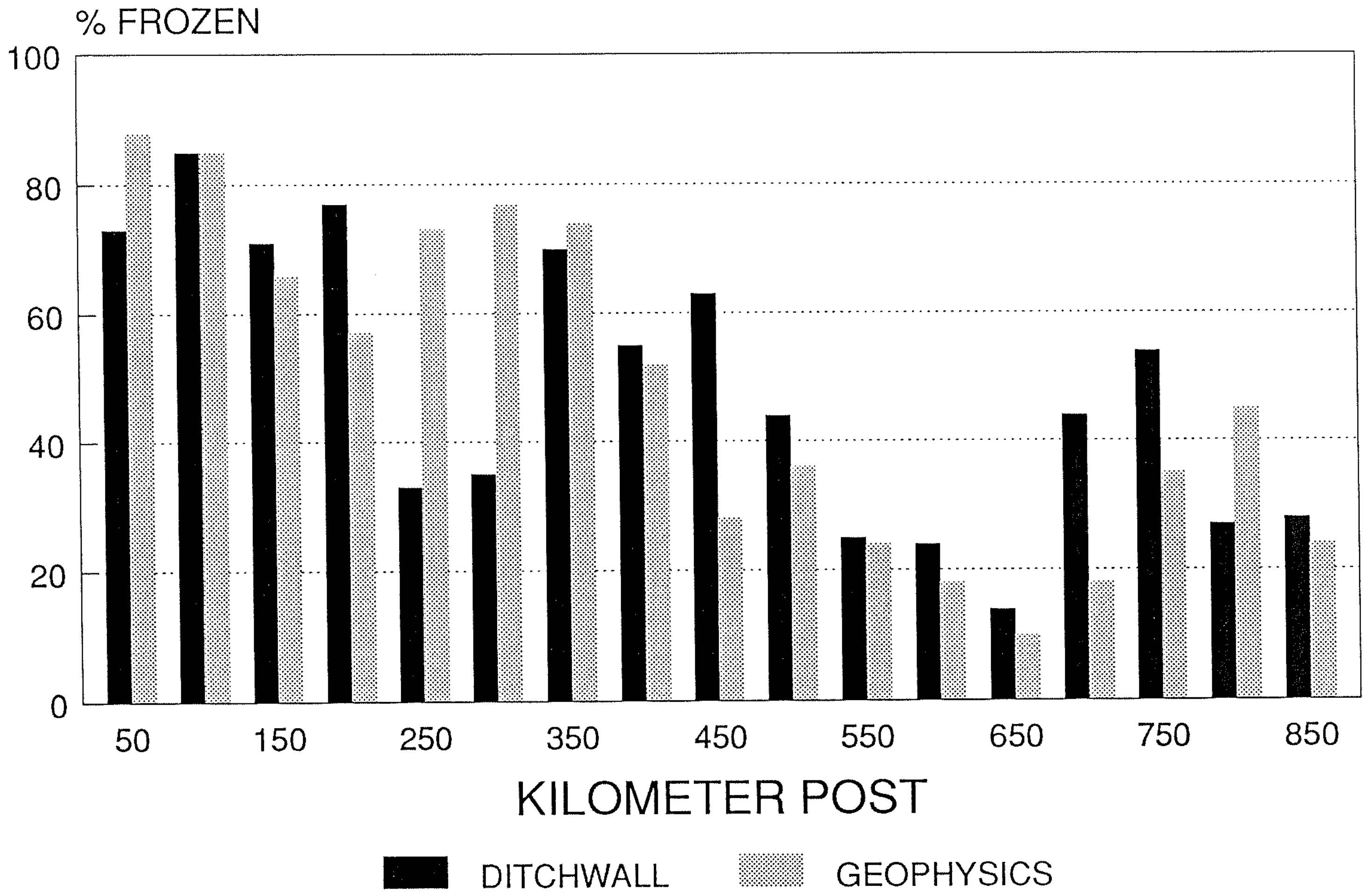
FROZEN GROUND DISTRIBUTION
CONSTRUCTION SPREADS



DITCHWALL DATABASE

FIGURE 15

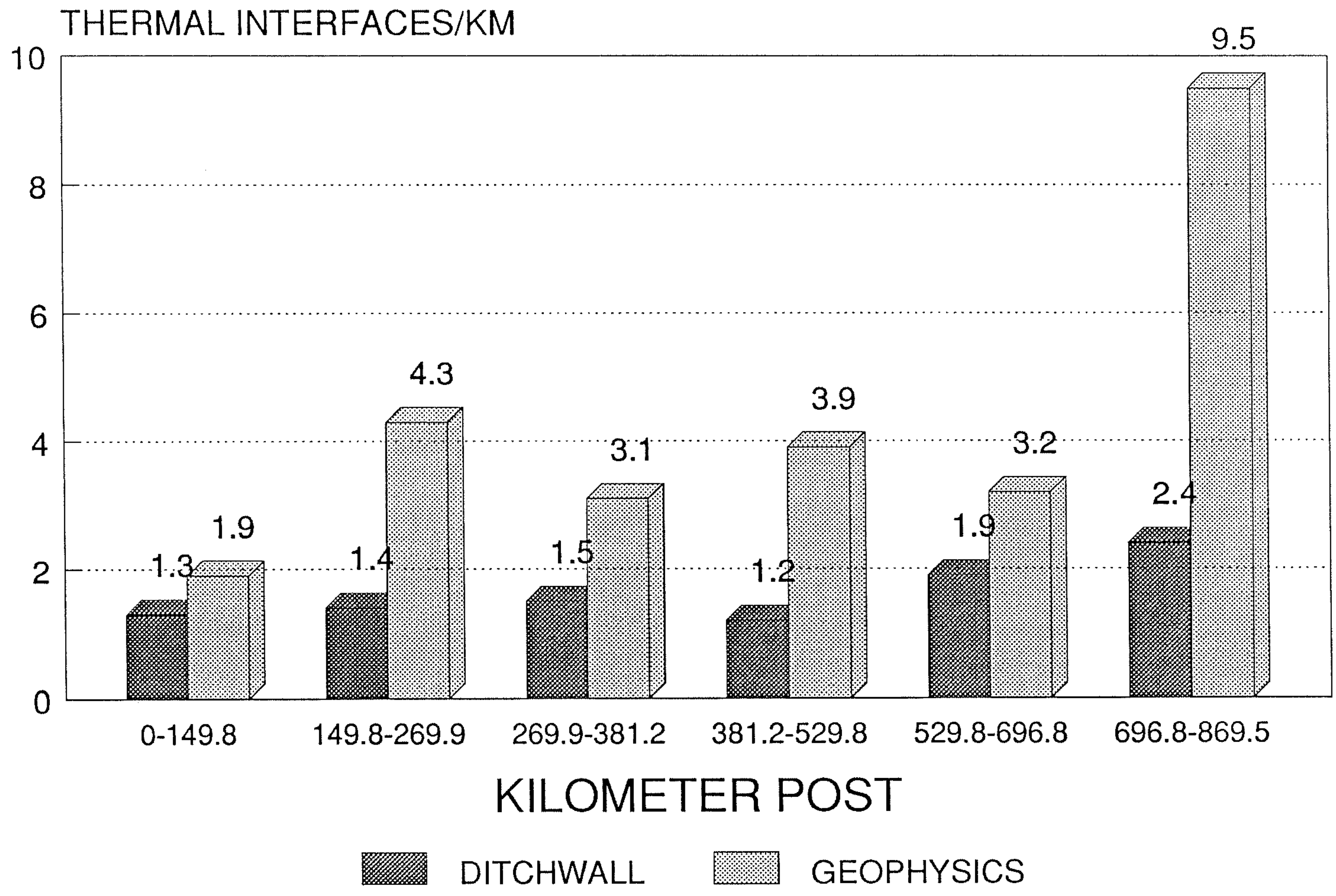
FROZEN GROUND DISTRIBUITION
50 KILOMETER INTERVALS



DITCHWALL DATABASE

FIGURE 16

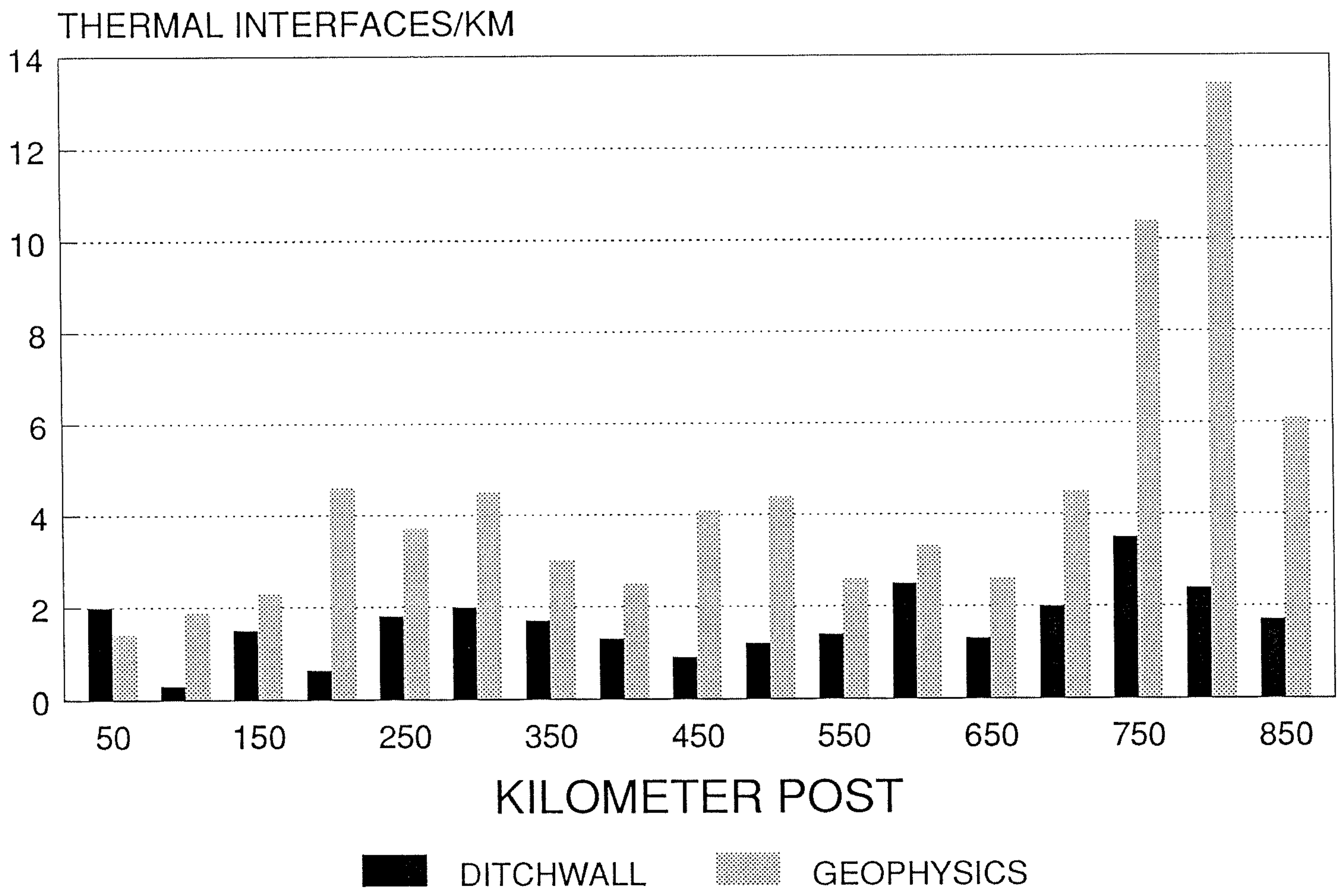
THERMAL INTERFACE DISTRIBUTION
CONSTRUCTION SPREADS



DITCHWALL DATABASE

FIGURE 17

THERMAL INTERFACE DISTRIBUITION
50 KILOMETER INTERVALS



DITCHWALL DATABASE

FIGURE 18

APPENDIX B

SAMPLE PRINTOUTS

SAMPLE PRINTOUT

DITCHWALL DATABASE
CONTINUOUS THERMAL CONDITIONS
(- derived from FROZ.PRN)

DITCHWALL DATABASE - CONTINUOUS THERMAL CONDITIONS

START_KP	END_KP	CONDITION	LENGTH(m)
.000	.780	F	780
.780	.828	U	48
.828	.847	F	19
.847	.880	U	33
.880	.960	F	80
.960	.985	U	25
.985	1.043	F	58
1.043	1.125	U	82
1.125	1.380	F	255
1.380	1.435	U	55
1.435	2.085	F	650
2.085	2.118	U	33
2.118	2.405	F	287
2.405	2.435	U	30
2.435	3.085	F	650
3.085	3.230	U	145
3.230	3.635	F	405
3.635	3.675	U	40
3.675	4.325	F	650
4.325	4.375	U	50
4.375	4.470	F	95
4.470	4.515	U	45
4.515	4.708	F	193
4.708	4.733	U	25
4.733	4.850	F	117
4.850	4.885	U	35
4.885	5.055	F	170
5.055	5.115	U	60
5.115	5.188	F	73
5.188	5.440	U	252
5.440	5.575	F	135
5.575	5.660	U	85
5.660	6.980	F	1,320
6.980	7.295	U	315
7.295	7.450	F	155
7.450	7.550	U	100
7.550	8.050	F	500
8.050	8.150	U	100
8.150	8.500	F	350
8.500	8.650	U	150
8.650	8.750	F	100
8.750	8.850	U	100
8.850	9.150	F	300
9.150	9.250	U	100
9.250	9.350	F	100
9.350	9.650	U	300
9.650	9.750	F	100
9.750	9.907	U	157
9.907	9.958	F	51
9.958	10.050	U	92
10.050	12.850	F	2,800
12.850	12.950	U	100
12.950	14.050	F	1,100
14.050	14.550	U	500
14.550	14.850	F	300
14.850	14.950	U	100
14.950	16.359	F	1,409

SAMPLE PRINTOUT

CONTINUOUS GEOPHYSICS
(- derived from GEOPHYS.PRN)

CONTINUOUS GEOPHYSICS LISTING (SAMPLE)

START_KP	END_KP	CONDITION	LENGTH(m)
.000	.374	F	374
.374	.418	U	44
.418	1.953	F	1,535
1.953	2.029	U	76
2.029	3.055	F	1,026
3.055	3.115	U	60
3.115	3.223	F	108
3.223	3.273	U	50
3.273	6.701	F	3,428
6.701	6.751	U	50
6.751	9.520	F	2,769
9.520	10.224	U	704
10.224	15.745	F	5,521
15.745	15.771	U	26
15.771	16.279	F	508
16.279	16.387	U	108
16.387	17.343	F	956
17.343	17.409	U	66
17.409	19.055	F	1,646
19.055	19.070	U	15
19.070	19.296	F	226
19.296	19.405	U	109
19.405	19.586	F	181
19.586	20.043	U	457
20.043	20.352	F	309
20.352	21.380	U	1,028
21.380	21.608	F	228
21.608	21.700	U	92
21.700	22.740	F	1,040
22.740	22.774	U	34
22.774	23.018	F	244
23.018	23.058	U	40
23.058	23.087	F	29
23.087	23.177	U	90
23.177	23.862	F	685
23.862	23.902	U	40
23.902	23.922	F	20
23.922	23.987	U	65
23.987	24.449	F	462
24.449	24.528	U	79
24.528	24.819	F	291
24.819	24.876	U	57
24.876	25.768	F	892
25.768	25.799	U	31
25.799	26.229	F	430
26.229	26.254	U	25
26.254	26.372	F	118
26.372	26.428	U	56
26.428	31.987	F	5,559
31.987	32.265	U	278
32.265	34.042	F	1,777
34.042	34.077	U	35
34.077	34.103	F	26
34.103	34.169	U	66
34.169	34.892	F	723
34.892	34.959	U	67
34.959	38.305	F	3,346