A PRELIMINARY INVESTIGATION OF SALT-WATER INTRUSION ON NUKUORO ISLAND, NUKUORO ATOLL, PONAPE STATE

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EVALUATION OF GROUNDWATER RESOURCES OF NUKUORO AND KUTTU ISLANDS

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INTRODUCTION

During the drought of 1983, the island community of Nukuoro Atoll experienced a serious shortage of staple food items, particularly taro and breadfruit. Among other factors, salt-water intrusion into areas of root-crop cultivation contributed significantly to the decline in food production. Due to the severity of the problem, personnel from the Water and Energy Research Institute, University of Guam, were requested by the Federated States of Micronesia to conduct field studies in order to determine the best approach to minimizing the effects of salt-water intrusion and increase the yield of food staples. Subsequently, a field trip to Nukuoro Atoll took place in May 1983. During the brief stay of four days, a number of activities were performed. The results from these activities and their implications are the subject of this report.

Purpose and Scope of the Study

The primary objectives of this study were to determine the major factors that influence salt-water intrusion into the area of taro cultivation and to make recommendations for the effective control of the problem. In order to achieve these objectives, a number of field and laboratory activities were conducted. These activities are outlined below.

Field Activities

1. Water samples were collected from 35 household wells and four taro-patch cisterns (at high and low tides) and analyzed for chloride-ion concentration, specific conductance, temperature, and relative salinity.

2. Additional water samples from 10 household wells were collected, prepared, and taken to the WERI water-quality laboratory for further analyses.

3. Two auger holes were drilled (by hand) into the fresh-water lens to a depth of about one foot below the low-tide level and a salinity profile was taken in each at high tide.

4. Several plant and soil samples were collected from the taro patch (unfortunately, these were inadvertently destroyed by Guam customs).

5. A seismic-refraction survey was conducted which consisted of 25 forward-reverse lines.

6. All water collection sites and salient features of the taro patch were mapped.

7. A questionnaire was administered to 33 community members.

8. All available rainfall records for the island were collected (Appendix A).

Laboratory Activities

1. Analysis of water samples for chloride, alkalinity, total hardness, calcium hardness, carbon dioxide, total phosphorus, nitrate + nitrite-nitrogen, and ammonia-nitrogen.

2. Analysis of seismic-refraction field data.

3. Interpretation of study results and preparation of the completion report.

Location and Description of the Study Area

Nukuoro Atoll is located approximately 300 miles southwest of Ponape, Eastern Caroline Islands (Figure 1). The atoll platform is nearly circular and is about 3½ to 4 miles in diameter. Over 40 islands and islets are located along the eastern half of the atoll margin (Figure 2). These islands are low lying and composed primarily of reef and lagoon derived carbonate sediment, typical of many atoll islands in the Western Pacific region.

The island of Nukuoro is situated along the southeastern margin of the atoll platform and is the largest in terms of land area (Figure 2). Nukuoro is long (about 5000 feet) and somewhat arcuate in shape with a maximum width of about 1000 feet at the northern end. Sediment in the size range of cobbles to boulders forms a ridge along the ocean shoreline. This very coarse- grained material grades rapidly inland to gravel and coarse sand. On the lagoon side, sediment in the sand-size range forms a low ridge. Away from the shorelines, the land is relatively flat. In the central portion of the island, there is a central depression (flat floored) which covers a rather large area (rough dimensions of 600 feet long by 200 feet wide). This central depression is the site of active taro cultivation (and salt-water intrusion) and probably has been enlarged and greatly modified from the original natural physiographic feature by this practice of food growing.

Nearly all the community members live along the lagoon side between the shoreline and the central depression. This part of the island is preferred mainly because of (1) the availability of fresh groundwater beneath the area and (2) the protection from storms offered by the lagoon and its enclosing reef.

Freshwater is acquired by two methods. These methods are (1) the collection of rainwater from roofs off either buildings or structures built over catchment tanks and (2) from hand dug wells. Although rainwater is preferred for drinking purposes, groundwater is used for consumption during those times when rainfall is not adequate to provide sufficient quantities of potable water. The general practice is to boil the well water prior to drinking. Catchment water is normally not treated in any way.

The primary food item that was in short supply for the community is taro. Salt-water intrusion into the central portion of Nukuoro where taro is cultivated resulted in a significant loss in production. In areas of

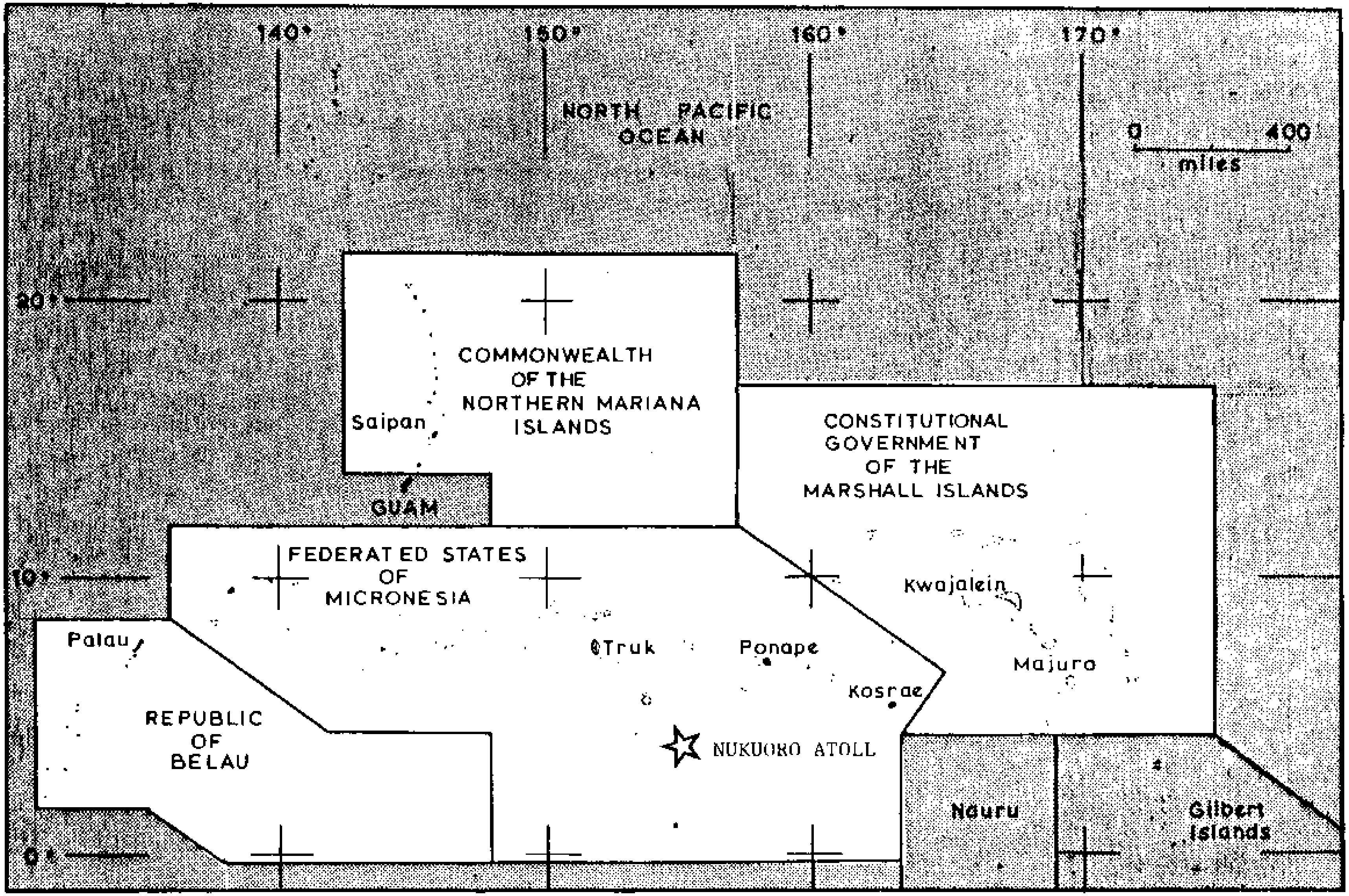

Figure 1. Map of Micronesia showing location of study area.

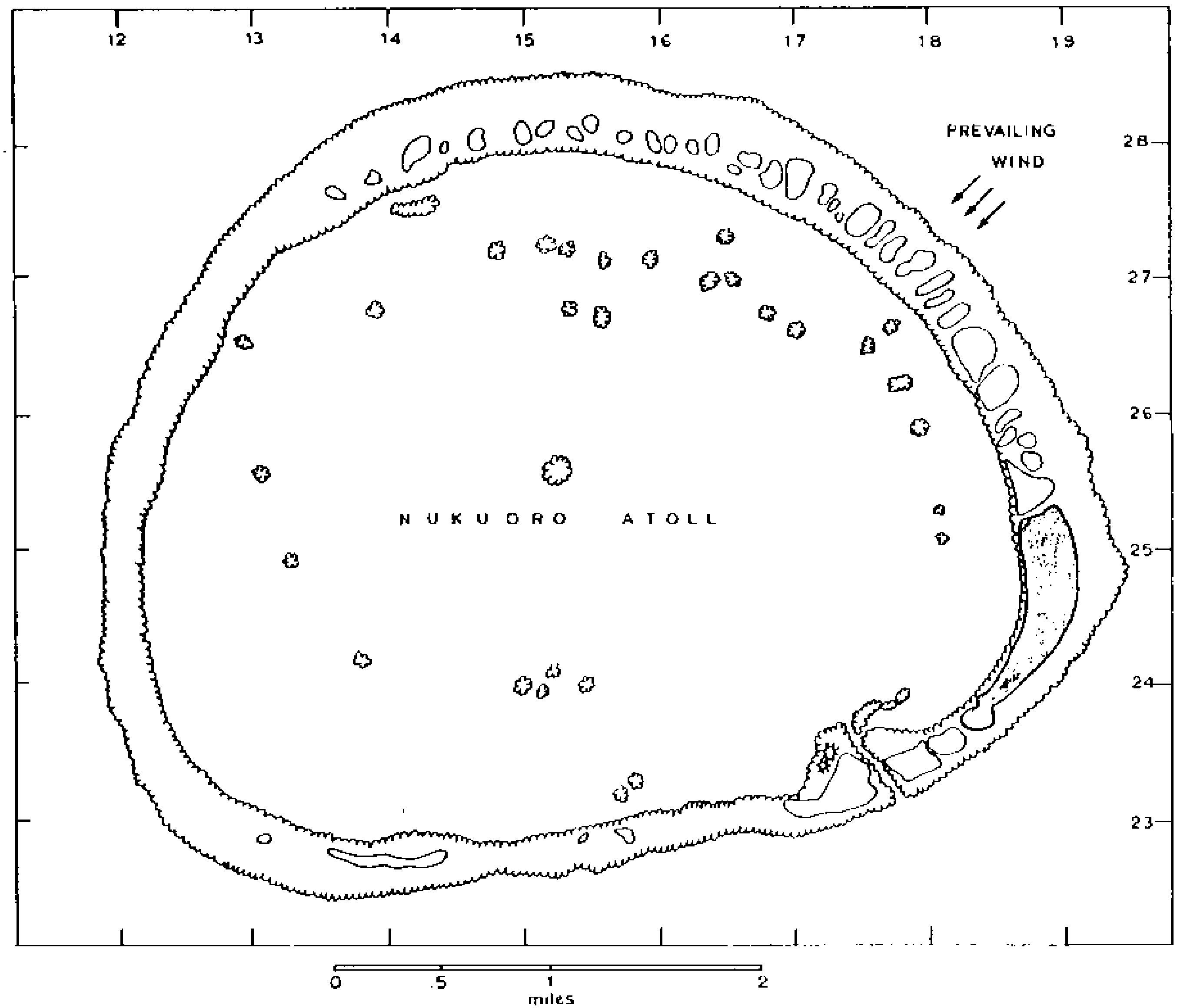

Figure 2. Map of Nukuoro Atoll.

grow normally and usually died after a short period of exposure. Salty groundwater caused the plant leaves to turn yellow and wither and the root system to decay. At the time of investigation, about one-third to one-half of the taro patch had been affected by salt-water intrusion (Figure 3). Although there was a recent improvement to the patch through the efforts of concerned community members, much has yet to be done to increase taro productivity to the point where the community is no longer dependent on the importation of staple food items.

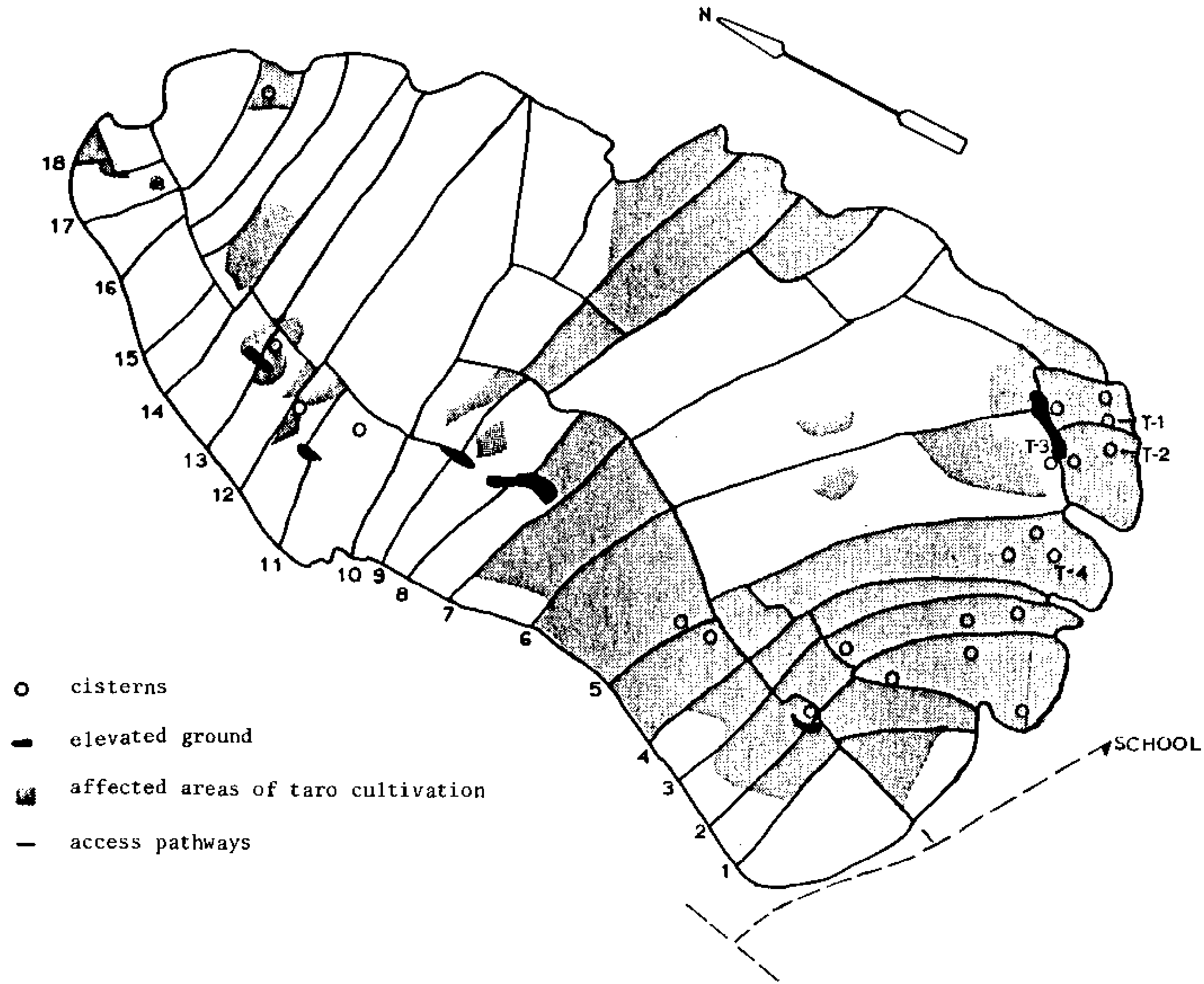

Figure 3. Map of the taro patch showing areas affected by salt-water intrusion.

METHODS

A number of field and laboratory methods were used during the course of the investigation. Specifically, these methods were (1) collection of water samples and subsequent analyses, (2) application of seismic-refraction techniques, and (3) administration of a questionnaire to selected members of the community. Details of these various study methods are presented below.

Water-Quality Analyses

Determinations of water quality are important aspects of any groundwater investigation. The most obvious benefit of such studies is the assessment of the resource in terms of its potability or fitness for human consumption and domestic use. However, water-quality data also can be used to evaluate natural processes within the subsurface hydrologic environment, such as the degree of mixing between fresh groundwater and seawater in the case of an insular setting or identifying sources of natural or artificial contamination in more general situations. Although no comprehensive program of water quality assessment was undertaken for this study, the methods outlined below were employed in order to obtain at least a general concept of water chemistry within the lens beneath Nukuoro Island.

Water samples were collected from a number of sites including household wells, taro patch cisterns, and auger holes (Figure 4). Both field and laboratory analyses were performed to determine temperature, specific conductance, relative salinity, chloride-ion concentration, and, in some cases, pH. Additional analyses included alkalinity, calcium hardness, total hardness, carbon dioxide, total phosphorus, nitrate-nitrogen, and ammonia-nitrogen. Field measurements were performed utilizing portable instruments and test kits. Laboratory analyses followed standardized procedures (American Public Health Association, 1980).

Field analyses on water obtained from household wells and taro-patch cisterns were performed on two sets of samples; one set collected at high tide and the other collected at low tide. The primary objective of this scheme was an attempt to determine if there were significant changes in constituent concentrations during the tidal cycle. Of particular interest was chloride-ion concentration differences as the lens moved up and down with the tides. A significant change between high and low tide might give an indication of lens thickness at a given site.

Samples for laboratory analysis were collected from selected household wells. The selection of these wells was base primarily on the criteria of location, that is, on their position relative to each other and their distance from the shoreline. For example, wells 23, 24, and 9, respectively, are located at increasing distances from the lagoon shoreline and as a group are situated near the southwestern end of the taro patch (see Figure 4). Another example is wells 16 and 15 which also are located at progressive distances from the lagoon shore and are located near the northwestern end of the taro patch. The reason for using this type of criteria is to determine any trend or pattern to the water-quality

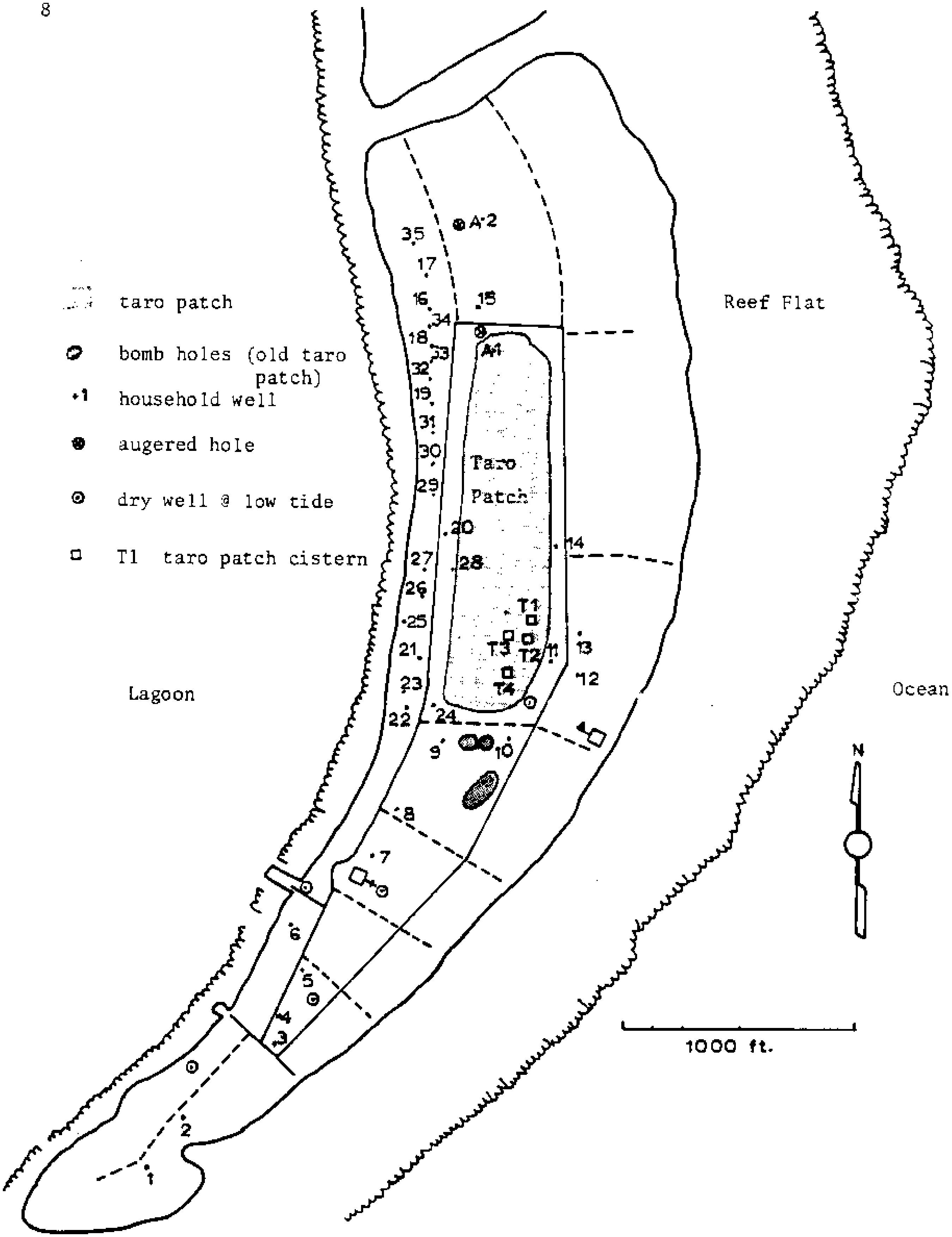

Figure 4. Map showing the location of all water sample sites.

characteristics in the vicinity of the taro patch and within the groundwater supply of the village.

Seismic-Refraction Profiling

Seismic-refraction methods have been used in a wide variety of investigations involving the determination of subsurface structure. Among these investigations are numerous applications of the method in groundwater- related studies. The object of refraction seismology is to obtain a time-distance graph from the first arrival of sound waves generated by an energy source. From time-distance graphs, seismic velocities can be calculated and depth determinations can be made.

Detection of refracted sound waves generated by controlled energy sources (e.g., hammer striking a steel plate, weight drop, or explosion) usually produces a seismic-record indicating one or more events that are caused by the change in velocity of the wave front. Seismic energy is transmitted through solid material as elastic waves. Abrupt changes in the elastic properties of the materials through which these waves are propagated will cause the waves to be refracted or bent. The degree to which the wave paths are refracted is related to Snell's Law, that is, the sine of the angle of incidence is equal to the sine of the angle of refraction. Another way of expressing this law is by the following equation:

$$\frac{\sin i}{\sin r} = \frac{V_1}{V_2}$$

where

- i = angle of incidence,
- r = angle of refraction
- V_1 = velocity of transmission of the elastic wave in the incidence medium, and
- V_2 = velocity of transmission of the elastic wave in the refraction medium.

A primary concept in refraction work is that of the critical angle. Where r is equal to 90°, $\sin i$ is equal to V_1/V_2. Here, the incident wave path or ray strikes the interface at the critical angle and the refracted wave travels parallel to the interface. A refracted wave front acts as a first arrival when its travel time from the source through the refraction medium to the detector is equal to or greater than the time required for the direct wave to travel from the source to the same detector. The path that first-arrival waves take is dependent upon the depth to the reference interface and the distance between the first detector and the energy source (Zohdy et al., 1974; Telford et al., 1976).

When the first-arrival times derived from seismograms are plotted on a time-distance graph, a break in slope of the curve will occur where the time taken for both direct and refracted waves to travel from the energy source to the detector is the same. Seismic velocities are obtained from the slope on the time-distance curve (i.e., velocity is the inverse of the slope).

The most widely used of all field techniques in refraction work is profile shooting. To obtain the necessary time-distance data, shot points and detectors or geophones are laid out on long lines and repeated shots are taken at various positions at the ends and middle of the geophone spread. If successive spreads are necessary, the lines are overlapped by at least one or two geophones.

During field activities, a total of 25 seismic-refraction lines were established (Figure 5). Each line was shot in both the forward and reverse order; several lines were shot at the midpoint of the spread. The energy source used in the refraction work was a sledge hammer striking a steel plate. Geophone spreads consisted of 12 detectors spaced at 25-foot intervals connected to a McSeis-1300 (model 1191) Signal Enhancement Seismograph. A permanent record was produced on light-sensitive paper.

Although a number of analytical approaches are available (i.e., Telford et al., 1976 and Dobrin, 1976), the least time-consuming method utilizes computer processing of the time-distance data. The computer program used to process the Nukuro data was first published by the U.S. Bureau of Mines (Scott, 1972). The program generates a two-dimensional model representing a layered-earth depth interpretation. Travel times are picked from the seismogram by the user. These times, together with shot point and geophone locations and refraction layer control information, are used as program input. A first approximation is then tested and improved by the computer through the use of a ray-tracing procedure in which ray travel times computed for the model are compared to field data. The model is subsequently adjusted in an interative manner such that the discrepancy between computed and measured travel times is minimized. Seismic velocities and depths to refractor interfaces, among other information, are printed as the final step.

Questionnaire Administration

The purpose of administering a questionnaire as part of the field activities was to collect background information related to the salt-water intrusion problem. In addition, the questionnaire addressed the subject of problem solution in terms of what a number of the community members felt could be done to improve taro production. A total of 33 people were interviewed, 20 males and 13 females of which 9 are in the 30 to 49-year age bracket and the remainder are over 50 years of age. No one under the age of 30 years was interviewed because the primary objective of the survey was to collect information on the recurrence of the problem and how the solution was addressed in the past.

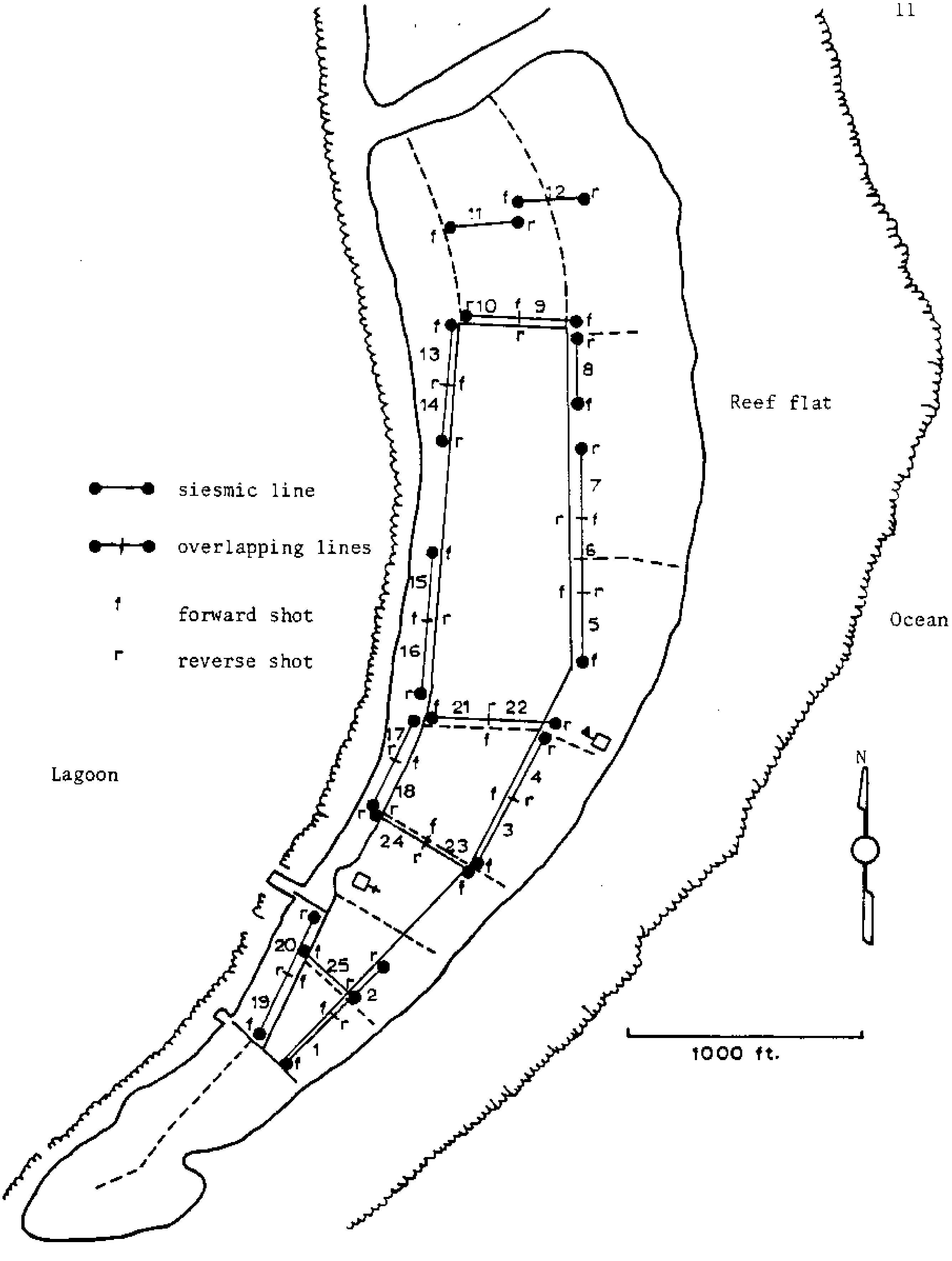

Figure 5. Map showing the locations of seismic-refraction lines.

RESULTS

The following is a presentation of the relevant findings of the study. These include a number of general observations, results of water-quality analysis, data reduction of the seismic-refraction survey, and tabulation of questionnaire responses. Implications of these findings are discussed in the next section.

General Observations

A number of general observations made during the course of the field work warrant consideration. These observations are listed below.

1. The reef-flat substrate was found at the bottom of several household wells located along the eastern and southern portion of the island and underlying a large part of the taro patch.

2. Most wells along the lagoon side of the island had sand bottoms and a few exhibited a hard cemented sand layer at or near the water table.

3. Within the taro patch, individual plots affected by salt-water intrusion contained a thin organic layer, few if any plants, and salt crusts on the soil surface.

4. At high tide, salty water would stand in depressions on the ground around a few of the cisterns (cement pipe or steel drum casing around "holes" in the substrate of the taro patch) and in some of the individual plots.

5. Taro plants within a few feet of a number of the cisterns were obviously affected by salt water.

6. Healthy taro plants were observed in the northern portion of the patch where the organic layer has been maintained by the plot owners.

7. Healthy taro plants were observed along a number of the built-up pathways across affected areas, although not observed in the severely affected parts of the patch (for example at the southeastern end).

Water-Quality Analyses

Three sets of results from analyses of water samples are presented here. These sets of results were obtained from (1) field analyses of water samples collected from household wells and taro-patch cisterns (Tables 1 and 2), (2) field analyses of water samples and measurements of electrical conductivity within auger holes (Tables 2 and 3), and (3) laboratory analyses of water samples collected from selected household wells (Table 4).

Table 1. Well water quality 28 March 1983 for high and low tide periods.

Well	Low Tide (Time 10:45 - 12:45) Water Depth (in)	Temp (°C)	Spec Conduc	Relative Salinity	Cl^-	pH	High Tide (Time 16:40 - 18:10) Water Depth (in)	Temp (°C)	Spec Conduc	Relative Salinity	Cl^-	Well Bottom Substrata
1	10	27.4	7000	4.4	4150	7.60	10	26.8	600	3.3	3250	Sand
2	20	27.0	6800	4.4	4500	7.45	24	27.3	6500	3.3	3450	Sand
3	3-6	27.8	820	1.1	280	8.00	3-6	26.8	720	1.1	310	Pavement (Coral in situ)
4	10	28.2	2300	1.7	1950	7.55	12	27.8	2800	2.2	1575	Pavement (Coral in situ)
5	10	28.4	3200	2.2	2250	7.72	18	27.8	4000	2.2	2400	Sand
6	30	29.0	5000	2.8	3800	7.82	24	27.3	6500	3.3	3350	Sand
7	8	29.3	1600	1.1	710	7.50	18	27.0	1700	0.5	1000	Sand/gravel
8	14	30.0	2000	1.1	1150	7.10	18	27.2	2000	1.1	800	Crusty sand & Pavement
9	12	28.3	1050	1.1	200	7.40	24	27.5	1300	0.5	600	Sand/gravel
10	2	28.0	9200	5.6	4700	7.50	14	72.7	9200	5.6	5100	Pavement
11	4	29.0	3000	2.2	2150	7.25	18	28.3	5800	2.2	3250	Pavement
12	2	31.5	6200	3.3	4025	8.00	18	28.0	3000	2.2	2130	Sand
13	4	33.4	6000	2.8	4025	7.40	12	28.8	6800	3.3	3200	Sand
14	12	28.4	7000	3.3	4700	7.60	8	27.8	7000	3.3	4700	Sand
15	14	28.6	1200	1.1	455	7.50	16	27.8	720	1.1	550	Sand
16	18	28.2	700	0	290	7.68	24	27.8	960	1.1	250	Sand/gravel
17	18	28.0	760	0	170	7.70	28	28.8	780	1.1	32	Sand/gravel
18	18	28.5	750	0	170	7.80	36	28.4	750	1.1	550	Gravel
19	14	28.6	1650	1.1	710	7.74	28	28.0	640	1.1	31	Gravel
20	8	28.4	1700	0	710	7.50	18	28.0	1700	1.1	1775	Sand
21	30	28.4	1550	0.6	710	7.45	36	29.4	2000	1.1	1325	Sand

Table 2. Well water quality 29 March 1983 for high and low tide periods.

	Low Tide (Time 10:45 - 12:45)					High Tide (Time 16:40 - 18:10)					
Well	Water Depth (in)	Temp (°C)	Spec Conduc	Relative Salinity	Cl^-	Water Depth (in)	Temp (°C)	Spec Conduc	Relative Salinity	Cl^-	Well Bottom Substrata
22	18	28.3	1200	1.1	1050	36	29.4	1500	1.7	1150	Sand
23	14	28.0	1000	1.1	600	24	28.5	950	1.7	700	Sand
24	14	28.3	1500	1.1	1325	24	28.8	1500	1.1	1325	Sand
25	12	28.6	1400	1.1	1350	30	29.3	1400	1.1	1300	Sand crust layer
26	18	28.6	1250	1.1	1325	36	29.0	1300	1.1	775	Sand crust layer
27	8	28.2	950	1.1	700	20	28.0	950	0.5	1325	Sand crust layer
28	14	29.5	750	0.5	100	24	28.0	950	0.5	1325	Sand
29	12	29.5	1150	1.1	850	18	28.5	1100	0.5	1000	Gravel
30	14	29.6	760	1.1	325	24	28.3	720	1.1	325	Pavement (Not in situ)
31	24	29.4	820	0.5	175	40	28.3	850	1.1	425	Sand
32	10	30.0	900	0.5	450	24	29.6	800	0.5	500	Sand crust layer
33	18	29.8	1000	0.5	450	30	28.8	980	1.1	700	Sand crust layer
34	12	29.4	850	1.1	450	30	28.3	800	0.5	75	Sand crust layer
35	24	28.8	810	1.1	175	28	28.0	800	1.1	250	Gravel
Auger 1						16	28.5	690	0.5	26	Pavement
Auger 2	8	28.6	710	1.1	28	7	30.0	660	0.5	26	Sand @ auger bottom

Table 2. continued.

Well	Low Tide (Time 10:45 - 12:45) Water Depth (in)	Temp (°C)	Spec Conduc	Relative Salinity	Cl^-	High Tide (Time 16:40 - 18:10) Water Depth (in)	Temp (°C)	Spec Conduc	Relative Salinity	Cl^-	Well Bottom Substrata
T-1	Taro Patch	30.0	14000	8.3	8200	29.6	14000	5.6	6200		
T-2	Taro Patch	31.0	18000	11.1	10500	29.6	22000	13.3	11700		
T-3	Taro Patch	30.0	13000	7.8	7600	29.4	13000	7.8	7600		
T-4	Taro Patch	31.6	25000	15.5	14100	29.4	21000	12.2	11100		

Table 3. Water quality in auger holes on March 29, 1983.

	Sample Time	Sampled Dept (ft)	Temp. (°C)	Specific Conduct.	Chloride (mg/l)
Auger Hole 1	1700	0	28.5	790	
	(high tide)	-0.8		850	
		-1.8		860	
	1710	0	28.5	690	26
		-1.8	28.7	850	180
Auger Hole 2	1100	0	28.6	710	28
	(low tide)				
	1715-1730	0	30.0	820	
	(high tide)	-0.9		800	
		-1.9		820	
		-2.9		880	
		-3.4		780	
	1735	0	30.0	740	26
		-3.4	29.4	740	150

Of the constituents determined in the analyses represented by the first set of results, specific conductance and chloride-ion concentrations are the most significant. These measurements are indicators of the magnitude of subsurface mixing between fresh groundwater and seawater. From the results listed in Tables 1 and 2, the amount of mixing in household wells ranges from relatively freshwater (35 mg/l to 1000 mg/l Cl^-) to that of slightly to moderately brackish water (1000 mg/l to 5100 mg/l Cl^-). Differences between high and low tide measurements in general, did not significantly change the quality of the well water. Groundwater with the highest chloride-ion concentration is beneath the southeastern portion of the taro patch and can be classified as very brackish (6200 mg/l to 14100 mg/l Cl^-) or 35% to 80% seawater. This portion of the taro patch is also nearly barren of plants.

The second set of results, listed in Tables 2 and 3, was obtained from field analyses of water samples collected from two shallow auger holes hand drilled into the water table. In addition to the sample analysis, specific conductance measurements were taken in situ at 1-foot intervals during high tide. Chloride-ion concentrations and conductance measurements indicate non-mixed freshwater to a depth of about 2 feet in Auger 1 and about 3.5 feet in Auger 2.

Listed in Table 4 are the results of laboratory analyses on water samples collected from selected household wells. From results of the more complete laboratory analyses (relative to the field tests) it appears that, in general terms, the quality of the groundwater beneath the village is good although hardness is rather high. A notable exception is in the vicinity of wells 5 and 6. Nitrate concentration in water samples from these wells is over the safe drinking water standard of 10 mg/l and may be unsafe for consumption by infants one year or less in age. The source of the nitrate is not known but warrants further investigation. In addition, well 5 has a very high concentration of total phosphorus and is many times higher than the 0.20 mg/l standard used by the Trust Territory Environmental Protection Board (Territorial Register, 1978). It should also be noted that well 15 exceeded this limit. The probable source of phosphorus is from the practice of bathing and clothes washing near the wells.

Seismic-Refraction Survey

There were 25 seismic-refraction surveys conducted on Nukuoro Island (Figure 5). The majority of these seismograms showed a definite 3-layer velocity profile while the remainder of the records indicated a 2-layer system. Each velocity layer represents a strata of sediment or rock with contrasting characteristics. From the analysis of the seismic records it was possible to determine the thickness of two of the layers (thus locate the top of the third layer) and determine the characteristic velocity of all three layers (i.e., the speed at which the hammer-generated wave passed through the subsurface). Results from the analysis of the 2-layer seismogram and 3-layer seismogram are listed in Tables 5 and 6, respectively. The distribution of seismic characteristics around Nukuoro is given in Tables 7 and 8. Additional information such as layer depths, time-distance graphs, and seismic profiles are contained in Appendix B.

Table 4. **Water quality at selected wells. Samples taken on March 30, 1983 with a falling tide.** Analyses **made at WERI using Standard Methods (1980).**

Well	Time	Water Depth (in)	Temp (°C)	Specific Conduct (μmho/cm)	Chloride (mg/l)	Alkalinity (mg/l)	Total Hardness ($mg/CaCO_3/l$)	Calcium Hardness ($mg/CaCO_3/l$)	Carbon Dioxide (mg/l)	Total Phosphorus (mg/l)	Nitrate Nitrogen (mg/l)	Ammonia Nitrogen (mg/l)
5	0820	18	27.5	3600	875	360	699	466	204	2.40	14.05	0.031
6	0825	30	27.8	6800	1700	290	912	466	58	0.165	12.50	0.049
9	0809	24	27.0	1000	230	390	555	347	170	0.055	0.480	0.043
24	0804	24	27.4	1450	240	380	605	377	210	0.135	0.335	0.138
23	0800	28	27.0	910	120	380	387	278	130	0.095	0.012	0.022
28	0752	30	26.8	700	150	210	426	287	202	0.095	0.268	0.104
26	0752	36	27.6	1450	360	320	446	317	104	0.047	0.027	0.038
25	0745	14	27.4	1400	310	320	456	307	128	0.033	0.199	0.040
15	0727	24	27.0	1000	230	400	505	377	192	0.480	0.002	0.022
16	0725	24	27.5	800	200	300	456	278	90	0.079	0.085	0.061

Table 5. Seismic velocities and surface-unit thicknesses for 2-layer seismograms.

Layer 1			Layer 2
Spread	Vel.(ft/s)	Thickness (ft)	Vel. (ft/sec)
1	1500	8.3	6391
2	1500	8.6	6798
3	1500	4.2	5812
4	1500	6.3	6368
5	1500	6.7	6920
6	1500	7.7	7703
7	1500	5.0	6092
25	1307	9.8	6350
*1 & 2	1500	8.4	6591
*3 & 4	1500	5.2	6084
*5 - 7	1500	7.0	6873
ave.	1482	6.7	6563

*Geophone spreads overlap and data are processed as such.

Table 6. Seismic velocities and unit depths for 3-layer seismograms.

	Layer 1	Layer 2		Layer 3	
Spread	Vel.(ft/s)	Vel.(ft/s)	Depth (ft)	Vel.(ft/s)	Depth (ft)
8	1500	9931	5.9	15152	41.1
9	1500	8428	6.7	9912	47.5
10	1500	5214	6.2	7194	49.0
11	1695	4884	8.6	8140	62.0
12	1500	7353	6.4	11236	52.0
13	1500	5420	9.0	7692	44.6
14	1500	5089	8.1	7293	53.8
15	1500	5130	7.9	6897	51.2
16	1603	5069	7.8	6897	58.9
17	1674	5227	13.4	7115	60.1
18	1458	5174	11.8	6061	35.8
19	1500	5749	9.7	7143	37.5
20	1500	6043	11.5	13359	71.8
21	1646	6003	9.1	8650	61.2
22	1347	5794	4.8	7951	65.0
23	1368	6346	7.1	8718	42.0
24	1424	5370	9.5	7752	67.4
ave.	1513	6013	8.4	8657	53.0

Table 7. Distribution of unit seismic velocities and depths for spreads along the ocean side of Nukuoro.

	Layer 1	Layer 2		Layer 3	
Spread	Vel(ft/s)	Vel(ft/s)	Depth(ft)	Vel(ft/s)	Dept(ft)
1	1500	6391	8.3	--	--
2	1500	6798	8.6	--	--
3	1500	5812	4.2	--	--
4	1500	6368	6.3	--	--
5	1500	6920	6.7	--	--
6	1500	7703	7.7	--	--
7	1500	6092	5.0	--	--
8	1500	9931	5.9	15152	41.1
9	1500	8428	6.7	9912	47.5
12	1500	7353	6.4	11236	52.0
22	1347	5794	4.8	7951	65.0
25	1368	6346	7.1	--	--
ave.	1463	69450	6.7	10594	49.5
range	1307-1500	5794-9931		7951-15152	
standard deviation					

Table 8. Distribution of unit depths and velocities for spreads along lagoon side of Nukuoro.

Spread	Vel(ft/s)	Vel(ft/s)	Dept(ft)	Vel(ft/s)	Depth(ft)
10	1500	5214	6.2	7194	49.0
11	1695	4884	8.6	8140	62.0
13	1500	5420	9.0	7692	44.6
14	1500	5089	8.1	7292	44.6
15	1500	5130	7.9	6897	51.2
16	1603	5069	7.8	6897	58.9
17	1674	5227	13.4	7114	60.1
18	1458	5174	11.8	6061	35.8
19	1500	5749	9.7	7143	37.5
24	1424	5370	9.5	7752	67.4
ave.	1535	5233	9.2	7218	52.0

A number of relevant points can be made with regard to the results from the seismic-refraction survey. These points are summarized below:

1. The average velocity of wave propagation through layer 1 is 1498 feet/second (ft/s) with a range of 1307 ft/s to 1695 ft/s. The average thickness of layer 1 is 8.0 feet with a range of 4.2 feet to 13.4 feet (71% of the values are in the range of 6.0 feet to 10.0 feet).

2. Two velocities are associated with layer 2; a low velocity beneath the area west of the taro patch and north of the church extending to the north end of the island (i.e., beneath the main portion of the village) and a high velocity beneath the remainder of the island. The low velocity portion of layer 2 has an average value of 5233 ft/s and ranges between 4884 ft/s and 5749 ft/s. The average for the higher velocity is 6945 ft/s and ranges between 5794 ft/s and 9931 ft/s. An average thickness of layer 2 associated with the low-velocity sector is 42.8 feet which is the same as the average thickness of the higher velocity sector.

3. Layer 3 is composed of two sectors of contrasting velocities in the same manner as that of layer 2. In general, velocities above 8000 ft/s are associated with the sector of layer 3 which corresponds in area with the higher velocity sector of layer 2. Velocities below 8000 ft/s correspond to the area beneath the main portion of the village (i.e., to the area occupied by the low-velocity sector of layer 2).

Questionnaire Responses

Responses to the various survey questions are generalized in Table 9. For purposes of brevity, only those most frequent responses to a number of important questions appear in the table. A complete set of answers in addition to the original questionnaire is presented in Appendix C.

Table 9. Generalized questionnaire reponses.

Question		Response	Number
What is the problem with the taro patch?	a)	Plants are damaged, dying, and stems are rotting.	44
	b)	Salt-water is causing the problem.	12
How many times has the problem occurred in the past?	a)	a year ago.	27
	b)	15-17 years ago.	16
What time of the year did the problem occur?	a)	End of year.	32
	b)	About September to January	18
	c)	Summer.	7
What are weather and sea conditions when there is no problem with the taro patch?	a)	Abundant rainfall.	19
	b)	Sea level not "high" and surface smooth and calm.	35
How well are foods like breadfruit and papaya growing?	a)	Some growing well (some not).	25
	b)	Not growing well.	7
	c)	Growing well.	
What was done in the past to correct problems with the taro patch?	a)	Refill taro patch with organic material.	23
	b)	Install cisterns around salt-water "holes" in taro patch.	22
What do you believe causes the problem and do you think can be solved?	a)	Thin soil and not refilling the taro patch.	28
	b)	Salt-water intrusion.	10
	c)	Bombing the island in WWII	3
	d)	Blasting the channel	2
	e)	Don't know.	5
	f)	Can be solved.	28
	g)	Can not be solved.	0
	h)	Not certain.	4
What do you believe can be done to correct the problem?	a)	Refill taro patch with organic material.	19
	b)	Community cooperation to work in the taro patch.	12
	c)	Not certain	1

DISCUSSION

The following discussion of the study results is based on the interpretation of water quality data and geophysical information combined with the questionnaire responses, general observations, and some of the findings presented in previous field-trip reports by Federated States of Micronesia and Ponape State officials. Three main topics are addressed below. Specifically, these are (1) the geologic framework of the island, (2) the occurrence of fresh and brackish groundwater and its distribution, and (3) the taro problem and its possible solution. The first two topics are discussed here in order to present what is currently known about the subsurface environment of Nukuoro so that a basic understanding of the mechanisms at work can be formulated and a logical approach to solving the problem of low taro yield can be initiated.

Geologic Framework

The geologic framework of Nukuoro Island can be deduced from the results of the seismic-refraction survey and, in part, from the general observations. Three distinct horizontal layers make up the structural components of the island (Table 10). The surface layer has an average thickness of about 8 feet (depends on elevation) and is composed of dry unconsolidated sands and gravels for the most part. Sediment size grades from sand on the lagoon side to gravel, cobbles, and boulders on the ocean side (readily observable on the surface). Layer 2, immediately beneath the surface layer is, in part, composed of material similar to that found on the reef flat and margin along the ocean side of the island. This material can be observed at the bottom of several wells and within a number of taro-patch cisterns. This higher velocity zone of layer 2 appears to underlie a large portion of Nukuoro as indicated in the map of Figure 6. Along the lagoon side, there appears to be a change in the composition of layer 2. Seismic velocities for this portion of the unit are characteristic of saturated unconsolidated to poorly cemented sands and fine gravels. Wells located in this area were observed to have sand bottoms and, in some cases, a relatively thin (about one foot) cemented crust near or at the water table. The thickness of layer 2 overall is about 43 feet. A similar velocity contrast and distribution was found for layer 3. Seismic velocities determined for that portion of layer 3 beneath the eastern portion of the island may indicate a crevised or porous limestone while velocities determined for layer 3 beneath the western portion may indicate a well-cemented sand, although other types of material are possible. The cross sections presented in Figure 7 summarize the 3-layer structure of Nukuoro.

Groundwater Occurrence and Water Quality

The occurrence and areal distribution of fresh and brackish groundwater relates directly to the geological composition and structural components of the island. In general, salty groundwater is associated with the higher velocity part of layer 2, that is, to the reef-flat type material and fresh groundwater is associated with that portion of layer 2 composed of sand and fine gravel underlying the western side of the island.

Table 10. Possible material type comparing the island based on seismic velocities.

Layer	Velocity Range (ft/s)	Possible Subsurface material*
1	1282 - 2500	Unsaturated, unconsolidated sand
2 (West)	4167 - 5434	Saturated, unconsolidated to consolidated sand and fine gravel
2 (East)	5555 - 9433	Saturated, consolidated reef flat (probably fractured)
3 (West)	6849 - 10000	Saturated, well cemented sand
3 (East)	10000 - 20000	Limestone, saturated

*Sources of information concerning velocity-material relationships are Bouwer (1978) and Mandel and Shiftan (1981).

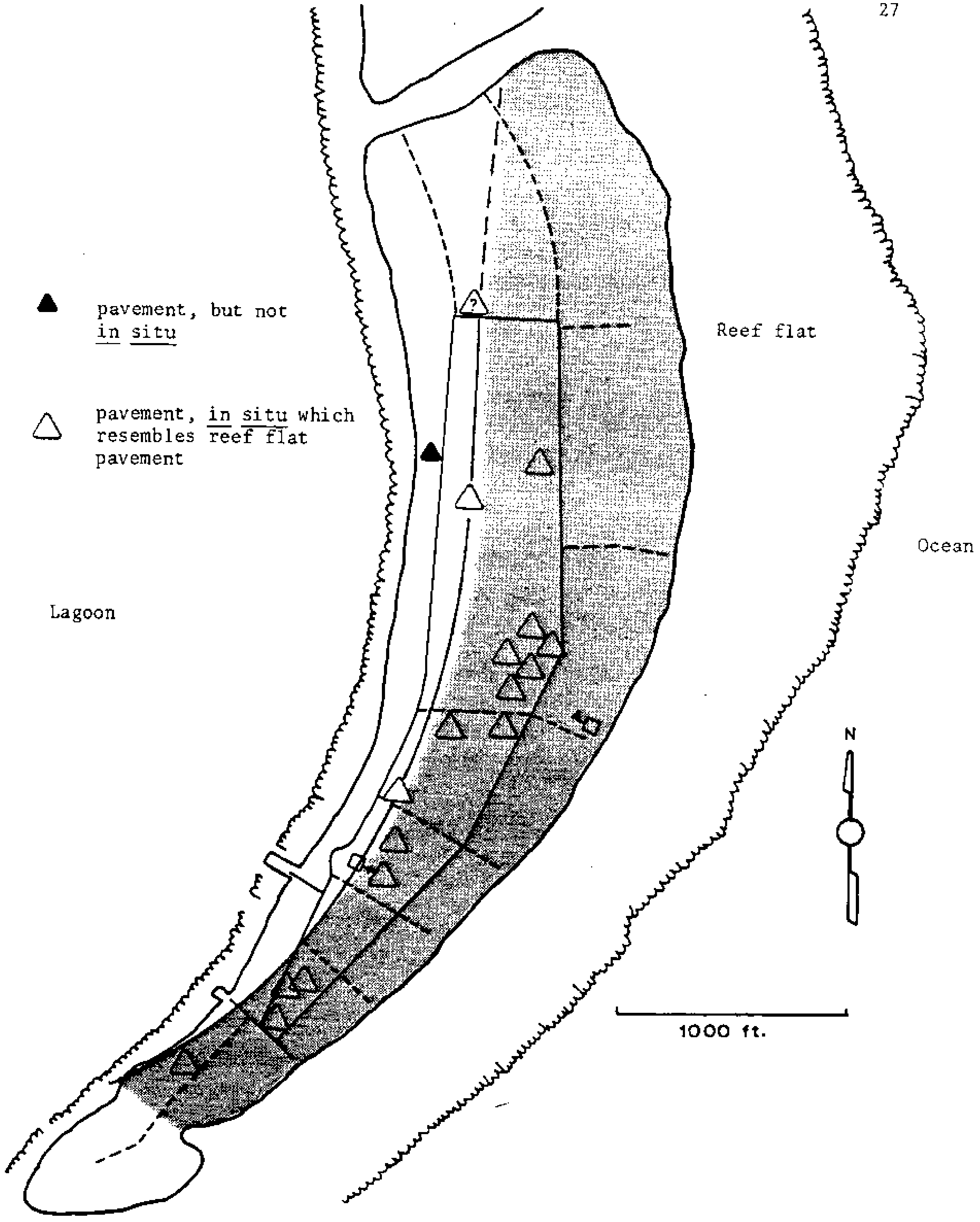

Figure 6. Distribution of the reef-flat pavement as determined by observation and the seismic-refraction survey.

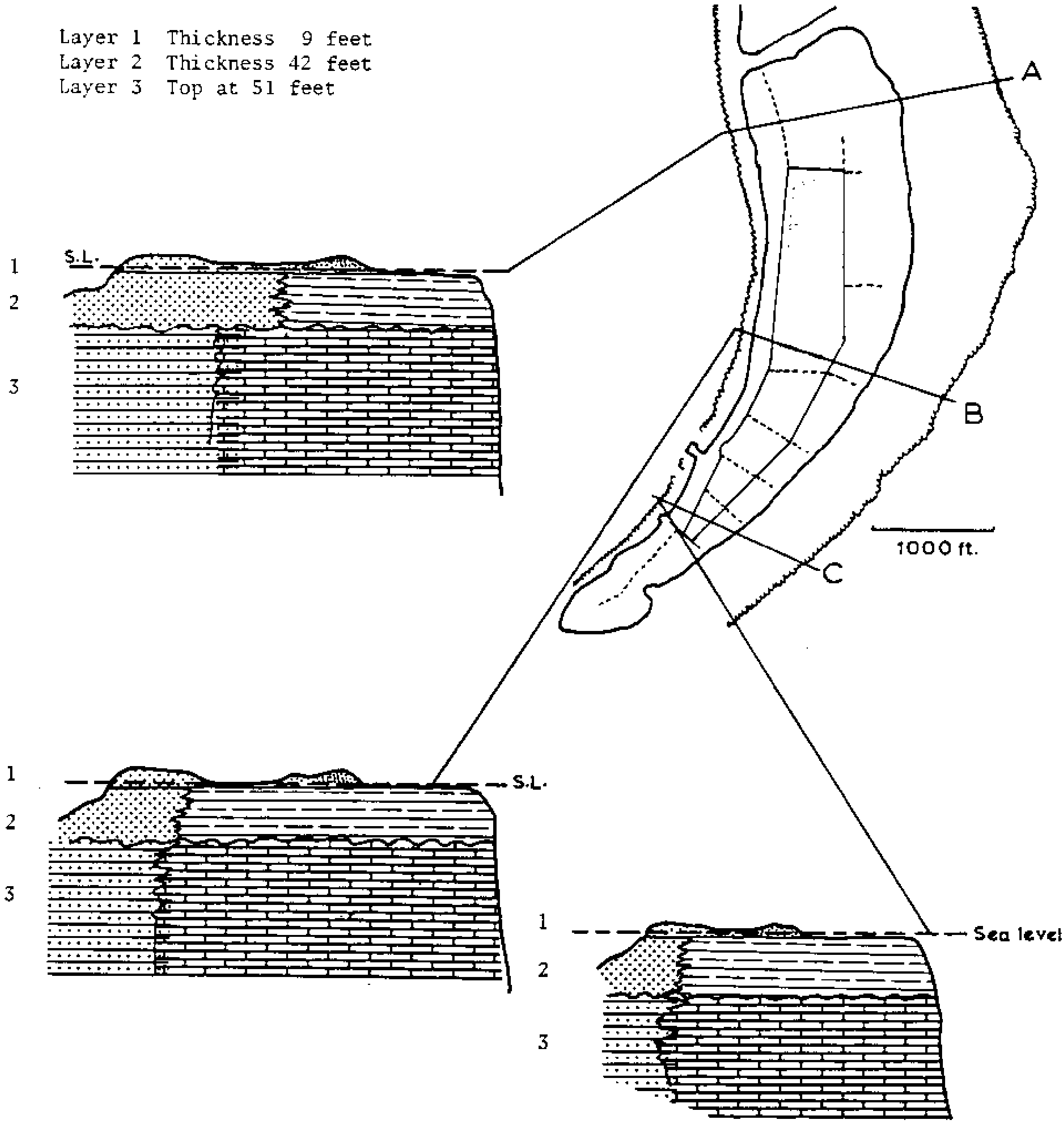

Figure 7. Cross sections showing the geologic structure of the subsurface as determined by the seismic-refraction survey.

This general relationship between the occurrence of groundwater and the geology of the island is illustrated by the contour maps of chloride-ion concentration in Figures 8 and 9. The maps represent conditions at low and high tides near the water table. It is readily apparent that very high chloride concentrations are within the southeastern part; lowest concentrations are along the western side and north of the church.

A comparison of chloride maps for low and high tides indicates little significant change in the configuration of the contours. This, in conjunction with profile data from Auger 2 (see Table 3), suggests that the groundwater body forms a lens which floats on and partially mixes with the underlying sea water. The freshest part of the lens is located along the lagoon side and the northwestern end of the island. From the conductivity profile of Auger 2 and from the configuration of the island and what is known of its geological makeup, the thickest part of the fresh-water lens is probably located in the vicinity of Auger 2. A minimum practical estimate of the thickness based on the profile taken in Auger 2 is 3.5 feet (at the time of measurement).

The volume of freshwater stored in the ground at any given time is dependent primarily on the rate at which rainfall recharges the system (for the small island case). From the available rainfall record, illustrated by the bar graph of Figure 10 (summary of Appendix A) and discussions with local residents, there was a significant decrease in rainfall over the past year as compared to previous years (except possibly 1981). This decrease in rainfall caused severe drought conditions which not only affected the vegetation but also the ground-water supply. The result was a probable significant decrease in the volume of freshwater in storage as compared to normal rainfall conditions. Table 11 lists chloride-ion data collected in February 1982 and during this study for the same sample sites. In general, there has been an increase in chloride-ion concentrations which suggests a decrease in the size of the fresh-water lens over that for 1982 conditions. Unfortunately, the rainfall record for the latter part of 1982 was not available and therefore a direct comparison of conditions could not be made. As long as drought conditions existed the size of the lens continued to decrease. Therefore, the minimum thickness estimate is only a temporary value.

In general, the water quality of the freshest part of lens is good. However, there is a notable exception that warrants concern. Nitrate concentrations measured in wells 5 and 6 exceed the standard upper limit of 10 mg/l. The map of Figure 11 indicates the area of high concentration in addition to concentrations found for other sample sites. Nitrate concentration in excess of the recommended limit may be hazardous to the health of infants one year or less in age and therefore water from this area should not be consumed (Lewis et al., 1980: p 6). The quality of water from wells along the lagoon side and north of the church indicates safe concentrations of nitrate.

The Problem and Its Solution

Taro production on Nukuoro has seriously decreased due to salt-water intrusion into the region of cultivation. The photographs in Figures 12

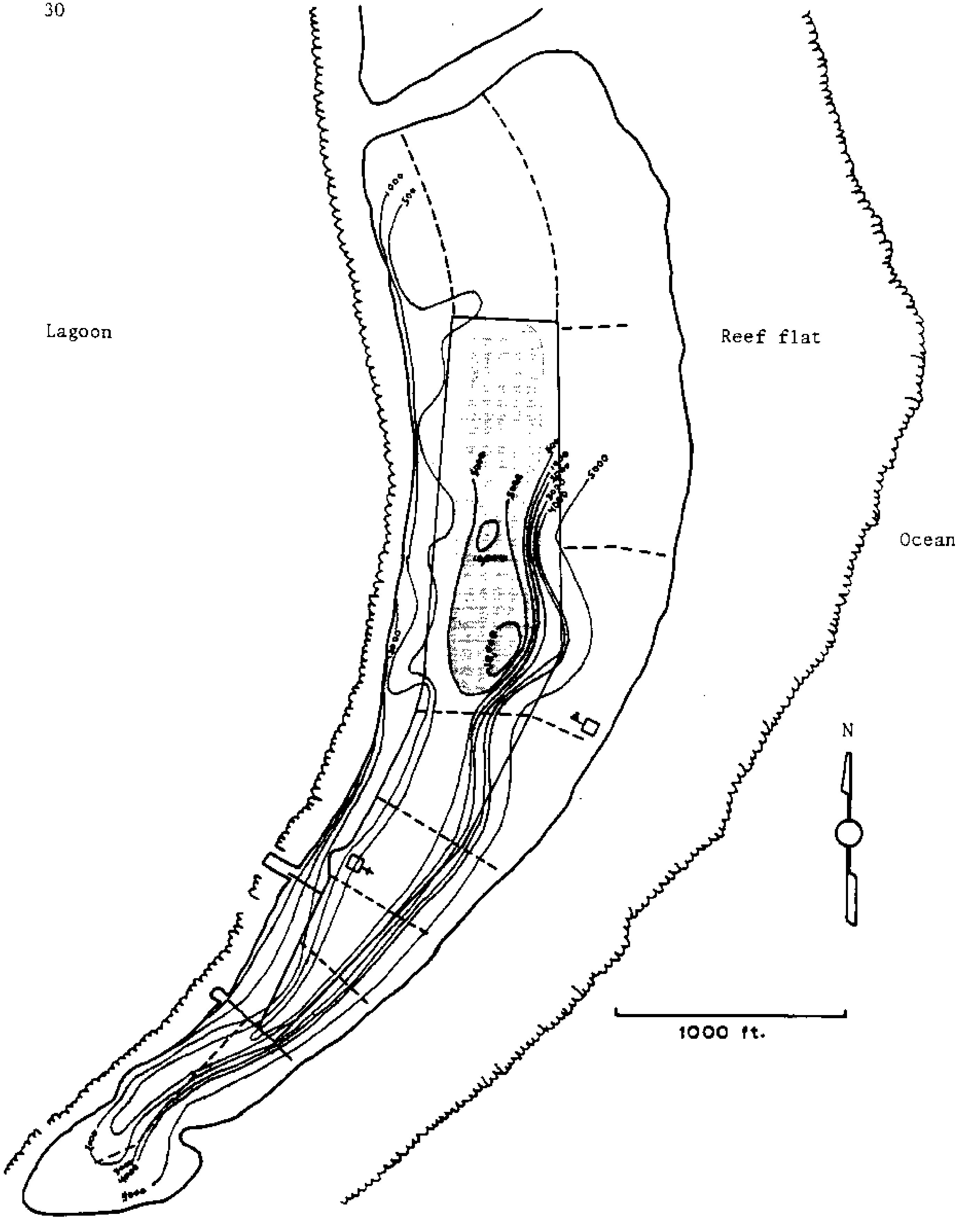

Figure 8. Contour map of chloride-ion concentration in ground-water samples at low tide. Contours are in mg/ℓ.

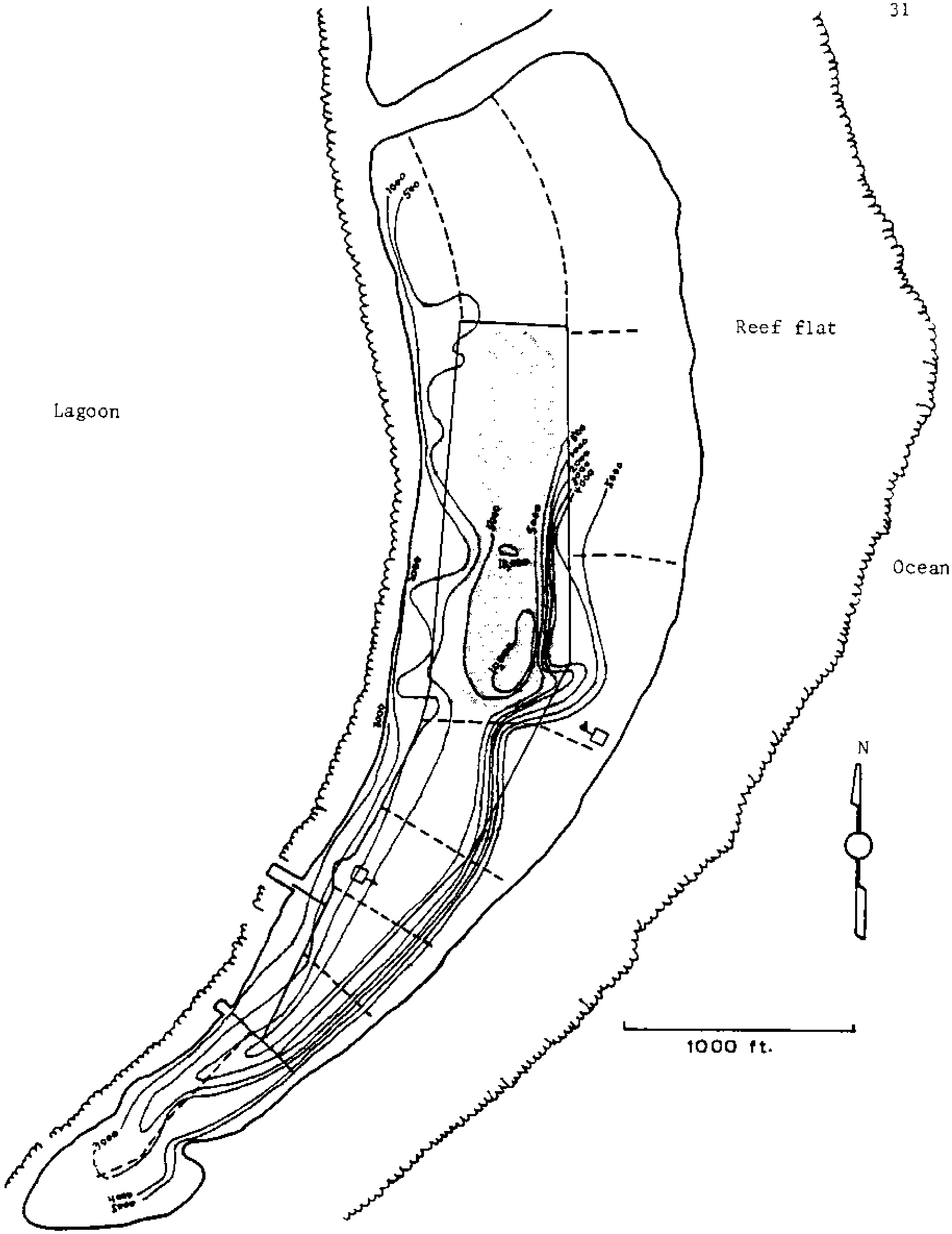

Figure 9. Contour map of chloride-ion concentration in ground-water samples at high tide. Contours are in mg/ℓ.

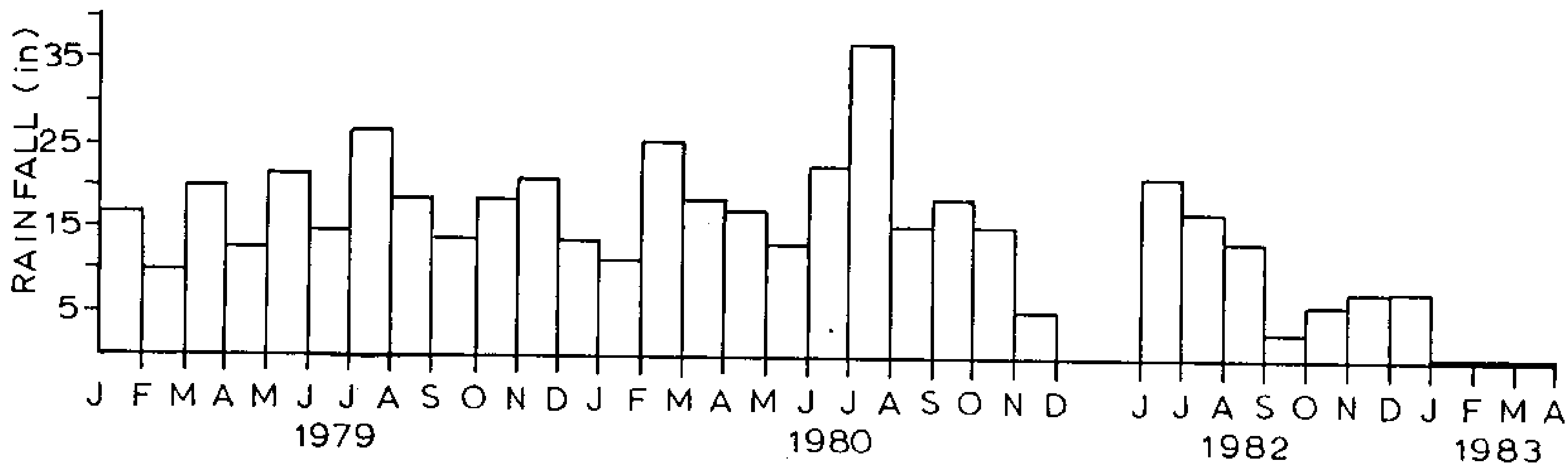

Figure 10. Available rainfall record for the Nukuoro station.

Table 11. Chloride readings taken in 1982 (Winkle, 1982) compared with values obtained in 1983.

	Chlorides (mg/l)		Apparent
Well No.	Feb 82	Apr 83	Change
1	500	710-1000	increase
9	1000	600-1050	none
15	250	455-550	increase
21	250	710-1325	increase
22	1000	1050-1150	none
24	1025	1325	increase
25	1750	1300-1350	decrease
26	250	775-1325	increase
27	500	35-700	none
32	1000	500-700	decrease
T-/T-2[+]	7900*	9150	similar range
T-4	9200*	12600	similar range

[+] taro patch cisterns
* mean of 6 values

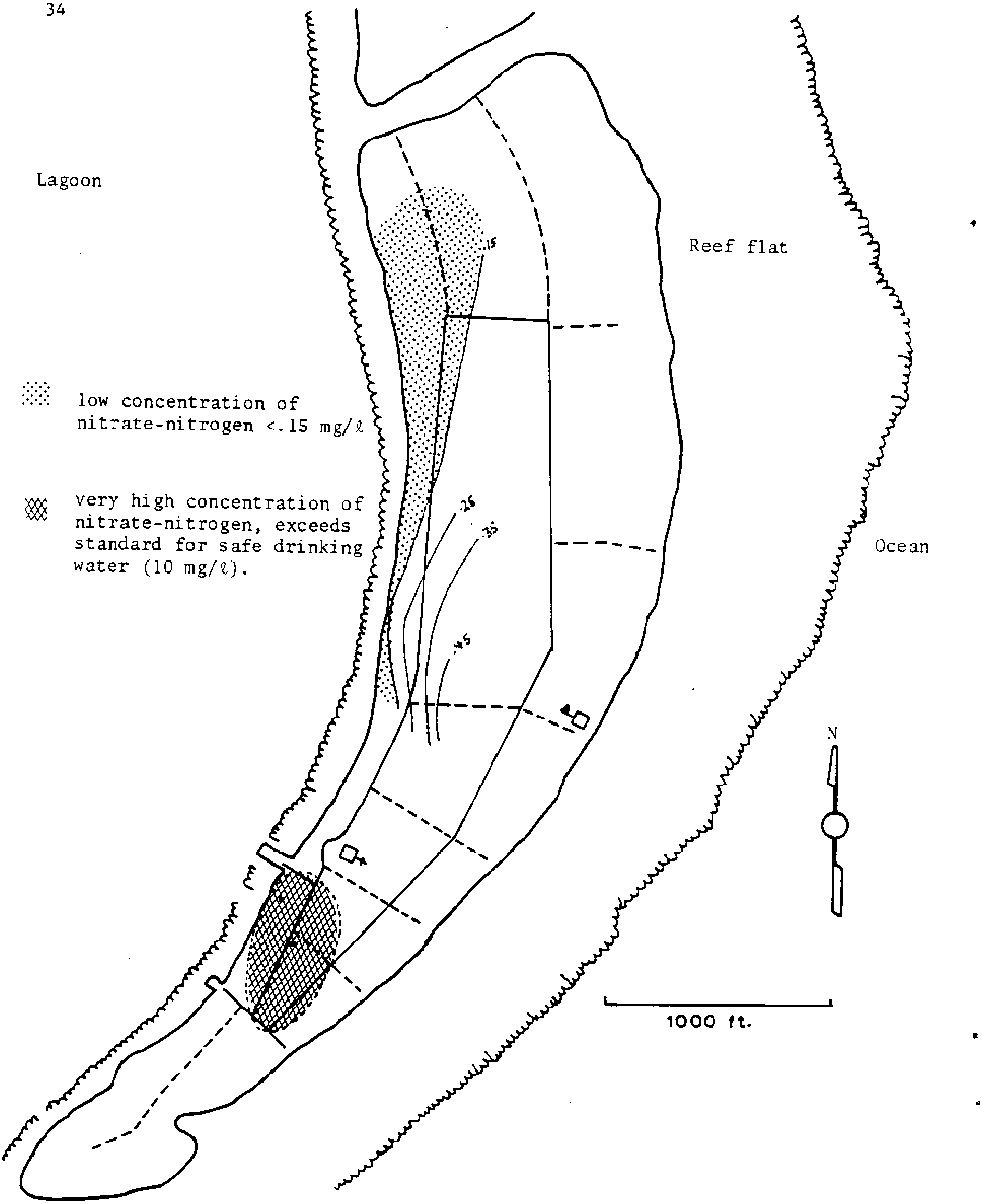

Figure 11. Nitrate-nitrogen concentrations in water samples from household wells.

and 13 were taken at the southern end of the taro patch, the most severely affected area. The organic soil layer is very thin and salty groundwater can be seen standing in small depressions at high tide. Taro plants are scarce in this area, and those that are growing are not usable. The soil itself contains high concentrations of salt as evident by crusts over large parts of the soil cover.

The current problem with taro cultivation is not an isolated one. Problems with salt water entering the taro patch have occurred in the past, either from waves inundating the island or from intrusion of salty groundwater. A listing of historical events is given in Table 12. This chronology of events was presented in a previous investigation by Pobuk (1982) and is reproduced here for comparative purposes. From the responses to the questionnaire and from the events listed in Table 12, the current problem seems to be the product of years of maintenance neglect and was initiated by unfavorable natural conditions.

Major factors that have contributed to the problem are (1) neglect of the practice of refilling the taro patch to maintain soil thickness, (2) prevalence of drought conditions, and (3) salt-water intrusion into the taro patch. These factors combined or singly have produced the following conditions.

1. Due to the drought, the normally slightly brackish groundwater beneath the taro patch has become very brackish. Freshwater usually derived from rainfall is absent; therefore, little freshwater is available for mixing with sea water within the lens.

2. Because of the thin soil layer over a large part of the taro patch, brackish groundwater rises to the level of the root zone and in some areas evaporates into the atmosphere leaving a salt crust on the soil surface.

3. In areas where the soil layer supports plants under normal weather conditions, the lack of rainfall and the high evaporation rates causes salt to be retained within the soil. Normal rainfall would otherwise rinse the salt from the soil cover.

In terms of a solution to the problem, nothing can be done about the current drought or the phenomenon of salt-water intrusion. The drought, although severe in its effects, is temporary. Results from the seismic-refraction study indicate that salty groundwater will probably always continue to invade the taro patch as it has done in the past, although its degree of saltiness will become less with the initiation of the wet season and the replenishment of the lens. The reason for the continued presence of the brackish groundwater is related to the type of subsurface material that contains it. That is, the material underlying the ocean side of the taro patch allows a free movement of both freshwater and seawater (i.e., high permeability) and thus allows a greater degree of mixing which produces the brackish groundwater.

As suggested by observations, responses to the questionnaire and the relative success of recent efforts to rehabilitate the taro patch, the most

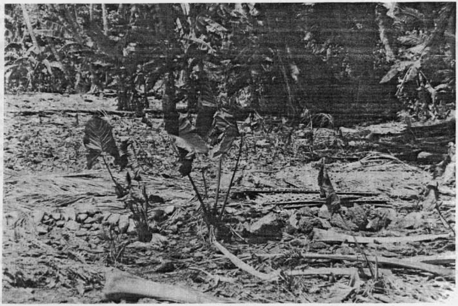

Figure 12. Photographs of the severely affected portion of the taro patch.

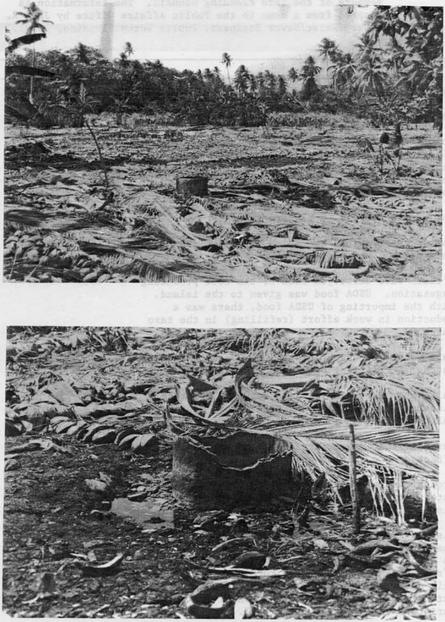

Figure 13. Photographs of severely affected area and cisterns of the taro patch.

Table 12. Historical events related to the taro patch as relayed by members of the Taro Planning Council. The information is adapted from a memo to the Public Affairs Office by Jack R. Pobuk (Water/Sewer Engineer, Public Works Division, 1982).

HISTORICAL EVENT	DATE
Typhoon generated waves flooded taro patch. A ditch was dug to drain patch with minimal taro damage.	1930's
Government changed from Namwaski system to an elected Chief Magistrate and Council system. Under the Namwaski system, all inhabitants refilled patch at least weekly. Under the new system, refilling became irregular.	1940's
Few bomb's dropped on Nukuoro island.	1940's
One of the original two holes ("nose of the taro patch") was plugged.	1940's
A tidal wave destroyed much of the food producing vegetation. USDA food was given to the island. With the importing of USDA food, there was a reduction in work effort (refilling) in the taro patch.	1959
Salt water intrusion through many opening in taro patch. A refilling operation was begun.	1960"s (early)
Salt water intrusion again occurred. Concrete cisterns were built around openings to contain salt water.	1966-1967
Periodic salt water intrusion with some areas affected more than others.	1970's
Drought and extremely high tides. Increased salt water intrusion which overflowed cisterns and flooded large area of patch during high tide.	1981 (Sept. to Dec.)
Visit by Jack R. Pobuk. He reported about half of the patch was damaged. In affected areas, the soil is black and wet with a hydrogen sulphide odor ("rotten egg"). Taro roots rotting with a uric acid odor. A couple of small sections only show extensive refilling. Introduction of new taro varieties which were growing well.	1982 (Jan. 29 - Feb. 3)

soil layer to a height that will ensure a safe distance between the root zone and the underlying brackish groundwater. An estimate of this safe distance can be made by inspecting portions of the taro patch where healthy plants are cultivated. Because of the relatively large area of the taro patch that has suffered from neglect, the process of refilling initiated through the efforts of the Chief Magistrate will probably take a considerable amount of time and work on the part of the community members. However, this appears to be the only viable method to increase taro production and promote selfsufficiency.

SUMMARY

The following is a summary of the results and conclusions of the study.

1. The geologic structure of Nukuoro consists of three distinct horizontal layers of differing physical properties. The surface layer, with a thickness of about 8 feet, is composed primarily of dry unconsolidated sediment. Beneath the surface unit is layer 2 which is about 43 feet thick and composed of reef-flat type material along the eastern portion of the island and unconsolidated to poorly cemented sands along the lagoon side. The lowermost layer appears to be composed of dense limestone and, in part, well consolidated sediment.

2. Brackish groundwater occurs within the reef-flat type material of layer 2 and underlies most of the taro patch. This salty groundwater invades the root zone in areas of the taro patch where the organic soil layer is thin and can be seen in small depressions at high tide. The brackish water ranges from 35% to 80% seawater in composition.

3. Fresh groundwater is associated mainly with the sandy portion of layer 2 which is beneath the main part of the village.

4. Groundwater beneath this portion of the island appears to occur as a fresh-water lens with an associated mixing zone. The thickness of the lens is not known but at the time of measurement there was a minimum thickness of about 3.5 feet. This measurement was taken in an area of the island where the thickest part of the lens would be expected.

5. Water quality within the freshest part of the lens is relatively good, except for high hardness in general and high nitrate concentration (in excess of the safe drinking water standard of 10 mg/l) in the vicinity of the southwestern portion of the island. Total phosphorus levels were also found to be high in two wells. The source of nitrates is not known; however, the high phosphorus concentration is probably due to the practice of bathing and clothes washing near the household wells.

6. Reduction in taro productivity appears to be related to three factors. Specifically, these factors are (1) thin organic soil layer within portions of the taro patch due to maintenance neglect, (2) salt-water intrusion into the root zone, and (3) prevalence of drought conditions. Because of the neglect of the practice of refilling the taro patch with organic material, the soil layer has deflated to a point where salt-water reaches the root zone. Coupled with the extremely dry condition that has existed since the beginning of the year, a large portion (about one-third) of the taro patch has been severely affected by the underlying brackish groundwater.

7. The most viable method to restore taro productivity is to expand the program of refilling the taro patch (program in effect at the present time was initiated through the efforts of the Chief Magistrate and a number of concerned community members). This method will rebuild the soil layer to its former level and ensure that the root zone is sufficiently above the underlying salty groundwater.

RECOMMENDATIONS

The following recommendations are made based on the findings of this study and, in part, on information obtained during previous field trips to Nukuoro by FSM officials.

1. The Chief Magistrate and the Taro Patch Planning Council should be given any required assistance to enhance their efforts to rehabilitate the taro patch through the soil rebuilding method of refilling with organic material.

2. The process of refilling the taro patch would be greatly speeded up with the aid of a mulching machine capable of chopping the type of materials traditionally used in the refilling process. Finer sized material would decrease the decay time and thus speed the process of soil buildup. Small portions of sand can be added to the mulched organic material in order to increase the bulk of the fill.

3. The refilling process should progress from the western side of the taro patch toward the most severely affected area in the southeast portion. Because the western side of the taro patch is probably underlain by fresher water, it is less susceptible to salt-water intrusion. Therefore, taro productivity would be increased in this area and the plants would be better protected against future unpredictable conditions of salt-water intrusion.

4. A number of cisterns within the taro patch are badly deteriorated. These should be either repaired or removed completely. If they are removed, the area should be thoroughly cleaned of soil such that the reef-flat substrate is bear. The hole or fracture where the cistern was located should be completed sealed with cement or mortar so that no leakage can occur.

5. During the dry season or when evaporation is high, the soil layer should be protected by a suitable cover (coconut found, large leaves, etc) to prevent direct loss of moisture from the ground.

6. Water from those wells in which high concentration of nitrate (wells 5 and 6) are present should not be given to infants one year or less in age. Water from wells in which high concentration of total phosphorus (wells 5 and 15) are present should not be used for drinking until the concentrations of total phosphorus are determined to be safe.

7. Bathing and clothes washing should not be done within a distance of 30 feet of any household well. All waste water from such practices should be directed away from the well.

8. An in-depth water quality survey should be conducted on an island-wide basis. This survey should include not only the drinking water standards but also bacteria and virus.

ACKNOWLEDGMENTS

This study was conducted at the request of the government of the Federated States of Micronesia and funded by the Trust Territory Environmental Protection Board and the South Pacific Commission. The Water and Energy Research Institute extends its appreciation to those individuals that cooperated in the study effort. Specifically, we thank Mr. Dan Perrin, Office of Planning and Statistics, Mr. Ehson Johnson, Disaster Control Officer, and Mr. John Sohl, Federal Programs Coordinator for their invaluable help in the organization of the field trip and for their logistic support. We also extend a special thanks to Mr. Hosea Fred, Chief Magistrate of Nukuoro for his invaluable help in all aspects of the field study, especially the administration of the questionnaire. We thank the people of Nukuoro for their generosity and hospitality during our visit to their atoll. Appreciation is also extended to Ms. Toby Smolar for her assistance in the preparation of the questionnaire and for her efforts in tabulating and organizing the responses.

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A P P E N D I X   A

Rainfall Data for Nukuoro Station

RAINFALL RECORD 1979 NUKUORO ATOLL - F. S. M.

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	
1	0	.68	0	.65	.55	0	.40	0	0	---	0	.10	1
2	1.0	.48	1.40	1.46	.02	0	1.05	1.23	0	1.00	0	---	2
3	.05	.34	---	2.00	.02	.10	5.81	1.36	---	2.10	1.70	3.52	3
4	0	0	1.30	0	2.22	.27	2.09	3.70	0	0	.09	.63	4
5	0	0	0	.30	3.82	.51	1.32	.98	0	4.95	1.48	1.05	5
6	0	0	.36	0	.67	.78	4.14	1.67	.18	---	2.34	.44	6
7	0	0	.13	0	.70	.30	0	.07	0	.70	0	.43	7
8	0	.10	2.15	.16	.45	.41	0	---	0	1.36	.41	.53	8
9	0	1.72	0	1.50	.30	.41	.65	.15	0	.39	1.60	.16	9
10	.08	1.84	0	1.25	2.25	---	1.77	1.38	0	0	.23	.21	10
11	0	0	---	1.00	3.45	.11	2.61	.99	0	.09	1.13	.35	11
12	0	0	---	0	0	.02	---	1.03	0	0	1.89	0	12
13	1.75	.13	---	0	1.28	.08	---	1.61	0	0	3.95	.78	13
14	2.64	.13	---	0	.99	2.20	---	.28	0	.10	1.90	0	14
15	.05	0	.12	0	.88	1.50	---	---	.33	.50	.16	---	15
16	0	1.00	1.08	.10	---	.40	---	---	.16	.51	.45	---	16
17	1.42	0	.24	0	.52	---	2.61	---	.17	.08	0	0	17
18	0	0	1.02	1.30	.10	1.63	.07	---	0	---	0	0	18
19	---	1.10	2.14	1.20	0	1.90	0	---	---	---	1.41	0	19
20	0	.06	1.16	0	.13	0	.17	2.10	---	---	.23	2.00	20
21	0	.06	.13	0	0	.45	.24	---	0	----	.10	1.12	21
22	3.72	.18	.13	0	.04	.13	0	1.23	.12	0	.12	0	22
23	2.25	.67	4.06	0	---	---	0	.27	.48	0	.08	0	23
24	.72	.06	.20	.60	.09	1.20	0	0	0	2.00	.95	.32	24
25	.17	.88	0	.11	.10	1.22	0	---	0	0	0	---	25
26	---	0	.20	0	.06	.01	0	---	.88	.11	.78	.16	26
27	---	.31	3.15	0	0	0	1.20	0	.05	0	0	0	27
28	---	0	0	0	.66	.45	0	0	1.30	0	.10	1.63	28
29	2.69		0	.41	.32	.38	0	0	2.70	.79	0	0	29
30	T		---	.83	0	.25	1.75	0	2.50	1.64	0	0	30
31	.27		---		.97		.50	.32		2.10		0	31
Total	16.81	9.74	18.97	12.87	21.40	14.71	26.38	18.37	8.87	18.42	21.10	13.43	

Total for 1979 = 201.07

RAINFALL RECORD 1980 NUKUORO ATOLL - E. S. M.

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	
1	0	-	.25	0	0	.43	0	.73	.83	0	0		1
2	0	--	0	0	--	.58	3.45	0	4.40	0	.05		2
3	0	--	.10	.14	0	1.02	3.00	0	1.50	1.73	0		3
4	.43	1.70	--	2.17	--	.09	.93	.71	3.10	.05	0		4
5	0	1.94	--	.42	0	1.30	1.43	1.20	3.19	.05	0		5
6	.10	0	-	.12	0	.31	.03	.05	.30	.27	--		6
7	.96	1.46	--	0	0	0	1.44	0	.03	0	0		7
8	.12	0	0	0	1.05	0	.29	0	.10	.78	1.30		8
9	0	-	--	.15	.71	2.73	1.01	1.26	.08	.48	.47		9
10	.10	4.00	0	.49	.17	.64	.36	1.40	.15	0	0		10
11	1.38	0	1.29	1.08	.09	.66	3.19	0	.04	.61	0		11
12	--	.22	.35	1.56	.40	1.65	1.75	0	1.22	0	0		12
13	3.67	.16	1.52	0	0	0	1.53	1.47	.12	0	0		13
14	0	0	2.93	0	1.05	.30	4.92	.05	.11	.97	0		14
15	1.26	6.20	1.65	.84	0	.24	3.77	0	1.08	0	0		15
16	.44	--	0	--	0	.01	3.24	.12	0	.09	.10		16
17	.21	.04	0	.13	1.13	0	.11	0	0	0	0		17
18	.65	.52	2.10	0	.37	.20	.15	0	0	0	0		18
19	1.12	1.05	0	.05	2.15	.30	1.90	1.22	0	.68	.10		19
20	1.12	1.19	0	0	0	2.60	1.90	1.90	0	.15	0		20
21	--	.85	--	0	.15	--	0	2.19	1.14	.43	1.76		21
22	.06	1.75	--	2.40	0	.90	0	.03	1.21	.77	0		22
23	--	2.77	0	.05	.66	2.88	0	.72	0	.28	0		23
24	0	0	4.70	1.85	0	.47	.67	0	0	1.21	.09		24
25	0	0	.82	.91	.29	1.96	.05	.36	0	.36	0		25
26	.18	1.20	0	.31	0	0	0	.36	0	1.90	0		26
27	0	0	0	0	0	0	0	0	0	.83	1.45		27
28	0	0	0	.50	0	0	.74	1.70	0	.90	0		28
29	0	.25	0	.60	0	.84	0	0	.15	0	.05		29
30	0		0	1.50	0	.55	.10	0	.10	2.45	0		30
31	--		--		0		.88	.15		.28			31
	11.80	25.36	18.71	17.04	8.22	22.56	36.89	15.62	18.85	15.27	5.27		

Total (less December) - 195.59

RAINFALL RECORD 1982 NUKUORO ATOLL - F. S. M.

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	
1						0	1.65	0	0	1.74	0.10	0	1
2						.80	.12	.20	.45	.37	0	.02	2
3						0	1.07	.20	0	1.18	0	.10	3
4						.45	---	0	0	0	0	---	4
5						.54	1.70	0	0	0	0	1.58	5
6						0	.70	.05	.06	.60	0	.01	6
7						0	0	0	0	.23	.15	.03	7
8						0	.50	.50	0	1.27	.07	.68	8
9						.10	.25	---	0	.10	2.10	.68	9
10						.13	0	.12	0	.11	1.15	.05	10
11						.40	.80	0	.50	0	1.22	.27	11
12						.08	1.60	.38	0	.07	2.15	.35	12
13						.65	1.20	0	0	.05	.45	.05	13
14						.14	1.52	2.18	0	.05	.72	.87	14
15						.08	0	0	0	.58	0	2.50	15
16						---	0	.24	0	.10	0	0	16
17						2.00	1.50	.58	0	0	0	---	17
18						.14	---	0	0	0	0	0	18
19						---	2.15	2.22	0	0	0	.20	19
20						---	1.80	0	0	0	0	0	20
21						2.49	0	0	0	0	0	0	21
22						6.56	0	0	0	0	0	.15	22
23						1.95	0	0	0	0	0	.04	23
24						1.00	0	.23	0	0	0	.03	24
25						.37	0	1.80	0	0	0	0	25
26						.10	0	.10	0	0	0	.40	26
27						2.00	0	.14	0	0	0	0	27
28						0	0	0	1.09	0	0	---	28
29						---	0	0	0	0	0	.45	29
30						1.59	0	0	.13	0	0	0	30
31							1.05	0		0		---	31
						21.57	17.61	8.94	3.03	6.45	8.11	8.46	

RAINFALL RECORD 1983 NUKUORO ATOLL

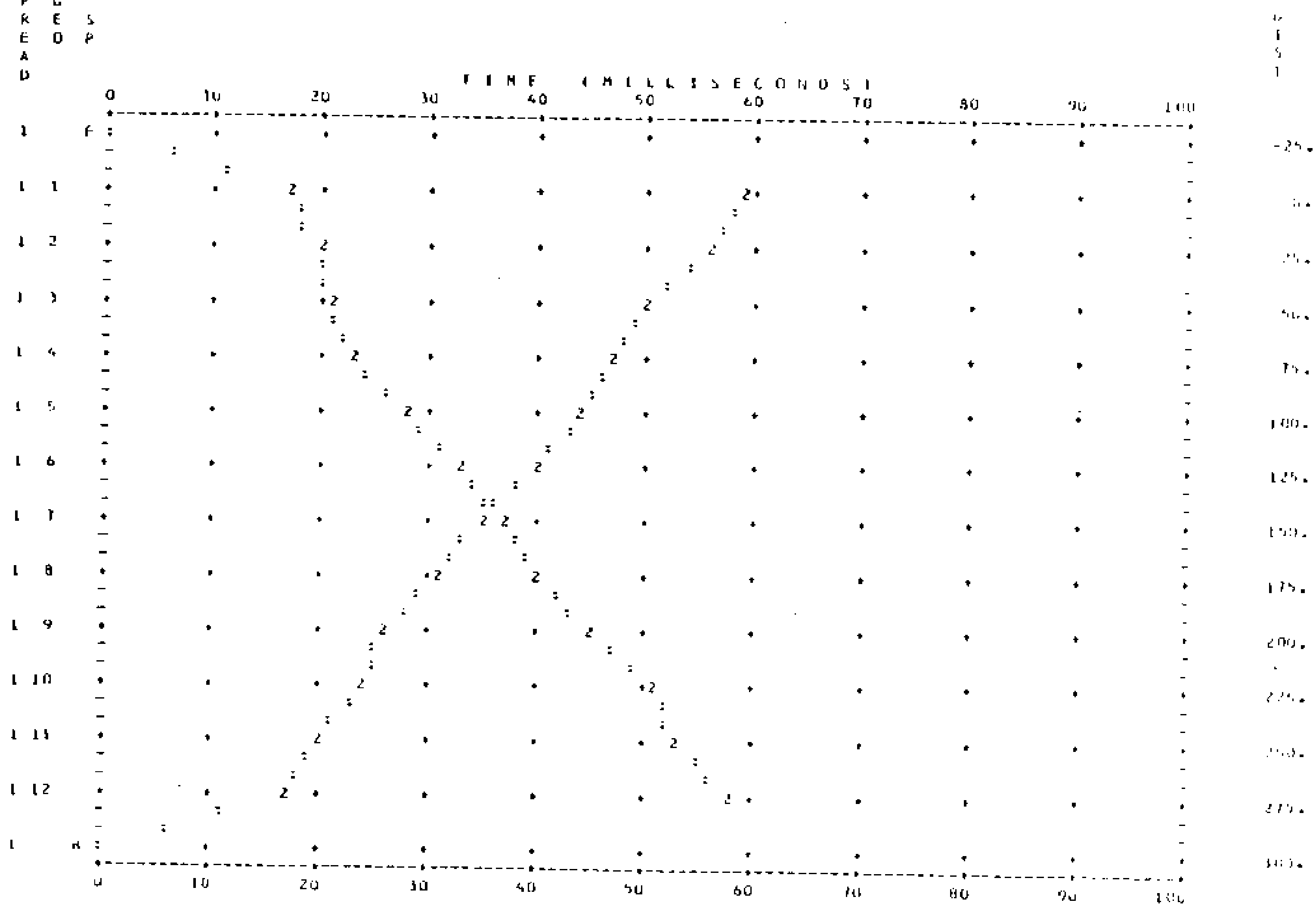
	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	
1	0												1
2	0												2
3	0												3
4	0												4
5	.40												5
6	0												6
7	0												7
8	0												8
9	0												9
10	0												10
11	0												11
12	0												12
13	0												13
14	0												14
15	0												15
16	0												16
17	.09												17
18	0												18
19	0												19
20	0												20
21	0												21
22	0												22
23	0												23
24	---												24
25	---												25
26	---												26
27	---												27
28	---												28
29	---												29
30	---												30
31	---												31
	0.49												

A P P E N D I X   B

Results of the Seismic-Refraction Survey

NUKUORO PROJECT SEISMIC REFRACTION SURVEY LINE 1

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT SEISMIC REFRACTION SURVEY LINE 1

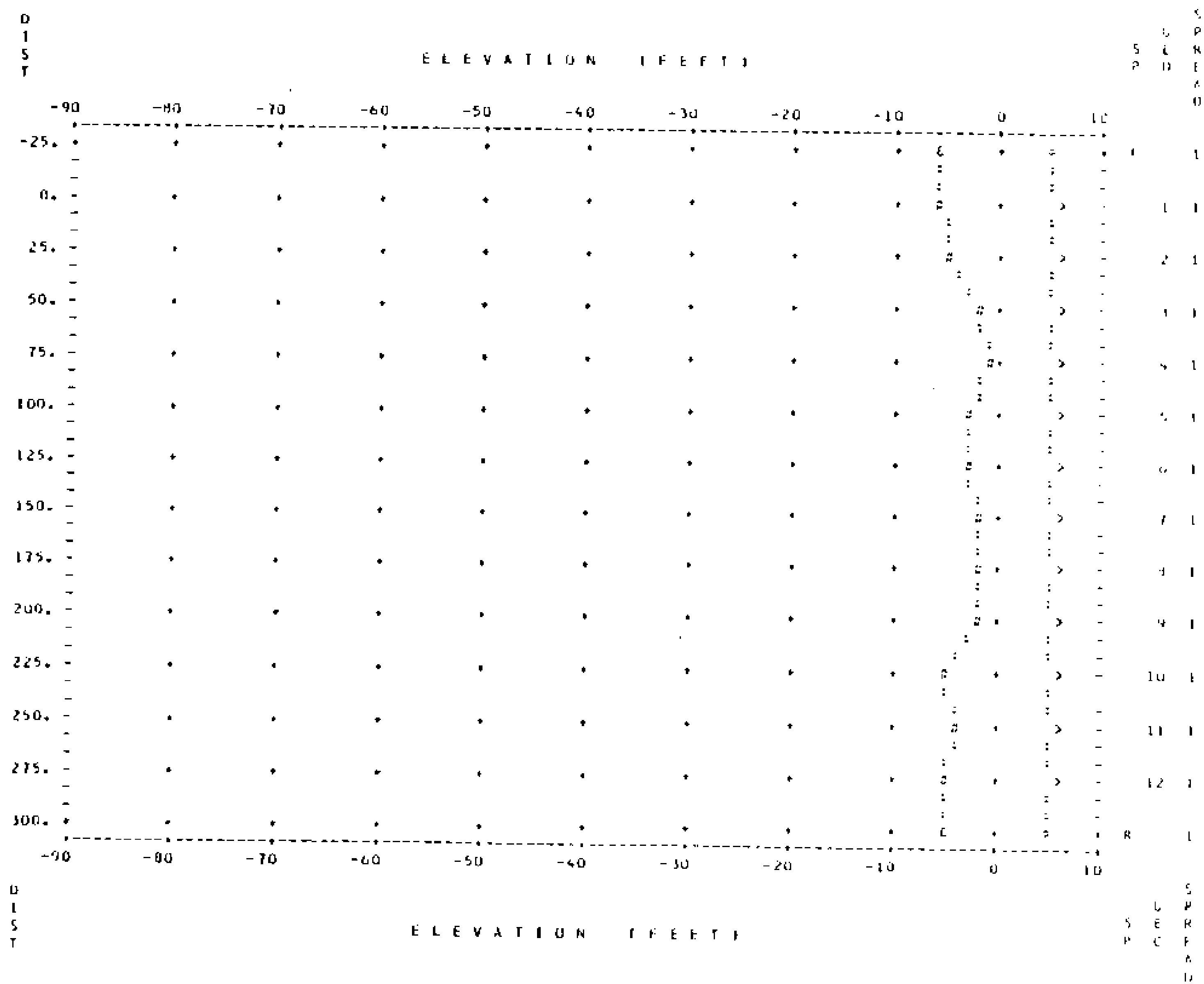
SPREAD 1   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV
F	-25.0	5.0	11.3	-6.3
R	300.0	5.0	10.5	-5.5
GEO				
1	0.0	5.0	10.7	-5.7
2	25.0	5.0	10.0	-5.0
3	50.0	5.0	7.3	-2.3
4	75.0	5.0	5.9	-0.9
5	100.0	5.0	7.7	-2.7
6	125.0	5.0	7.9	-2.9
7	150.0	5.0	7.2	-2.2
8	175.0	5.0	6.9	-1.9
9	200.0	5.0	7.4	-2.4
10	225.0	5.0	9.8	-4.8
11	250.0	5.0	9.0	-4.0
12	275.0	5.0	9.8	-4.8

VELOCITIES USED:

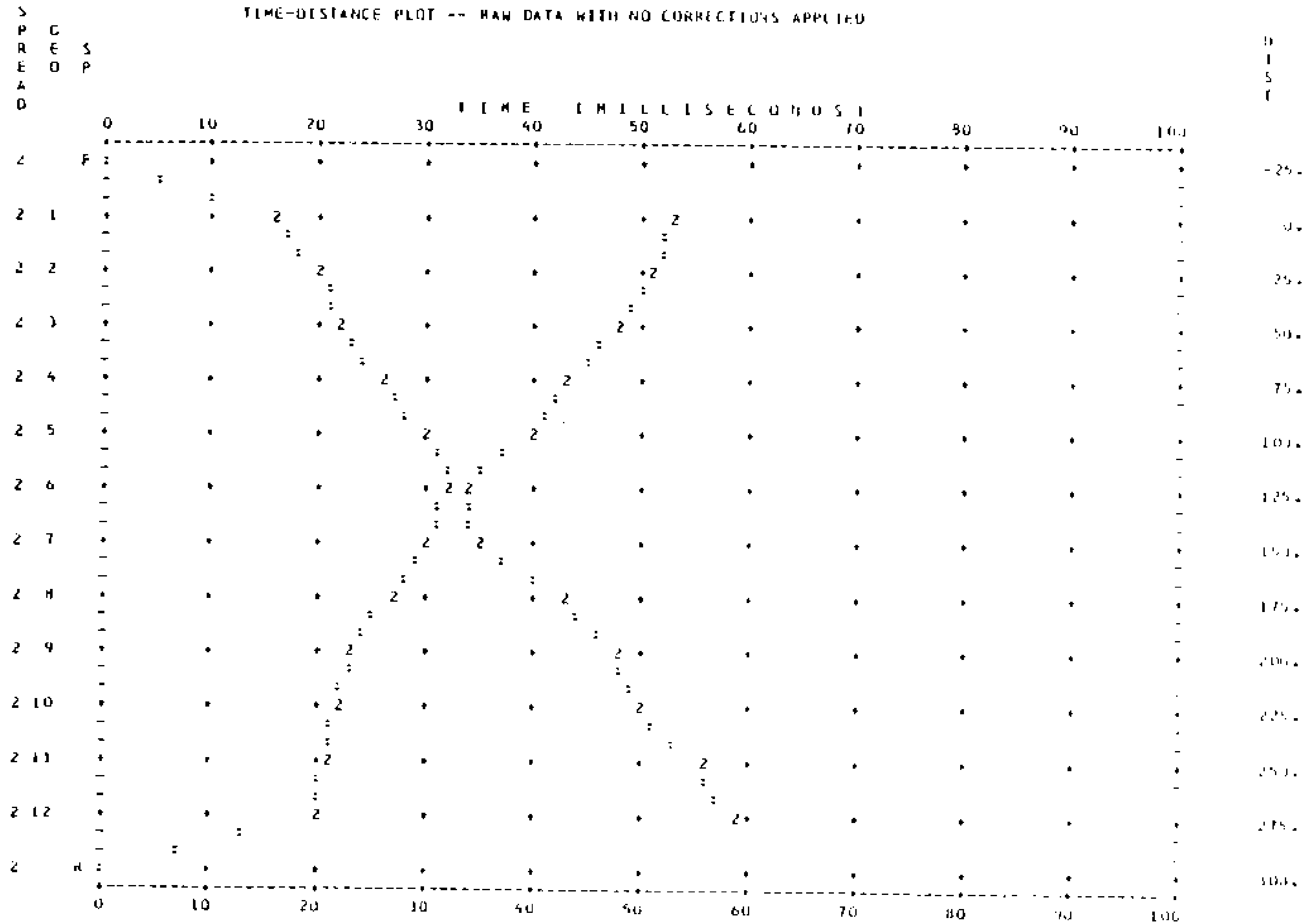
	LAYER 1	LAYER 2
VERTICAL	1500.	
HORIZONTAL		6391.

NUKUORO PROJECT SEISMIC REFRACTION SURVEY LINE 1



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 2

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 2

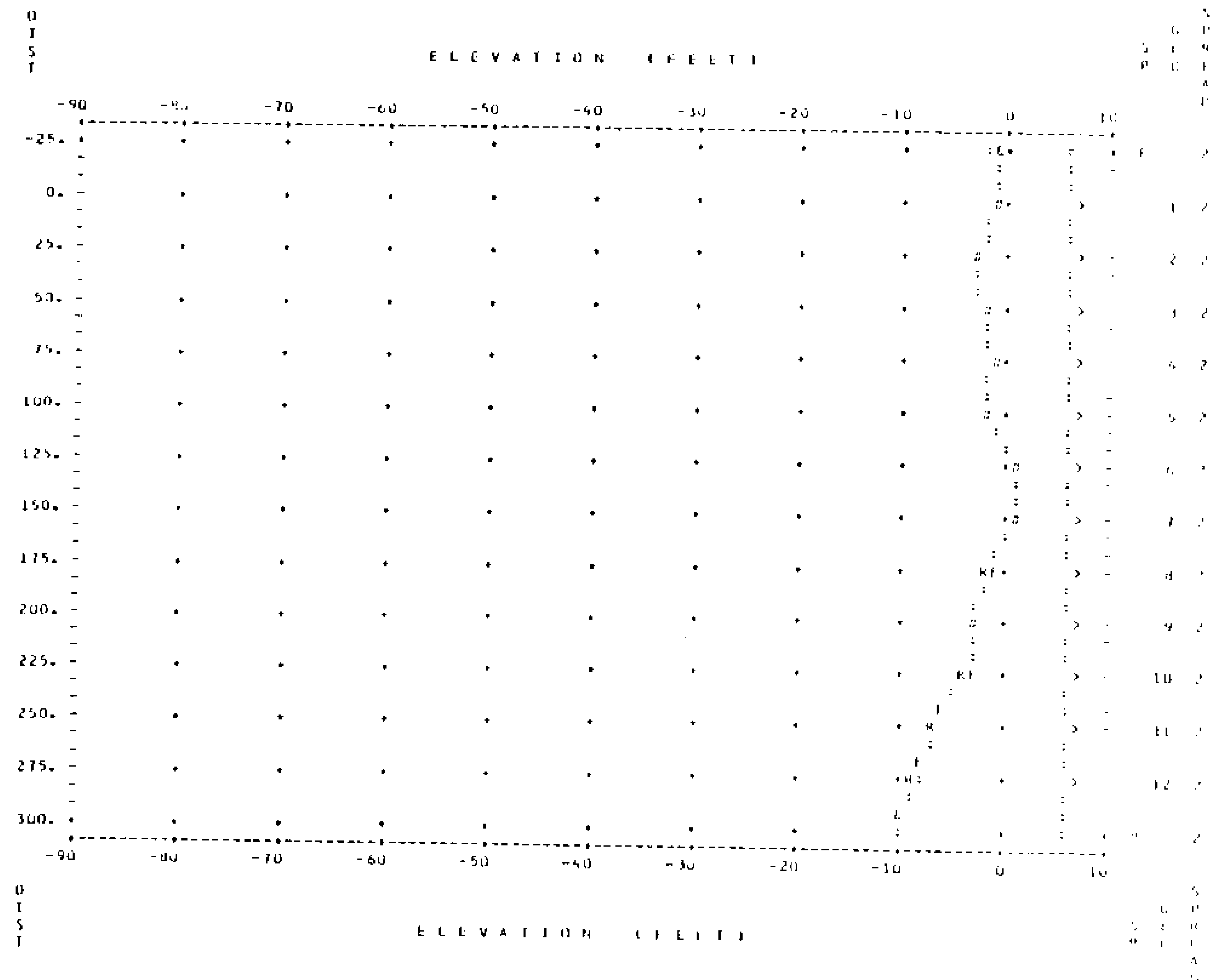
SPREAD 2   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2	
SP	POSITION	SURF ELEV	DEPTH	ELEV
F	-25.0	6.0	7.6	-1.6
R	300.0	6.0	16.3	-10.3
GEO				
1	0.0	6.0	7.1	-1.1
2	25.0	6.0	8.9	-2.9
3	50.0	6.0	8.4	-2.4
4	75.0	6.0	7.4	-1.4
5	100.0	6.0	7.7	-1.7
6	125.0	6.0	5.1	0.9
7	150.0	6.0	4.8	1.2
8	175.0	6.0	7.6	-1.6
9	200.0	6.0	9.1	-3.1
10	225.0	6.0	9.6	-3.6
11	250.0	6.0	12.8	-6.8
12	275.0	6.0	14.5	-8.5

VELOCITIES USED:

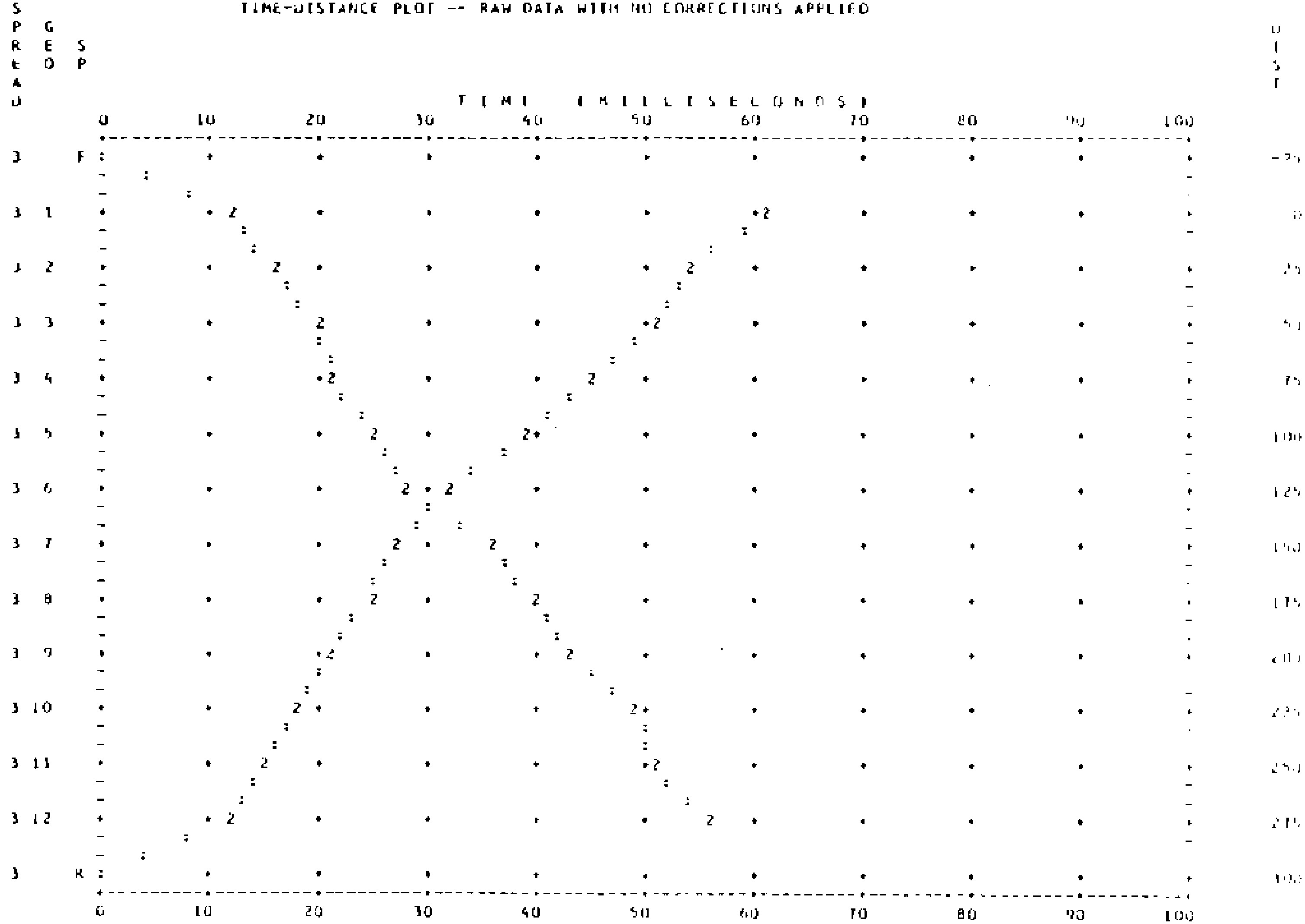
	LAYER 1	LAYER 2
VERTICAL	1500.	
HORIZONTAL		6793.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 2



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 3

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 3

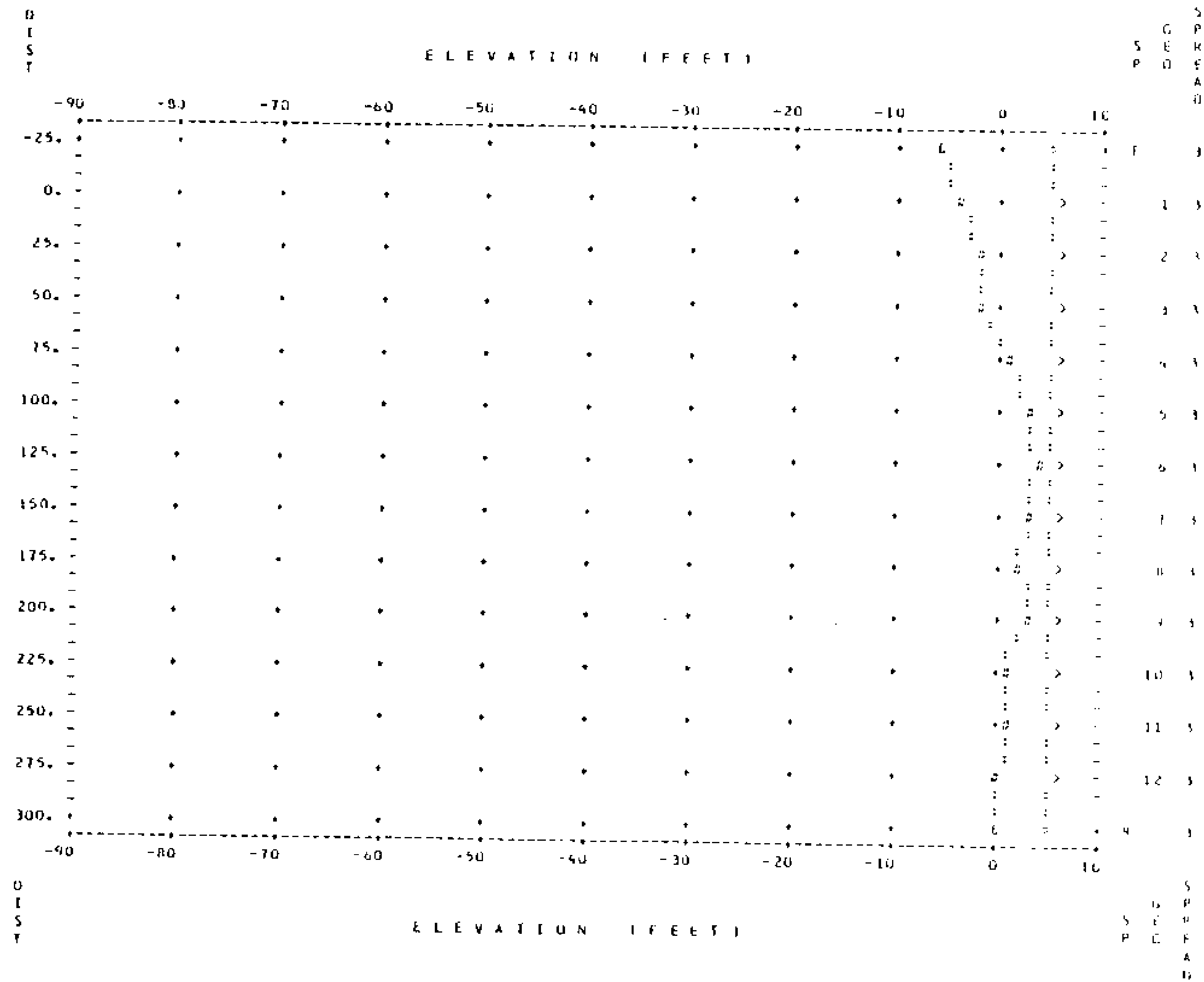
SPREAD 3   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV
F	-25.0	5.0	10.7	-5.7
R	300.0	5.0	5.4	-0.4
GEO				
1	0.0	5.0	9.1	-4.1
2	25.0	5.0	6.9	-1.9
3	50.0	5.0	7.3	-2.3
4	75.0	5.0	4.1	0.9
5	100.0	5.0	2.4	2.6
6	125.0	5.0	1.3	3.7
7	150.0	5.0	2.2	2.8
8	175.0	5.0	2.7	2.3
9	200.0	5.0	2.0	3.0
10	225.0	5.0	4.4	0.6
11	250.0	5.0	3.6	1.4
12	275.0	5.0	4.9	0.1

VELOCITIES USED:

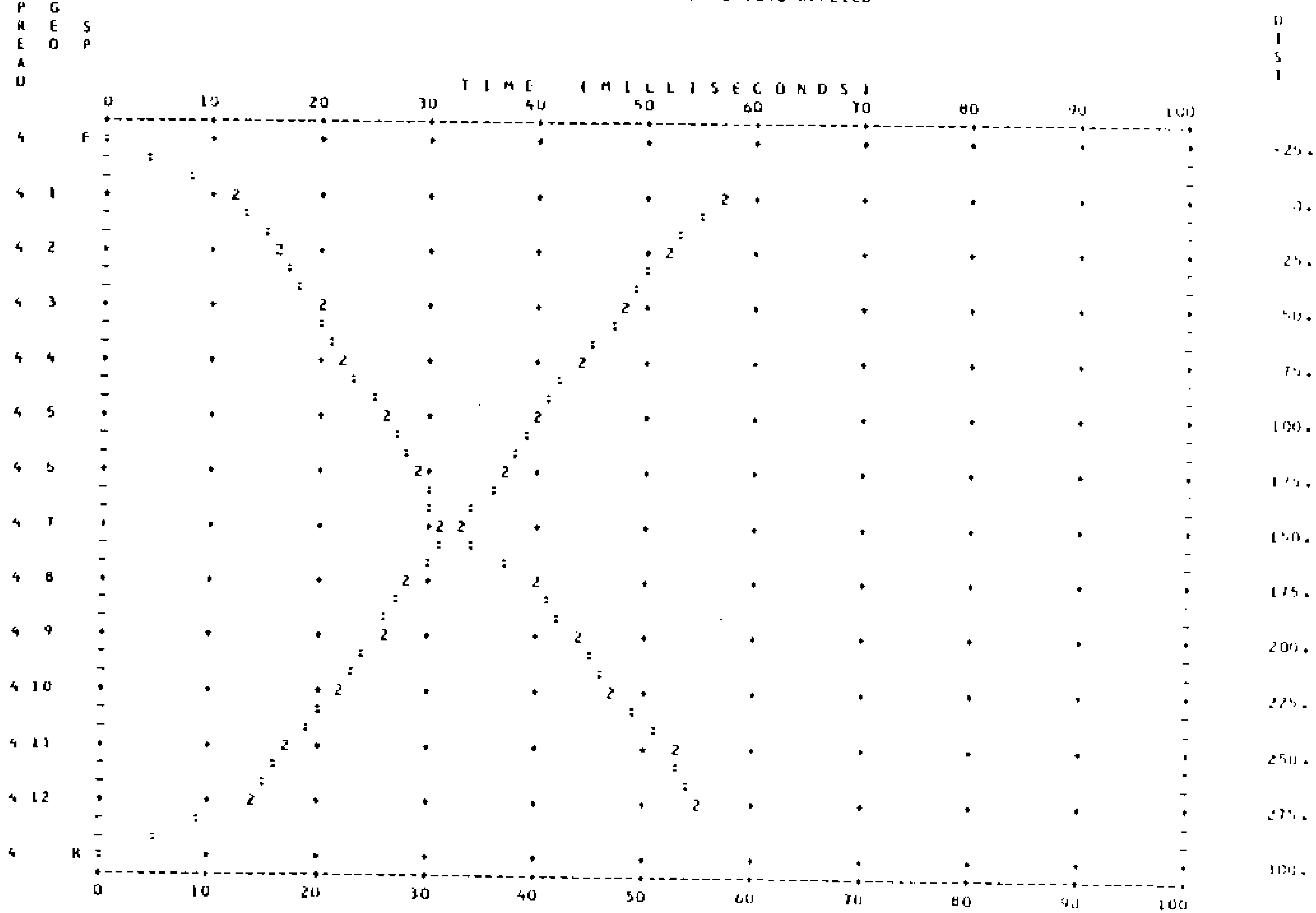
	LAYER 1	LAYER 2
VERTICAL	1500.	
HORIZONTAL		5812.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 3



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 4

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 4

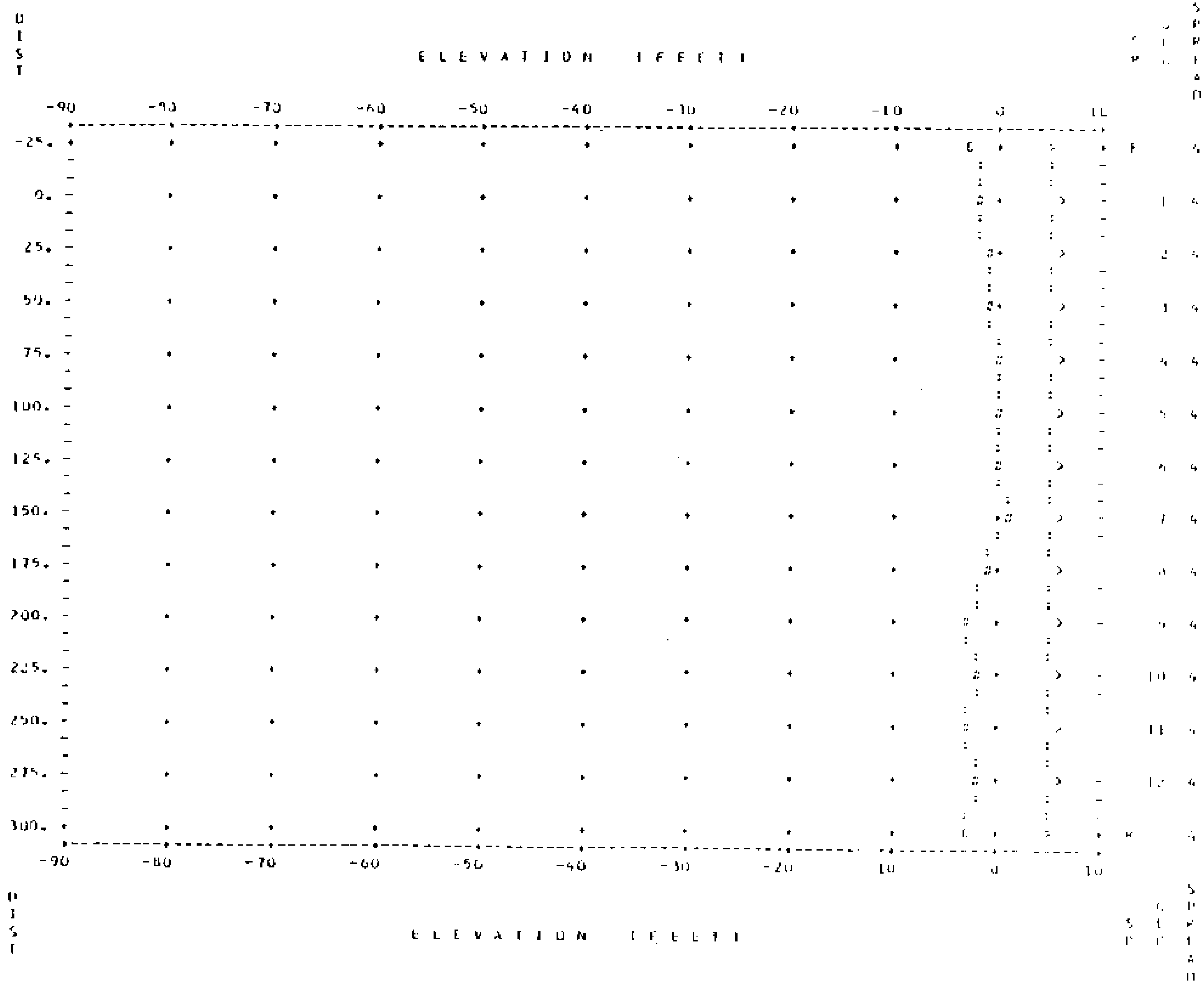
SPREAD 4 SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV
F	-25.0	5.0	7.6	-2.6
R	300.0	5.0	7.8	-2.8
GEO				
1	0.0	5.0	7.1	-2.1
2	25.0	5.0	6.4	-1.4
3	50.0	5.0	6.3	-1.3
4	75.0	5.0	5.0	0.0
5	100.0	5.0	5.2	-0.2
6	125.0	5.0	5.2	-0.2
7	150.0	5.0	3.9	1.1
8	175.0	5.0	6.3	-1.3
9	200.0	5.0	7.8	-2.8
10	225.0	5.0	7.3	-2.3
11	250.0	5.0	7.8	-2.8
12	275.0	5.0	7.2	-2.2

VELOCITIES USED:

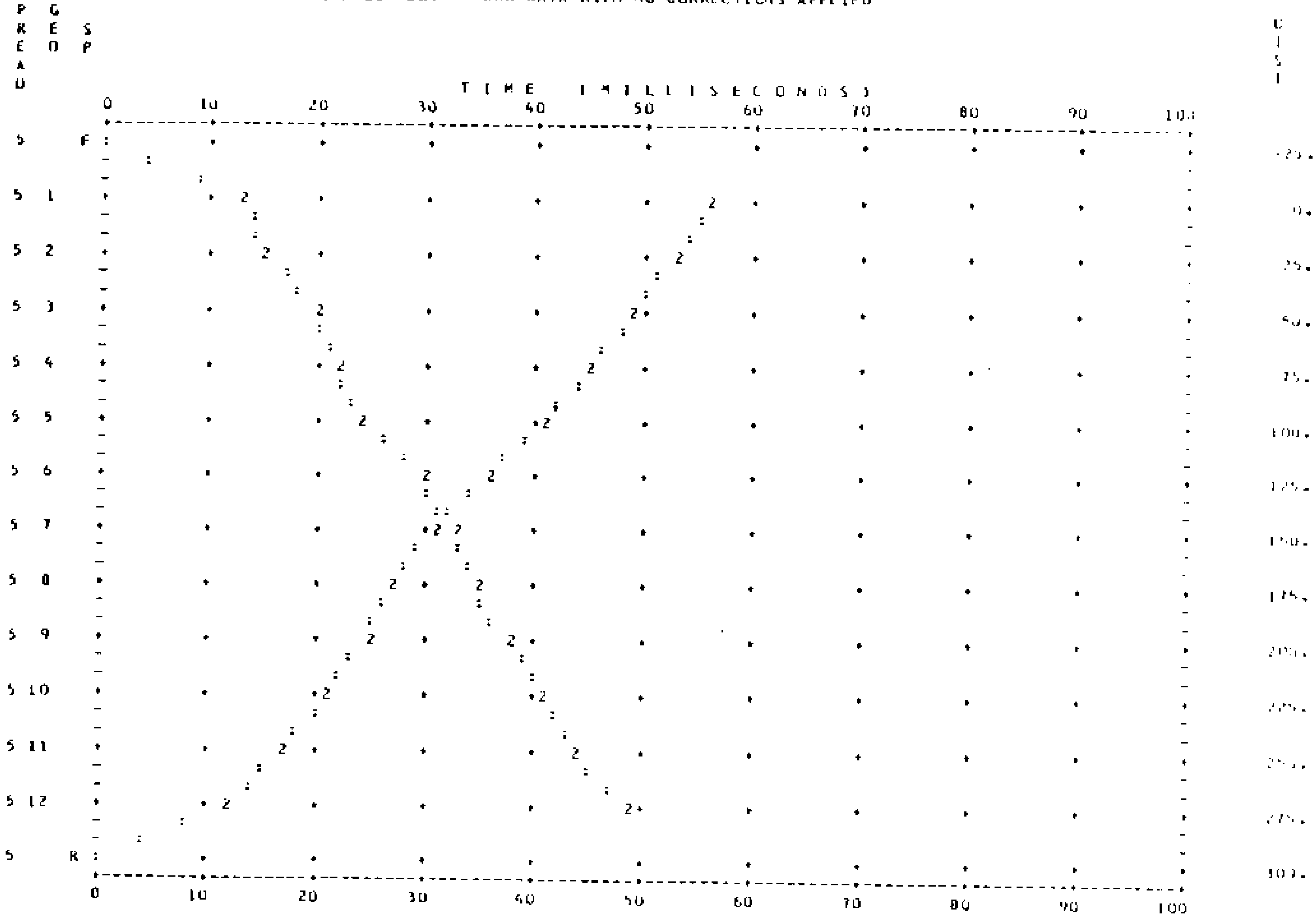
	LAYER 1	LAYER 2
VERTICAL	1500.	
HORIZONTAL		6361.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 4



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 5

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 5

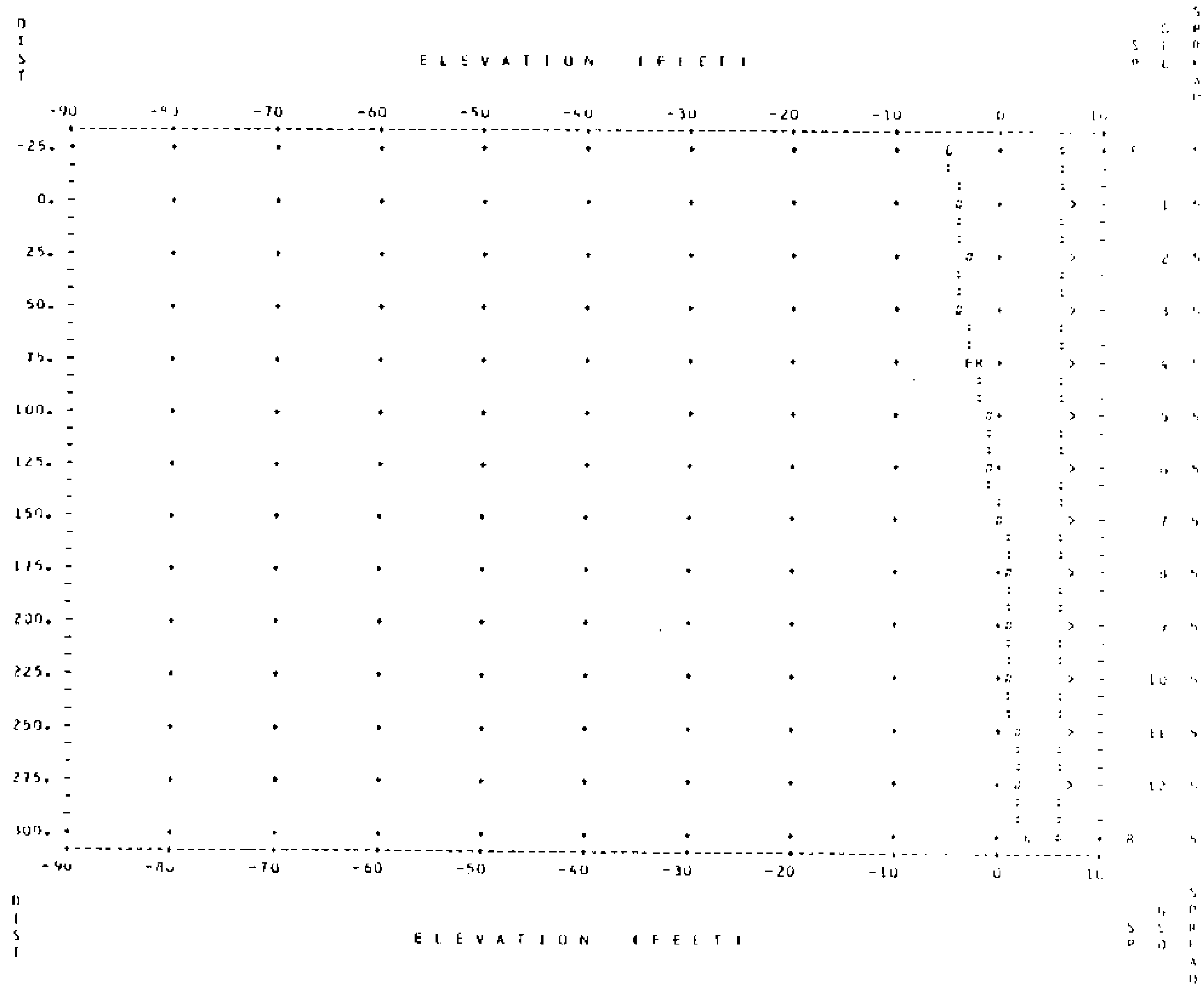
SPREAD 5   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV
F	-25.0	6.0	10.9	-4.9
R	300.0	6.0	3.5	2.5
GEO				
1	0.0	6.0	10.2	-4.2
2	25.0	6.0	9.3	-3.3
3	50.0	6.0	10.0	-4.0
4	75.0	6.0	8.5	-2.5
5	100.0	6.0	7.3	-1.3
6	125.0	6.0	7.1	-1.1
7	150.0	6.0	5.7	0.3
8	175.0	6.0	4.6	1.4
9	200.0	6.0	4.8	1.2
10	225.0	6.0	4.9	1.1
11	250.0	6.0	4.4	1.6
12	275.0	6.0	3.8	2.2

VELOCITIES USED:

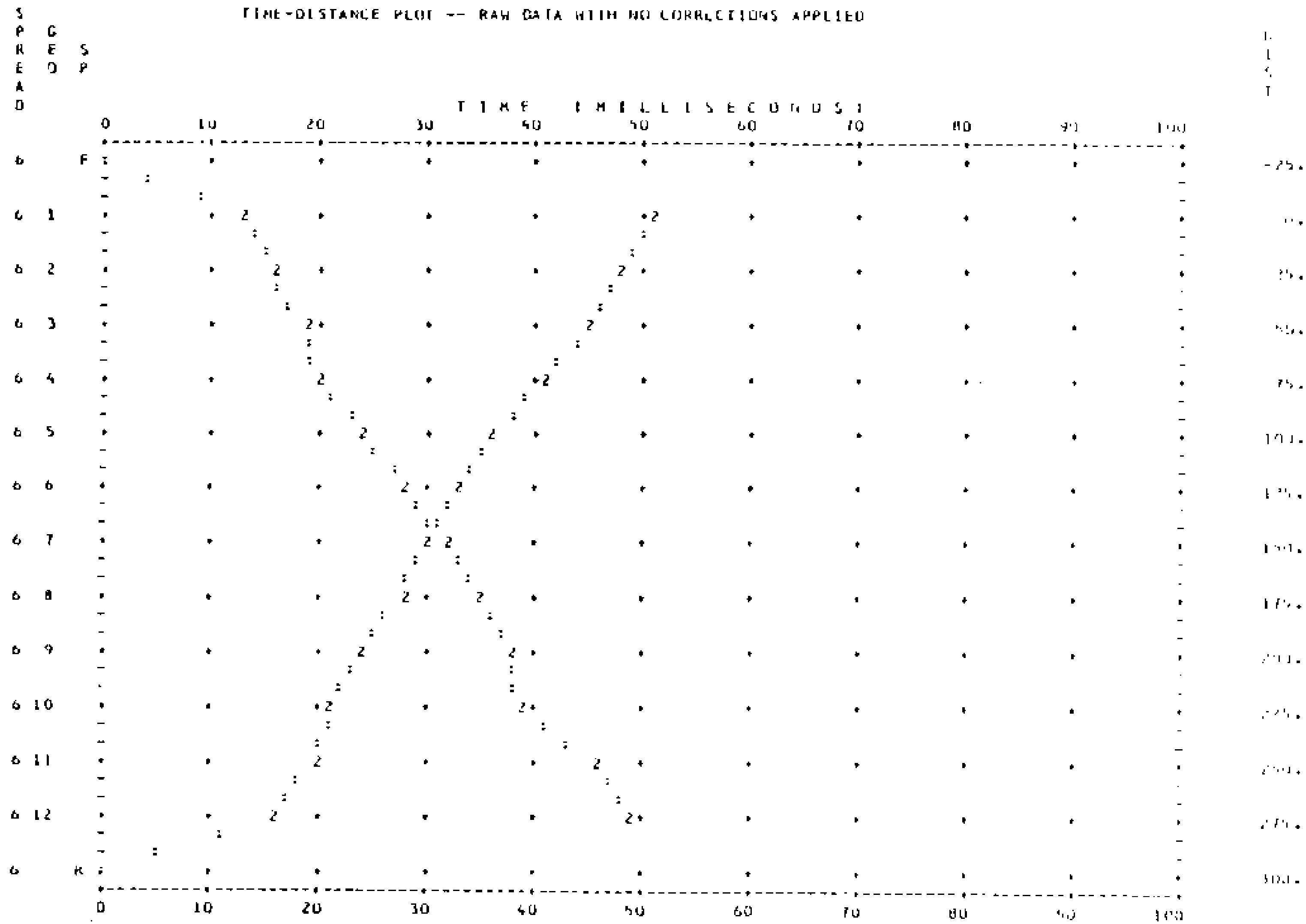
	LAYER 1	LAYER 2
VERTICAL	1500.	
HORIZONTAL		6920.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 5



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 6

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 6

SPREAD 6 SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

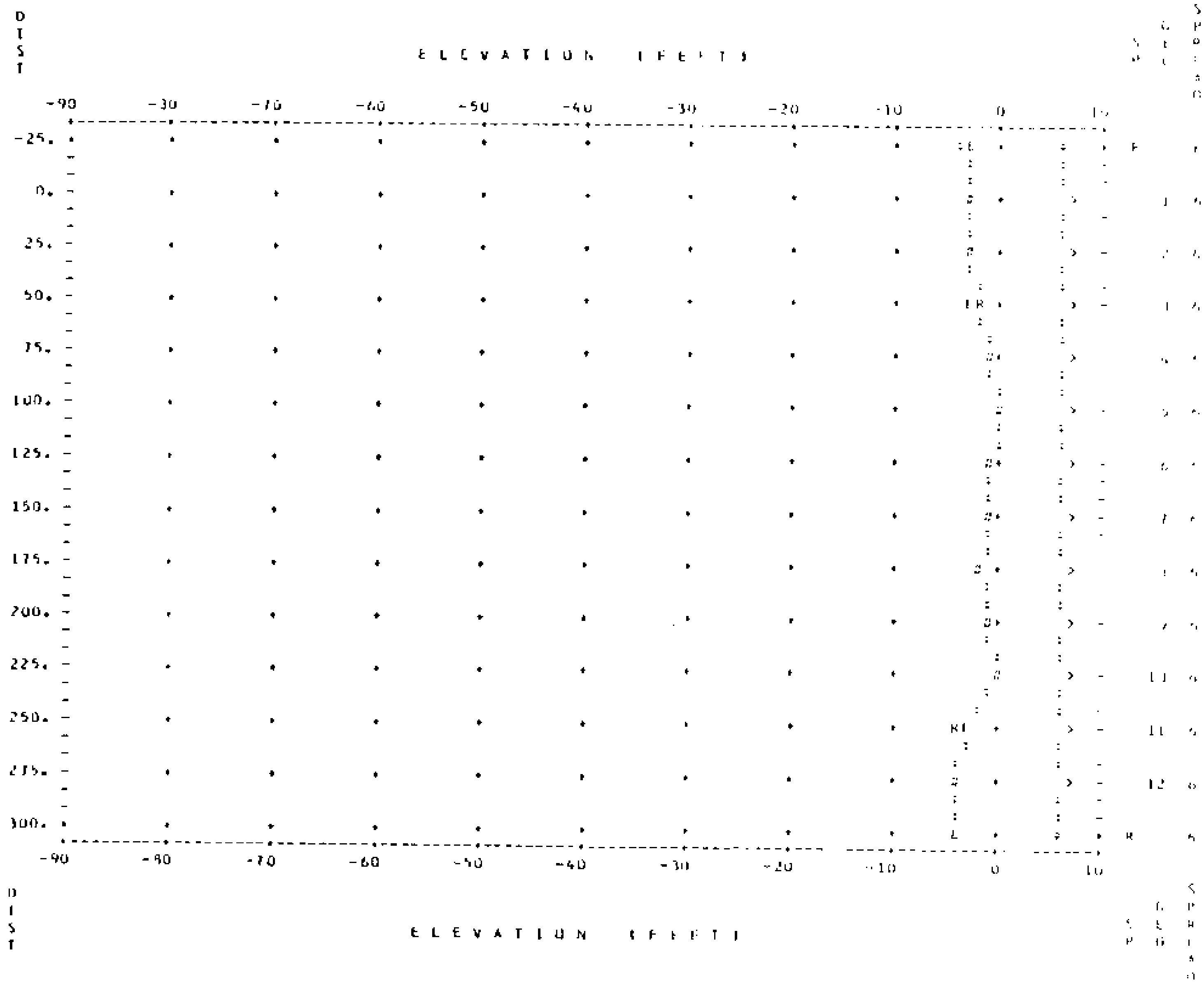
SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV
F	-25.0	6.0	9.6	-3.6
R	300.0	6.0	10.2	-4.2

GEO	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV
1	0.0	6.0	8.9	-2.9
2	25.0	6.0	8.6	-2.6
3	50.0	6.0	8.4	-2.4
4	75.0	6.0	6.8	-0.8
5	100.0	6.0	6.0	0.0
6	125.0	6.0	6.6	-0.6
7	150.0	6.0	7.1	-1.1
8	175.0	6.0	7.7	-1.7
9	200.0	6.0	7.0	-1.0
10	225.0	6.0	6.1	-0.1
11	250.0	6.0	9.3	-3.3
12	275.0	6.0	9.7	-3.7

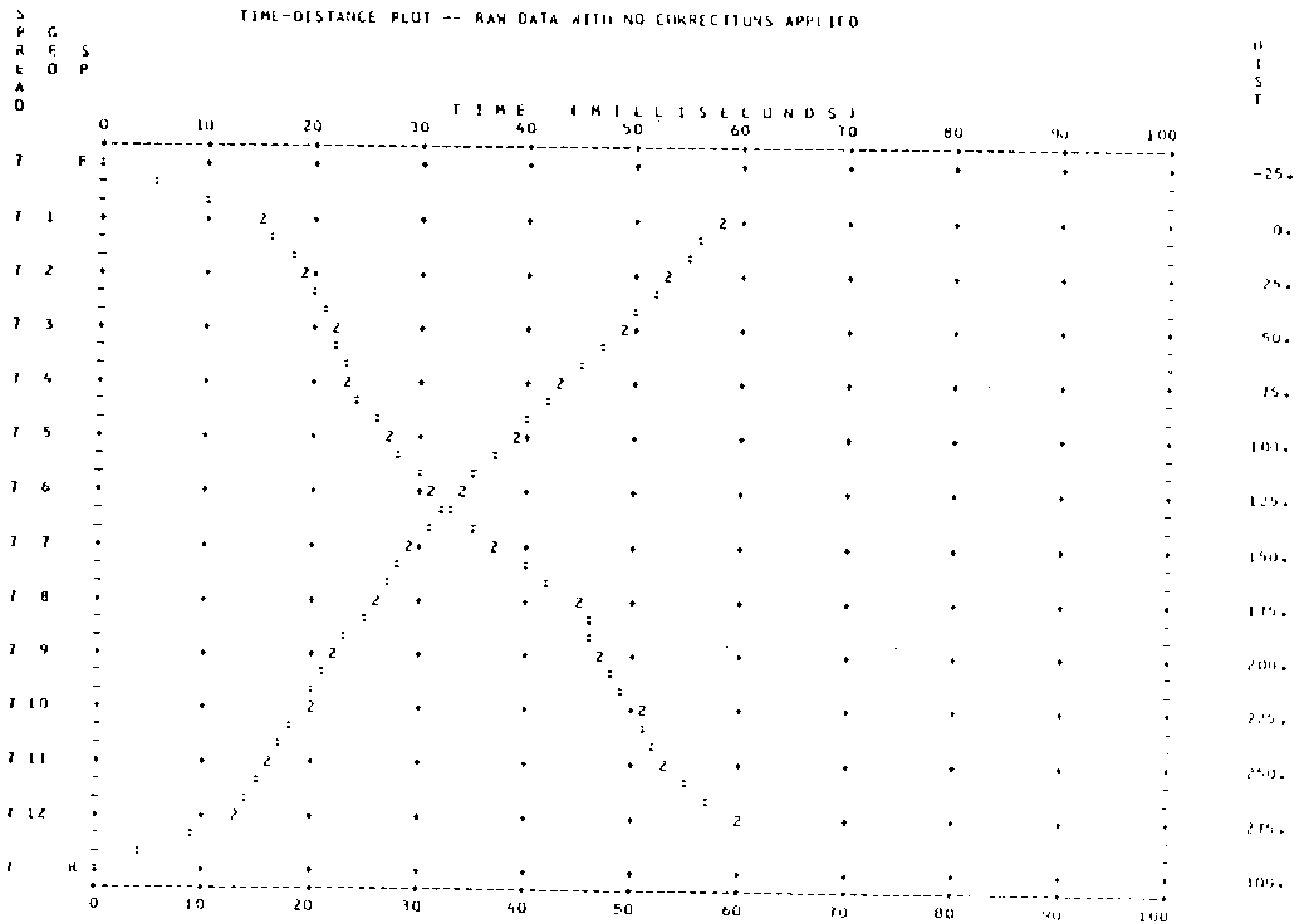
VELOCITIES USED:

	LAYER 1	LAYER 2
VERTICAL	1500.	
HORIZONTAL		7703.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 6



NUKUNKO PROJECT--SEISMIC REFRACTION SURVEY LINE 7



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 7

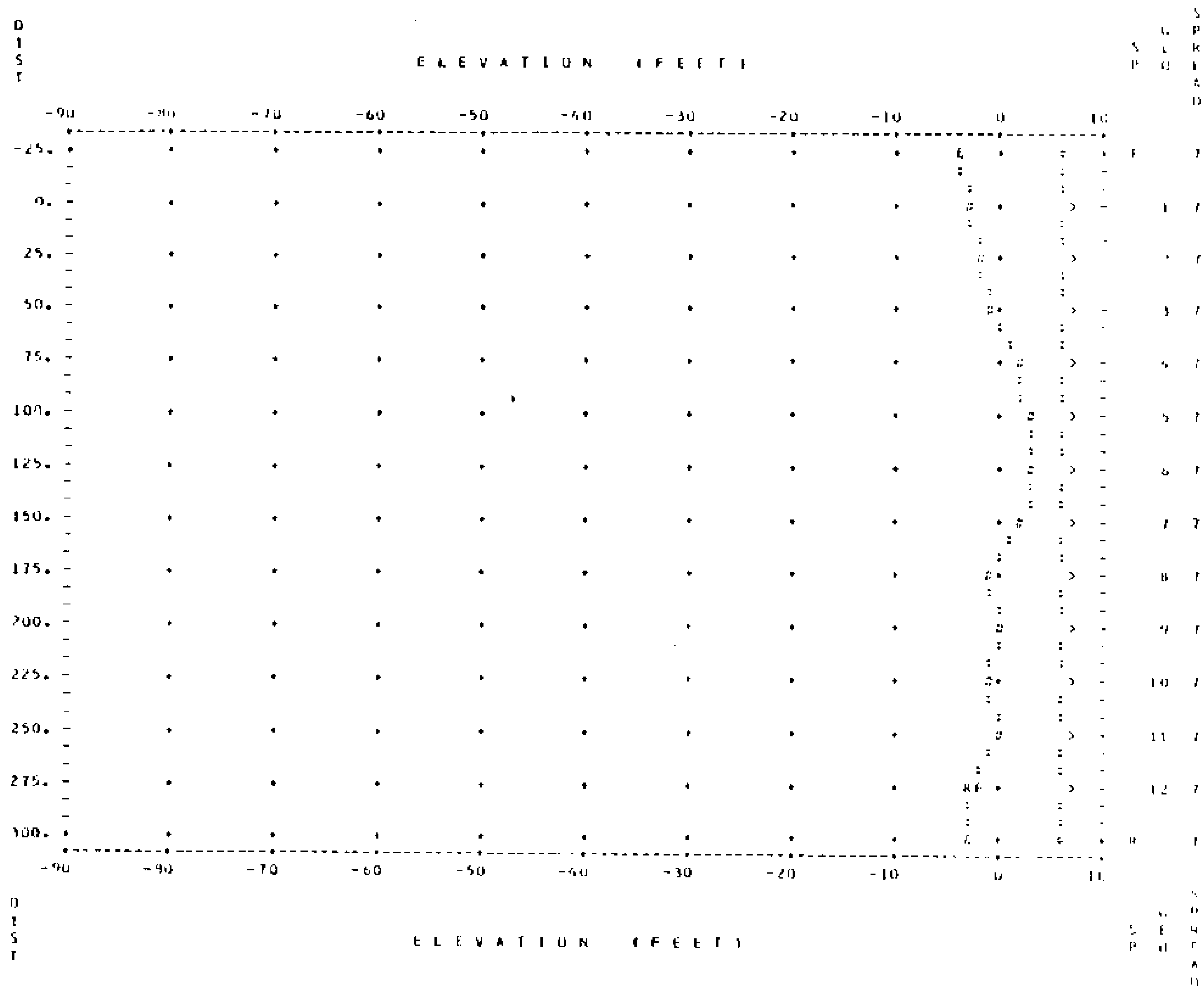
SPREAD 7   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV
F	-25.0	6.0	10.1	-4.1
R	300.0	6.0	9.1	-3.1
GEO				
1	0.0	6.0	8.8	-2.9
2	25.0	6.0	8.3	-2.3
3	50.0	6.0	7.0	-1.0
4	75.0	6.0	3.9	2.1
5	100.0	6.0	3.3	2.7
6	125.0	6.0	2.6	3.4
7	150.0	6.0	3.9	2.1
8	175.0	6.0	7.1	-1.1
9	200.0	6.0	6.2	-0.2
10	225.0	6.0	6.7	-0.7
11	250.0	6.0	6.2	-0.2
12	275.0	6.0	8.5	-2.5

VELOCITIES USED:

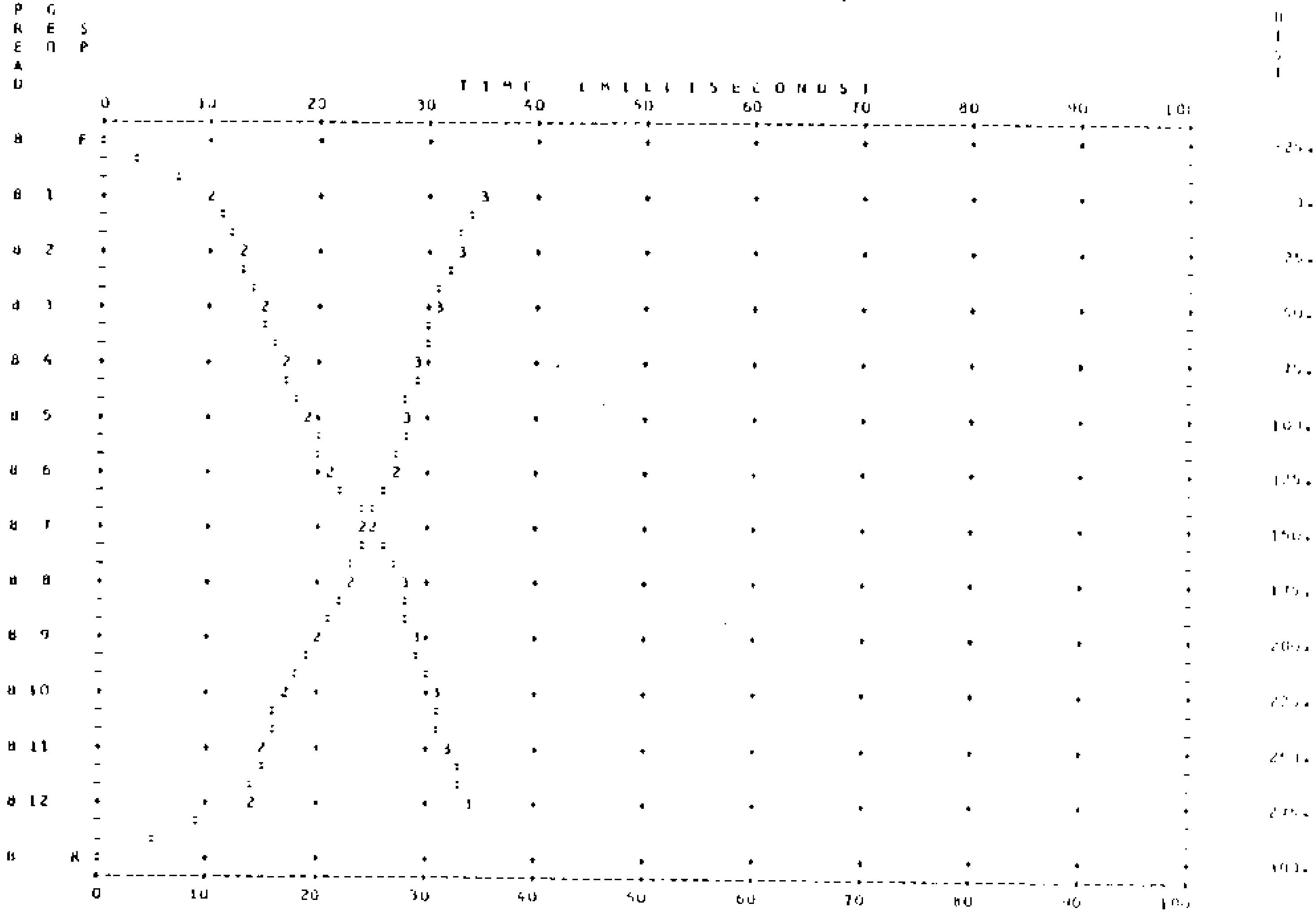
	LAYER 1	LAYER 2
VERTICAL	1500.	
HORIZONTAL		6092.

NOKUIKO PROJECT--SEISMIC REFRACTION SURVEY LINE 7



MUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 8

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 8

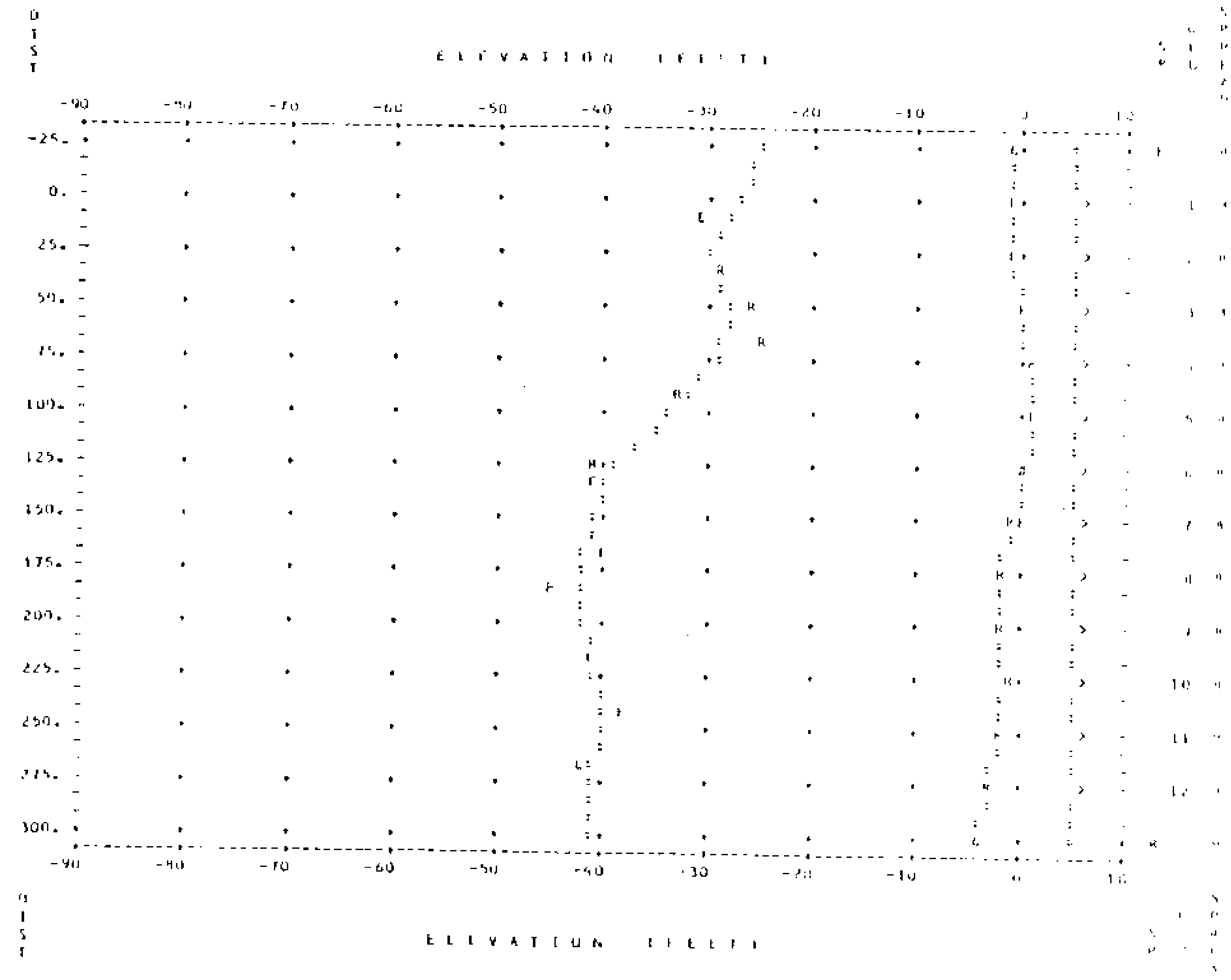
SPREAD 8 SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV	LAYER 3 DEPTH	LAYER 3 ELEV
F	-25.0	5.0	5.9	-0.9	29.9	-24.9
R	300.0	5.0	8.7	-3.7	45.7	-40.7
GEO						
1	0.0	5.0	5.6	-0.6	31.9	-26.9
2	25.0	5.0	5.6	-0.6	34.6	-29.6
3	50.0	5.0	5.4	-0.4	33.0	-28.0
4	75.0	5.0	4.1	0.9	34.4	-29.4
5	100.0	5.0	4.0	1.0	38.5	-33.5
6	125.0	5.0	4.7	0.3	43.7	-38.7
7	150.0	5.0	5.5	-0.5	46.2	-41.2
8	175.0	5.0	7.4	-2.4	47.0	-42.0
9	200.0	5.0	7.0	-2.0	46.9	-41.9
10	225.0	5.0	6.3	-1.3	45.6	-40.6
11	250.0	5.0	7.0	-2.0	45.0	-40.0
12	275.0	5.0	8.4	-3.4	45.9	-40.9

VELOCITIES USED:

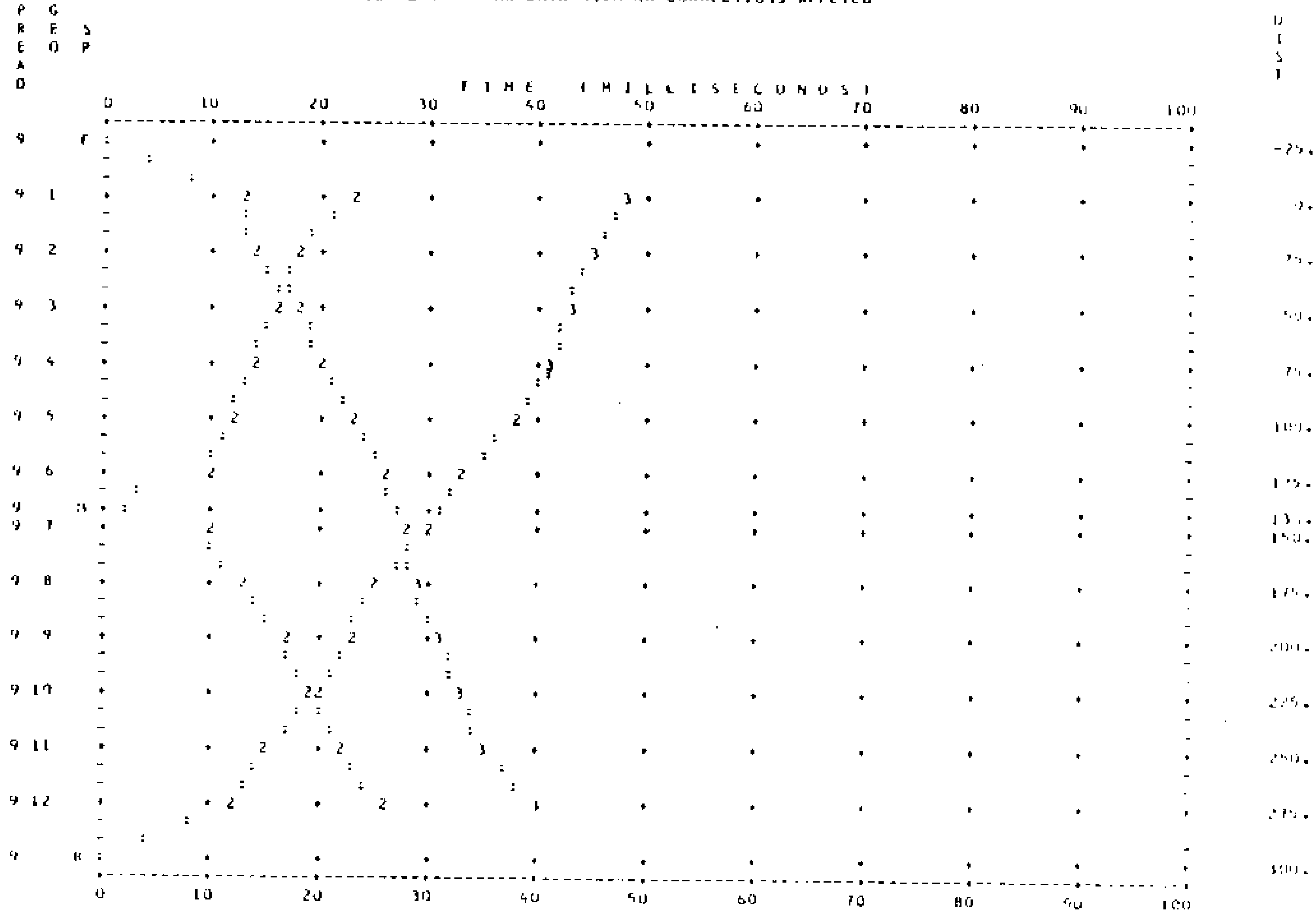
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1500.	9931.	
HORIZONTAL		9931.	15152.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE H



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 9

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 9

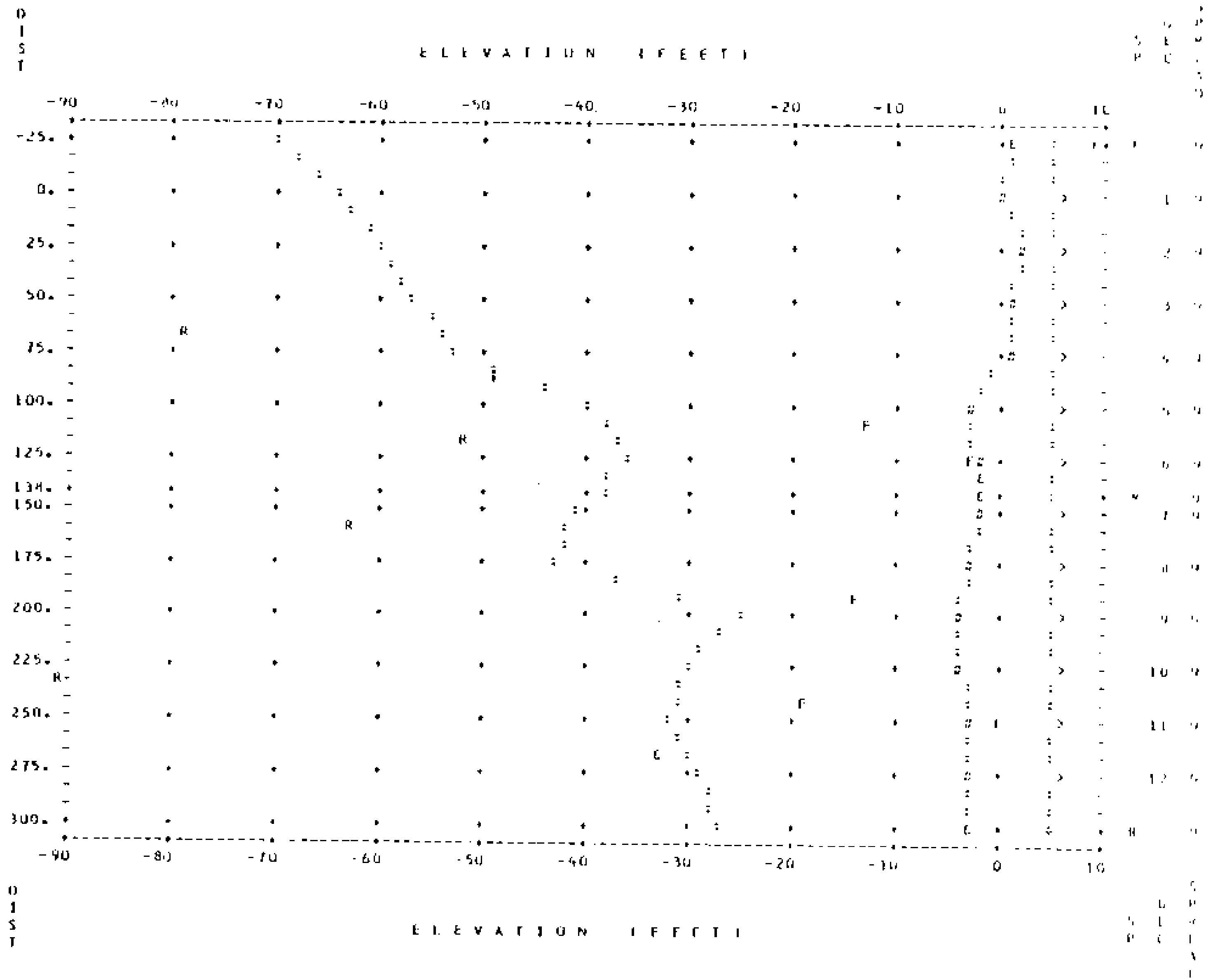
SPREAD 9 SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	-25.0	5.0	4.2	0.8	74.7	-69.7
M	137.5	5.0	7.4	-2.4	43.5	-38.5
R	300.0	5.0	7.9	-2.9	31.7	-26.7
GEO						
1	0.0	5.0	5.0	-0.0	68.8	-63.8
2	25.0	5.0	2.7	2.3	65.2	-60.2
3	50.0	5.0	4.3	0.7	61.7	-56.7
4	75.0	5.0	4.3	0.7	58.1	-53.1
5	100.0	5.0	8.1	-3.1	44.7	-39.7
6	125.0	5.0	7.5	-2.5	40.6	-35.6
7	150.0	5.0	7.2	-2.2	46.4	-41.4
8	175.0	5.0	7.8	-2.8	48.0	-43.0
9	200.0	5.0	8.9	-3.9	30.0	-25.0
10	225.0	5.0	8.9	-3.9	35.3	-30.3
11	250.0	5.0	7.6	-2.6	36.9	-31.9
12	275.0	5.0	7.8	-2.8	34.2	-29.2

VELOCITIES USED:

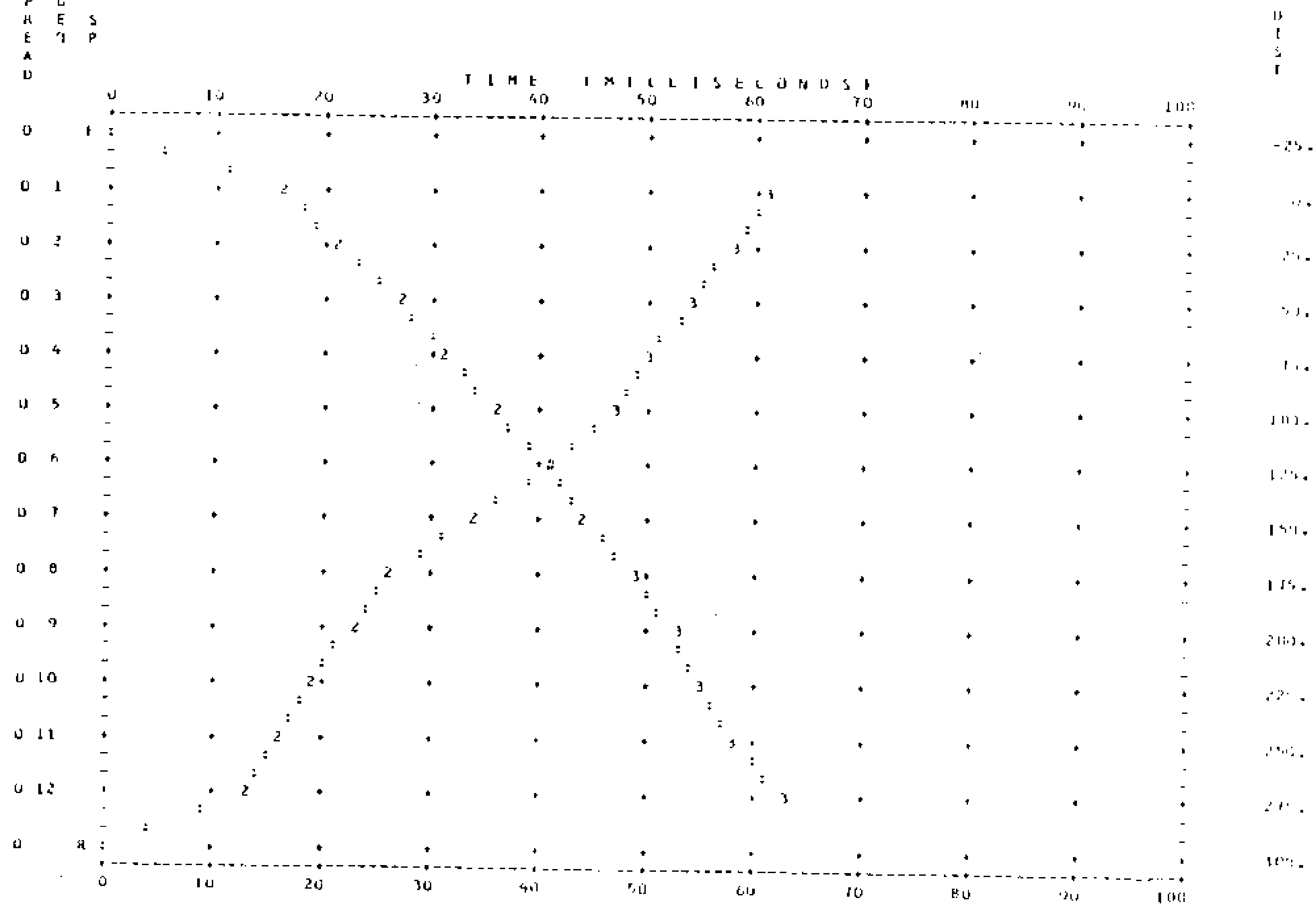
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1500.	8429.	
HORIZONTAL		8423.	9912.

NUKGORO PROJECT--SEISMIC REFRACTION SURVEY LINE 9



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 10

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 10

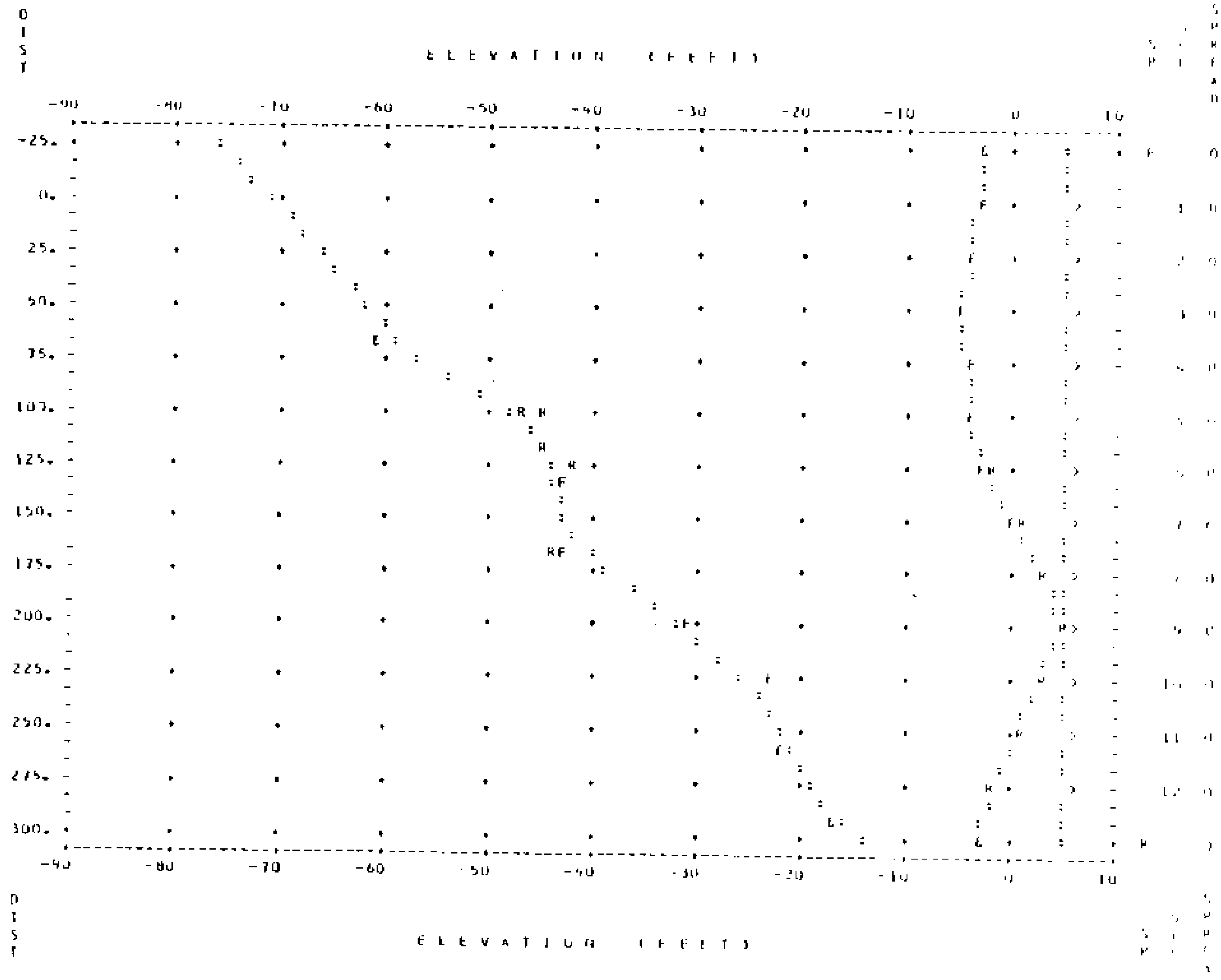
SPREAD 0   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	-25.0	5.0	8.5	-3.5	81.3	-76.3
R	300.0	5.0	7.7	-2.7	19.3	-14.3
GEO						
1	0.0	5.0	8.4	-3.4	75.7	-70.7
2	25.0	5.0	8.9	-3.9	71.2	-66.2
3	50.0	5.0	9.8	-4.8	66.8	-61.8
4	75.0	5.0	9.4	-4.4	62.3	-57.3
5	100.0	5.0	9.1	-4.1	52.6	-47.6
6	125.0	5.0	7.7	-2.7	48.8	-43.8
7	150.0	5.0	4.7	0.3	48.2	-43.2
8	175.0	5.0	1.8	3.2	43.7	-38.7
9	200.0	5.0	0.4	4.6	36.5	-31.5
10	225.0	5.0	2.3	2.7	30.6	-25.6
11	250.0	5.0	4.4	0.6	27.2	-22.2
12	275.0	5.0	7.1	-2.1	24.3	-19.3

VELOCITIES USED:

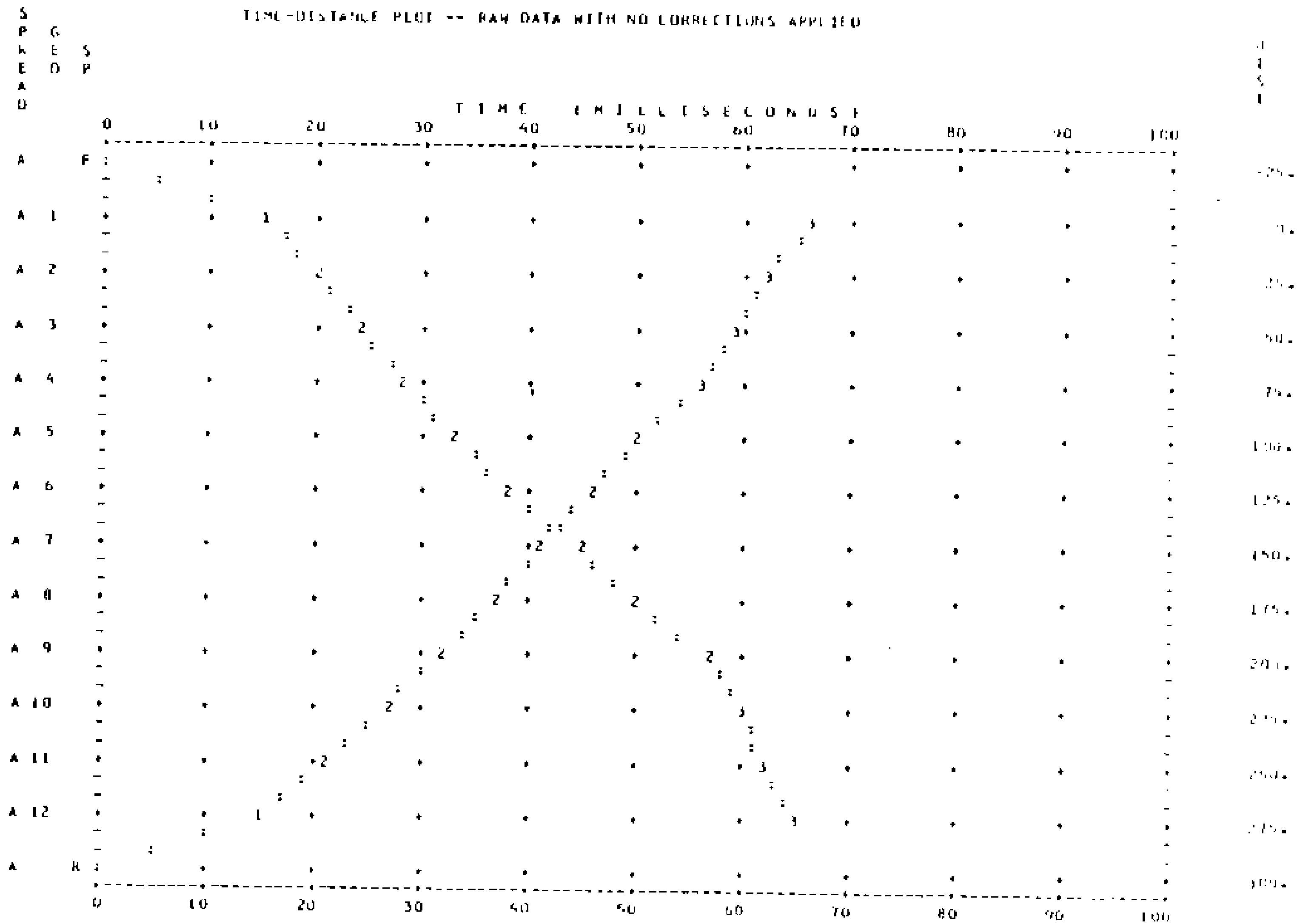
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1500.	5214.	
HORIZONTAL		5214.	7194.

NUKDORO PROJECT--SEISMIC REFRACTION SURVEY LINE 10



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE II

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 11

SPREAD A SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

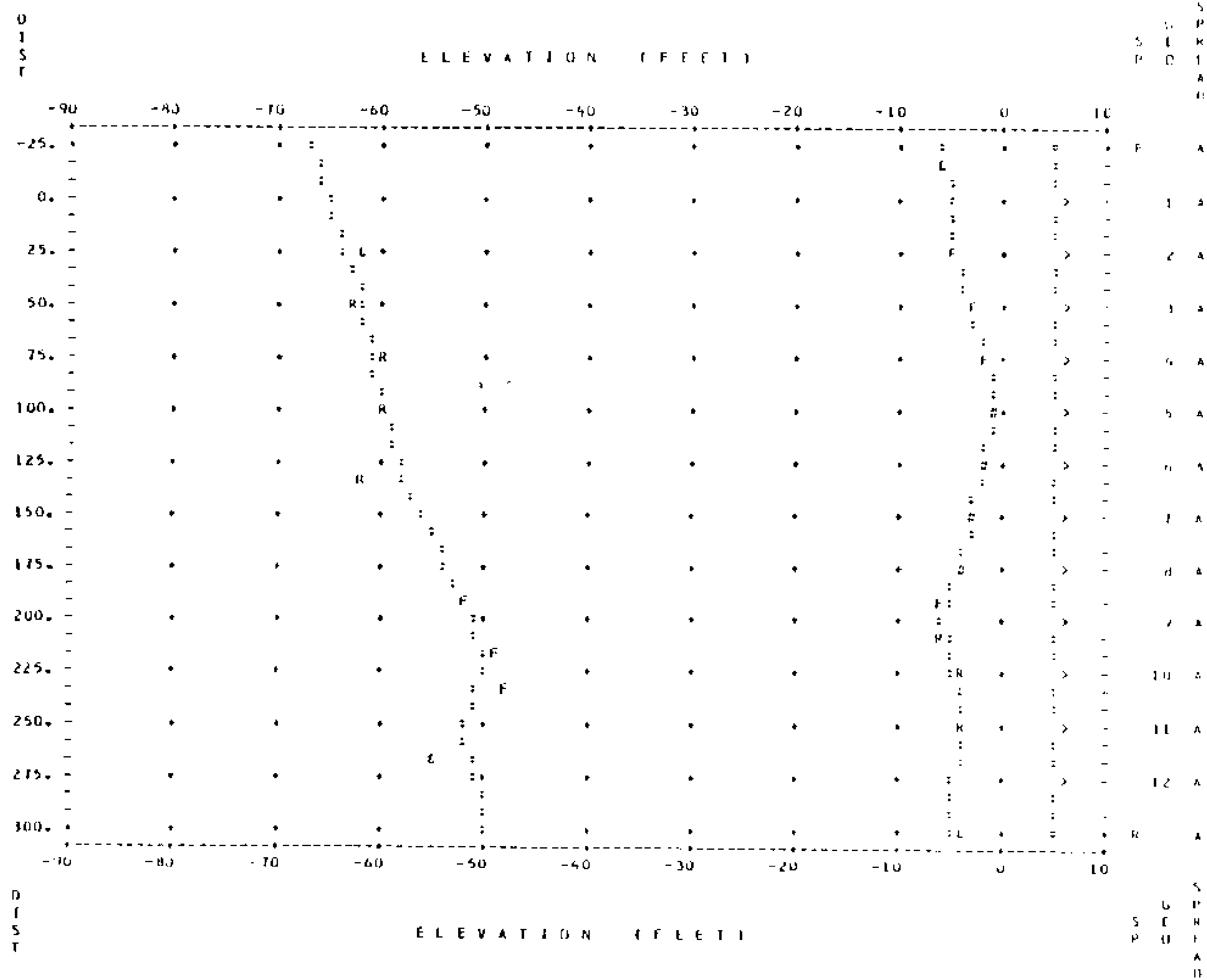
SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV	LAYER 3 DEPTH	LAYER 3 ELEV
F	-25.0	5.0	11.0	-6.0	71.6	-66.6
R	300.0	5.0	9.7	-4.7	54.6	-49.6

GEO	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV	LAYER 3 DEPTH	LAYER 3 ELEV
1	0.0	5.0	10.2	-5.2	70.2	-65.2
2	25.0	5.0	9.8	-4.8	68.6	-63.6
3	50.0	5.0	8.2	-3.2	66.9	-61.9
4	75.0	5.0	6.6	-1.6	66.2	-61.2
5	100.0	5.0	6.0	-1.0	64.9	-59.9
6	125.0	5.0	6.8	-1.8	63.3	-58.3
7	150.0	5.0	8.1	-3.1	61.0	-56.0
8	175.0	5.0	9.1	-4.1	58.6	-53.6
9	200.0	5.0	10.6	-5.6	56.3	-51.3
10	225.0	5.0	9.6	-4.6	55.0	-50.0
11	250.0	5.0	8.9	-3.9	57.1	-52.1
12	275.0	5.0	9.5	-4.5	55.5	-50.5

VELOCITIES USED:

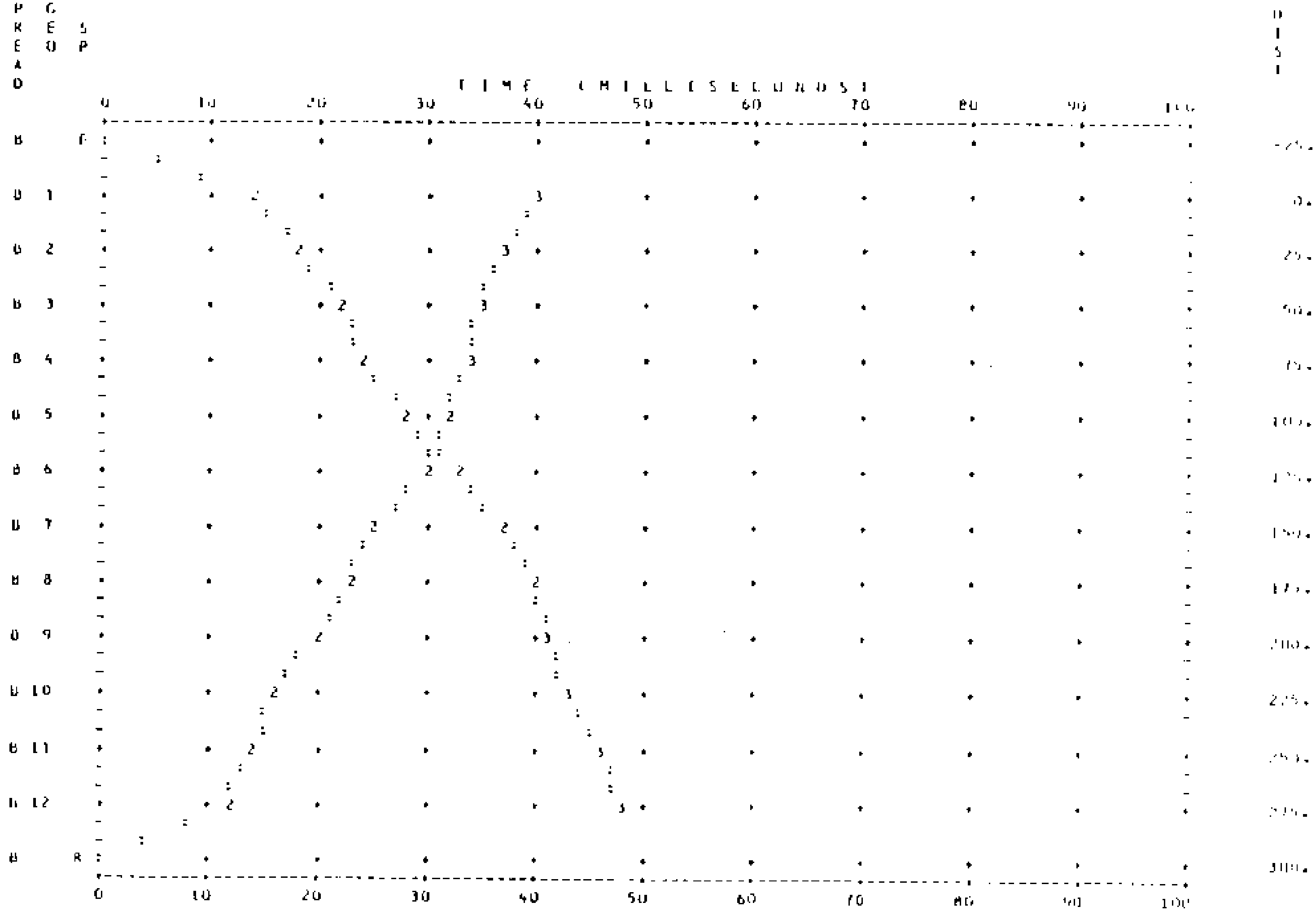
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1695.	4884.	
HORIZONTAL		4884.	8140.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 11



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 12

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 12

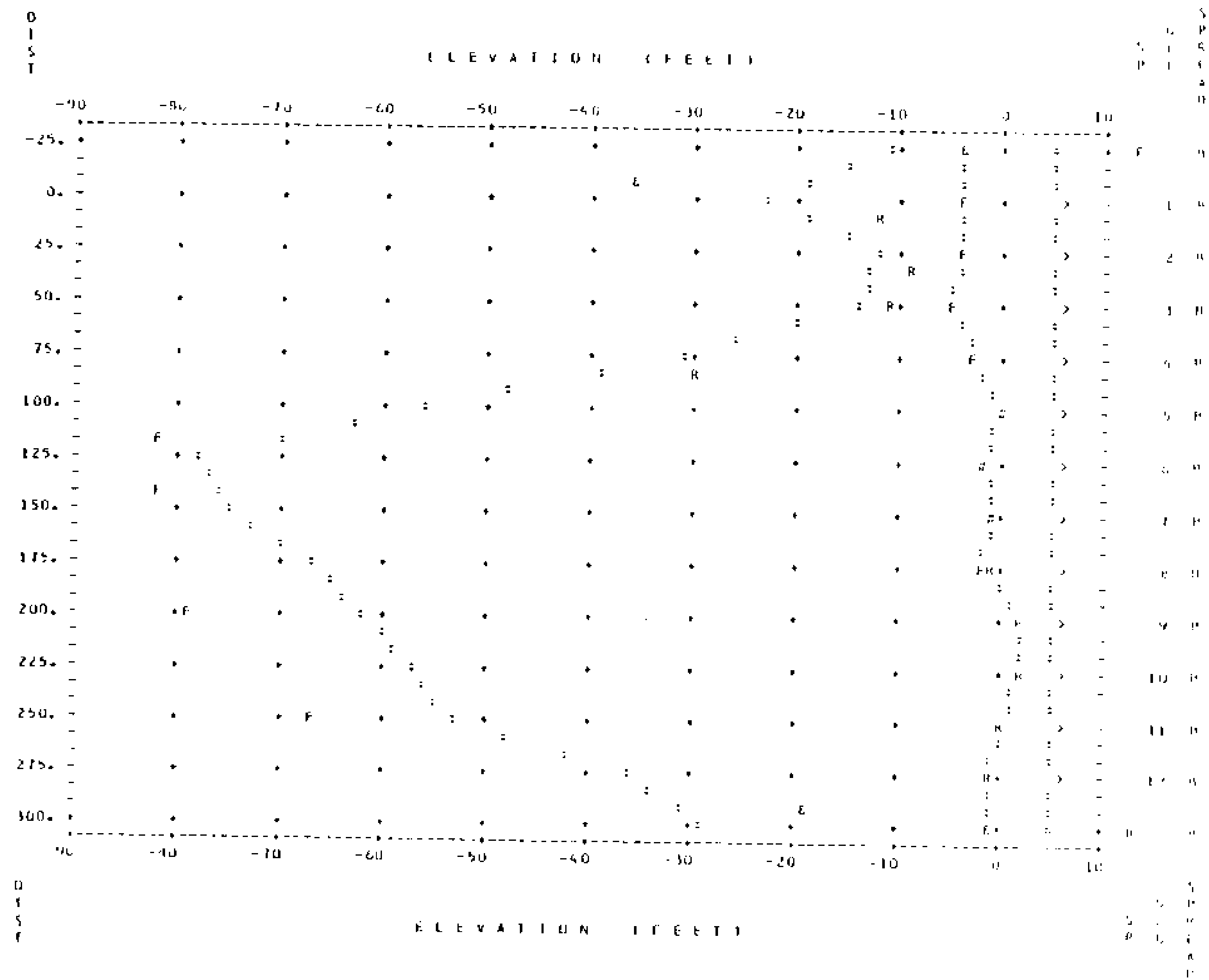
SPREAD B SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	-25.0	5.0	9.3	-4.3	16.1	-11.1
R	300.0	5.0	5.9	-0.9	34.1	-29.1
GEO						
1	0.0	5.0	8.6	-3.6	28.2	-23.2
2	25.0	5.0	9.3	-4.3	16.6	-11.6
3	50.0	5.0	9.6	-4.6	19.2	-14.2
4	75.0	5.0	7.8	-2.8	36.4	-31.4
5	100.0	5.0	5.0	-0.0	60.7	-55.7
6	125.0	5.0	6.5	-1.5	82.9	-77.9
7	150.0	5.0	6.4	-1.4	80.2	-75.2
8	175.0	5.0	6.6	-1.6	72.2	-67.2
9	200.0	5.0	3.2	1.8	66.7	-61.7
10	225.0	5.0	2.9	2.1	62.5	-57.5
11	250.0	5.0	4.8	0.2	58.3	-53.3
12	275.0	5.0	6.1	-1.1	41.0	-36.0

VELOCITIES USED:

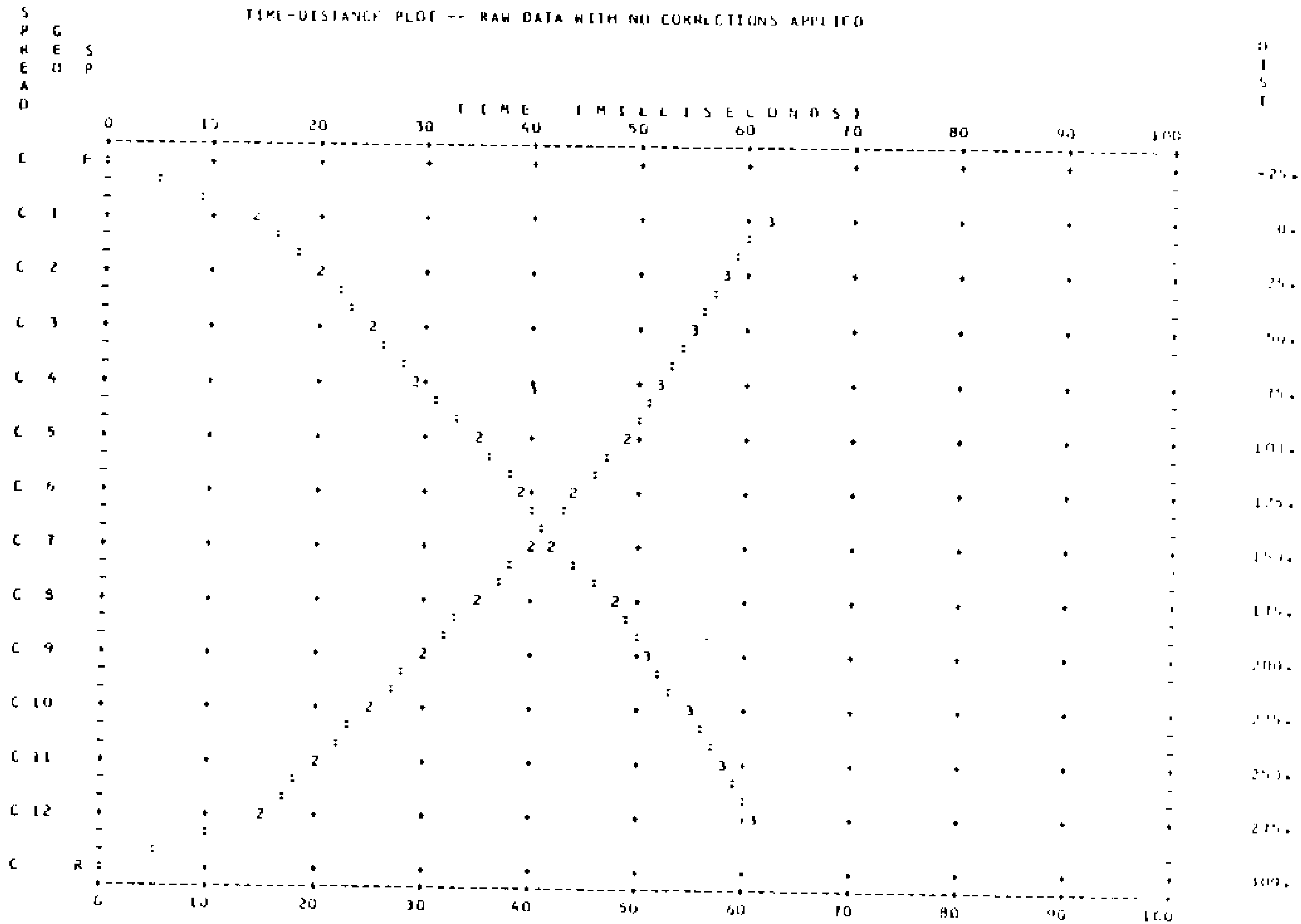
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1500.	7353.	
HORIZONTAL		7353.	11236.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 12



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 13

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 13

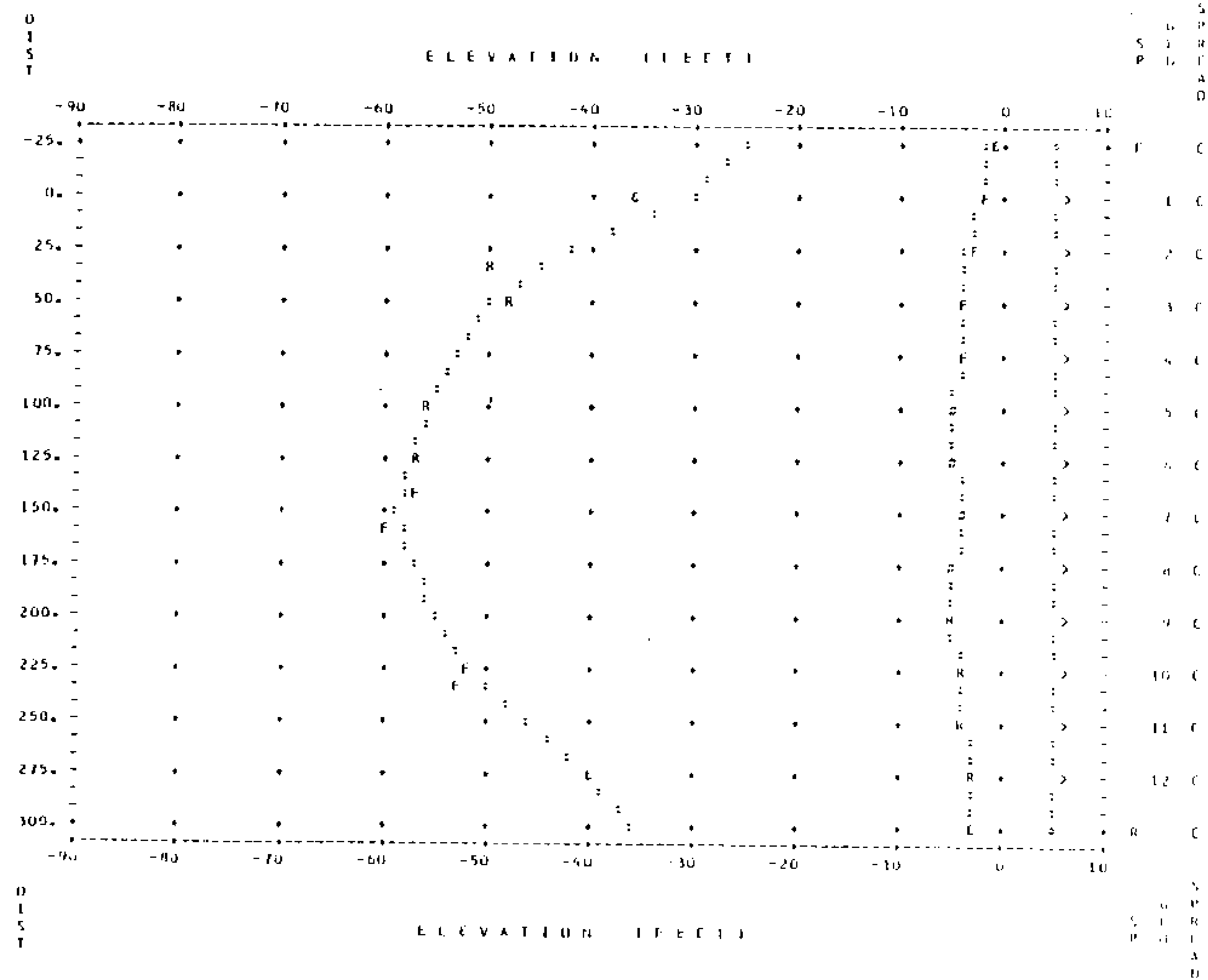
SPREAD C SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	-25.0	5.0	6.5	-1.5	30.1	-25.1
R	300.0	5.0	7.9	-2.9	41.0	-36.0
GEO						
1	0.0	5.0	7.0	-2.0	35.2	-30.2
2	25.0	5.0	8.6	-3.6	46.9	-41.9
3	50.0	5.0	9.1	-4.1	55.0	-50.0
4	75.0	5.0	8.9	-3.9	57.7	-52.7
5	100.0	5.0	10.0	-5.0	61.0	-56.0
6	125.0	5.0	9.8	-4.8	62.2	-57.2
7	150.0	5.0	8.9	-3.9	64.0	-59.0
8	175.0	5.0	9.7	-4.7	62.1	-57.1
9	200.0	5.0	9.7	-4.7	60.0	-55.0
10	225.0	5.0	9.3	-4.3	57.5	-52.5
11	250.0	5.0	8.7	-3.7	51.1	-46.1
12	275.0	5.0	8.1	-3.1	44.8	-39.8

VELOCITIES USED:

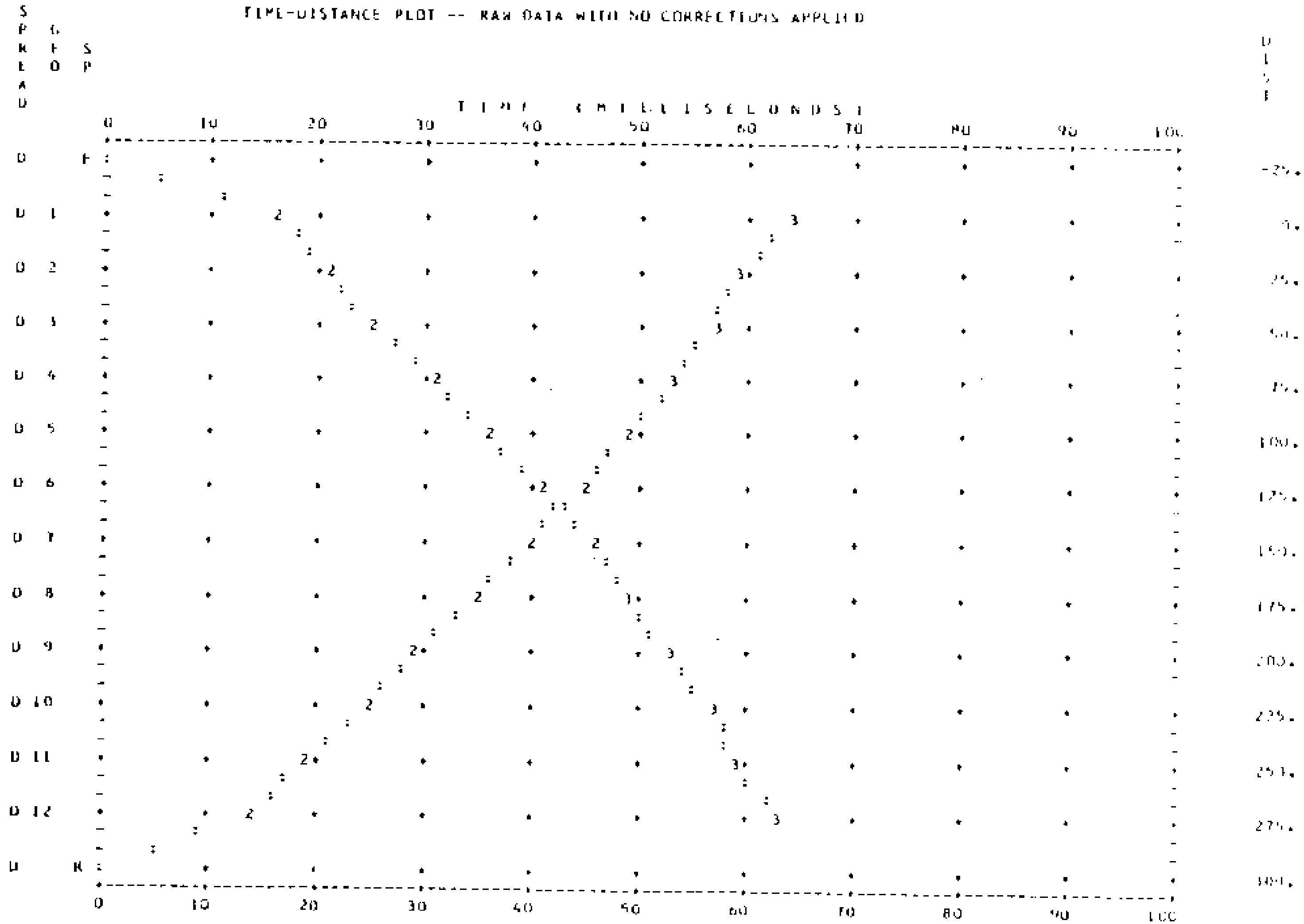
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1500.	5420.	
HORIZONTAL		5420.	7692.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 13



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 14

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 14

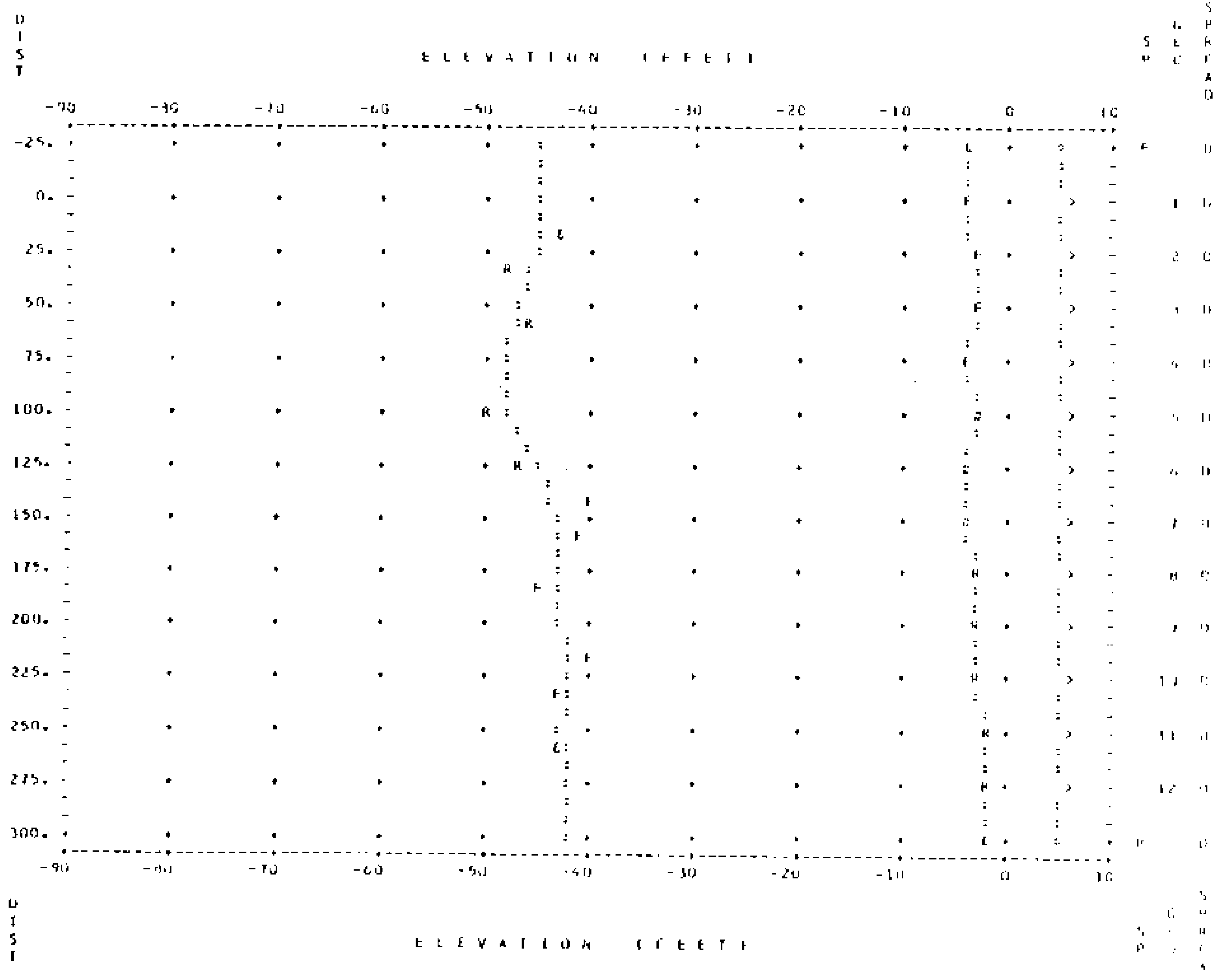
SPREAD D SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	-25.0	5.0	8.8	-3.8	50.0	-45.0
R	300.0	5.0	6.7	-1.7	46.5	-41.5
GEO						
1	0.0	5.0	8.8	-3.8	50.3	-45.3
2	25.0	5.0	8.3	-3.3	49.9	-44.9
3	50.0	5.0	8.1	-3.1	51.9	-46.9
4	75.0	5.0	8.8	-3.8	53.2	-48.2
5	100.0	5.0	8.2	-3.2	52.5	-47.5
6	125.0	5.0	8.7	-3.7	50.0	-45.0
7	150.0	5.0	8.7	-3.7	48.2	-43.2
8	175.0	5.0	8.3	-3.3	48.0	-43.0
9	200.0	5.0	7.7	-2.7	47.5	-42.5
10	225.0	5.0	7.8	-2.8	47.1	-42.1
11	250.0	5.0	7.3	-2.3	47.6	-42.6
12	275.0	5.0	7.0	-2.0	46.8	-41.8

VELOCITIES USED:

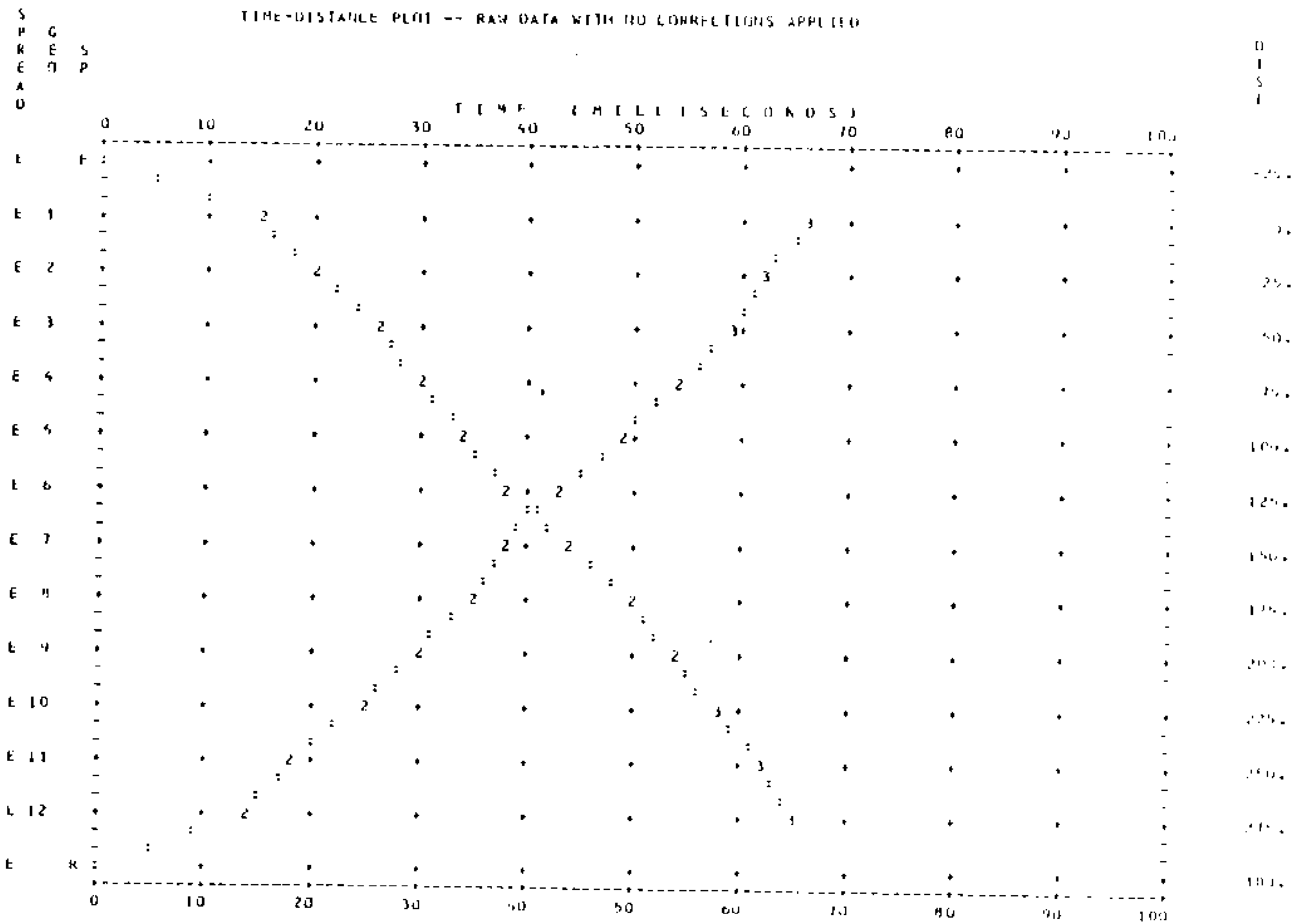
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1500.	5089.	
HORIZONTAL		5089.	7293.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 14



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 15

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 15

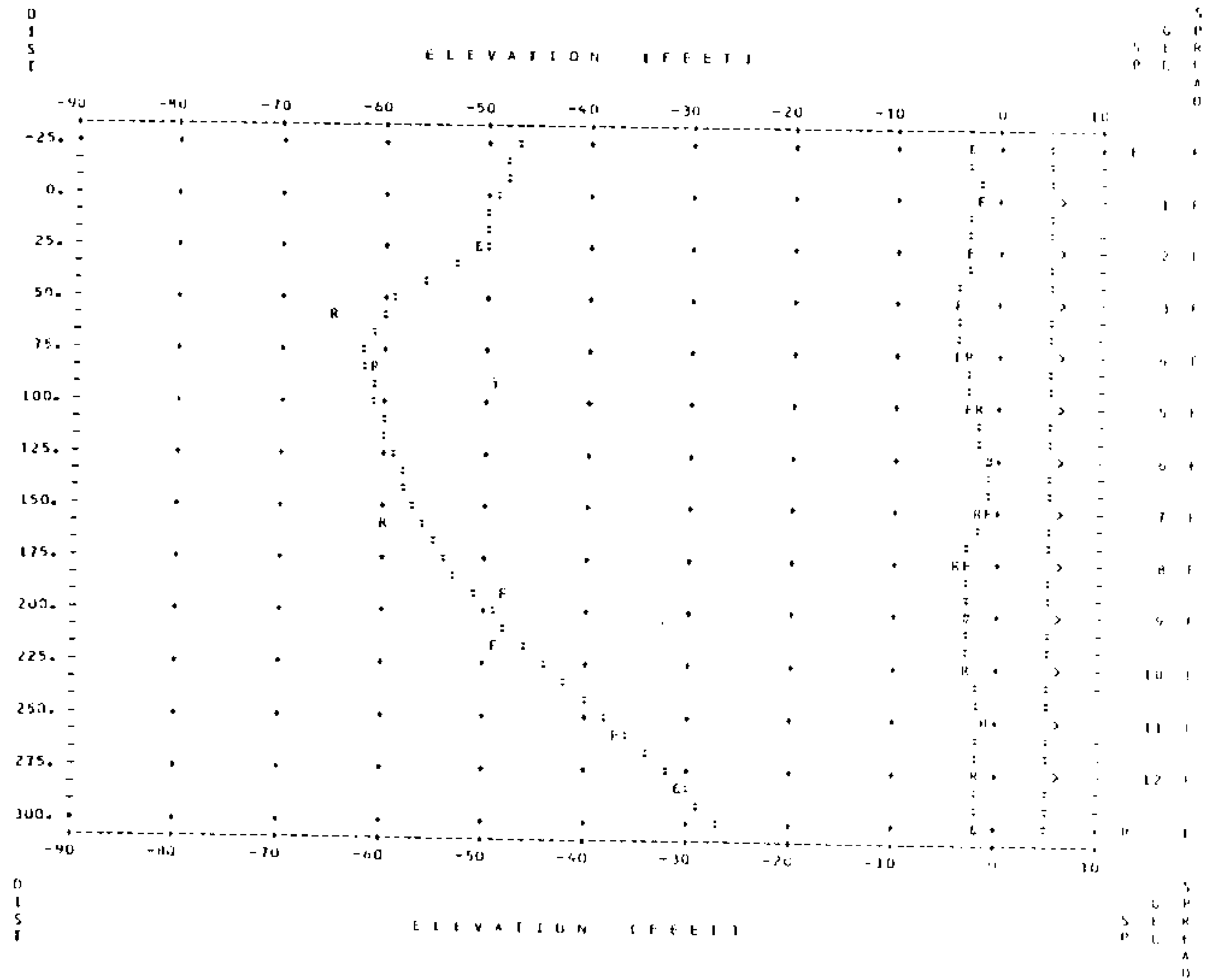
SPREAD E   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	-25.0	5.0	7.7	-2.7	51.9	-46.9
R	300.0	5.0	6.8	-1.8	32.0	-27.0
GEO						
1	0.0	5.0	7.4	-2.4	54.3	-49.3
2	25.0	5.0	8.2	-3.2	55.2	-50.2
3	50.0	5.0	8.8	-3.8	64.0	-59.0
4	75.0	5.0	8.6	-3.6	67.3	-62.3
5	100.0	5.0	7.5	-2.5	65.7	-60.7
6	125.0	5.0	6.1	-1.1	64.0	-59.0
7	150.0	5.0	6.5	-1.5	62.2	-57.2
8	175.0	5.0	8.6	-3.6	59.2	-54.2
9	200.0	5.0	8.0	-3.0	54.3	-49.3
10	225.0	5.0	7.9	-2.9	49.1	-44.1
11	250.0	5.0	6.4	-1.4	43.4	-38.4
12	275.0	5.0	6.9	-1.9	37.1	-32.1

VELOCITIES USED:

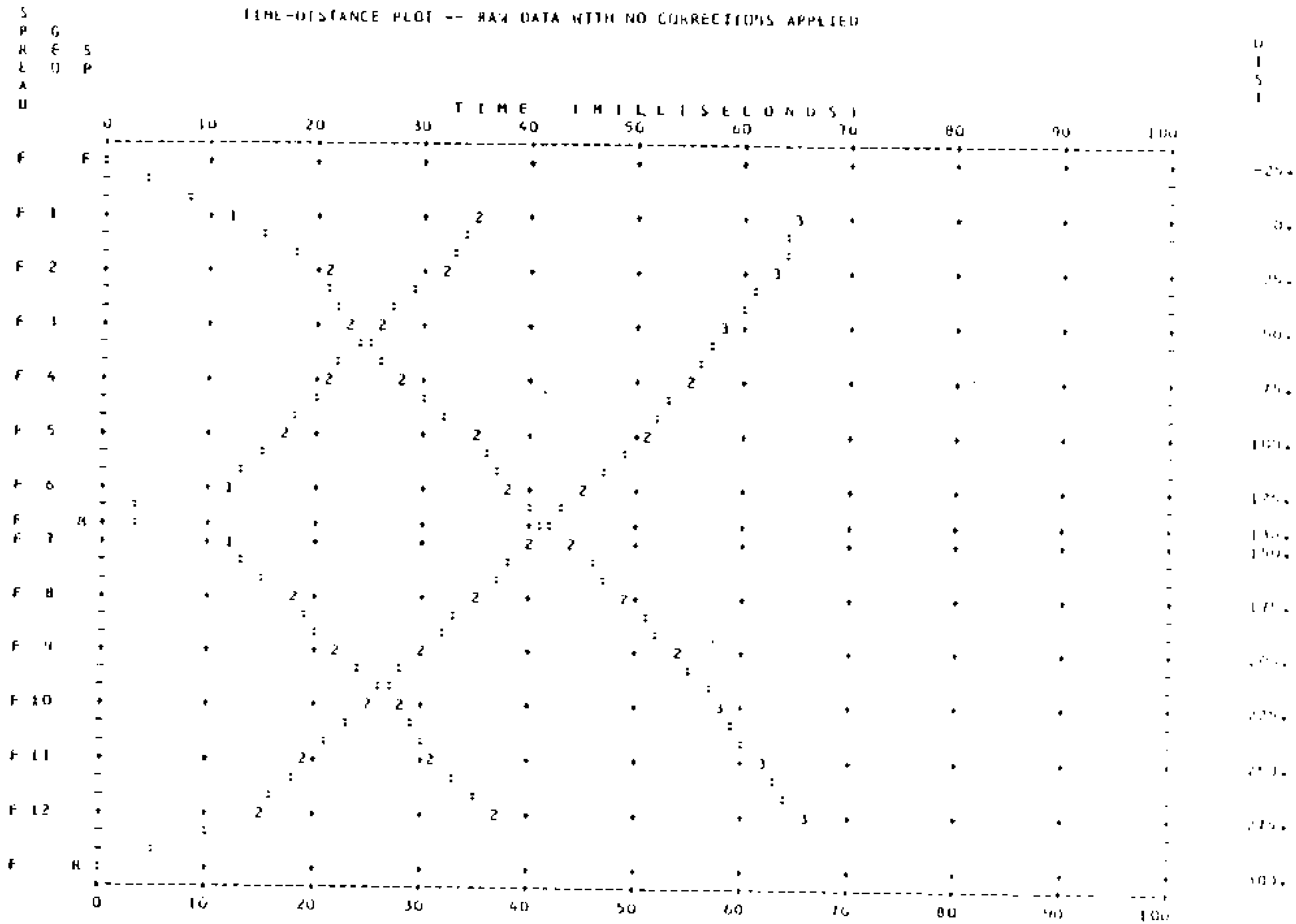
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1500.	5130.	
HORIZONTAL		5130.	6897.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 15



NUKUDRO PROJECT--SEISMIC REFRACTION SURVEY LINE 16

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 16

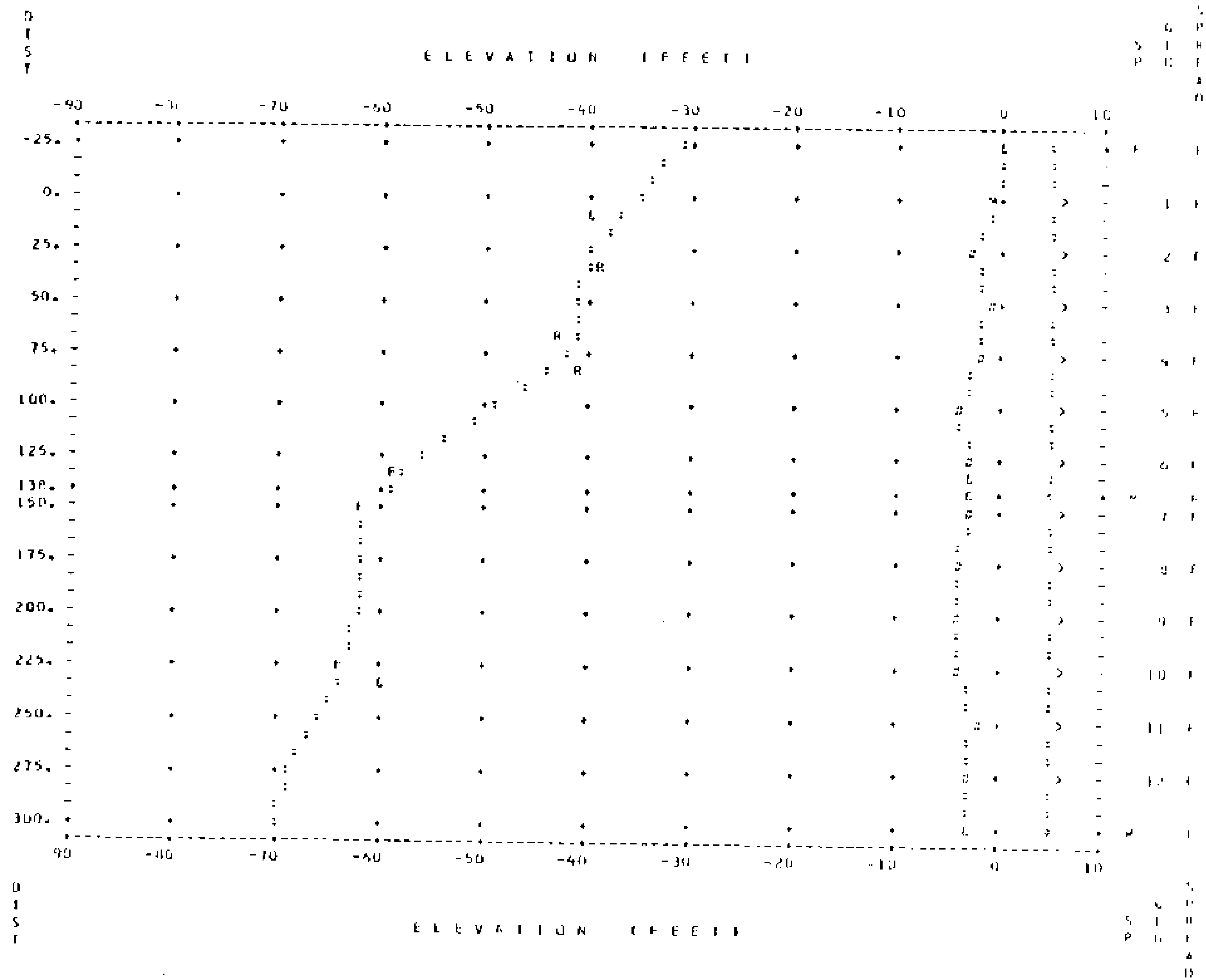
SPREAD F SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	-25.0	5.0	5.1	-0.1	36.4	-31.4
M	137.5	5.0	8.4	-3.4	63.9	-58.9
R	300.0	5.0	8.2	-3.2	75.3	-70.3
GEO						
1	0.0	5.0	5.6	-0.6	40.1	-35.1
2	25.0	5.0	8.1	-3.1	44.8	-39.8
3	50.0	5.0	6.2	-1.2	45.9	-40.9
4	75.0	5.0	7.2	-2.2	46.7	-41.7
5	100.0	5.0	8.7	-3.7	53.8	-48.8
6	125.0	5.0	8.4	-3.4	61.0	-56.0
7	150.0	5.0	8.4	-3.4	66.8	-61.8
8	175.0	5.0	8.6	-3.6	66.8	-61.8
9	200.0	5.0	8.5	-3.5	67.4	-62.4
10	225.0	5.0	8.6	-3.6	68.5	-63.5
11	250.0	5.0	7.2	-2.2	71.2	-66.2
12	275.0	5.0	8.3	-3.3	73.9	-68.9

VELOCITIES USED:

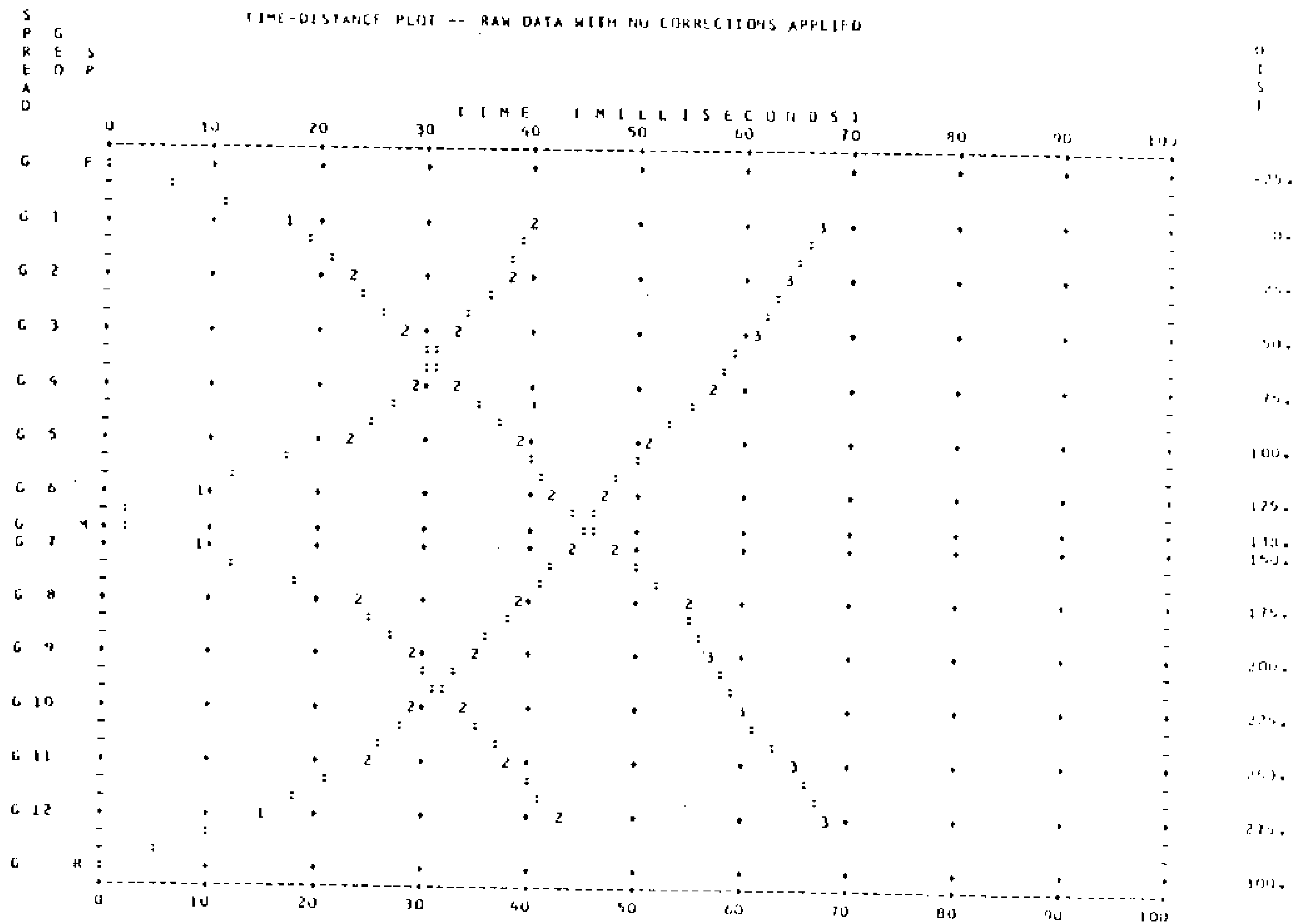
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1603.	5069.	
HORIZONTAL		5069.	6897.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 16



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 17

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 17

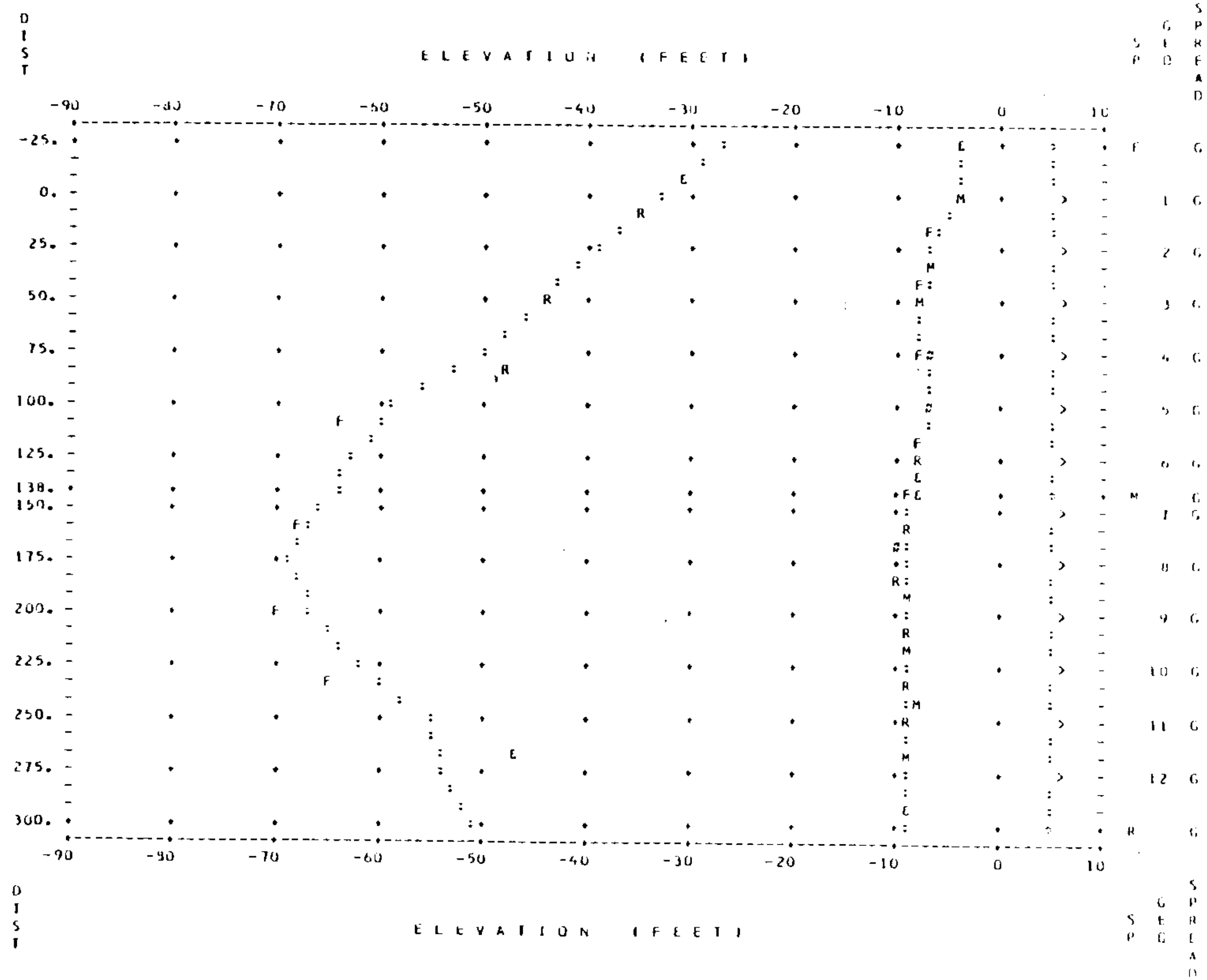
SPREAD G   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	-25.0	5.0	9.0	-4.0	31.6	-26.6
M	137.5	5.0	13.2	-8.2	69.3	-64.3
R	300.0	5.0	14.2	-9.2	55.9	-50.9
GEO						
1	0.0	5.0	9.5	-4.5	37.8	-32.8
2	25.0	5.0	11.9	-6.9	43.7	-38.7
3	50.0	5.0	12.7	-7.7	49.5	-44.5
4	75.0	5.0	12.5	-7.5	55.1	-50.1
5	100.0	5.0	12.1	-7.1	64.3	-59.3
6	125.0	5.0	12.7	-7.7	67.5	-62.5
7	150.0	5.0	13.8	-8.8	71.1	-66.1
8	175.0	5.0	14.5	-9.5	74.1	-69.1
9	200.0	5.0	14.1	-9.1	71.6	-66.6
10	225.0	5.0	13.6	-8.6	67.4	-62.4
11	250.0	5.0	13.5	-8.5	60.4	-55.4
12	275.0	5.0	14.2	-9.2	59.0	-54.0

VELOCITIES USED:

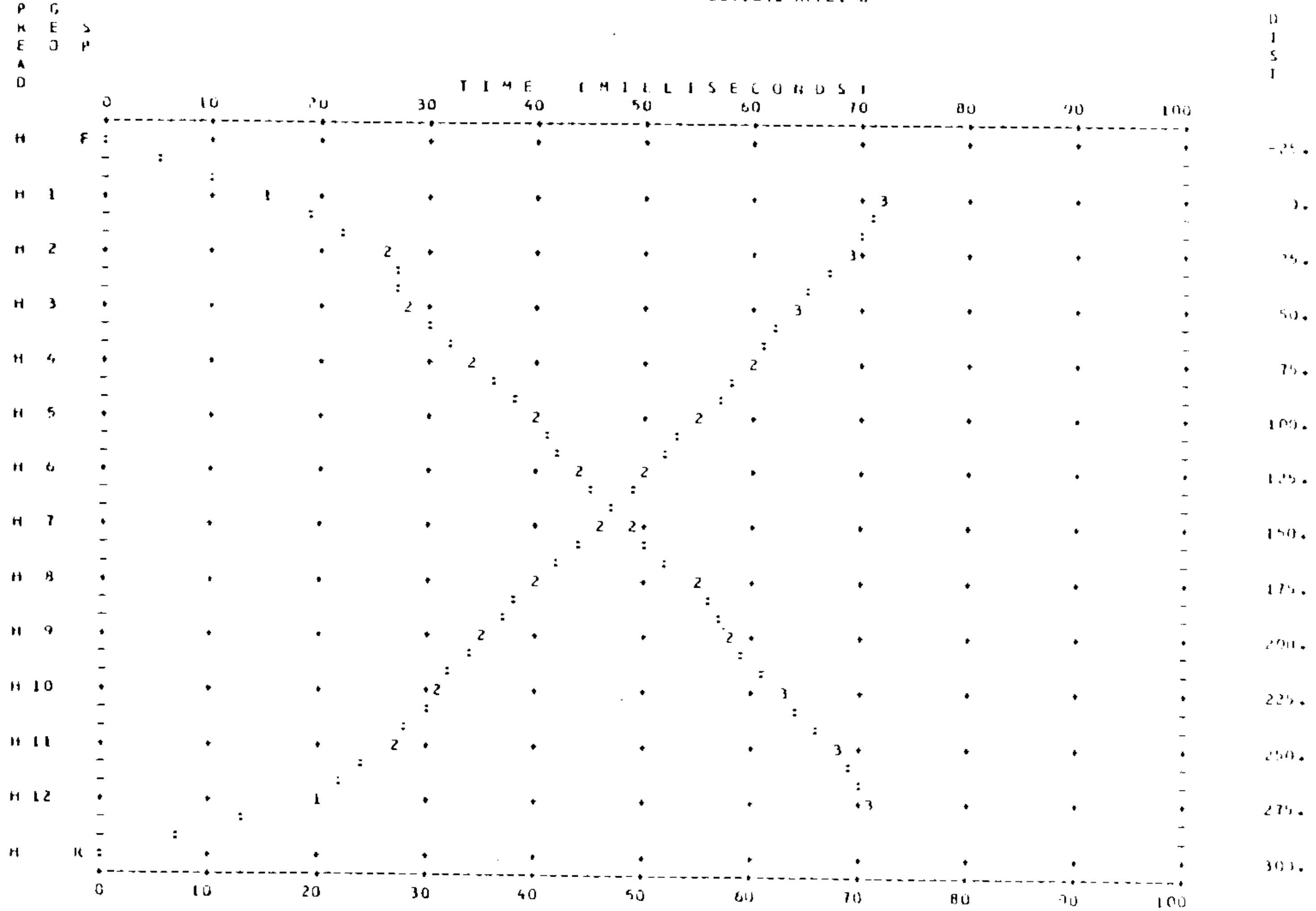
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1674.	5227.	
HORIZONTAL		5227.	7114.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 17



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 18

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 18

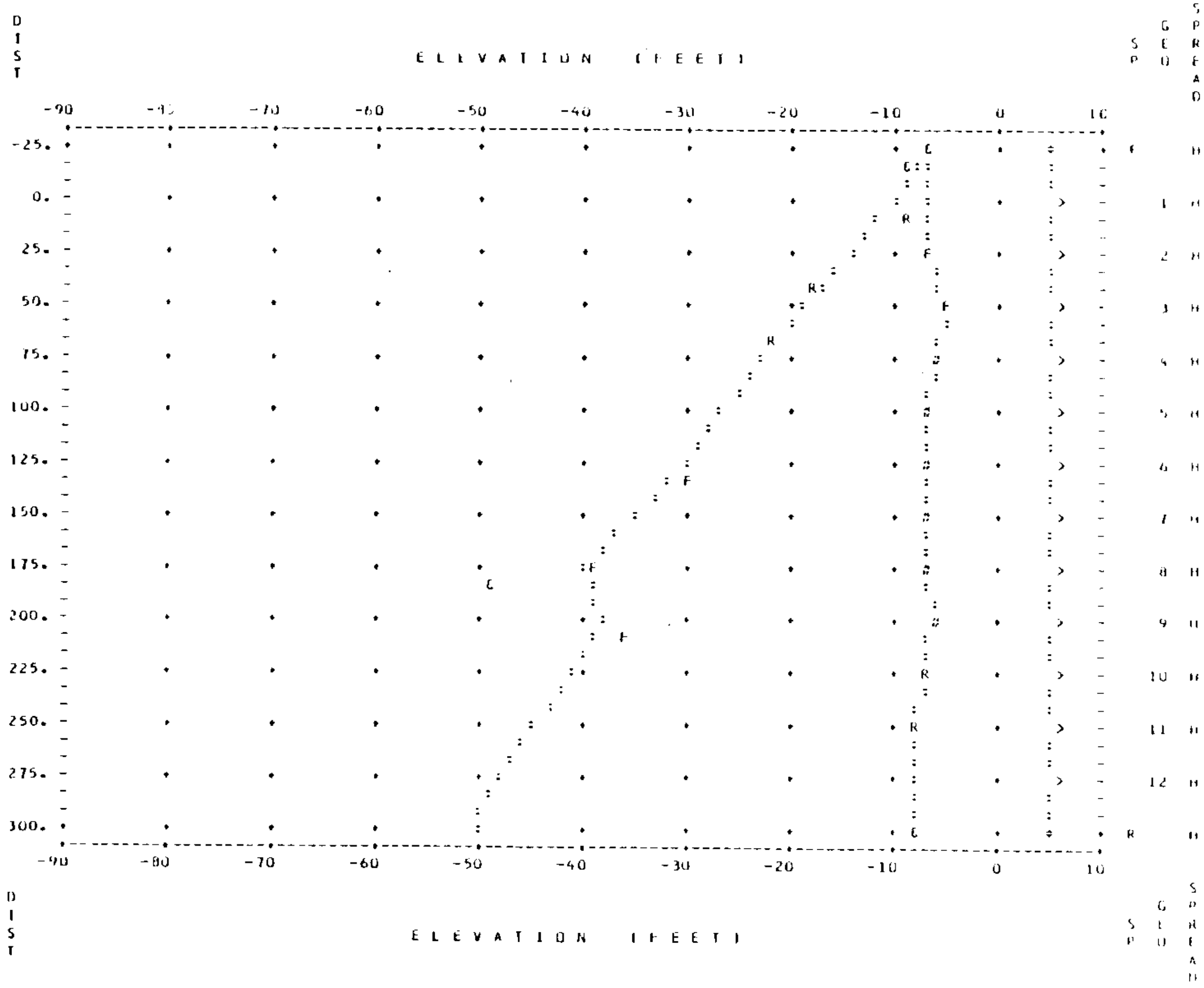
SPREAD H SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	-25.0	5.0	11.7	-6.7	11.7	-6.7
R	300.0	5.0	13.2	-8.2	55.3	-50.3
GEO						
1	0.0	5.0	11.7	-6.7	15.4	-10.4
2	25.0	5.0	11.9	-6.9	19.4	-14.4
3	50.0	5.0	10.1	-5.1	23.9	-18.9
4	75.0	5.0	11.2	-6.2	27.9	-22.9
5	100.0	5.0	11.9	-6.9	31.6	-26.6
6	125.0	5.0	11.7	-6.7	35.3	-30.3
7	150.0	5.0	11.7	-6.7	39.9	-34.9
8	175.0	5.0	11.9	-6.9	45.0	-40.0
9	200.0	5.0	11.2	-6.2	42.8	-37.8
10	225.0	5.0	12.2	-7.2	46.2	-41.2
11	250.0	5.0	12.8	-7.8	49.6	-44.6
12	275.0	5.0	12.9	-7.9	53.0	-48.0

VELOCITIES USED:

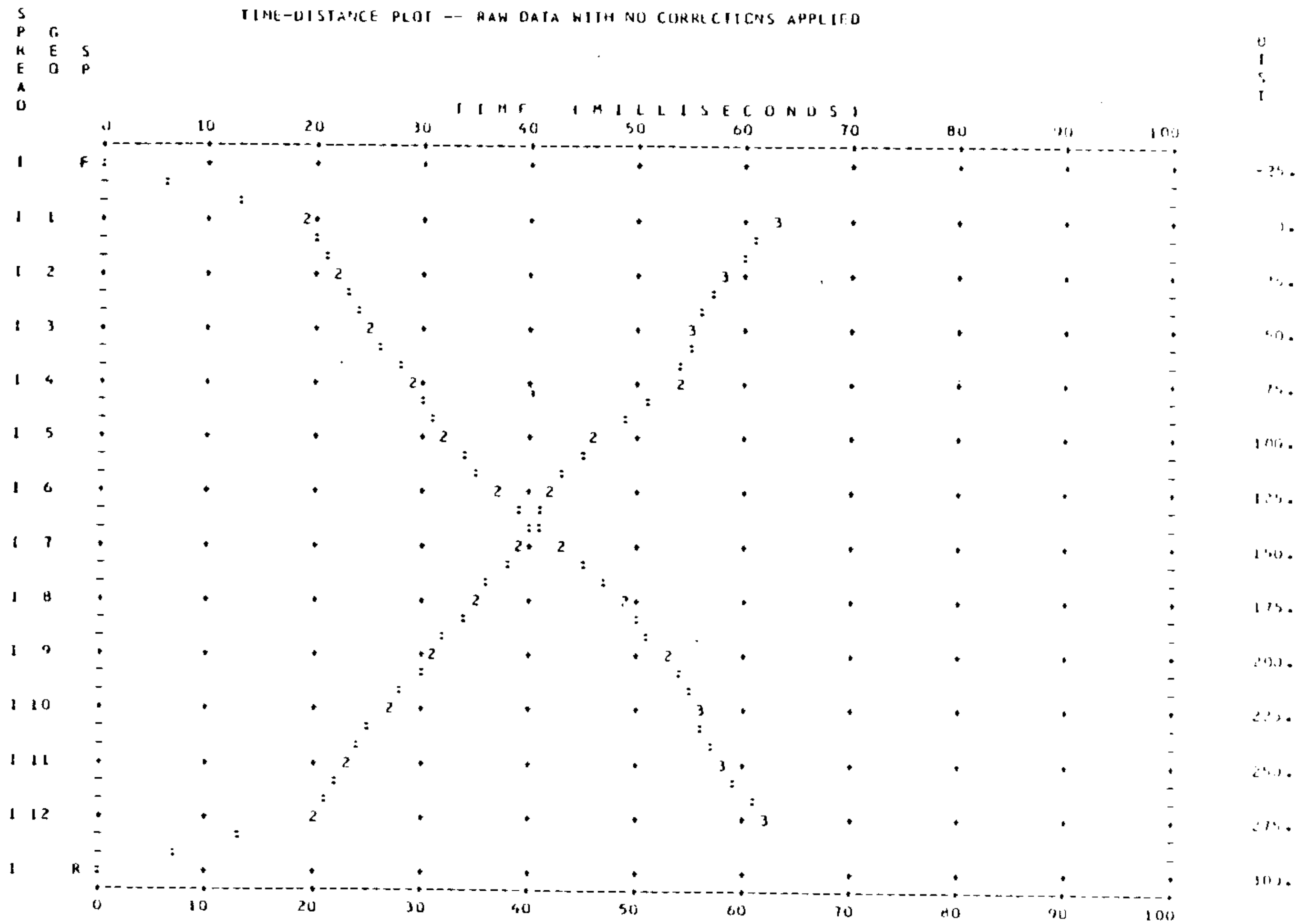
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1458.	5174.	
HORIZONTAL		5174.	6061.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 18



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 19

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 19

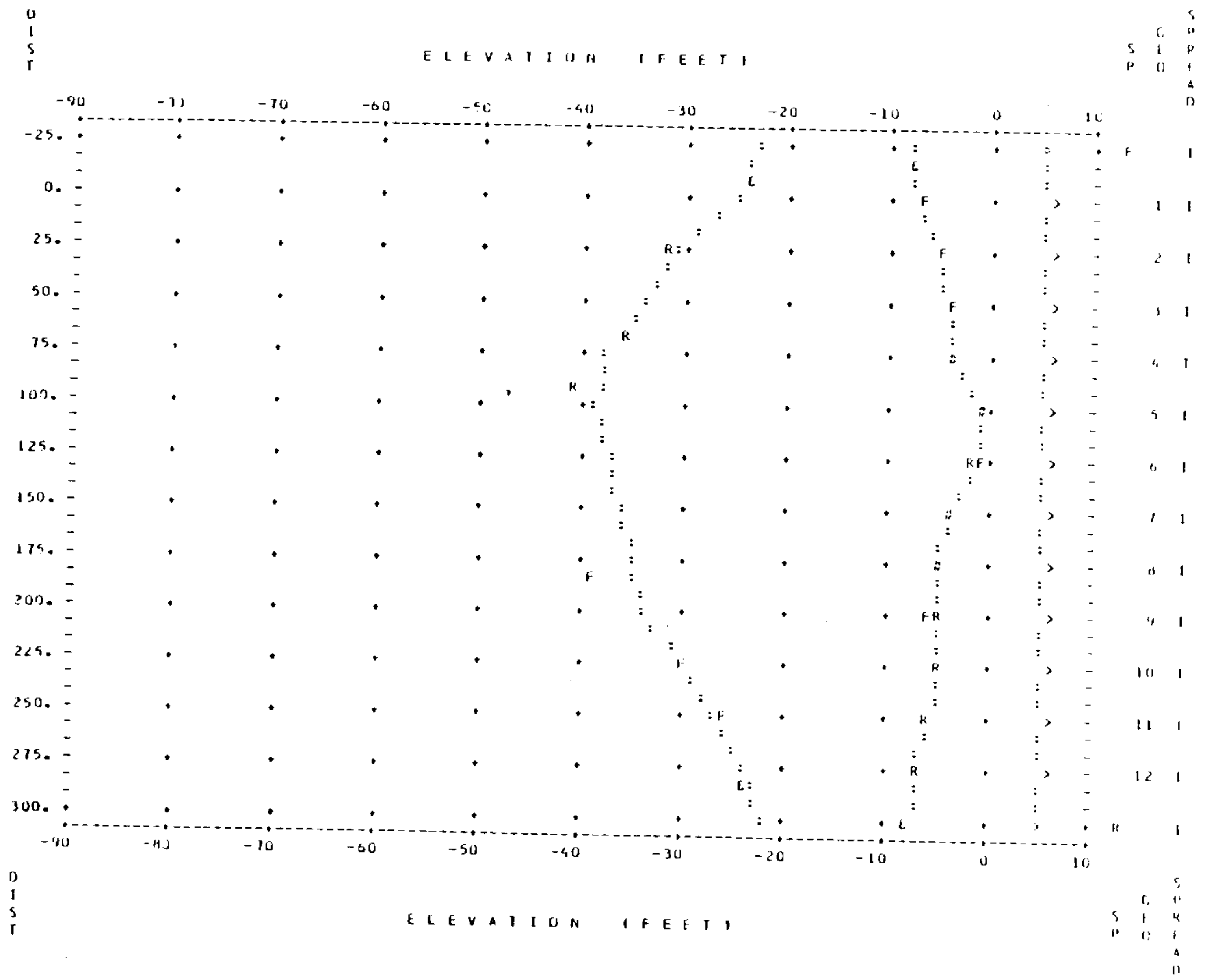
SPREAD I SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	-25.0	5.0	13.4	-8.4	27.7	-22.7
R	300.0	5.0	12.5	-7.5	26.7	-21.7
GEO						
1	0.0	5.0	12.2	-7.2	30.3	-25.3
2	25.0	5.0	10.3	-5.3	35.7	-30.7
3	50.0	5.0	9.2	-4.2	39.1	-34.1
4	75.0	5.0	9.1	-4.1	42.6	-37.6
5	100.0	5.0	6.3	-1.3	43.7	-38.7
6	125.0	5.0	6.6	-1.6	42.5	-37.5
7	150.0	5.0	9.0	-4.0	41.3	-36.3
8	175.0	5.0	10.2	-5.2	40.1	-35.1
9	200.0	5.0	10.5	-5.5	38.9	-33.9
10	225.0	5.0	9.8	-4.8	34.9	-29.9
11	250.0	5.0	10.6	-5.6	31.6	-26.6
12	275.0	5.0	12.1	-7.1	29.2	-24.2

VELOCITIES USED:

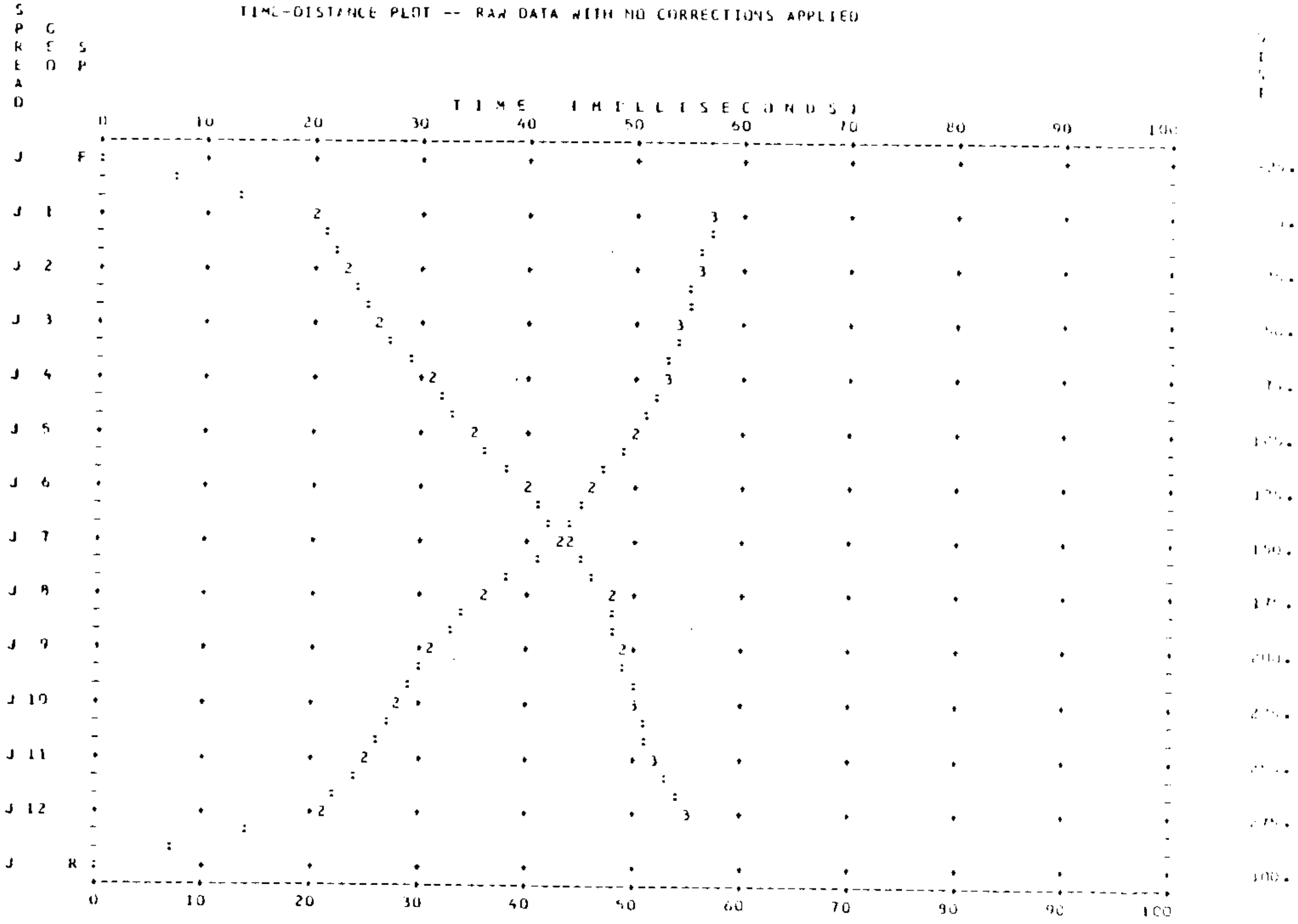
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1500.	5749.	
HORIZONTAL		5749.	7143.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 19



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 20

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 20

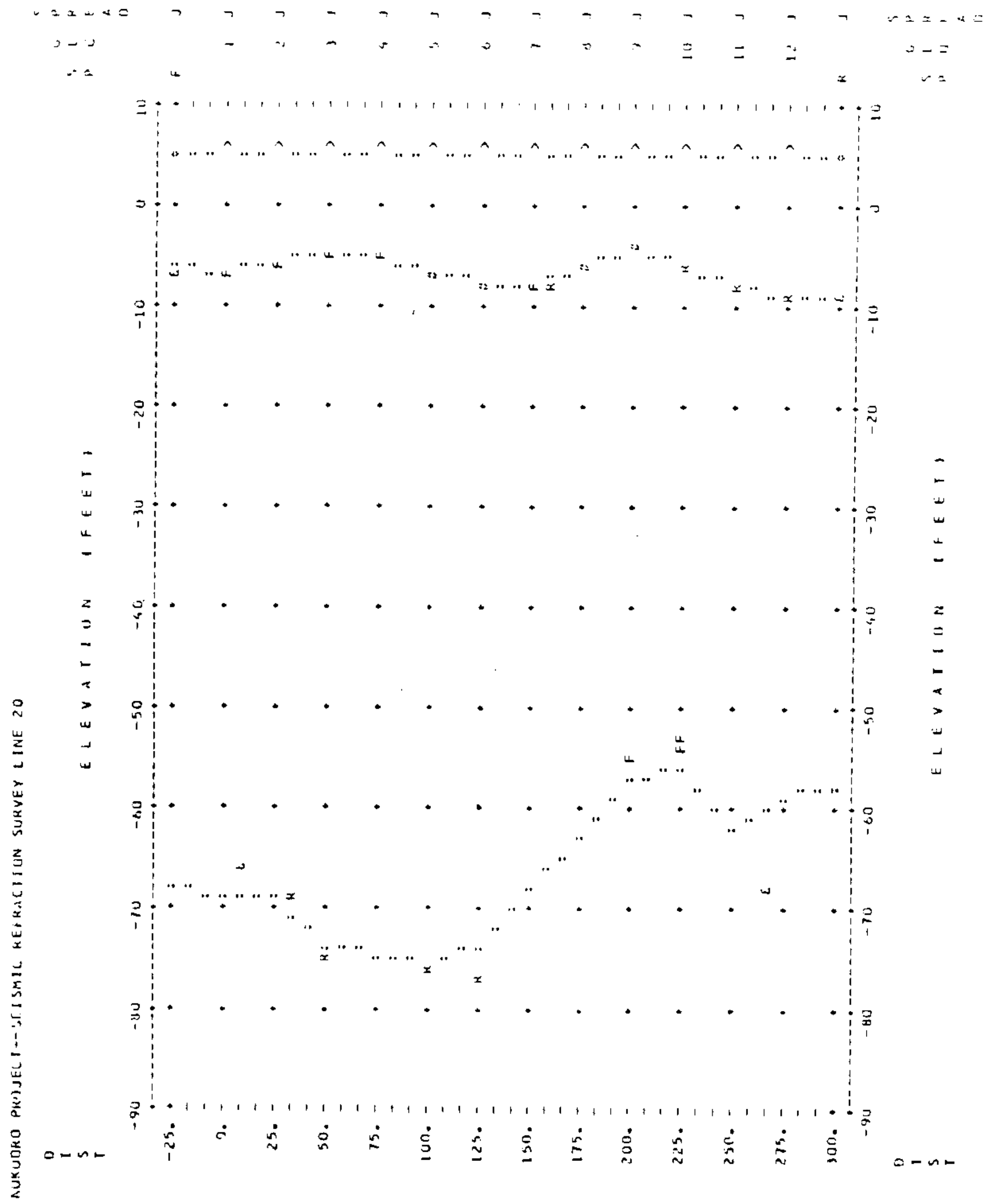
SPREAD J SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV	LAYER 3 DEPTH	LAYER 3 ELEV
F	-25.0	5.0	11.4	-6.4	72.7	-67.7
R	300.0	5.0	14.1	-9.1	62.5	-57.5

GEO	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV	LAYER 3 DEPTH	LAYER 3 ELEV
1	0.0	5.0	11.7	-6.7	73.9	-68.9
2	25.0	5.0	10.8	-5.8	73.8	-68.8
3	50.0	5.0	9.7	-4.7	79.1	-74.1
4	75.0	5.0	10.3	-5.3	79.5	-74.5
5	100.0	5.0	12.0	-7.0	80.9	-75.9
6	125.0	5.0	12.7	-7.7	78.6	-73.6
7	150.0	5.0	13.2	-8.2	73.2	-68.2
8	175.0	5.0	11.1	-6.1	67.8	-62.8
9	200.0	5.0	8.8	-3.8	62.5	-57.5
10	225.0	5.0	10.9	-5.9	61.0	-56.0
11	250.0	5.0	13.0	-8.0	67.1	-62.1
12	275.0	5.0	13.8	-8.8	63.9	-58.9

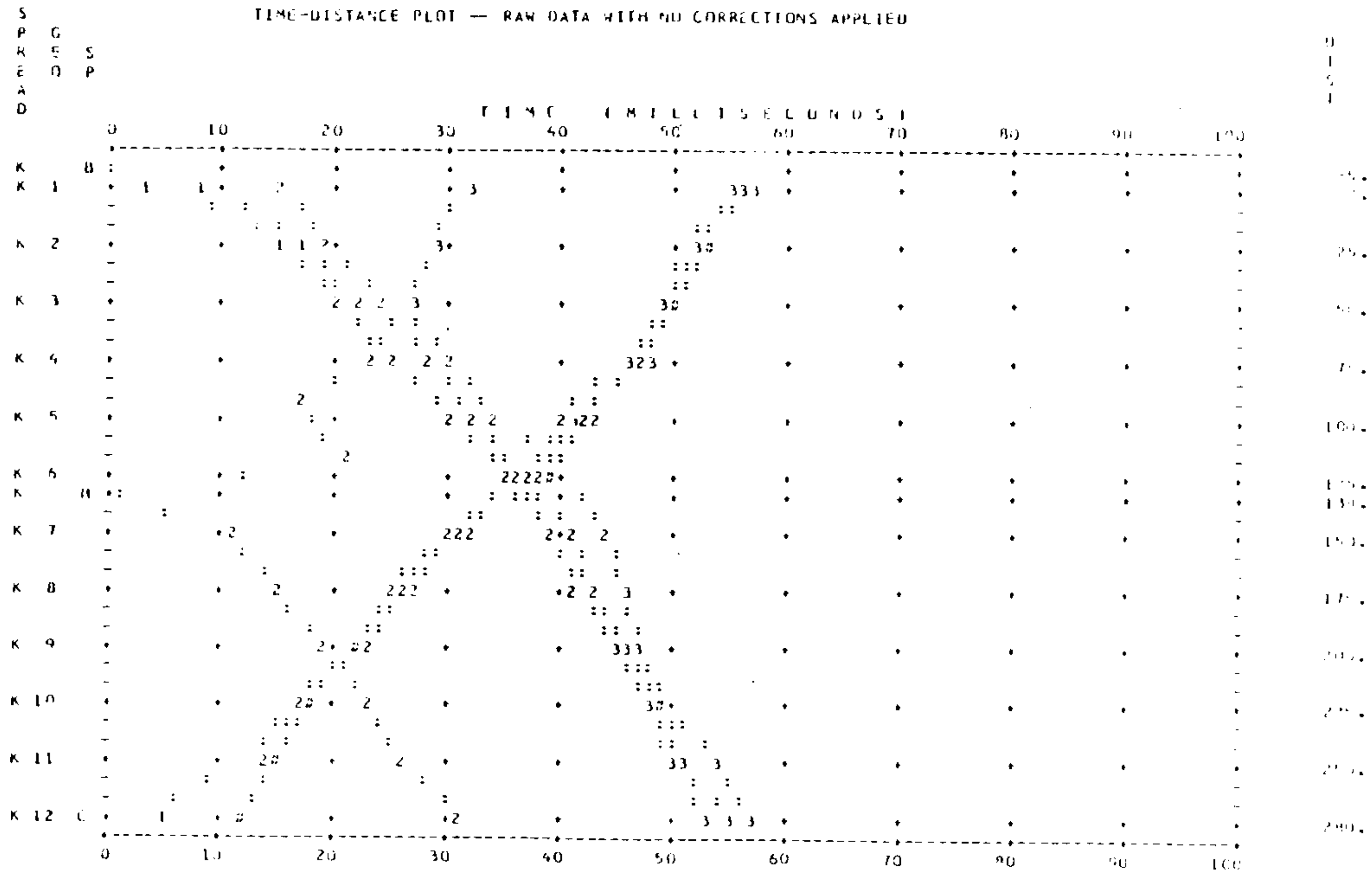
VELOCITIES USED:

	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1500.	6043.	
HORIZONTAL		6043.	13359.


NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 20
ELEVATION (FEET)
DIST
SPREAD
SHOT
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10
-25. 0. 25. 50. 75. 100. 125. 150. 175. 200. 225. 250. 275. 300.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 21

TIME-DISTANCE PLOT — RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 21

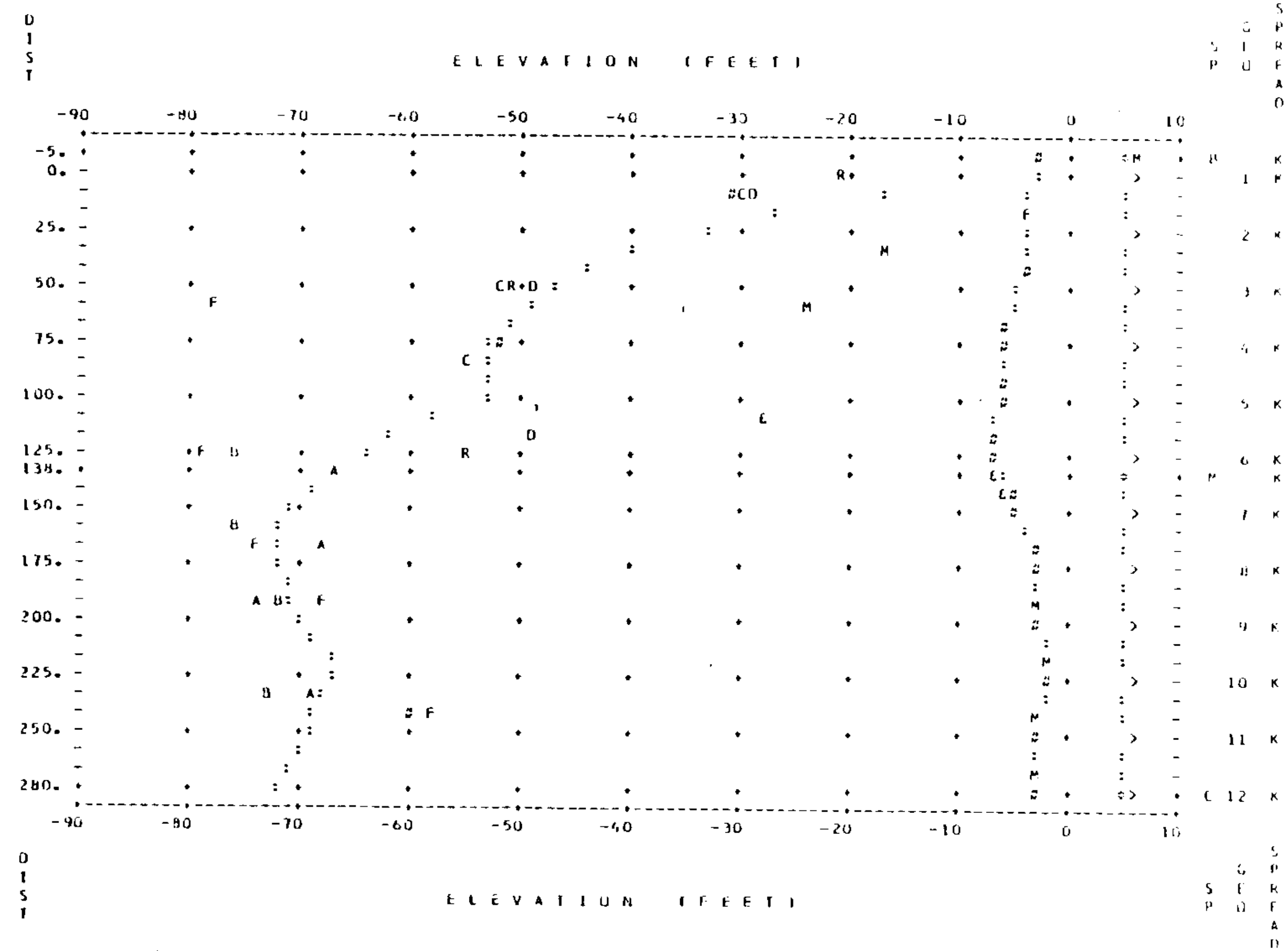
SPREAD K   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV	LAYER 3 DEPTH	LAYER 3 ELEV
B	-5.0	5.0	8.3	-3.3	8.3	-3.3
M	137.5	5.0	11.1	-6.1	72.4	-67.4
C	280.0	5.0	8.1	-3.1	76.7	-71.7
GEO						
1	0.0	5.0	8.5	-3.5	8.5	-3.5
2	25.0	5.0	8.8	-3.8	38.3	-33.3
3	50.0	5.0	9.5	-4.5	51.8	-46.8
4	75.0	5.0	11.0	-6.0	57.6	-52.6
5	100.0	5.0	11.0	-6.0	58.4	-53.4
6	125.0	5.0	12.2	-7.2	68.9	-63.9
7	150.0	5.0	10.1	-5.1	75.9	-70.9
8	175.0	5.0	7.7	-2.7	77.2	-72.2
9	200.0	5.0	7.6	-2.6	75.5	-70.5
10	225.0	5.0	7.0	-2.0	71.8	-66.8
11	250.0	5.0	7.7	-2.7	74.3	-69.3
12	275.0	5.0	8.2	-3.2	76.8	-71.8

VELOCITIES USED:

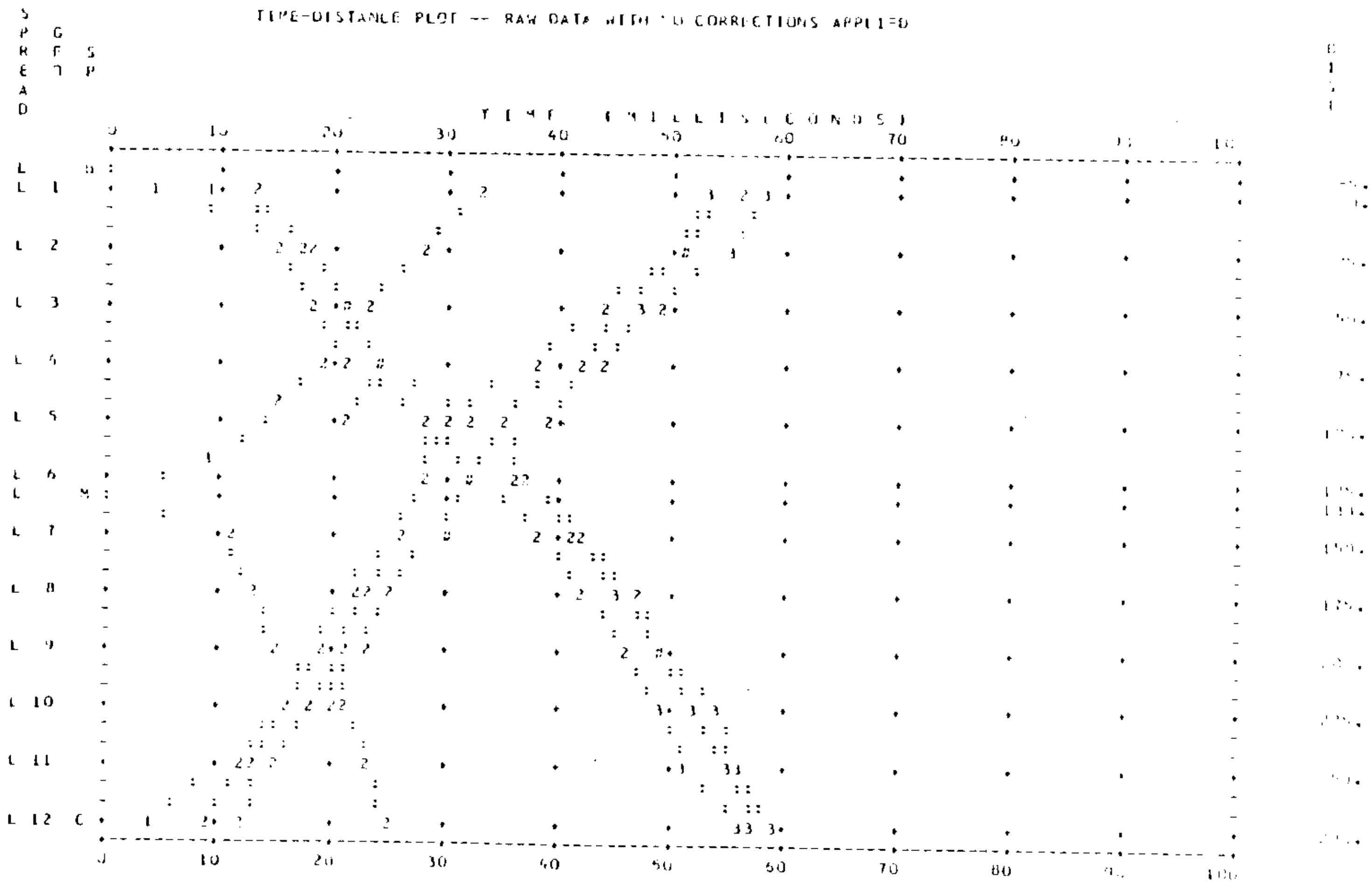
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1646.	6003.	
HORIZONTAL		6003.	8650.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 21



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 22

TIME-DISTANCE PLOT -- RAW DATA WITH 'U CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 22

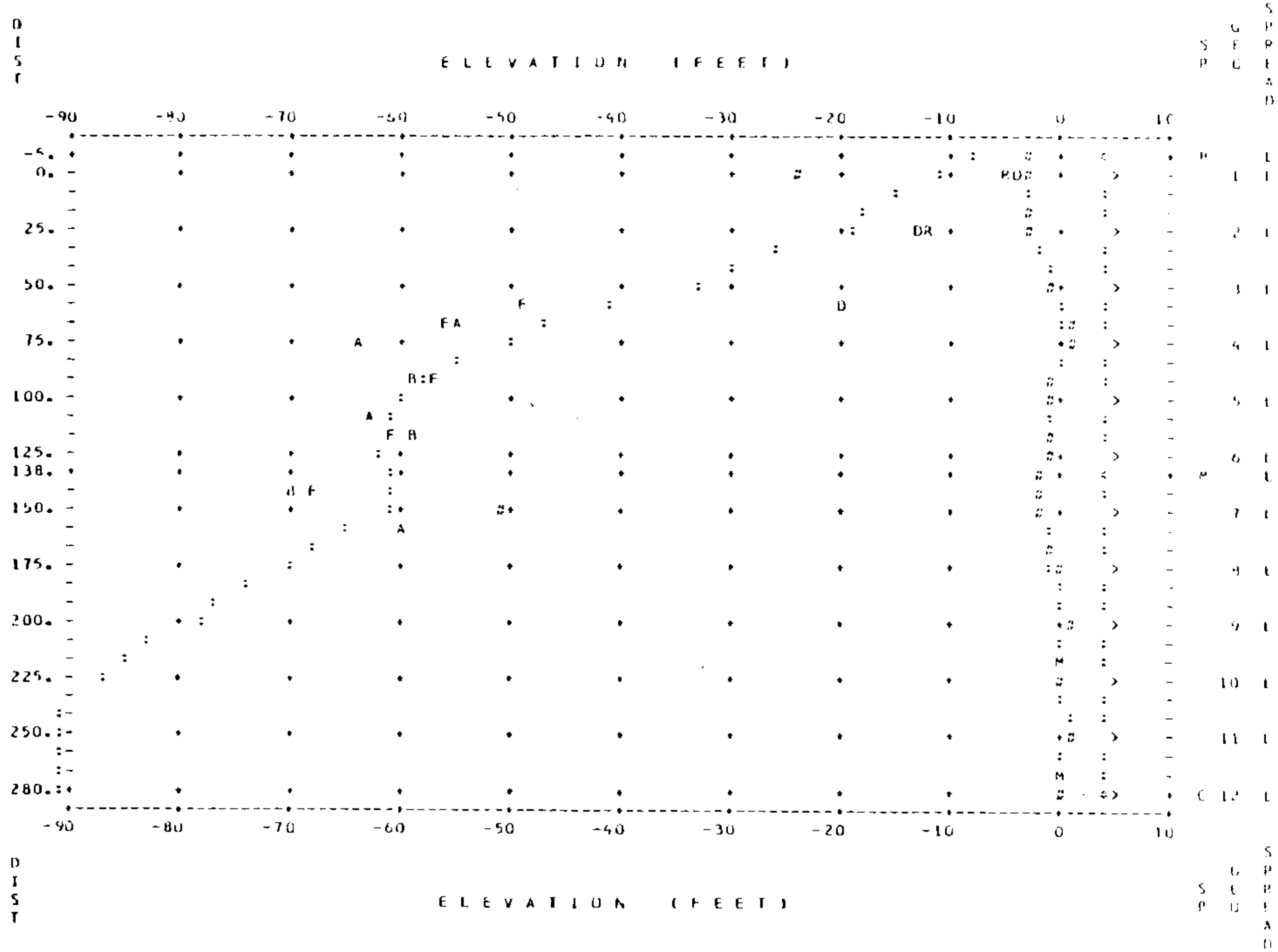
SPREAD L SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
B	-5.0	4.0	7.0	-3.0	12.4	-8.4
M	137.5	4.0	5.6	-1.6	65.4	-61.4
C	280.0	4.0	4.0	0.0	110.4	-106.4
GEO						
1	0.0	4.0	6.9	-2.9	14.6	-10.6
2	25.0	4.0	7.0	-3.0	23.4	-19.4
3	50.0	4.0	5.0	-1.0	36.8	-32.8
4	75.0	4.0	3.3	0.7	53.9	-49.9
5	100.0	4.0	5.0	-1.0	64.4	-60.4
6	125.0	4.0	5.5	-1.5	65.8	-61.8
7	150.0	4.0	5.7	-1.7	65.0	-61.0
8	175.0	4.0	4.5	-0.5	73.7	-69.7
9	200.0	4.0	3.5	0.5	82.5	-78.5
10	225.0	4.0	4.0	-0.0	91.2	-87.2
11	250.0	4.0	3.2	0.8	99.9	-95.9
12	275.0	4.0	4.0	-0.0	108.7	-104.7

VELOCITIES USED:

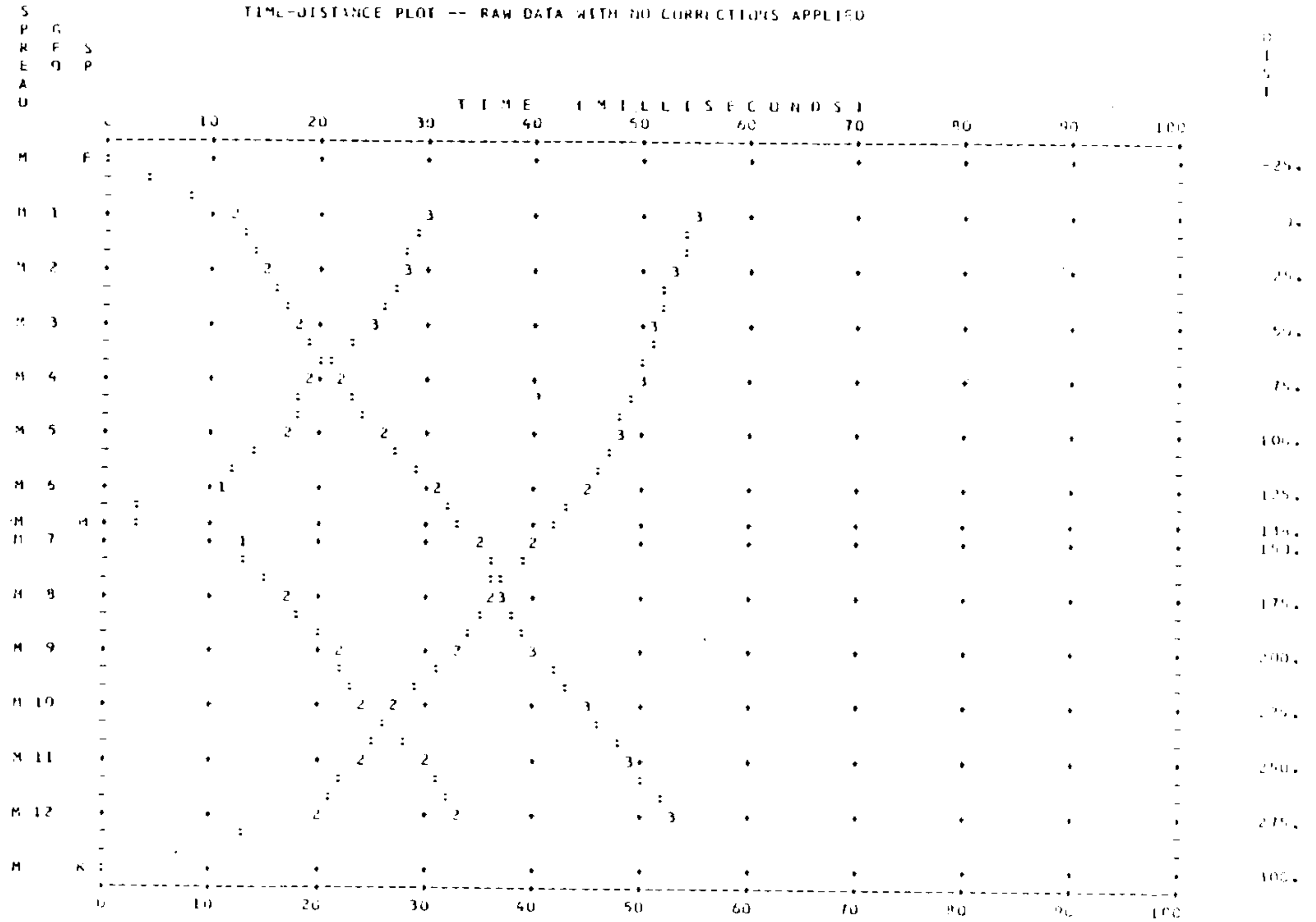
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1347.	5794.	
HORIZONTAL		5794.	7951.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 22



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 23

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 23

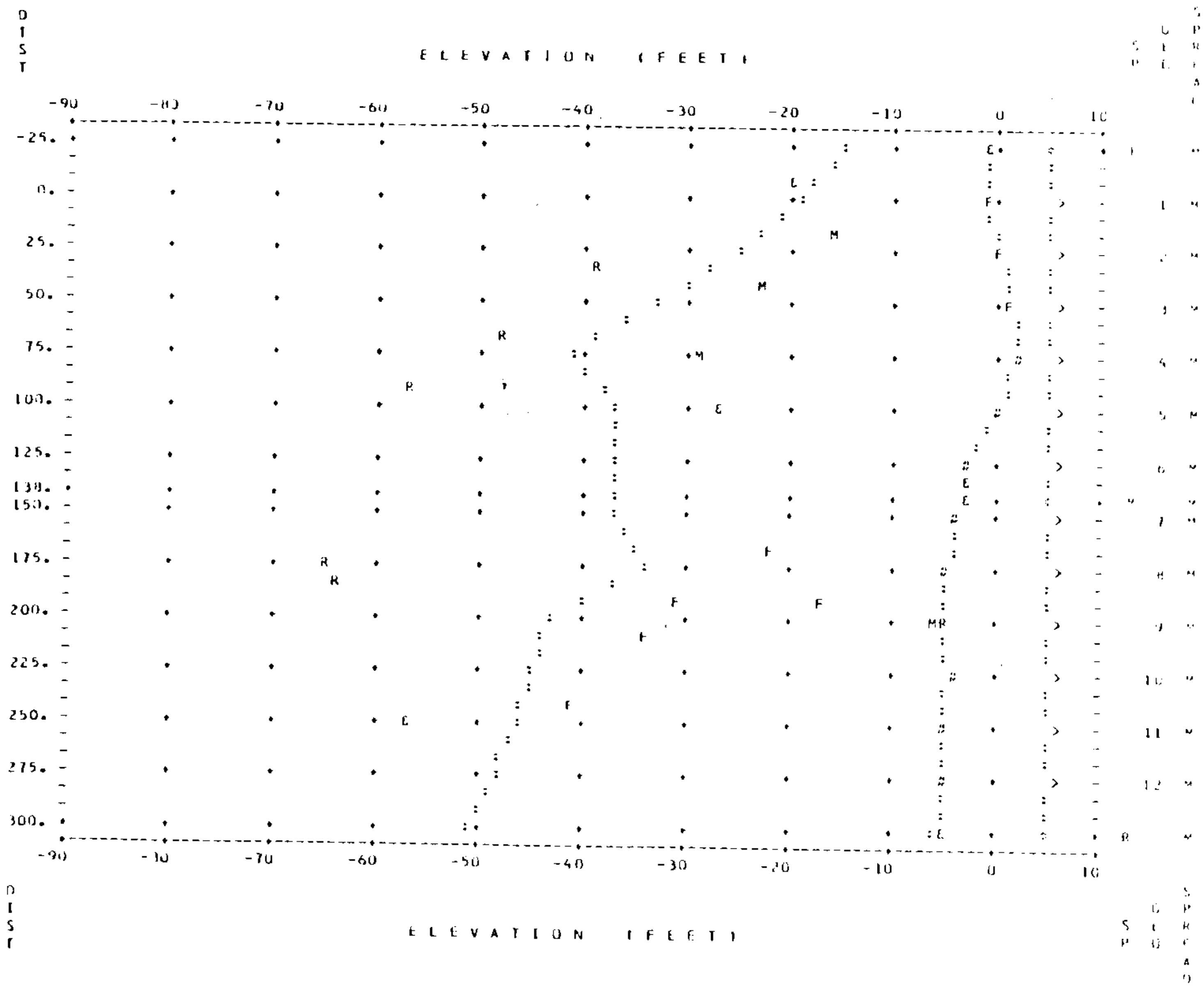
SPREAD M   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	-25.0	5.0	5.8	-0.8	20.0	-15.0
M	137.5	5.0	8.2	-3.2	41.9	-36.9
R	300.0	5.0	10.5	-5.5	55.8	-50.8
GEO						
1	0.0	5.0	6.0	-1.0	23.8	-18.8
2	25.0	5.0	4.9	0.1	29.7	-24.7
3	50.0	5.0	3.7	1.3	38.4	-33.4
4	75.0	5.0	3.1	1.9	46.3	-41.3
5	100.0	5.0	4.8	0.2	41.5	-36.5
6	125.0	5.0	7.7	-2.7	41.9	-36.9
7	150.0	5.0	8.8	-3.8	41.8	-36.8
8	175.0	5.0	9.7	-4.7	38.8	-33.8
9	200.0	5.0	10.5	-5.5	48.2	-43.2
10	225.0	5.0	9.1	-4.1	49.8	-44.8
11	250.0	5.0	10.4	-5.4	51.4	-46.4
12	275.0	5.0	10.3	-5.3	53.1	-48.1

VELOCITIES USED:

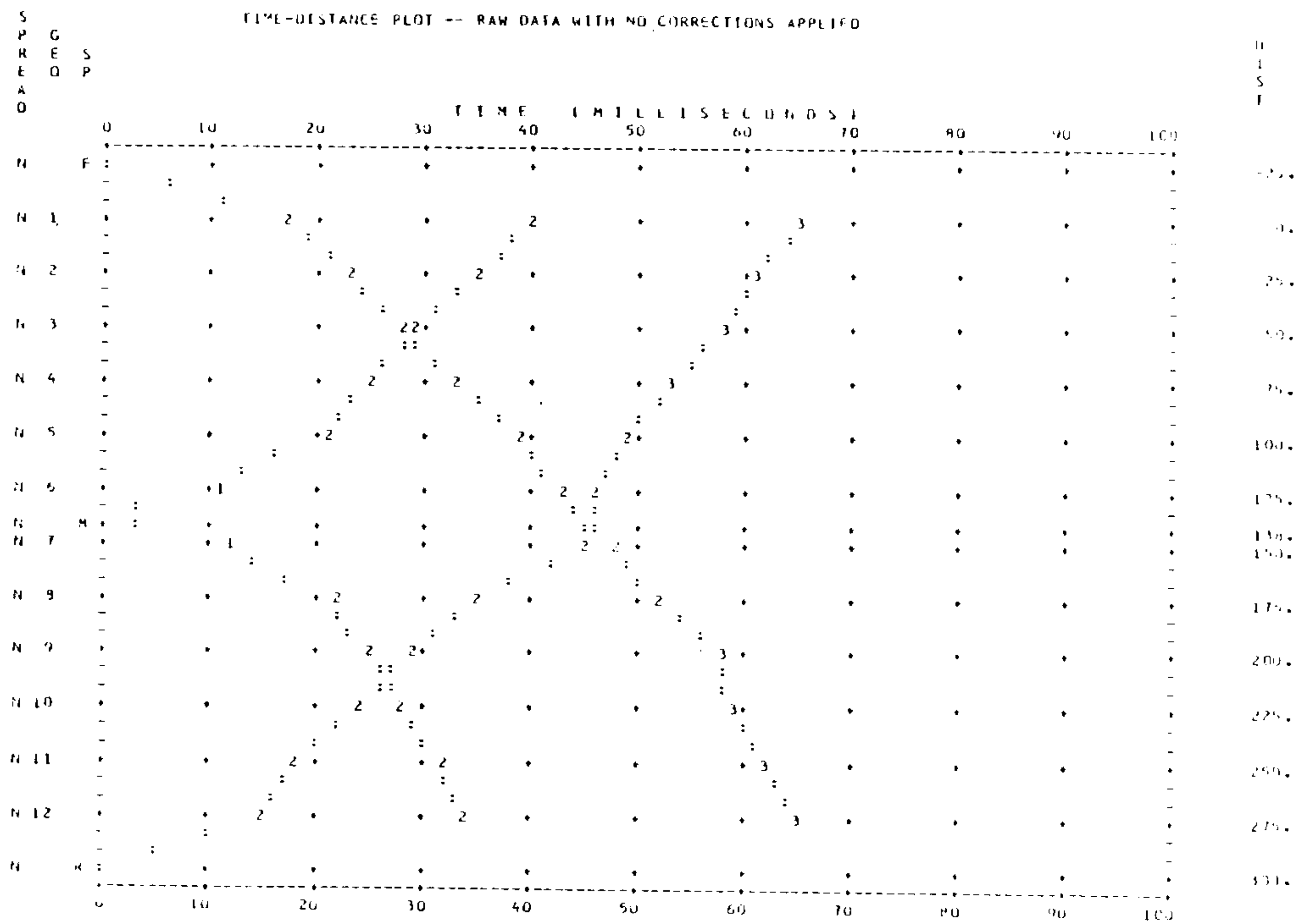
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1368.	6346.	
HORIZONTAL		6346.	8718.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 23



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 24

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 24

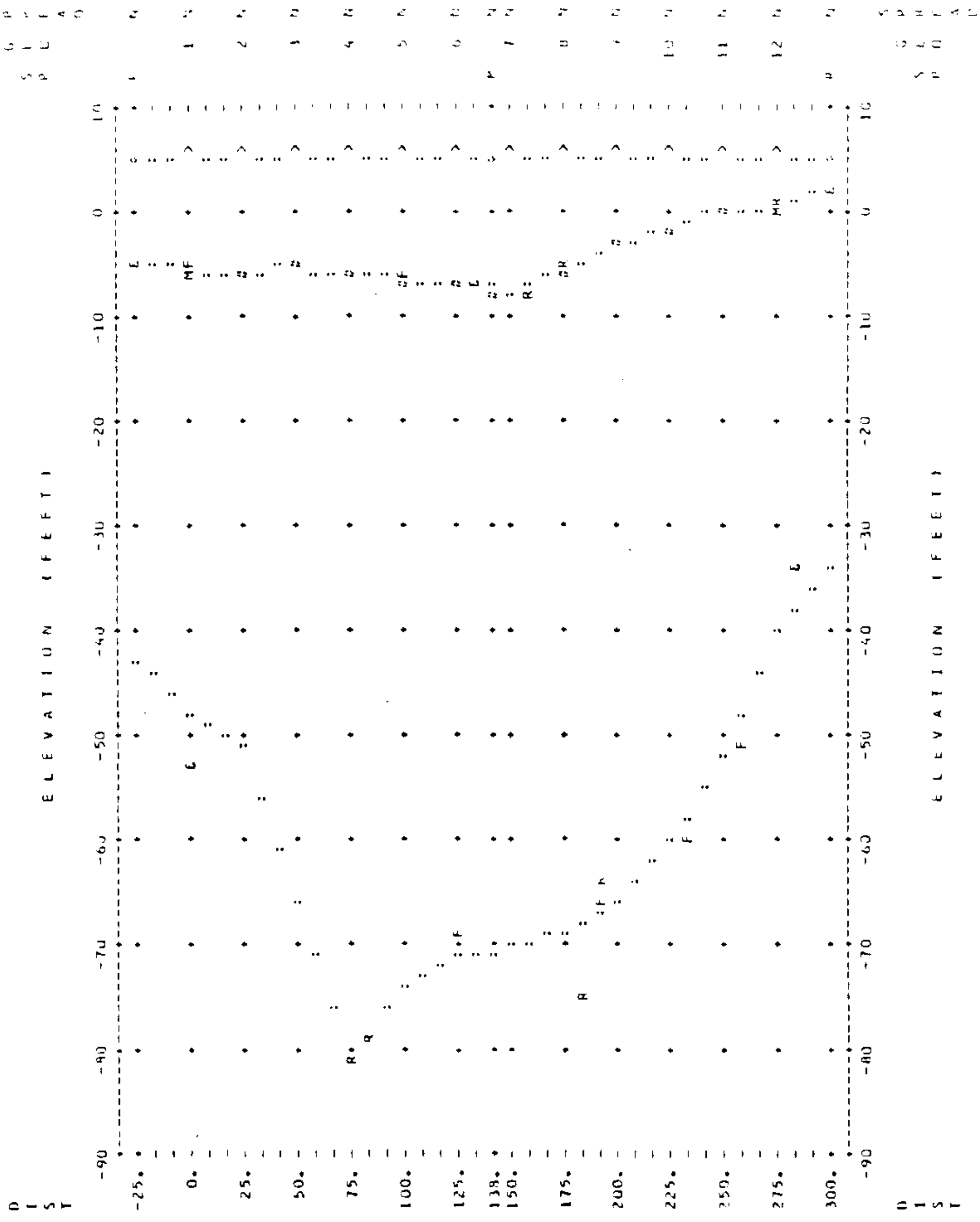
SPREAD N SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV	LAYER 3 DEPTH	LAYER 3 ELEV
F	-25.0	5.0	10.2	-5.2	47.5	-42.5
M	137.5	5.0	12.4	-7.4	75.7	-70.7
R	300.0	5.0	2.7	2.3	38.7	-33.7
GEO						
1	0.0	5.0	10.5	-5.5	53.2	-48.2
2	25.0	5.0	10.7	-5.7	56.2	-51.2
3	50.0	5.0	10.3	-5.3	70.7	-65.7
4	75.0	5.0	11.1	-6.1	85.6	-80.6
5	100.0	5.0	11.5	-6.5	79.4	-74.4
6	125.0	5.0	12.2	-7.2	76.3	-71.3
7	150.0	5.0	12.7	-7.7	75.1	-70.1
8	175.0	5.0	10.8	-5.8	73.9	-68.9
9	200.0	5.0	8.1	-3.1	71.0	-66.0
10	225.0	5.0	6.7	-1.7	65.2	-60.2
11	250.0	5.0	4.7	0.3	57.3	-52.3
12	275.0	5.0	4.5	0.5	44.7	-39.7

VELOCITIES USED:

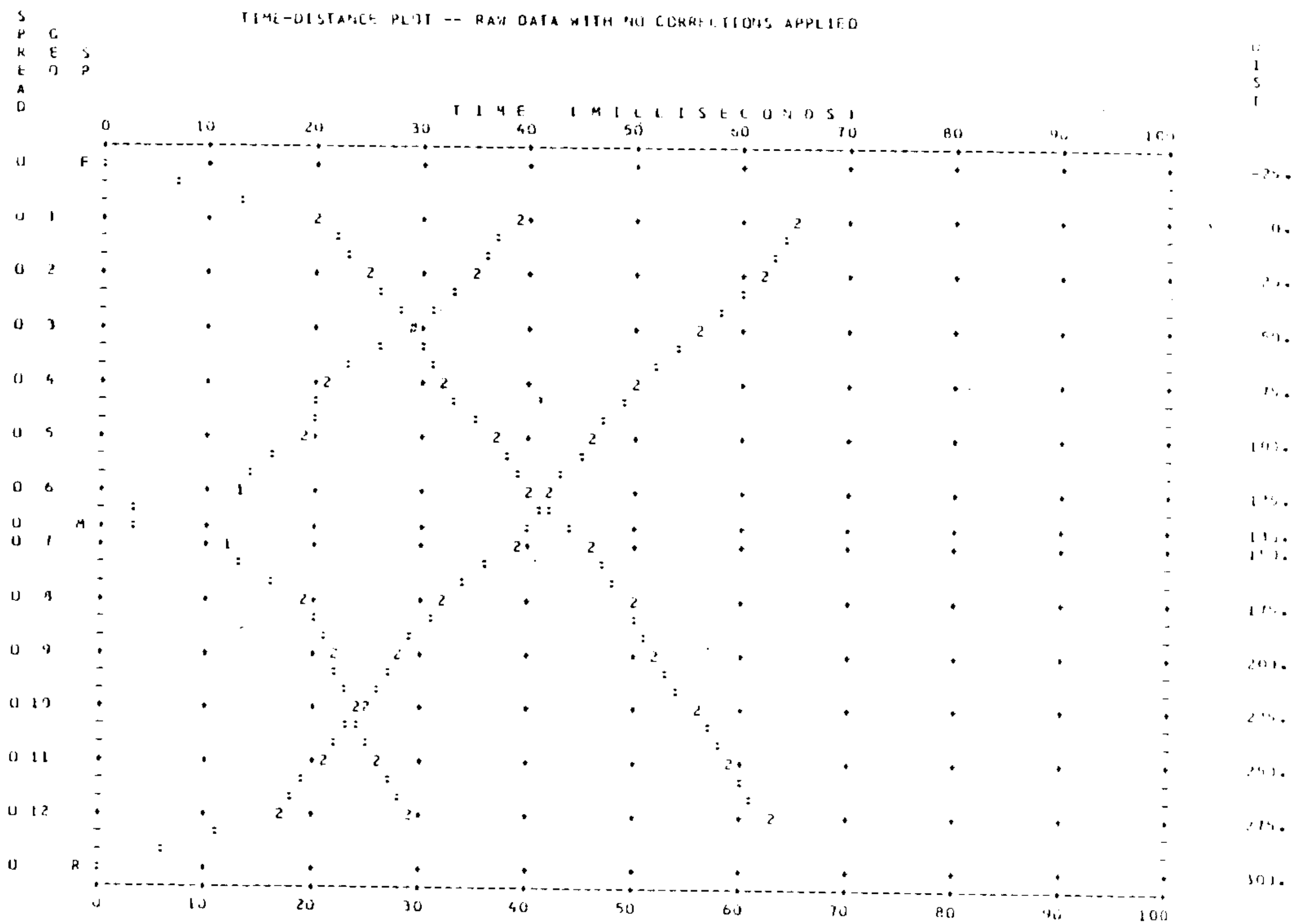
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1424.	5370.	
HORIZONTAL		5370.	7752.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 24



NUKUHRO PROJECT--SEISMIC REFRACTION SURVEY LINE 25

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 25

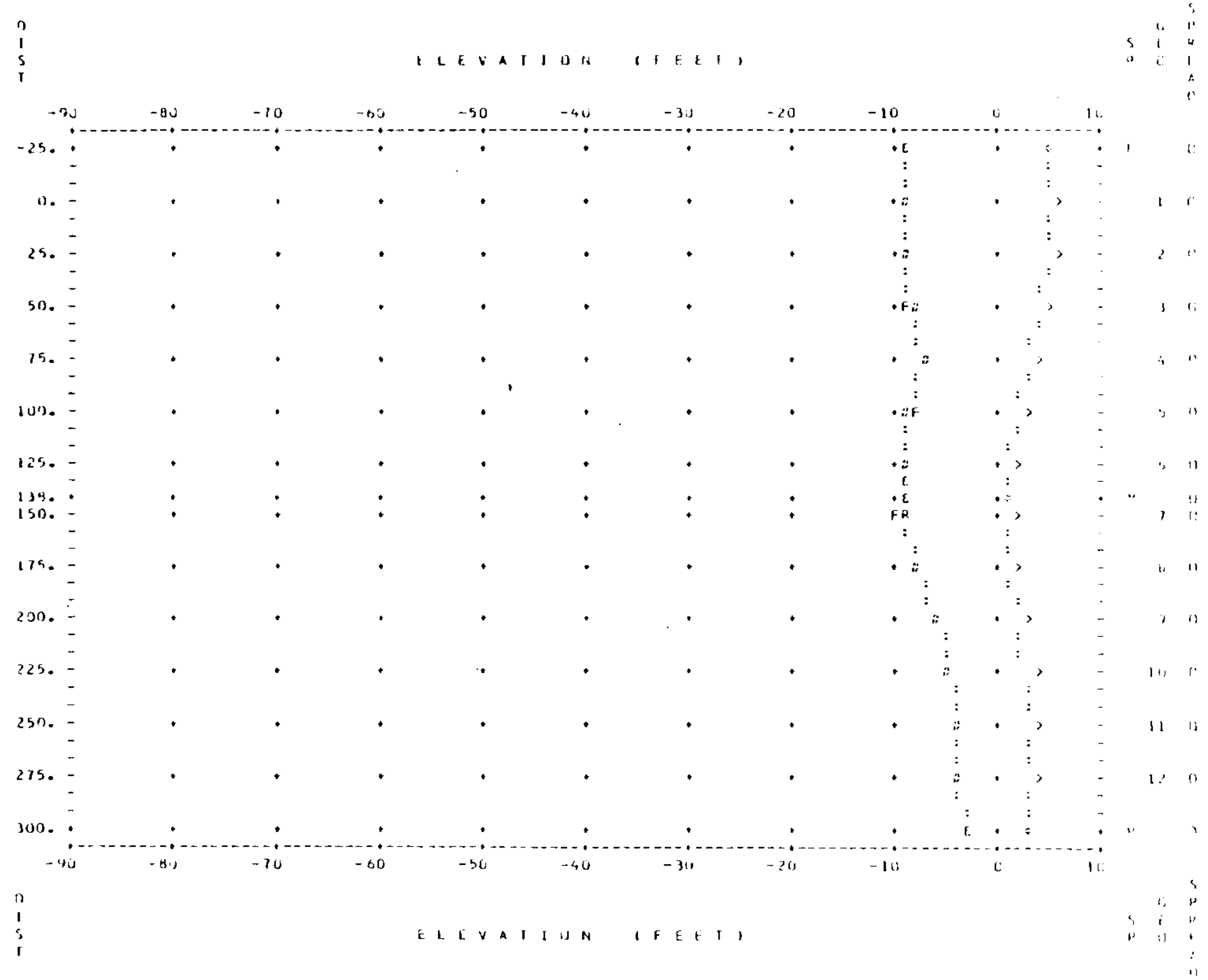
SPREAD D SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2	
SP	POSITION	SURF ELEV	DEPTH	ELEV
F	-25.0	5.0	13.6	-8.6
M	137.5	1.0	10.0	-9.0
R	300.0	3.0	5.7	-2.7
GEO				
1	0.0	5.0	13.6	-8.6
2	25.0	5.0	14.1	-9.1
3	50.0	4.0	12.6	-8.6
4	75.0	3.0	10.1	-7.1
5	100.0	2.0	10.5	-8.5
6	125.0	1.0	9.7	-8.7
7	150.0	1.0	10.2	-9.2
8	175.0	1.0	9.0	-8.0
9	200.0	2.0	7.8	-5.8
10	225.0	2.5	7.2	-4.7
11	250.0	2.5	6.2	-3.7
12	275.0	3.0	6.9	-3.9

VELOCITIES USED:

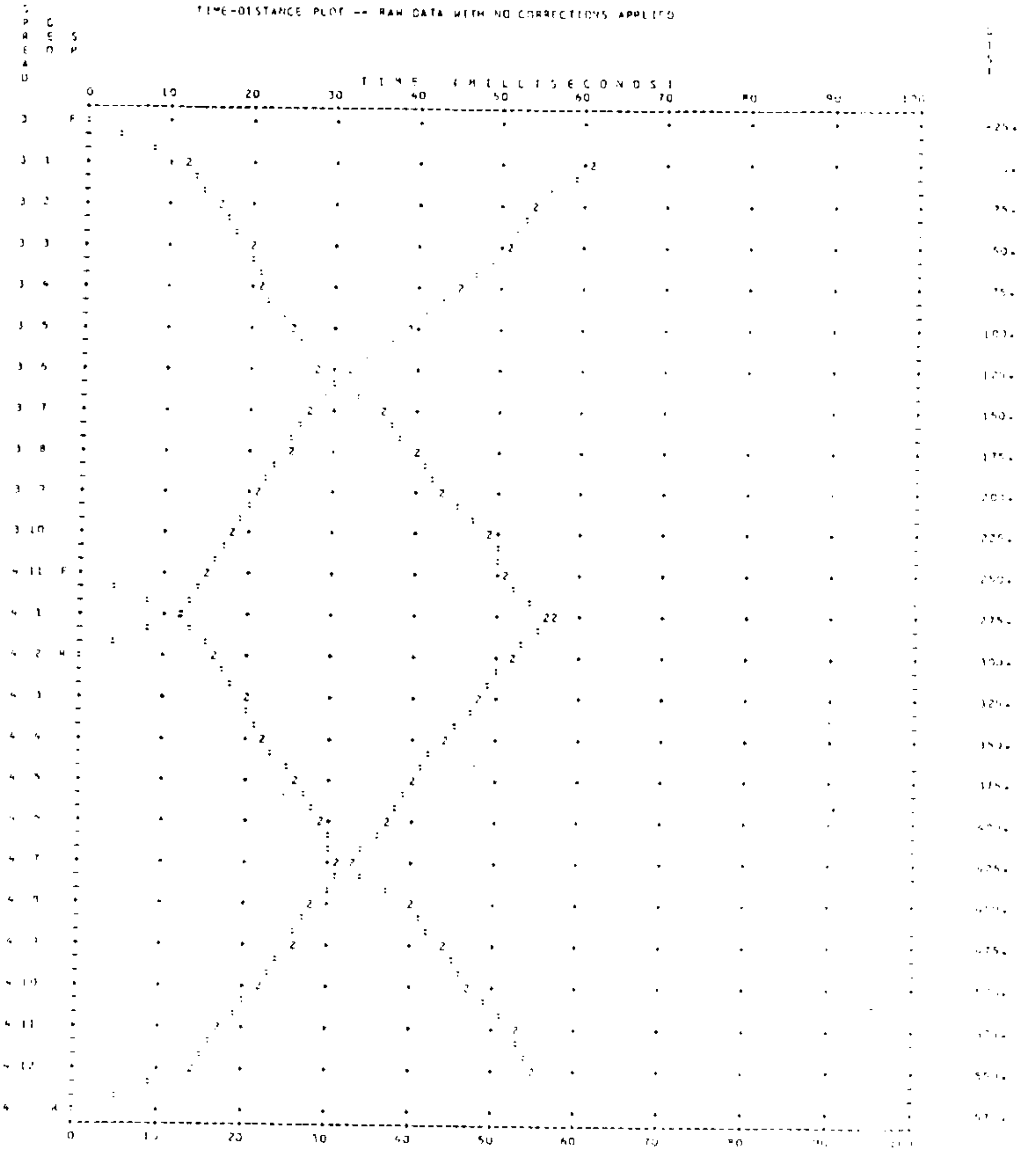
	LAYER 1	LAYER 2
VERTICAL	1307.	
HORIZONTAL		6350.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 25



NUKUORO PROJECT SEISMIC LINES 3 AND 4 (OVERLAPPED AT GEO 12)

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT SEISMIC LINES 3 AND 4 (OVERLAPPED AT GEO 12)

SPREAD 3 SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV
F	-25.0	5.0	12.8	-7.8
R	300.0	5.0	4.1	0.9
GEO				
1	0.0	5.0	11.0	-6.0
2	25.0	5.0	8.9	-3.9
3	50.0	5.0	9.1	-4.1
4	75.0	5.0	6.0	-1.0
5	100.0	5.0	4.2	0.8
6	125.0	5.0	1.5	3.5
7	150.0	5.0	3.1	1.9
8	175.0	5.0	4.5	0.5
9	200.0	5.0	4.0	1.0
10	225.0	5.0	6.3	-1.3
11	250.0	5.0	5.5	-0.5
12	275.0	5.0	6.0	-1.0

VELOCITIES USED:

	LAYER 1	LAYER 2
VERTICAL	1500.	
HORIZONTAL		6034.

NUKUORO PROJECT SEISMIC LINES 3 AND 4 (OVERLAPPED AT GEO 12)

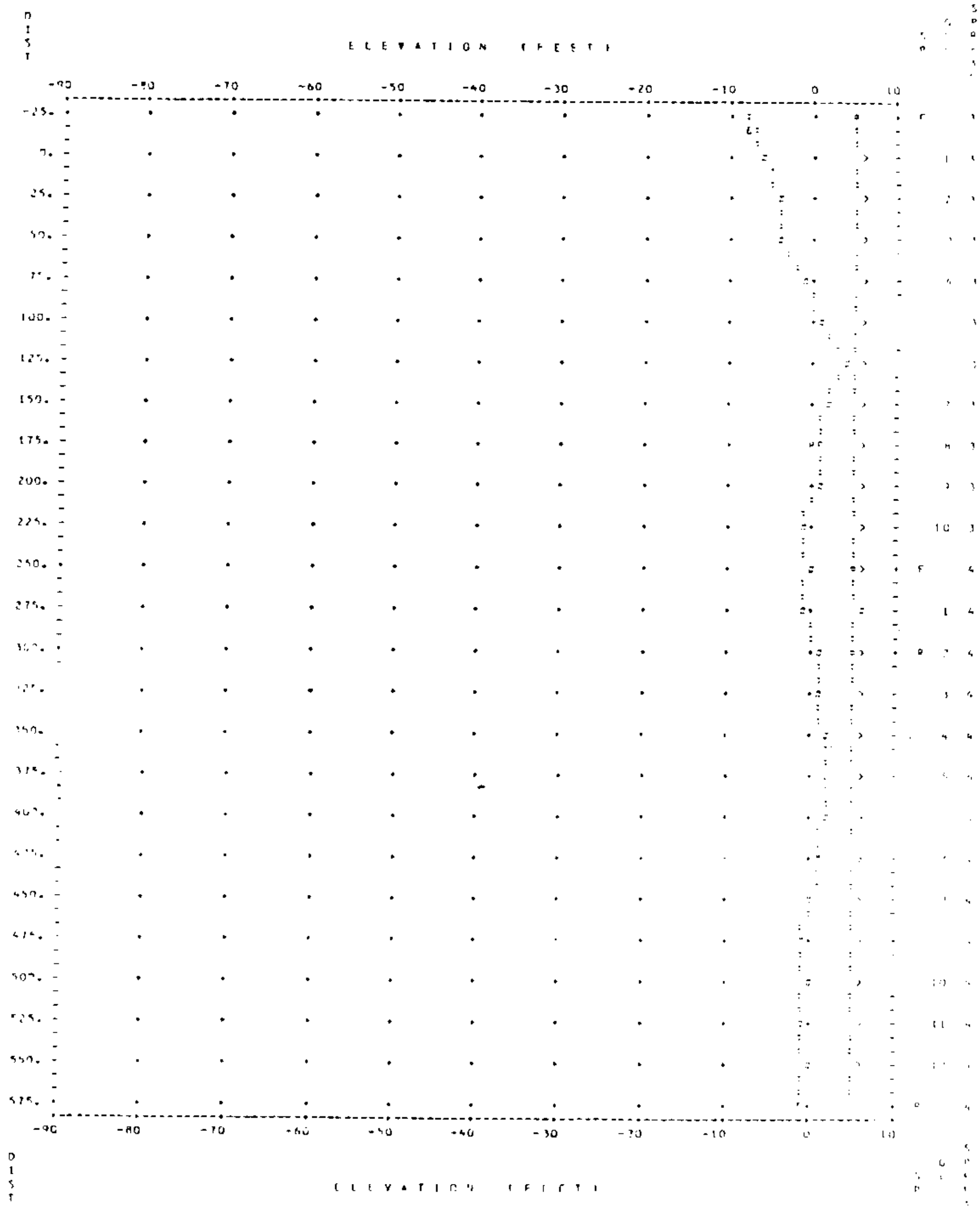
SPREAD 4   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

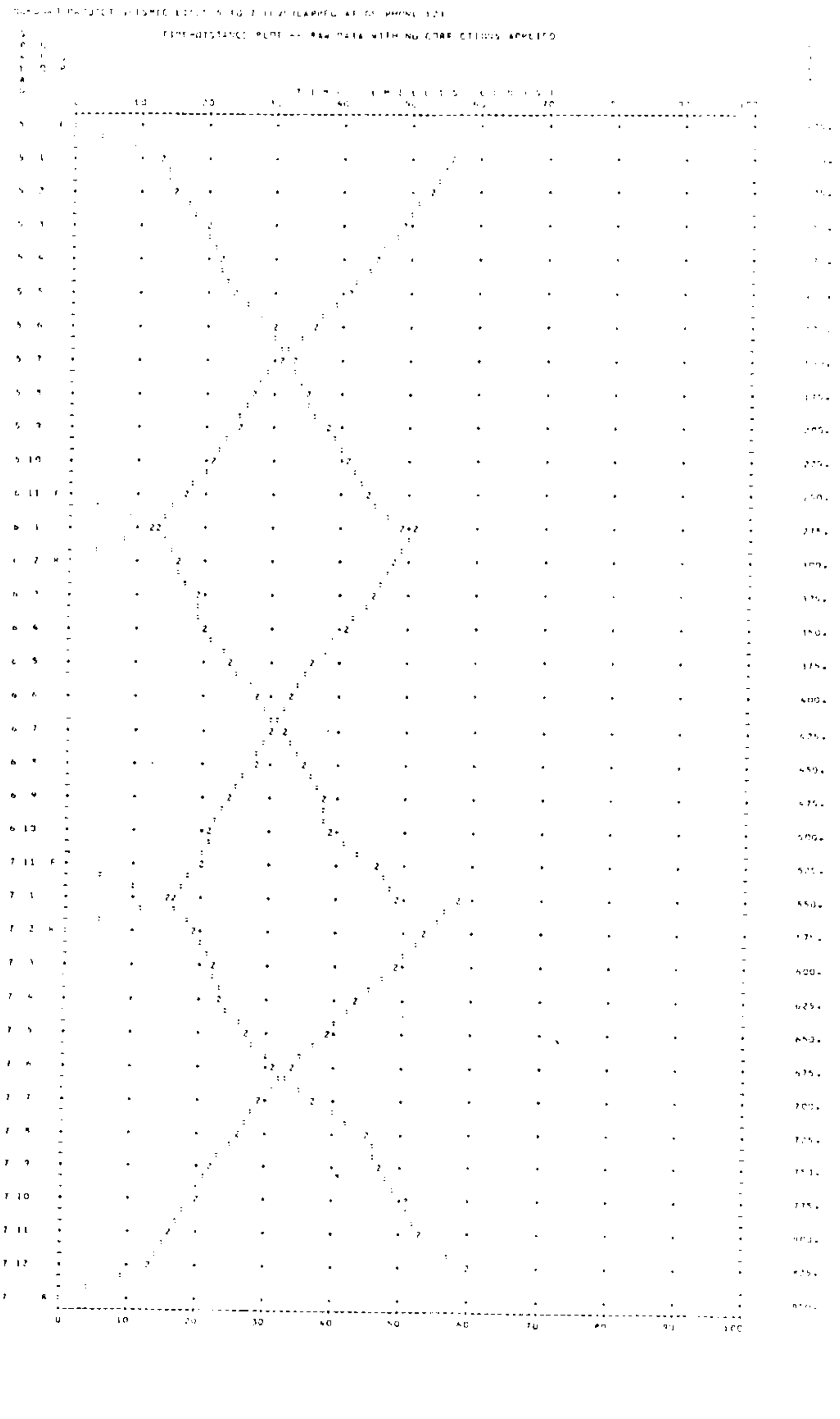
SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV
F	250.0	5.0	5.5	-0.5
R	575.0	5.0	5.8	-0.8
GEO				
1	275.0	5.0	6.0	-1.0
2	300.0	5.0	4.1	0.9
3	325.0	5.0	4.4	0.6
4	350.0	5.0	3.1	1.9
5	375.0	5.0	3.4	1.6
6	400.0	5.0	3.4	1.6
7	425.0	5.0	3.7	1.3
8	450.0	5.0	4.6	0.4
9	475.0	5.0	6.0	-1.0
10	500.0	5.0	5.5	-0.5
11	525.0	5.0	6.0	-1.0
12	550.0	5.0	5.4	-0.4

VELOCITIES USED:

	LAYER 1	LAYER 2
VERTICAL	1500.	
HORIZONTAL		6084.

NUKUORO PROJECT SEISMIC LINES 3 AND 4 (OVERLAPPED AT GEO 12)





NUKUORO PROJECT SEISMIC LINES 5 TO 7 (OVERLAPPED AT GEOPHONE 12)

SPREAD 5 SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV
F	-25.0	6.0	10.6	-4.6
R	300.0	6.0	5.1	0.9
GEO				
1	0.0	6.0	10.0	-4.0
2	25.0	6.0	9.1	-3.1
3	50.0	6.0	9.7	-3.7
4	75.0	6.0	8.2	-2.2
5	100.0	6.0	7.1	-1.1
6	125.0	6.0	6.9	-0.9
7	150.0	6.0	5.5	0.5
8	175.0	6.0	4.4	1.6
9	200.0	6.0	4.6	1.4
10	225.0	6.0	4.7	1.3
11	250.0	6.0	5.1	0.9
12	275.0	6.0	4.4	1.6

VELOCITIES USED:

	LAYER 1	LAYER 2
VERTICAL	1500.	
HORIZONTAL		6873.

NUKUORO PROJECT SEISMIC LINES 5 TO 7 (OVERLAPPED AT GEOPHONE 12)

SPREAD 6 SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2	
SP	POSITION	SURF ELEV	DEPTH	ELEV
F	250.0	6.0	5.1	0.9
R	575.0	6.0	11.3	-5.3
GEO				
1	275.0	6.0	4.4	1.6
2	300.0	6.0	5.1	0.9
3	325.0	6.0	4.6	1.4
4	350.0	6.0	2.8	3.2
5	375.0	6.0	2.1	3.9
6	400.0	6.0	2.8	3.2
7	425.0	6.0	3.2	2.8
8	450.0	6.0	3.9	2.1
9	475.0	6.0	3.2	2.8
10	500.0	6.0	4.5	1.5
11	525.0	6.0	6.2	-0.2
12	550.0	6.0	9.3	-3.3

VELOCITIES USED:

	LAYER 1	LAYER 2
VERTICAL	1500.	
HORIZONTAL		6873.

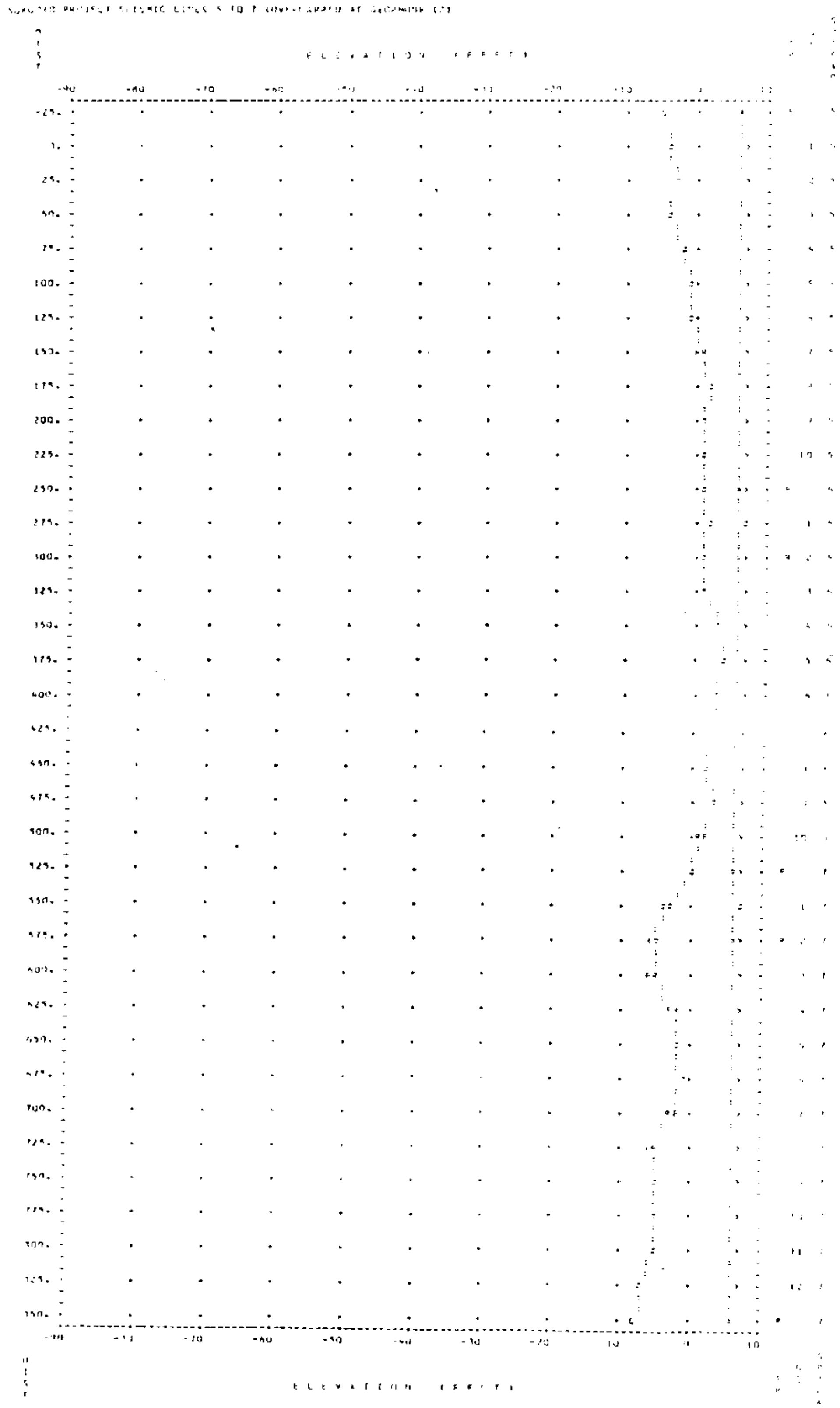
NUKUORO PROJECT SEISMIC LINES 5 TO 7 (OVERLAPPED AT GEOPHONE 12)

SPREAD 7   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV
F	525.0	6.0	6.2	-0.2
R	850.0	6.0	13.6	-7.6
GEO				
1	550.0	6.0	9.4	-3.4
2	575.0	6.0	11.3	-5.3
3	600.0	6.0	11.3	-5.3
4	625.0	6.0	8.6	-2.6
5	650.0	6.0	8.0	-2.0
6	675.0	6.0	7.3	-1.3
7	700.0	6.0	8.6	-2.6
8	725.0	6.0	11.5	-5.5
9	750.0	6.0	10.9	-4.9
10	775.0	6.0	11.3	-5.3
11	800.0	6.0	11.0	-5.0
12	825.0	6.0	13.0	-7.0

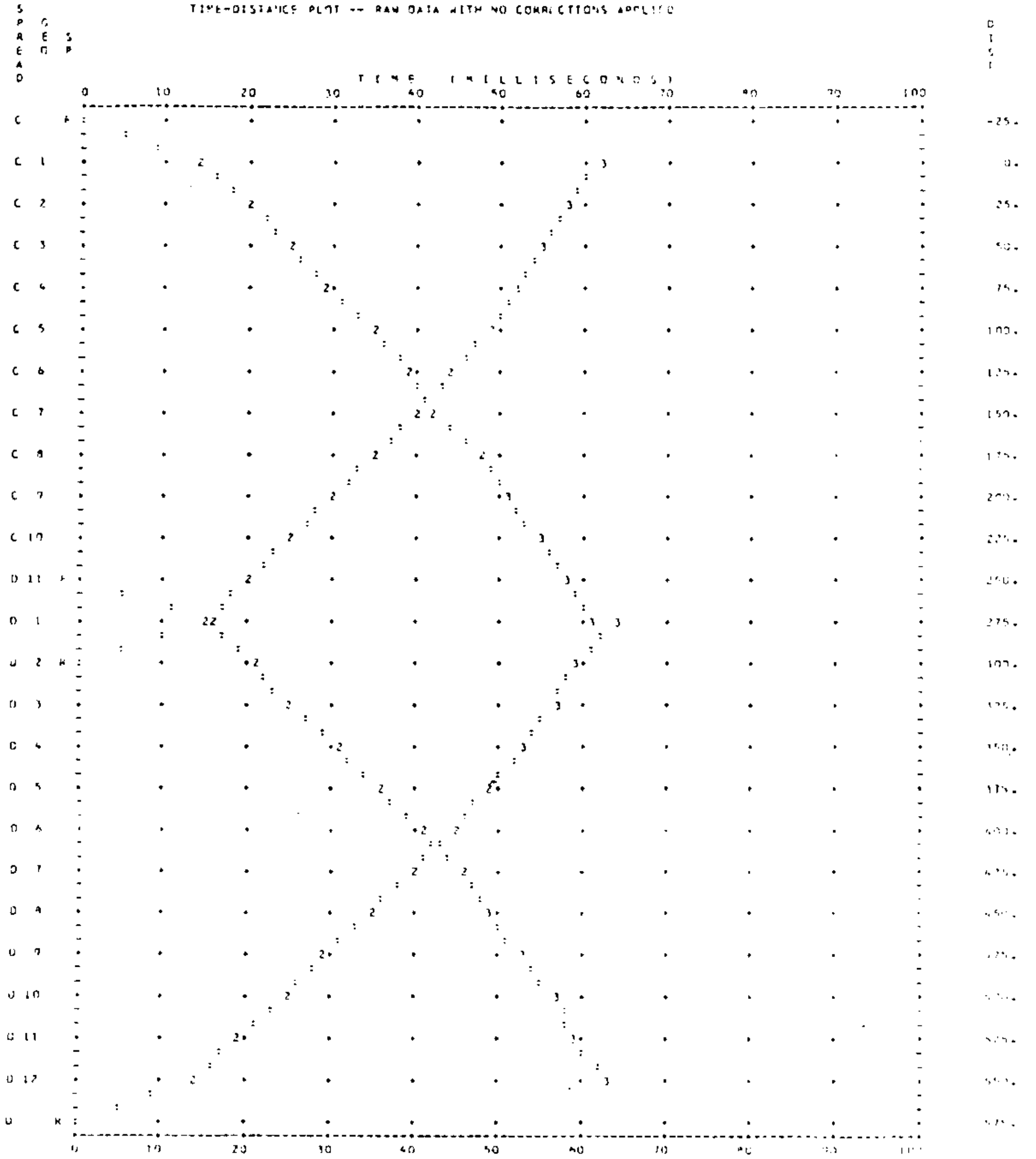
VELOCITIES USED:

	LAYER 1	LAYER 2
VERTICAL	1500.	
HORIZONTAL		6873.



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINES 13 AND 14 (OVERLAPPED)

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINES 13 AND 14 (OVERLAPPED)

SPREAD C   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	-25.0	5.0	6.5	-1.5	49.9	-44.9
R	300.0	5.0	8.6	-3.6	54.4	-49.4
GEO						
1	0.0	5.0	6.3	-1.8	50.2	-45.2
2	25.0	5.0	8.2	-3.2	50.2	-45.2
3	50.0	5.0	8.5	-3.5	51.0	-46.0
4	75.0	5.0	8.0	-3.0	51.0	-46.0
5	100.0	5.0	8.7	-3.7	51.7	-46.7
6	125.0	5.0	8.4	-3.4	51.5	-46.5
7	150.0	5.0	7.5	-2.5	49.9	-44.9
8	175.0	5.0	8.4	-3.4	48.8	-43.8
9	200.0	5.0	8.8	-3.8	48.8	-43.8
10	225.0	5.0	8.6	-3.6	47.7	-42.7
11	250.0	5.0	8.4	-3.4	45.9	-40.9
12	275.0	5.0	8.5	-3.5	47.2	-42.2

VELOCITIES USED:

	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1500.	5264.	
HORIZONTAL		5264.	7476.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINES 13 AND 14 (OVERLAPPED)

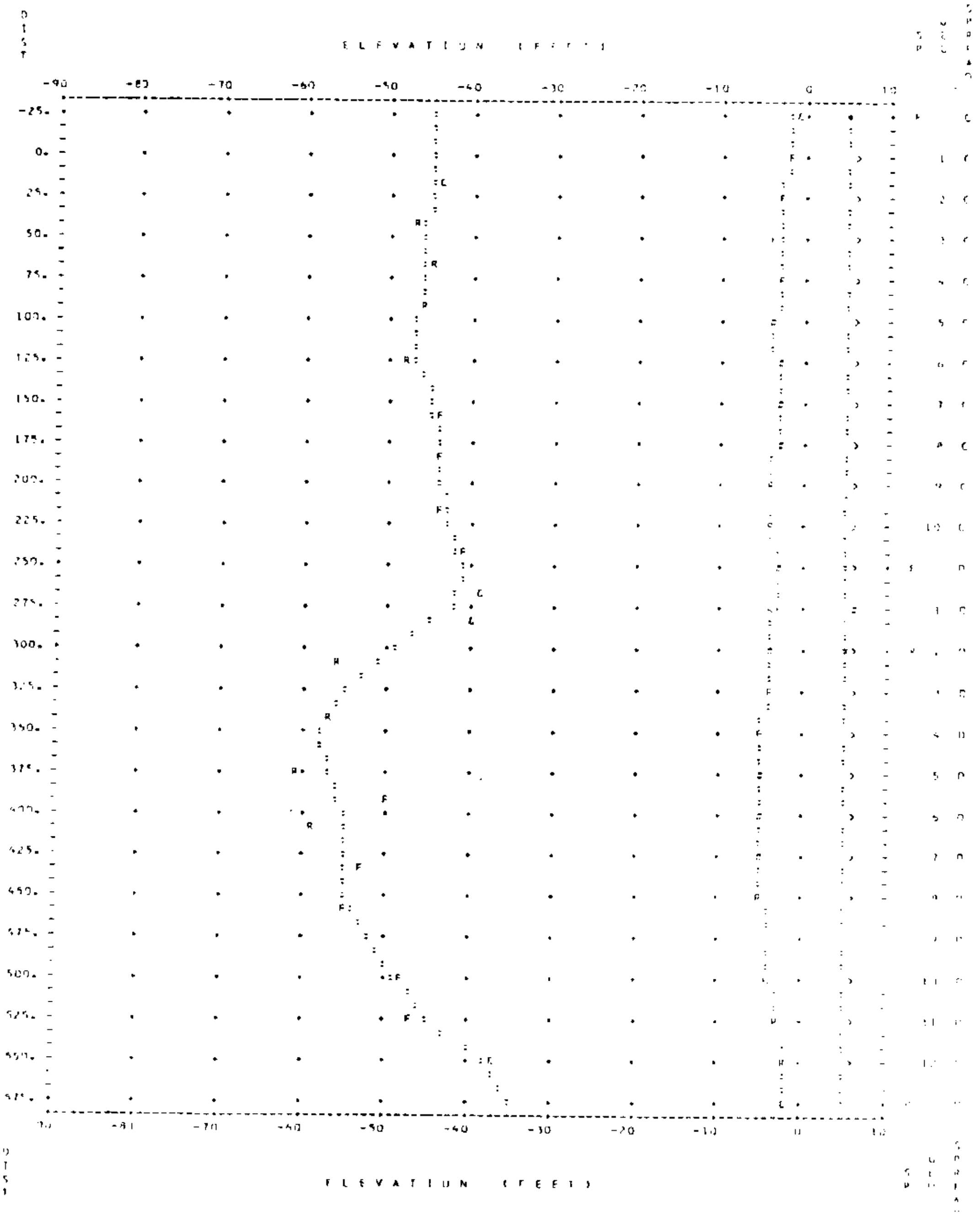
SPREAD D SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV	LAYER 3 DEPTH	LAYER 3 ELEV
F	250.0	5.0	8.4	-3.4	45.9	-40.9
R	575.0	5.0	6.7	-1.7	39.9	-34.9
GEO						
1	275.0	5.0	8.5	-3.5	47.2	-42.2
2	300.0	5.0	8.6	-3.6	54.4	-49.4
3	325.0	5.0	8.9	-3.9	60.1	-55.1
4	350.0	5.0	9.9	-4.9	62.9	-57.9
5	375.0	5.0	9.8	-4.8	62.0	-57.0
6	400.0	5.0	10.3	-5.3	60.5	-55.5
7	425.0	5.0	10.3	-5.3	60.4	-55.4
8	450.0	5.0	9.6	-4.6	59.6	-54.6
9	475.0	5.0	8.8	-3.8	56.7	-51.7
10	500.0	5.0	8.6	-3.6	53.7	-48.7
11	525.0	5.0	7.8	-2.8	49.8	-44.8
12	550.0	5.0	7.3	-2.3	43.3	-38.3

VELOCITIES USED:

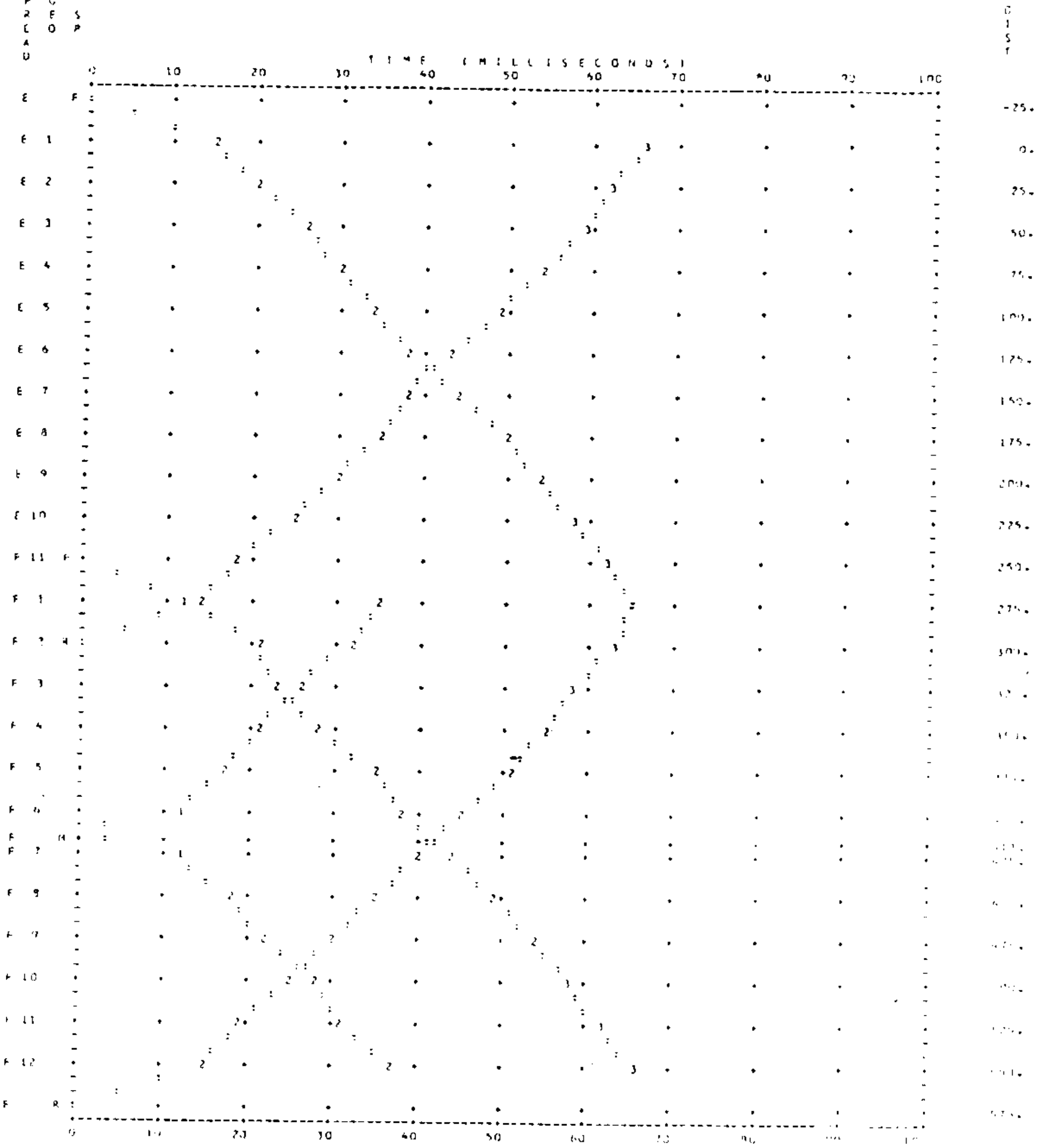
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1500.	5264.	
HORIZONTAL		5264.	7476.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINES 13 AND 14 (OVERLAPPED)



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 15 & 16 (OVERLAPPED)

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 15 & 16 (OVERLAPPED)

SPREAD E   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	-25.0	5.0	8.3	-3.3	35.5	-30.5
R	300.0	5.0	7.9	-2.9	45.4	-40.4
GEO						
1	0.0	5.0	7.9	-2.9	39.5	-34.5
2	25.0	5.0	8.7	-3.7	48.7	-43.7
3	50.0	5.0	9.2	-4.2	53.6	-48.6
4	75.0	5.0	8.8	-3.8	56.3	-51.3
5	100.0	5.0	7.6	-2.6	58.7	-53.7
6	125.0	5.0	6.1	-1.1	60.4	-55.4
7	150.0	5.0	6.6	-1.6	61.8	-56.8
8	175.0	5.0	8.8	-3.8	62.6	-57.6
9	200.0	5.0	8.3	-3.3	63.4	-58.4
10	225.0	5.0	8.4	-3.4	62.5	-57.5
11	250.0	5.0	7.3	-2.3	55.8	-50.8
12	275.0	5.0	6.8	-1.8	49.6	-44.6

VELOCITIES USED:

	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1603.	5090.	
HORIZONTAL		5090.	6897.

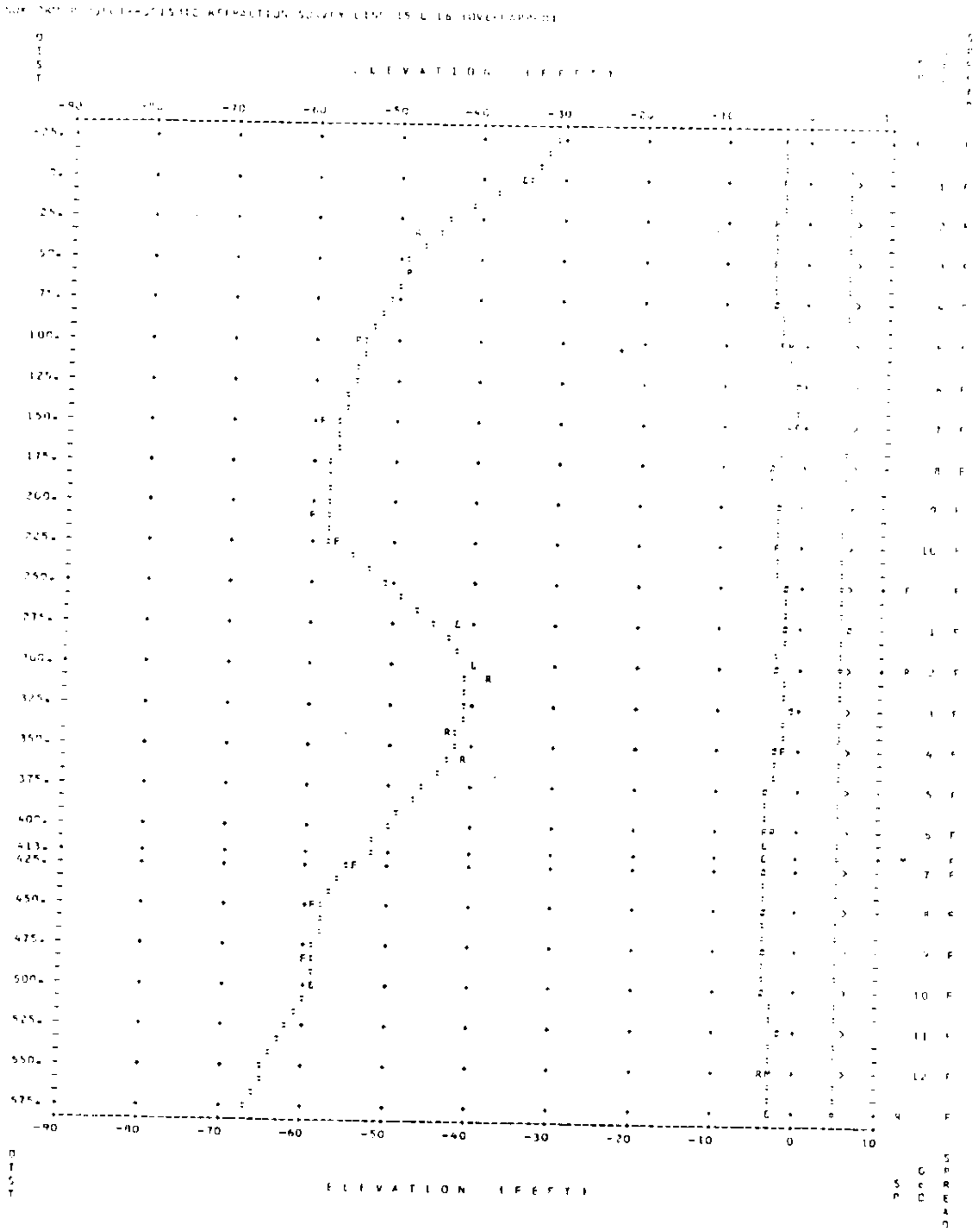
NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 15 & 16 (OVERLAPPED)

SPREAD F SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	250.0	5.0	7.3	-2.3	55.8	-50.8
M	412.5	5.0	8.6	-3.6	57.4	-52.4
R	575.0	5.0	8.3	-3.3	71.6	-66.6
GEO						
1	275.0	5.0	6.8	-1.8	49.6	-44.6
2	300.0	5.0	7.9	-2.9	45.4	-40.4
3	325.0	5.0	6.3	-1.3	45.9	-40.9
4	350.0	5.0	7.4	-2.4	46.8	-41.8
5	375.0	5.0	8.8	-3.8	50.8	-45.8
6	400.0	5.0	8.5	-3.5	55.2	-50.2
7	425.0	5.0	8.6	-3.6	59.6	-54.6
8	450.0	5.0	8.8	-3.8	62.5	-57.5
9	475.0	5.0	8.7	-3.7	63.8	-58.8
10	500.0	5.0	8.7	-3.7	64.3	-59.3
11	525.0	5.0	7.3	-2.3	67.0	-62.0
12	550.0	5.0	8.4	-3.4	69.8	-64.8

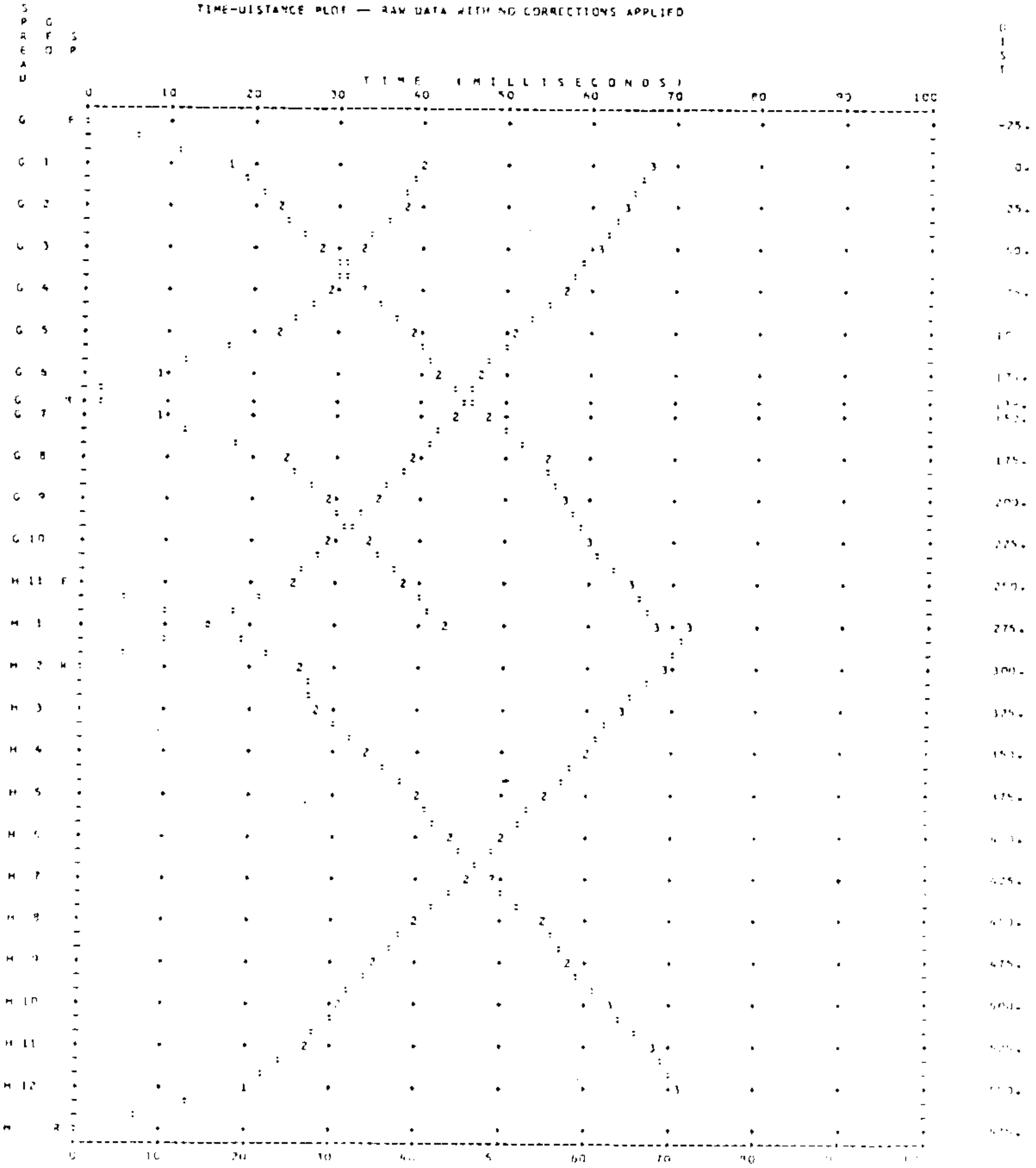
VELOCITIES USED:

	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1603.	5090.	
HORIZONTAL		5090.	6897.


ELEVATION (FEET)
DIST
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
10
SP
GEO
SPREAD

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 17G 18 (OVERLAPPED)

TIME-DISTANCE PLOT — RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 17C 18 (OVERLAPPED)

SPREAD G SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV	LAYER 3 DEPTH	LAYER 3 ELEV
F	-25.0	5.0	8.4	-3.4	38.2	-33.2
M	137.5	5.0	12.5	-7.5	52.9	-47.9
R	300.0	5.0	12.9	-7.9	42.3	-37.3
GEO						
1	0.0	5.0	8.8	-3.8	40.4	-35.4
2	25.0	5.0	11.3	-6.3	42.9	-37.9
3	50.0	5.0	12.0	-7.0	42.7	-37.7
4	75.0	5.0	11.8	-6.8	44.7	-39.7
5	100.0	5.0	11.4	-6.4	49.1	-44.1
6	125.0	5.0	12.0	-7.0	52.1	-47.1
7	150.0	5.0	13.0	-8.0	53.8	-48.8
8	175.0	5.0	13.7	-8.7	55.9	-50.9
9	200.0	5.0	13.3	-8.3	56.1	-51.1
10	225.0	5.0	12.9	-7.9	53.3	-48.3
11	250.0	5.0	12.8	-7.8	48.7	-43.7
12	275.0	5.0	13.4	-8.4	43.0	-38.0

VELOCITIES USED:

	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1602.	5208.	
HORIZONTAL		5208.	6586.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 17E 1B (OVERLAPPED)

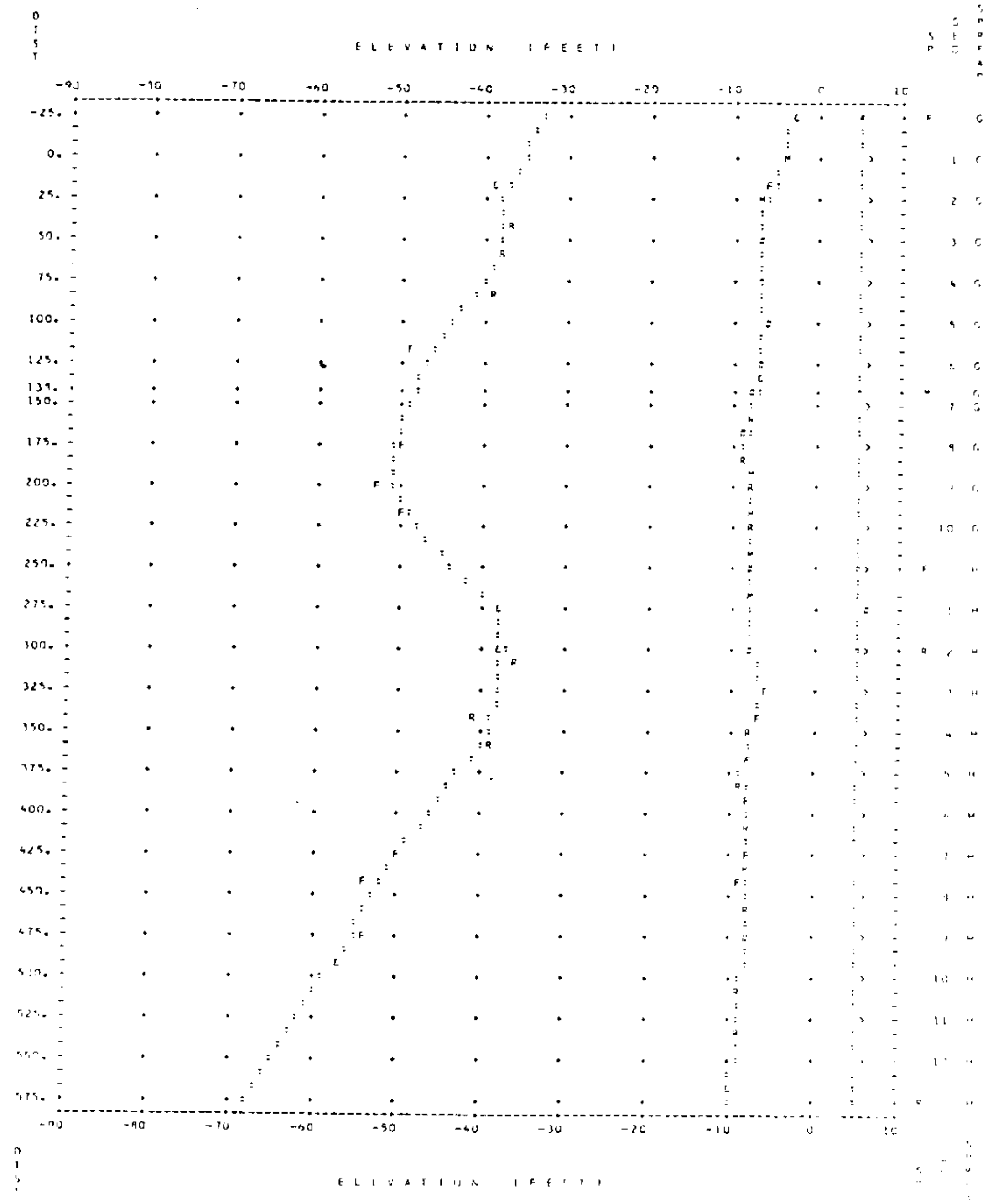
SPREAD H SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

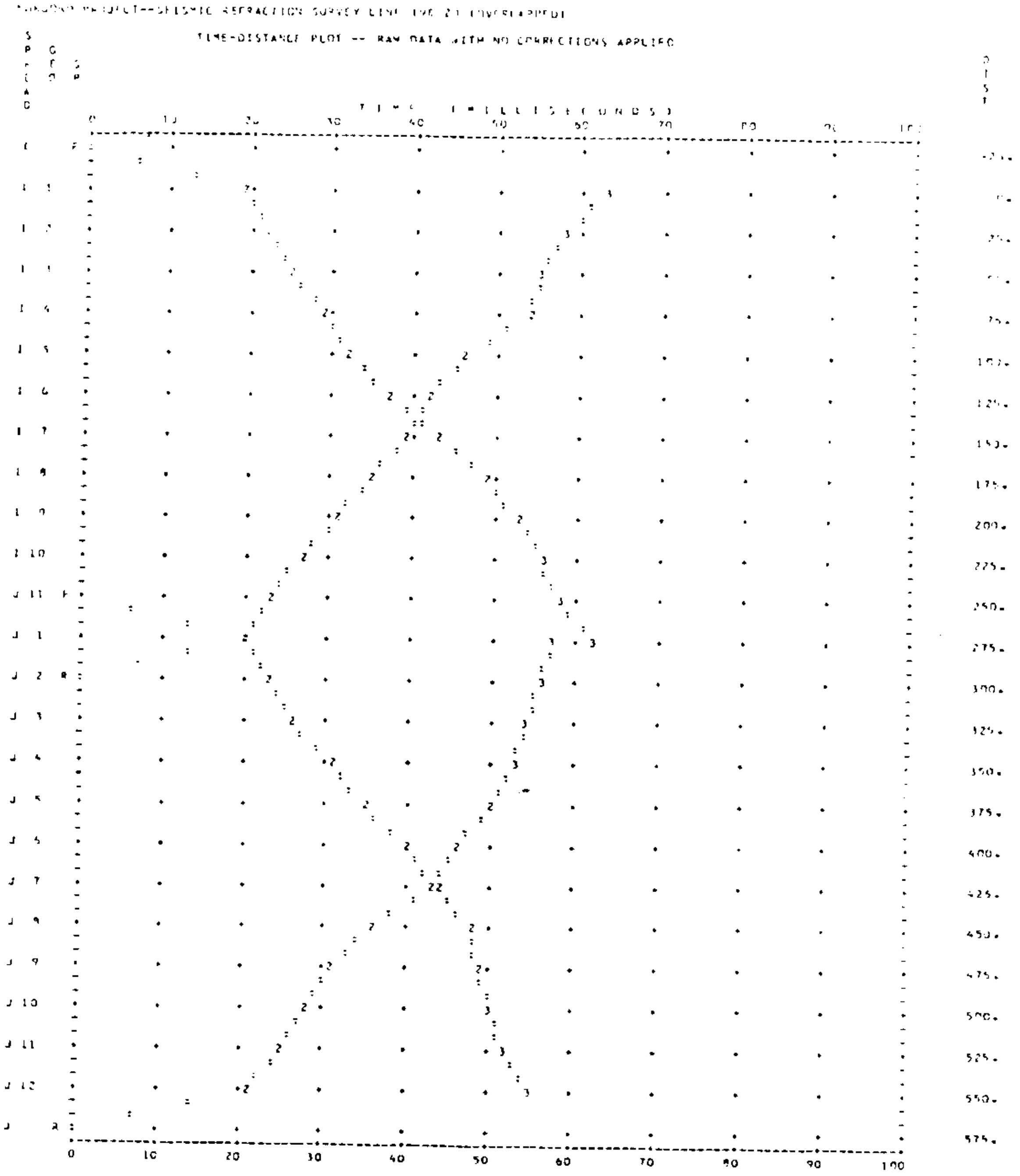
			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	250.0	5.0	12.8	-7.8	48.7	-43.7
R	575.0	5.0	14.7	-9.7	73.2	-68.2
GEO						
1	275.0	5.0	13.4	-8.4	43.0	-38.0
2	300.0	5.0	12.9	-7.9	42.3	-37.3
3	325.0	5.0	11.5	-6.5	43.0	-38.0
4	350.0	5.0	12.7	-7.7	44.2	-39.2
5	375.0	5.0	13.5	-8.5	47.5	-42.5
6	400.0	5.0	13.4	-8.4	51.2	-46.2
7	425.0	5.0	13.4	-8.4	54.9	-49.9
8	450.0	5.0	13.4	-8.4	58.1	-53.1
9	475.0	5.0	12.8	-7.8	60.3	-55.3
10	500.0	5.0	13.7	-8.7	63.6	-58.6
11	525.0	5.0	14.3	-9.3	66.9	-61.9
12	550.0	5.0	14.5	-9.5	70.2	-65.2

VELOCITIES USED:

	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1602.	5208.	
HORIZONTAL		5208.	6586.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 17C 18 (OVERLAPPED)




SEISMIC REFRACTION SURVEY
TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED
T I M E
0
10
20
30
40
50
60
70
80
90
100
200.
225.
250.
275.
300.
325.
350.
375.
400.
425.
450.
475.
500.
525.
550.
575.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 19E 20 (OVERLAPPED)

SPREAD I SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV	LAYER 3 DEPTH	LAYER 3 ELEV
F	-25.0	5.0	13.3	-8.3	72.2	-67.2
R	300.0	5.0	10.8	-5.8	49.1	-44.1
GEO						
1	0.0	5.0	12.4	-7.4	73.3	-68.3
2	25.0	5.0	10.6	-5.6	72.8	-67.8
3	50.0	5.0	9.7	-4.7	78.3	-73.3
4	75.0	5.0	10.0	-5.0	80.1	-75.1
5	100.0	5.0	7.3	-2.3	81.2	-76.2
6	125.0	5.0	7.7	-2.7	75.7	-70.7
7	150.0	5.0	10.0	-5.0	70.8	-65.8
8	175.0	5.0	11.2	-6.2	65.9	-60.9
9	200.0	5.0	11.4	-6.4	61.0	-56.0
10	225.0	5.0	10.4	-5.4	56.5	-51.5
11	250.0	5.0	11.2	-6.2	52.8	-47.8
12	275.0	5.0	12.0	-7.0	49.2	-44.2

VELOCITIES USED:

	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1500.	5888.	
HORIZONTAL		5888.	9531.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 19& 20 (OVERLAPPED)

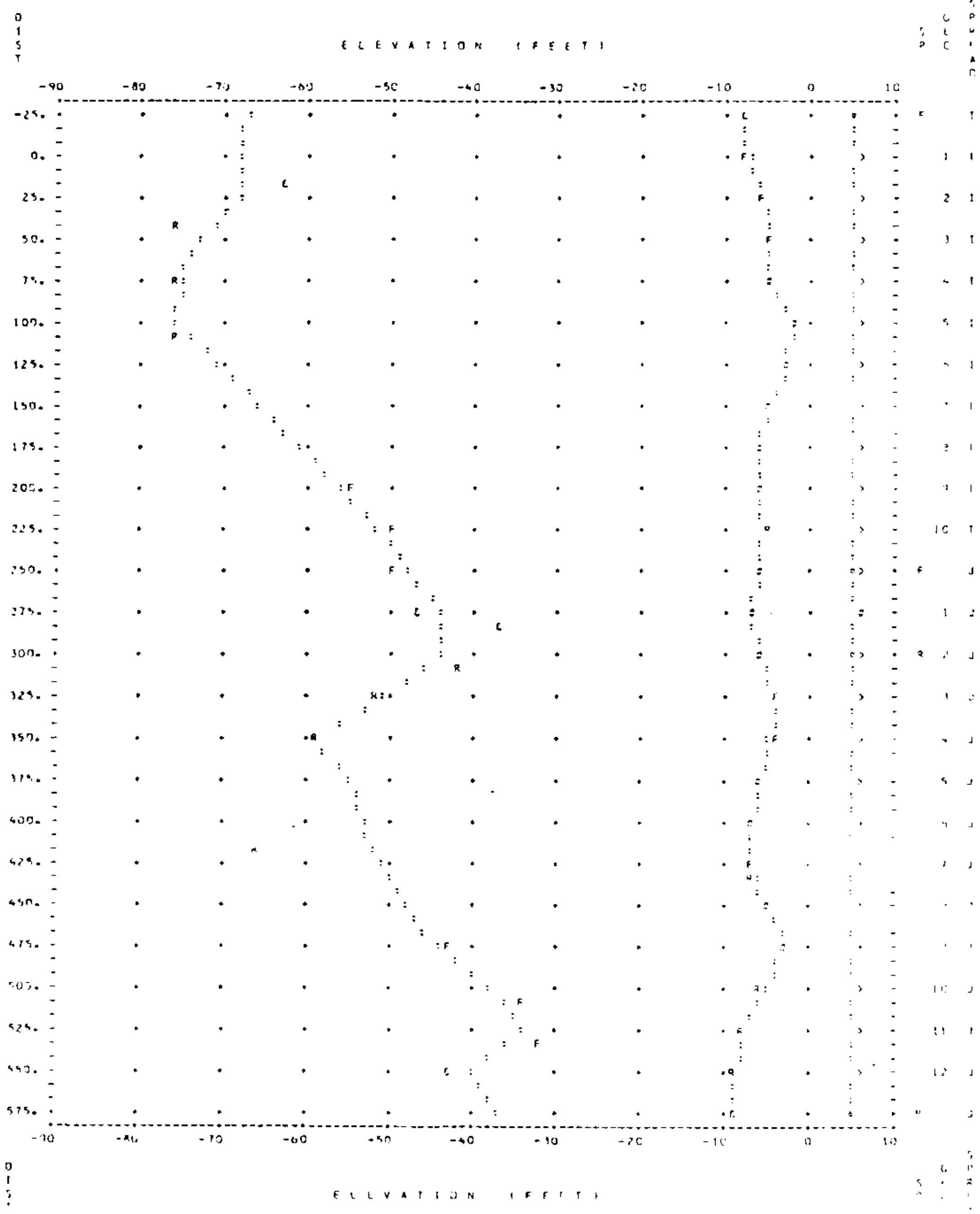
SPREAD J   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	250.0	5.0	11.2	-6.2	52.8	-47.8
R	575.0	5.0	14.2	-9.2	42.4	-37.4
GEO						
1	275.0	5.0	12.0	-7.0	49.2	-44.2
2	300.0	5.0	10.8	-5.8	49.1	-44.1
3	325.0	5.0	9.2	-4.2	55.5	-50.5
4	350.0	5.0	9.6	-4.6	64.0	-59.0
5	375.0	5.0	11.0	-6.0	59.8	-54.8
6	400.0	5.0	11.6	-6.6	58.5	-53.5
7	425.0	5.0	12.1	-7.1	55.6	-50.6
8	450.0	5.0	10.0	-5.0	52.7	-47.7
9	475.0	5.0	7.7	-2.7	49.4	-44.4
10	500.0	5.0	10.3	-5.3	42.5	-37.5
11	525.0	5.0	12.7	-7.7	39.3	-34.3
12	550.0	5.0	13.6	-8.6	45.2	-40.2

VELOCITIES USED:

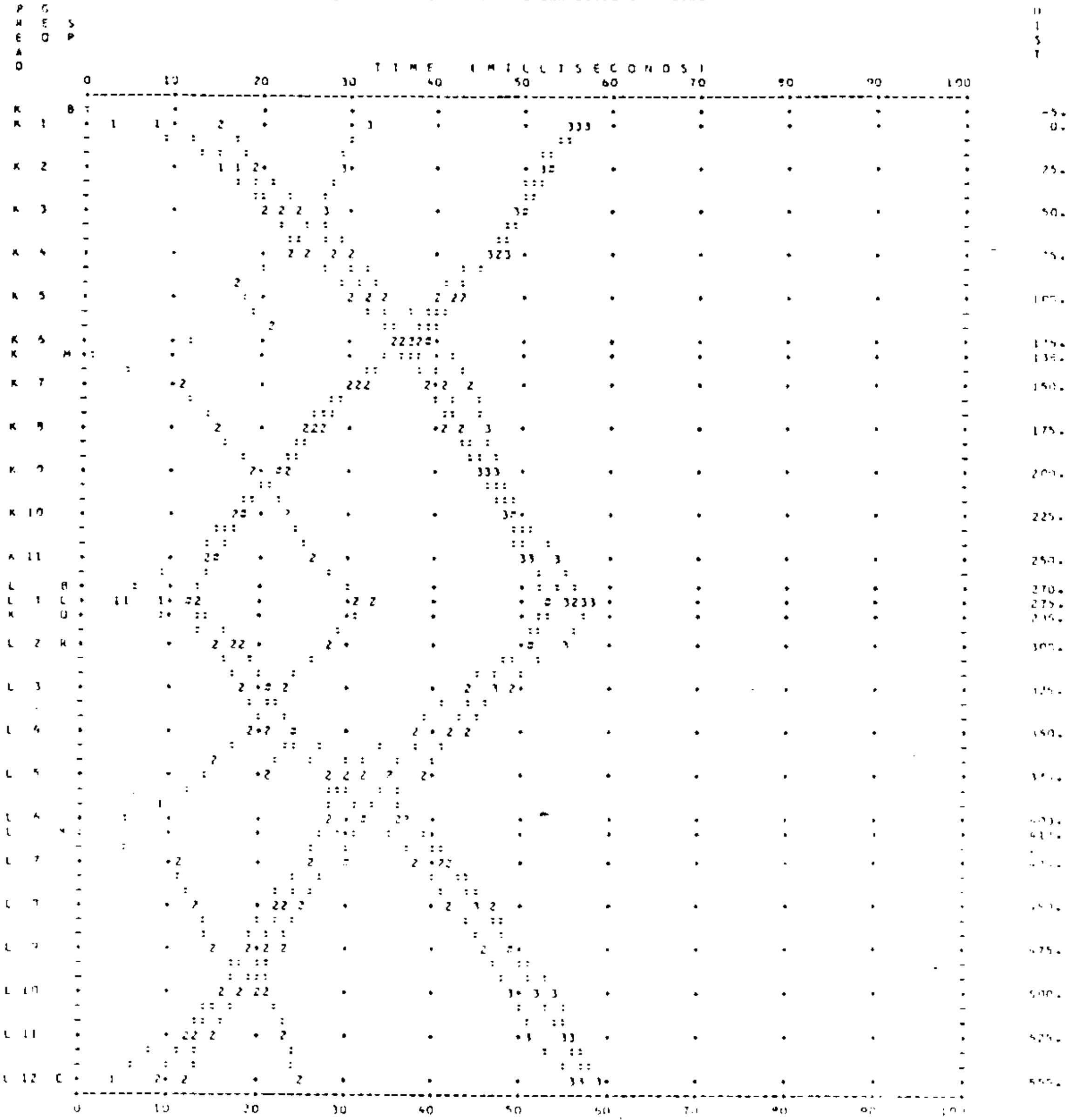
	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1500.	5888.	
HORIZONTAL		5888.	9531.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 19C 20 (OVERLAPPED)



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 21 & 22 (OVERLAPPED)

TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED



NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 21 & 22 (OVERLAPPED)

SPREAD K SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
B	-5.0	5.0	7.7	-2.7	37.4	-32.4
M	137.5	5.0	9.6	-4.6	48.5	-43.5
C	280.0	5.0	8.5	-3.5	40.0	-35.0
GEO						
1	0.0	5.0	7.8	-2.8	37.7	-32.7
2	25.0	5.0	7.9	-2.9	38.9	-33.9
3	50.0	5.0	8.4	-3.4	51.0	-46.0
4	75.0	5.0	9.6	-4.6	46.9	-41.9
5	100.0	5.0	9.3	-4.3	44.8	-39.8
6	125.0	5.0	10.6	-5.6	47.5	-42.5
7	150.0	5.0	8.6	-3.6	49.6	-44.6
8	175.0	5.0	6.3	-1.3	55.0	-50.0
9	200.0	5.0	6.4	-1.4	55.4	-50.4
10	225.0	5.0	6.0	-1.0	52.9	-47.9
11	250.0	5.0	6.8	-1.8	48.7	-43.7
12	275.0	5.0	8.3	-3.3	41.6	-36.6

VELOCITIES USED:

	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1514.	5883.	
HORIZONTAL		5883.	8383.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 21 & 22 (OVERLAPPED)

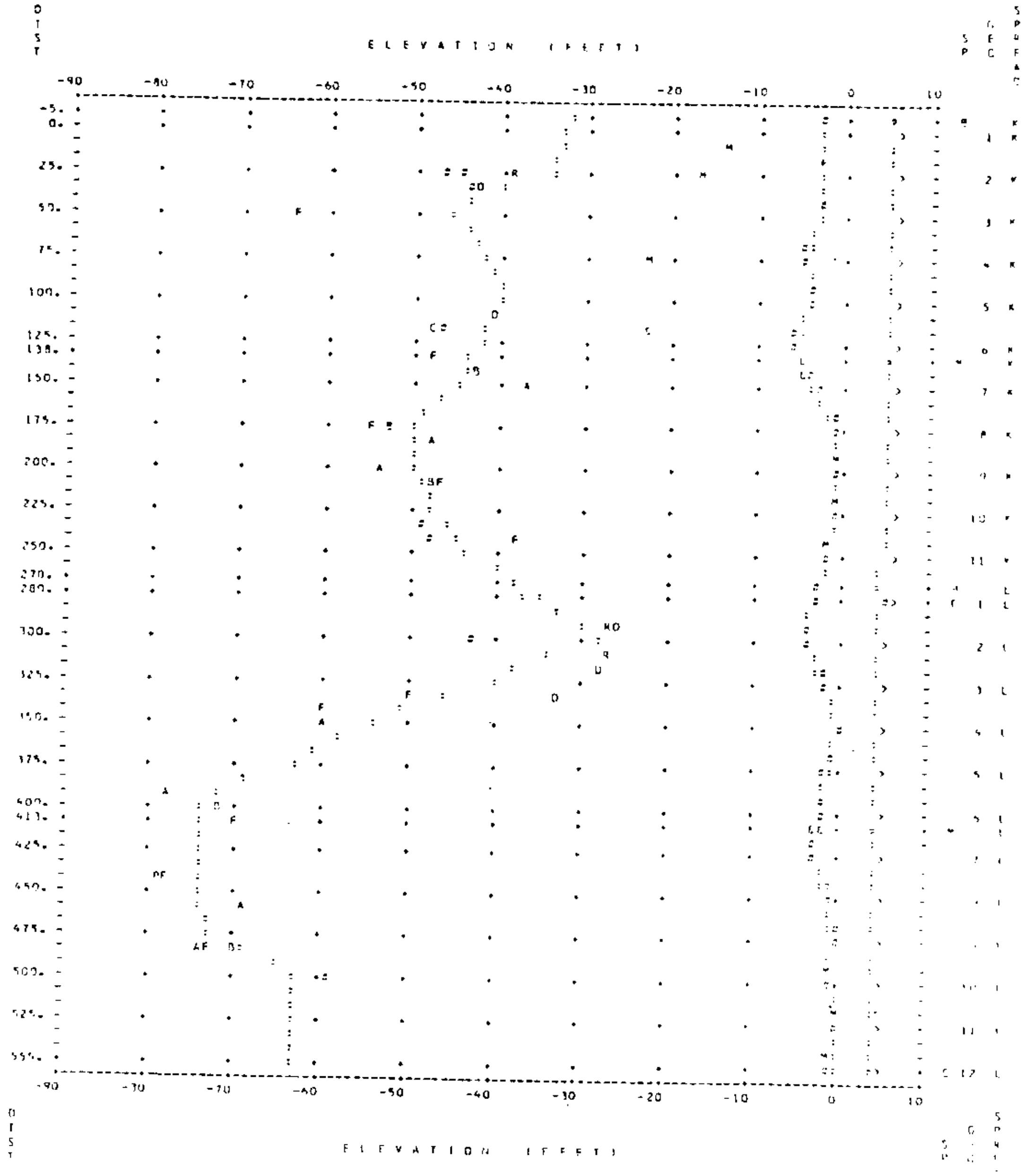
SPREAD L SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

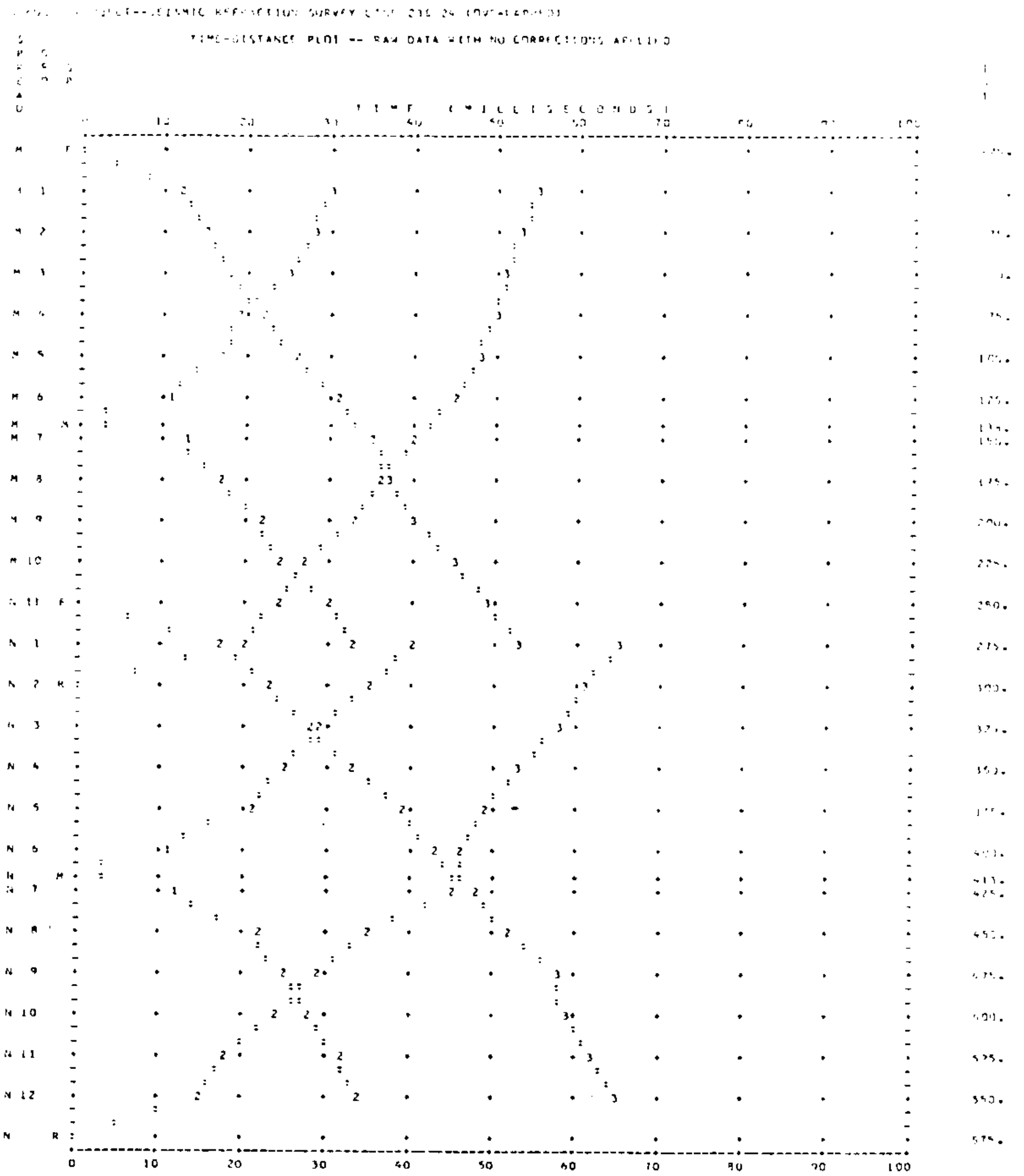
			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
B	270.0	4.0	7.0	-3.0	42.1	-38.1
M	412.5	4.0	6.4	-2.4	78.4	-74.4
C	555.0	4.0	4.4	-0.4	66.5	-62.5
GEO						
1	275.0	4.0	7.3	-3.3	40.6	-36.6
2	300.0	4.0	8.3	-4.3	32.3	-28.3
3	325.0	4.0	6.3	-2.3	44.1	-40.1
4	350.0	4.0	4.3	-0.3	57.6	-53.6
5	375.0	4.0	5.5	-1.5	67.4	-63.4
6	400.0	4.0	6.1	-2.1	78.3	-74.3
7	425.0	4.0	6.7	-2.7	78.4	-74.4
8	450.0	4.0	5.3	-1.3	78.3	-74.3
9	475.0	4.0	4.3	-0.3	77.1	-73.1
10	500.0	4.0	4.8	-0.8	67.3	-63.3
11	525.0	4.0	3.7	0.3	67.2	-63.2
12	550.0	4.0	4.5	-0.5	67.1	-63.1

VELOCITIES USED:

	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1514.	5883.	
HORIZONTAL		5883.	8383.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 21 & 22 (OVERLAPPED)




TIME-DISTANCE PLOT -- RAW DATA WITH NO CORRECTIONS APPLIED
TIME (MILLISECONDS)
0
10
20
30
40
50
60
70
80
90
100

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 23& 24 (OVERLAPPED)

SPREAD M   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

SP	POSITION	SURF ELEV	LAYER 2 DEPTH	LAYER 2 ELEV	LAYER 3 DEPTH	LAYER 3 ELEV
F	-25.0	5.0	5.5	-0.5	8.8	-3.8
M	137.5	5.0	6.1	-1.1	38.9	-33.9
R	300.0	5.0	11.4	-6.4	88.5	-83.5
GEO						
1	0.0	5.0	5.4	-0.4	14.2	-9.2
2	25.0	5.0	3.8	1.2	18.3	-13.3
3	50.0	5.0	2.0	3.0	26.9	-21.9
4	75.0	5.0	1.2	3.8	32.4	-27.4
5	100.0	5.0	2.9	2.1	36.9	-31.9
6	125.0	5.0	5.6	-0.6	39.8	-34.8
7	150.0	5.0	6.7	-1.7	38.0	-33.0
8	175.0	5.0	8.0	-3.0	41.4	-36.4
9	200.0	5.0	8.9	-3.9	50.3	-45.3
10	225.0	5.0	7.4	-2.4	58.9	-53.9
11	250.0	5.0	8.8	-3.8	67.6	-62.6
12	275.0	5.0	10.1	-5.1	76.2	-71.2

VELOCITIES USED:

	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1396.	5748.	
HORIZONTAL		5748.	8323.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 23& 24 (OVERLAPPED)

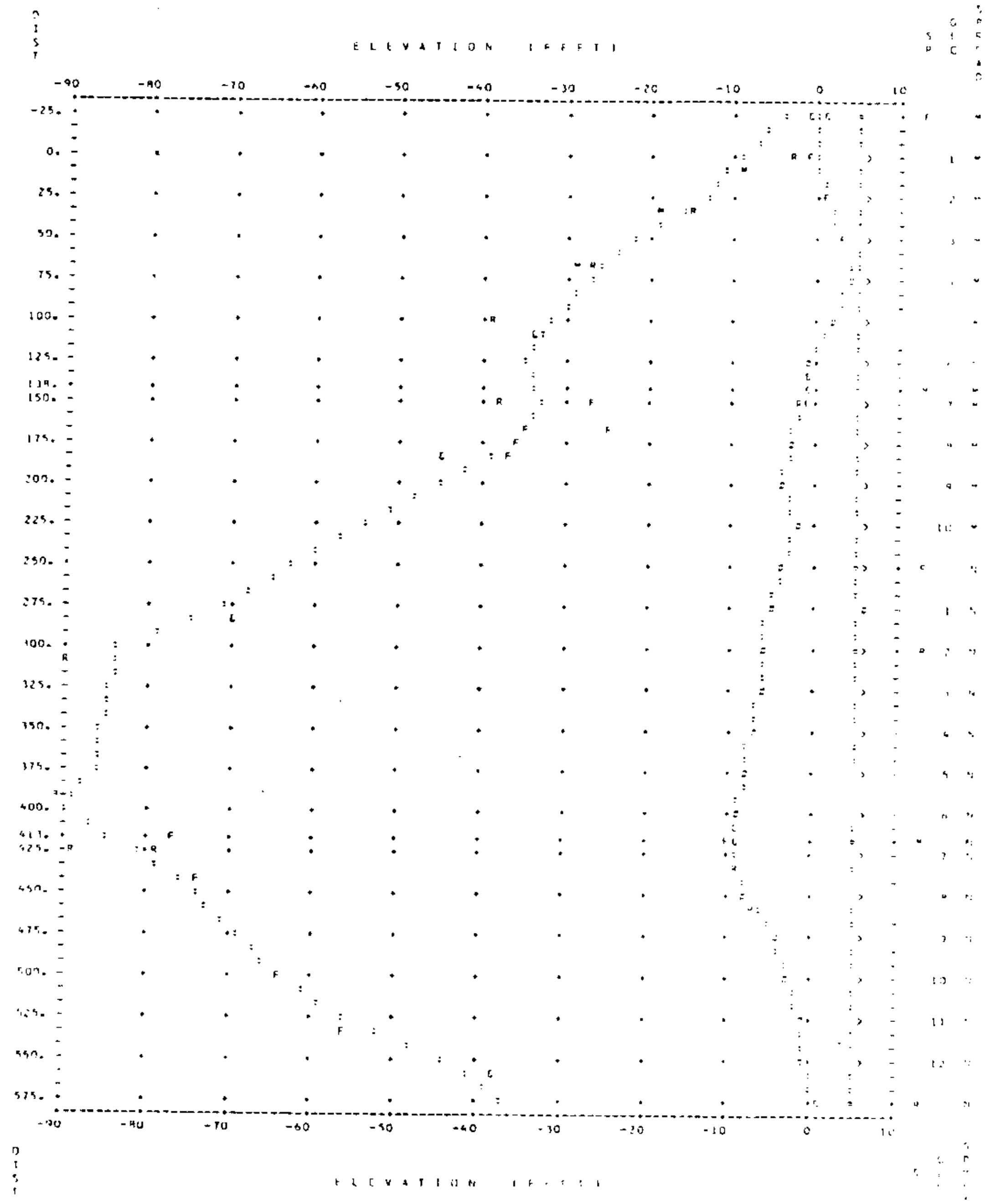
SPREAD N   SMOOTHED POSITION OF LAYERS BENEATH SHOTPOINTS AND GEOPHONES

			LAYER 2		LAYER 3	
SP	POSITION	SURF ELEV	DEPTH	ELEV	DEPTH	ELEV
F	250.0	5.0	8.8	-3.8	67.6	-62.6
M	412.5	5.0	14.1	-9.1	90.3	-85.3
R	575.0	5.0	4.0	1.0	41.8	-36.8
GEO						
1	275.0	5.0	10.1	-5.1	76.2	-71.2
2	300.0	5.0	11.4	-6.4	88.5	-83.5
3	325.0	5.0	11.4	-6.4	89.7	-84.7
4	350.0	5.0	12.3	-7.3	90.6	-85.6
5	375.0	5.0	13.2	-8.2	91.5	-86.5
6	400.0	5.0	13.8	-8.8	95.1	-90.1
7	425.0	5.0	14.4	-9.4	85.6	-80.6
8	450.0	5.0	12.5	-7.5	79.4	-74.4
9	475.0	5.0	9.4	-4.4	74.2	-69.2
10	500.0	5.0	7.9	-2.9	68.9	-63.9
11	525.0	5.0	6.0	-1.0	61.0	-56.0
12	550.0	5.0	5.8	-0.8	48.8	-43.8

VELOCITIES USED:

	LAYER 1	LAYER 2	LAYER 3
VERTICAL	1396.	5748.	
HORIZONTAL		5748.	8323.

NUKUORO PROJECT--SEISMIC REFRACTION SURVEY LINE 23C 24 (OVERLAPPED)



A P P E N D I X C

Sample Questionnaire and Summary of Responses

Question #1: Has your family had any problems with their taro patch?

Responses	No. of People
No	1
Yes	32
Problems with their taro patch:	
Soil too dry	2
Soil smells bad	1
Patches are damaged	3
Taro dying out	23
Taro stems rotten	17
Taro leaves died	1
Openings in taro patch ("hole")	2
Water comes up in	1
Root (tuber) damaged	1
Plants grew weak	1
Salt water intrusion	9
Hot sunshine	1

Question #2: How many times have you had this problem with the taro patch, as far back as you can remember? (Give number of times).

3 years	4
2 years	23
1 year	2
0	4

How many years ago?

1	1
2	27
3	1
5	2
6	2
7	1
8	1
Over 10	1
12	1
14	1
15	3
16	7
17	6
18	1
20	1
52-typhoon 1930's	1

What season?

Oct. to Jan.	6
End of year	32
Fall	7
Summer	7
Winter	5

Question #3: Does your family own the plot they work in?

Responses	No. of People
Yes	32
No	1

Who is responsible for working in the taro patch?

Clearly male names	16
Stated someone else responsible	24

Question #4: Who takes care of the taro patch if the one responsible for it is not there?

(Close) relatives/family	32

Question #5: Are there taro patches near you that are no longer being used?

No	28
No answer	3
Yes	2

When were they last used?

3 years ago

Why did people stop using them?

"There was a hole where salt water came through"

Question #6: What is the weather like when there is no taro problems? (Please describe).

Rain & sunlight everyday Enough rain to cool the taro Rains alot, often	19
Tide not too high Tide normal level	4
Low tides [so the salt water won't spread]	2
Good weather	5
No drought	1
Sunshine	4
Little sunshine	1
Not hot Not too hot	7
Normal	2
Not much wind	1

What is the weather like when there is a taro problem?

Too much sunlight	1
Not rain as usual	1
Not enough rain Less rain. Drought No rain for months (Note: if they said "less rain" and "drought, I counted twice)	30
Very high tide Tide high most of the time Tide higher than normal	6
Tide is too low	1
"The first time tidal waves"	1
Rains alot (Water stays in taro patch-sun heats water and kills taro)	1
Bad weather	2
Rough seas	2
Windy	3
Too hot (for a longer period of time): Sun too hot	13
Sunshine for a longer time	1

Question #7: What is the ocean like when there is no taro problem?

Normal level/normal during low &/or high tides	27
Rises to normal level and falls back gradually	1
Low tide and calm	2
Very smooth	1
Falls back to normal low tide level	1
Not rough	1
No storms	1
Calm and not very high tide	1

What is the ocean like when there is a taro problem?

Tide/ocean higher than normal	18

Salt water seeps up through	1
Ocean lower for a long time	3
Ocean both lower and higher	2
Lower for a whole year's time	3
Higher and lower for a longer period (one stated lower for a period of over six months)	6
High tide	1
Windy or rough	3
Wind blows inward	1
Not normal	1
High tide w/rough seas frequently	1
Storm, strong waves and current	1
Waves, strong wind	1

Question #8: Please list the foods that are usually eaten by you and your family.

Rice	6
Taro	32
Coconut	29
Breadfruit	26
Banana	31
Fish	20
Papaya	1
Bread	2
Copra	1
Imported food	2

What 3 or 4 foods do you eat most often now?

Rice	32
Taro	10
Canned meat	22
Banana	13

Orange juice	10
Bread	1
Breadfruit	8
Milk	16
Coconut	9
Fish	5

Question #9: How well are other foods growing on the island (like bread-fruit, yams, papaya?

Not growing well	7
Some growing well (some not)	25
Growing well	6

Question #10: When Nukuoro had problems with taro patches before, what was done to correct the problem? (Please give details)

Put dead leaves/decaying materials in patches Refill it	27
C.D. put cisterns in ("around the opening to prevent the the flowing around") ("Looked for sections where salt water was coming up, and put drums or cement around it so the water won't spill to the other parts during high tide")	22
Men irrigate the land to drain the water out to the sea	1
Request assistance from the Disaster Offce	1
Keep up old ways of working patches - "rehabilitate" the patch	1
Not all people refilled plots - only a few	2
People worked hard & drained out salt water from their taro patches	1
Patches had problems only when [salt water intrusion] - as soon as salt water is gone, taro is good	1

What was most helpful?

To refill (w/decaying materials - coconut husks, pandanus leaves, tree trunks	27
Refill but not dig up	2

Stop salt water from coming up in patches	1
Everyone should work together, or set up a group to do the filling	2
Drawing salt water from patch	1
Assistance from Disaster Office	1
(In past times) the weather	1

Question #11: What do you believe causes the problem with the taro patches?

The weeding of grasses	1
Not filling taro patches w/decaying materials	3
Salt water intrusion	5
Openings in the patches	2
Don't know	5
People digging up the soil too deep	1
Caused by the movement of the tides	1
Bombing of island during WWII	3
Soil is lower &/or too thin (in patches)	13
People are not too lazy	1
People too lazy to keep up good work; people not keeping up work in patches	11
Drought	1
Dynamiting of the channel	1
"The closing of the nose of the taro patch" (?)	2
The plugging up of the hole in the taro patch	1
People against the nature of the channel	1

Question #12: Do you think the problem can be solved?	
Responses	No. of People
No	0
Yes	28
Not certain	4
Why?	
Because of working process/schedule	10
People now working to refill patches	8
Rehabilitation	3
In the beginning, it looked good, but now it looks bad	1
There are people God is using to find ways	1
If people work hard it can be solved	1
Yes, because seeking assistance from experts	1
Yes, because it was not like this in the beginning	1

Question #13: What do you feel could be done to correct this problem?	
Refill patch with decaying materials Keep up the refilling	16
Community to work together - have everybody work or Set up a working day for taro patches [community to work in]	12
Stop the salt water from coming in	1
Water taro patch more often	1
Work in the plots as before	1
DCO provide cisterns	1
Continue w/refilling with State/National gov't. assistance	1
Not certain	1
Have the old people show the young generation how to work in the taro	1

Assistance from outside experts	1
Open the old openings in the taro patch and pathway at the southern end of the island	1

Question #14: Is there anything else you would like to tell me about the problem the island is having with the taro patches?	
People are suffering - need assistance for food People do not have food - not enough to eat; Hard time finding food; less to eat	18
People have not much to rely on as they used to	1
Need pump to pump out water from the patches during high tides	1
Need planting materials	1
"Unless there is a way to prevent salt water and make it rain once or twice a month"	1
Should continue the rehabilitation project from now on, as a lifetime project	1
Request extension of USDA assistance	1
Problem: it takes 4-6 years for taro to develop good roots for eating. So, have to wait.	1
The current problem is hard to understand and is continuing to increase throughout the taro patch	1

Other comments about the interview	
Having a hard time convincing people to work in plots/fill with decaying materials	1
He is one who understands island's culture/customs; she understands taro patches & nature - knows history of the atoll	4
A well-known person in the community	2
Suggestion: set day aside as a community working day in taro patches	1
Hard working person	2
Knows all methods of improvement in community	1

He has been working hard in (own land and) taro plots since he was young	4
Has been refilling own taro patch/working hard in patch	8
Is encouraging people to work hard in taro patches - insist on working as in the past	5
Many of family plot are being damaged	2
Having a hard time finding food because of taro plot damage	2
Cooperation with others	1
Has been off Nukuoro - knows little about situation	1
Does <u>not</u> work much in taro patch	1