A NOISE MONITORING STUDY
FOR
THE REGIONAL COPPER NICKEL STUDY

PREPARED BY

THE MINNESOTA POLLUTION CONTROL AGENCY

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As with any major project, the assistance of several people from a variety of backgrounds was necessary for the completion of this study.

This report incorporates many acoustical and statistical procedures, which due to the unprecedented nature of this project, had to be devised on an as-needed basis. The majority of the above said procedures were developed by Dr. Roger Sipson of the Physics Department of Moorhead State University, Moorhead, Minnesota. Specifically, Dr. Sipson is responsible for all of the procedures used in Sections 4.20 through 4.22, 4.30 through 4.32 (with the exception of the method used to smooth out spectral plots for winter data). These sections deal primarily with analysis of residual sound data both by spectral analysis and correlation with wind statistics. Dr. Sipson was also instrumental in the organization of the procedures used in the wind on the microphone study (Appendix C) along with the methods outlined in Appendices E, F, G, J, K, M, and O. All spectral analyses were conducted in the Acoustics Laboratory of Moorhead State University. Dr. Sipson was also helpful in critiqueing this report.

Other technical input was provided by Dr. Richard VanDoeren and Roger Anderson of Midwest Acoustics, Minneapolis, Minnesota. Their contributions were principally concerned with equipment checks and calibrations, although Dr. VanDoeren was helpful throughout the entire project in the development of some of the procedures as well as the overall direction of the study.

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1.00 ABSTRACT

A noise monitoring study was conducted in an undeveloped wooded area of northeastern Minnesota to assess baseline sound levels prior to future Copper-Nickel mining. Sounds were found to be produced by either natural or artificial sources. The most commonly experienced natural sound was wind interaction with vegetation (residual sounds) and was found to vary as a function of season, vegetation type and wind speeds. Birch stands during the summer months were found to produce the highest levels with an $\bar{X}$=36dBA and a SD=12.1, whereas clearcut areas in the winter were the quietest with an $\bar{X}$=24dBA and a SD=5.1. A direct correlation between wind speeds and residual sound levels was assumed and dBA levels were specified for discreet wind speeds for a variety of vegetation types.

Artificial sounds were characterized based on auditory observations for specific regions of the study area.

Artificial and natural sounds were also analyzed for frequency content via third octave band analysis.

The baseline data presented in this report will be utilized in the development of a model which will specify noise impacts of proposed mining activities in and around the area of interest. Also, the data add to an area of environmental acoustics, which has been only recently been studied and will probably broaden in the coming years.

2.00 Introduction

A by-product of future Copper-Nickel mining in Northeastern Minnesota will be increased noise levels. Because many of the locations of the potential minesites border on noise sensitive areas, such as the Boundary Waters Canoe Area (BWCA), concern has been raised over the degradation of such wilderness regions. In response to these concerns, the Minnesota Pollution Control Agency, under contract from the Regional Copper-Nickel Study of the Minnesota Environmental Quality Board conducted an extensive noise monitoring program to assess current baseline sound levels in and around the future minesite areas. The results of that program are presented in this report.

The primary purpose of this study was to characterize the acoustic environment of a specific portion of land designated by the Minnesota Department of Natural Resources as the "minesite" region. (See Figure 1). This region, referred to in this report as the "study area," is a diagonal strip of land consisting of 560 square miles, stretching southwest from Ely to Hoyt Lakes, Minnesota and bordered on the north by the BWCA. The majority of the study area is forested land and, for the most part, humanly uninhabited. Industrial concerns in the area are principally taconite mining operations by Erie and Reserve Mining companies in the form of open pit mines, and tree harvesting for pulp by both large paper companies, and private individuals. Therefore, sounds present within the region are produced by two principal types of sources, artificial or man-made sources, and natural sources, such as wildlife activities.

Because few noise monitoring studies have attempted to characterize naturally produced sounds, the primary emphasis of this project was to do so. At some locations, within the study region, particularly in the central-western portion, however, it was virtually impossible to avoid artificial sounds, given the presence of certain noise producers such as mining. The noise impact by these sources is reflected in the results. Basically, though, the workplans and methodologies used for this project were designed to emphasize the measurement of naturally produced sounds that one might expect to hear within the study area given any set of seasonal, geographical, vegetative, and meteorological conditions.

Included in the study area are the towns of Babbitt and Hoyt Lakes, with Aurora and Ely located to the west. Noise monitoring studies have previously been conducted within such small communities (e.g. Fillmore, California, U.S. EPA, 1971). Thus, due to time considerations, a comprehensive monitoring program was not undertaken within the above mentioned towns. However, to ensure that the acoustical environments of these communities were not radically different from comparable towns previously studied, a limited noise survey was conducted in Ely in September, 1977, as part of this monitoring study. (See Appendix A).

Of special interest to the project was the BWCA. Because this region is a designated wilderness area, encroachment from proposed mining activities on its borders may pose a threat to its unique quietude. Practical considerations, such as difficult accessibility, precluded an extensive baseline monitoring program within the BWCA. Special efforts were made, however, during the course of this study to travel into the area and conduct monitoring surveys for several days. The results of these surveys are given in Appendix B.

The results of the baseline monitoring program presented in this report will be utilized in the subsequent development of a model, which will then be used to assess the noise impact of proposed Copper-Nickel mining activities. This model, which is currently being constructed by Dr. Roger Sipson of Moorhead State University, Moorhead, Minnesota, will consider the monitored sound levels given in this report, as well as sound propagation characteristics in the study area and source power levels of machinery used in open pit mining operations.

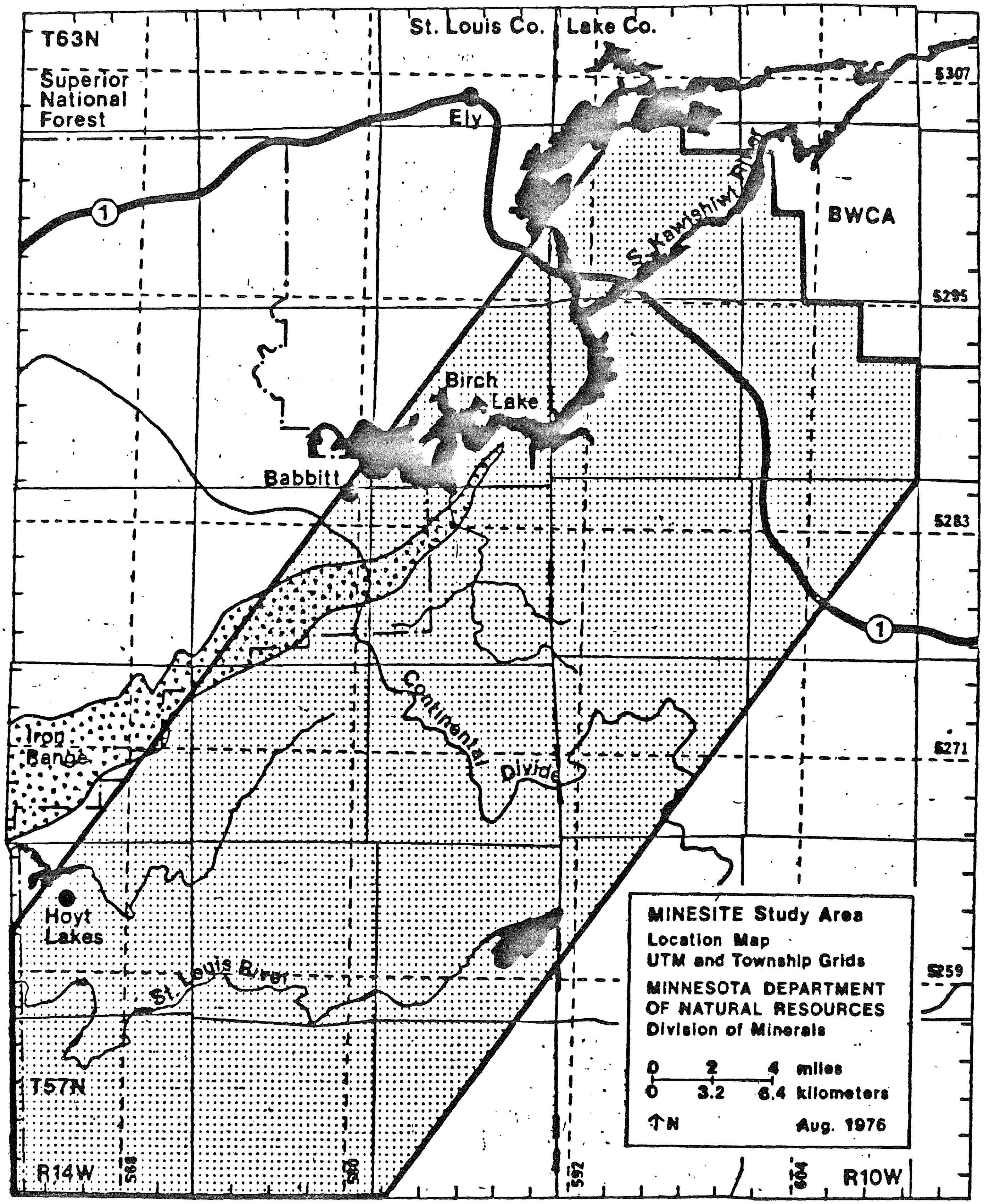


FIGURE 1. DNR "Minesite" Region, designated as the Study Area

The results and methodologies used in this study also establish a much needed base of understanding of acoustics in natural undeveloped settings. As industry, as well as various other types of development, continue to encroach upon such areas, particularly the few remaining wilderness regions, the need for assessment of resulting noise impacts will also increase. As yet, few studies have extensively measured the quietude present in such undeveloped regions. Therefore, the instrumentation, procedures, and data described in this report constitute a starting point for a new area of noise research, which will probably broaden in the coming years.

3.00 Method

Because few noise monitoring studies have attempted to characterize the acoustical environment of a large portion of forested land, development of the methodologies for this study dominated the initial phases of the project. Initially, two workplans were used for data collection on a trial basis, before a third was finally decided upon. Only the acoustical data obtained from implementation of the third plan were considered for analysis, since each workplan specified a different set of sites and measurement conditions. However, observations made at sites from the two trial plans were used in determining the extent of artificial noise producing events within the study area (See Appendix R for site descriptions and Appendix V for site photos).

Workplan I was designed by Consultant Dr. Richard VanDoeren of Midwest Acoustics, Minneapolis, Minnesota, and was used for data collection from March 10 to August 1, 1976 (See Appendix S for a detailed description). This plan divided the study region into four zones, with approximately seven sites in each zone (See Figure 2). One site in every zone was designated as a control point and during each measurement was equipped with an automatic sound level analyzer having storage capability, monitoring on a continual basis. Data were sampled simultaneously, from the other sites within the zone using another automatic sound level analyzer for specific time intervals in an attempt to correlate levels from these sites to those of the control point. Due to the near field effects at the monitoring stations, little correlation was found and this approach was discontinued.

From August 1, 1976 to January 17, 1977, sound level data were obtained from sites outlined in Workplan II. These sites were chosen to fit one of three vegetation types--heavy deciduous, mixed deciduous-coniferous, and clearcut (See sites, Figure 3). Sound levels were measured with the sound level analyzers used in the first workplan. After collecting about 30 hours of data, this approach was expanded into a third workplan in order to include other vegetation types.

From the field measurements made under the first two workplans, it became apparent that the source of most of the residual (See glossary, Appendix W) levels within the study region was primarily wind interaction with various types of vegetation cover. Thus, a plan was devised to measure a variety of vegetation stands, canopied and noncanopied, during a whole range of wind conditions. Further, because some sites, particularly those located in the central-western portion of the study area, were constantly exposed to artificial noise, mostly from mining and logging activities, the region was split into areas that were close, or distant (either north or south) from current mining operations. The end result was a three-way matrix, which specified sites corresponding to one of several vegetation types, located in three zones relative to the distance from mining activities (distant-north, close, and distant-south), and measured under three general wind conditions, low, medium, and high. For ease of accessibility, all sites chosen were located near a U.S. Forest Service Road.

Because this system, Workplan III, was designed during the winter months, site selection was limited to a certain degree due to poor traveling conditions. Thus, only five vegetation types were chosen for winter monitoring. The resulting matrix used for winter data collection between January 17 and May 12, 1977, is given in Figure 4a (Due to winter

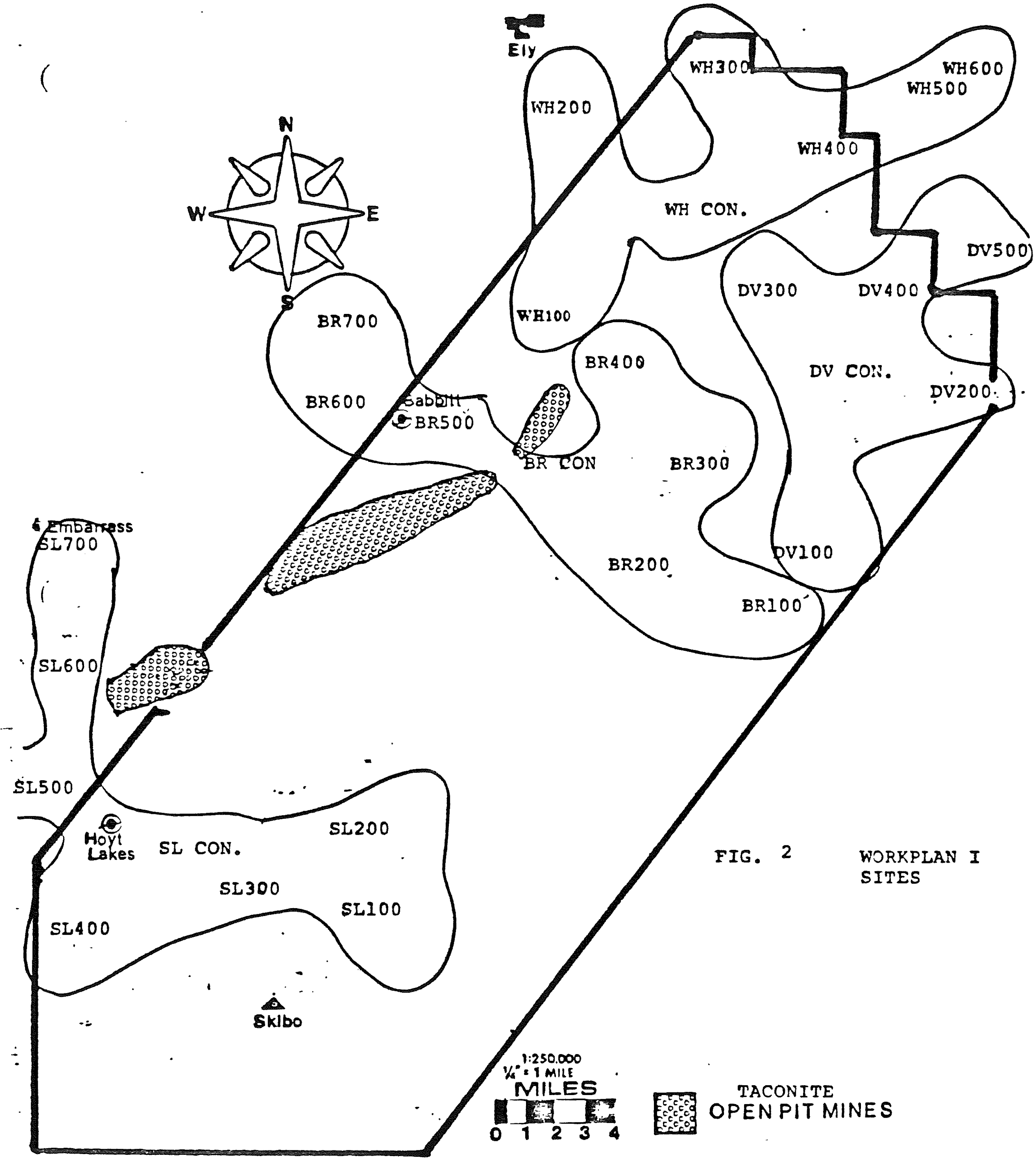


FIG. 2 WORKPLAN I SITES

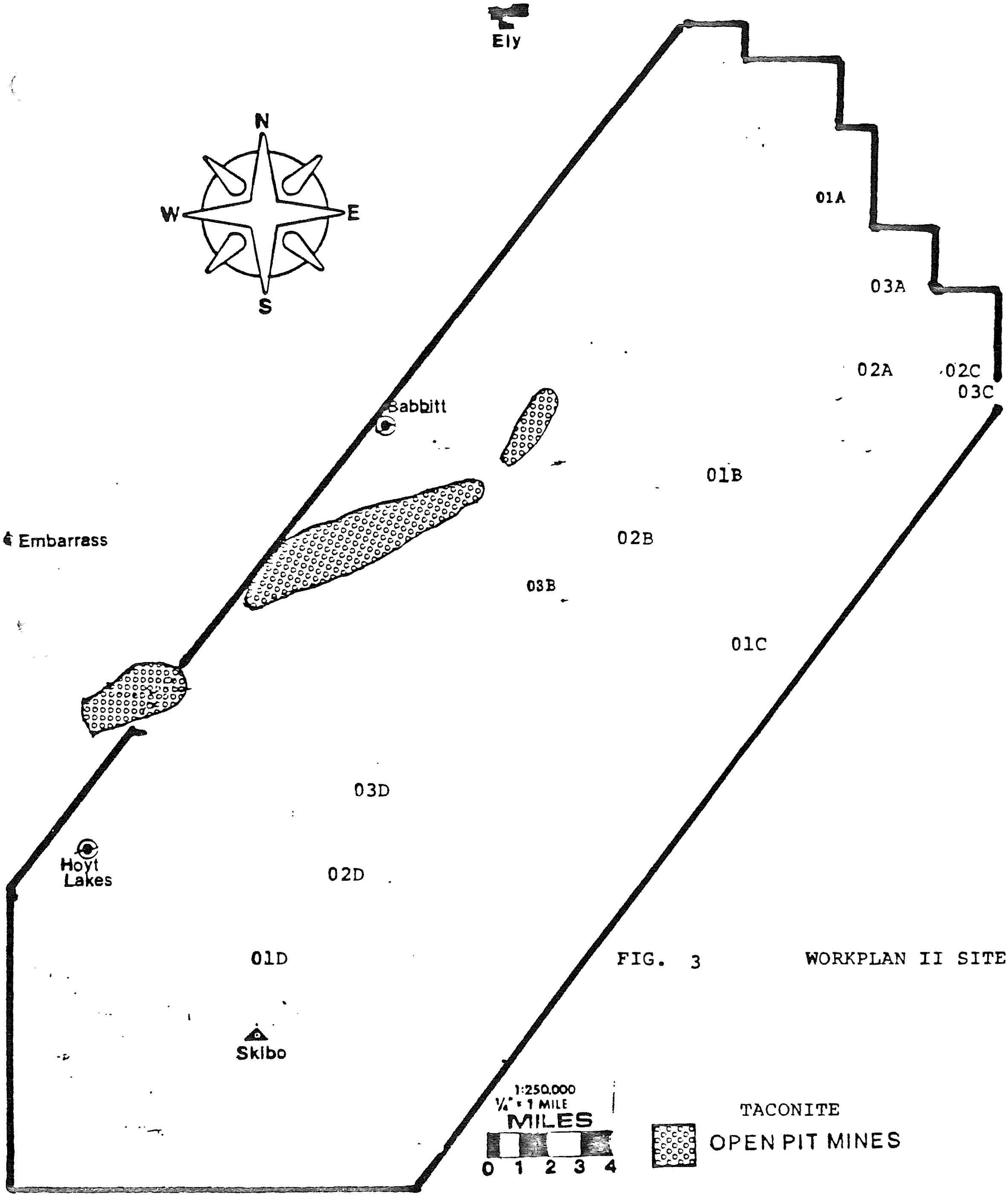


FIG. 3 WORKPLAN II SITES

VEG. TYPE		JACKPINE			BIRCH			BLACK SPRUCE		
SITES		Dist. North B-8	Close B-9	Dist. South VP-2	Dist. North VP-9	Close VP-7	Dist. South VP-8	Dist. North VP-5	Close VP-16	Dist. South VP-30
WIND CONDITION	HIGH									
	MEDIUM									
	LOW									

VEG. TYPE		SPARSE VEGETATION			CLEAR-CUT					
SITES		Dist. North VP-36N	Close B-25	Dist. South VP-37N	Dist.North VP-31	Close 03B	Dist. South (no site)			
WIND CONDITION	HIGH									
	MEDIUM									
	LOW									

FIG. 4a Site matrix used for data collection during no-foliage season 1977

conditions, a distant south clearcut site could not be located). After May 12, when trees were fully foliated, three new vegetation types, red pine, aspen, and sapling aspen, were added to the winter matrix, as shown in Figure 4b. Also, a site was added to the birch category in order to place a birch stand closer to the mines, and a clearcut site from Workplan I, WH 100, was added to increase the data base from these areas. Most of the monitoring sites shown in the two matrices were stands picked by the Terrestrial Biology staff of the Regional Copper-Nickel Study. These sites are all denoted by either "B-00," "VP-00" or "G-00;" all other sites were chosen by the noise monitoring personnel. A map with all sites from Workplan III is given in Figure 5.

Most of the field measurements under Workplan III consisted of simultaneous recording of acoustical data with the automatic sound level analyzer and a field cassette tape recorder. Input into these units was provided by either one microphone for each system (See Test Procedures CN-1 and CN-3, Appendix N) of one microphone for both systems, using a signal splitter (See Test Procedure CN-4, Appendix N). For a brief period of time, battery problems precluded the use of the sound level analyzer in the field; thus tape recorded data were run through the analyzer in the laboratory immediately after the field measurement (See Test Procedure CN-7, Appendix N). During each measurement, all auditory observations were noted on data sheets for subsequent tabulation. All measurements were one hour in length.

The low sound levels observed at times during the course of monitoring posed two measurement-related problems. First, levels were low enough at times such that the noise resulting from wind on the microphone was often the dominant source. Thus a special system of windscreens was developed and tested for field monitoring (See Appendix C). Second, even with a 20 dB preamplification, levels at times approached the noise floor of the measurement apparatus, which equalled about 6 dBA. Thus, the noise floor was assessed and third octave analysis of questionable data revealed the point at which system noise was a problem (See Appendix D for a more detailed discussion of the instrument noise floor).

4.00 Results

The results are divided into three principal sections. Part one gives an overall physical description of the study region followed by a summary of auditory observations made during the course of each measurement. Part two is an acoustical and statistical description of residual sound levels as measured under the guidelines of Workplan III. As such, the data were sampled as outlined by the site matrices described in the foregoing sections. Part three is a summary of all artificial noise observed within the study region. This summary is basically a series of tabulations based on auditory observations made during all measurements taken throughout the entire project. Here, observations from all three workplans are considered. Following this summary, is an acoustical description of artificial noise as analyzed via one-third octaves.

As will become evident in the following sections, mining noise was clearly audible at some of the monitoring stations. However, beginning August 1, 1977, and continuing through the end of the monitoring project, mine workers over the entire Iron Range went on strike, thereby greatly reducing mining noise impact at the above said monitoring sites. Thus, data sampled from these sites during the strike were not considered in the determination of current mining noise impact.

4.10 Physical Description

The study area is a diagonal strip of mostly wooded land, populated primarily with birch, aspen, and coniferous tree cover. Low-lying and swampy areas exist in the region along with clearcut and sparsely vegetated areas as a result of logging. Major bodies of water include Birch Lake, Seven Beaver Lake, Big Lake, the St. Louis and Kawishiwi

VEG.TYPE		JACKPINE			RED PINE			BLACK SPRUCE			BIRCH			
SITES		Dist.North B-8	Close B-9	Dist.South VP-2	Dist.North NS-8	Close B-3	Dist.South B-20	Dist.North VP-5	Close VP-16	Dist.South VP-30	Dist.North VP-9	Close VP-7	Close NS-2	Dist.South VP-8
WIND CONDITION	HIGH													
	MEDIUM													
	LOW													

VEG.TYPE		ASPEN			SAPLING ASPEN			SPARSE-MIXED			CLEAR-CUT			
SITES		Dist.North 01A	Close NS-3	Dist.South G-12	Dist.North VP-36N	Close NS-5	Dist.South NS-6	Dist.North NS-9	Close B-25	Dist.South VP-36N	Dist.North VP-31	Dist.North WH100	Close 03B	Dist.South NS-7
WIND CONDITION	HIGH													
	MEDIUM													
	LOW													

FIG **4b** Site matrix used for data collection during foliage season 1977

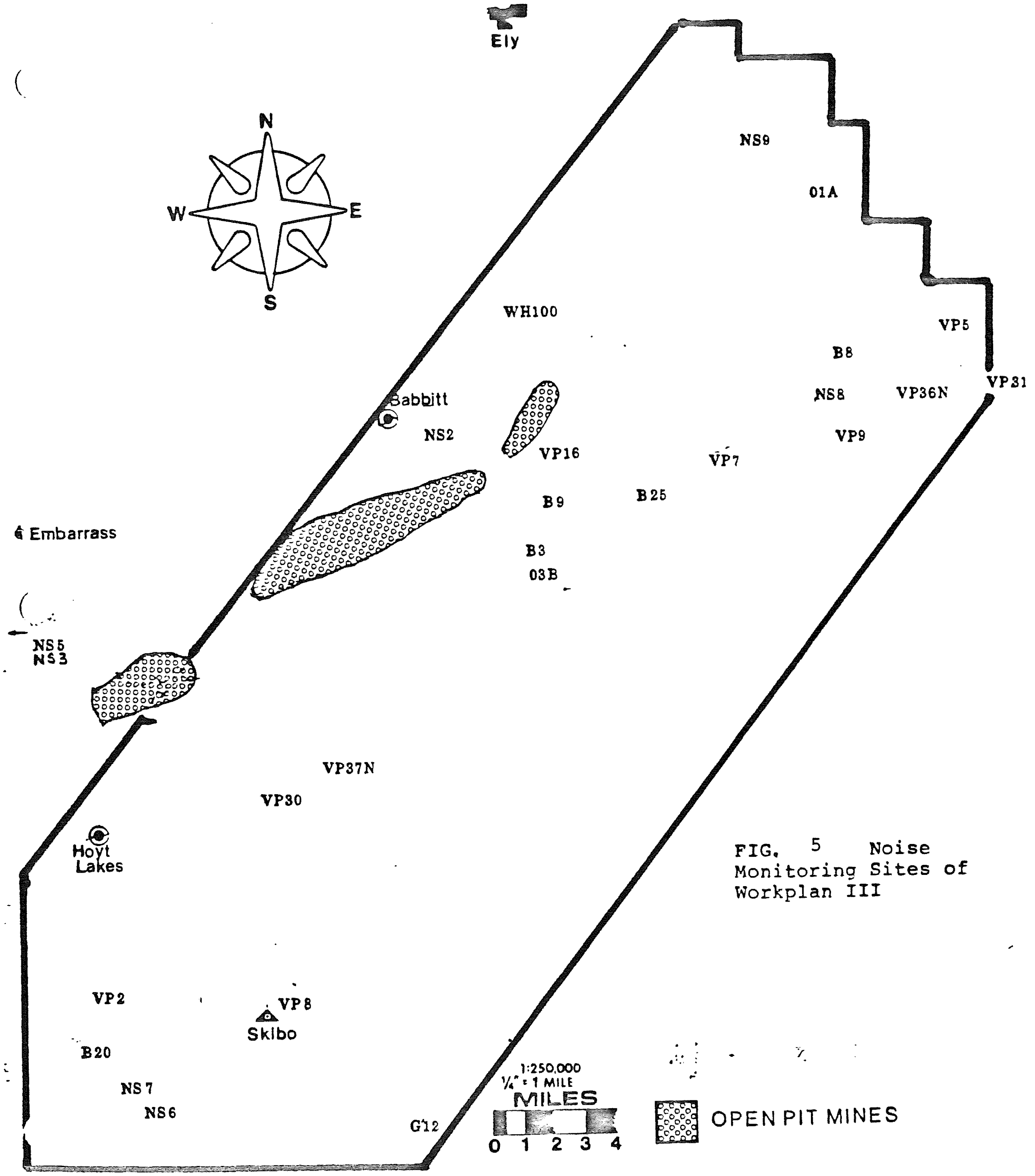


FIG. 5 Noise Monitoring Sites of Workplan III

Rivers, and numerous small streams and ponds.

Few population centers, other than the towns of Babbitt and Hoyt Lakes, are located within the region. Two resorts, Stony River and River Lake, are also primary residential locations but are seasonal. Numerous resorts and seasonal homes are located on large lakes on the periphery of the study area, including White Iron, Bear Island, and South Farm lakes. One major campground, the Birch Lake campground, is within the study area.

The two major commercial concerns of the area are taconite mining and tree harvesting for pulp. Two open pit mines, belonging to Erie and Reserve Mining companies are in the central-western portion of the region. Erie has two other pits located in the southwestern portion of the study area. Located between those two pits is Erie's taconite processing plant, and the mines are connected by a series of railroad lines for ore transport. Private unpaved roads also connect the mining complex.

Most of the logging is located in the central and southern portions of the region. The heaviest concentration of activity is currently in the central portion.

The region is travelable through a series of unpaved roads maintained by the U.S. Forest Service as shown in Figure 6. Branching off from these roads are a series of unpaved roads constructed by the logging industry, which are not kept up after their usefulness to transport pulp has ended. Paved roads in the area include County Highways 21, and 902 and State Highway 1.

4.11 Summary of General Observations

A variety of sounds were observed at sampling sites throughout the monitoring program. Generally, these auditory observations fell into one of two principal categories. Sounds were either a result of some naturally occurring activity or were a by-product of some form of man-made or artificial activity.

Naturally occurring sounds observed were a result of a large assortment of biological and physical events which one would expect to find in a wooded area. Due to this wide range of activities, a vast range of sounds was observed. Levels ranged from the extreme quietude of a calm winter's day to the loud roar of a foliated deciduous forest blowing in a high, gusty summer wind. Natural sounds were either relatively steady, as with a flowing stream, or very sporadic, such as the occasional peeping of a songbird.

Generally, the most common type of naturally occurring sound was the interaction of wind with vegetation cover. This seemed to comprise the majority of residual sound levels experienced in the study region. As one might expect, the exact nature of this type of sound was dependent on many factors. The type of vegetation cover was an important determinant. A deciduous forest was generally louder than a coniferous stand in response to a given wind speed. Also, the flat leaves of a deciduous stand responded to wind with a "crackling" sound as opposed to the "whooshing" sound of a coniferous forest. The condition of the foliage seemed to determine the loudness of a stand in response to wind, specifically for deciduous stands. Nonfoliated stands, as in the winter months, were generally quieter in response to a given wind than the same areas during the foliage season. The magnitude of the wind was another factor that affected the loudness of various vegetation stands. The higher the wind speed the louder was the particular stand. With very high winds, the effects of turbulent eddies could be seen in the movement of the treetops. The canopy seemed to be jostled about in all directions, tracing the movement of these turbulent flows.

Various forms of wildlife activity seemed to account for the next most common type of naturally produced sound observed throughout the monitoring program. Owing to periodic migration and hibernation

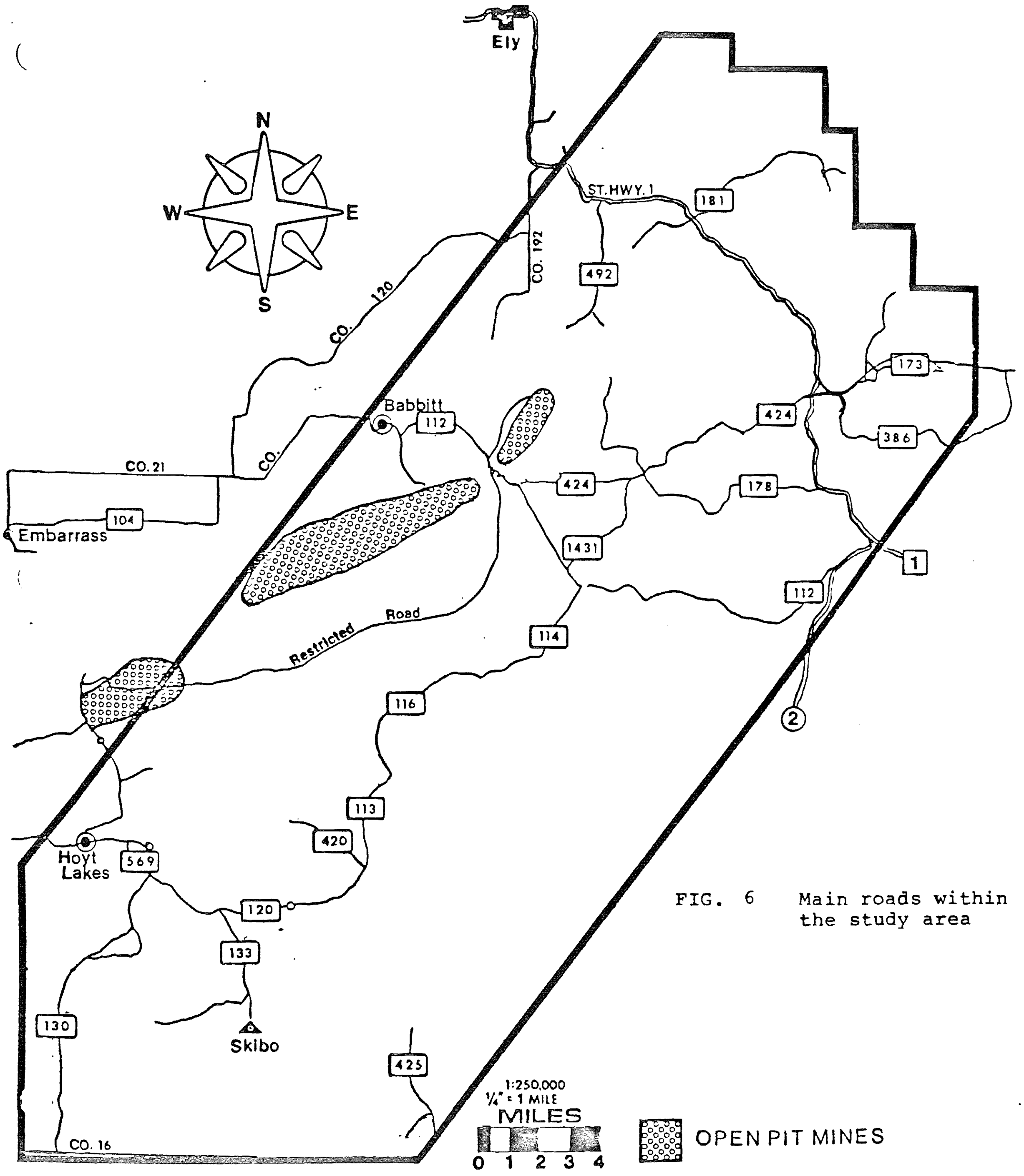


FIG. 6 Main roads within the study area

instincts, the extent of most wildlife activities varied seasonally. Spring appeared to be the most active time of year with the calls of various songbirds being the dominant sound source. With the approach of summer, songbird activity dwindled, and sounds from other small forms of wildlife, mainly chipmunks and squirrels, began to dominate. Frequently observed at these spring and summer measurements was the sound of various flying insects, usually bees and large deer flies. These creatures were attracted to the large microphone windscreen and would at times remain for an entire measurement. As one might expect, wildlife sounds in the winter months were fairly uncommon. Occasionally, a songbird would make its presence known, although ravens were the most frequently heard form of wildlife.

Other types of natural sounds were less common and observed only once or twice throughout the measurement program. One of the most interesting sounds was that observed in a jackpine forest on a cold winter day of about -22°F. The sap contained in the trees was cold enough that it began to contract, causing a relatively loud "popping" sound. Coincidentally, during that same measurement, an animal snort was heard halfway through the measurement period. This was probably produced by a nearby moose or deer, although the animal was not seen.

Artificial noise within the study region was also a result of a wide range of activities. Since most of the monitoring stations were located near travelable roads, vehicle noise was observed quite frequently. Passengers cars and pickup trucks were the most common vehicle type, although large diesel trucks and road graders occasionally passed by the monitoring sites. Other intrusive noise sources included air traffic, mining and logging related activities, guns, and snowmobiles in the winter months. A more detailed description of artificial noise, observed throughout the monitoring program is given in section 4.30 of the results.

4.20 Natural Residual Sounds within the Study Area

A total of 65 hours of sound level data was collected in five vegetation types in the winter from 1/17 to 4/27/77, and 70 hours of summertime sound levels were monitored in eight vegetation types from 5/12 to 9/20/77. A map of the study area, which lists all sites along with the hours of winter and summer data, is shown in Figure 7.

Because wind interaction with vegetation cover was assumed to be the principal cause of residual sound levels, wind speed data were utilized for the respective winter and summer periods. The data were sampled at Hibbing, Minnesota by the flight service department of the Hibbing Airport and analyzed by the meteorology staff of the Copper-Nickel Study. Wind speed and direction were sampled every hour from a height of twenty-one feet using an anemometer, model F-420C manufactured by Electric Speed Indicator Company of Cleveland, Ohio.

Initially, sound level data were analyzed automatically using a Metrosonic Sound Level Analyzer (Model db-601) and expressed in terms of L_n values or levels exceeded N percent of the time. Data were then transcribed onto data summary forms (See Appendix T for summary forms and Appendix U for field data sheets).

Sound levels between L_{10} and L_{90}, inclusive, were then plotted at L_n intervals of ten on probability paper as a function of the percent of time they were exceeded. Only this range of L_n values, which includes 80 percent of the data was considered in order to eliminate skewing effects represented by extreme L_n values. The other 20 percent of the data, which was typically some temporary event such as a singing bird, was not included in the following analyses, due to the prime emphasis on characterization of residual data. However, the sounds that constituted this small data range are discussed in Sections 4.21 and 4.22 of this report.

Plotting the data on probability paper gave an idea as to the

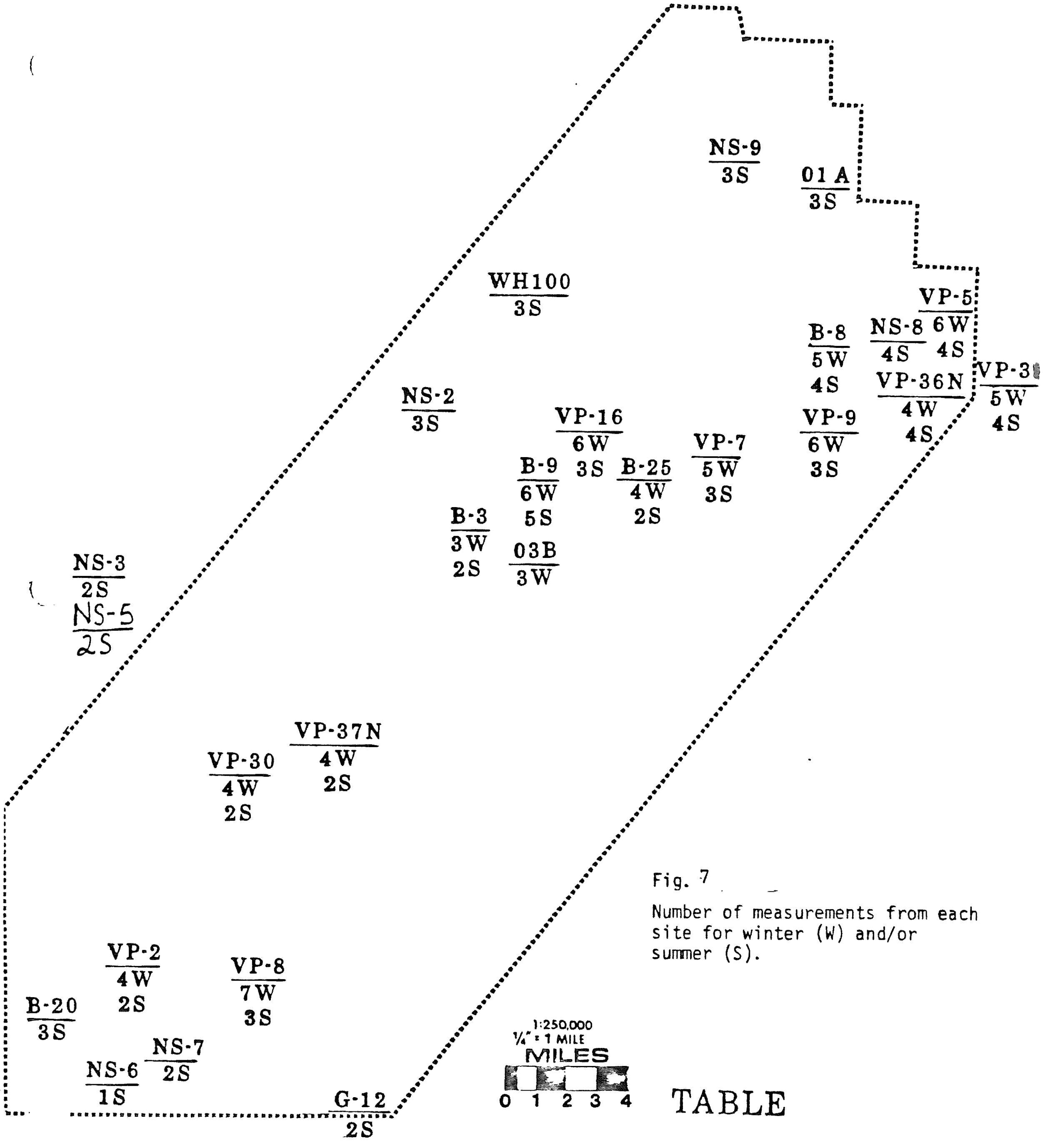


Fig. 7

Number of measurements from each site for winter (W) and/or summer (S).

character of the sound level distributions. The points along the X-axis of probability paper are placed at distances from the center point, which are proportional to the distances of those points from the mean of a normal distribution. As such, plotting a normal distribution yields a straight line. For the range of data in question, i.e., L_{10}-L_{90}, most of the sound level distributions did indeed plot as a straight line of points, and as a result were considered to be normally distributed (See Appendix T for probability plots).

Based on this assumption, the method of linear regression was used to statistically fit a line to the probability plots (See Appendix E for method), which then characterized each distribution in the form $Y = MX+b$.

The data on probability paper fit to the above equation as follows:

$L_n = SD(Tn)+L_{50}$, where:

1. $Y = L_n$; any point along the Y-axis of probability paper represents a specific L_n value. Thus, $Y = L_n$.
2. M = standard deviation (SD); according to the normal curve model, 34 percent of the data is located at one standard deviation from the mean ($\overline{X}$). Assuming the L_{50} of a sound level distribution equals the $\overline{X}$, the L_{84} would then be one SD from the L_{50}. Subtracting the data value of the L_{50} from that of the L_{84} are X data points and their corresponding values are Y data points. Thus, if $L_{50} = X_o$, and, $L_{84} = X_1$ and their corresponding Y values equal Y_o-Y_1, the SD would equal Y_o-Y_1/X_o-X_1. Because this is the derivation of the slope of a line, the slope (m) equals the SD on probability paper.
3. $X = Tn$; the value for any X data point on probability paper is a percentage or specifically the "n" of the L_n. In order to transform these percents into a number, each X point is set equal to the number of standard deviations from the $\overline{X}$ or Tn. Thus L_{84} becomes equal to 1, L_{50} equals 0, and L_{16} equals -1.
4. $b = \overline{X}$ or L_{50}; by changing the X-axis as described above, the 0 point is now the L_{50} or the $\overline{X}$. In the linear equation, $Y = MX+b$, the value that falls on this 0 point is the Y intercept, b. Thus b = the $\overline{X}$ or L_{50}.

Therefore, $L_n = SD(Tn)+L_{50}$ is a linear relationship representing the sound level data as plotted on probability paper.

Further, the confidence limits of the distributions were ascertained by computing the standard error of estimate (δ). This measure was determined as follows:

$\delta = \sqrt{1-r^2}\ (SD'$ where:

r^2 = correlation coefficient
and
SD' = the standard deviation of only the Y data points.

The value for δ gives the average variation of all plotted data points from a perfectly straight line. Thus, a δ of 1 indicates a normal distribution, plus or minus 1 dBA.

Tables 8a and 8b list the $\overline{X}$ (L_{50}), SD, and δ for all measured sound level distributions for the range of data considered. For most of the distributions, i.e., 94 percent, the δ factor was less than or equal to one. Thus, most of the distributions are normal between L_{10} and L_{90}.

Individual sound level distributions were then combined for similar vegetation types for each season. Table 9 shows the $\overline{X}$, SD, and δ of

VEGETATION TYPE	SITE NO.	DATA							
JACKPINE	B-8	$\bar{X}$	13	41	31	33	30		
		SD	2.8	3.5	3.6	3.6	6.1		
		δ	.57	.39	.22	.23	.51		
	B-9	$\bar{X}$	43	40	34	34	35	26**	
		SD	3.6	2.6	2.9	2.3	3.3	4.1	
		δ	.23	.37	.37	.24	.33	.42	
	VP-2	$\bar{X}$	28	41	38	17			
		SD	3.5	3.3	3.6	4.5			
		δ	.39	.21	.59	.54			
BIRCH	VP-9	$\bar{X}$	20	28	32	21	34	45	
		SD	3.5	4.0	3.2	0.9	6.9	3.0	
		δ	.64	.42	.48	.31	1.21	.32	
	VP-7	$\bar{X}$	32	31	43	31	37		
		SD	4.6	4.9	2.9	4.6	3.4		
		δ	.45	1.43	.37	.23	.33		
	VP-8	$\bar{X}$	28	20	29	42	38	22	14
		SD	3.0	2.8	3.0	4.3	4.2	4.7	1.5
		δ	.28	.20	.28	.30	.35	.23	.24
BLACK SPRUCE	VP-5	$\bar{X}$	33	30	20	33	33	25	
		SD	2.8	3.8	0.5	3.4	2.8	6.8	
		δ	.20	.12	.28	.40	.43	.34	
	VP-16	$\bar{X}$	31	35	33	22**	38	24**	
		SD	4.2	4.2	2.8	3.0	4.4	3.0	
		δ	.28	.54	.25	.28	.38	.51	
	VP-30	$\bar{X}$	26	45	20	24*			
		SD	5.1	5.4	4.0	5.9			
		δ	.58	.34	.59	.48			
CLEAR-CUT	VP-31	$\bar{X}$	21	25	25	23	22		
		SD	3.1	4.8	1.9	5.9	5.9		
		δ	.39	.86	.50	.72	.34		
	03B	$\bar{X}$	28	23	31				
		SD	3.0	2.3	4.7				
		δ	.28	.48	.29				
SPARSE	VP-36N	$\bar{X}$	30	16	46	19			
		SD	3.6	3.6	3.3	5.2			
		δ	.23	.23	.31	.71			
	B-25	$\bar{X}$	30	41	40	25			
		SD	2.6	2.3	3.9	2.1			
		δ	.34	.70	.65	.42			
	VP-37N	$\bar{X}$	27	23	25	19			
		SD	4.1	3.7	5.1	3.3			
		δ	.43	.57	.51	.54			

Table 8a Winter Sound Level Statistics

$\bar{X}$ = mean
SD = standard deviation
δ = standard error of estimate of combined distributions for all vegetation types for both seasons

*data adjusted for skewing factor
**data omitted for combination of vegetation types due to presence of artificial noise

VEGETATION TYPE	SITE NO.	DATA					
JACKPINE	B-8	$\overline{X}$	33	44	32	21	
		SD	4.3	3.3	2.4	2.1	
		δ	.28	.31	.36	.32	
	B-9	$\overline{X}$	3.4	39	36	30	43
		SD	2.3	2.4	4.3	2.8	4.0
		δ	.24	.28	.57	.98	.42
	VP-2	X	30	34			
		SD	2.8	4.3			
		δ	.21	1.03			
RED PINE	NS-8	$\overline{X}$	26	43	25	41	
		SD	3.9	3.6	1.8	4.4	
		δ	1.01	.23	.34	.32	
	B-3	$\overline{X}$	31	44	26		
		SD	4.4	5.7	5.6		
		δ	.38	.45	.54		
	B-20	$\overline{X}$	29	18	33		
		SD	2.2	2.1	3.7		
		δ	.38	.32	.33		
SPARSE-MIXED	NS-9	$\overline{X}$	30	27	39		
		SD	4.3	2.5	3.1		
		δ	.28	.51	.41		
	B-25	$\overline{X}$	32	26			
		SD	4.2	3.8			
		δ	.61	.43			
	VP-37N	$\overline{X}$	34	42			
		SD	3.8	3.3			
		δ	.43	.21			
CLEARCUT	VP-31	$\overline{X}$	23	29	27	24	
		SD	5.9	4.1	2.1	1.6	
		δ	.72	.42	.36	.30	
	03B	$\overline{X}$	25	16			
		SD	3.8	3.5			
		δ	.43	.55			
	WH-100	$\overline{X}$	27	30	20		
		SD	3.3	2.4			
		δ	.31	.28	.40		

VEGETATION TYPE	SITE NO.	DATA				
ASPEN	01A	$\overline{X}$	36	22	31	
		SD	3.6	3.2	4.5	
		δ	.52	.78	.47	
	NS-3	$\overline{X}$	41	35		
		SD	4.7	5.5		
		δ	.54	.27		
	G-12	$\overline{X}$	39	20*		
		SD	5.9	5.0		
		δ	.34	.41		
BLACK SPRUCE	VP-5	$\overline{X}$	25	41	23	15
		SD	4.5	4.2	4.1	1.8
		δ	.54	.28	1.00	.28
	VP-16	$\overline{X}$	39	23**	22	
		SD	4.8	2.6	5.4	
		δ	.44	.42	1.73	
	VP-30	$\overline{X}$	27	41		
		SD	4.0	4.7		
		δ	.42	.45		
SAPLING ASPEN	VP-36N	$\overline{X}$	31	37	52	19*
		SD	5.0	2.8	2.7	3.3
		δ	.43	.20	3.2	.21
	NS-5	$\overline{X}$	36	2.9		
		SD	2.8	2.3		
		δ	.62	.45		
	NS-6	$\overline{X}$	40			
		SD	4.0			
		δ	.23			
BIRCH	VP-9	$\overline{X}$	45	52	16	
		SD	4.1	4.7	2.1	
		δ	.42	2.3	.52	
	NS-2	$\overline{X}$	21**	37**	34**	
		SD	5.2	9.3	4.7	
		δ	.73	1.02	.71	
	VP-7	$\overline{X}$	38	32	22	
		SD	5.9	5.5	1.6	
		δ	.26	.67	.27	
	VP-8	$\overline{X}$	42	40	36	
		SD	3.8	3.7	4.2	
		δ	.12	.33	.38	

Table 8b Summer Sound Level Statistics

$\overline{X}$ = mean
SD = standard deviation
δ = standard error of estimate of combined distributions for all vegetation types for both seasons

*data adjusted for skewing factor
**data omitted for combination of vegetation types due to presence of artificial noise

Table 9 Mean ($\overline{X}$), standard deviation (SD), standard error of estimate (δ) of combined distributions for all vegetation types for both seasons. (dBA)

	$\overline{X}$	SD	(δ)	No. of Distributions
<u>WINTER DATA</u>				
Jackpine	32	10.3	2.26	14
Birch	30	10.0	.43	15
Black Spruce	30	7.4	.57	15
Sparse	28	10.1	1.76	13
Clearcut	24	5.1	.53	8
				Total = 65
	$\overline{X}$	SD	(δ)	No. of Distributions
<u>SUMMER DATA</u>				
Birch	36	12.1	1.89	11
Sapling Aspen	35	10.5	1.14	7
Aspen	34	10.3	.98	7
Jackpine	34	6.9	.33	11
Sparse-Mixed	33	7.0	.75	7
Red Pine	31	9.4	.76	10
Black Spruce	29	11.7	1.19	8
Clearcut	25	5.4	4.5	9
				Total = 70

the overall seasonal distributions for each vegetation type. (See Appendix F for method). The data chosen for combination exhibited two properties: one - the individual sound level distributions were Gaussian, and two - data reflected only wind interacting with vegetation cover, i.e., residual levels. In line with these assumptions, sound level distributions chosen for this procedure had to have a standard error of estimate of less than or equal to one. Distributions that were skewed, i.e., which exhibited a standard error of significantly greater than one, were adjusted to eliminate the skewing factor (See Appendix G for this procedure). Also, measurements made when little or no wind activity was present, were not considered for sites close to a steady artificial noise source (Sites B-9, VP-16, and NS-2). Rather, calm data from a site with comparable vegetation cover was used twice.

Clearcut sites constituted a unique situation. After observing data on a real-time one-third octave analyzer, it became evident that even with windscreen protection, some of the data were being affected by wind noise on the microphone. Thus, the residual sounds in clearcut areas were probably somewhat lower than the levels reported in the data. Nevertheless, for both seasons, clearcut areas showed the lowest mean sound levels as compared to vegetative areas.

As indicated in Figure 10, the range of means for winter data was relatively small, (28 to 32 dBA) for vegetated areas with canopies, with jackpine stands having the highest mean level. In summer, however, the range of means extended, with the deciduous canopied stands being the loudest. Birch stands exhibited the highest mean of 36 dBA, and black spruce stands had the lowest mean, 29 dBA.

Based on the limited data obtained, several points are clear. First, the SD's for canopied areas in the winter were all around 10.0, with the exception of the black spruce stands, indicating that these areas varied less about the mean than the other vegetated sites. Also, all of the deciduous stands showed SD's of greater than or equal to 10.0 during both seasons. Thus, it seems that these stands, i.e., deciduous, show a consistently higher variability than the coniferous stands.

The standard error of estimate indicates that most of the combined distributions are within one dBA of being Gaussian. The most skewed case was the winter-jackpine condition. The skewing factors here are two extremely quiet measurements; one with a mean equal to 17 dBA, the other had a mean of 13 dBA. However, given the general trend that most of the data appears Gaussian, it is believed that a larger data base would have smoothed out the skewing.

The wind data, received from the Hibbing Airport, were subfiled (on computer storage) to include only 0600 to 1600 hours so as to coincide with the hours during which sound levels were monitored. W_n data, or wind speeds (Knots - see Appendix W) exceeded N percent of the time, were tabulated and plotted on probability paper, and, as with sound statistics, fit with a line via linear regression. (See Appendix H for data reduction method.) Figures 11a and 11b show the wind probability plots along with the computed W_{10} to W_{90} for both monitoring seasons. Also given are the mean ($\overline{X}$), standard deviation (SD), correlation coeffecient (r^2), and standard error of estimate (δ) for both distributions. The δ factor for both seasons is only a fraction of a knot, pointing to the fact that wind statistics, like residual sound levels statistics, are Gaussian in character.

It should be noted here that a certain range of wind data values were used for analysis; specifically for winter - $W_{86.2}$ (3 knots) to $W_{12.3}$ (14 knots) and for summer - $W_{76.7}$ (3 knots) to $W_{11.6}$ (13 knots). The upper limit was placed on the data to eliminate the skewing factor of sudden high speed wind gusts, and the lower limit of 3 knots was imposed due to measuring limitations of the sensing apparatus at low speeds.

Assuming that ambient sound level statistics were perfectly correlated with the wind statistics and that the Hibbing wind data represents wind conditions over the entire study area, a functional relationship was mathematically established between sound level and wind statistics. Given that data from both sound and wind distributions were

MEAN SOUND LEVELS OF COMBINED DISTRIBUTIONS FOR BOTH SEASONS

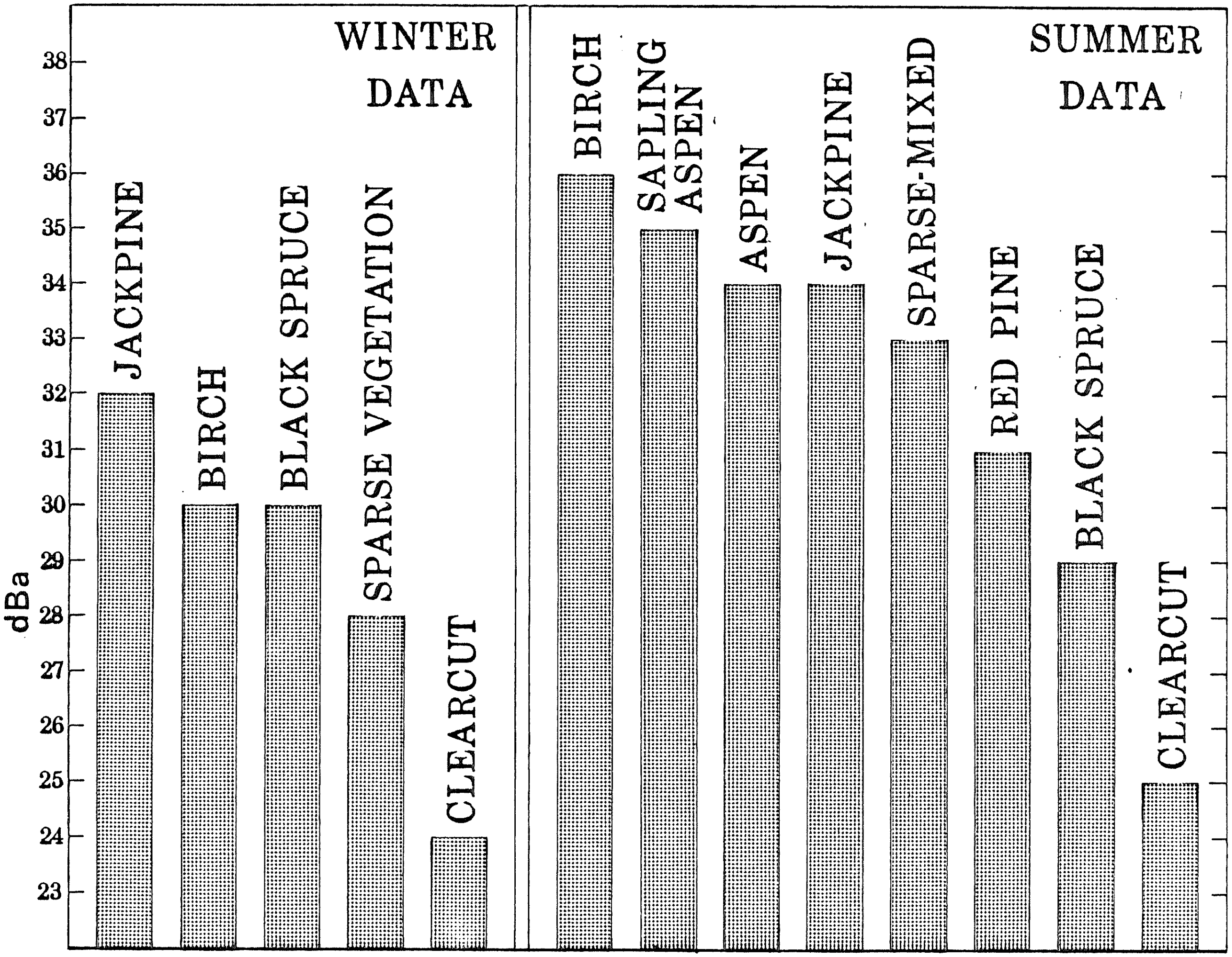


FIGURE 10

WIND DATA SAMPLED FOR WINTER PERIOD

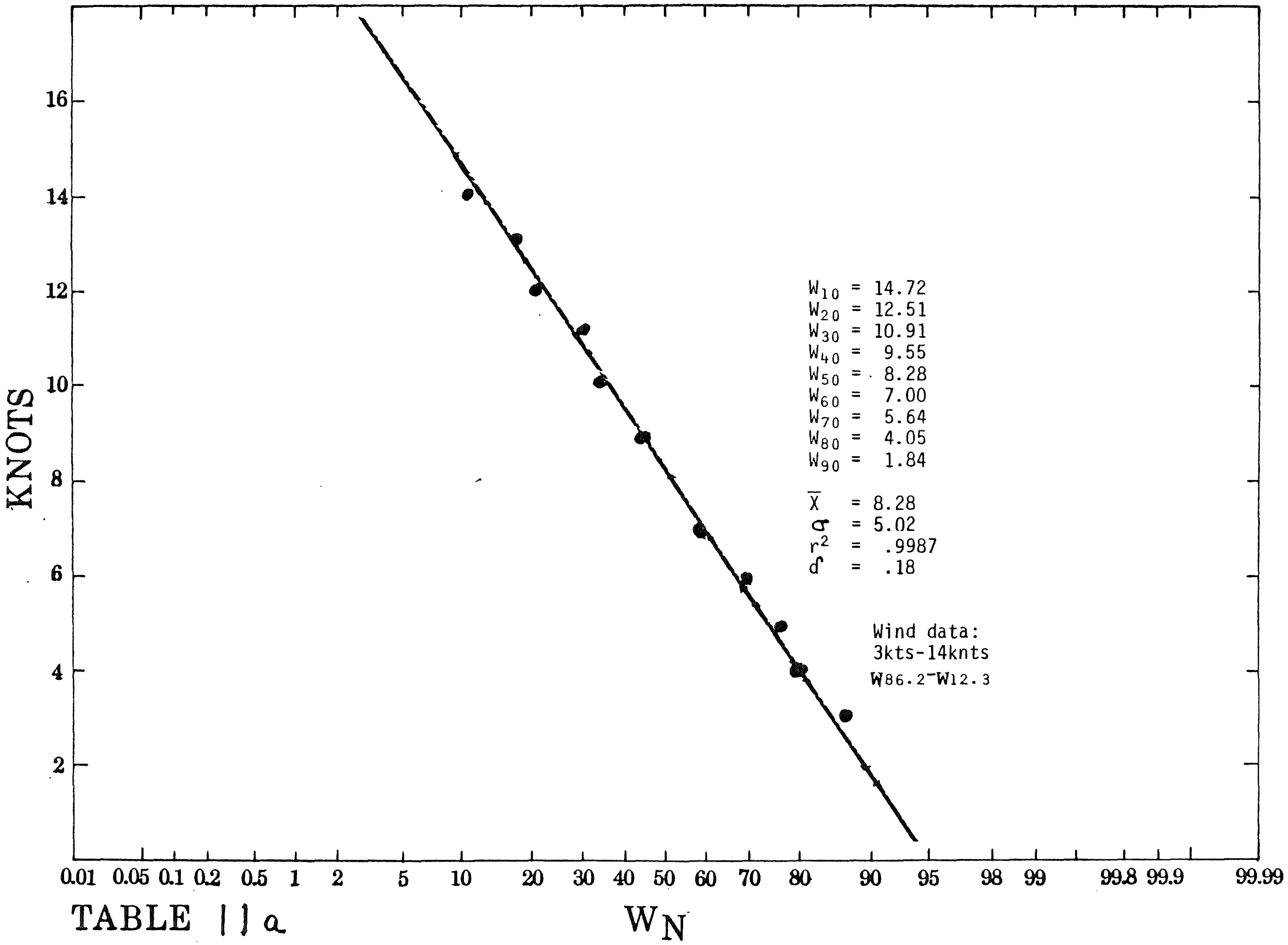


TABLE ||a

WIND DATA SAMPLED FOR SUMMER PERIOD

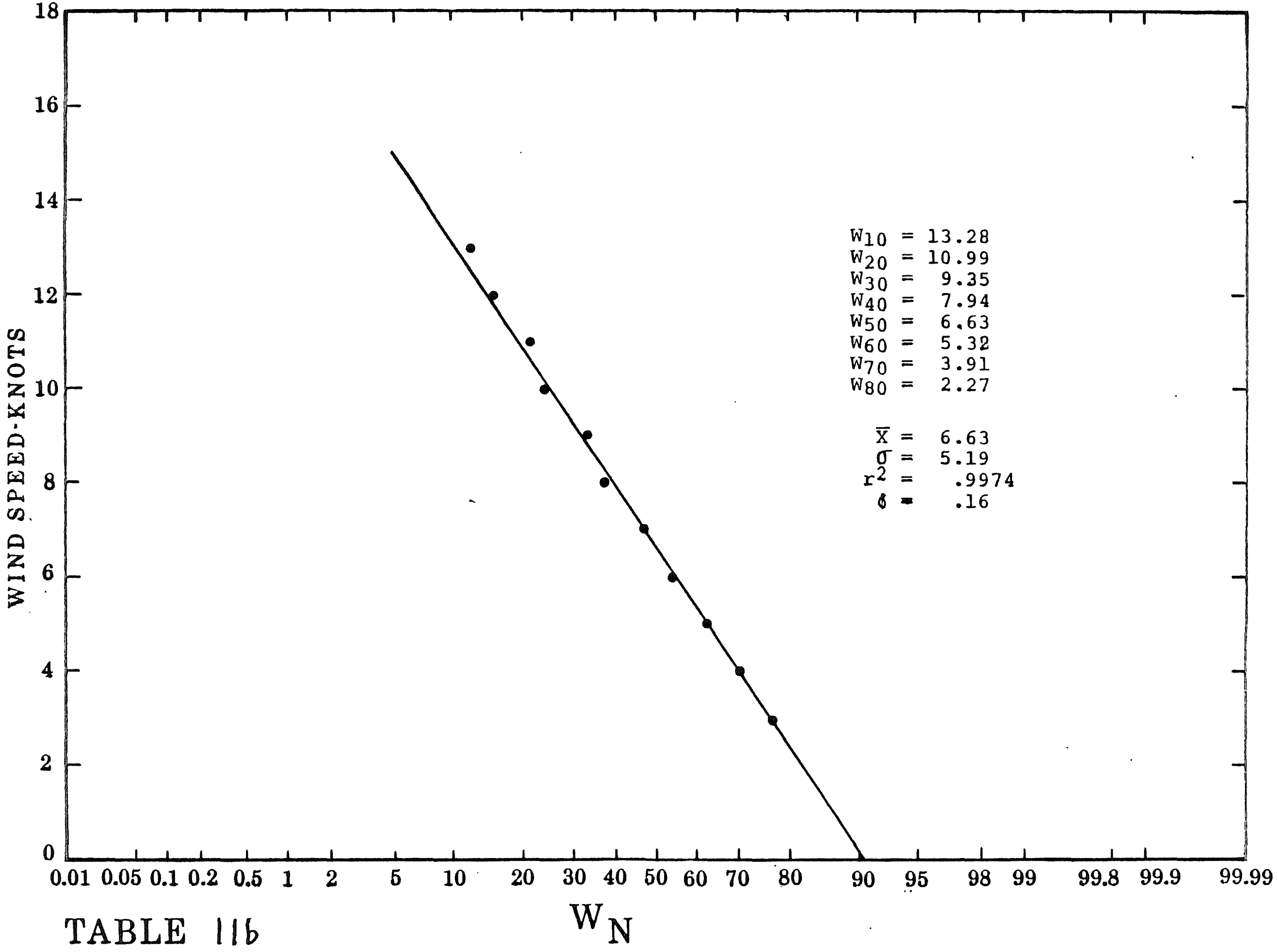


TABLE IIb

Gaussian in character, plotting any sound or wind distribution on probability paper fit the relationships:

1. $L_n = SD_s(Tn)+L_{50}$ (sound data)

2. $W_n = SD_w(Tn)+W_{50}$ (wind data)

Solving for Tn in equation 2:

$$Tn = 1/SD_w(W_n-W_{50})$$

Substituting for Tn in equation 1:

$$L_n = SD_s(W_n-W_{50}/SD_w)+L_{50}$$

Substituting the mean sound level, $\overline{X}_{SL}$, for the L_{50}, the given wind speed, V, for W_n, and the mean wind speed, $\overline{X}_w$, for the W_{50}, the resulting sound level as function of a given wind speed equals:

$$SL = SD_s(V-\overline{X}_w/SD_w)+\overline{X}_{SL}$$

For winter wind data, the mean equaled 8.28 knots and the standard deviation was 5.02. Thus, the relationship for winter would be:

$$SL = SD_{SL}(V/5.02-1.65)+\overline{X}_{SL}$$

For summer, the $\overline{X}_w = 6.63$ and the $SD_w = 5.19$, so the summer equation would be:

$$SL = SD_{SL}(V/5.19-1.28)+\overline{X}_{SL}$$

As an example, using data from the winter birch stands $\overline{X}_{SL} = 30$ and $SD_{SL} = 10.0$; for a 10 knot wind:

$$SL = 10.0\ (10/5.02-1.65)+30$$

$$SL = 33\ \text{dBA}$$

Tables 12a and 12b show the results of using the above formulas to determine residual sound levels from a given wind speed. It should be kept in mind, however, that because the preceding analyses considered about 80 percent of sound and wind data, the derived equations are applicable to only the wind speeds listed in the tables. Thus, the given formulas probably could not be used reliably to ascertain sound levels resulting from calm (< 3 knots) or extremely windy conditions (> 13 knots).

4.21 Spectral Analysis of Natural Residual Sounds

Residual sounds were recorded on cassette tapes at each field measurement for subsequent laboratory analysis and were then analyzed at the Acoustics Laboratory of Moorhead State University in Moorhead, Minnesota. Tapes were "A" weighted in the lab and run through a one-third octave real-time analyzer for frequency content (See Appendix N, Test Procedure CN-13).

Residual sound segments were isolated by playing the tape through a monitoring speaker and noting when a relatively long passage of only residual sounds occurred. The tape was then rewound to the start of the segment of interest and played through the real-time analyzer for an optimum integration time of sixteen seconds. The end of the integration period was signaled by the appearance of the spectral plot on the display scope. dBA levels were then printed out for each one-third octave between 25 and 8,000 Hz, inclusive, and the system was reset for another run.

Data were ordered into dBA increments of five and grouped by vegetation type. An attempt was made to get as many sites and as many five dBA intervals as possible. At least three separate runs of each dBA interval plus or minus one dBA were made from two or more sites. Given the amount of field data available, most vegetation types yielded levels from 20 to 50 dBA, although two types, red pine and birch, went as high as

Table 12a. Sound levels of winter vegetation types for winds 3 to 14 knots

W_n	Wind (Knots)	SOUND LEVELS (dBA) Jackpine	Birch	Black Spruce	Sparse	Clearcut
86.2	3	21	19	22	17	18
79.7	4	23	21	23	19	19
74.0	5	25	23	25	21	20
66.8	6	27	25	26	23	21
59.0	7	29	27	28	25	22
50.4	8	31	29	29	27	23
45.6	9	33	31	31	29	24
35.3	10	35	33	32	31	25
31.7	11	37	35	34	33	26
22.8	12	39	37	35	35	27
18.1	13	41	39	36	37	28
12.3	14	43	41	38	39	29

Table 12b. Sound levels of summer vegetation types for winds 3 to 13 knots

		SOUND LEVELS (dBA)							
W_n	Wind (Knots)	Jack Pine	Red Pine	Birch	Aspen	Black Spruce	Sapling Aspen	Sparse-Mixed	Clearcut
76.9	3	29	24	27	26	20	27	28	21
69.8	4	30	26	29	28	23	29	29	22
62.4	5	31	28	32	30	25	31	30	23
53.8	6	33	29	34	32	27	33	32	24
46.6	7	34	31	36	34	29	35	33	25
37.2	8	35	33	39	36	32	37	34	26
33.4	9	37	35	41	38	34	39	36	27
24.4	10	38	37	43	40	36	41	37	28
21.0	11	39	38	46	42	38	43	38	29
15.2	12	41	40	48	44	41	45	40	30
11.6	13	42	42	50	46	43	47	41	31

60 dBA for the summer months. Isolating specific dBA increments proved to be rather tedious for very high levels, due to the erratic nature of high wind gusts, and for very low levels, due to the confounding factor of other sound producing sources. Thus, it became necessary to shorten the integration time and/or lessen the number of data runs for some of these extreme values.

Separate runs of equal dBA increments were then combined by averaging the levels corresponding to individual third octave bands. For example, all the printouts for birch stands which had a total energy of 25 dBA were averaged for each third octave band. Averages were made by converting to an energy value, averaging, and reconverting back to dBA, (rms averaging) i.e.:

$$10 \log \frac{(10^{a/10} + 10^{b/10} + \ldots\ldots 10^{x/10})}{N} \text{ where:}$$

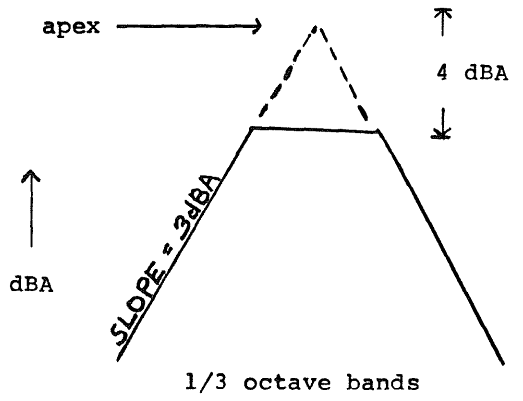
- a, b, and x = specific dBA levels

- N = number of levels considered for average

Averaged third octave data were then plotted on graphs, the end result being a family of spectra plots at five dBA increments for each vegetation type, for both monitoring seasons (See Appendix J for all spectral graphs).

Given the relatively irregular nature of the third octave plots, it was not feasible to superimpose the dBA increments on a single graph for each vegetation type. Thus, two methods were devised to "smooth" out the plots, primarily for ease of viewing. Different procedures were used to represent the winter and summer data due to the fact that all the winter data were characterized by one very predictable pattern, whereas the summer data were more irregular. A secondary reason for separate analysis was simply to test the utility of the two methods. Only data from full stands of trees were considered due to the lack of wind effects on the microphone, and also because of time constraints of the project.

Winter data from three vegetation types, jackpine, black spruce, and birch stands, were all fit reasonably well by a certain truncated triangular shape as indicated by the solid line shown in the following diagram.



The slope of each side of the triangle is three, i.e. for each third octave, the line rises three dBA. The truncated portion is four dBA from the apex if the two sides were allowed to intersect. Given this shape, one need only to know the exact apex in order to characterize third octave spectra plots for any of the three winter canopied vegetation stands. Table 13 lists these points for the dBA increments of the winter data, and Figures 14a, 14b, and 14c show the corresponding plots. The solid line portion of the graphs indicates that the actual spectral

Table 13. Imaginary apexes for spectral plots for winter data
X = center frequency of third octaves
Y = dBA

VEGETATION TYPE

		Jackpine		Black Spruce		Birch	
		X	Y	X	Y	X	Y
	55			1600	52	1000	52
	50	800	47	1250	46	800	47
	45	800	42	1000	42	800	42
dBA	40	800	37	800	37	800	37
	35	800	32	800	32	800	32
	30	630	27	800	27	630	27
	25	630	22	800	22	500	22
	20			630	17		

Figure 14a Smoothed Spectra Plots for Winter-Jackpine Stands

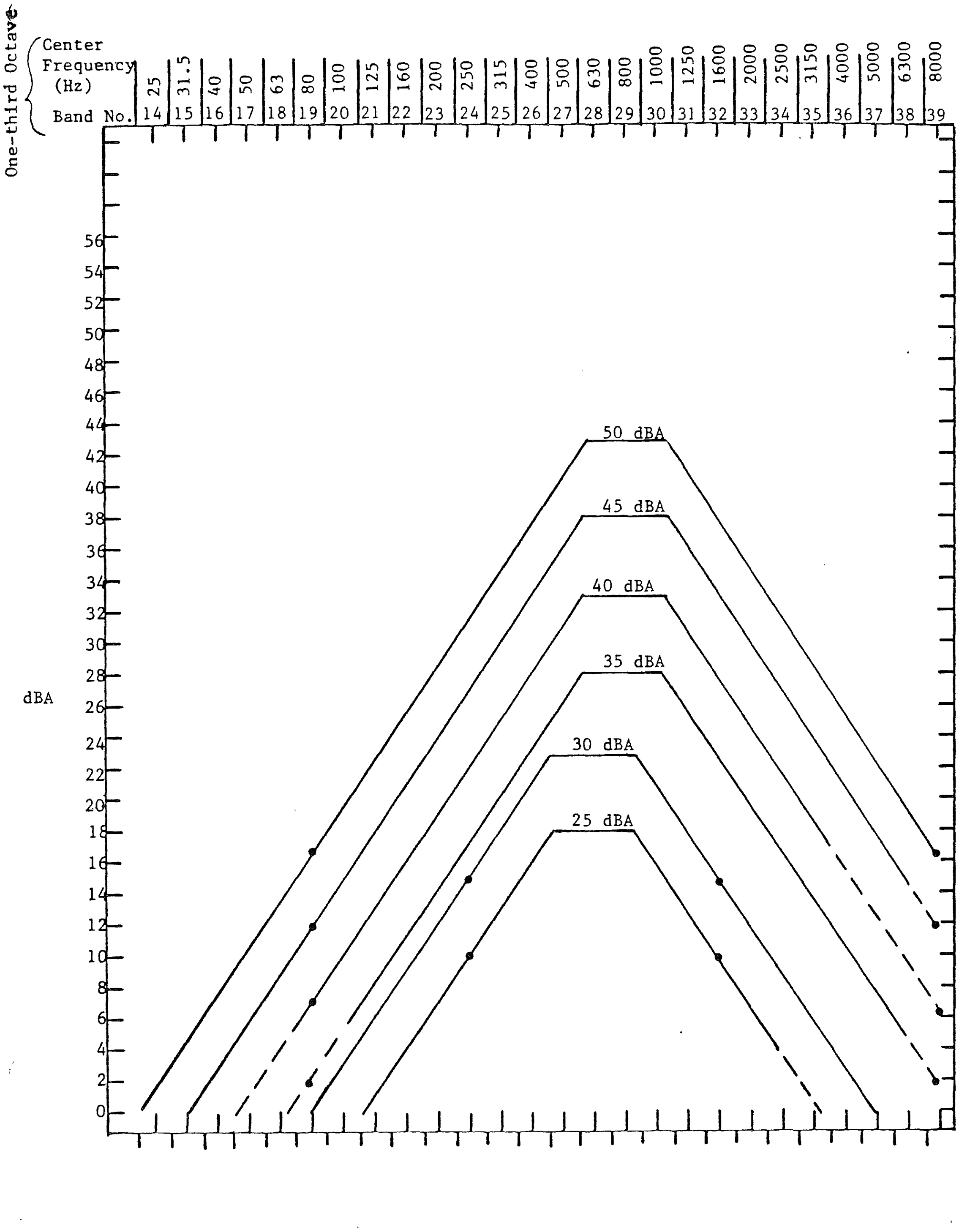


Figure 14b Smoothed Spectra Plots for Winter-Black Spruce Stands

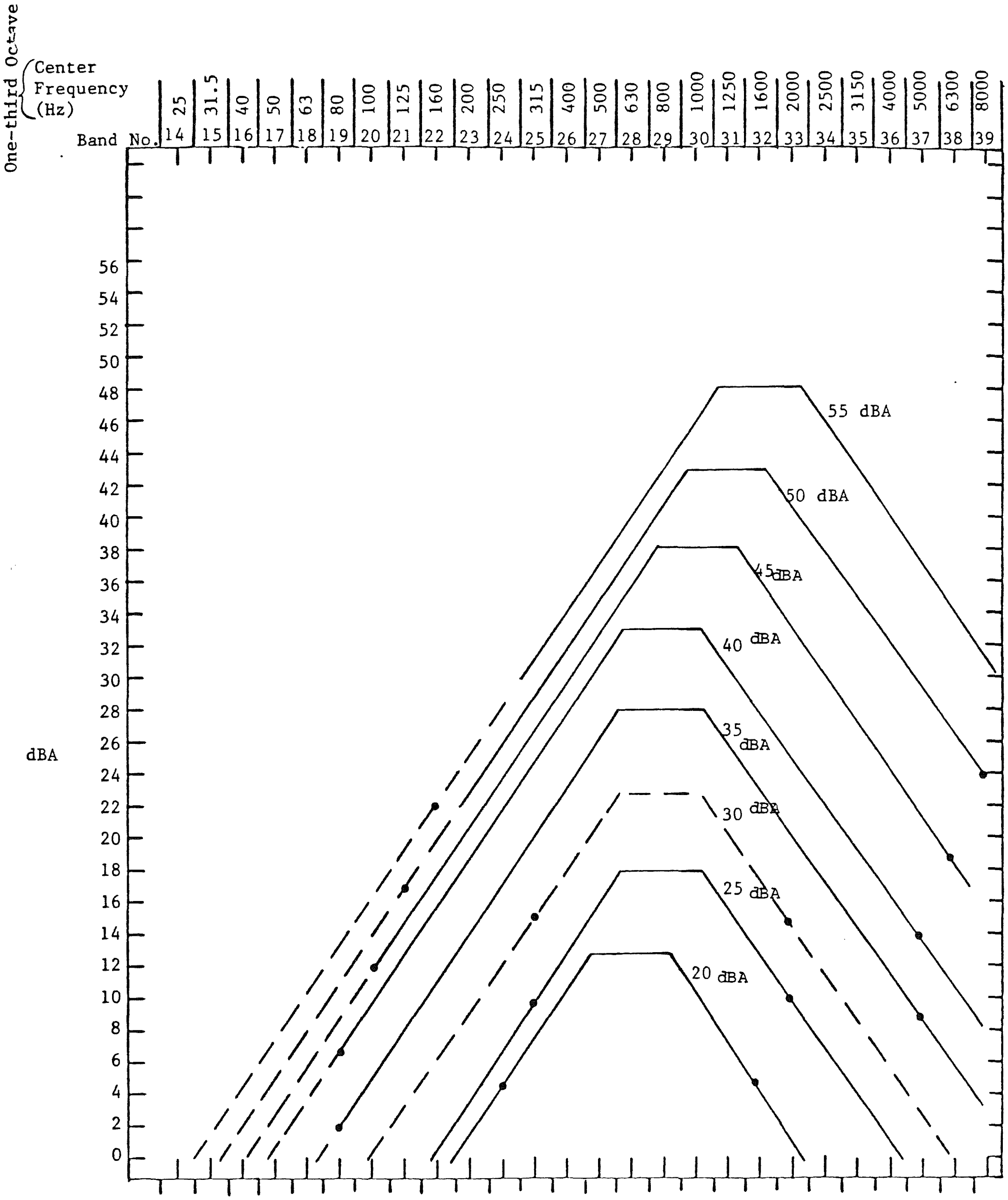
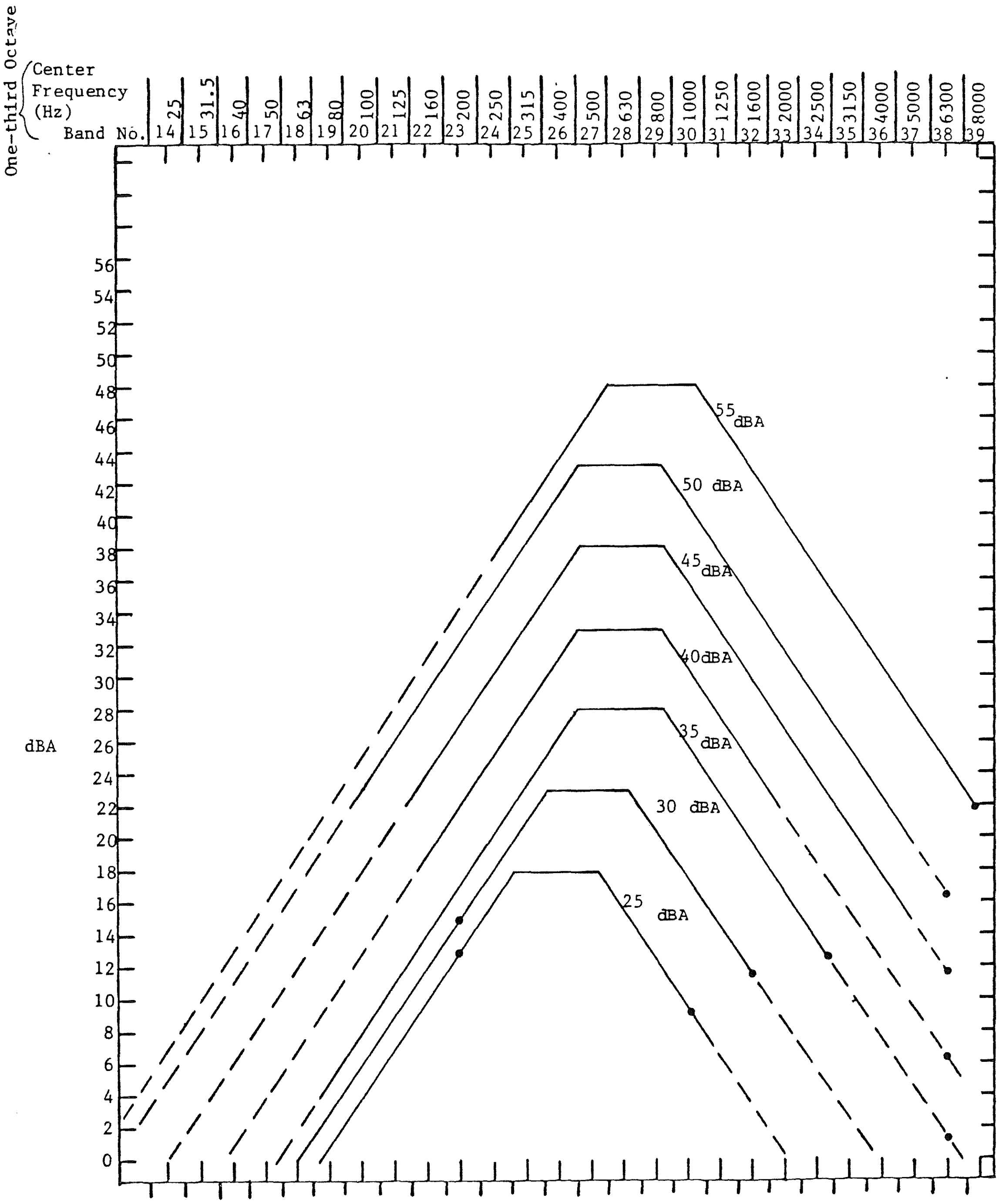


Figure 14c Smoothed Spectra Plots for Winter-Birch Stands



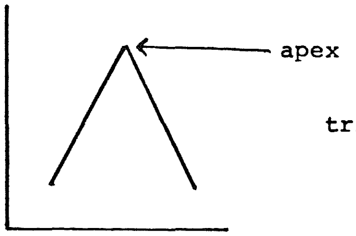
data fit the smoothed curve plus or minus three dBA. The dashed portion, on the other hand, represents an error of greater than three. (The actual data were usually higher than the dashed line indicates.)

Summer spectral plots consisted of two additional vegetation stands, aspen and red pine and, as mentioned, were represented in a manner different than that of the winter data. Each summer plot for full stands of trees was individually fit with a set of lines that approximated the data as closely as possible. This was done by sectioning the original data plot with two or three lines computed by the method of linear regression.

Figure 15 shows an example of how a spectral plot, was fit with a set of lines. The exact placement of the lines was determined by entering the data coordinate points into a hand calculator, (Hewlett-Packard, HP-25), programmed for linear regression. The program output gave the coordinates of each best-fit line, the slope and the correlation coefficient. From this information it was possible to plot the set of best-fit lines as well as determine the confidence limits, or how good was the fit.

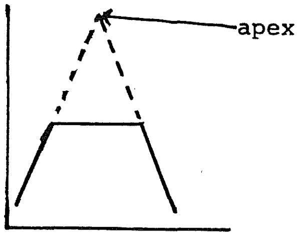
The three main shapes that resulted from the best-fit procedure are shown below with the solid line portions being the best-fit lines.

a.



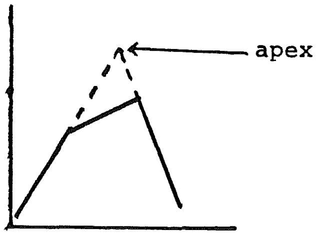
triangle

b.



truncated triangle

c.



truncated triangle with a sloped top

The statistical and graphical descriptions for one of these shapes are given for each spectral plot in the spectral summaries listed in Tables 16a through 16e. Each table is specific to the dBA intervals of only one vegetation type. All shapes are anchored by a specific apex point, the coordinates of which are listed in the tables. For shape "a," this point is an actual data value, whereas for "b" and "c," it is the intersection of the two main slopes if they were allowed to extend. Listed next in the tables are the number of Y values, or dBA, below the

Figure 15 Best fit lines to actual data for summer Black Spruce Stands- 30 dBA

Total Energy in Bands 20 to 38= 29.66 dBA

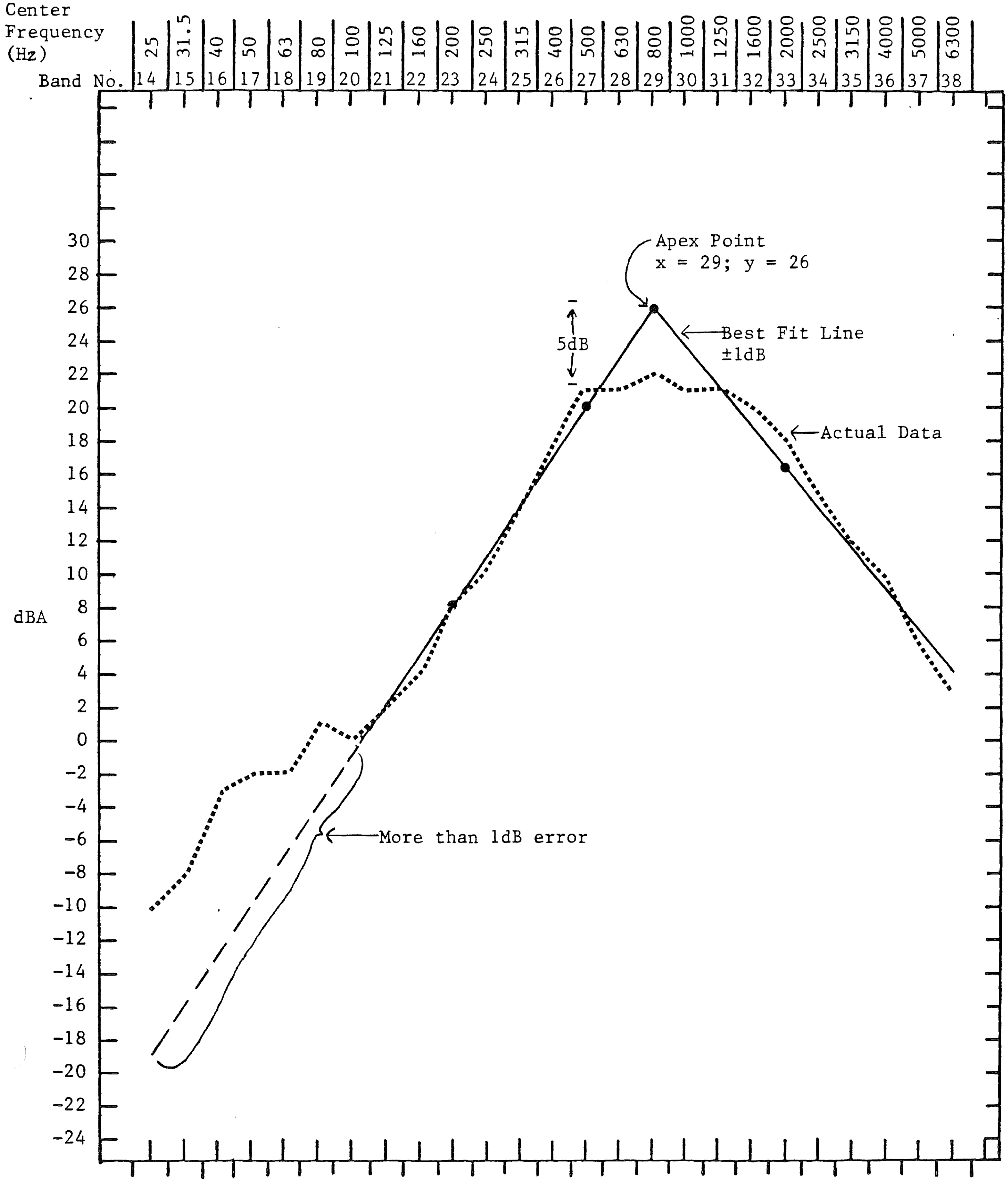


TABLE 16a

SUMMER JACKPINE SPECTRAL SUMMARY

dBA	APEX X	POINT Y	Trunk Intersection Point # dBs Below APEX POINT	BANDS Used to Fit Line	TOTAL Energy in Bands Used	SLOPE	δ
	BAND#	dBA					
50	29	44	0	21-29	50.78	3.52	.87
				29-38		-1.14	.61
45	29	40	2	21-29	45.28	3.57	1.17
				29-30			
				30-38		-1.73	.96
40	28-29	35	2	21-28	41.23	3.57	1.06
				28-30			
				30-38		-1.43	1.16
35	27	26	0	21-27	34.95	3.82	1.55
				27-38		-0.34	.88
30	27-28	27	6	20-26	30.23	4.04	1.78
				26-31			
				31-38		-1.71	1.06
25				NO DATA			
20				NO DATA			
15	27-28	7	0	14-28		1.64	4.13
				28-38		-1.18	.56

TABLE 16b

SUMMER RED PINE SPECTRAL SUMMARY

dBA	APEX X	POINT Y	Trunk Point # dBs Below APEX POINT	BANDS Used to Fit Line	TOTAL Energy in Bands Used	SLOPE	δ
60	30	54	0	20-29 31-38	60.58	2.96 -1.58	1.28 1.06
55	29-30	49	0	20-29 31-38	55.08	3.32 -1.48	0.98 0.63
50	28	44	3	21-27 27-30 30-38	49.46	4.07 1.63 -1.43	.88 ±0 .80
45	28	40	3	21-27 27-29 31-38	44.93	4.21 1.63 -1.88	.91 ±0 .66
40	28	35	2	21-27 27-29 29-38	40.04	4.29 -- -1.77	0.66 ±1 0.54
35	38	31	6	21-27 27-31 31-38	34.89	3.82 -- -1.43	.59 ±1 1.10
30	28-29	25	5	22-27 27-31 31-38	29.51	3.37 -- 1.68	.90 1.00 1.37
25	28-29	18	3	20-27 27-30 30-38	24.08	2.46 -- -1.62	1.45 ±0 .78

TABLE 16b (Cont.)

SUMMER RED PINE SPECTRAL SUMMARY

dBA	APEX X	POINT Y	Trunk Point # dBs Below APEX POINT	BANDS Used to Fit Line	TOTAL Energy in Bands Used	SLOPE	δ
20	28-29	14	3	21-27	20.01	1.36	1.89
				27-30		--	+0
				30-38		-1.63	1.23

TABLE 16c

SUMMER BIRCH SPECTRAL SUMMARY

dBA	APEX X	POINT Y	Trunk Point #dBs Below APEX POINT	BANDS Used to Fit Line	TOTAL Energy in Bands Used	SLOPE	δ
60	30	50	0	17-30 30-38	60.58	2.21 0.17	.97 1.09
55	29	42	0	19-30 30-38	54.99	2.28 0.33	1.22 1.23
50	28-29	38	0	19-30 30-38	50.14	2.69 0.28	1.16 1.22
45	29	35	0	20-29 29-38	45.45	2.57 0.07	1.11 1.40
40	28-29	30	0	21-29 29-38	40.44	2.60 -0.23	1.25 1.15
35	30	25	0	20-30 30-38	35.24	1.63 0.02	.54
30	29	23	2	21-29 29-31 31-38	30.40	2.43 -- -0.94	1.17 0.89
25	30	16	0	21-30 30-33; 37-38	23.66	2.26 -0.60	.68 .37

TABLE 16d

SUMMER BLACK-SPRUCE SPECTRAL SUMMARY

dBA	APEX X	POINT Y	Trunk Intersection Point # dBs Below APEX POINT	BANDS Used to Fit Line	TOTAL Energy in Bands Used	SLOPE	δ
	BAND#	dBA					
50	31-32	48	7	19-30	49.89	2.81	1.02
				30-34		--	±20
				34-38		-3.60	.57
45	29-30	42	6	20-27	44.84	3.37	.58
				27-31		1.10	.40
				31-38		-2.68	1.66
40	29	37	6	20-27	40.38	3.73	.65
				27-31		0.80	.44
				31-38		-2.15	.37
35	29	31	4	20-28	35.63	3.18	.87
				28-31		--	±10
				31-38		-1.99	.70
30	29	26	5	20-27	29.66	3.02	0.69
				27-31		--	±10
				31-38		-2.46	0.86
25	28-29	22	6	21-27	25.20	3.32	1.26
				27-31		--	±10
				31-38		-2.18	1.22
20	28	15	3	21-27	20.37	2.71	1.07
				27-31		--	±10
				31-38		-2.07	1.39

TABLE 16e

SUMMER ASPEN SPECTRAL SUMMARY

dBA	APEX X	POINT Y	Trunk Point # dBs Below APEX POINT	BANDS Used to Fit Line	TOTAL Energy in Bands Used	SLOPE	δ
	BAND#	dBA					
50	32	46	7	20-28 28-34 34-38	49.98	2.65 1.00 -1.20	.73 .68 1.10
45	31	40	6	20-27 27-34 34-38	45.28	2.80 0.87 -0.80	.69 .54 1.10
40	32	35	5	21-30 30-34 34-38	40.67	2.28 0.99 -1.22	1.22 .53 -1.04
35	31-32	30	4	21-30 30-34 34-38	35.38	2.14 -- -1.30	1.00 ±10 1.04
30	29	23	3	21-27 27-31 31-38	30.03	2.50 0.50 -0.93	.77 .28 .72
25	27-28	19	4	20-26 26-31 31-38	24.32	3.50 -- -1.43	1.91 ±1 1.75
20	26-27	13	0	20-26 26-38	19.05	3.89 -1.32	1.72 1.81

apex point required to intersect the truncated line. For shape "a" this number is obviously zero, since there is no trunk line. Next given are the sets of bands, or X data points, used to fit each individual line. Since shape "a" has only two sets of lines, two sets of bands are listed, whereas shapes "b" and "c" are comprised of three sets. For each line, the slope is given along with its direction, either positive or negative. Next to each slope is the standard error of estimate (δ), which denotes the goodness of fit. For practically all the plots, δ equals about one. This is indicative of a very good fit to the data, plus or minus only one dBA.

Because of the inherent irregular nature of the actual data, not all bands were used in the best-fit procedure. Thus, the energy was totalled for the bands that were used, the value of which is given in dBA in the summary tables. In almost all cases this value is a fraction of a dBA from the overall energy.

The information conveyed in the spectral summaries is sufficient for one to replicate any of the plots and know the confidence limits. Figures 17a through 17e show these plots as arranged for each vegetation type. Slopes of all lines, other than those parallel to the X-axis, are denoted on each plot along with the dBA interval. The solid lines indicate the best-fit data, and the dashed lines cover bands that were not considered in the procedure. In most cases, the actual data were usually above the dashed lines. It is not exactly clear what may have caused this low frequency effect, although it seems fairly consistent in all the data.

4.22 Spectral Analysis of Various Natural Sounds

Up to this point, the results section has concerned itself with analysis of residual sounds, which were assumed to be a result of wind interaction with various forms of vegetation cover. These sounds accounted for the majority of monitored sound levels, given the Gaussian character of most of the sound level distributions. However, this was not the only type of naturally produced sound observed. Sounds produced by different types of wildlife and other naturally occurring events such as thunder were observed during sound level measurements.

Examples of naturally produced sounds were analyzed for spectral content from portions of tape recordings made during each measurement. These spectral plots along with the tape number are given in Appendix K.

4.30 Artificial Noise Within the Study Area

While each sound measurement was being conducted, audibility notes of artificial sounds were recorded by the experimenter. The results of these observations were then grouped and tabulated for both monitoring seasons, no-foliage and foliage. Sites derived from all three workplans were considered for this analysis and are represented on Figure 18 by their listing number and a star to mark their locations. (A summary of major noise producers is given in Appendix L.)

In order to classify the many types of artificial noises observed, they were divided into three principal categories. Category 1 represents a type of noise that was heard quite often throughout the study area. It appeared as a low frequency rumble of machinery operating at some unknown distance. Given the location of most of the sites where this noise was observed, it is most likely that the source was local mining or logging activities. Table 19 gives a summary of the frequency of occurrence of this noise for each site and for both seasons. The first column lists the total number of measurements for every site; the second column gives the total number of measurements during which the mining - logging noise was heard; and the third column gives the percent of measurements that the noise was audible. Practically all sites that exhibit a percentage of greater than 50 are located in the central-western portion of the study region, which is where most mining and logging activities are primarily located. Figures 20a and 20b show the sites at which this noise

Figure 17a. Smoothed Spectra Plots for Summer-Jackpine Stands

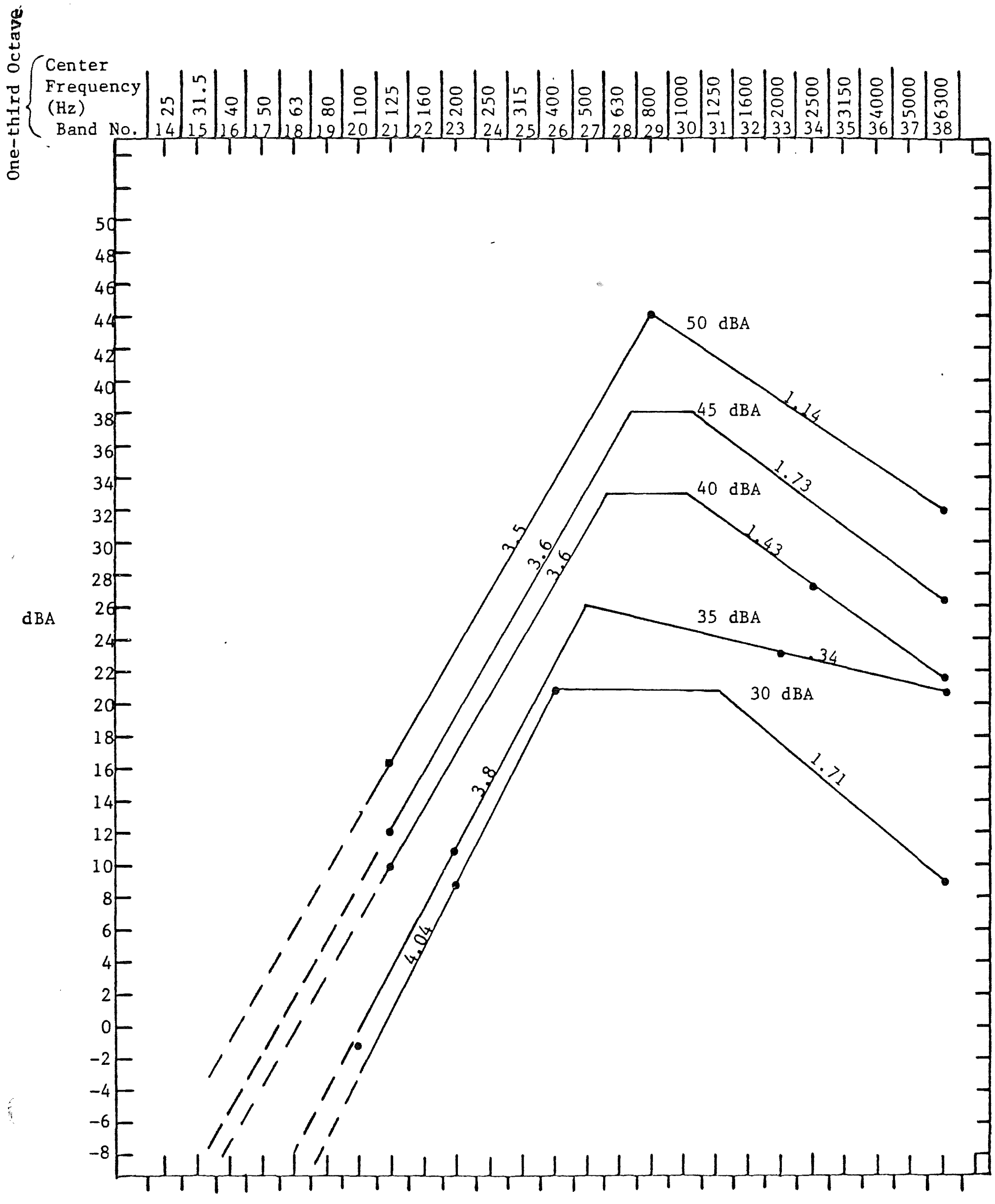


Figure 17b Smoothed Spectra Plots for Summer-Red Pine Stands

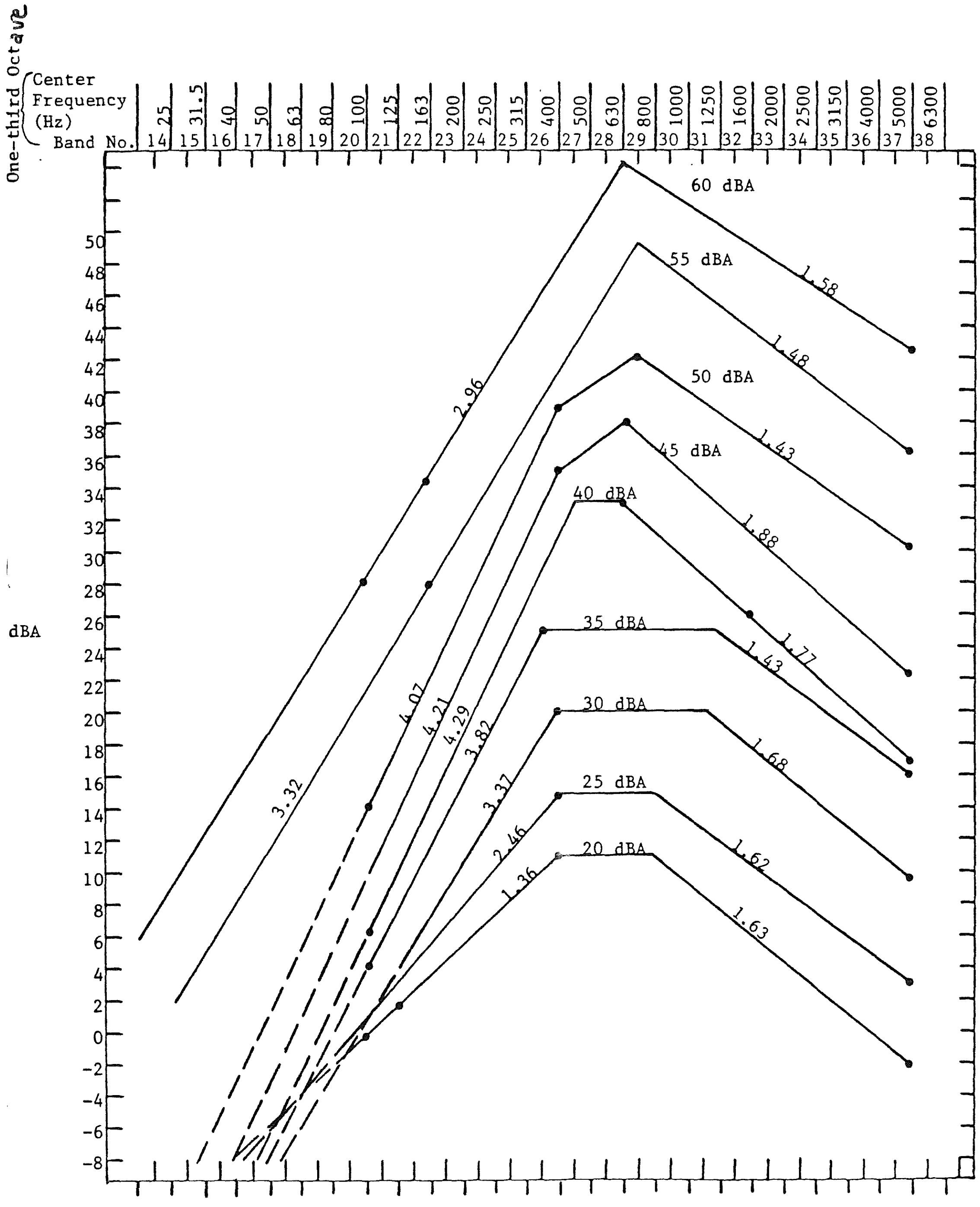


Figure 17c Smoothed Spectra Plots for Summer Birch Stands

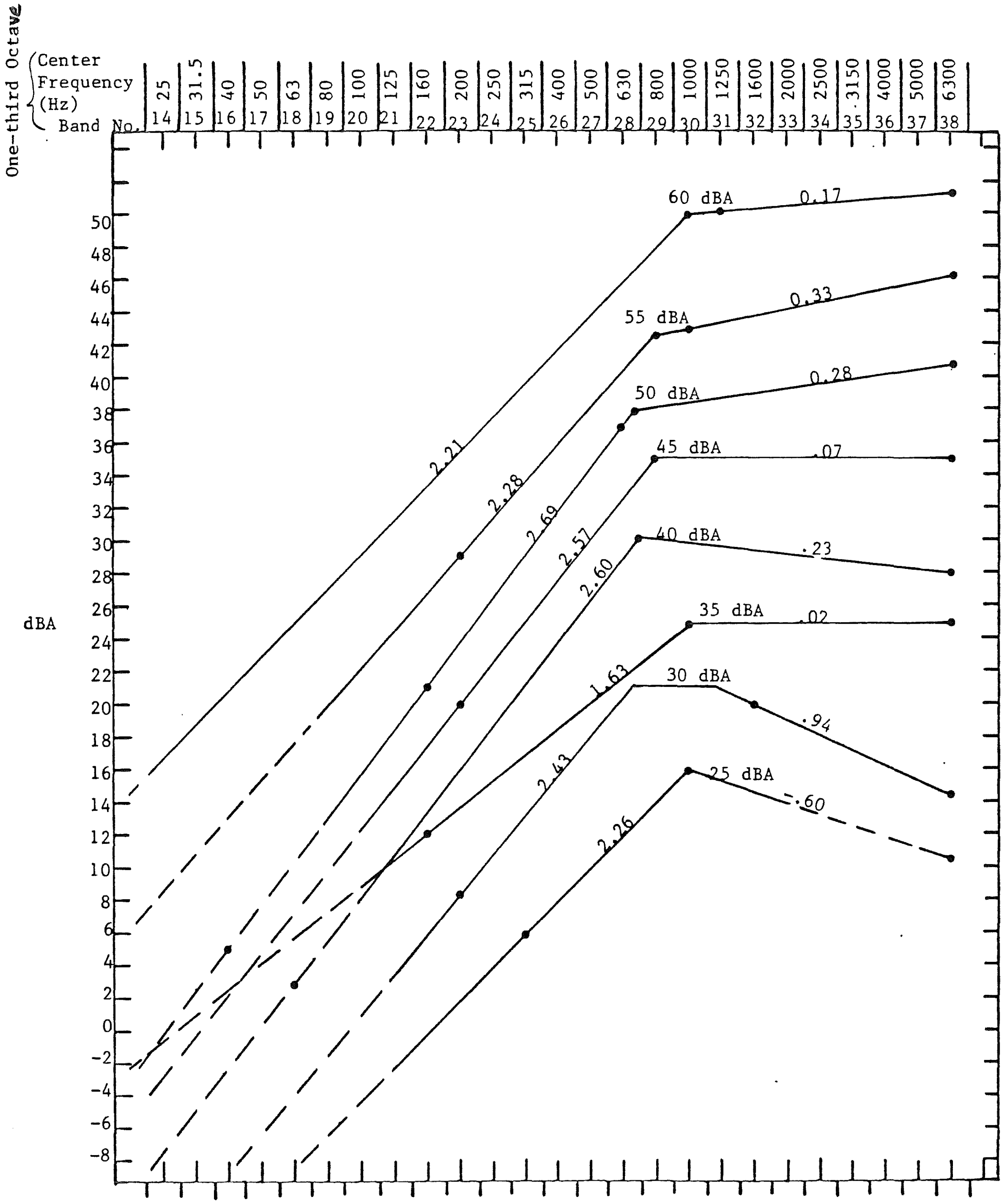


Figure 17d Smoothed Spectra Plots for Summer-Black Spruce Stands

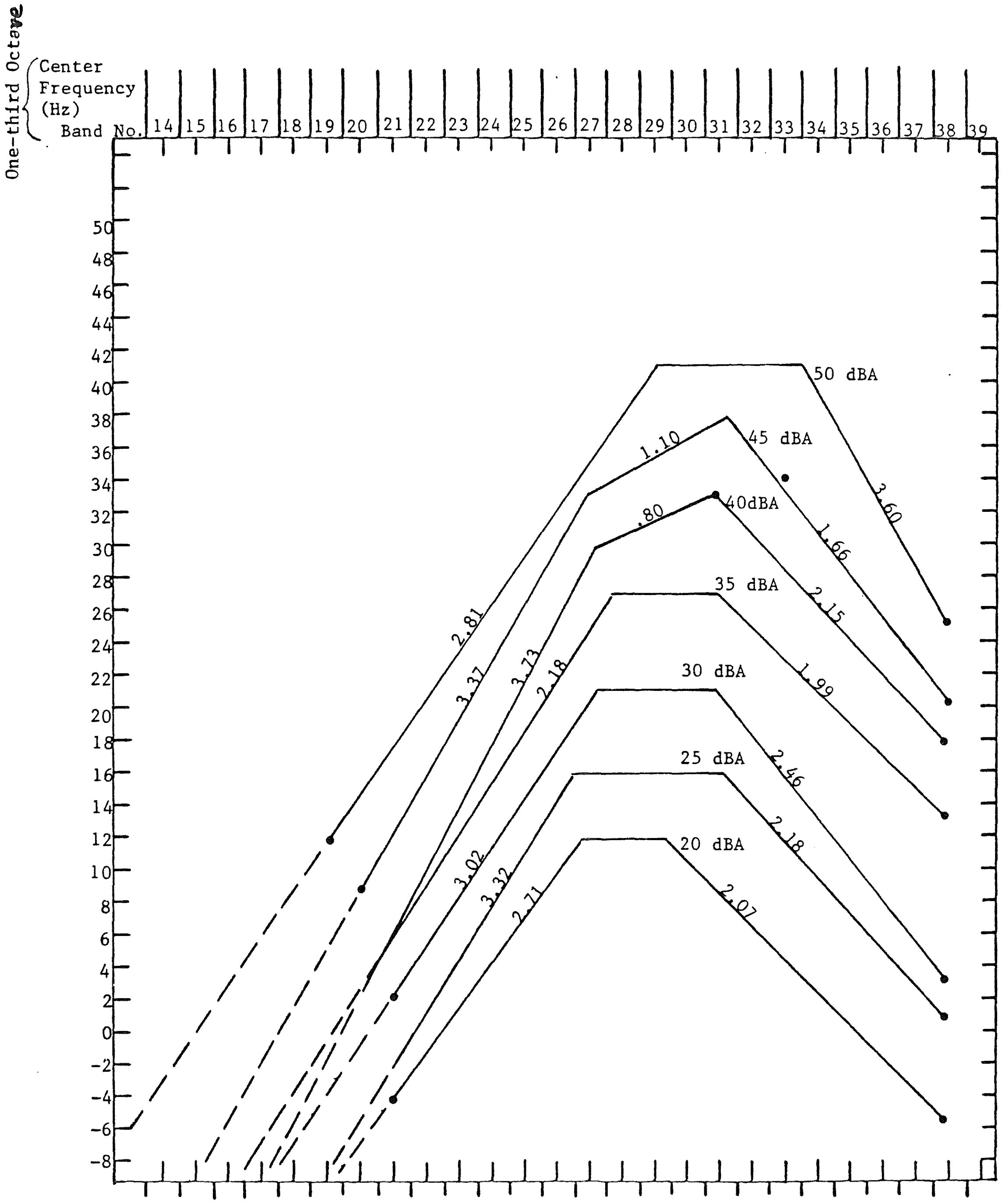
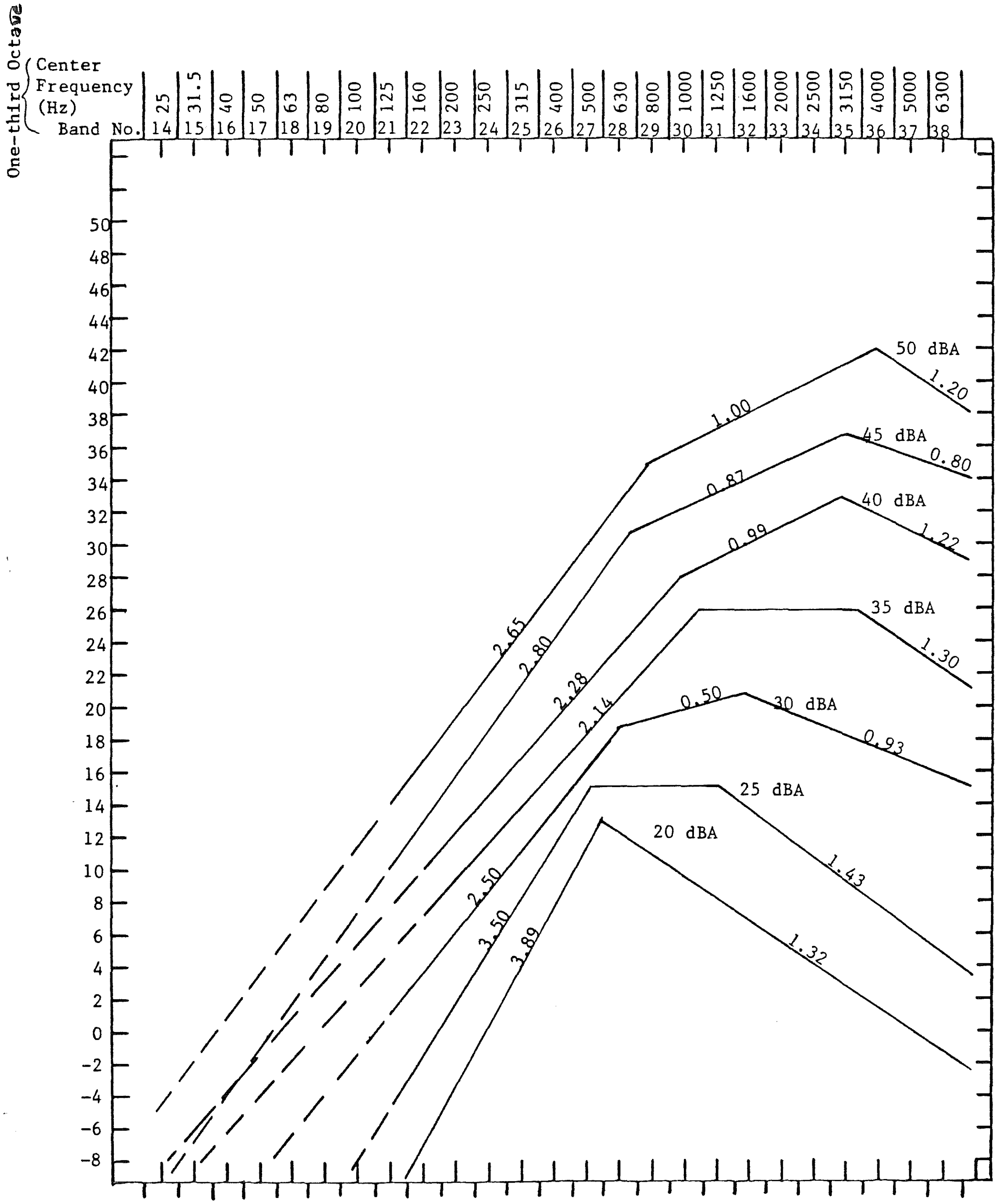


Figure 17e Smoothed Spectra Plots for Summer-Aspen Stands



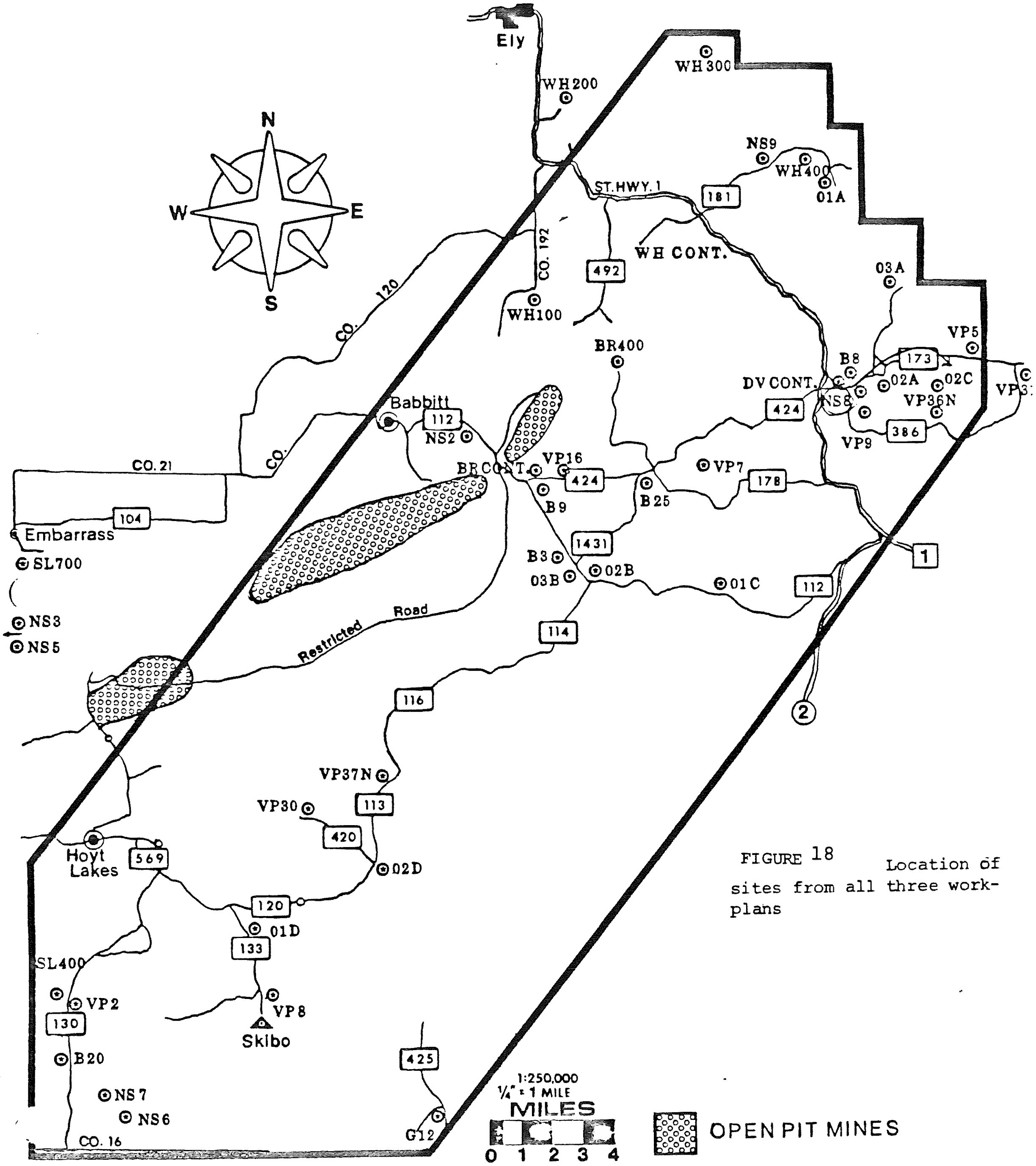


FIGURE 18 Location of sites from all three work-plans

SITE NAME	TOTAL # MSMTS		# MSMTS. OF MINING & LOGGING HEARD		% OF MEASUREMENTS MINING & LOGGING HEARD	
	FOLIAGE	NO FOLIAGE	FOLIAGE	NO FOLIAGE	FOLIAGE	NO FOLIAGE
WH 200		2		0		0
WH 300	3	3	0	0	0	0
WH 400		4		0		0
0 1 A	9		0		0	
NS-9	3		0		0	
WH CONT.		3		0		0
DV400(03A)	5		0		0	
WH 100	6	3	0	1	0	33
VP-5	4	6	0	0	0	0
VP-31	6	5	0	1	0	20
B-8	5	5	0	2	0	40
BR 400		2		0		0
NS-8	4		0		0	
DV CONT.		3		0		0
0 2 A	6		0		0	
0 2 C	6		1		17	
VP-9	3	6	0	1	0	17
VP-36N	4	4	0	1	0	25
VP-7	6	8	2	5	33	63
NS-2	1		0		0	
BR CONT.		3		3		100
VP-16	2	6	2	6	100	100
B-9	5	6	0	3	0	50
B-25	2	5	1	4	50	80
B-3	1		1		100	
0 3 B	2	3	1	3	50	100
0 2 B	2		0		0	
SL 700	2		0		0	
0 1 C	5		0		0	
NS-3	2		2		100	
NS-5	2		0		0	
VP-87N	2	4	1	3	50	75
VP-30	2	4	1	2	50	50
0 2 D	3		0		0	
0 1 D	3		0		0	
SL 400	2		0		0	
VP-2	3	4	1	3	33	75
VP-8	3	7	1	3	33	43
B-20	3		2		67	
NS-7	2		0		0	
NS-6	1		0		0	
G-12	3		0		0	

TABLE 19 Measurements during which mining-logging noise was heard for both seasons. Category 1

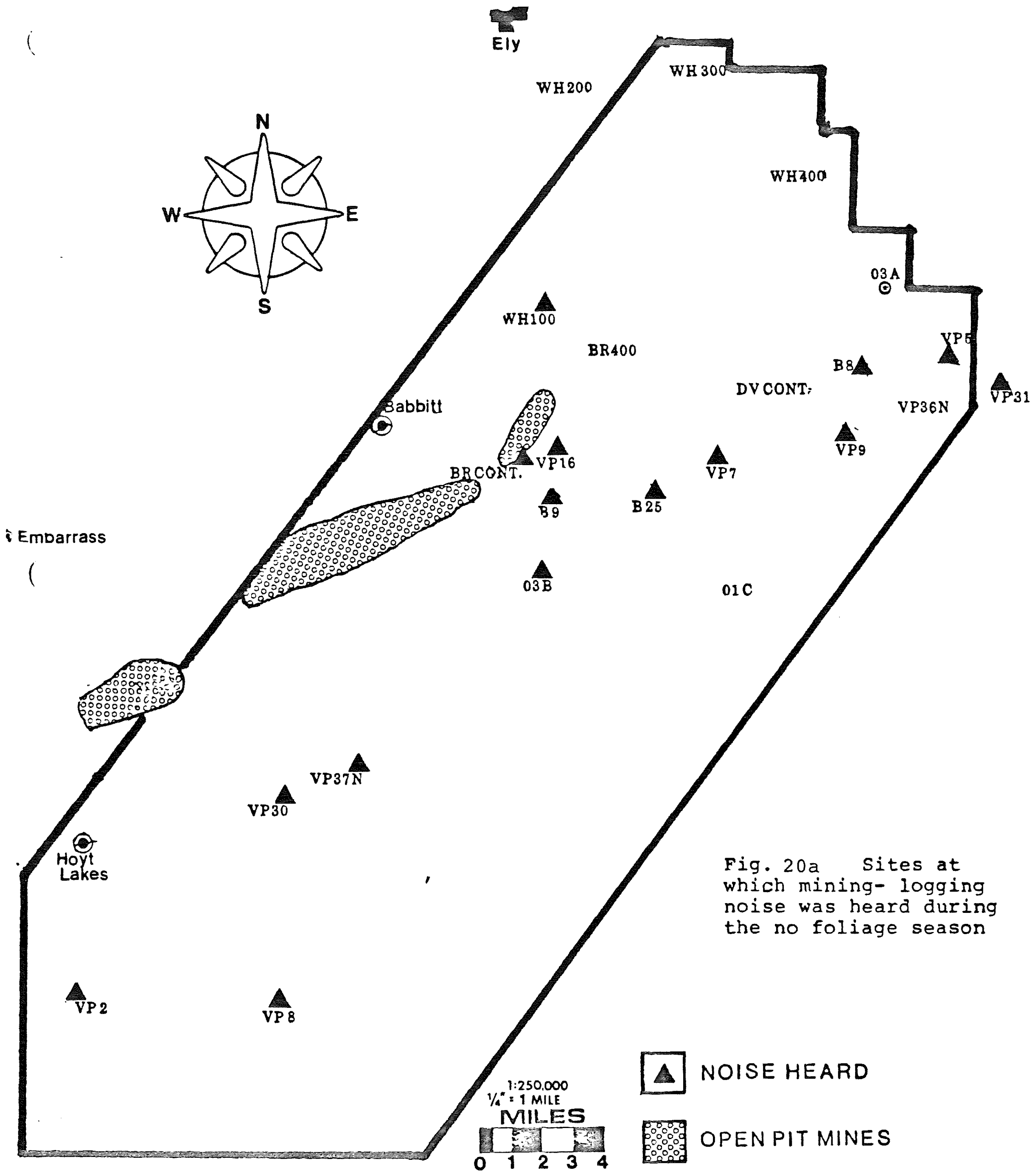


Fig. 20a Sites at which mining- logging noise was heard during the no foliage season

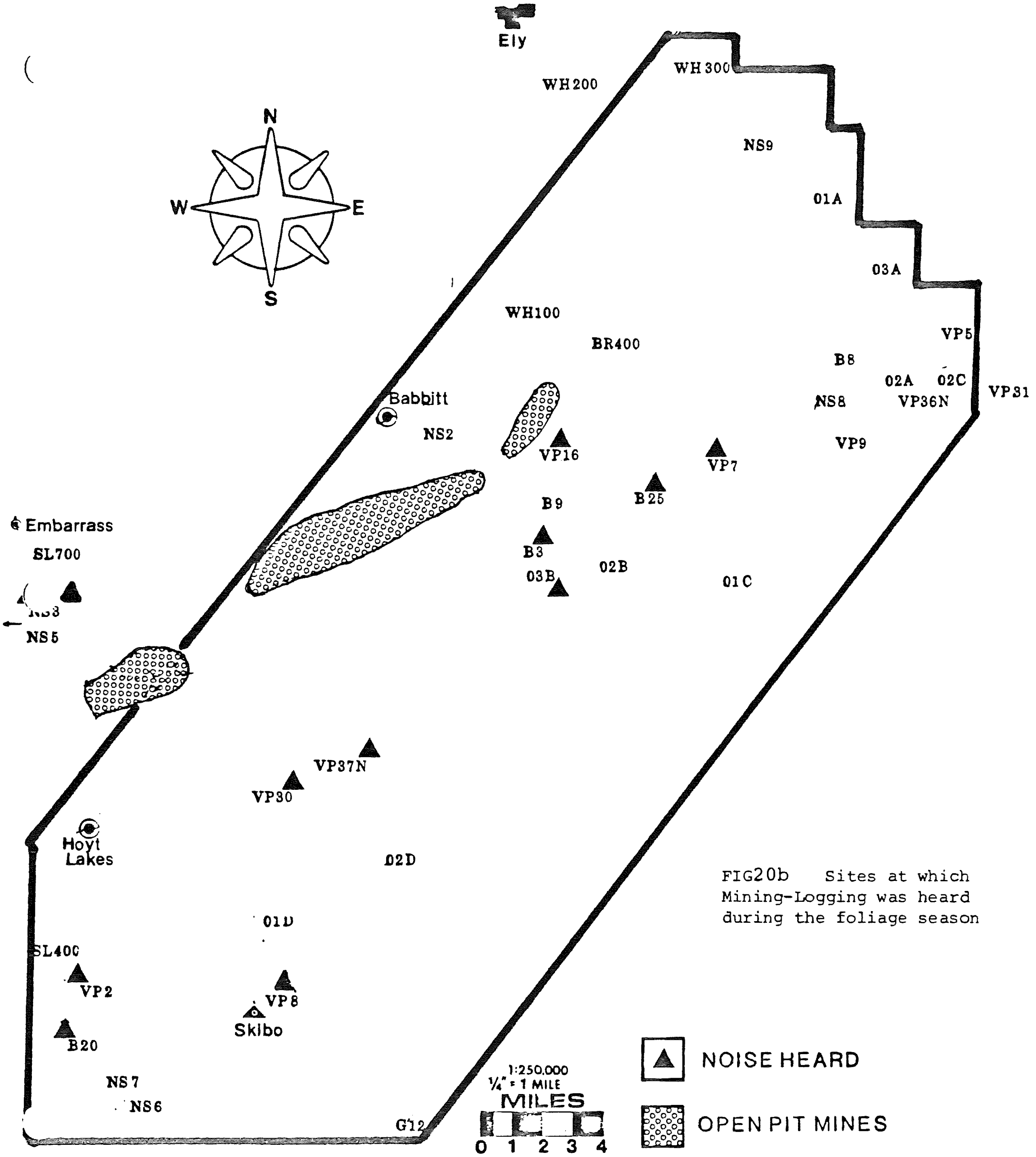


FIG20b Sites at which Mining-Logging was heard during the foliage season

was observed for each season.

Category 2 is a summary of vehicle traffic that passed by every site during the course of each measurement. Most of the vehicles were either passenger cars, pickup trucks, or large semi-trucks hauling cut timber out of the area. Other vehicles that were observed included motorcycles, and snowmobiles. These vehicle pass-bys were totalled for four time periods and along with the total measurements of each period are given in Tables 21a and 21b for each season. In the last column of each table the total number of vehicles observed, and the total hours of data at each site along with the average vehicles per hour are given. This latter figure was simply calculated by dividing the total vehicles by the total hours of data.

Data tabulated in Category 3 represents all other types of artificial noise observed. The three principal types of noise resulted from small aircraft, jet flyovers, and trains. Other noises, observed less frequently, were from chain saws, gunshots, the Linde Oxygen Plant (located in the central portion of the region), blasts, and periodic sirens, presumably from the mines. Tables 22a and 22b show the data summarized for each season and for all sites. Data is presented in these tables in the same manner as in the vehicle traffic tables.

In order to assess the scope of all types of artificial noise within the study area, a method was devised to rate each site as having either a high or low noise impact. For Category 1 all percentages below the mean percent were considered "low" and those above were considered "high." For Categories 2 and 3, the units per hour, given in the last column of the summary tables, were averaged. All values above the average were labeled "high" and those below the average were considered to have a "low" impact. These impact ratings are given for both seasons in Table 23 for all sites. The "index" number for Categories 2 and 3 is the average occurrence per hour. The percent given for Category 1 is the percentage of measurements that the mining/logging noise was observed.

Figures 24a and 24b show the impact rating for each site with respect to location for both seasons. The three symbols Δ, O, and □ stand for mining/logging noise (Category 1), vehicle noise (Category 2), and other artificial noise (Category 3, respectively. A blackened symbol indicates high impact; the cleared symbol represents low impact.

For both seasons, the central portion of the study region is clearly the most impacted by all three categories of artificial noise, which seems reasonable since the majority of noise-producing activities are currently located within this area. The least impacted area seems to be the extreme northeast section of the region, bordering on the Boundary Waters Canoe Area. This is as expected, given the relatively small amount of noise-producing activity presently taking place within that tract of land.

4.31 Spectral Analysis of Artificial Noise

Various types of artificial noise, recorded at field monitoring stations, were analyzed for spectral content at the Moorhead State University Acoustics Laboratory. From the audibility notes, taken during all field measurements, specific events were isolated on tape, "A" weighted, and played through a third octave band analyzer for a one-eighth second averaging time (See Test Procedure CN-13, Appendix N). Connected to the output of the analyzer was a digital printer, which printed out dBA levels for all third octave bands between 25 and 8,000 Hz, inclusive. Data from printout sheets were then plotted on standard quarter inch graph paper (See Appendix M for all plots).

As data were played through the analyzer, the actual sounds were heard through a studio speaker while corresponding third octave levels could be seen on the display scope. Thus, peak band levels resulting from various types of noise, could be visually correlated with auditory signals played over the speaker. In this way, it was possible to observe when segments of artificial noise would rise above the normal background levels.

SITE NAME	0500-1000					1000-1300					1300-1600					1600-2000					TOTAL VEHICLES	TOTAL HOURS	VEHICLES /HOUR
	CARS	PICK -UPS	TRUCKS	OTHER	#HOURS	CARS	PICK -UPS	TRUCKS	OTHER	#HOURS	CARS	PICK -UPS	TRUCKS	OTHER	#HOURS	CARS	PICK -UPS	TRUCKS	OTHER	#HOURS			
WH 200					0					.50					1.00					0	0	1.50	0
WH 300					1.00					0	2.00				1.00	5.00				1.00	7.00	3.00	2.33
WH 400					1.00		1.00			2.00	1.00				1.00					0	2.00	4.00	.50
0 1 A																							
NS-9																							
WH CONT.	4.00				1.00	10.00				2.00					0					0	14.00	3.00	4.67
DV400(03A)																							
WH 100					1.00					1.00					0					0	0	2.00	0
VP-5					0	1.00				4.00					2.00					0	1.00	6.00	.17
VP-31					1.00					4.00					.50					0	0	5.50	0
B-8	3.00				2.00					2.00	2.00				1.00					0	5.00	5.00	1.00
BR 400					0					1.00					1.00					0	0	2.00	0
NS-8																							
DV CONT.					0	1.00				2.50					0					0	1.00	2.50	.40
0 2 A																							
0 2 C																							
VP-9					2.00					1.00				1.00	3.00					0	1.00	6.00	.17
VP-36N					1.00					2.00					1.00					0	0	4.00	0
VP-7		1.00	5.00		3.00			1.00		2.50			1.00		1.00					0	8.00	6.50	1.23
NS-2																							
BR CONT.					0	8.00				2.00	4.00		1.00		1.00					0	13.00	3.00	4.33
VP-16		2.00			1.00		3.00	3.00		1.00	3.00	4.00	4.00		4.00					0	19.00	6.00	3.17
B-9		2.00	1.00		2.00		2.00	1.00		3.00	1.00		2.00		1.00					0	9.00	6.00	1.50
B-25	4.00		1.00		2.00			2.00		2.00		3.00	2.00	2.00	1.00					0	14.00	5.00	2.80
B-3					.50																		
0 3 B			1.00							0					1.00					1.00	1.00	2.50	.40
0 2 B																							
SL 700																							
0 1 C																							
NS-3																							
NS-5																							
VP-87N	1.00				3.00			1.00		1.00					0					0	2.00	4.00	.50
VP-30					1.00					2.00		2.00			1.00					0	2.00	4.00	.50
0 2 D																							
0 1 D																							
SL 400					2.00	1.00				1.50					0					0	2.00	3.50	.57
VP-2	1.00				1.00					3.00	1.00				3.00					0	1.00	7.00	.14
VP-8																							
B-20																							
NS-7																							
NS-6																							
G-12																							

TABLE 21a Vehicle traffic that passed by sites during the no-foliage season

Category 2

SITE NAME	0500-1000					1000-1300					1300-1600					1600-2000					TOTAL VEHICLES	TOTAL HOURS	VEHICLES /HOURS
	CARS	PICK-UPS	TRUCKS	OTHER	#HOURS OF DATA	CARS	PICK-UPS	TRUCKS	OTHER	#HOURS OF DADA	CARS	PICK-UPS	TRUCKS	OTHER	#HOURS OF DATA	CARS	PICK-UPS	TRUCKS	OTHER	#HOURS OF DATA			
WH 200																							
WH 300	7.00				1.50	4.00				1.00	2.00				1.00	5.00				1.00	18.00	4.50	4.00
WH 400																							
0 1 A					1.50		2.00			1.00	2.00		2.00		2.00	2.00		2.00		1.50	10.00	6.00	1.67
NS-9					1.00					0	2.00				2.00					0	2.00	3.00	.67
WH CONT.																							
DV400(03A)					.50					2.00					0					.50	0	3.00	0
WH 100					1.00					0	3.00	1.00			2.50					1.00	4.00	4.50	.89
VP-5	1.00				1.00	1.00		2.00		1.00			2.00		2.00					0	6.00	4.00	1.50
VP-31					1.50					2.50					.50					0	0	4.50	0
B-8	1.00	1.00			1.00					0	5.00	1.00	4.00	1.00	4.00					0	13.00	5.00	2.60
BR 400																							
NS-8		2.00			1.00	4.00		5.00		2.00	1.00				1.00					0	12.00	4.00	3.00
DV CONT.																							
0 2 A					.50					.50					.50	1.00				1.50	1.00	3.00	.33
0 2 C					.50					1.25					1.00					.50	0	3.25	0
VP-9					1.00					1.00		3.00			1.00					0	3.00	3.00	1.00
VP-36N					1.00					1.50					1.00					0	0	3.50	0
VP-7	1.00				.50	2.00		1.00		4.00					.50					0	4.00	5.00	.80
NS-2					0	23.00	21.00	5.00	13.00	2.50					0					0	62.00	2.50	24.80
BR CONT.																							
VP-16			1.00		1.00					0	4.00	4.00	1.00		2.00					0	10.00	3.00	3.33
B-9			2.00		1.00	1.00	4.00			1.00	3.00	3.00	5.00	3.00	3.00					0	21.00	5.00	4.20
B-25					0					0					1.50					0	0	1.50	0
B-3					0	1.00	1.00			1.00	3.00	2.00	2.00		2.00					0	9.00	3.00	3.00
0 3 B					0		1.00	3.00		2.00					1.00					0	4.00	3.00	1.33
0 2 B			2.00		.50					.50					0					0	2.00	1.00	2.00
SL 700					0	9.00	2.00			1.00	19.00	3.00	1.00		1.00					0	34.00	2.00	17.00
0 1 C	2.00		1.00		.50		2.00			2.50					0					0	5.00	3.00	1.67
NS-3					0	1.00	2.00			1.00					1.00					0	3.00	2.00	1.50
NS-5					0					1.00					1.00					0	0	2.00	0
VP-87N					0		1.00			1.00					0			3.00		1.00	4.00	2.00	2.00
VP-30					0					1.00					1.00					0	0	2.00	0
0 2 D	1.00				.50			1.00		.50					0					0	2.00	1.00	2.00
0 1 D					.50					.50					0					.50	0	1.50	0
SL 400					0					2.00					0					0	0	2.00	0
VP-2					0					1.00	2.00				.50					0	2.00	1.50	1.33
VP-8					0					0					2.00					1.00	0	3.00	0
B-20					0		5.00			1.00					1.50					0	5.00	2.50	2.00
NS-7					0					0					2.00					0	0	2.00	0
NS-6					0					0					1.00					0	0	1.00	0
G-12					0	12.00	7.00	16.00		2.50					0					0	35.00	2.50	14.00

TABLE 21b Vehicle traffic that passed by sites during the foliage season.

Category 2

SITE NAME	0500-1000					1000-1300					1300-1600					1600-2000					TOTAL # NOISES	TOTAL # HOURS DATA	NOISE/HR.
	PLANE	JET	TRAIN	OTHER	# HOURS DATA	PLANE	JET	TRAIN	OTHER	# HOURS DATA	PLANE	JET	TRAIN	OTHER	# HOURS DATA	PLANE	JET	TRAIN	OTHER	# HOURS DATA			
WH 200					0	3.00				.50	6.00				1.00	1.00				0	9.00	1.50	6.00
WH 300					1.00					0					1.00					1.00	1.00	3.00	.33
WH 400					1.00	2.00				2.00				1.00	1.00					0	4.00	4.00	1.00
0 1 A																							
NS-9																							
WH CONT.	1.00				1.00	1.00				2.00					0					0	2.00	3.00	.67
DV400(03A)																							
WH 100		1.00			1.00				1.00	1.00				0	0					0	2.00	2.00	1.00
VP-5					0	8.00				4.00		1.00			2.00					0	9.00	6.00	1.50
VP-31		6.00			1.00	6.00			1.00	4.00					.50					0	13.00	5.50	2.36
B-8					2.00	1.00				2.00	1.00	1.00		1.00	1.00					0	4.00	5.00	.80
BR 400					0					1.00	1.00	2.00			1.00					0	3.00	2.00	1.50
NS-8																							
DV CONT.					0	1.00	3.00			2.50					0					0	4.00	2.50	1.60
0 2 A																							
0 2 C																							
VP-9					2.00					1.00	5.00			1.00	3.00					0	6.00	6.00	1.00
VP-36N	1.00				1.00				1.00	2.00					1.00					0	2.00	4.00	.50
VP-7	2.00				3.00	2.00			1.00	2.50					1.00					0	5.00	6.50	.77
NS-2																							
BR CONT.					0				8.00	2.00	3.00			1.00	1.00					0	12.00	3.00	4.00
VP-16	2.00		2.00		1.00					1.00	1.00				4.00					0	5.00	6.00	.83
B-9	3.00		1.00	3.00	2.00	2.00		1.00	5.00	3.00				1.00	1.00					0	16.00	6.00	2.67
B-25	1.00			2.00	2.00				2.00	2.00					1.00					0	5.00	5.00	1.00
B-3																							
0 3 B				1.00	.50					0	1.00		3.00	3.00	1.00					1.00	8.00	2.50	3.20
0 2 B																							
SL 700																							
0 1 C																							
NS-3																							
NS-5																							
VP-87N	5.00	5.00	2.00	1.00	3.00			1.00	1.00	1.00					0					0	15.00	4.00	3.75
VP-30	1.00		1.00		1.00	2.00		1.00	3.00	2.00	1.00				1.00					0	9.00	4.00	2.25
0 2 D																							
0 1 D																							
SL 400																							
VP-2			1.00		2.00				1.00	1.50					0					0	2.00	3.50	.57
VP-8				1.00	1.00	5.00	1.00		4.00	3.00	1.00	1.00		1.00	3.00					0	14.00	7.00	2.00
B-20																							
NS-7																							
NS-6																							
G-12																							

TABLE 22a Other types of artificial noise observed at sites during the no-foliage season

Category 3

SITE NAME	0500-1000					1000-1300					1300-1600					1600-2000					TOTAL # NOISES	TOTAL # HOURS DATA	NOISE/HR.
	PLANE	JET	TRAIN	OTHER	#HOURS DATA	PLANE	JET	TRAIN	OTHER	#HOURS DATA	PLANE	JET	TRAIN	OTHER	#HOURS DATA	PLANE	JET	TRAIN	OTHER	#HOURS DATA			
WH 200																							
WH 300	1.00				1.50	2.00	1.00			1.00					1.00					1.00	4.00	4.50	.89
WH 400																							
0 1 A	1.00				1.50	3.00				1.00	2.00				2.00	3.00				1.50	9.00	6.00	1.50
NS-9	6.00				1.00	3.00				0	3.00				2.00					0	12.00	3.00	4.00
WH CONT.																							
DV400(03A)	2.00				.50					2.00					0	2.00	1.00			.50	5.00	3.00	1.67
WH 100	9.00				1.00	3.00				0	9.00				2.50	6.00				1.00	27.00	4.50	6.00
VP-5					1.00					1.00					2.00					0	0	4.00	0
VP-31					1.50	1.00	1.00			2.50	1.00				.50					0	3.00	4.50	.67
B-8					1.00					0	1.00	5.00			4.00					0	6.00	5.00	1.20
BR 400																					1.00		
NS-8					1.00	1.00				2.00					1.00					0	1.00	4.00	.25
DV CONT.																							
0 2 A					.50	2.00				.50					.50					1.50	2.00	3.00	.67
0 2 C	1.00				.50	5.00				1.25					1.00					.50	6.00	3.25	1.85
VP-9					1.00		4.00			1.00	1.00	5.00			1.00					0	10.00	3.00	3.33
VP-36N	1.00				1.00	1.00	1.00			1.50		1.00		1.00	1.00					0	5.00	3.50	1.43
VP-7					.50	1.00				4.00					.50					0	1.00	5.00	.20
NS-2					0	7.00		1.00	19.00	2.50					0					0	27.00	2.50	10.80
BR CONT.																							
VP-16	4.00			2.00	1.00					0	8.00	2.00		1.00	2.00					0	17.00	3.00	5.67
B-9	1.00		1.00	2.00	1.00	1.00		2.00	1.00	1.00	7.00	1.00		4.00	3.00	1.00			1.00	0	22.00	5.00	4.40
B-25					0					0	1.00	1.00			1.50					0	2.00	1.50	1.33
B-3					0					1.00	4.00	1.00		4.00	2.00					0	9.00	3.00	3.00
0 3 B					0	6.00	2.00	1.00	2.00	2.00	3.00	1.00		2.00	1.00					0	17.00	3.00	5.67
0 2 B				1.00	.50	1.00				.50					0					0	3.00	1.00	3.00
SL 700					0	1.00			1.00	1.00					1.00					0	2.00	2.00	1.00
0 1 C					.50	3.00			1.00	2.50					0					0	4.00	3.00	1.33
NS-3					0	1.00			2.00	1.00	2.00	1.00			1.00					0	6.00	2.00	3.00
NS-5					0				2.00	1.00	2.00				1.00					0	4.00	2.00	2.00
VP-87N					0	2.00			1.00	1.00					0	1.00				1.00	4.00	2.00	2.00
VP-30									1.00	1.00	1.00			1.00	1.00					0	3.00	2.00	1.50
0 2 D					.50					.50					0					0	0	1.00	0
0 1 D					.50					.50					0	1.00			1.00	.50	2.00	1.50	1.33
SL 400					0	1.00			1.00	2.00					0					0	2.00	2.00	1.00
VP-2					0					1.00	1.00	1.00		1.00	.50					0	3.00	1.50	2.00
VP-8					0		2.00	1.00		0				2.00	2.00					1.00	5.00	3.00	1.67
B-20					0				1.00	1.00				1.00	1.50					0	2.00	2.50	.80
NS-7					0					0	1.00				2.00					0	1.00	2.00	.50
NS-6					0					0					1.00					0	0	1.00	0
G-12					0	1.00	2.00			1.00	2.50				0					0	4.00	2.50	1.60

TABLE 22b Other types of artificial noise observed at sites during the foliage season.

Category 3

SITE NAME	1. MINING-LOGGING				2. VEHICLES				3. ARTIFICIAL NOISE (other)			
	FOLIAGE		NO FOLIAGE		FOLIAGE		NO FOLIAGE		FOLIAGE		NO FOLIAGE	
	%	RATING	%	RATING	INDEX#	RATING	INDEX#	RATING	INDEX#	RATING	INDEX#	RATING
WH 200			0	LOW			0	LOW			6.00	HIGH
WH 300	0	LOW	0	LOW	4.00	HIGH	2.33		.89	LOW	.33	LOW
WH 400			0	LOW			.50	LOW			1.00	LOW
0 1 A	0	LOW			1.67	LOW			1.50	LOW		
NS-9	0	LOW			.67	LOW			4.00	HIGH		
WH CONT.			0	LOW			4.67	HIGH			.67	LOW
DV400(03A)	0	LOW			0	LOW			1.67	LOW		
WH 100	0	LOW	33	LOW	.89	LOW	0	LOW	6.00	HIGH	1.00	LOW
VP-5	0	LOW	0	LOW	1.50	LOW	.17	LOW	0	LOW	1.50	LOW
VP-31	0	LOW	20	LOW	0	LOW	0	LOW	.67	LOW	2.36	HIGH
B-8	0	LOW	40	HIGH	2.60	LOW	1.00	LOW	1.20	LOW	.80	LOW
BR 400			0	LOW			0	LOW			1.50	LOW
NS-8	0	LOW			3.00	HIGH			.25	LOW		
DV CONT.			0	LOW			.40	LOW			1.60	LOW
0 2 A	0	LOW			.33	LOW			.67	LOW		
0 2 C	17	LOW			0	LOW			1.85	LOW		
VP-9	0	LOW	17	LOW	1.00	LOW	.17	LOW	3.33	HIGH	1.00	LOW
VP-36N	0	LOW	25	LOW	0	LOW	0	LOW	1.43	LOW	.50	LOW
VP-7	33	HIGH	63	HIGH	.80	LOW	1.23	HIGH	.20	LOW	.77	LOW
NS-2	0	LOW			24.80	HIGH			10.80	HIGH		
BR CONT.			100	HIGH			4.33	HIGH			4.00	HIGH
VP-16	100	HIGH	100	HIGH	3.33	HIGH	3.17	HIGH	5.67	HIGH	.83	LOW
B-9	0	LOW	50	HIGH	4.20	HIGH	1.50	HIGH	4.40	HIGH	2.67	HIGH
B-25	50	HIGH	80	HIGH	0	LOW	2.80	HIGH	1.33	LOW	1.00	LOW
B-3	100	HIGH			3.00	HIGH			3.00	HIGH		
0 3 B	50	HIGH	100	HIGH	1.33	LOW	.40	LOW	5.67	HIGH	3.20	HIGH
0 2 B	0	LOW			2.00	LOW			3.00	HIGH		
SL 700	0	LOW			17.00	HIGH			1.00	LOW		
0 1 C	0	LOW			1.67	LOW			1.33	LOW		
NS-3	100	HIGH			1.50	LOW			3.00	HIGH		
NS-5	0	LOW			0	LOW			2.00	LOW		
VP-87N	50	HIGH	75	HIGH	2.00	LOW	.50	LOW	2.00	LOW	3.75	HIGH
VP-30	50	HIGH	50	HIGH	0	LOW	.50	LOW	1.50	LOW	2.25	HIGH
0 2 D	0	LOW			2.00	LOW			0	LOW		
0 1 D	0	LOW			0	LOW			1.33	LOW		
SL 400	0	LOW			0	LOW			1.00	LOW		
VP-2	33	HIGH	75	HIGH	1.33	LOW	.57	LOW	2.00	LOW	.57	LOW
VP-8	33	HIGH	43	HIGH	0	LOW	.14	LOW	1.67	LOW	2.00	HIGH
B-20	67	HIGH			2.00	LOW			.80	LOW		
NS-7	0	LOW			0	LOW			.50	LOW		
NS-6	0	LOW			0	LOW			0	LOW		
G-12	0	LOW			14.00	HIGH			1.60	LOW		

TABLE 23 Impact ratings for three categories of artificial noise.

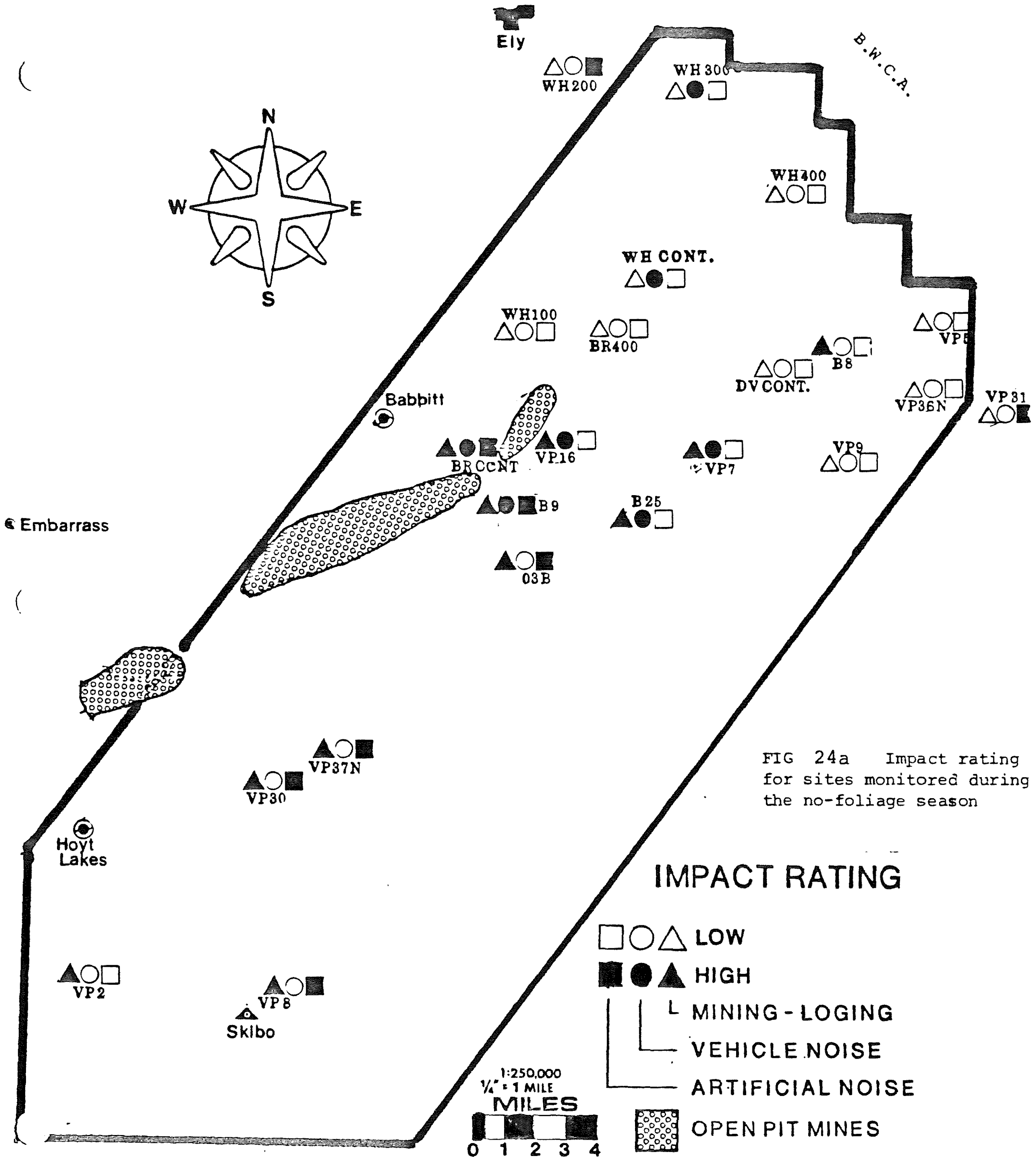


FIG 24a Impact rating for sites monitored during the no-foliage season

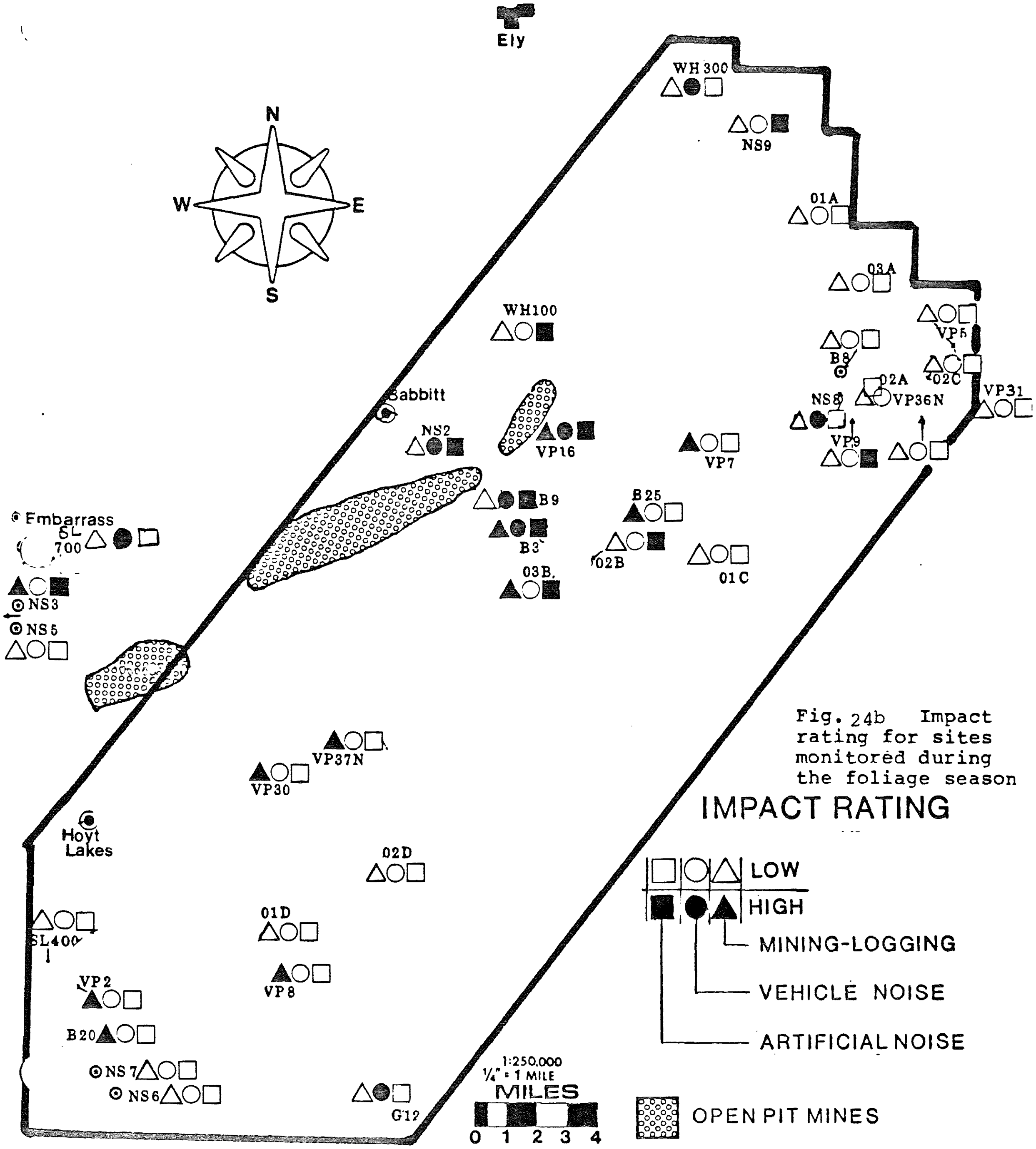


Fig. 24b Impact rating for sites monitored during the foliage season

Background sounds were characterized by printing out levels (for all third octave bands) of sixteen second segments of lulls between peaks of noise. For each tape, three segments were printed and dBA levels averaged across all bands on an energy basis. The data were then superimposed on the spectral graphs of corresponding noises. In most cases, the background plot assumes a relatively smooth shape, whereas the noise graph appears as a peak or set of peaks, giving an idea of the spectral content of the most common artificial noises monitored.

4.32 Mining-Related Noise

Many of the third octave plots showed peaks at the bands between 200 and 800 Hz, inclusive (bands 23 to 29). Specific noise sources could not always be precisely located, although it is suspected that these peaks were probably the result of local mining activities, specifically the large ore-hauling trucks. Several factors would seem to suggest that this was the case. First, only data from about 38 percent of the monitoring stations exhibited these peaks, and these sites were all closest to the mines. Second, auditory signals that resulted in the peaks appeared as the same type of noise usually associated with the diesel-electric vehicles used within the mining pit area. Third, although it was not possible to directly monitor the vehicles in question at the source, due to a worker's strike and subsequent layoff, the analysis of tapes made from similar vehicles* showed peaks within the same bands. Also, these vehicles emitted the same type of noise observed at field monitoring stations.

The mine worker's strike, that lasted from August to December of 1977, provided an opportunity to test the possibility that noise recorded at some of the monitoring sites was indeed the result of mining activities. A pre-strike and a post-strike tape were recorded at a site located about a mile and a half southeast of Erie Mining Company's Dunka Pit. This site, VP-16 - a black spruce stand, had been the location of numerous measurements prior to the strike, all of which were observed to have the distant sound of machinery, presumably from the mining operations.

Figure 25 shows the spectral plots from portions of the two tapes, ST-97B and ST-102B. Perhaps, the most manifest characteristic of the two plots is that the pre-strike tape has very pronounced peaks at 315, 400, and 630 Hz. The shape of the plot taken from the post-strike tape, however, is characterized by fewer peaks and in fact closely resembles the shape of the 20 dBA spectral plot for winter black spruce, residual sounds. A sharp peak is observed at the 63 Hz band, for this tape, which was probably due to the 60 Hz "hum" induced by an AC inverter used for that measurement.

Further testing of these tapes was conducted, in the laboratory, by playing the tapes through a band pass filter, such that only the 250, 315, and 400 Hz bands (i.e. bands that showed peaks in Tape ST-97B) were analyzed. The output of the filter was fed into the linear input mode of a Metrosonic dB-602 Sound Level Analyzer for the purpose of obtaining sound level statistics of the data. (Principally, this set-up was a modification of lab test Procedure CN-13.) Both tapes were run for a period of ten minutes and analyzed in terms of L_n values by the Metrosonic. Given in Table 26 is every tenth L_n value of the data from each tape, as analyzed with the band pass filter. Also given for each tape are the dBA levels as measured in the field. It should be pointed out that the levels, as analyzed with the filter, were "A" weighted prior to entry into the third octave analyzer.

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*The trucks that were monitored were 85 ton diesel trucks from Eveleth Taconite Company, Eveleth, Minnesota and 170 ton diesel-electric trucks from Hibbing Taconite Company, Hibbing, Minnesota. These measurements were conducted on January 19 and 20, 1978, as part of the Noise Modelling Study for the Copper-Nickel Project.

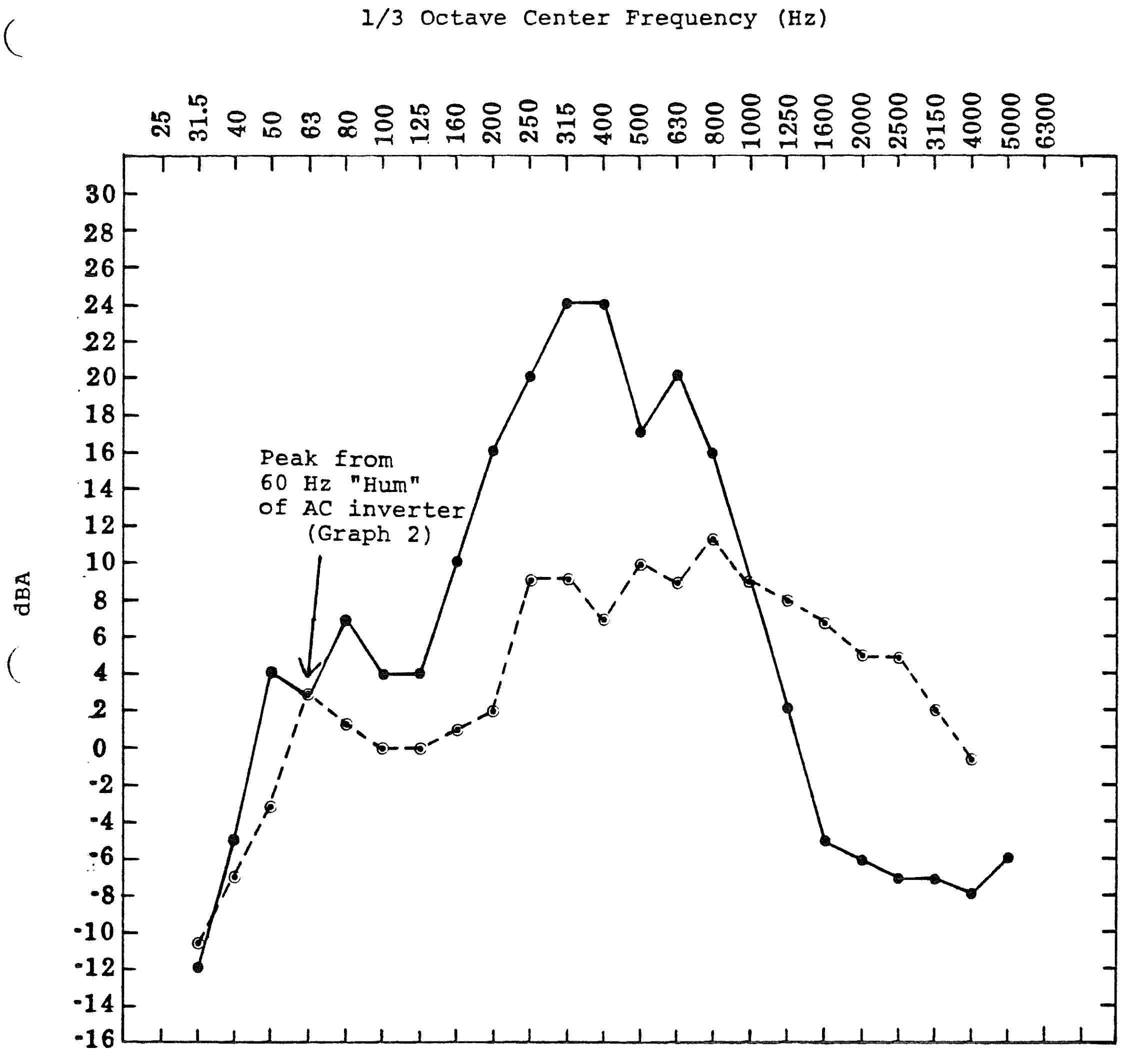


FIGURE 25
Two tapes made
at same location
before and
during strike.

●——● GRAPH 1
Tape ST-97B made
prior to strike 7/26/77
29 dBA

⊙---⊙ GRAPH 2
Tape ST-102B
made after strike 8/4/77
20 dBA

Thus, all levels are in dBA.

	Tape ST-97B Prior to Strike		Tape ST-102B After Strike	
	Levels with Band Pass Filter	Levels as Measured in Field	Levels with Band Pass Filter	Levels as Measured in Field
L10	26	27	18	32
L20	23	25	16	27
L30	22	24	16	23
L40	21	23	15	21
L50	20	23	14	20
L60	20	22	14	20
L70	19	21	13	19
L80	19	21	13	18
L90	17	20	12	17

Table 26 Sound levels (dBA) of pre and post-strike data for the 250, 315, and 400 Hz bands (band pass filter) and for all bands, i.e., no filter - as measured in the field.

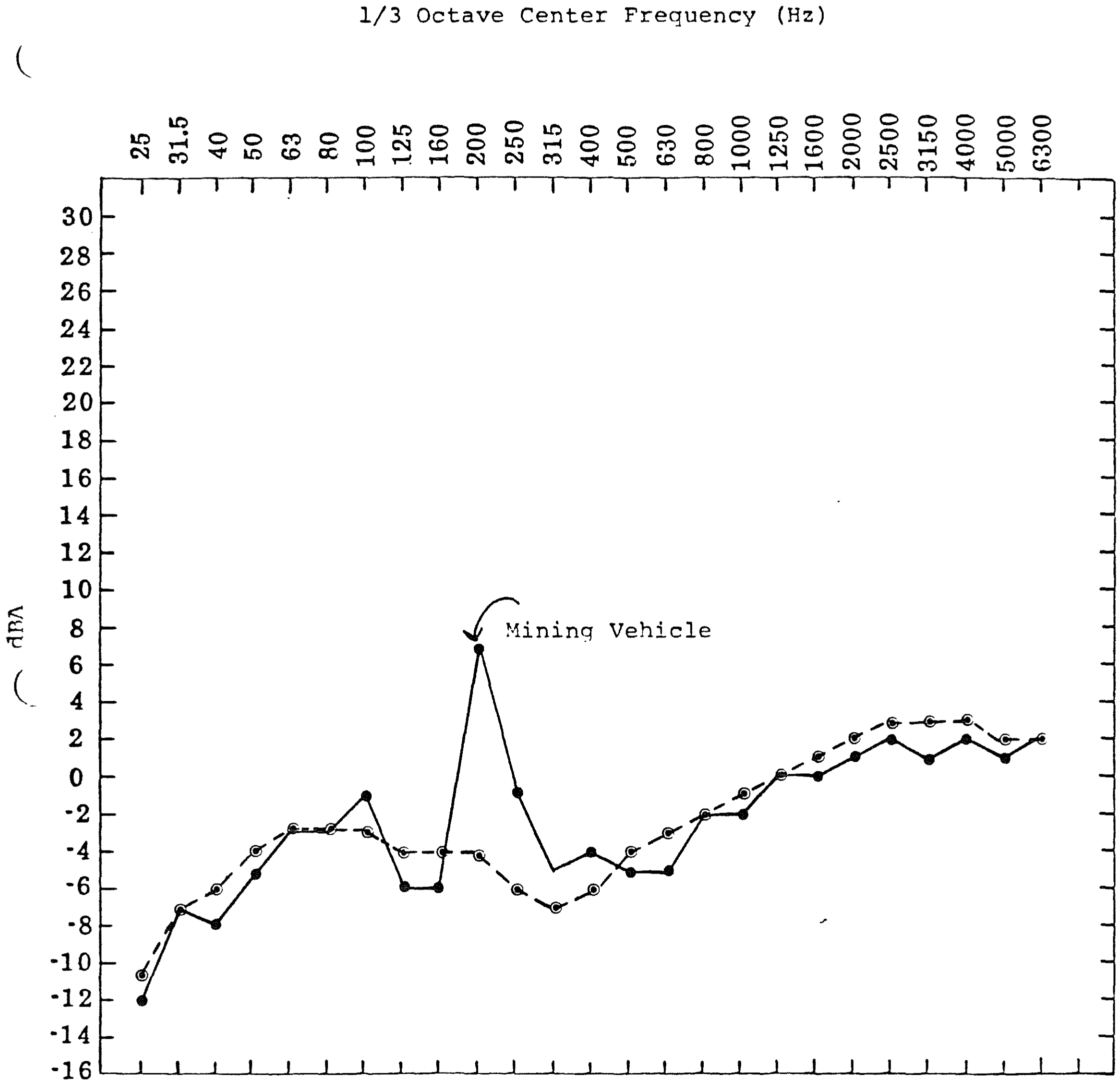
For tape ST-97B there is a difference of only about one to three dBA between the levels filtered in the lab and those measured in the field. Tape ST-102B, however, shows differences of about five to six dBA between the two conditions. This indicates that for the tape recorded while mining activities were present, ST-97B, a large amount of the total spectral energy is concentrated within the 250, 315, and 400 Hz bands, while for ST-102B this is not the case. Thus, the above test strongly suggests that the machinery-type noise experienced at site VP-16 was due to mining and had a great deal of spectral energy concentrated in third octave bands between 200 and 800 Hz. Since the same type of noise, i.e., with the same audible and spectral characteristics, was observed and measured at sites other than VP-16, it can be assumed that these sites were also within audible range of the mines.

Whether any one site was within the audible range of mining noise depended on distance from the mines, background levels, and numerous propagation conditions. At times during the monitoring study, noise, presumably from the mines, was audible at sites located relatively large distances from the actual mining operations. As an example, a measurement made on January 27, 1977, at Site B-8, a jackpine stand located about 11 miles northeast of the mines, produced an L_{50} of only 13 dBA. However, mining noise was still audible. Figure 27 is a spectral plot, third octave bands, from that measurement, which shows a segment of background levels superimposed over a segment with a peak at 200 Hz. Two points are evident from these plots. First, if the peak at 200 Hz is in fact from the mines, then given the appropriate conditions, mining noise can propagate over great distances through vegetated areas, i.e., at least 11 miles. Second, both plots in Figure 27 have the same total energy of only about 14 dBA, which should emphasize the importance of considering the spectral content of mining-related noise as opposed to the sole reliance on dBA as a measure of audibility and impact.

5.00 Discussion

Natural Residual Sound Levels

From the data presented in section 4.21, several points are evident regarding natural residual levels measured within the study area. First, the range of means for canopied vegetation stands substantially differs as a function of season. Specifically, the range broadens from 30-32 dBA for the winter months to 29-36 dBA for the summer. It is interesting to note that the lower end of both ranges stays fairly consistent



TAPE ST-5A

●——● = 14.25 dBA - mining vehicle at 200 Hz winter, about 11 miles from mine.

⊙---⊙ 13.61 dBA - background of same tape.

FIGURE 27 Two segments from same tape averaged 1/8 second - background and background with mining vehicle.

whereas the upper end rises for the summer season. This upper end increase is primarily the result of a rise in mean sound levels measured in deciduous canopied stands. Thus, as one might expect, the seasonal variable of foliage seems to significantly affect residual levels.

Further substantiation of this effect can be seen in the results of the clearcut sites, which, due to their year-round lack of foliage, can be viewed as a control. In contrast to canopied areas, clearcuts show little fluctuation in residual levels from one season to the next. In fact, the cumulative sound level distributions for these sites are practically identical for both the foliage and no-foliage seasons. Thus, given that a principal physical difference between clearcut and canopied areas is the presence of various concentrations of deciduous vegetation cover, it can be assumed that the seasonal variation observed in canopied sites is due to the presence or absence of deciduous foliage.

In order to test for differences of residual levels among various types of deciduous stands, the deciduous category was broadened at the outset of the summer monitoring season from only birch stands to include birch, aspen and sapling aspen. The data indicate, however, that this was unnecessary as only a 1 to 2 dBA difference is noted among these three types for the summer season. Further, the fact that sapling aspens, which are only about 3 meters tall, produce the same levels as mid-age to mature stands seems to indicate that age of deciduous vegetation is not necessarily an important factor in the residual levels within those stands. Thus, for the months of full foliage, there appears to be a rather distinct uniformity in background sound levels in deciduous vegetation stands within the study area.

Coniferous stands, on the other hand, appear to be characterized by greater variability of mean sound levels. For example, three types of conifers, black spruce, redpine, and jackpine, which were measured during the foliage season all exhibit very different results. Black spruce stands have a mean level of 29 dBA and a standard deviation of 11.7, while the jackpine sites produce a mean of 34 dBA with a standard deviation of 6.9. These differences are probably due to the varying concentrations of aspen and birch mixed in with these coniferous trees. As the results indicate, deciduous trees produce levels in response to a given wind which appear to be louder than levels of conifers. Thus, because there were few pure-type coniferous stands, the mixed-in birch and aspen at times probably dominated the measurements. It is conceivable that further study could be done on this issue to assess how given percentages of mixed-in deciduous foliage affect residual levels within coniferous stands. The variability of sound level distributions in coniferous areas could then be accounted for by correlating mean sound levels with various percent concentrations of deciduous trees.

The analysis presented in section 4.20 describes a functional relationship between wind speeds and resulting residual sound levels. This procedure is based on the assumption that a direct relationship exists between wind in the trees and resultant sound levels, and this assumption is based primarily upon observations. Although the sound levels calculated as a function of wind speed look reasonable when compared to actual monitored levels, the need to empirically establish the exact nature of the relationship is still quite evident. It is possible that this relationship is in actuality an exponential one. One point that would seem to indicate this is that the linear formula, described in this report, cannot account for extreme winds, either high or low. A very high wind, for example, would predict sound levels which would be rather unrealistic for a wooded area. Thus, at some point, the true relationship levels off. Time and budgetary restrictions of this project did not allow for testing to determine the specific nature of the wind-sound relationship, although in principle it would not be difficult to ascertain. Each site would need to be equipped with a wind tower as well as 24-hour sound monitoring instrumentation, both of which would simultaneously sample data on a continual basis. In addition, the above procedure would characterize nighttime levels, which in this study was not done, but is an important aspect of the acoustical environment within the study area. Inasmuch as the wind-sound relationship holds constant for the 24-hour cycle, sound levels for nighttime hours could be calculated using the formulas derived by this project given the appropriate wind statistics. However, a more accurate method would employ around-the-clock monitoring stations, for both seasons.

As a result of spectral analysis, several trends are evident regarding residual sound data produced by the wind-vegetation interaction. The most obvious characteristic is that the winter spectral plots are characterized by a very regular and repeatable shape for all three analyzed vegetation stands. Summer plots on the other hand are more irregular and less predictable. Here again, the evidence suggests that the seasonal variable of deciduous foliage has a primary effect on the character of residual levels. Owing to these seasonal variables, it was necessary to develop separate procedures for smoothing the spectral plots for winter and summer conditions. The method used for smoothing winter plots has the advantage of characterizing all data with only one shape, which is useful in the development of masking curves for a noise model. The relative disadvantage is that one has to accept an error of plus or minus 3 dBA. The method used for summer data reverses the trade off by reducing the margin of error to plus or minus 1 dBA, but at the same time uses several shapes to fit the data. Thus, both procedures are useful to some degree for spectral data interpretation, although each has its own inherent disadvantage. It should be stressed that each method was developed specifically for the particular season for which it was used, and so the two are not necessarily interchangeable. Given the fact that the various spectral shapes of winter data are relatively similar as compared to summer data, the method used for smoothing these shapes seems the most appropriate. Similarly, because the spectral shapes of summer data appear more irregular, presumably as the result of deciduous foliage, the procedure used for this season seems to be the most applicable. However, further study of this issue is needed to develop other more effective methods, and also to analyze spectral content of other types of vegetation cover not considered in this report.

Artificial Noise Within the Study Area

Based on the year-round observations made during each field measurement, some areas within the study region are more impacted by artificial noise than others. According to the impact maps, the central portion (close-sites) seems to be exposed the most frequently to artificial noise with the western portion sustaining the greatest impact. As the summaries of noise sources indicate (Appendix L), this region supports the heaviest amount of noise-producing activity, primarily mining and logging. Sites located further south (distant-south) are also exposed to artificial noise, but not to the extent as the close-sites. One would expect to encounter occurrences of man-made noise in this region, due to the proximity to population centers such as Hoyt Lakes. The quietest portion of the study area with regard to artificial noise is the northern section (distant-north sites), particularly close to the border of the BWCA. There are few, if any, point sources in this region with the primary impact being from transportation-related sources such as vehicle and air traffic. Occasionally, mining-related noise was observed within this section, as a result of conducive propagation conditions and low background levels. The fact that these sites were located 10 to 12 miles from mining activities indicates that given the appropriate conditions, mining noise might be detectable over great distances. Thus, plans to conduct open-pit mining near the border of the BWCA could conceivably produce an impact within that region. The noise model, currently being assessed, should give a better idea as to the magnitude of the impact.

Because the above discussed noise impacts were based primarily on field observations, there is a need for further study to develop specific noise contours based on acoustical data. Many of the noises observed were single events, such as aircraft flyovers and as such their contributions can be seen in the L_{00} to L_{10} values. These values were not considered in the data analysis due to the prime emphasis placed on characterizing natural residual levels. Given previously developed noise models, such as for vehicular traffic, however, some of the information presented in this report can be used in the development of such noise contours.

As previously discussed in this report, the scope of this study was limited due to the large area in question coupled with limited amount of monitoring time. Ideally, the best method for characterizing such a vast section of undeveloped land would have been to set up continual 24-hour monitoring at several stations in and around the region. However, after implementation of the first workplan, this method became more and more unrealistic. Had specific monitored locations been designated at the study's onset, 24-hour monitoring would have been more practical and probably would have been conducted. However, given the above-mentioned restrictions, the next best plan, i.e. characterizing the wind-vegetation interaction, was opted for. Thus, a need exists for more year-round monitoring within such portions of undeveloped land, with a primary emphasis on studying residual sounds and intrusive noises for the 24-hour cycle.

REFERENCE

U.S. Environmental Protection Agency, Community Noise, NTID 300.3, December 31, 1971, pp. A-57, A-61.

APPENDIX A

CITY STUDY--ELY, MINNESOTA

As part of the Regional Noise Monitoring Project, a noise study of Ely, Minnesota was conducted September 14 to 18, 1977. A 24-hour noise monitor was set up at two locations collecting a total of 96 hours of data.

Because the advent of Copper-Nickel mining could bring many demographic and socioeconomic changes that could significantly alter the activity levels within Ely, the town's acoustic environment could become noisier. The data presented in this section serve as a baseline upon which changes in noise levels, due to impending mining activities, can be ascertained.

The data reported are applicable only to the particular sites monitored and, the specific time of year at which the surveys were conducted. A better acoustic characterization of Ely would have required monitoring stations at several locations at representative times of year. However, time and personnel limitations along with adverse weather conditions precluded this approach. The results of this study are, nevertheless, useful in describing noise levels for a 24-hour cycle in Ely for the early fall season.

Description of Ely, Minnesota

Ely is located 44 miles northeast of Virginia, Minnesota on Highway 169 and just to the south of the Boundary Waters Canoe Area (BWCA). The city is about 1.5 by .5 miles and is 1,451 feet above mean sea level (See Figure A-1).

Ely's population is 4,904*, although due to the tourist influx, the population increases by about 25 percent during summer months.

The primary source of employment is the mining industry, accounting for 35 percent of the work force. Twenty-six percent are employed in retail business, 26 percent in professional services, and 13 percent in other areas of employment.

State Highway 169 runs east to west through the main section of Ely and State Road 1 and County Road 21 lead out of town to the south. Ely is bordered on the north by Shagawa Lake.

Three airports operate in the Ely vicinity. Wilderness Wings and the U.S. Forest Service have seaports on Shagawa Lake, and both have implemented takeoff patterns to avoid flying directly over town. Ely is served by a municipal airport located nine miles south on Highway 1.

Sites

Two sites, a downtown location and a residential home, were chosen from which to collect 24-hour noise data. Site CS-1 was on the second floor of the Shagawa Hotel, Room 14, overviewing Sheridan Avenue, which is the main street of town. The hotel is at the intersection of Sheridan Avenue and Central Avenue, which are both relatively heavily used streets. A traffic count by the Minnesota Department of Highway in 1975 indicated an average daily volume for that intersection of 4,940 vehicles. Located on the east side of the hotel are shops, bars, and a gas station. To the west of the hotel are mostly private residences (See photos, Figure A-2a).

Site CS-2 was a residence at 203 James Avenue, located in the southwest corner of town. The site is surrounded by other homes and is six short blocks south of the downtown area. County Road 21 is three long blocks to the west. This is the road to the next closest town, Babbitt, and thus it has heavy vehicular use (See photos, Figure A-2b).

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*U.S. Bureau of Census, 1970.

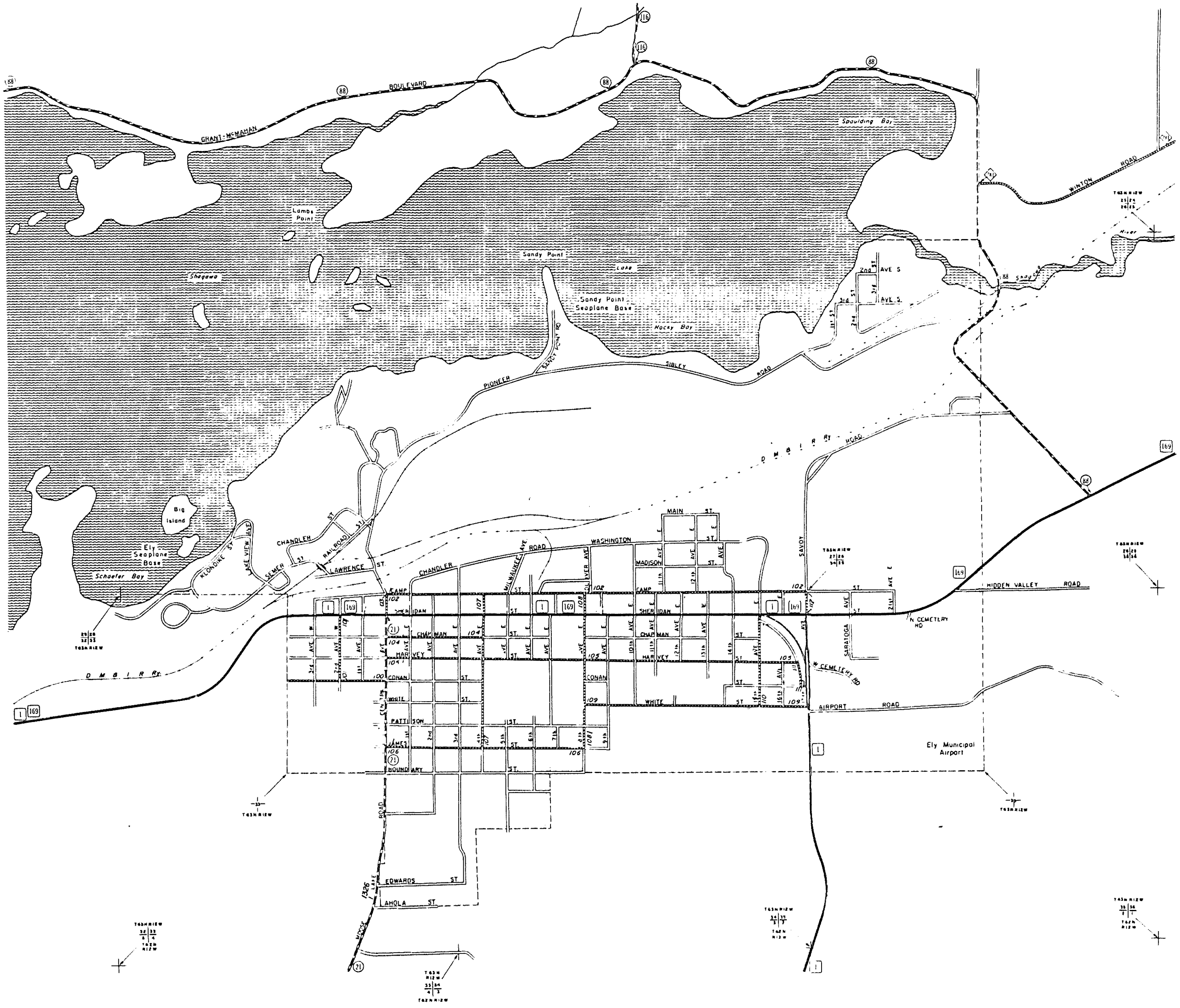


Figure A-1 Ely, Minnesota

1975 TRAFFIC MAP
MUNICIPALITY OF
ELY

ISSUED BY THE
MINNESOTA DEPARTMENT OF HIGHWAYS
IN COOPERATION WITH THE
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
DATA OBTAINED AND MAP PREPARED BY THE
TRANSPORTATION AND TRANSIT
PLANNING AND PROGRAMMING DIVISION
OFFICE OF
TRANSPORTATION AND PLANNING

SCALE
800 0 800

1975
BASIC DATA 1966

N

LEGEND

- INTERSTATE TRUNK HIGHWAY
- U.S. NUMBERED TRUNK HIGHWAY
- STATE NUMBERED TRUNK HIGHWAY
- COUNTY STATE AID HIGHWAY
- COUNTY ROAD
- COUNTY STATE AID HIGHWAY IN ADJOINING COUNTY
- COUNTY ROAD IN ADJOINING COUNTY
- CORPORATE LIMITS

MUNICIPAL STATE AID STREET SYSTEM

LEGEND

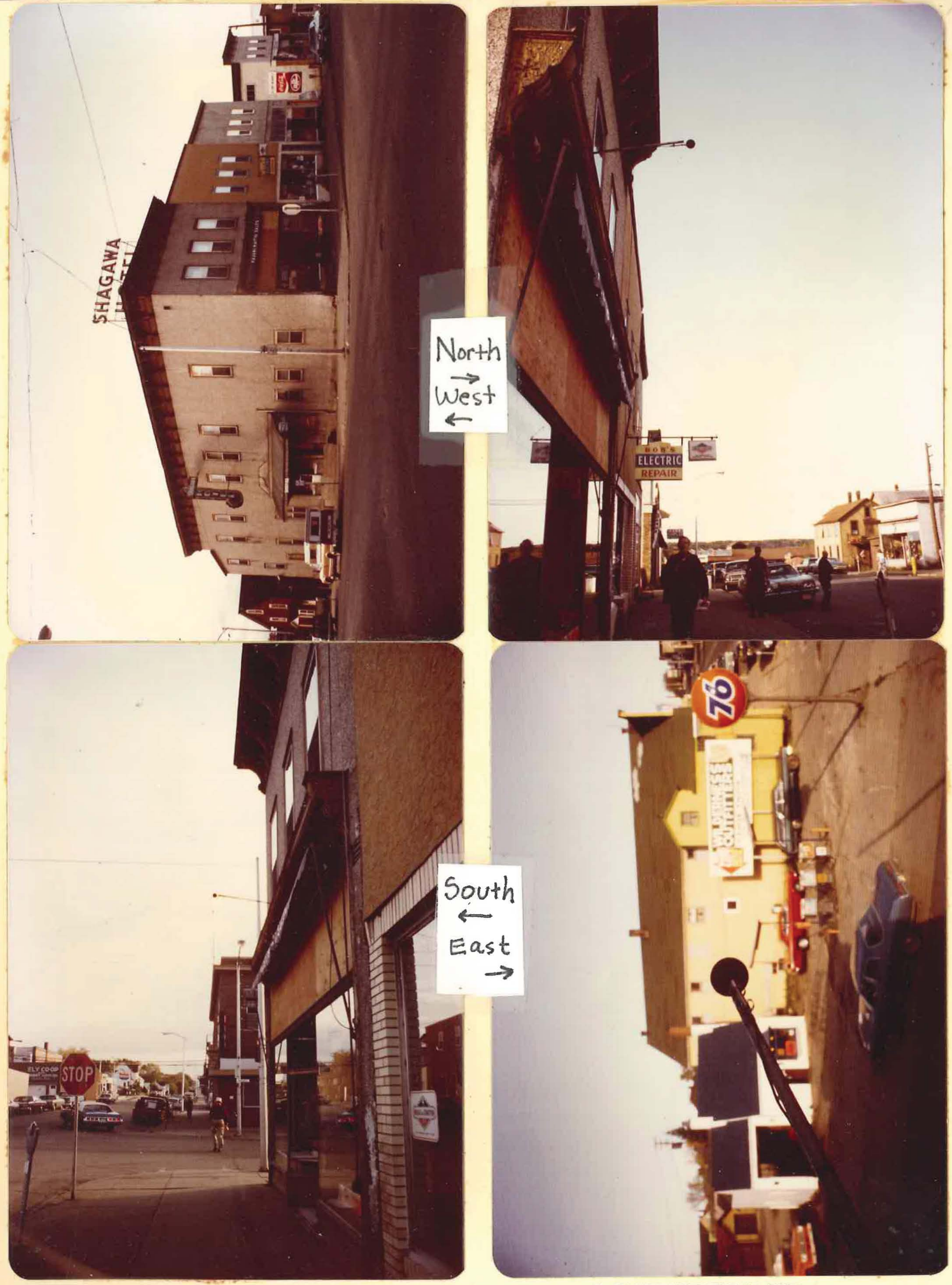
- CORPORATE LIMITS
- COUNTY STATE AID HIGHWAY
- MUNICIPAL STATE AID STREET
- MUNICIPAL COUNTY STATE AID STREET
- COUNTY ROAD
- TRUNK HIGHWAY

RED NUMERALS INDICATE AVERAGE DAILY
TRAFFIC VOLUMES ON DESIGNATED ROADS.
NOTE: T.H. VOLUMES ARE 1974 A.D.T.

COPIES OF THIS MAP ARE AVAILABLE
FOR PUBLIC USE AT A NOMINAL COST
MINNESOTA DEPARTMENT OF HIGHWAYS
STATE HIGHWAY BUILDING
ST. PAUL, MINNESOTA 55155

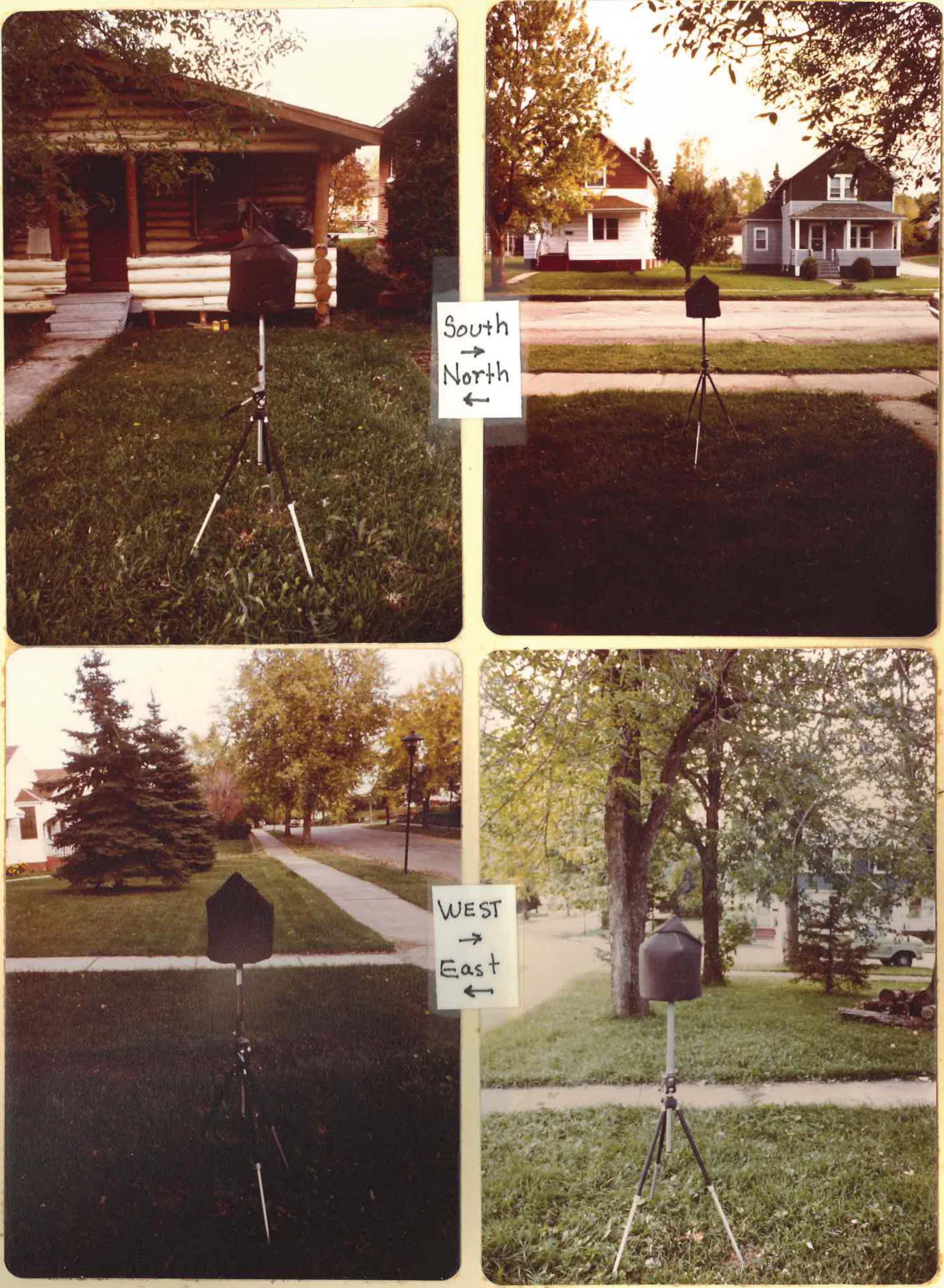
1970 U.S. CENSUS POP. 5,219

1975 TRAFFIC MAP
ELY (ST. LOUIS CO.)
ELY M.S.A.S.



SITE CS-1 SHAGAWA HOTEL 7 WEST SHERIDAN AVE.

Figure A-2a



SITE CS-2 203 JAMES AVE.

Figure A-2b

Apparatus

Twenty-four hour noise data were sampled with a Metrosonic db-602 Sound Level Analyzer, Serial Number 1109. The input into the unit was provided by Bruel and Kjaer one inch condenser microphone, Model 4161, Serial Number 559631, coupled with a general radio preamplifier, Model P42, Serial Number 3272.

For the residential test, the microphone and preamplifier were mounted on a Kalt tripod, Model MR-913, and covered with a Bruel and Kjaer Windscreen UA0207 and a large cylindrical windscreen of wire mesh covered with 1/4 inch foam*. A shielded three conductor 100 foot extension cable was used between the sound level analyzer and the microphone (See Figure A-3).

For the test made at the downtown site, the system was identical to the one described, with the following exceptions: 1) Instead of the tripod, the microphone was placed on a 4 foot boom and extended from a second story window; and 2) The Bruel and Kjaer UA0207 windscreen was used without the large foam covered cylindrical windscreen (See Figure A-3), because wind noise was not expected to affect the measurements due to expected low winds (<5 mph) and high sound levels (>50 dBA).

Procedure

For all measurements, Test Procedure CN-6 was followed (Appendix N). The preamplifier was set on a X10 gain to make the system 20 dB more sensitive for night measurements. The db-602 Sound Level Analyzer was operated on the multiple interval mode with L_{10}, L_{50}, L_{90}, and L_{99} dialed into the four memory banks. The time sequence dial was set at "04" so that the unit would take one hour interval samples. The analyzer was powered from standard 110 volt current, and the system was periodically checked to ensure reliable data were being stored. The entire 24 hours of data were retrieved at the end of the 24-hour sampling period. Audibility notes and other observations were taken periodically throughout the test.

The microphone at Site CS-1 was extended 4 feet out the southeast window on the second floor with a Bruel and Kjaer windscreen placed over the protective grill for the entirety of the test.

At Site CS-2, the microphone was placed on a tripod 4 feet from the ground and located in front of the residence about 10 feet from the sidewalk. The microphone at this site was covered with the Bruel and Kjaer windscreen plue a large 1/4 inch foam covered windscreen.

Data were sampled for two consecutive 24-hour periods at Site CS-1 during the week and one 24-hour period on the following weekend. Residential sounds at Site CS-2 were monitored for one 24-hour segment during the week.

Results--Physical Description

At the downtown site, CS-1, vehicle traffic was the most frequently observed noise source. Passenger cars, pickup trucks, and four-wheel drive vehicles were the most common type of vehicular traffic that passed by the site, although not necessarily the loudest. The noisiest vehicles were large diesel trucks and construction equipment, such as dump trucks, road graders, and front loaders. The volume of traffic was heaviest during the hours of 8 a.m. to 4 p.m., during the normal work week, and was lightest at nighttime. Located directly across the street on the east site of the road was a gas station that seemed to be a center for young drivers with so-called "muscle-cars." Many of these automobiles had either worn out or glass-pack type mufflers, and the owners would frequently accelerate their engines while idling and squeal their tires as they drove away from the station. Other noises heard at the downtown location included small aircraft taking off from Shagawa Lake, occasional slamming of car doors, people talking, as well as a general type of "city din." Located

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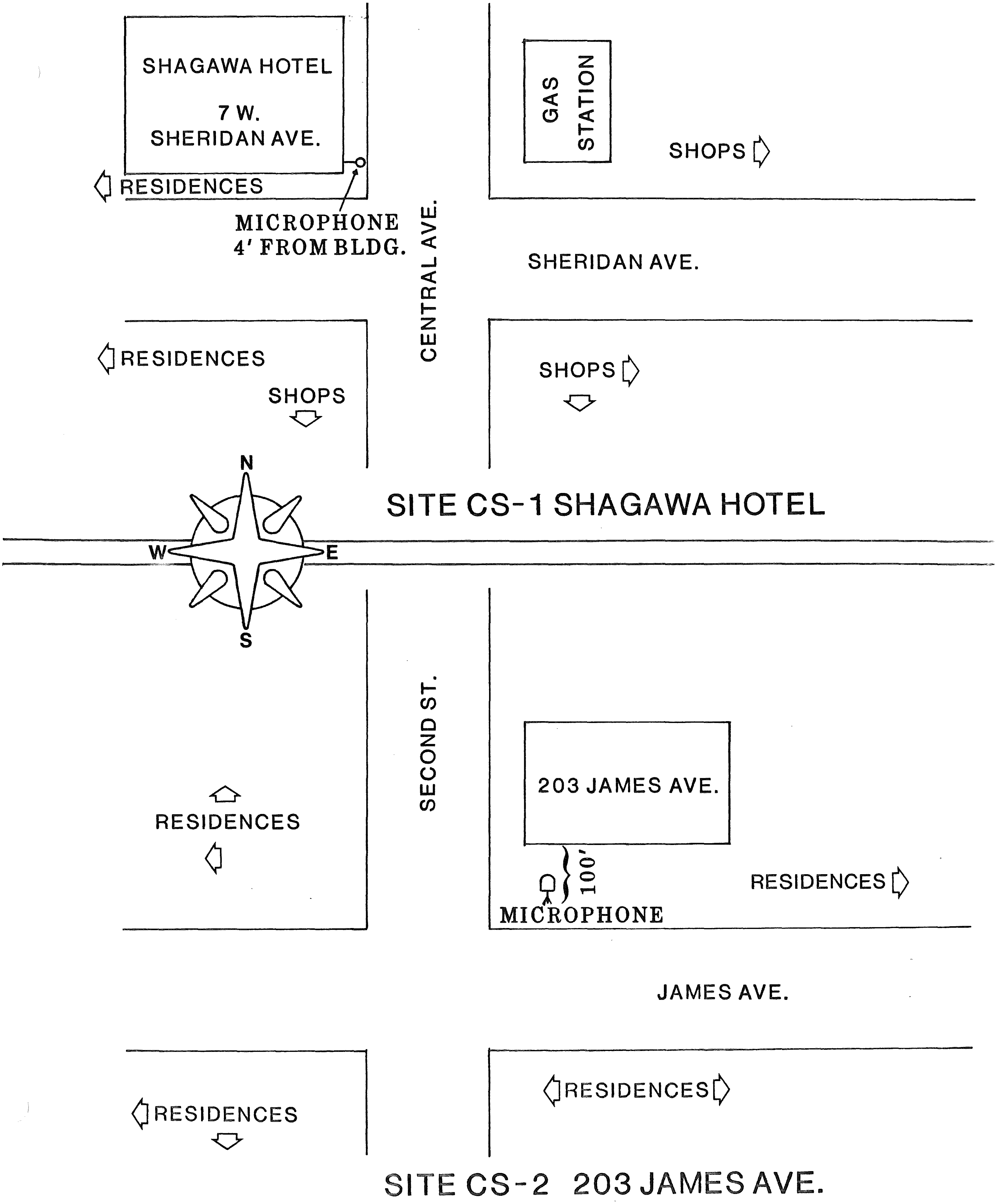
*Designed by Midwest Acoustics, Minneapolis, Minnesota.

Figure A-3 Measurement locations for sites CS-1 and CS-2



diagonally across the street was a veterinarian, which accounted for several instances of barking dogs.

In the residential location, CS-2, vehicular traffic, as with the downtown site, was the most frequent although not the loudest noise source. Practically all vehicles that passed by the site were either automobiles or pickup trucks. At night when background noise was at a minimum, traffic noise from County Road 21 could also be heard. The most intrusive noise observed at this site was from four to five gas-powered lawn mowers operating simultaneously for a one to two hour period. The reason for this is that rains had been fairly relentless for the previous three to four weeks, thus, several people must have decided to take advantage of the temporarily good weather and mow their lawns. Other noises heard at this site were barking and howling dogs, small aircraft flyovers and wind blowing in the trees. At night vehicular traffic from County Road 21 could be heard occasionally, but generally the area was very quiet.

Results--Statistical Description

Noise level data were statistically analyzed, automatically, by the db-602 Sound Level Analyzer. Sound levels were "A" weighted and stored in the analyzer until the end of each 24-hour test. At that time, data were retrieved in the form of Ln or the sound level exceeded N percent of the time, as computed by the db-602. For each 24-hour period of each test condition, four Ln values, L_{10}, L_{50}, L_{90}, and L_{99}, were computed and stored every hour.

Given in Figure A-4 are the rms average L_{10}, L_{50}, L_{90}, and L_{99} for all test conditions for day and night (Day is defined as 0700 to 2200 hours; night is 2200 to 0700 hours). As one would expect, the residential location averaged to be considerably quieter during the week than the downtown site, and nighttime levels were generally lower than daytime levels for all test conditions. For daytime hours, there were small differences among the average levels of the weekend and the two weekday samples. However, at night, the average levels for the weekend sample downtown were substantially higher than for any of the other three conditions. This would be expected, due to increased entertainment activities downtown on the weekend.

Figures A-5a, A-5b, and A-5c are probability plots for day and night averages for the three principal test conditions: downtown weekday, downtown weekend, and residential weekday. Probability plots are essentially a useful method for characterizing the variability of a distribution. Sound levels are plotted as a function of the percent of time that a level was exceeded. For example, an L_{50} of 65 would be a point with an abscissa of 50 and an ordinate of 65. For normal distributions 50 percent of the area of the curve would be above 65 and 50 percent below. Furthermore, the X-axis of the probability paper is arranged so that for a perfectly normal or Gaussian distribution, values plotted as a function of the percentage value result in a straight line graph. From the slope of the line, the standard deviation of the distribution can then be computed. According to the normal curve model, one standard deviation is located at the point which is 34 percent on either side of the mean. Thus, to find the standard deviation from the probability plots, one has to subtract the value corresponding to the 50 percent point from the value at the 84 percent point. The steeper the slope of the line, the larger the standard deviation and thus, the greater the variability.

Several points are clear from these graphs. First, none of the distributions are perfectly normal and so straight lines had to be approximated to the data. Second, as pointed out in Figure A-5c, the residential location was considerably quieter than the downtown site as shown by the fact that plots in Figure A-5c are much lower on the Y-axis. Finally, the distribution of the downtown site became much more variable from day to night than did the residential site. This difference can be seen by the fact that the slopes in Figure A-5a are not at all parallel but are almost so in Figure A-5c. The standard deviations in Figures A-5a and A-5b vary

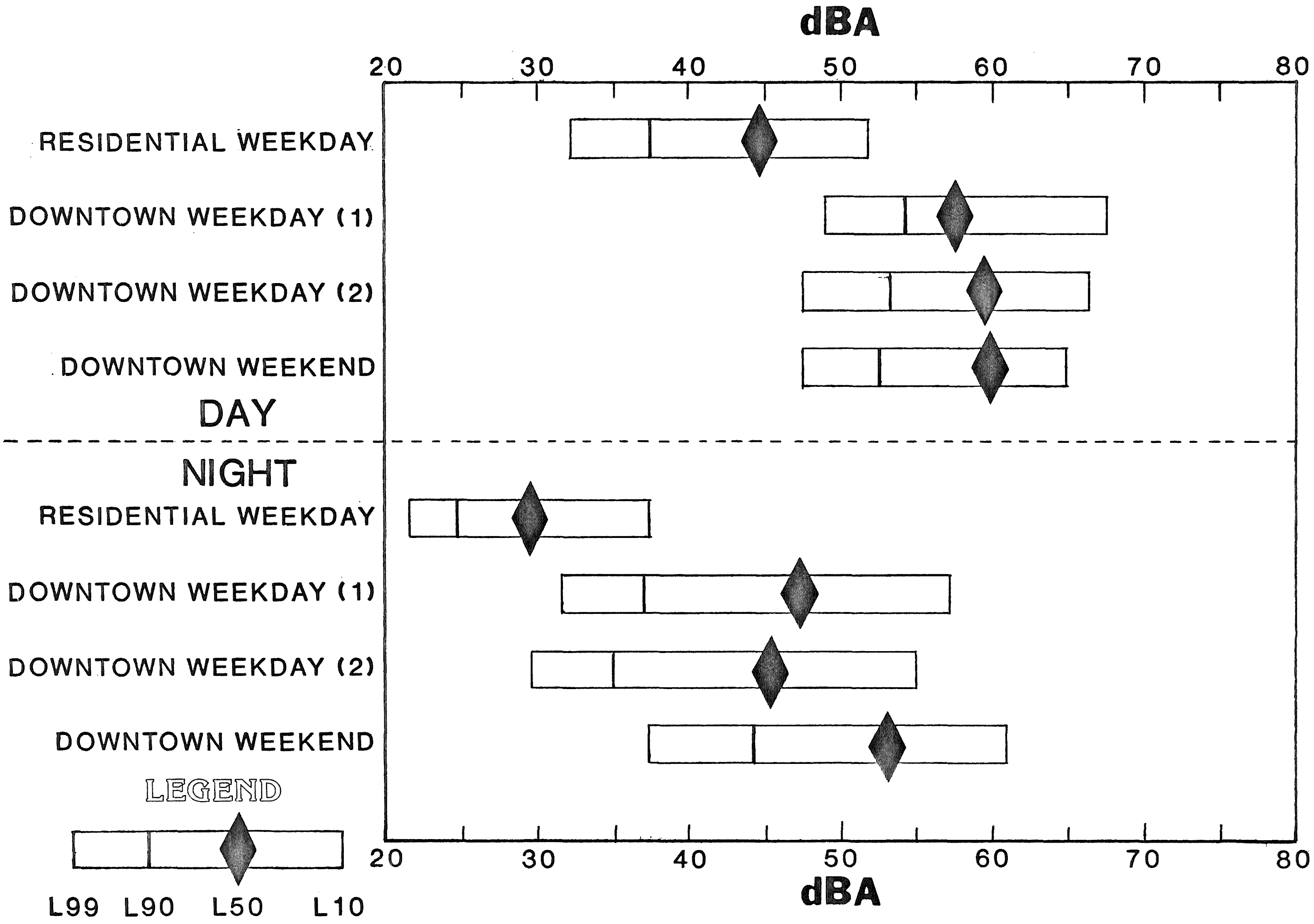


Figure A-4 AVERAGE L10,L50,L90,AND L99 FOR DAY AND NIGHT FOR ALL CONDITIONS.

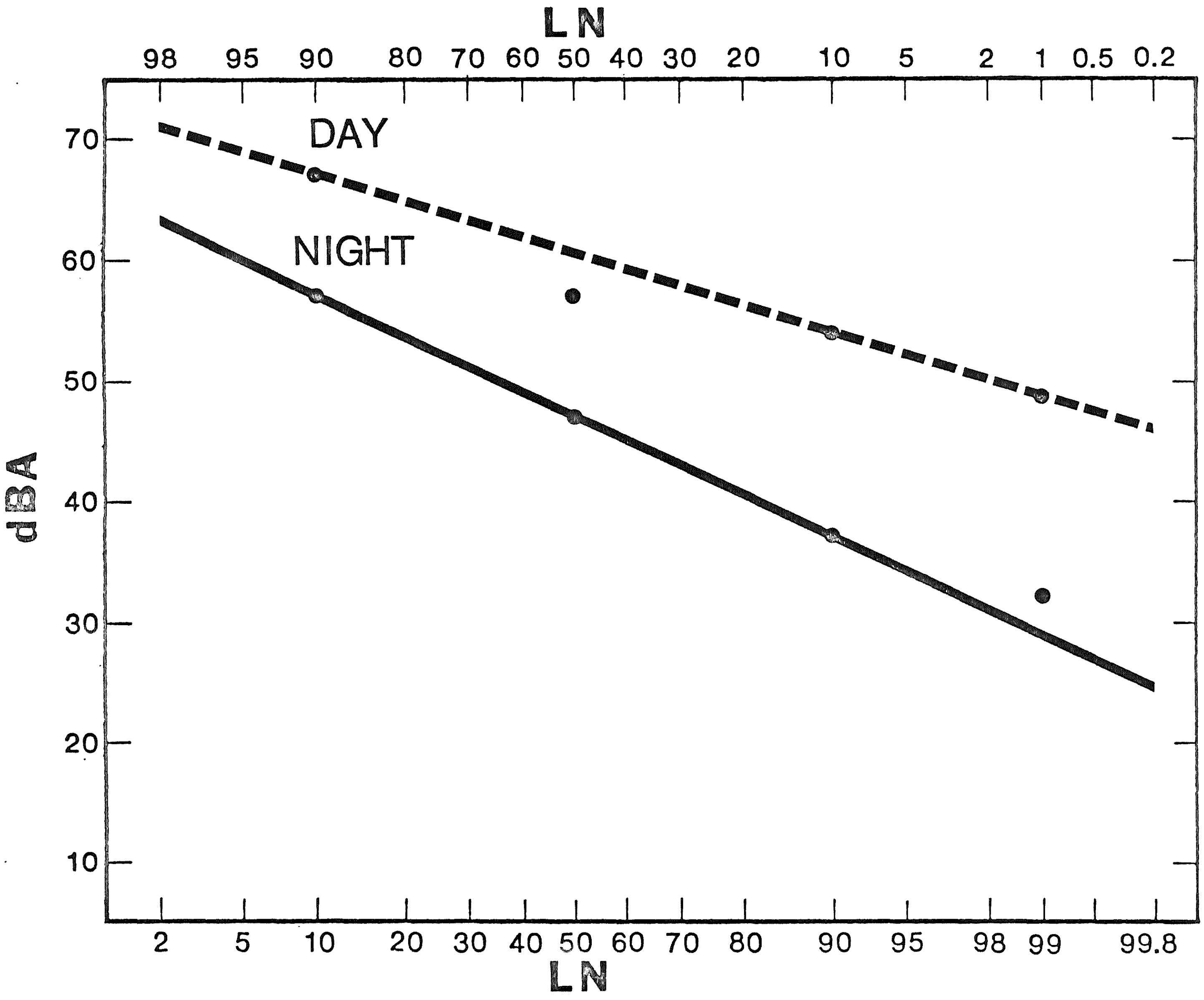


Figure A-5a Probability plot for day and nighttime averages for the downtown location during the week

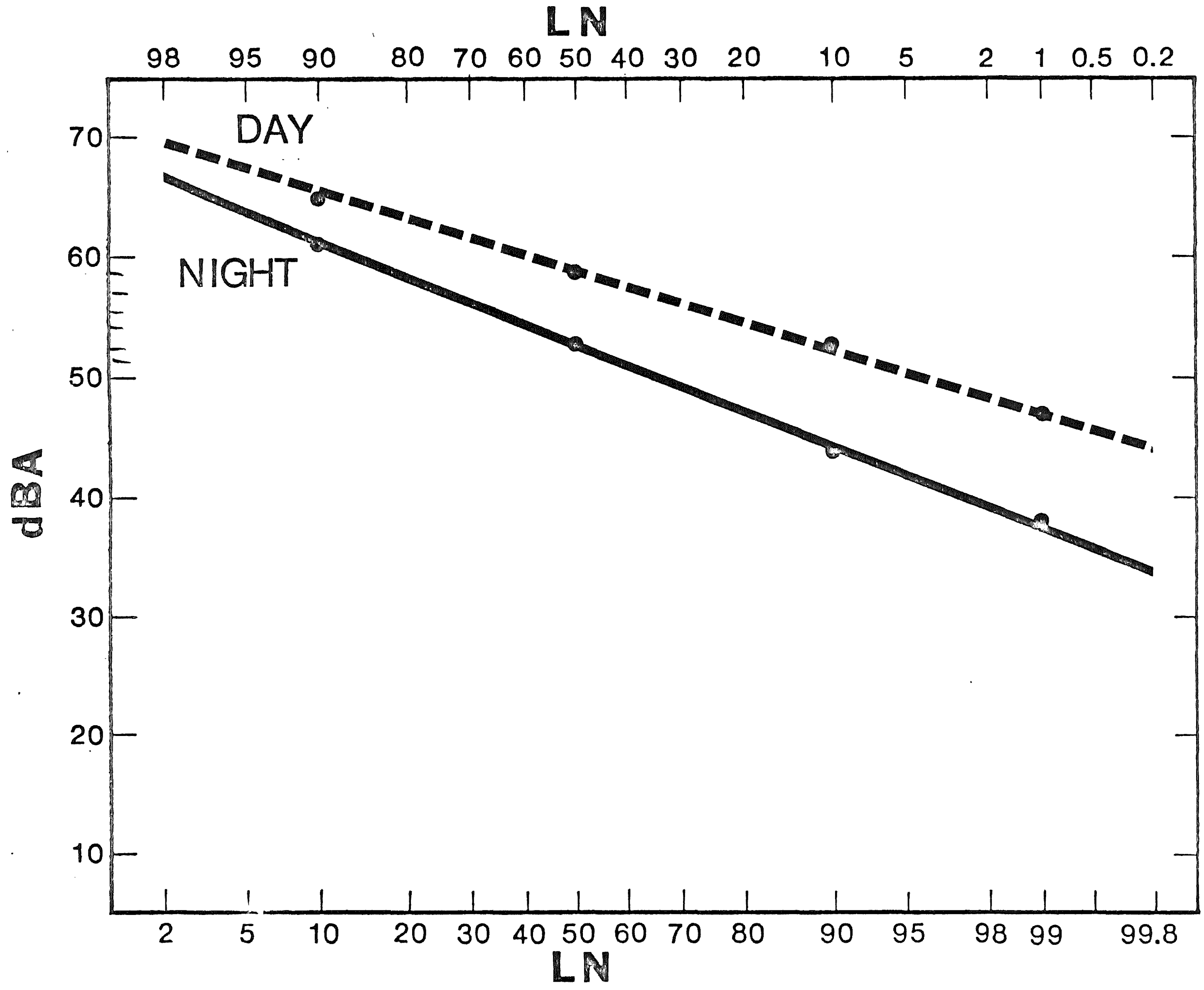


Figure A5b Probability plot for day and nighttime averages for the downtown location during the weekend

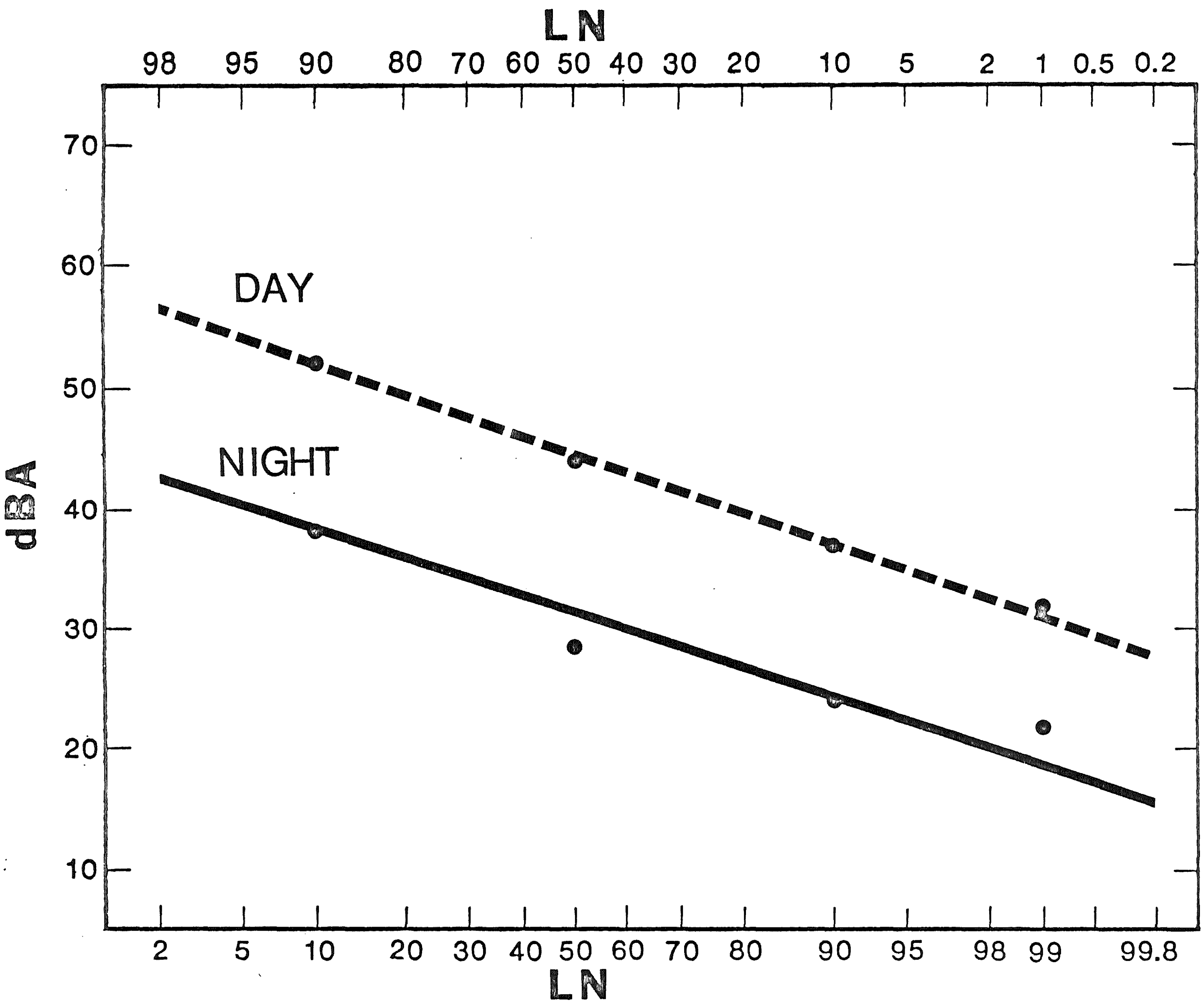


Figure A5c Probability plot for day and nighttime averages for the residential location during the week by 2.0 and 3.5, respectively, from day to nighttime averages but by only .5 in Figure A-5c. This change in variability is a result of the higher L values, L_{90} and L_{99}, dropping more drastically in relation to the lower Ln values, i.e., the L_{10} from day to night for the downtown location. L_{90} and L_{99} are descriptors of the background noise while the L_{10} characterizes temporary events such as vehicular traffic. Thus, one would expect background noise levels in the downtown area, to drop more abruptly than the levels produced by temporary events, i.e., traffic due to the closing of retail businesses, between the hours of 4 p.m. to 6 p.m., as well as the sudden decline of the general city din.

Figures A-6a, A-6b, and A-6c show the L_{10}, L_{50}, L_{90}, and L_{99} tabulated for the end of every hour for all sampling periods, along with the day and night averages. Generally, these graphs show hourly trends in sound level data, as a result of activities throughout the 24-hour cycle. Each graph possesses its own characteristic "peaks" in sound levels for particular hours. Data from the residential site (Figure A-6c) has its most marked peak at 12 noon, with L_{10}, L_{50}, and L_{90} all making a sharp increase. This was the hour that several people had decided to mow their lawns. The downtown location, during the work week (Figure A-6a) had two prominent peaks between the hours of 6 a.m. to 8 a.m. and 4 p.m. to 6 p.m., which were probably related to the coming and going of people to work. The same site on the weekend also showed two prominent peaks, although for different hours between 4 p.m. and 6 p.m. and between 10 p.m. and 11 p.m. These peaks reflect the incoming and outgoing volume of traffic as a result of activities related to nighttime entertainment.

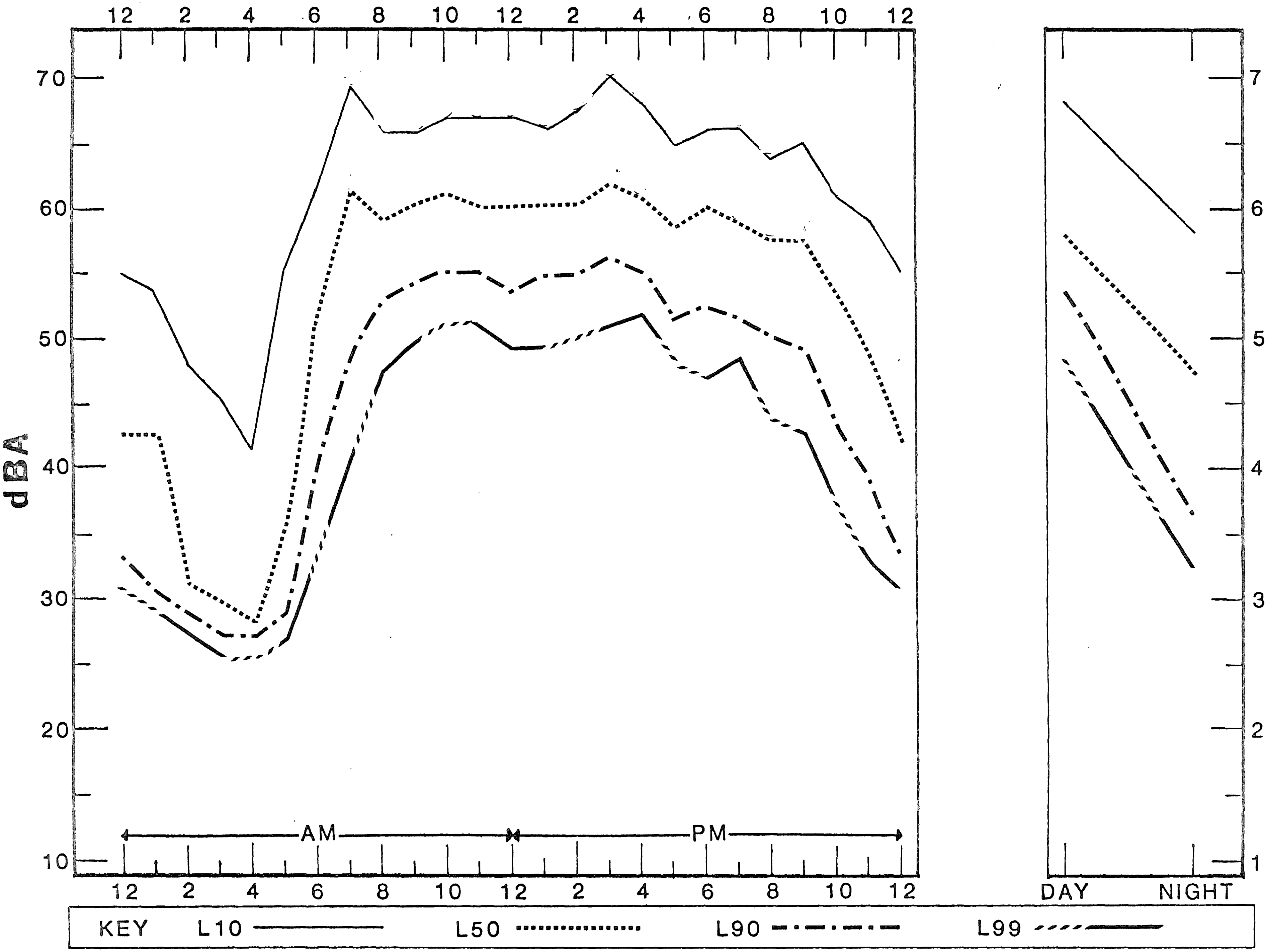


FIG. A-6a L_{10}, L_{50}, L_{90}, and L_{99} for 24 hours of noise data in Ely, Minnesota 9/15-9/16/77
DOWNTOWN-WEEKDAY

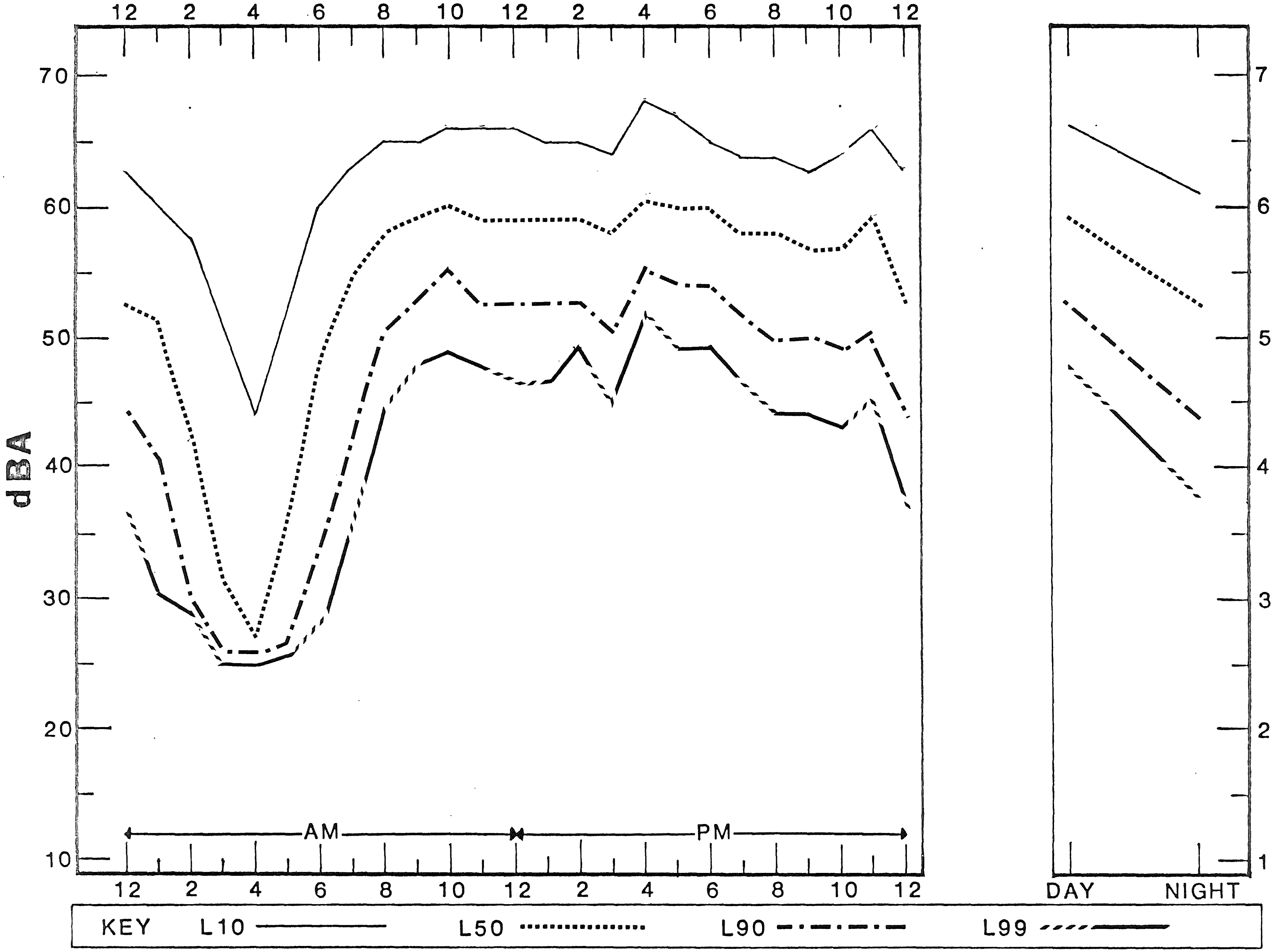


FIG A-6b L_{10}, L_{50}, L_{90}, L_{99} for 24 hours of noise data in Ely, Minnesota 9/17-9/18/77
DOWNTOWN-WEEKEND

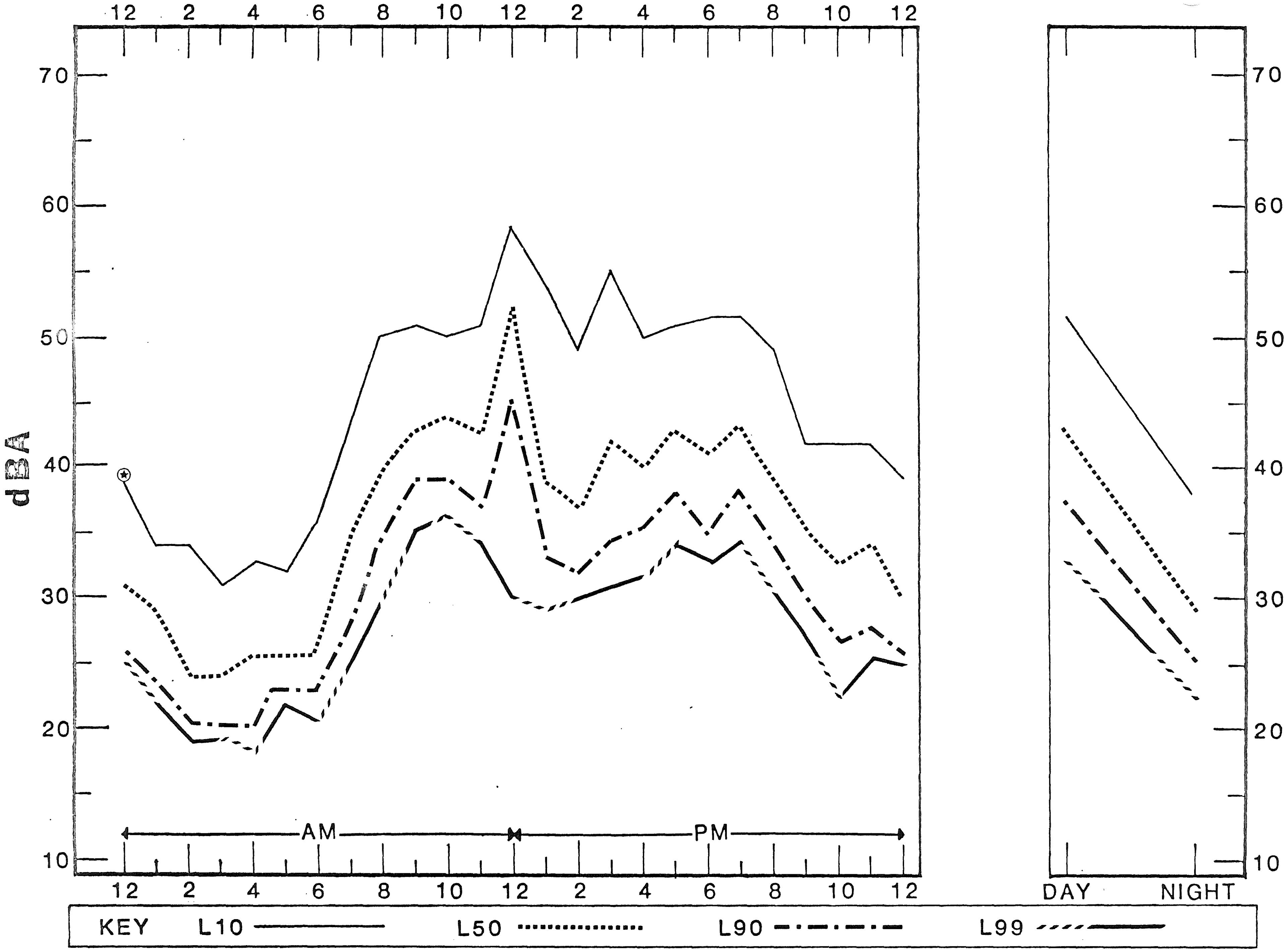


FIG. A-6c L_{10}, L_{50}, L_{90}, and L_{99} for 24 hours of noise data in Ely, Minnesota 9/14-9/15/77
RESIDENTAL-WEEKDAY

APPENDIX B

BWCA TRIP--JULY 8-JULY 11, 1977

Introduction

The Boundary Waters Canoe Area (BWCA) is of principal concern to the Noise Monitoring Project, because of its unique designation as a wilderness area. If mining activities are to be located directly next to its border, the resulting noise impact could be felt by persons using the BWCA for recreational purposes. As part of the baseline assessment of sound levels within the study region, a short-term monitoring study was conducted to assess the current acoustic environment within the BWCA. Because this is such a noise-sensitive area, extensive baseline monitoring should have been conducted on a year-round basis, but given the difficult accessibility coupled with the cumbersome nature of the monitoring equipment, it was possible to schedule only a four-day trip.

The data presented in this appendix represents sound levels sampled from two monitoring sites, which were designated camping areas on Gabbro and Gull Lakes. Data were sampled at each site for several hours during the 24-hour cycle and were analyzed in the lab after the trip.

Sites

Shown in Figure B-1 are the locations of the two monitoring sites. Site Number 1, a campsite on a peninsula located on the eastern shore of Gabbro Lake, is only about two miles from the outer perimeter of the BWCA. The area is forested principally with mature redpine and secondarily with mixed birch, aspen, and fir. This site was chosen mainly because of its location on a designated motorized vehicle route for the purposes of observing occurrences of artificial noise, as well as naturally produced residual levels.

Site Number 2 is an island located on Gull Lake and is primarily populated with white spruce with some scattered jackpine and aspen tree cover. This area was selected because of its relative accessibility as well as its expected quietude due to its location on a non-motorized route.

Procedure

Data were recorded on cassette tapes for subsequent laboratory analysis for half-hour segments using a variation of Test Procedure CN-3 (See Appendix N), as developed by Dr. Roger Sipson of Moorhead State University. The method called for the output of the microphone system to be fed into a General Radio 1561-C Sound Level Meter, Serial Number 6544, for the purposes of amplification or attenuation of the signal by adjusting the window of the meter accordingly. The signal was then directed into the line input of the Nakamichi Cassette Tape Recorder, bypassing the microphone input amplifier. This set-up, due to the wide range of the sound level meter, had the advantage over CN-3 of increasing the sensitivity of the system without increasing the noise floor. All recordings were made with the General Radio set on the linear mode although one, measurement number 3 was recorded as "A" weighted. The sound level meter was set on "slow" response, except for measurement number 4, when it was placed on "fast response.

Three recordings were made at Site 1 on July 8, 1977, during the afternoon, evening, at nighttime hours, and one measurement was made the next morning. During all measurements, meteorological data were noted along with auditory observations. Three more measurements were made at Site 2 on July 10, 1977, during the morning, afternoon, and evening hours. A night measurement was aborted due to instrumentation problems.

Data were analyzed following the trip by feeding the tapes into the low level ("A" weighted) input of a Metrosonic db-601 Sound Level Analyzer (See Test Procedure CN-7, Appendix N). Measurement 3, which was

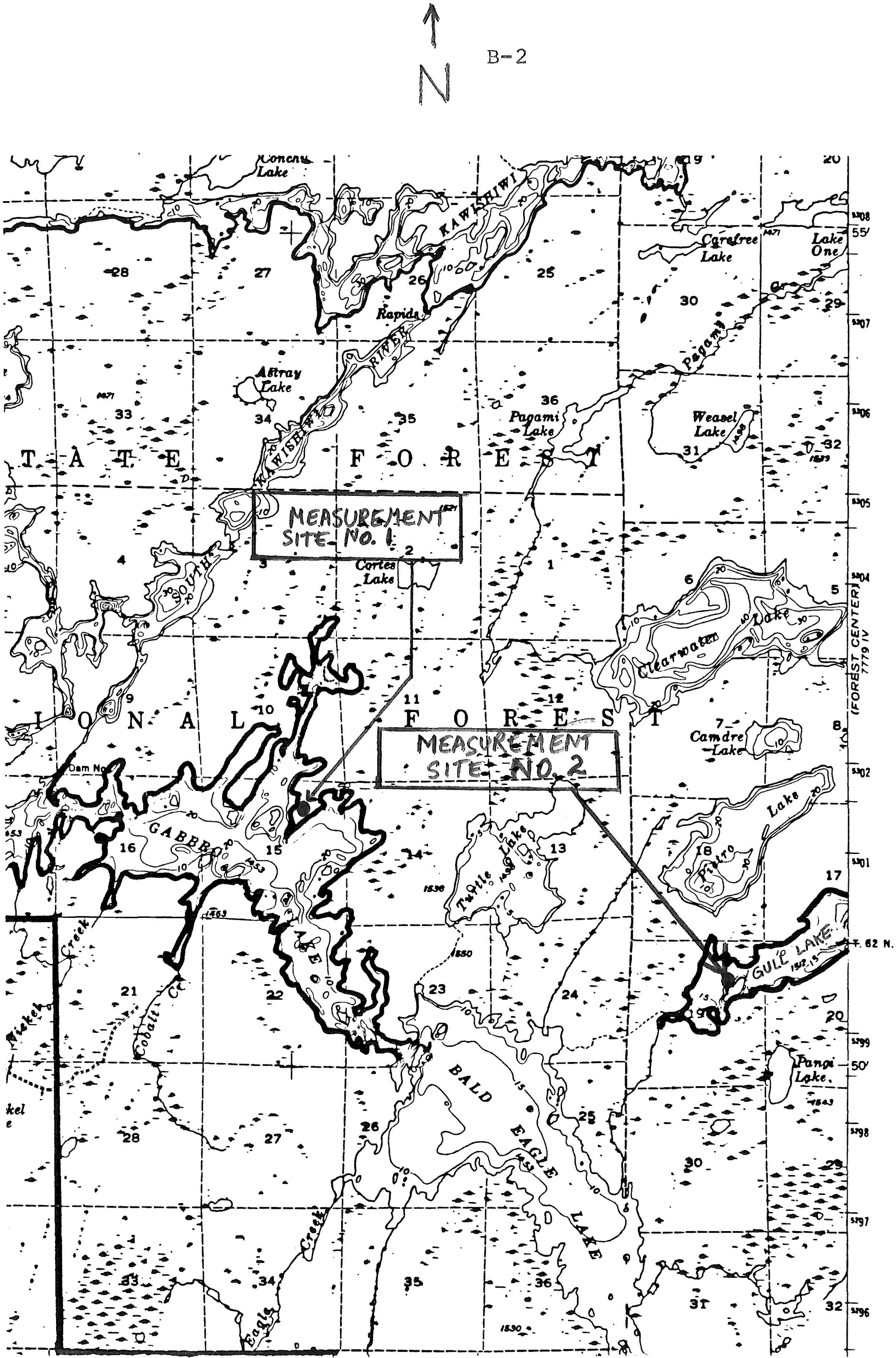


FIG. B-1 Locations of Measurement Sites in BWCA

"A" weighted in the field, was played into the high level (linear) input of the Metrosonic. All values were noted between L_{00} and L_{99}.

Results

Data for all measurements are given at the end of this appendix on data summary forms. Each form lists, in addition to Ln data, meteorological information, specifics of the test procedure used, as well as comments and general observations. Along with each data sheet is given a probability plot for all measurements, except 4. Measurement 4 does not represent totally accurate data due to the fact that recording with the General Radio set on "fast" response forced the needle to go off scale at times, which introduced noise into the system.

Given below in Table B-2 are the mean ($\overline{X}$), standard deviation (SD), and standard error of the mean (δ) for each measurement, except 4, as calculated using the same method of linear regression used for the residual sound level analysis discussed in Appendix E.

Measurements	$\overline{X}$	SD	δ
1	38	2.34	.22
2	44	3.23	.29
3	19	1.62	.46
5	34	3.03	.28
6	31	4.74	.60
7	31	4.11	.29

Table B-2 Sound level (dBA) statistics for BWCA data.

It is difficult to note any specific trends given the small amount of data, although several points are clear. First, the above means and standard deviations all seem to approximate the data given in the results section for summer coniferous vegetation stands. Of interest here is that the δ factor is quite low for all measurements, which further substantiates the normality of sound level distributions resulting from natural sounds.

Measurement 3 seems to exhibit the smallest mean and least variability. This measurement was made at 10 p.m. at Site 1, when levels were consistently very low. The loudest measurement, number 5, was made under very windy conditions, with winds on the shore measured as high as 20 mph. Thus, the data represent a large range of naturally occurring sound levels within the BWCA. The levels given primarily reflect wind interaction with vegetation cover as do most of the residual measurements of the project. However, other naturally produced sounds, such as birds and insects around the microphone, were observed and taped.

Few instances of artificial noise were heard during the trip. The most commonly experienced noise sources were small engine aircraft, which were taped during measurements 4, 5, 6, and 7. Also heard during measurement 7 and at various other times were military jet flyovers, which seemed to stay within audible range for sometimes up to an hour. The only other type of artificial noise observed was a passing motorboat on Gabbro Lake during measurement 4. However, the boat was barely audible, and therefore, not a contributing part of the measurement.

COPPER-NICKEL NOISE
FIELD DATA SHEET

SITE BWCA - GABBRO LAKE

DATE 7/8/77

VEGETATION Mature red pine with mixed birch and fir

DATA SHEET # Measurement #1

TAPE # ST-86A.

TIME START 12:56 AM [✓ PM]

TEST PROCEDURE(S) 1. *

2.

3.

TIME FINISH 1:30 AM [✓ PM]

WEATHER DATA

CALIBRATION(S) 1. ✓

TEMPERATURE 65°F

2.

RELATIVE HUMIDITY

3.

BAROMETRIC PRESSURE

SITE MONITORING ☑

WIND SPEED (AREA) 10-20 NW (WELY)

OTHER

PART I:
* Mic B&K 4161 x P_{42} 10 → 5151C G.R.
SLM → Nakamichi 550
Cal (113 at 1000Hz)
X10 — SLM reads 143 = -7_{vu} on Nak
(140 in GR window)

PART II: with 80 in GR window
Cal = 53dB = -7vu on Nak
≈ 60dB = 0Vu Nak

DIRECTION NW

SOURCE OF WIND INFO. WELY

WIND ON MIC 0-2 mph

SKY CONDITIONS overcast

RESULTS (dBA):

		0	1	2	3	4	5	6	7	8	9
L 00-09		46	43	43	42		42			41	41
L 10-19		41		41							40
L 20-29		40									40
L 30-39		39									39
L 40-49		39	38								38
L 50-59		38					37				37
L 60-69		37									37
L 70-79		37			36						36
L 80-89		36								35	35
L 90-99		35						34		34	34

113
53
60

K Kajander

Signature of Investigator

COPPER-NICKEL NOISE
FIELD DATA SHEET

SITE BWCA-Gabbro Lake

DATE 7/8/77

VEGETATION Coniferous with some aspen

DATA SHEET # Msmt #2

TAPE # ST-86B

TIME START 5:25 AM [✓ PM]

TEST PROCEDURE(S) 1. CN-3

2.

3.

TIME FINISH 5:55 AM [✓ PM]

WEATHER DATA

CALIBRATION(S) 1. A (63=0Vu)

2.

3.

TEMPERATURE 63°F

RELATIVE HUMIDITY

BAROMETRIC PRESSURE

SITE MONITORING ☑

WIND SPEED (AREA) 10-20

OTHER

DIRECTION NW

SOURCE OF WIND INFO. WEZY

WIND ON MIC 0-3 mph

SKY CONDITIONS overcast

RESULTS (dBA):

			0	1	2	3	4	5	6	7	8	9
L	00-09		55	51	50	49	-	48				
L	10-19		48		47	47						
L	20-29		47	46								
L	30-39		45									
L	40-49		45	44	44							
L	50-59		44		43	43						
L	60-69		43							42		
L	70-79		42									
L	80-89		41									40
L	90-99		40	-	39					38	-	37

113
63
50

K Kajander

Signature of Investigator

COPPER-NICKEL NOISE
FIELD DATA SHEET

SITE BWCA - Gabbro Lake (same as msmts 1 & 2)

DATE 7/8/77

VEGETATION Mature red pine w/ mixed birch & fir

DATA SHEET # Msmt #3

TAPE # ST-87A

TIME START 10:00 AM [✓ PM]

TEST PROCEDURE(S) 1. *
√ 2.
3.

TIME FINISH 10:30 AM [✓ PM]

WEATHER DATA

CALIBRATION(S) 1.
2.
3.

TEMPERATURE 60°F

RELATIVE HUMIDITY

BAROMETRIC PRESSURE

SITE MONITORING ☐

WIND SPEED (AREA) calm

OTHER

DIRECTION

SOURCE OF WIND INFO.

WIND ON MIC calm

SKY CONDITIONS

* PART I:
4161 mic → P_{42} (x10) →
GR 5161C SLM ('A weighted') →
Nakamichi 550
Cal: 113 at 1000 Hz → P_{42}(x10) = 143 on 5161C set at -7vu on Nak

PART II:
Tape with 5161C set at 50 i.e. 90 dB more sensitive
∴ 50 dB = 20 dB on 5161 C

∴ -7Vu = 23 dB
0Vu = 30 dB } Nak

RESULTS (dBA):

		0	1	2	3	4	5	6	7	8	9
L 00-09	X	32	25	24	24	24	23				22
L 10-19	X	22				21					21
L 20-29	X	21			20						20
L 30-39	X	20					19				19
L 40-49	X	19									19
L 50-59	X	19									19
L 60-69	X	19				18					18
L 70-79	X	18									18
L 80-89	X	18									18
L 90-99	X	18							17		17

K Kajander

Signature of Investigator

COPPER-NICKEL NOISE
FIELD DATA SHEET

SITE BWCA Gabbro Lake (same as 1,2,3)

DATE 7/9/77

VEGETATION Mature red pine w/ mixed birch and fir

DATA SHEET # Msmt #4

TAPE # ST-87B

TIME START 11:00 [✓ AM] PM

TIME FINISH 11:41 [✓ AM] PM

TEST PROCEDURE(S) 1. *

2. ↓

3.

WEATHER DATA

TEMPERATURE

CALIBRATION(S) 1.

2.

RELATIVE HUMIDITY

3.

BAROMETRIC PRESSURE

SITE MONITORING ☑

WIND SPEED (AREA) 0-4 mph

OTHER

DIRECTION

SOURCE OF WIND INFO.

WIND ON MIC calm

SKY CONDITIONS

* PART I:
4161 mic → GR P42 (x10) → GR SLM 5161C → Nak 550
Cal: 113 at 1000 Hz → P42 (x10) = 143 – set on GR SLM at 143 → set at –7Vu on Nak.

PART II: GR set at 70 dB making –7Vu = 43 dB
∴ 0Vu = 50 dB

RESULTS (dBA):

			0	1	2	3	4	5	6	7	8	9
L	00-09		47	39	37	35	34	33		32	31	31
L	10-19		30		29		28			27		26
L	20-29		26			25						24
L	30-39		24								23	
L	40-49		23								22	
L	50-59		22									
L	60-69		21									
L	70-79		21		20							
L	80-89		20				19					
L	90-99		19		18					~~16~~ 17		17

110
50
60

K Kajander

Signature of Investigator

COPPER-NICKEL NOISE
FIELD DATA SHEET

SITE BWCA-Gull Lake

DATE 7/10/77

VEGETATION white spruce (predom.) some jackpine & brush

DATA SHEET # Msmt #5

TAPE # ST-90A

TIME START 9:03 [✓ AM] PM

TEST PROCEDURE(S) 1. CN-3

2.

3.

TIME FINISH 9:33 [✓ AM] PM

WEATHER DATA

TEMPERATURE 60°F

CALIBRATION(S) 1. A-1 (51=0m)

2.

3.

RELATIVE HUMIDITY

BAROMETRIC PRESSURE

SITE MONITORING ☑

WIND SPEED (AREA) Calm-7mph.

OTHER

DIRECTION

SOURCE OF WIND INFO.

WIND ON MIC Calm

SKY CONDITIONS

RESULTS (dBA):

			0	1	2	3	4	5	6	7	8	9
L	00-09		51	41		40	39	39			38	38
L	10-19		38		37		37					36
L	20-29		36	36							35	35
L	30-39		35	35								35
L	40-49		34				34					34
L	50-59		34		33					33		33
L	60-69		33			32					32	32
L	70-79		32			31			31			31
L	80-89		31			30			30			30
L	90-99		30	29	29				28	28		27

117
51
60

K Kajander

Signature of Investigator

COPPER-NICKEL NOISE
FIELD DATA SHEET

SITE BWCA - Gull Lake

DATE 7/20/77

VEGETATION Predom. white spruce, some jackpine and brush

DATA SHEET # Msmt. #6

TAPE # ST-90B

TIME START 1:41 AM [✓ PM]

TEST PROCEDURE(S) 1. CN-3

2. ____

3. ____

TIME FINISH 2:10 AM [✓ PM]

WEATHER DATA

CALIBRATION(S) 1. A (63=0Vu)

2. ____

3. ____

TEMPERATURE ____

RELATIVE HUMIDITY ____

BAROMETRIC PRESSURE ____

SITE MONITORING ☑

WIND SPEED(AREA) med-high

OTHER ____

DIRECTION ____

SOURCE OF WIND INFO. ____

WIND ON MIC 0-3

SKY CONDITIONS ____

RESULTS (dBA):

			0	1	2	3	4	5	6	7	8	9
L	00-09	X	49	43	42	41	41	40		39		39
L	10-19	X	38		38	37		37	36			35
L	20-29	X	35			34				34	33	33
L	30-39	X	33			33		32				32
L	40-49	X	32		31					31		31
L	50-59	X	31	30				30			29	29
L	60-69	X	29			29			28			28
L	70-79	X	28			27						27
L	80-89	X	27			27	26					26
L	90-99	X	26		25			25	24		24	23

113
63
50

K Kajander

Signature of Investigator

COPPER-NICKEL NOISE
FIELD DATA SHEET

SITE BWCA - Gull Lake

DATE 7/10/77

VEGETATION Predom. spruce and some jackpine & brush

DATA SHEET # Msmt. #7

TAPE # ST-88A

TIME START 6:30 AM [✓ PM]

TEST PROCEDURE(S) 1. CN-3

2.

3.

TIME FINISH 7:03 AM [✓ PM]

WEATHER DATA

CALIBRATION(S) 1. A (63=0Vu)

2.

3.

TEMPERATURE

RELATIVE HUMIDITY

BAROMETRIC PRESSURE

SITE MONITORING ☑

WIND SPEED (AREA) calm - medium

OTHER

DIRECTION

SOURCE OF WIND INFO.

WIND ON MIC calm

SKY CONDITIONS

RESULTS (dBA):

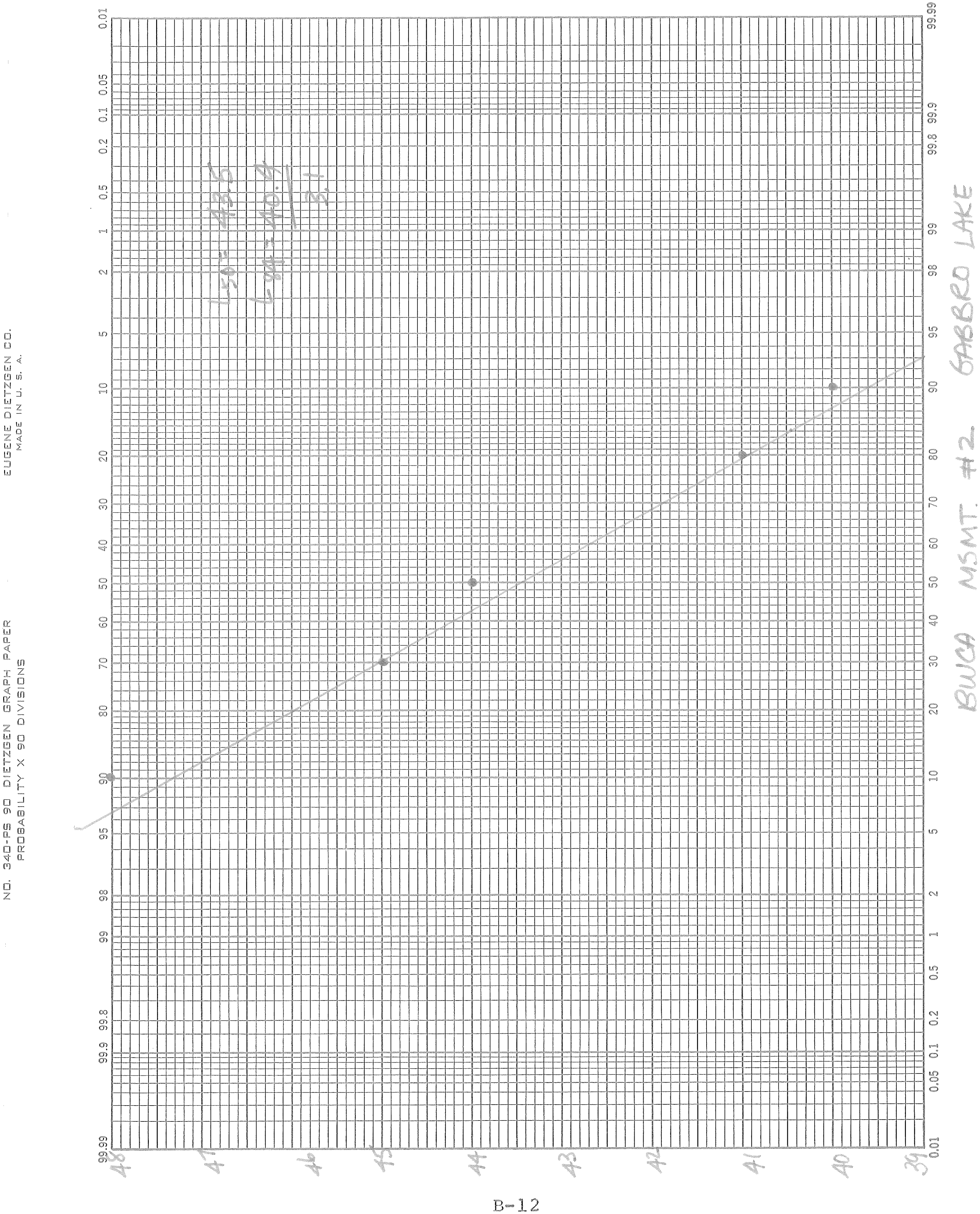
			0	1	2	3	4	5	6	7	8	9
L	00-09		57	52	45	43	40	39	38	38	37	37
L	10-19		36				35					35
L	20-29		35	34								33
L	30-39		33								32	32
L	40-49		32								31	31
L	50-59		31							30		30
L	60-69		30				29					29
L	70-79		29		28							28
L	80-89		27						26			26
L	90-99		26				25					25

~~108~~
113
63
50

1/8

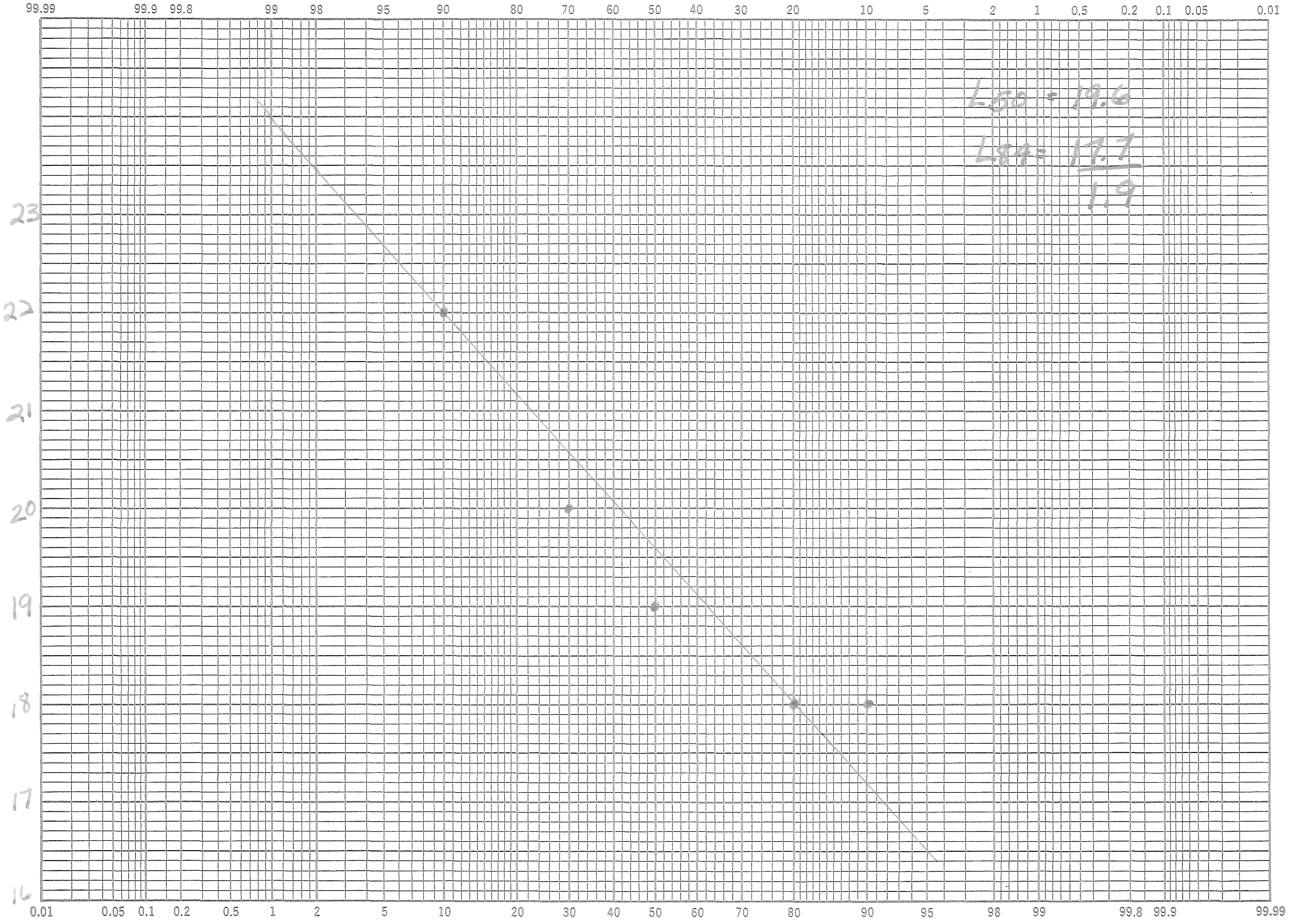
K Kajander

Signature of Investigator

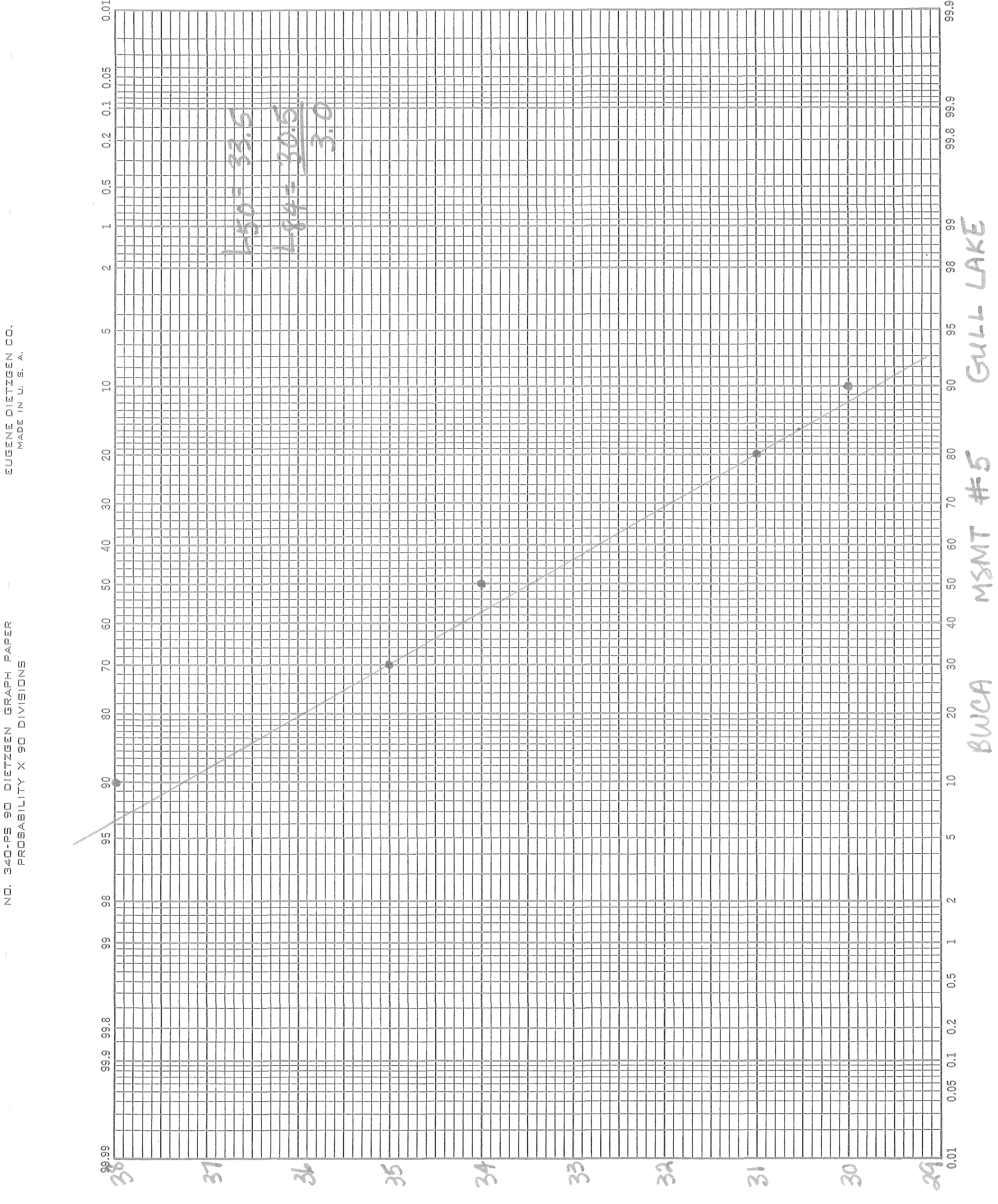

NO. 340-PS 90 DIETZGEN GRAPH PAPER
PROBABILITY X 90 DIVISIONS
EUGENE DIETZGEN CO.
MADE IN U. S. A.
BWCA MSMT. #2 GABBRO LAKE
L50 = 43.5
L84 = 40.4
3.1
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
48
47
46
45
44
43
42
41
40
39

NO. 340-PS 90 DIETZGEN GRAPH PAPER
PROBABILITY X 90 DIVISIONS

EUGENE DIETZGEN CO.
MADE IN U. S. A.



BWCA MSMT #3 GABBRO LAKE



L50 = 33.5
L84 = 30.5
3.0

BWCA MSMT #5 GULL LAKE

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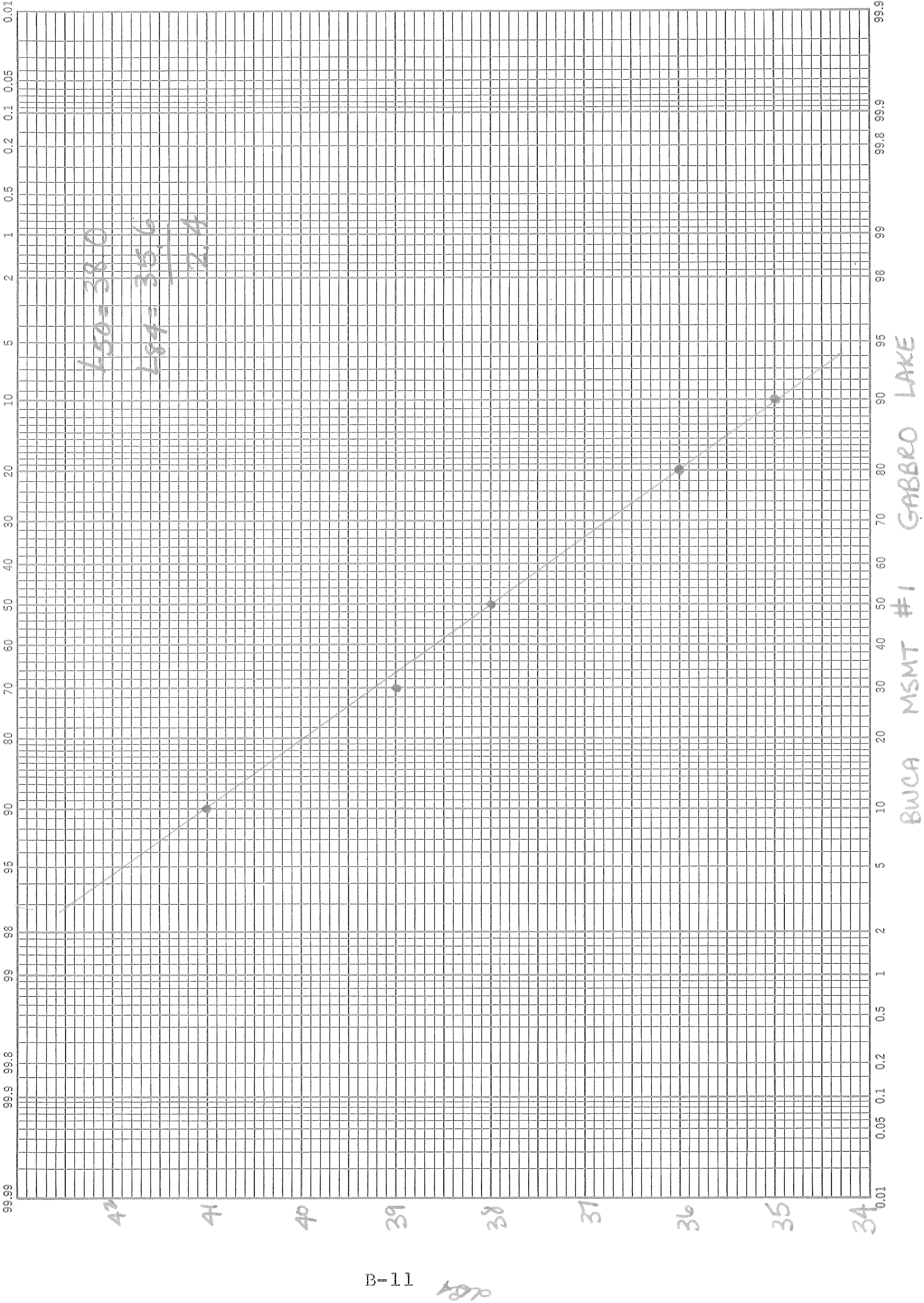
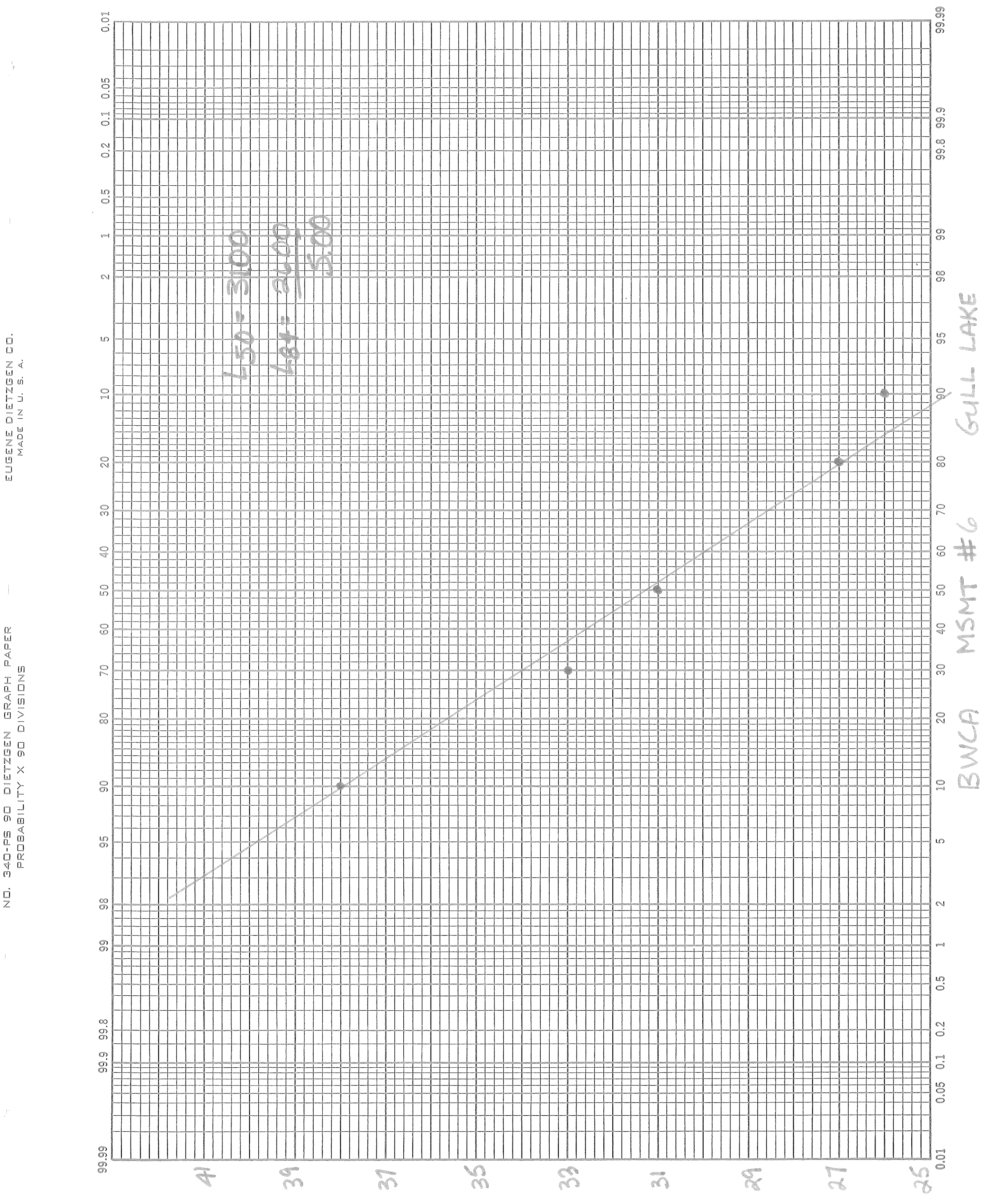
PROBABILITY X 90 DIVISIONS

EUGENE DIETZGEN CO.
MADE IN U. S. A.

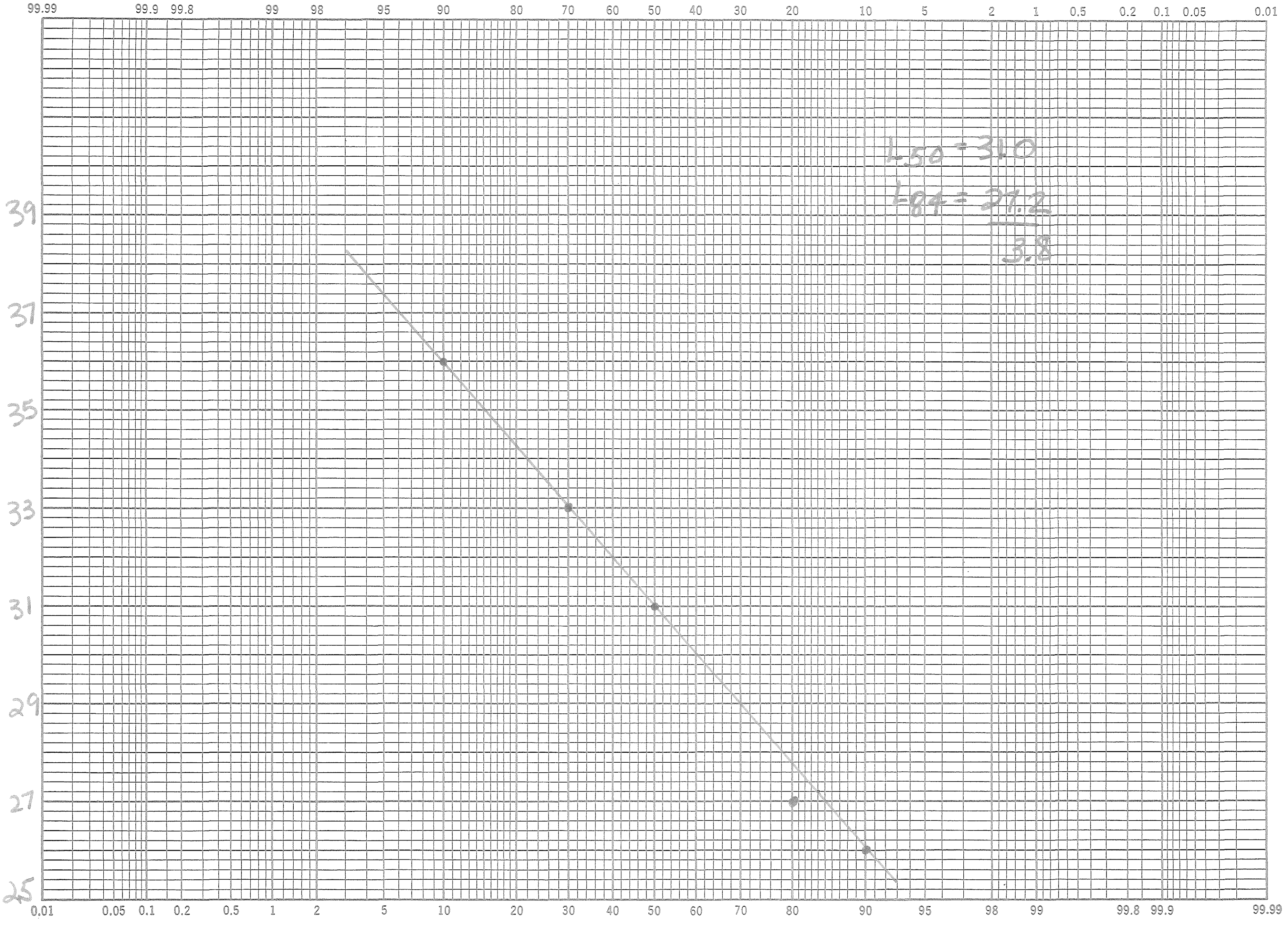



NO. 340-PS 90 DIETZGEN GRAPH PAPER
PROBABILITY X 90 DIVISIONS
EUGENE DIETZGEN CO.
MADE IN U. S. A.
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
L50 = 3100
L84 = 3600
500
BWCA MSMT #6 GULL LAKE
41
39
37
35
33
31
29
27
25

468

NO. 340-PS 90 DIETZGEN GRAPH PAPER
PROBABILITY X 90 DIVISIONS

EUGENE DIETZGEN CO.
MADE IN U. S. A.



BWCA MSMT #7 GULL LAKE

APPENDIX C

WIND ON THE MICROPHONE STUDY

Introduction

One of the most constraining methodological problems in making outdoor sound measurements is that of wind. Air impinging on an exposed microphone will tend to form pressure pulses on the diaphragm which is interpreted by the instrumentation as noise. As a result, the true value of a measured sound level distribution is difficult to ascertain accurately.

This problem of wind noise has been alleviated to some degree by the use of windscreens which tend to dissipate air flow around the microphone without attenuation of acoustical energy. The windscreen, in effect, transfers the turbulent flow to a greater distance from the diaphragm. This process does not totally eliminate wind generated noise but substantially reduces it such that acoustical signals from the environment essentially mask the wind noise. Thus, the effectiveness of any windscreen is somewhat dependent on the overall amplitude of the acoustical signals of interest.

Another important determinant of how well a windscreen will reduce wind noise is the type of material used in its construction. Typically, porous materials either as a solid mass or wrapped over a wire mesh frame, have been found to be most effective. Kelnhoffer, in a review of the literature, reported no significant differences between solid and framed windscreens, although he found a wide range of results for several types of porous materials (Kelnhoffer, 1972). Nylon material with a flow resistance of 5 to 10 rayls (dynes/Cm^3 per second) was reported to produce significant wind noise reduction in the 30 to 8,000 Hz range for winds less than 30 mph. Other investigators, however, found nylon with a flow resistance of 2 to 5 rayls produced optimum results for winds under 40 mph. With subsequent testing, Burroughs, according to Kelnhoffer, showed that these materials resulted in high frequency attenuation, surface noise, and a variance of effectiveness with humidity. After experimenting with several materials, Burroughs concluded that 1/4 inch polyester foam with a density of two pounds per cubic foot was the most efficacious in reducing wind generated noise.

The shape of the windscreen is an important factor in its effectiveness, depending on the type of wind for which it is used. For unidirectional winds, such as in a duct or wind tunnel, streamlined shapes faced into the direction of air flow, have been most widely used. Bruel has demonstrated wind noise attenuation of up to 15 dB with a metal nose coned type windscreen which also acts as the protective grid over the diaphragm (Bruel, 1960). Further, by extending the same principle of construction to a streamlined windscreen that fits over the entire microphone, he produced wind noise attenuation of as high as 25 dB for a 12 mph wind. Kelnhoffer also reports success with the streamlined shape (Kelnhoffer, 1972). He describes a dynamic microphone, designed by G. VanNiekirk, to be totally streamlined, which resulted in significant wind noise reduction. He goes on to say, however, that shapes other than streamlined ones have been used successfully for unidirectional winds. Beranek, for example, obtained wind noise reduction of up to 30 dB using a cylindrical windscreen positioned perpendicular to the air flow.

For multidirectional air flows, i.e., winds in the natural environment, principally two shapes, spherical and hemispherical have been utilized. Four inch diameter foam spheres have been very widely used with a large degree of success (e.g., Bruel, 1960, Beranek, 1971), although the literature frequently points out that larger versions of these shapes are the most effective. Breeland showed the optimum size for hemispherical windscreens to be 3 feet in diameter (Breeland, 1967) and Kelnhoffer reported a diameter of 18 inches to be the most efficient for spheres (Kelnhoffer, 1972). However, given the cumbersome nature of these large windscreens, smaller screens are more practical for most field measurements.

Skode performed a series of tests on the above mentioned 4 inch windscreen to demonstrate its effectiveness (Skode, 1966). He determined that it substantially reduces wind noise for winds under 37 mph when the microphone is placed perpendicular to the direction of the wind. At speeds above 37 mph, maximum effectiveness is achieved when the microphone is placed parallel to the direction of the flow, which he concluded was due to the microphone protection grid acting as a windscreen itself.

By means of third octave analysis, he showed that a large portion of wind noise energy is located at frequencies below the 1,000 Hz band. Further, he determined that wind noise reduction for these frequencies is more substantial for a relatively low wind, 19 mph, as opposed to a high wind, 75 mph. Conversely, for frequencies above the 1,000 Hz band, wind noise is reduced more for the high wind. He goes on to speculate that an "A" weighting would essentially smooth out these differences due to the low frequency filtering of the "A" network.

Further testing by Skode showed that a constant wind produces less wind noise, particularly in the low frequencies, than variable winds that averaged out to the same value. The latter type of wind would be more representative of winds experienced in field measurements. Also, after testing several sizes of windscreens, a 24 cm (9.45 inches) diameter sphere was found to produce the best results, which is in agreement with the previously cited literature.

Purpose

Many of the outdoor sound measurements made throughout the Copper-Nickel Noise Monitoring Project monitored such low levels that wind on the microphone often times posed a problem. As a result, a special windscreen system was developed, tested, and used for all field measurements during the study.

The system was tested to determine the amount of wind noise it allowed to pass and also to establish whether the windscreens caused attenuation of signals from the environment. This first test (Test 1) was conducted as a field experiment in an environment where the only acoustical signals encountered were solely due to wind. Wind speeds were monitored simultaneously with sound levels in an attempt to quantify a correlation between specific wind speeds and dBA levels. After this relationship was established, a spectral analysis was performed to determine frequency content of sound levels corresponding to each wind speed increment. The second test (Test 2) performed in the laboratory, was setup so that the microphone system measured the same pulse tones both with and without the windscreen system. The output of the microphone was analyzed for spectral content for both conditions to determine if any attenuation resulted due to the presence of the windscreens.

Test 1--Method

Site

The site opted for was Snowbank Lake located 24 miles northeast of Ely, Minnesota. Data was collected during the winter months (December 21, 1976 to February 2, 1977) while lake ice was strong enough to support the monitoring vehicle.

Snowbank Lake is about four by three miles at its longest points. Due to its close proximity to the Boundary Waters Canoe Area, there is very little activity on the shorelines. Snowbank Lodge was the only active dwelling on the shoreline at the time of the measurements, Although sounds from the lodge were not detectable. Data were collected from a site that was approximately one half mile away from all shorelines (Figure C-1).

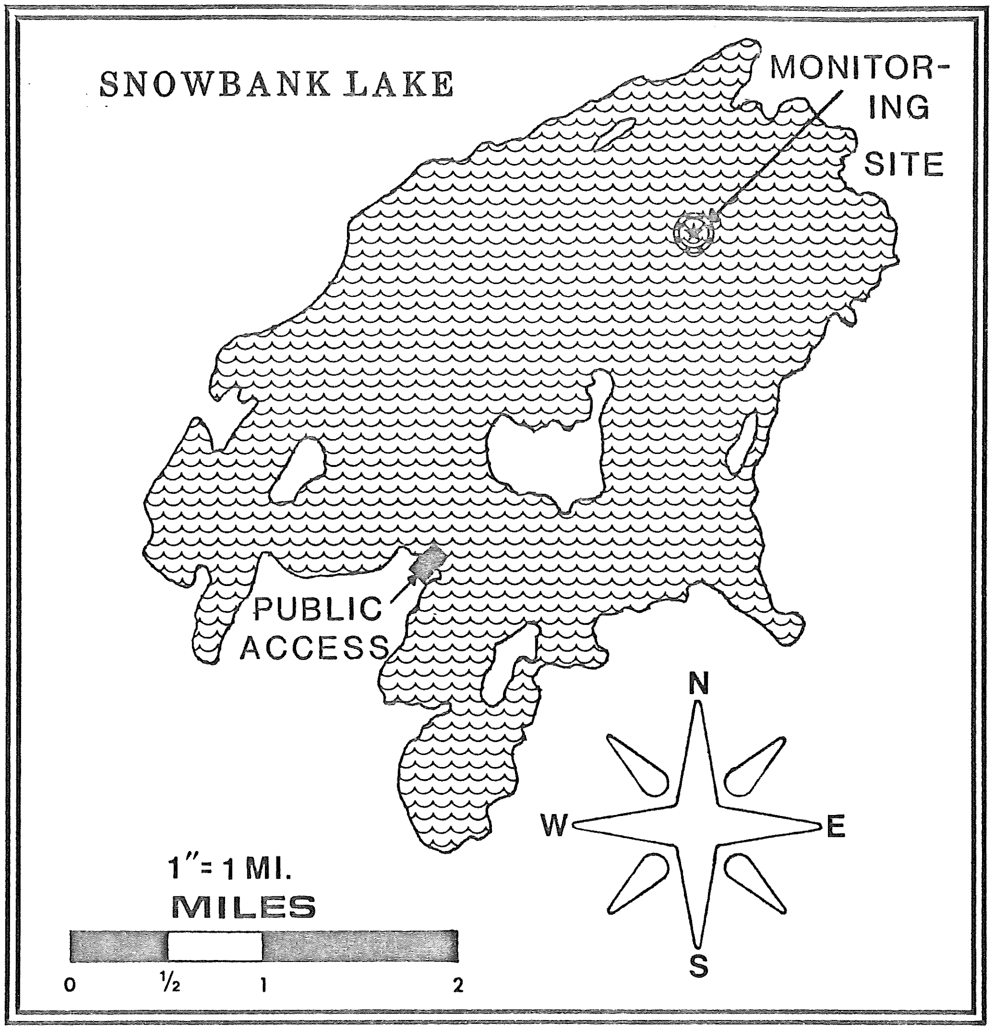


FIG.

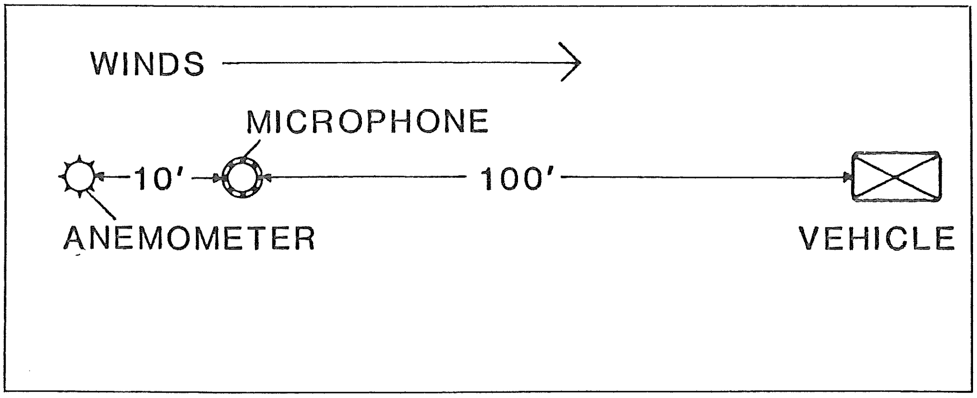


FIG. C-1
PLACEMENT OF MICROPHONE & ANEMOMETER IN RELATION TO WIND DIRECTION

Procedure

The windscreen system used consisted of a Bruel and Kjaer 4 inch UA0207 windscreen, 8 inches in diameter with a cone top. It was formed by wrapping 1/4 inch polyester foam around a frame of 1/2 inch wire mesh, composed of 1/32 inch wire (See photos, Figure C-2).

Wind noise was recorded with a Nakamichi Cassette Tape Recorder with the microphone windscreen system placed 100 feet upwind from the monitoring vehicle (See Test Procedure CN-3, Calibration A, Appendix N). Placed 10 feet upwind from the microphone was an anemometer mounted on a tripod and adjusted to the same height as the microphone (See Figure C-1). Wind speeds were monitored in the vehicle via a remote readout gauge (See Test Procedure CN-11, Appendix N).

Wind noise was recorded on tape for 20 one-minute segments, with each segment separated by a five second pause. During each taping interval wind speeds were noted every five seconds. An attempt was made to record as many ranges of wind speeds as possible from calm to 20 mph.

A total of 14 tests were conducted in the field and later analyzed at Moorhead State University. Tapes were run through a third octave analyzer in order to isolate specific data intervals for which the wind remained constant to within one mile per hour (See Test Procedure CN-13, Appendix N). Below 8 mph this was possible, although above 8 mph it was necessary to accept a ±1 mph tolerance. Speeds greater than or equal to 10 mph were analyzed in 2 mph increments due to the increasing gustiness of higher wind speeds. Where possible, three 32 second data intervals for each wind speed were analyzed and the resulting band levels rms averaged. When it was not possible to find enough data to make three 32 second runs, fewer recording or shorter integration times were used. All band levels were "A" weighted. After analysis, band levels were summed using a programmable hand calculator to determine the overall dBA level.

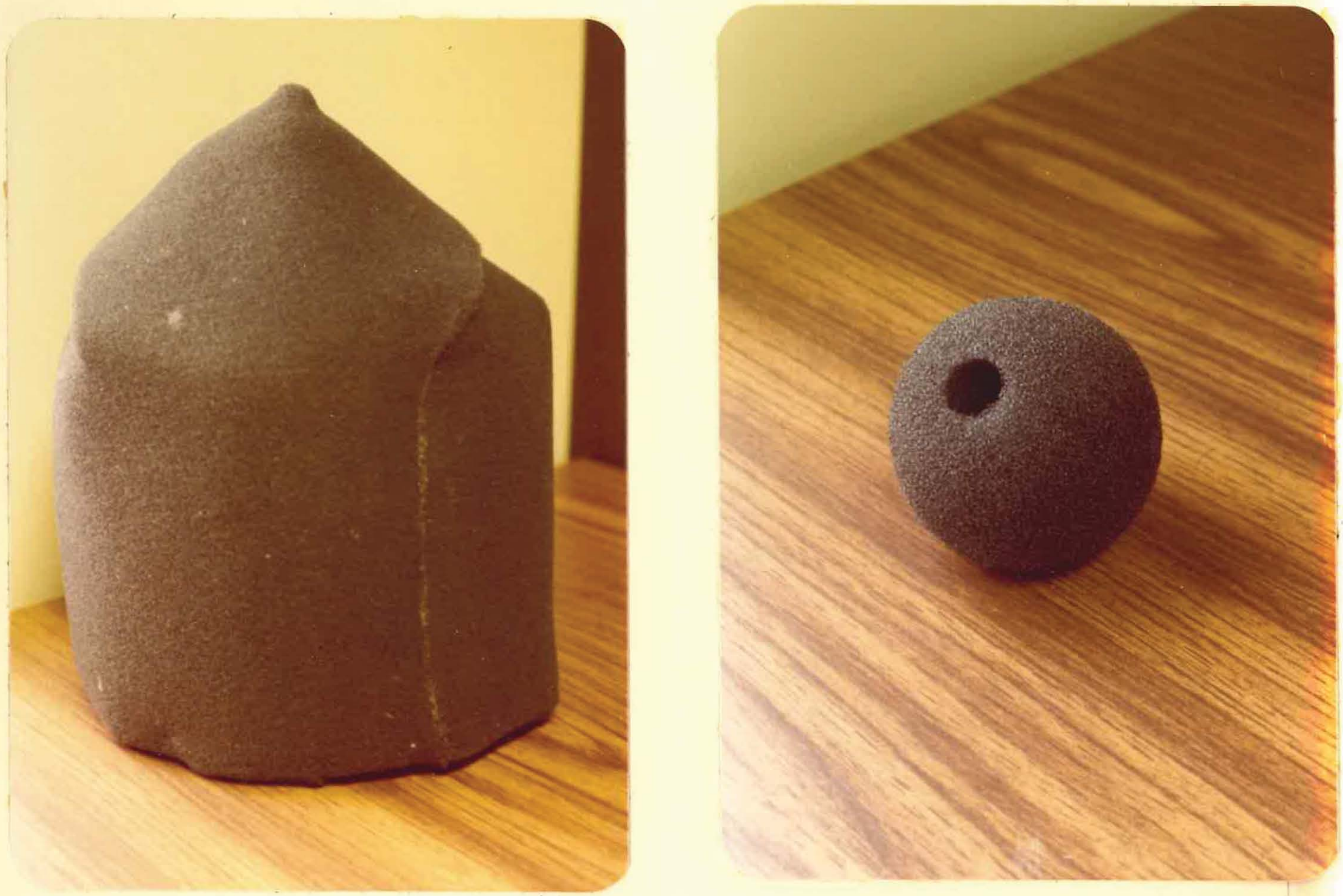
Results

Table C-2 shows the third octave band levels of wind noise for speeds of 3 to 20 mph along with the "A" weighted total. Each speed is graphed in Figures C-3a through C-3d. The shapes of the graphs indicate that for wind speeds below 8 mph, the "A" weighted level is probably the result of electronic noise in the bands above 1,000 Hz. Essentially for these speeds, wind noise is buried in the noise floor of the instrumentation. Thus, for speeds of 3 to 7 mph, an "A" weighted total of the 25 Hz to the 1,000 Hz band would be a better indicator of wind noise, as given below.

MPH	LEVEL (dBA)
3	9
4	10
5	12
6	13
7	17

"A" weighted bands 25 Hz to 1,000 Hz

The high frequency components of wind noise above 8 mph become very distinct in the third octave band spectra. Previous studies of wind noise have shown most of the energy to be in the lower bands, with a gradual drop in the high frequencies. The results of this study, then, are in contrast with results found by previous investigators. It is possible that the material used in the construction of the windscreen (1/4 inch foam) could have produced these high frequency signals in response



1/4" foam windscreen- designed
by Midwest Acoustics, Minneapolis,
Minnesota

B&K 4" sphere windscreen
model UA0207

FIG.C-2 TWO WINDSCREENS USED FOR TEST 1

1/3 Octave Center Frequency	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	"A" Weighted Total
3 mph	-11	-6	-5	-2	-1	-1	0	-6	-7	-7	-8	-6	-6	-5	-2	-1	-1	1	1	2	3	3	3	3	3	5	14
4 mph	-10	-4	-2	1	1	1	1	-3	-4	-5	-7	-5	-6	-5	-2	-2	0	0	1	1	2	2	3	3	3	4	14
5 mph	-5	-1	-2	0	1	1	2	1	2	0	-2	-2	-2	-1	1	0	1	1	2	2	3	4	4	4	4	5	16
6 mph	0	4	2	2	1	-1	-1	-2	-2	-3	-3	-2	-1	-1	1	1	1	1	2	2	3	4	4	4	4	6	16
7 mph	4	7	8	7	6	4	4	2	2	2	1	2	3	3	4	3	3	2	3	2	4	4	4	4	3	5	18
8 mph	6	9	8	10	9	7	7	6	6	6	5	5	6	6	7	5	5	4	4	3	4	4	4	4	4	5	20
10 mph	6	11	17	18	16	15	16	14	14	14	14	14	15	16	18	18	17	17	16	14	12	11	9	9	10	12	29
12 mph	12	17	18	21	22	22	23	21	22	21	20	20	22	23	25	25	24	25	25	24	25	23	19	17	16	18	37
14 mph	13	18	20	22	24	24	24	22	23	22	22	21	23	24	27	26	26	27	27	27	28	25	22	20	19	20	38
16 mph	18	22	25	28	28	28	30	28	29	27	26	26	27	27	29	29	29	29	29	30	32	32	30	28	26	26	42
18 mph	20	24	26	29	30	30	31	30	30	29	28	27	28	28	31	31	31	30	30	31	33	33	31	30	28	27	44
20 mph	22	27	28	33	33	34	35	34	34	32	32	31	32	33	35	36	36	36	35	36	37	37	36	35	33	31	48

TABLE C-2

"A" Weighted 1/3 Octave Band Levels for Wind Speed Increments

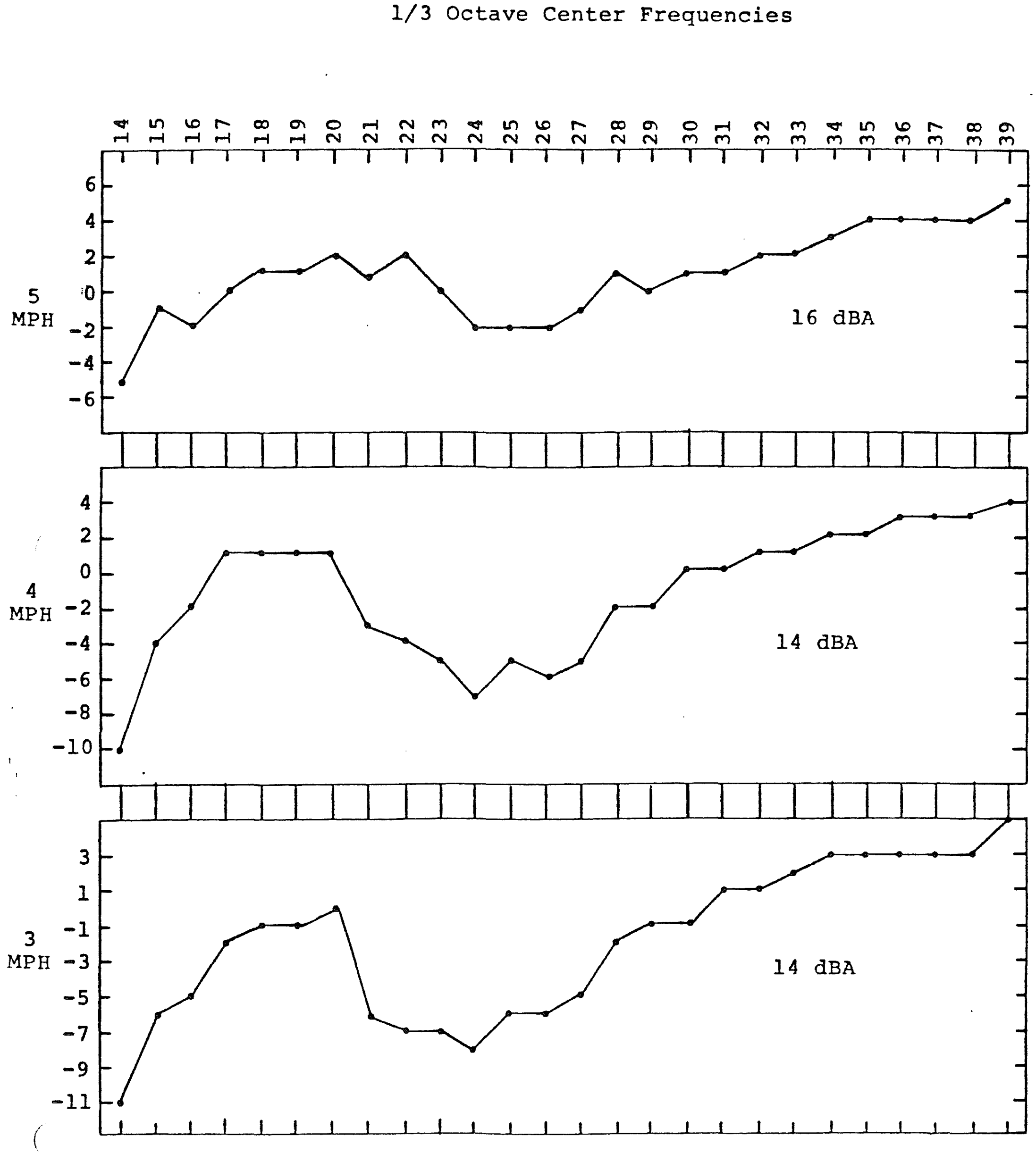


Figure C-3a 1/3 octave levels for windspeed increments

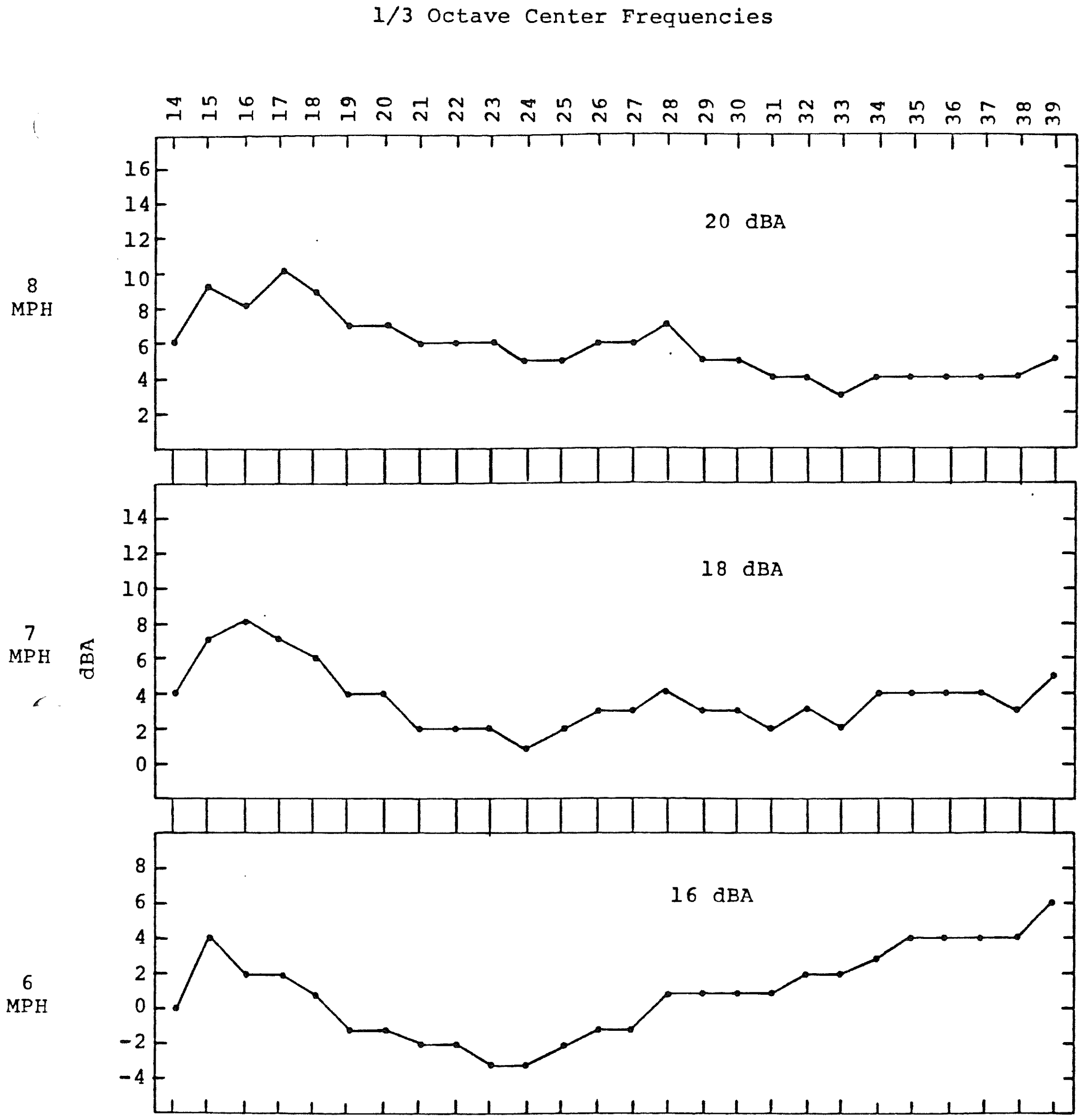


Figure C-3b 1/3 octave levels for windspeed increments

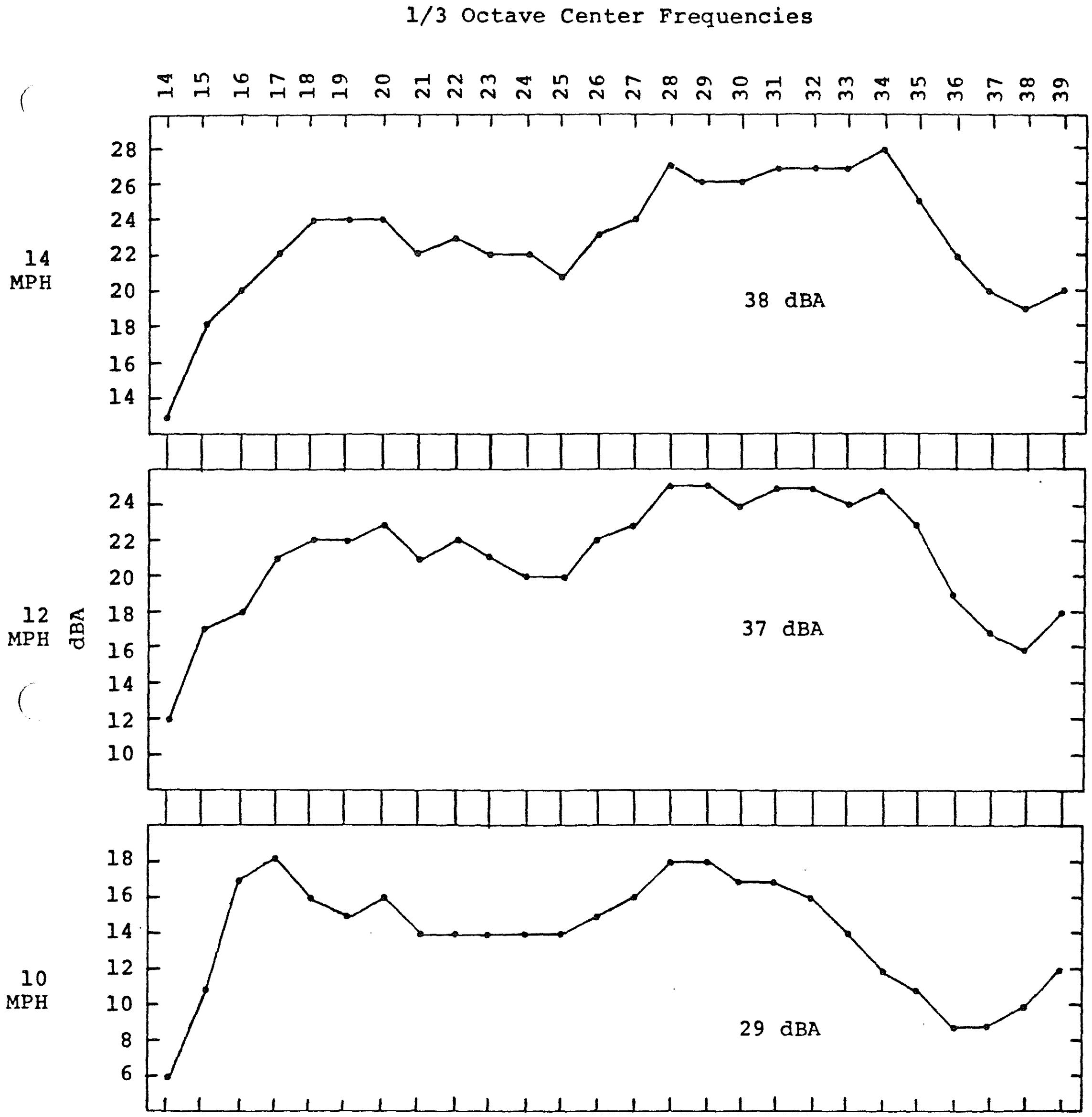


Figure C-3c 1/3 octave levels for windspeed increments.

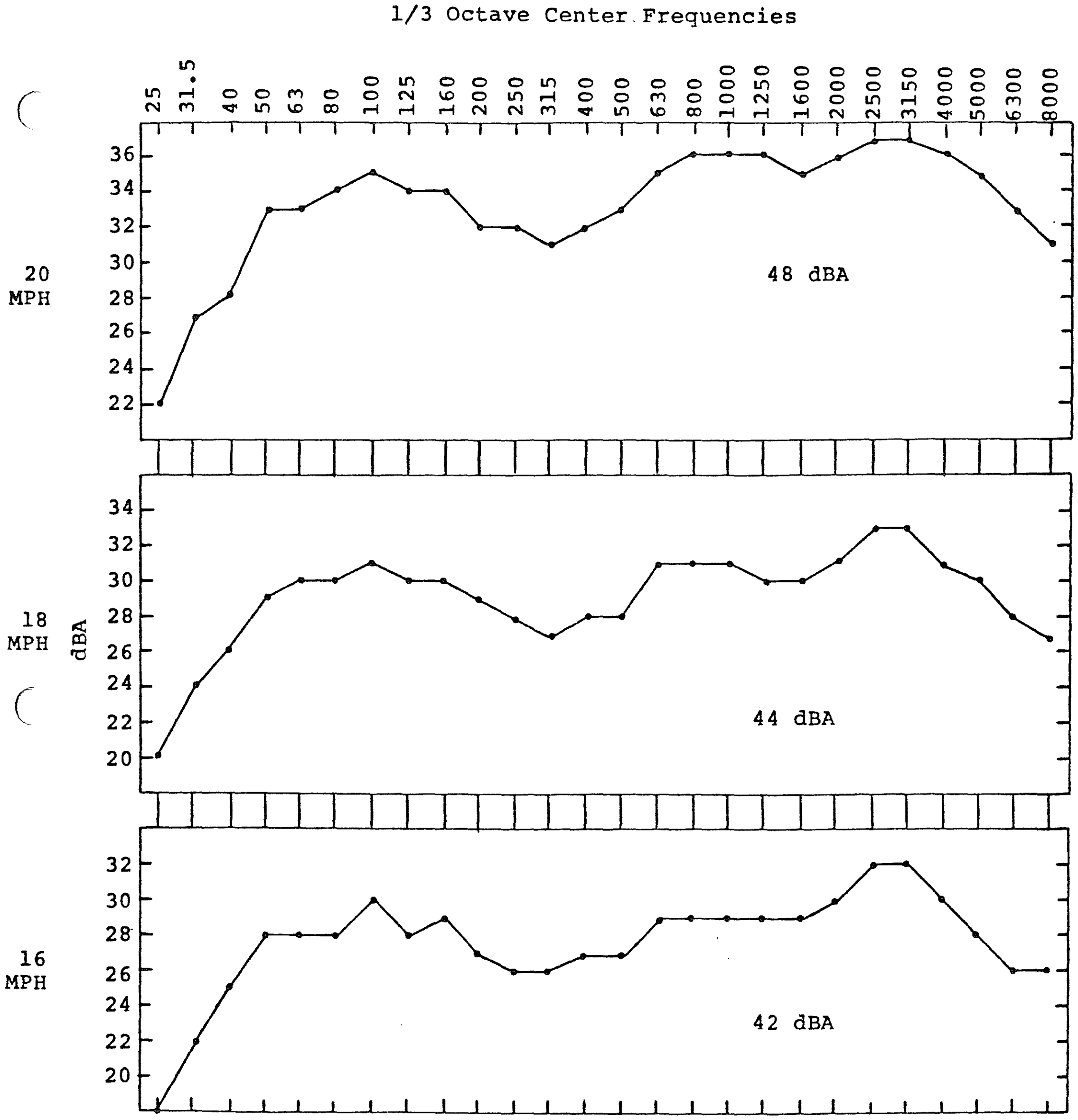


Figure C-3d 1/3 octave levels for windspeed increments.

to winds. Another possibility, perhaps more likely given results from previous investigators, is that the 1/2 inch wire mesh used in the frame construction could have produced these signals. Although very little information is given in the literature regarding the types of materials and methods used in frame construction, several schematic illustrations have indicated that thicker wire spaced farther apart has been used most frequently. Since the 1/2 inch mesh with wire of 1/32 inch diameter used in this study constituted practically the entire shape of the windscreen, it is conceivable that these small openings together with the small diameter wire could have produced the high frequency signals in response to wind.

Test 2

Test 2 was performed in the laboratory to assess whether the windscreens used for the project caused any attenuation of the acoustical signals. In addition to the 4 inch Bruel and Kjaer and the 1/4 inch foam large windscreens, a large windscreen covered with 1/2 inch foam was also tested. This 1/2 inch foam windscreen was identical to the 1/4 inch foam windscreen with regard to shape, size, and frame material with the exception of the foam covering.

Tests were conducted on a consultant basis by Dr. Richard VanDoeren of Midwest Acoustics, Minneapolis, Minnesota on February 15, 1978. In lieu of securing an anechoic chamber to minimize room effects, Dr. VanDoeren utilized a pulse-tone technique under free field conditions. Four combinations of the three windscreens were tested with each combination compared to a "no-windscreen" condition. The microphone's output was fed into an octave band analyzer, which considered bands between 500 and 10,000 Hz*. Data were analyzed on both peak and impulse response modes.

Given in Table C-4 are the results for each octave band tested for all four conditions. The difference is noted between the windscreen conditions for both response modes, and is plotted as a function of octave bands in Figures C-5a and C-5b. The general trend in both figures is for the graphs to shift downward with frequency, thus pointing to greater attenuations at the high frequencies. Of special interest is that the 1/4 inch plus Bruel and Kjaer and the 1/4 inch alone show an amplification of 1 dB at the 8 KHz band. Further, at the 10 KHz band, only the 1/4 inch plus Bruel and Kjaer combination shows an amplification of approximately 2 dB. It is not exactly clear what may have caused this result, although the actual field data showed very little energy within these bands. Thus, it is doubtful whether residual sound data were affected.

Discussion

During each field residual sound measurement made during the Noise Monitoring Study, peak wind speeds were monitored at the microphone. In almost all measurements within the canopied vegetation stands, winds at the microphone rarely exceeded 5 mph, which according to the data presented in this section equals a sound level of only 12 dBA. For the measurements where 5 mph winds were encountered, the measured residual levels were always much higher than 12 dBA, and, in fact, were usually greater than 30 dBA.

The only measurements where wind noise posed a significant problem were in clearcut areas. Often the sound spectra for these sites looked very similar to wind noise spectra, indicating that many of these measurements were probably affected by winds on the microphone. The time allotted for analysis did not allow for quantifying this effect for clearcut stands, although by superimposing various overall levels of wind noise spectra over clearcut data, this problem could be rectified. The sound level distributions for clearcut areas, nevertheless, did average out to be the quietest sites. Thus, the data presented for these areas is in all probability higher than the actual residual levels.

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* Previous testing by Dr. Van Doeren at the onset of the Copper-Nickel Noise Monitoring Project indicated no appreciable effects due to the presence of the windscreens for frequencies below 500 Hz.

Octave Band Center Freq.	500 Hz		1 KHz		2 KHz		4 KHz		8KHz		10 KHz	
Response Mode	Peak	Impulse	Peak	Impulse	Peak	Impulse	Peak	Impulse	Peak	Impulse	Peak	Impulse
¼" windscreen and B&K 4"	93.2	78.9	106.4	92.1	115.1	99.3	111.9	90.7	105.5	89.6	104.2	88.9
no windscreen	92.9	78.8	106.5	92.1	114.7	99.1	111.6	90.5	104.3	88.3	102.3	86.5
difference	+0.3	+0.1	-0.1	0	+0.4	+0.2	+0.3	+0.2	+1.2	+1.3	+1.9	+2.4
¼" windscreen alone	91.6	77.7	105.1	90.5	112.6	97.2	111.7	95.6	104.1	88.3	101.6	86.1
no windscreen	91.4	77.6	105.1	90.5	112.8	97.3	112.1	96.0	103.6	87.3	102.0	87.4
difference	+0.2	+0.1	0	0	-0.2	-0.1	-0.4	-0.4	+0.5	+1.0	-1.2	87.4
½" windscreen and B&K 4"	94.7	80.0	107.7	93.1	117.0	101.7	112.8	96.9	105.6	89.4	103.4	86.4
no windscreen	94.7	80.9	108.0	93.3	116.5	101.3	114.1	98.2	106.8	91.2	105.5	89.2
difference	0	-0.9	-0.3	-0.2	-0.5	-0.4	-1.3	-1.0	-1.2	-0.7	-1.1	-1.3
½" windscreen alone	104.0	90.1	116.9	102.2	116.8	101.5	112.3	97.5	106.5	90.6	104.2	88.3
no windscreen	103.9	90.0	116.7	101.9	116.7	101.4	114.0	98.2	106.9	91.5	105.1	88.3
difference	+0.1	+0.1	+0.2	+0.3	+0.1	+0.1	-0.7	-0.7	-0.4	-0.9	-0.9	0

TABLE C-4 Octave band results for 4 windscreen conditions for peak and impulse response (dB).

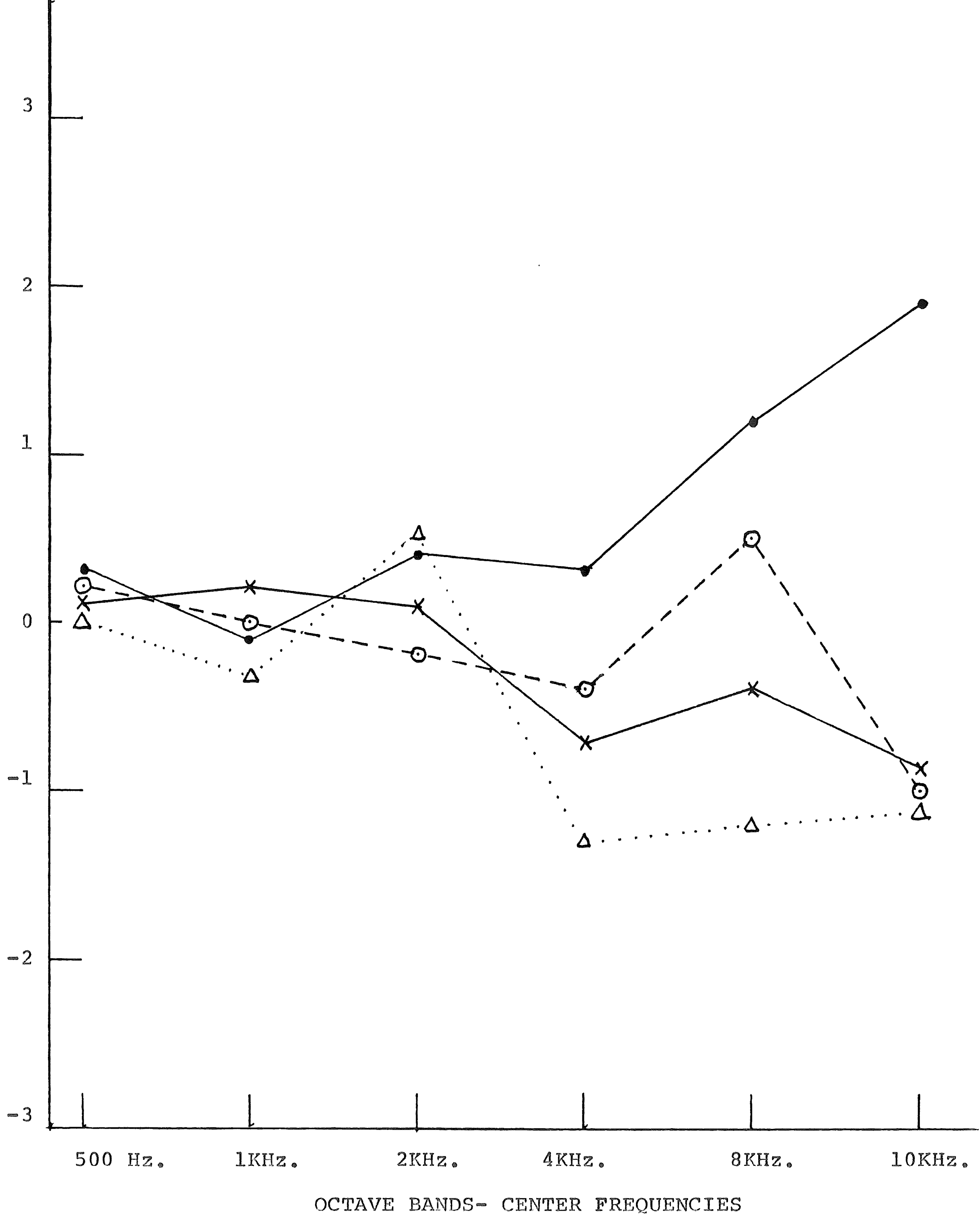


FIG. C-5a Differences between control and test conditions for four windscreen combinations- peak response

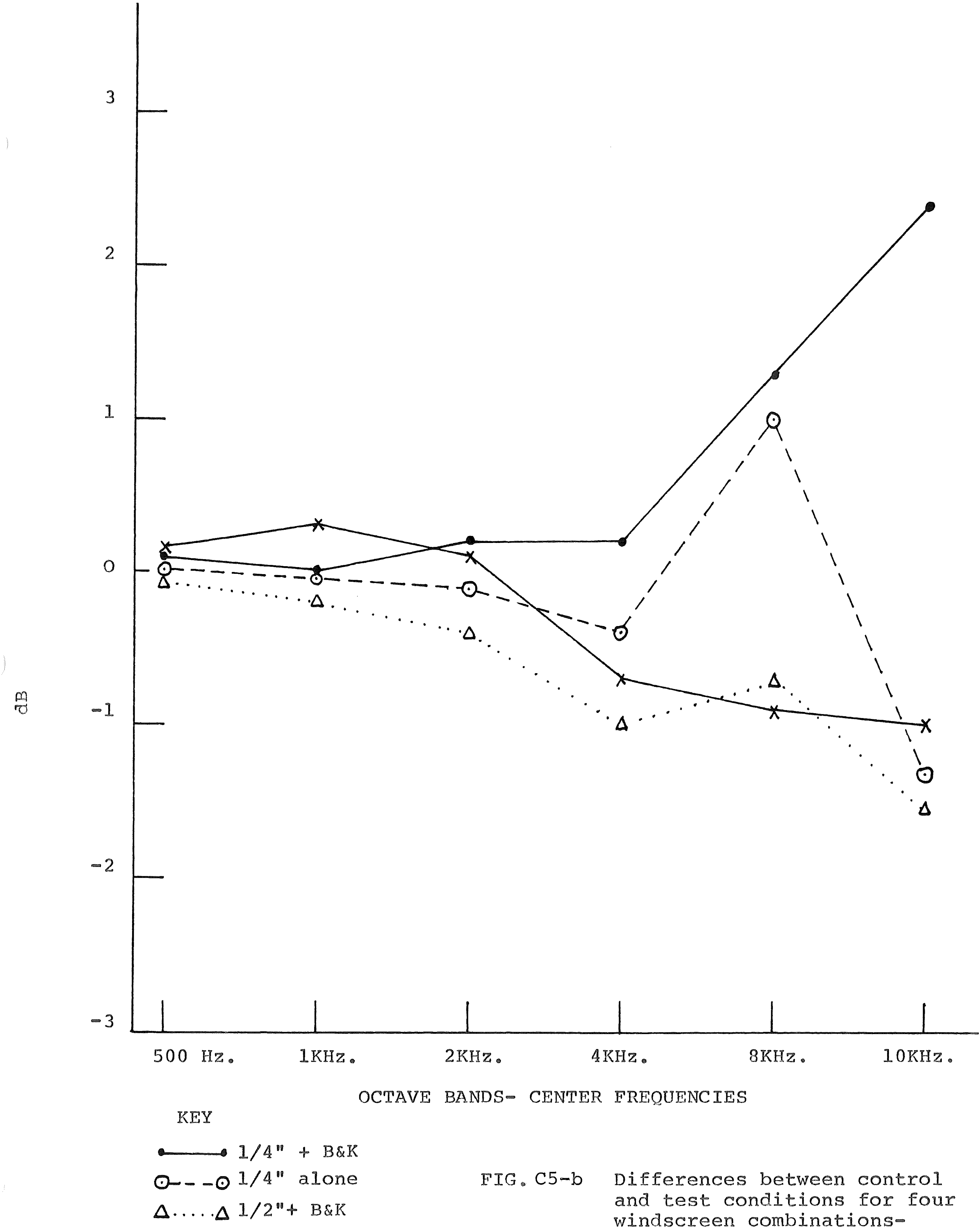


FIG. C5-b Differences between control and test conditions for four windscreen combinations-impulse response

REFERENCES

1. Beranek, L.L.; Noise and Vibration Control, McGraw-Hill, New York, 1971, pp. 87-90.

2. Breeland, A.H. and Bonner, R.S.; "Results of Tests Involving Hemispheric Windscreens in the Reduction of Wind Noise," Atmosphere Science Laboratory, White Sands Missle Range, New Mexico, DA Task-IVO25991-6A-126-01, CCOM-5119, April, 1967, DDC AD 653 005.

3. Bruel Per. V.; "Aerodynamically Induced Noise of Microphones and Windscreens," Bruel and Kjaer Technical Review, No. 2, 1960, pp. 3-27.

4. Kelnhoffer, W.J.; "Aerodynamics of Acoustic Windscreens--A Report of the State of the Art." Submitted to the National Bureau of Standards, May 11, 1972, pp. 10-12.

5. Skode, Frede; "Windscreening of Outdoor Microphones," Bruel and Kjaer Technical Review, No. 2, 1960, pp. 3-27.

APPENDIX D

ELECTRONIC NOISE FLOOR OF MEASUREMENT APPARATUS

Due to the fact that this project was at times a study of quietude, sound levels at times dipped into the system noise floor of the field instrumentation. The noise floor of the Bruel and Kjaer 4161 Microphone—General Radio P_{42} preamplifier combination was measured both during and at the end of the project and found to be 6 dBA with the preamplifier set on a x10 gain. The microphone system used in conjunction with the Metrosonic Sound Level Analyzer was also tested to be 6 dBA. Finally, the Nakamichi Cassette Tape Recorder exhibited a noise floor of 57 dB below 0 Vu, which was in line with specifications outlined by the manufacturer. The above mentioned tests were performed by Dr. Richard VanDoeren of Midwest Acoustics, Minneapolis, Minnesota, (See Appendix Q for results of all equipment checks and calibrations performed during and at the end of the project).

Data taken during the monitoring study and during the wind on the microphone study that were affected by the system noise floor were noted as such during third octave band analysis. Electronic noise could be seen in the high frequencies, usually above 1,000 Hz for levels of less than or equal to 0 dBA. The few measurements that exhibited this characteristic during analysis of the windscreen study data were analyzed up to only 1,000 Hz, as noted in the study's results section. About two or three residual sound level measurements included levels that came within 10 dBA of the 6 dBA system noise floor. During spectral analysis, these low levels were not a problem because the procedure considered levels down to 20 dBA. These measurements were, however, included in the "combination of vegetation types" procedure. Thus, the lower limit given for residual sound levels is in all likelihood probably lower than the results indicate.

APPENDIX E

LEAST SQUARES FIT ON L_n DATA

When a series of L_n data, e.g., L_{10}, L_{20}...L_{90}, are plotted on probability paper and appear to fall on a straight line, it is often desirable to determine the best straight line fit to their data. Sound levels are plotted as a function of the percent of time exceeded. Thus, a straight line of points indicates a normal distribution. The horizontal scale units are chosen so that one standard deviation equals one unit and then is centered at the L_{50} level. A table of the normal probability function follows:

Percentile Level	L10	L20	L30	L40	L50	L60	L70	L80	L90
Corresponding X Value	-1.282	-.841	-.524	-.253	0	.253	.524	.841	1.282

Thus, if the data is normally distributed, a plot of $L_{10} \longrightarrow L_{90}$ over the corresponding X value should be a straight line for which the X=0 intercept is the mean value (L50). Further, since X=1 corresponds to one standard deviation, the slope of this line gives the standard deviation. This is because the slope of a line (y = mx + b) is the change in the y value that results from a unit change in the X value.

The procedure for a least squares fit is then as follows: using the least squares fit (linear regression) program of a programmable calculator, designed to fit pairs of data points (Y_iX_i) to the equation Y = mx + b, enter the following percent pairs of data points:

Y_i	L10	L20	L30	L40	L50	L60	L70	L80	L90
X_i	-1.282	-.841	-.524	-.253	0	.253	.524	.841	1.282

Based on these data points, the value for b that the program arrives at is the value for L50 from the best fit straight line and the value for m is negative of the standard deviation corresponding to the best fit straight line on probability paper. The straight line corresponding to this fit is determined by plotting b at the horizontal 50 percent line on probability paper and plotting b-SD at the 84 percent line on the paper.

If the correlation coefficient, r, is also determined, one can use standard statistical formulae to find a useful measure of the goodness with which the least squares straight line fits the data points. Let σ' be the value of the standard deviation of the 9 numbers which are the values of $L_{10} \longrightarrow L_{90}$ about their mean (This value is not the same as the SD). Then the standard deviation of the actual data points about the values predicted by the least squares fit line is given by $\sqrt{1-r^2}\,(\sigma')$. This value is called the standard error of estimate, δ.

Since the values of X_i are always the same, it is possible to develop a program for a programmable calculator which only requires the input of the nine values $L_{10} \longrightarrow L_{90}$. The least squares fit formulae:

$$1.\ \text{Slope} = m = \left[\left(\frac{\Sigma X_i Y_i}{N}\right) - \bar{X}\,\bar{Y}\right] \div (SD_X)^2$$

2. Intercept = $b = \bar{Y} - m \bar{X}$

3. Correlation coefficient $r = \frac{m(SD_X)}{\sigma' Y}$

4. $(SD_X)^2 = \frac{\Sigma X_i{}^2}{N} - \bar{X}^2$

5. $(\sigma' Y)^2 = \frac{\Sigma Y_i{}^2}{N} - \bar{Y}^2$

$\sigma' Y$ is as discussed above. For the particular value of X_i given in the above table.

6. $\bar{X} = 0$

7. $SD_X{}^2 = .5976$

Taking these results into account for this problem.

8. $m = \frac{\Sigma X_i Y_i}{5.379}$

9. $L_{50} = \bar{Y}$

10. $r = \frac{SD(.7730)}{\sigma' Y}$

11. Standard error of estimate δ =

$$\sqrt{(1-r)^2(\sigma' Y)^2}$$

$$= \sqrt{(\sigma' Y)^2-(SD\ .7730)^2}$$

A listing for a program for a Texas Instrument SR-52 calculator is given together with user instructions.

User Instruction

1) Start by entering the program

2) then enter the following numbers into the memory

.252 → STO in 04

.524 → STO in 05

.841 → STO in 06

1.282 → STO in 07

5.379 → STO in 10

.7731 → STO in 11

3) press 2nd rset

4) press run read 0

5) enter L_{50} press run

6) enter L_{40} press run

7) enter L_{60} press run

8) enter L_{30} press run

9) enter L_{70} press run

10) enter L_{20} press run

11) enter L_{80} press run

12) enter L_{10} press run

13) enter L_{90} press run

14) read out L_{50}

15) press run

16) read out SD

17) press run

18) read out δ, the goodness of fit parameter

Steps 5-13 must be run as listed, the order of input of the L values is important. Additional runs may be made by starting with step 3.

000	0	025	1	050	7	075	2
001	STO	026	5	051	STO	076	RCL
002	0	027	0	052	0	077	0
003	1	028	RCL	053	0	078	1
004	STO	029	0	054	Sub	079	HLT
005	0	030	5	055	1	080	X^2
006	2	031	STO	056	5	081	$^+/_-$
007	STO	032	0	057	0	082	+
008	0	033	0	058	RCL	083	RCL
009	3	034	Sub	059	0	084	0
010	HLT	035	1	060	1	085	2
011	Sum	036	5	061	÷	086	=
012	0	037	0	062	9	087	STO
013	1	038	RCL	063	=	088	0
014	X^2	039	0	064	STO	089	2
015	Sum	040	6	065	0	090	RCL
016	0	041	STO	066	1	091	0
017	2	042	0	067	RCL	092	3
018	RCL	043	0	068	0	093	÷
019	0	044	Sub	069	2	094	RCL
020	4	045	1	070	÷	095	1
021	STO	046	5	071	9	096	0
022	0	047	0	072	=	097	=
023	0	048	RCL	073	STO	098	HLT
024	Sub	049	0	074	0	099	X

APPENDIX F

COMBINATION OF INDIVIDUAL SOUND LEVEL DISTRIBUTIONS GIVEN THE MEAN, $\overline{X}$, AND STANDARD DEVIATION, SD

Appendix E explained how through least squares fit, the $\overline{X}$ and SD of a given sound level distribution were computed. Using the $\overline{X}$ and SD of several distributions, a method was developed to combine several discreet distributions into an overall sound level distribution.

Data from each distribution were computed to yield L values at intervals of L_{05}. Each L_{05} interval, L_{05}, L_{15}, L_{25}, L_{35} etc., was the mid data point between each L_{10} value, i.e. L_{05} represented data between L_{00} and L_{10}. Given that the value for the L_{05} interval was equal to the Y coordinate on probability paper, and assuming a Gaussian distribution, the values could then be calculated using a table which told how many standard deviations from the mean were the particular L_{05} interval. Each interval, then, was computed as follows:

$L_{05} = L_{50} + 1.645$ SD
$L_{15} = L_{50} + 1.037$ SD
$L_{25} = L_{50} + .674$ SD
$L_{35} = L_{50} + .385$ SD
$L_{45} = L_{50} + .126$ SD
$L_{55} = L_{50} - .385$ SD
$L_{65} = L_{50} - .674$ SD
$L_{85} = L_{50} - 1.037$ SD
$L_{95} = L_{50} - 1.645$ SD

Each L_{05} interval was then plotted on a histogram for each distribution. The L_{10} through L_{90} at L_{10} steps were tabulated by counting 10 percent steps on the resulting histogram. After calculating the combined L_n distribution, it was plotted on probability paper and using the method of linear regression, as explained in Appendix E, the $\overline{X}$, SD, and δ for the combined data were tabulated. The result was an overall sound level distribution for each vegetation type.

To facilitate the computation of the L_{05} intervals, a programmable hand held calculator, Hewlett-Packard, HP-25, was used. Data inputs were the $\overline{X}$ and SD of a given distribution and the outputs were the L_{05} intervals. The program appears at the end of this appendix.

Procedure for combining distributions using HP-25 calculator.

1. Enter program - switch to "Run" mode.

2. .126 STO 0
   .385 STO 1
   .674 STO 2
   1.037 STO 3
   1.645 STO 4

3. For each distribution, store L_{50} in Register 5 and store the standard deviation in Register 6.

4. To run the program press f, fix, 0, then r/s 10 times, each time putting an X on the histogram for each result.

5. Repeat steps 3 and 4 until all distributions have been plotted.

6. To find L_{90}, L_{80}, L_{70}...L_{10} from the histogram count entries on the histogram, starting from the lowest end. If there were n separate distributions combined, L_{90} will be the level that is n entries from the lowest, L_{80} will be 2n entries from the lowest, etc. There results can then be plotted on probability paper to obtain the combined distribution.

Entry Keys - with Calculator in "Program" Mode

```
 1    RCL 0
 2     ↑
 3    RCL 6
 4     X
 5     ↑
 6    RCL 5
 7     +
 8    R/S
 9    RCL 1
10     ↑
11    RCL 6
12     X
13     ↑
14    RCL 5
15     +
16    R/S
17    RCL 2
18     ↑
19    RCL 6
20     X
21     ↑
22    RCL 5
23     +
24    R/S
25    RCL 3
26     ↑
27    RCL 6
28     X
29     ↑
30    RCL 5
31     +
32    R/S
33    RCL 4
34     ↑
35    RCL 6
36     X
37     ↑
38    RCL 5
39     +
40    R/S
41    RCL 6
42    CHS
43    STO 6
44    GTO 01
```

APPENDIX G

PROCEDURE FOR ADJUSTING L_n DISTRIBUTIONS

During the course of the monitoring project, a few measurements were made in which the L_n distribution was affected by sporadic sound producing sources. These sources, either a natural or artificial event, had a skewing effect on residual sound data that were usually normally distributed. This skewing could be seen when the L_n distributions were plotted on probability paper, the effect of which was to not form a straight line. Typically, the lower L_n values showed a very sharp increase with respect to the majority of data.

When statistics from only natural residual sounds were desired, a procedure was developed to best fit a line to the set of data points which seemed close to a straight on probability paper and presumably characterized only residual sound levels.

A line was fit to the set of data points between L_{30} and L_{90} by means of a programmable hand calculator, Hewlett-Packard, HP-25. The program instructions are given in Figure G-1 and can be found on page 87 of the Applications Programs that comes with the HP-25. The X coordinates for the line were the number of standard deviations from the mean for L_{30} through L_{90}, the Y coordinates were the corresponding dBA levels. The output of the program was a formula for a line fitted to the above mentioned points, with the slope being the standard deviation and the Y intercept being the mean. The program also computed the correlation coefficient, r^2, from which was determined the standard error of estimate (See Appendix E). The L_{10} and L_{20} were then computed by the calculator and the resulting line plotted on probability paper.

Figures G-2a through G-2d show the probability plots and statistics for the four measurements on which this procedure was performed. The actual data is also plotted on each graph, along with a notation indicating the skewing factor(s).

DISPLAY		KEY ENTRY	X	Y	Z	T	COMMENTS
LINE	CODE						
00			y	x			Steps 1-7 for summation
01	31	↑	y	y	x		
02	15 02	g x^2	y^2	y	x		
03	23 51 02	STO + 2	y^2	y	x		Σy^2
04	22	R↓	y	x		y^2	
05	21	x⇄y	x	y		y^2	
06	25	Σ+	n	y		y^2	n, Σy, Σxy, Σx^2, Σx
07	13 00	GTO 00	n	y		y^2	
08	24 05	RCL 5	Σxy				
09	24 07	RCL 7	Σx	Σxy			
10	24 04	RCL 4	Σy	Σx	Σxy		
11	61	x	$\Sigma x \, \Sigma y$	Σxy			
12	24 03	RCL 3	n	$\Sigma x \, \Sigma y$	Σxy		
13	71	÷	$\Sigma x \, \Sigma y/n$	Σxy			
14	41	–	C				$C = \Sigma xy - (\Sigma x \, \Sigma y/n)$
15	24 06	RCL 6	Σx^2	C			
16	24 07	RCL 7	Σx	Σx^2	C		
17	15 02	g x^2	$(\Sigma x)^2$	Σx^2	C		
18	24 03	RCL 3	n	$(\Sigma x)^2$	Σx^2	C	
19	71	÷	$(\Sigma x)^2/n$	Σx^2	C	C	
20	41	–	D	C	C	C	$D = \Sigma x^2 - [(\Sigma x)^2/n]$
21	71	÷	a_1	C	C	C	$a_1 = C/D$
22	23 01	STO 1	a_1	C	C	C	
23	24 07	RCL 7	Σx	a_1	C	C	
24	61	x	$a_1 \, \Sigma x$	C	C	C	
25	32	CHS	$-a_1 \, \Sigma x$	C	C	C	
26	24 04	RCL 4	Σy	$-a_1 \, \Sigma x$	C	C	
27	51	+	$\Sigma y - a_1 \, \Sigma x$	C	C	C	
28	24 03	RCL 3	n	$\Sigma y - a_1 \, \Sigma x$	C	C	
29	71	÷	a_0	C	C	C	$a_0 = \bar{y} - a_1 \bar{x}$
30	23 00	STO 0	a_0	C	C	C	
31	74	R/S	a_0	C	C	C	Halt to display a_0
32	24 01	RCL 1	a_1	a_0	C	C	
33	74	R/S	a_1	a_0	C	C	Halt to display a_1
34	21	x⇄y	a_0	a_1	C	C	
35	22	R↓	a_1	C	C	a_0	
36	61	x	a_1 C	C	a_0	a_0	
37	24 02	RCL 2	Σy^2	a_1 C	C	a_0	
38	24 04	RCL 4	Σy	Σy^2	a_1 C	C	
39	15 02	g x^2	$(\Sigma y)^2$	Σy^2	a_1 C	C	
40	24 03	RCL 3	n	$(\Sigma y)^2$	Σy^2	a_1 C	
41	71	÷	$(\Sigma y)^2/n$	Σy^2	a_1 C	a_1 C	
42	41	–	E	a_1 C	a_1 C	a_1 C	$E = \Sigma y^2 - [(\Sigma y)^2/n]$
43	71	÷	r^2	a_1 C	a_1 C	a_1 C	$r^2 = a_1 \, C/E$
44	13 00	GTO 00	r^2	a_1 C	a_1 C	a_1 C	
45							
46							
47							
48							
49							

REGISTERS	
R_0	a_0
R_1	a_1
R_2	Σy^2
R_3	n
R_4	Σy
R_5	Σxy
R_6	Σx^2
R_7	Σx

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS				OUTPUT DATA/UNITS
1	Key in program						
2	Initialize		f	REG	f	PRGM	
3	Perform for i = 1,..., n:						
	Input x-value and y-value	x_i	↑				
		y_i	R/S				i
4	Compute regression constants		GTO	08	R/S		a_0 *
			R/S				a_1 *
5	Compute coefficient of determination		R/S				r^2
6	To calculate a projected y-value, input the x-value	x	RCL	1	x	RCL	
			0	+			$\hat{y}$
7	Perform step 6 as many times as desired						
8	For a new case, go to step 2.						
	* The contents of the stack should not be disturbed at these points.						

FIGURE G-1 Programs for least squares fit on Hewlett Packard hand calculator, HP-25

ST-100A
T-228

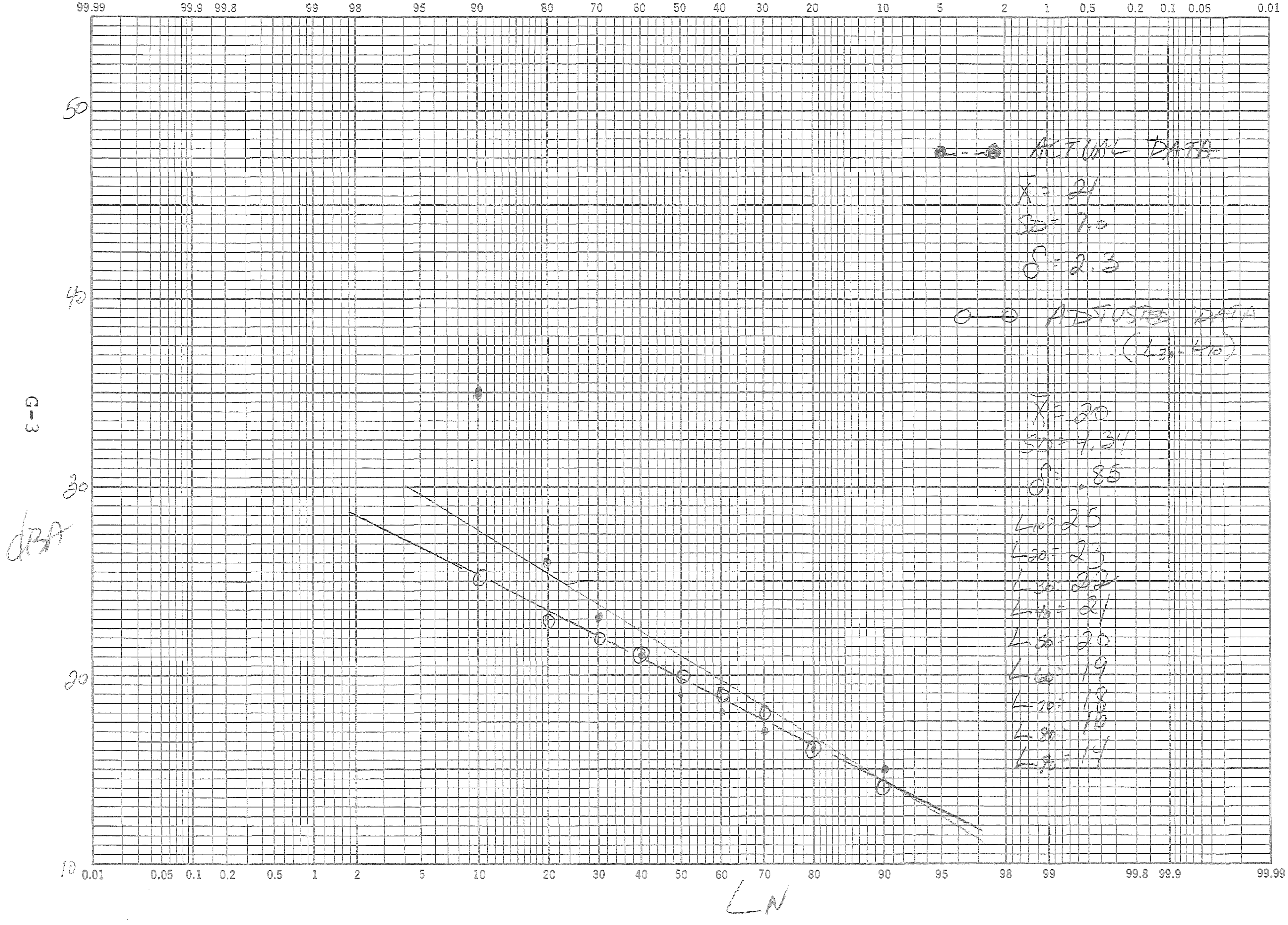
G-12

NO. 340-PS 90 DIETZGEN GRAPH PAPER
PROBABILITY X 90 DIVISIONS

EUGENE DIETZGEN CO.
MADE IN U. S. A.

MEASUREMENT ADJUSTED
FOR TRAFFIC

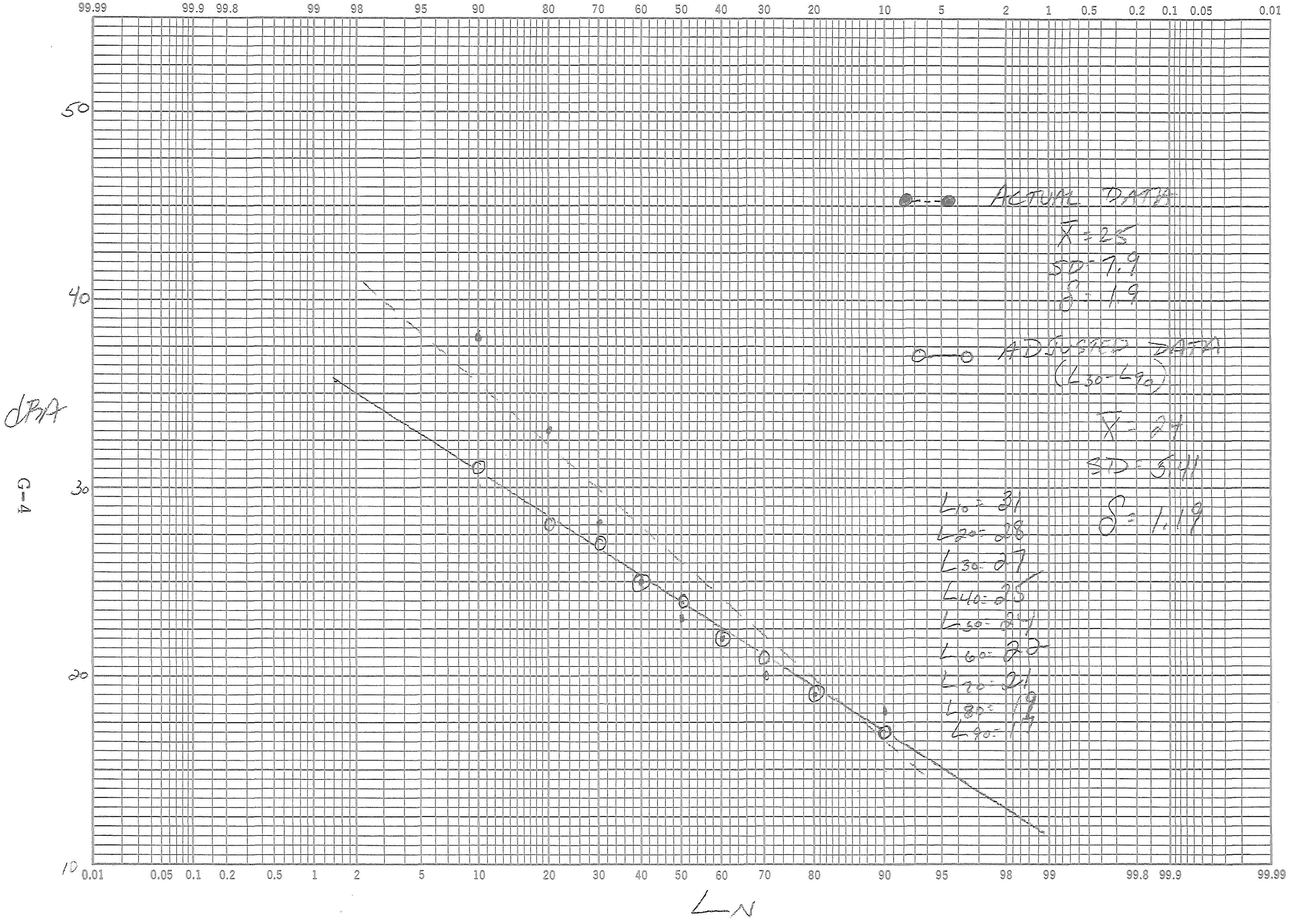
Figure G-2a



ST-58A VP-30
T-171

MEASUREMENT ADJUSTED DUE TO BIRDS

Figure G2-b

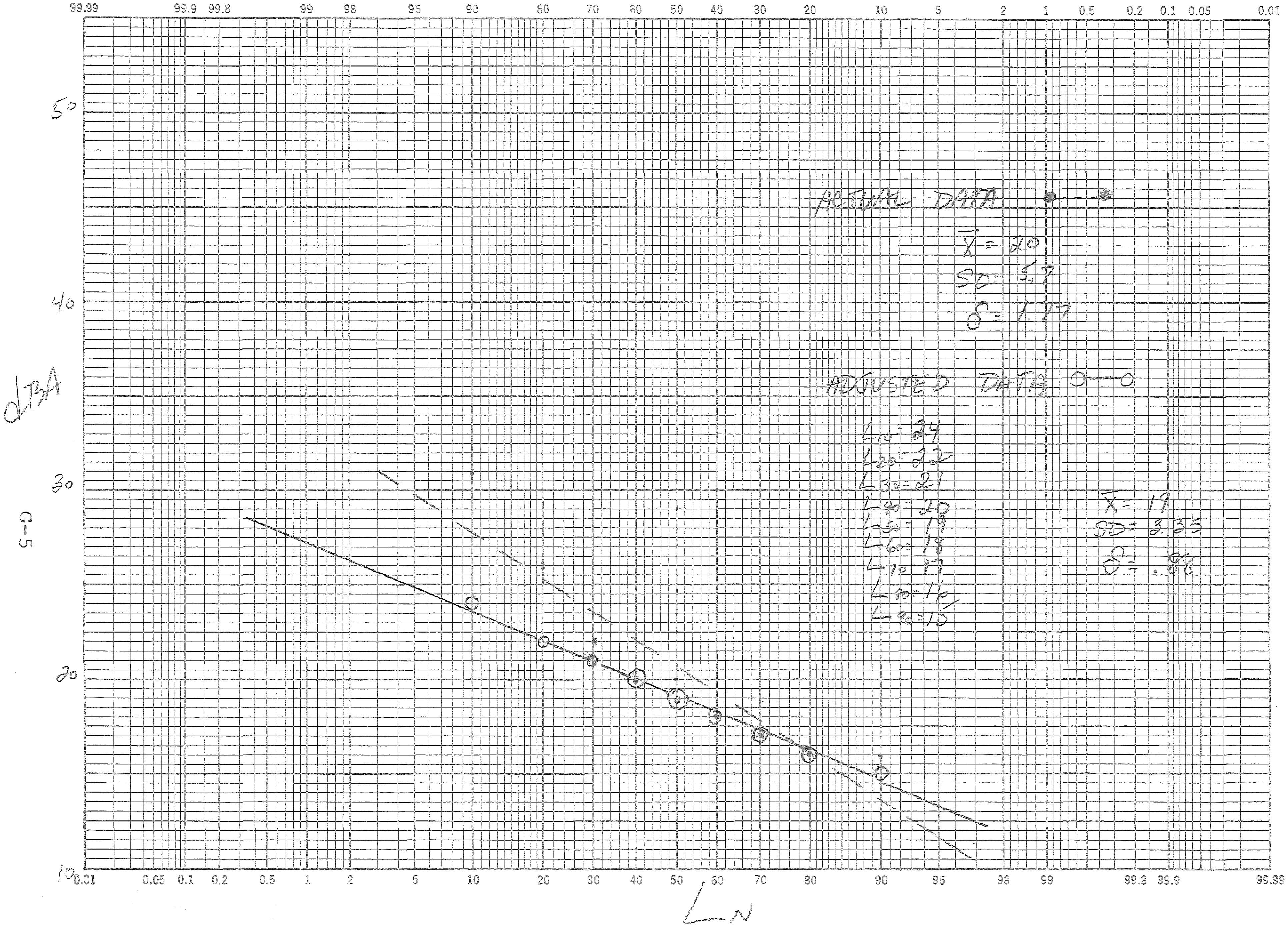


NO. 340-PS 90 DIETZGEN GRAPH PAPER
PROBABILITY X 90 DIVISIONS

EUGENE DIETZGEN CO.
MADE IN U. S. A.

ST-92A VP-36N
T-212 MEASUREMENT ADJUSTED FOR BIRD ACTIVITY

Figure G-2c



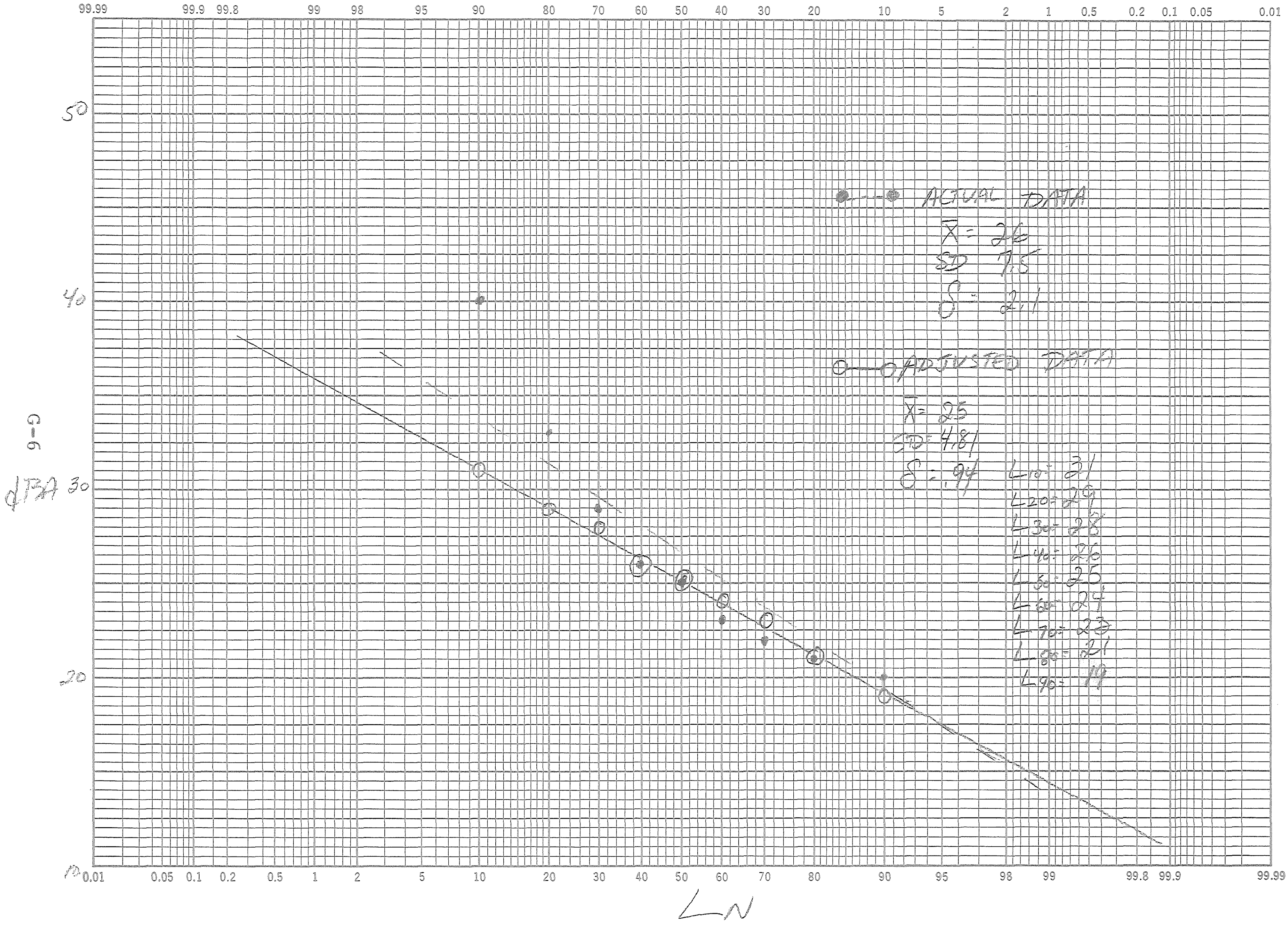
NO. 340-PS 90 DIETZGEN GRAPH PAPER
PROBABILITY X 90 DIVISIONS

EUGENE DIETZGEN CO.
MADE IN U. S. A.

ST-50
T-158

VP-37N
MEASUREMENT ADJUSTED FOR TRAIN NOISE

Figure G-2d



APPENDIX H

WIND SPEED DATA REDUCTION

Figures H-1a and H-1b show the wind speed data as received from computer processing from the Copper-Nickel staff. Column 1 lists wind speeds in knots, column 5 lists the cumulative percents, and column 6 lists the W_n's derived by subtracting column 5 values from 100. Also given is an indication of the specific sets of wind speeds used for analysis.

The data were reduced by first plotting the given W_n values on probability paper. Using the least squares fit method, a line was then fit to the data. This was accomplished by programming a hand calculator, (Hewlett-Packard, HP-25) for linear regression and entering the X and Y coordinates for the W_n limits (See Appendix G). The X value was the number of standard deviations from the mean of a particular W_n value, and the Y value corresponded to the specific wind speed. The program computed a best-fit line in the form Y = mx + b, where m = slope, or the standard deviation, and b = the Y intercept or mean. Further, the correlation coefficient was given and used to determine the standard error of estimate via the formula:

$$\delta = \sqrt{1-r^2} \text{ (SD of the Y data points)}$$

The W_{10} to W_{90} were then calculated by entering the corresponding X values into the program.

	Wind Speed (Knots)	Absolute Freq.	Cum. Freq. (PCT)	W_n
	0	279	12.4	87.6
Used in Analysis	3.	33	13.8	86.2
	4.	147	20.3	79.7
	5.	128	26.0	74.0
	6.	162	33.2	66.8
	7.	175	41.0	59.0
	8.	196	49.6	50.4
	9.	107	54.4	45.6
	10.	233	64.7	35.3
	11.	80	68.3	31.7
	12.	202	77.2	22.8
	13.	106	81.9	18.1
	14.	130	87.7	12.3
	15.	139	93.8	6.2
	16.	32	95.3	4.7
	17.	42	97.1	2.9
	18.	31	98.5	1.5
	19.	5	98.7	1.3
	20.	14	99.3	0.7
	21.	5	99.6	0.4
	22.	5	99.8	0.2
	23.	1	99.8	0.2
	24.	3	100.0	0

Table H-1a Wind statistics for winter monitoring period (knots).

	Wind Speed (Knots)	Absolute Freq.	Cum. Freq. (PCT)	W_n
	0	752	21.9	78.10
	2.	5	22.1	77.90
Used in Analysis	3.	42	23.3	76.70
	4.	239	30.2	69.80
	5.	251	37.6	62.40
	6.	295	46.2	53.80
	7.	250	53.4	46.60
	8.	321	62.8	37.20
	9.	132	66.6	33.40
	10.	309	75.6	24.40
	11.	114	79.0	21.00
	12.	199	84.8	15.20
	13.	124	88.4	11.60
	14.	131	92.2	7.80
	15.	120	95.7	4.30
	16.	34	96.7	3.30
	17.	45	98.0	2.00
	18.	26	98.7	1.30
	19.	4	98.9	1.10
	20.	27	99.7	.30
	22.	2	99.7	.30
	23.	2	99.8	.2
	25.	6	99.9	.1
	27.	1	100.0	0

Table H-1b Wind statistics for summer monitoring period (knots).

APPENDIX I

TAPE LISTINGS OF VARIOUS SOUNDS

A tape library is presented in this appendix for the reader who wishes to listen to various sounds recorded during the course of the field monitoring project. The library listings are divided into two principal sections: natural sounds, and artificial noise. All tapes, except for L-03 and W-12B, were made within the study area as part of a sound monitoring measurement.

Tape W-12B was recorded on Snowbank Lake during the winter of 1977 as part of the wind on the microphone study (See Appendix C). Tape L-03 is a special tape of a lone wolf, who, with the howls from former wolf project worker, Steve Lampman, was lured to within about 30 to 50 yards of the microphone. A barred owl is also on this tape and at times often seemed to return the wolf's calls. Since the tape lasts 45 minutes to an hour, a condensed edited version is available on a reel to reel tape. (For recording procedure of all field tapes, see Test Procedures CN-3 and CN-4 in Appendix N.)

Natural Sounds	Tape Listings
1. Breeze Noise	ST-17; ST-41; ST-60
2. Ice Cracking on Large Lake	W-12B
3. Birch Bark Rattling in Winter	ST-8; ST-16; ST-11; ST-9A
4. Rainfall	ST-36; ST-77B (last 3 min.)
5. Snowfall	ST-4
6. Snow Melting from Trees	ST-37; ST-38
7. Thunder	ST-81A (7th min. of tape)
8. Sap Cracking in Jackpine Stand Due to Extreme Cold	ST-5
9. Rushing Stream	ST-56B; ST-54B; ST-99A; ST-103A (1st 15 min.)
10. Bugs (Flies) Near Microphone	ST-67A; ST-60
11. Black Spruce Trees Creaking from Wind	ST-7; ST-21
12. Birds	ST-67A; ST-60; ST-95A; ST-102A; ST-59A; ST-58; ST-19
13. Loud Deer Snort	ST-5B (22nd min.)
14. Timber Wolf and Barred Owl	L-03 (available on reel tape)

Artificial Noise	Tape Listings
1. Blast	ST-60; ST-51A (end of tape) ST-97B; ST-27A (3rd min.)
2. Train	ST-57A; ST-60B (7th Min.); ST-98A
3. Linde Oxygen Plant	ST-7; ST-17; ST-24
4. Siren	ST-60B; ST-102A (2nd 15 min.); ST-63A
5. Train Whistle	ST-37; ST-57A; ST-60 (7th min.); ST-98A
6. Gunshots	ST-78
7. Chain Saw	ST-24; ST-25; ST-35; ST-43; ST-49

APPENDIX J

SPECTRAL PLOTS OF RESIDUAL DATA

Contained in this appendix are spectral plots (one-third octave) of residual sounds monitored within the study area. Graphs are expressed in dBA as a function of one-third octaves for each vegetation type and for both seasons. Plots are spaced at five dBA intervals. With each plot is given the vegetation type, season (i.e. winter or summer), and total dBA value. One-third octaves are denoted by band numbers 14 to 39. This was done primarily for convenience during the analysis process. The band number relates to the center frequency as follows:

$$\text{Center Frequency} = 10^{\frac{\text{Band Number}}{10}}$$

For example, the center frequency for band 30 would be $10^{3.0}$ or 1000 Hz.

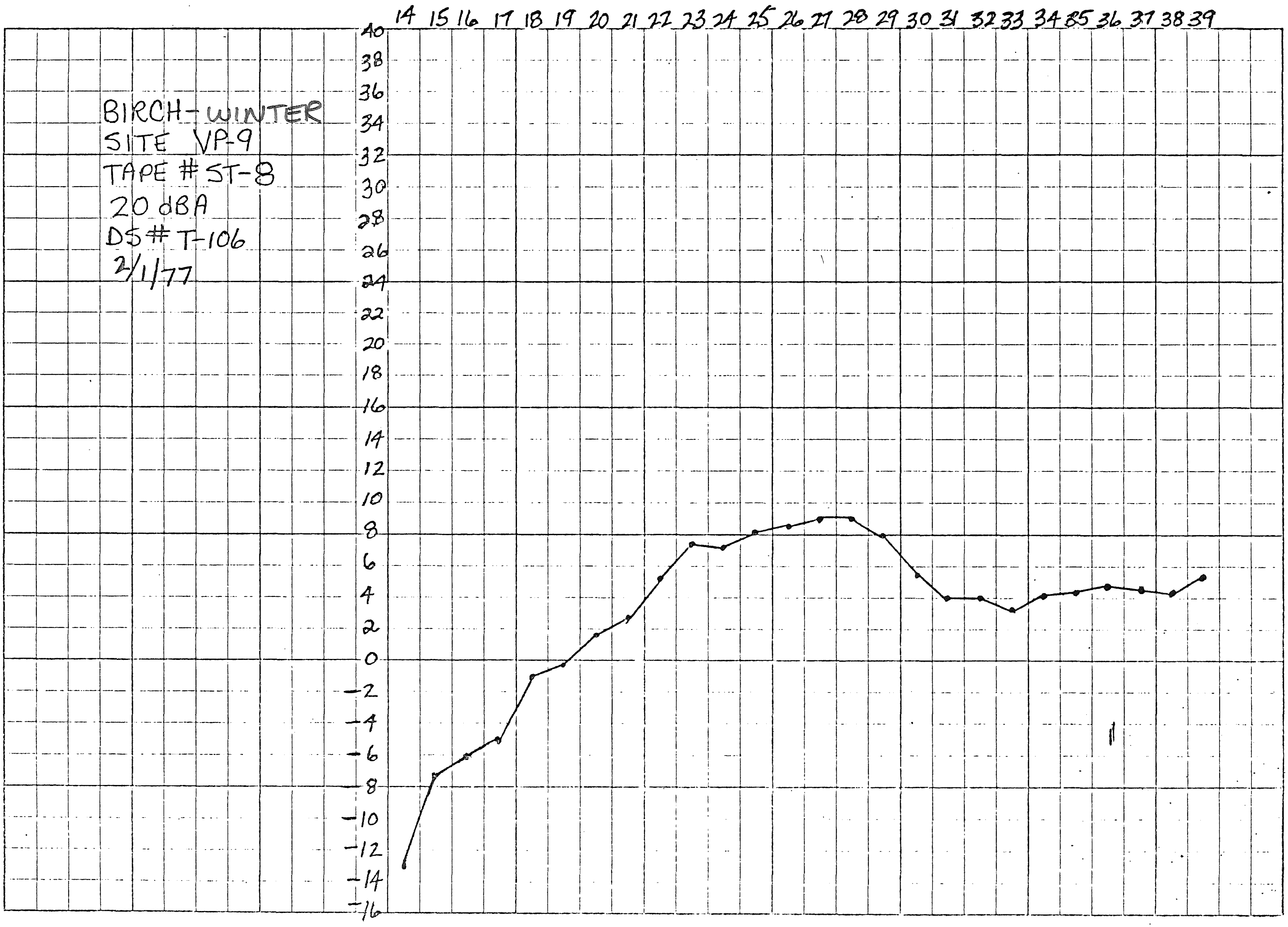
A conversion chart is given below:

Band Number	Center Frequency (Hz)	Band Number	Center Frequency (Hz)
14	25	27	500
15	31.5	28	630
16	40	29	800
17	50	30	1,000
18	63	31	1,250
19	80	32	1,600
20	100	33	2,000
21	125	34	2,500
22	160	35	3,150
23	200	36	4,000
24	250	37	5,000
25	315	38	6,300
26	400	39	8,000

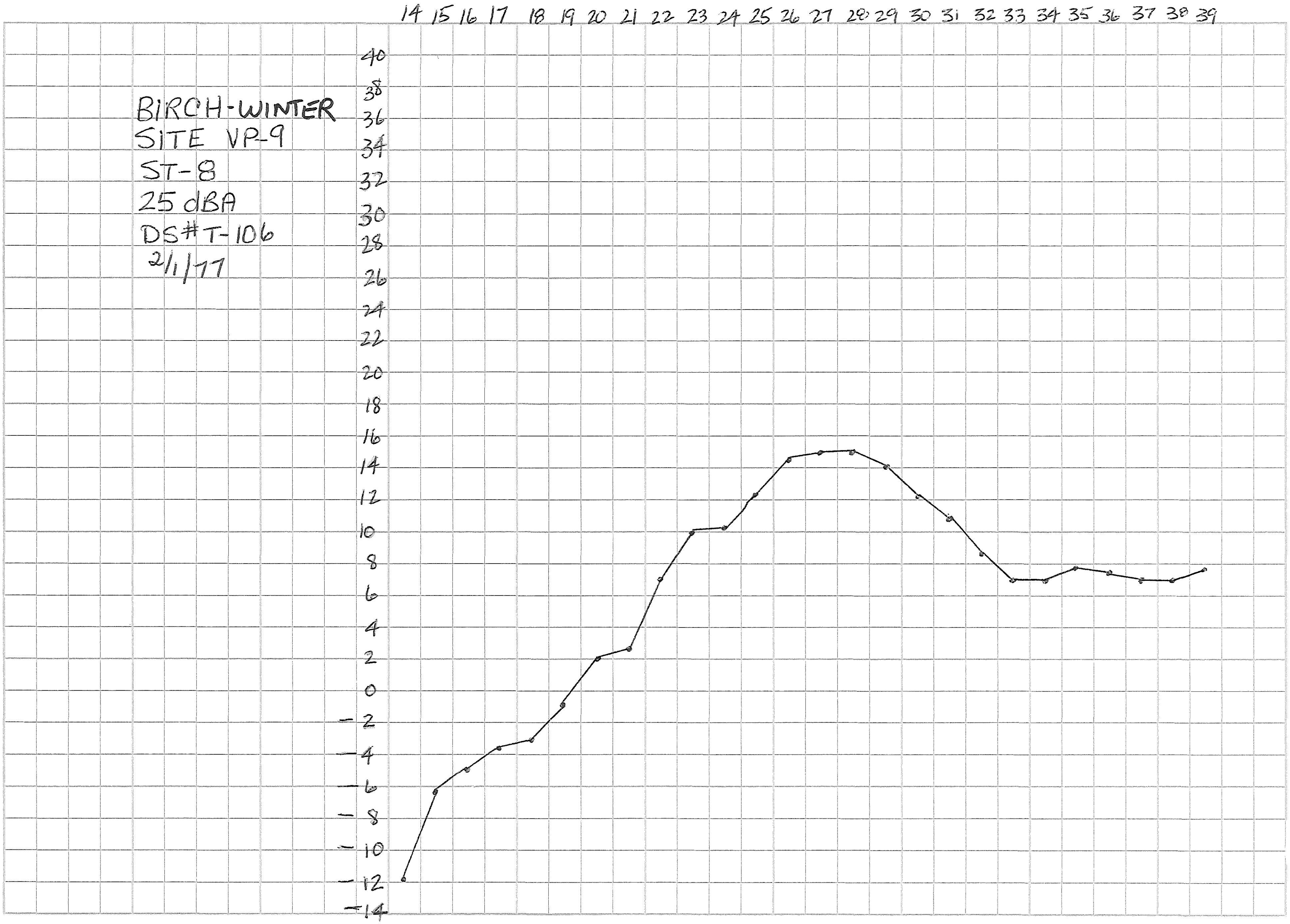
Graphs are arranged with all winter (no-foliage) sites given followed by all summer (foliage sites). The plots are ordered as follows:

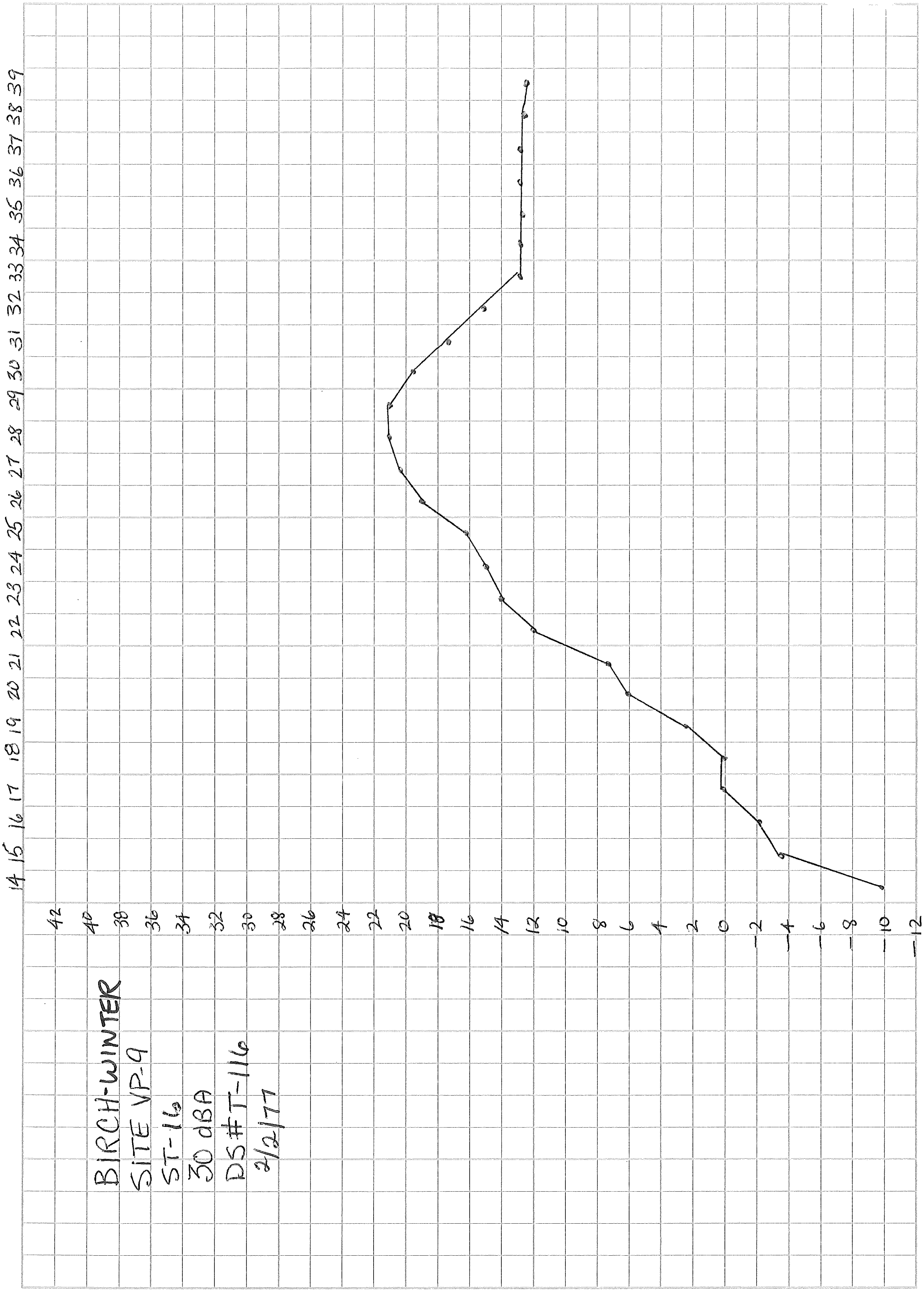
Winter	Page
Birch	J-3
Jack Pine	J-12
Black Spruce	J-21
Sparse	J-29
Clearcut	J-36

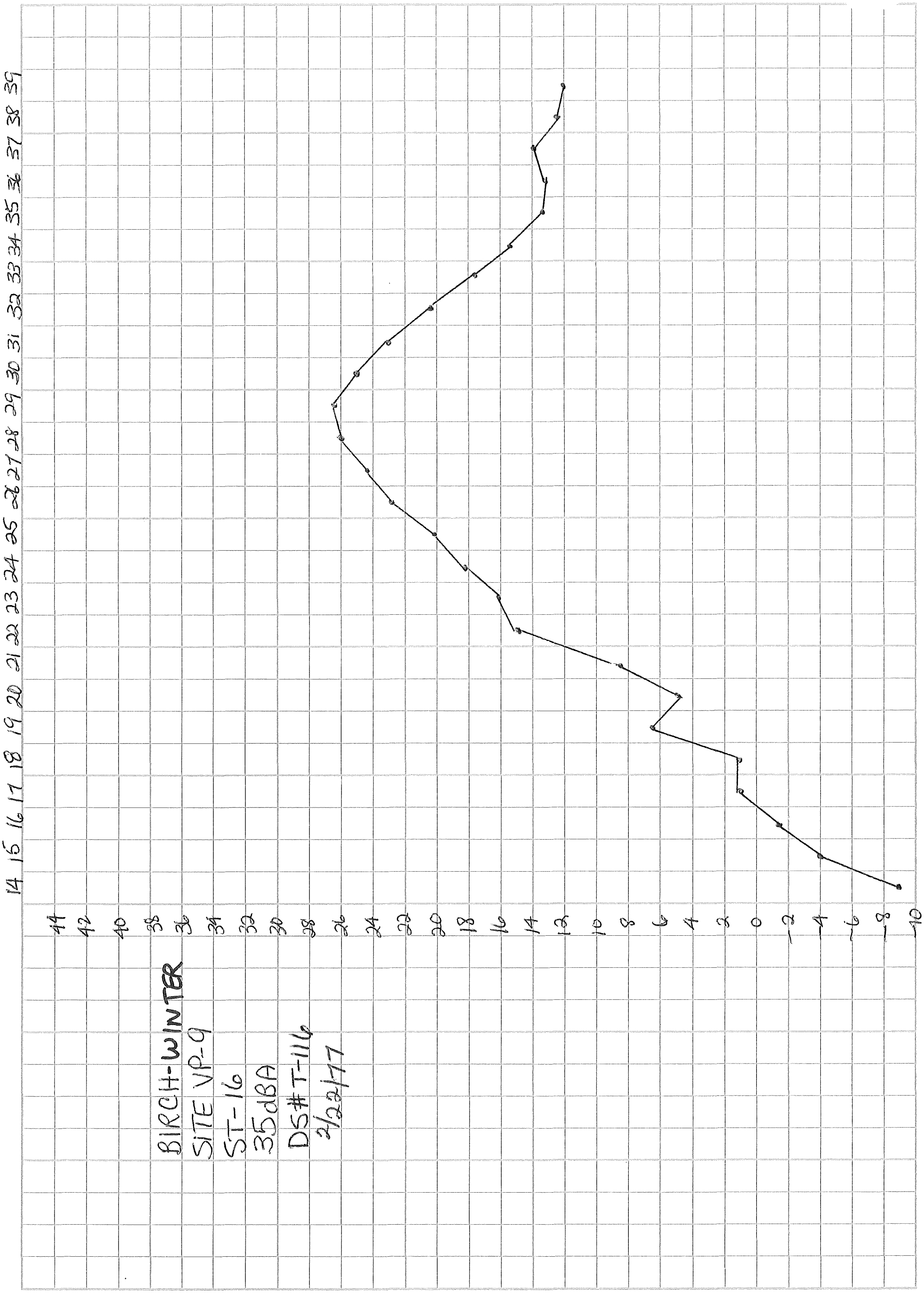
Summer	Page
Jack Pine	J-41
Red Pine	J-46
Birch	J-55
Aspen	J-63
Black Spruce	J-70
Sapling Aspen	J-77
Sparse Mixed	J-84
Clearcut	J-90



BIRCH-WINTER
SITE VP-9
TAPE # ST-8
20 dBA
DS # T-106
2/1/77


BIRCH-WINTER
SITE VP-9
ST-8
25 dBA
DS#T-106
2/1/77
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14


BIRCH-WINTER
SITE VP-9
ST-16
30 dBA
DS#T-116
2/2/77


BIRCH-WINTER
SITE VP-9
ST-16
35dBA
DS#T-116
2/22/77
14
15
16
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19
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21
22
23
24
25
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27
28
29
30
31
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44
42
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36
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32
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28
26
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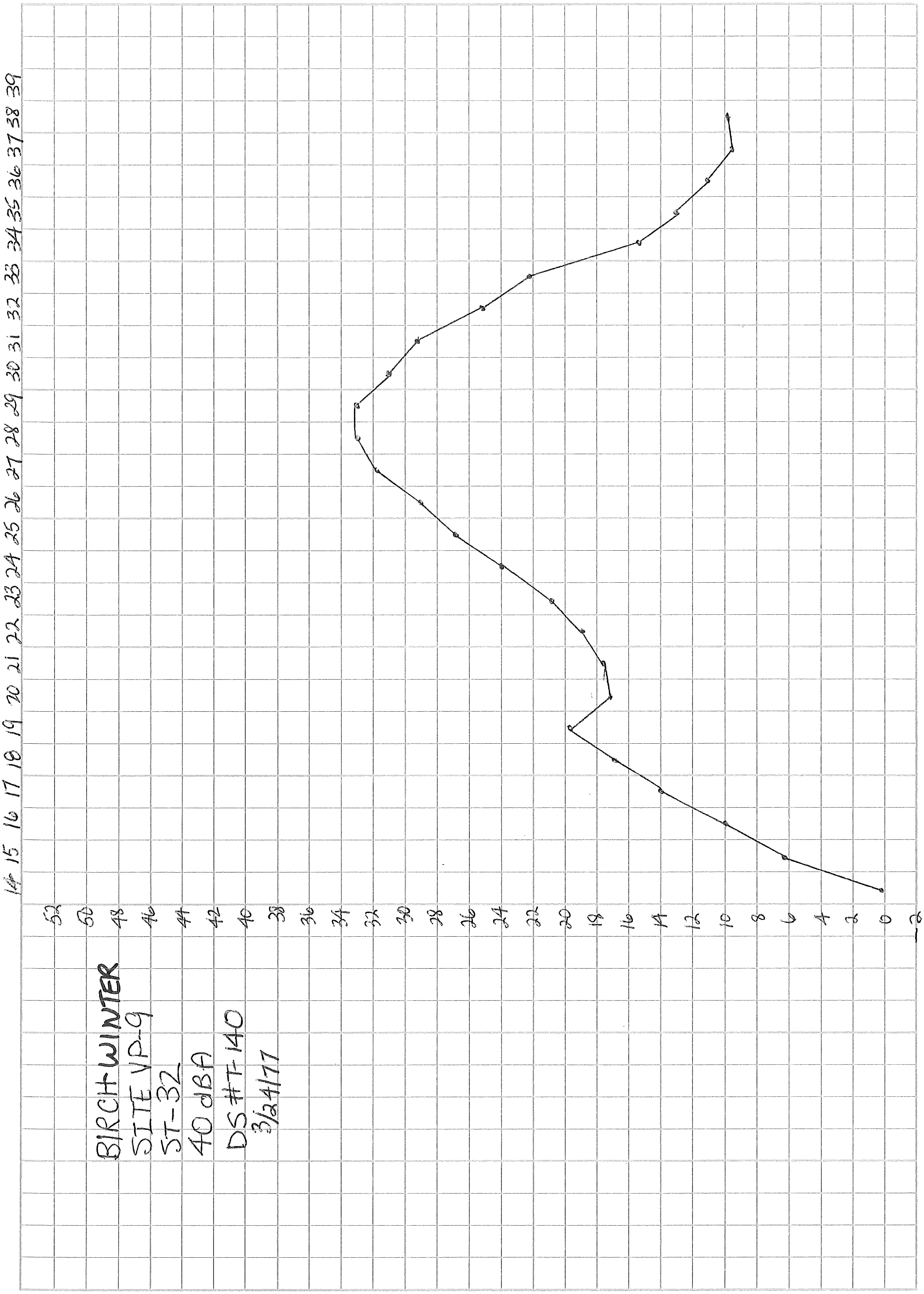
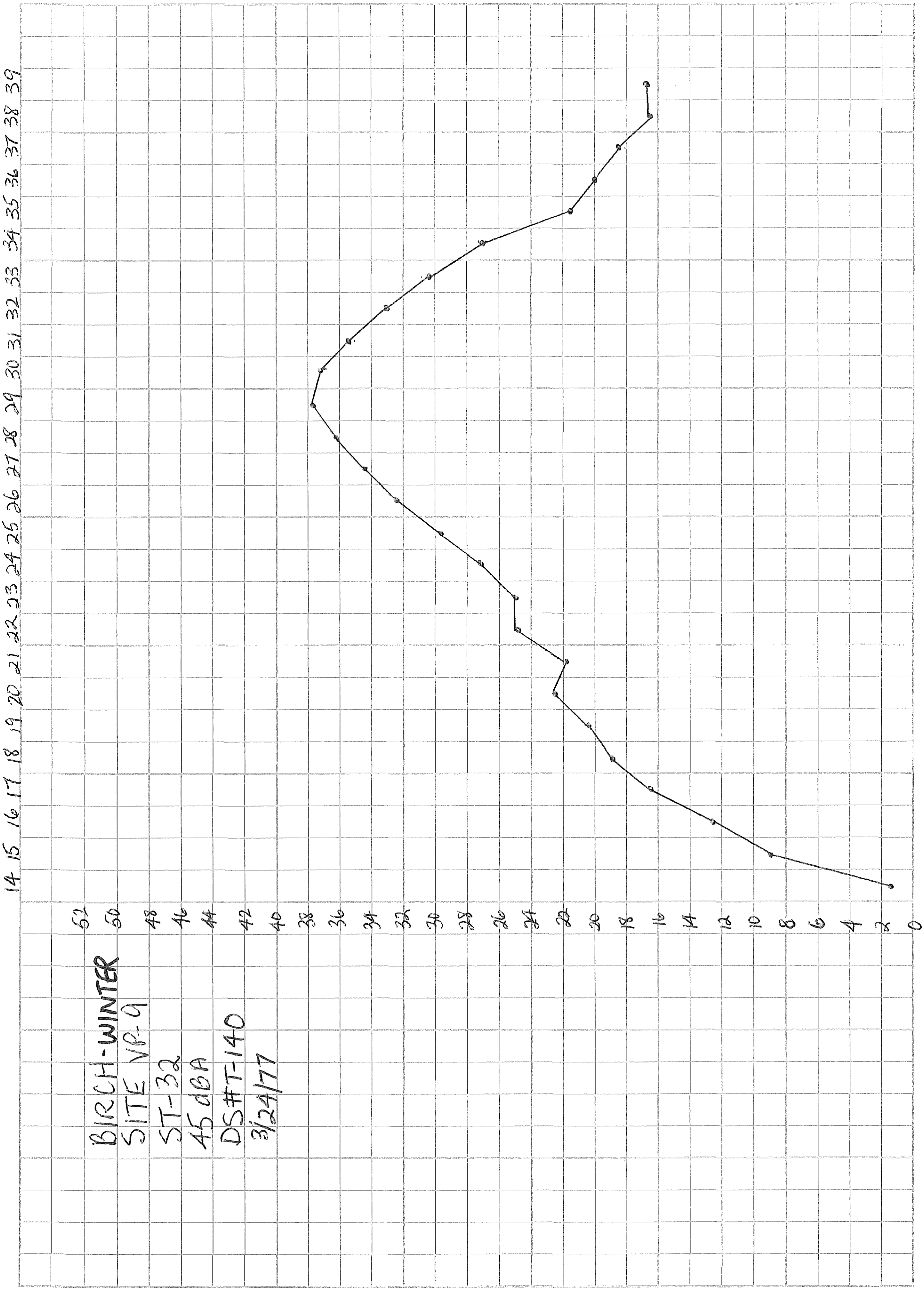
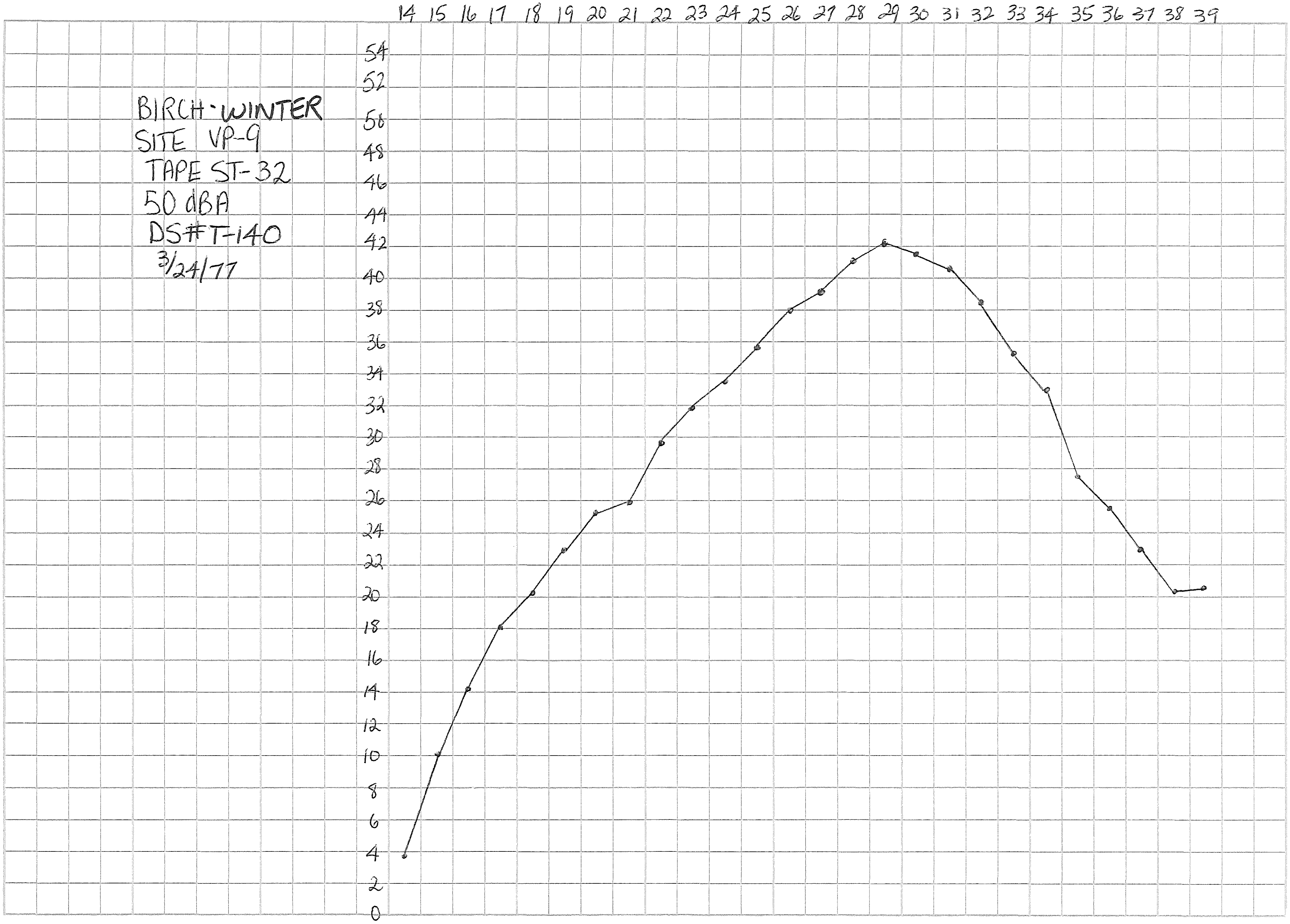
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10



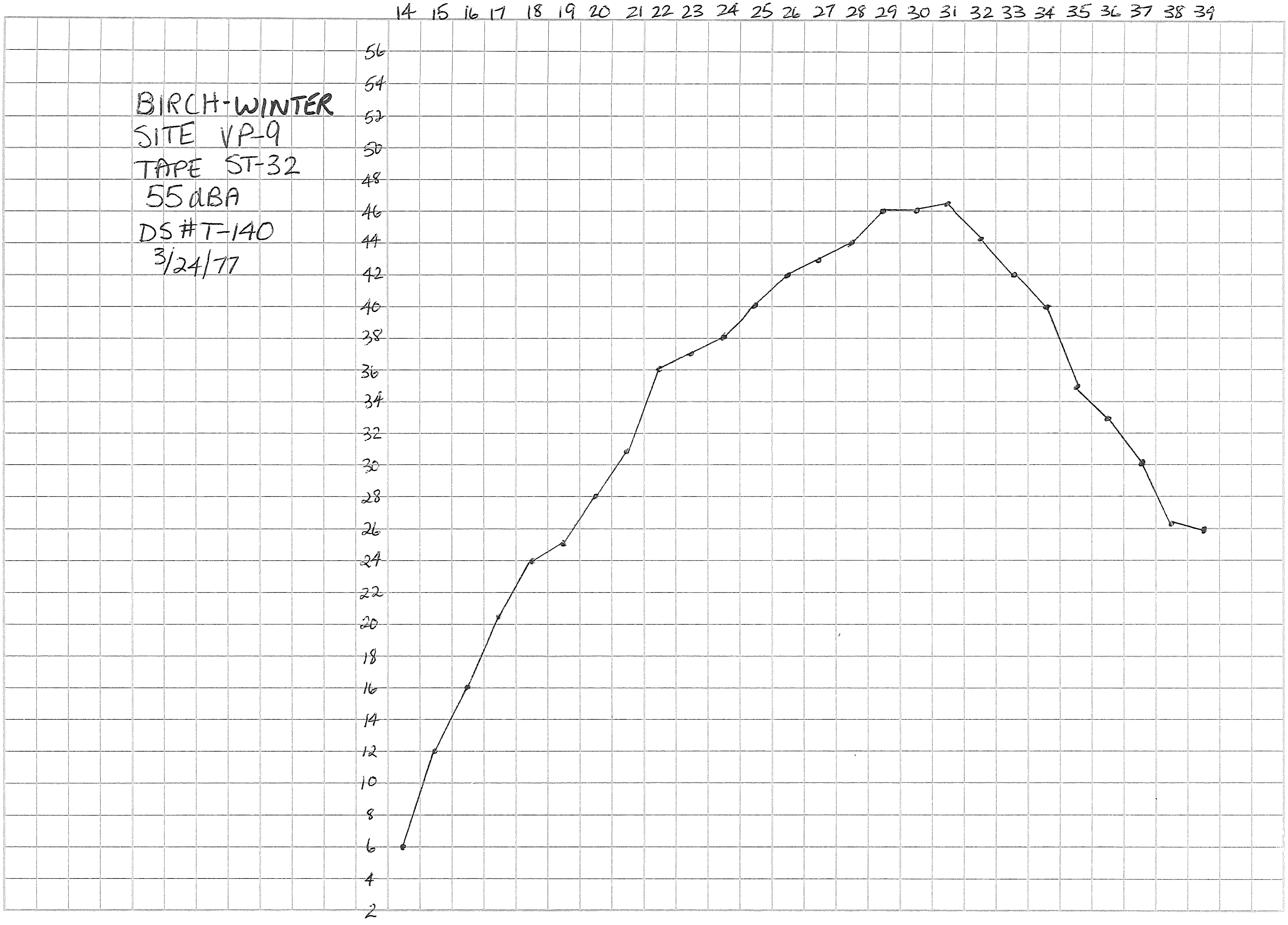
BIRCH WINTER
SITE VP-9
ST-32
40 dBA
DS #T-140
3/24/77



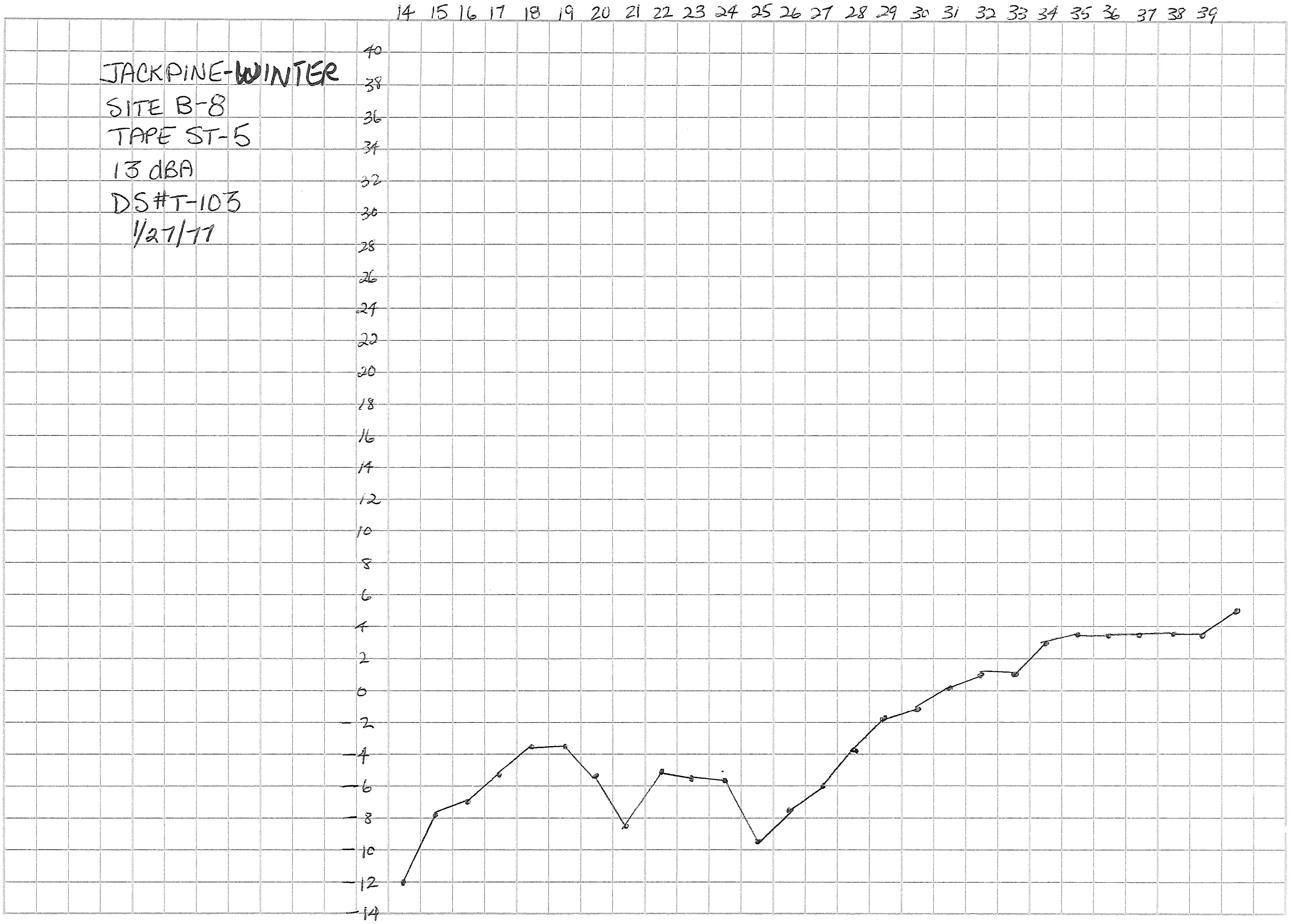
BIRCH-WINTER
SITE VB.9
ST-32
45dBA
DS#T-140
3/24/77



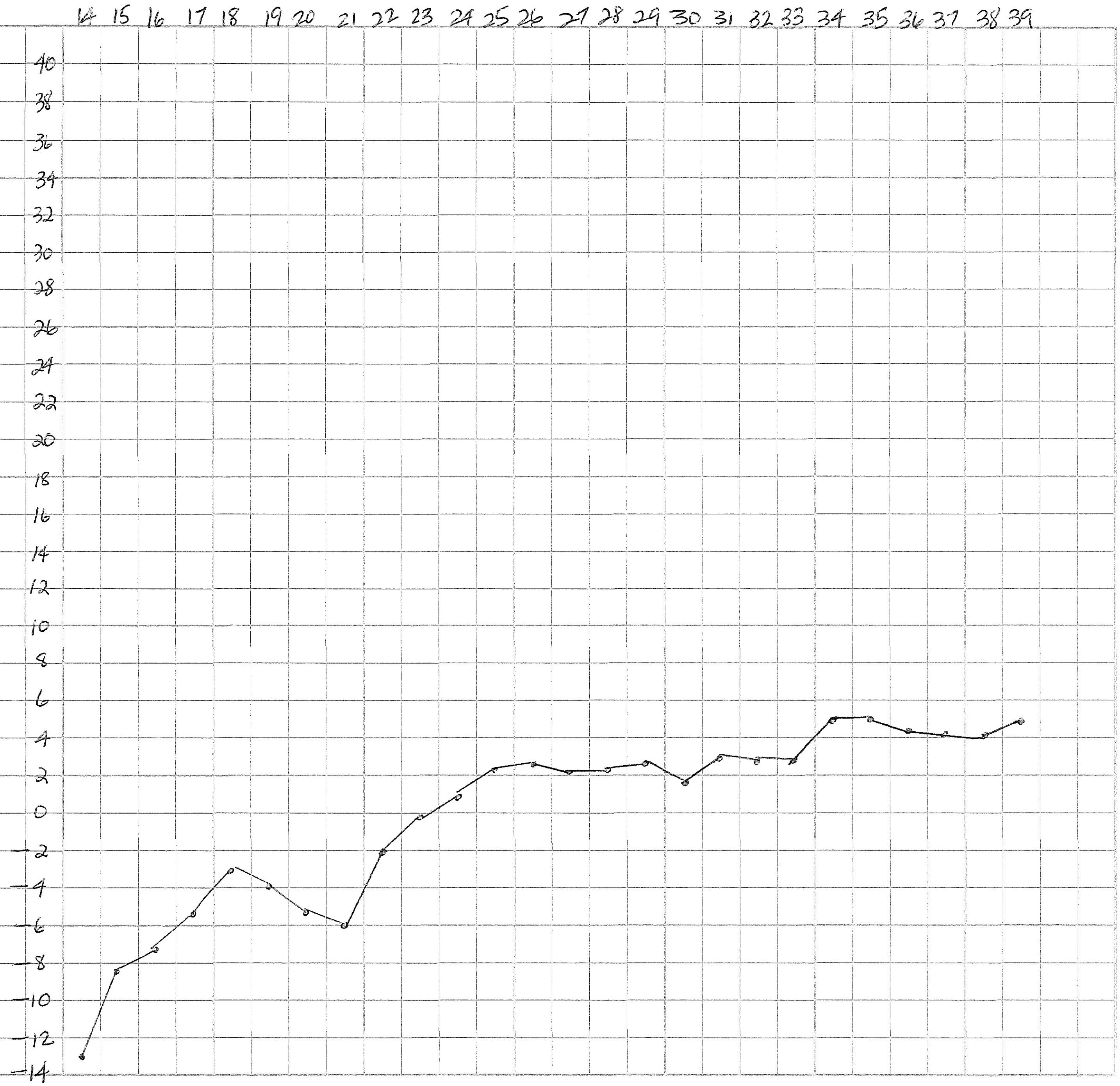
BIRCH-WINTER
SITE VP-9
TAPE ST-32
50 dBA
DS#T-140
3/24/77

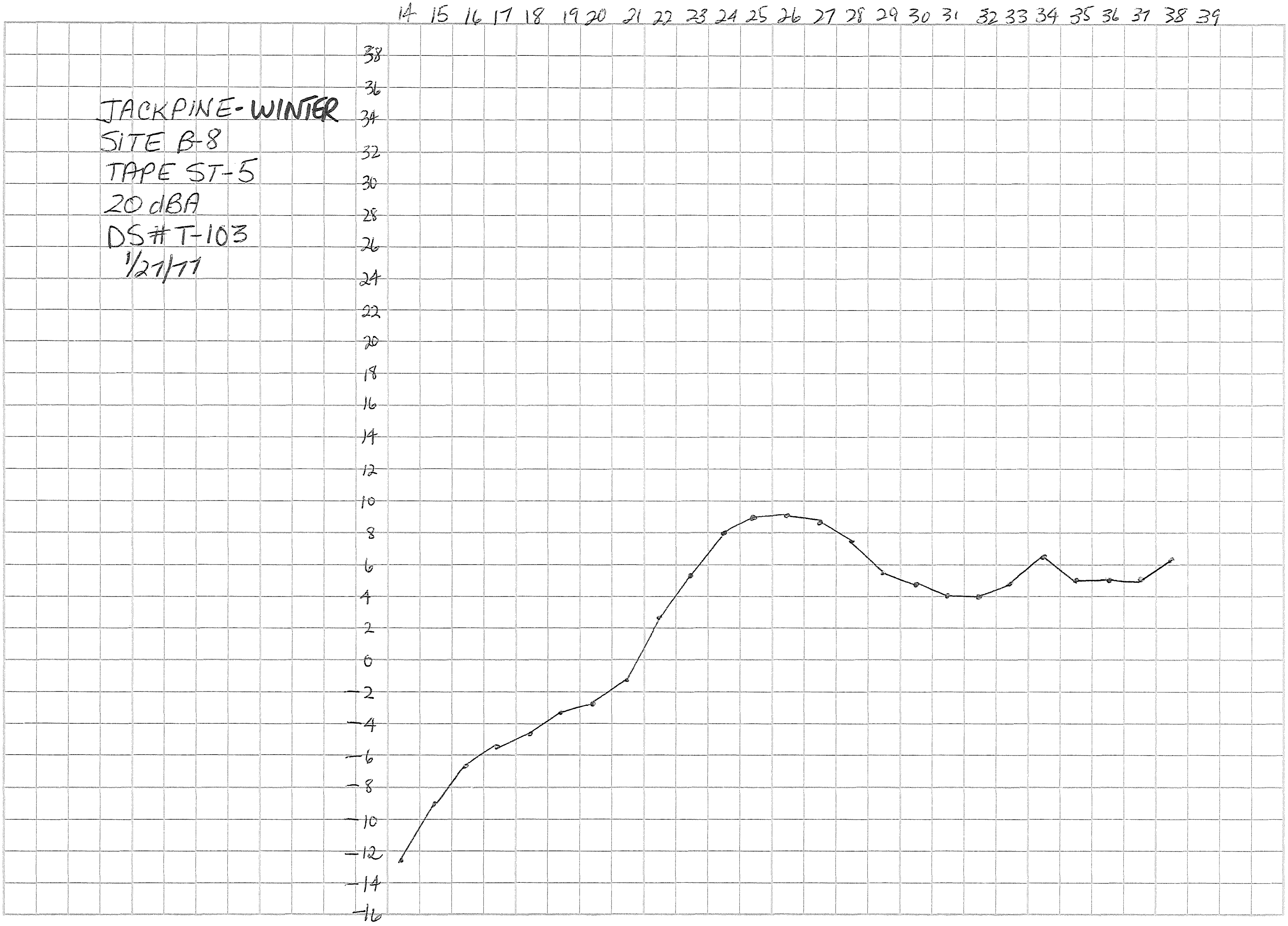


BIRCH-WINTER
SITE VP-9
TAPE ST-32
55dBA
DS#T-140
3/24/77


JACKPINE-WINTER
SITE B-8
TAPE ST-5
13 dBA
DS#T-103
1/27/77

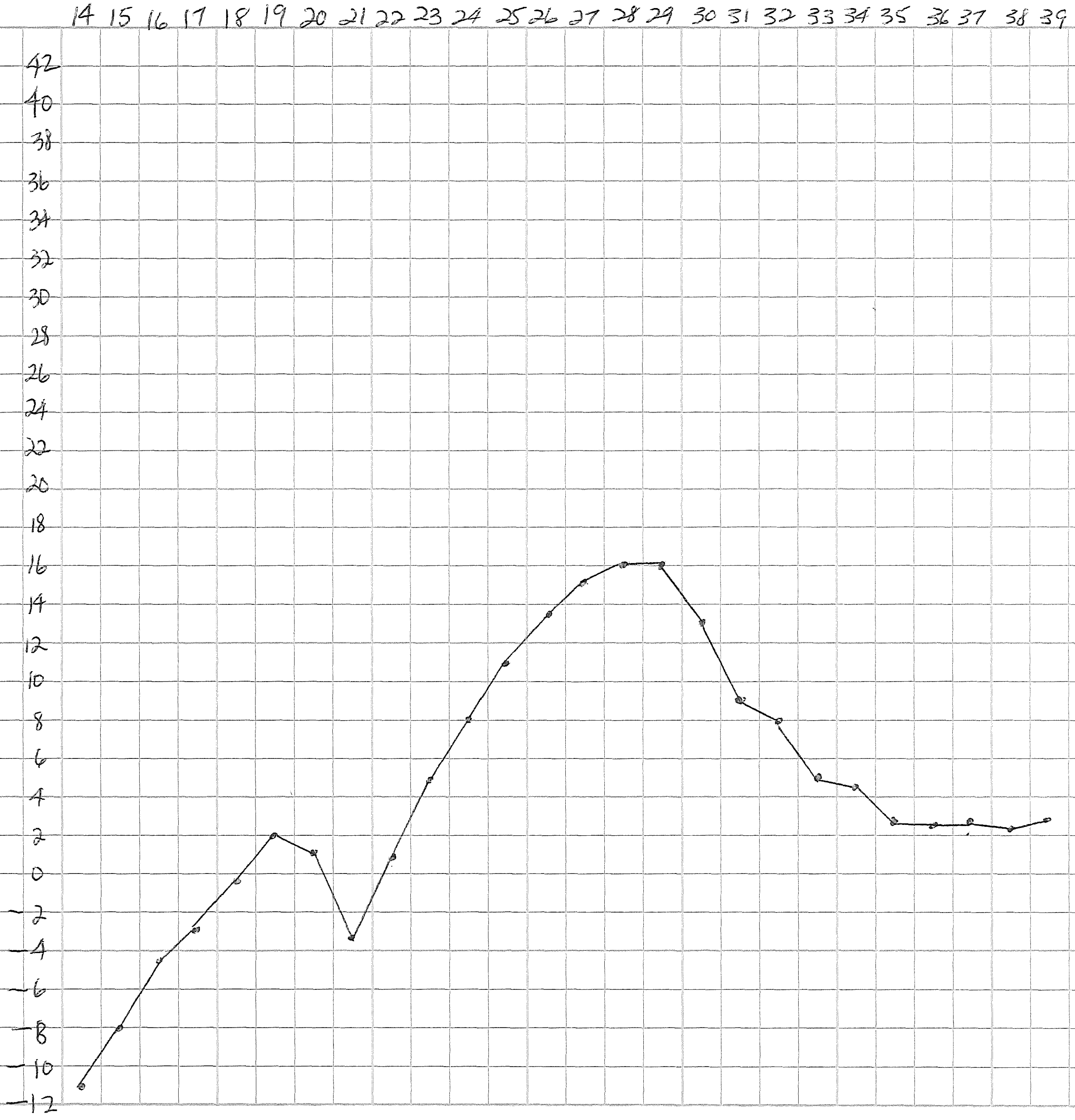
JACKPINE-WINTER
SITE B-8
TAPE ST-5
15 dBA
DS#T-103
1/27/77

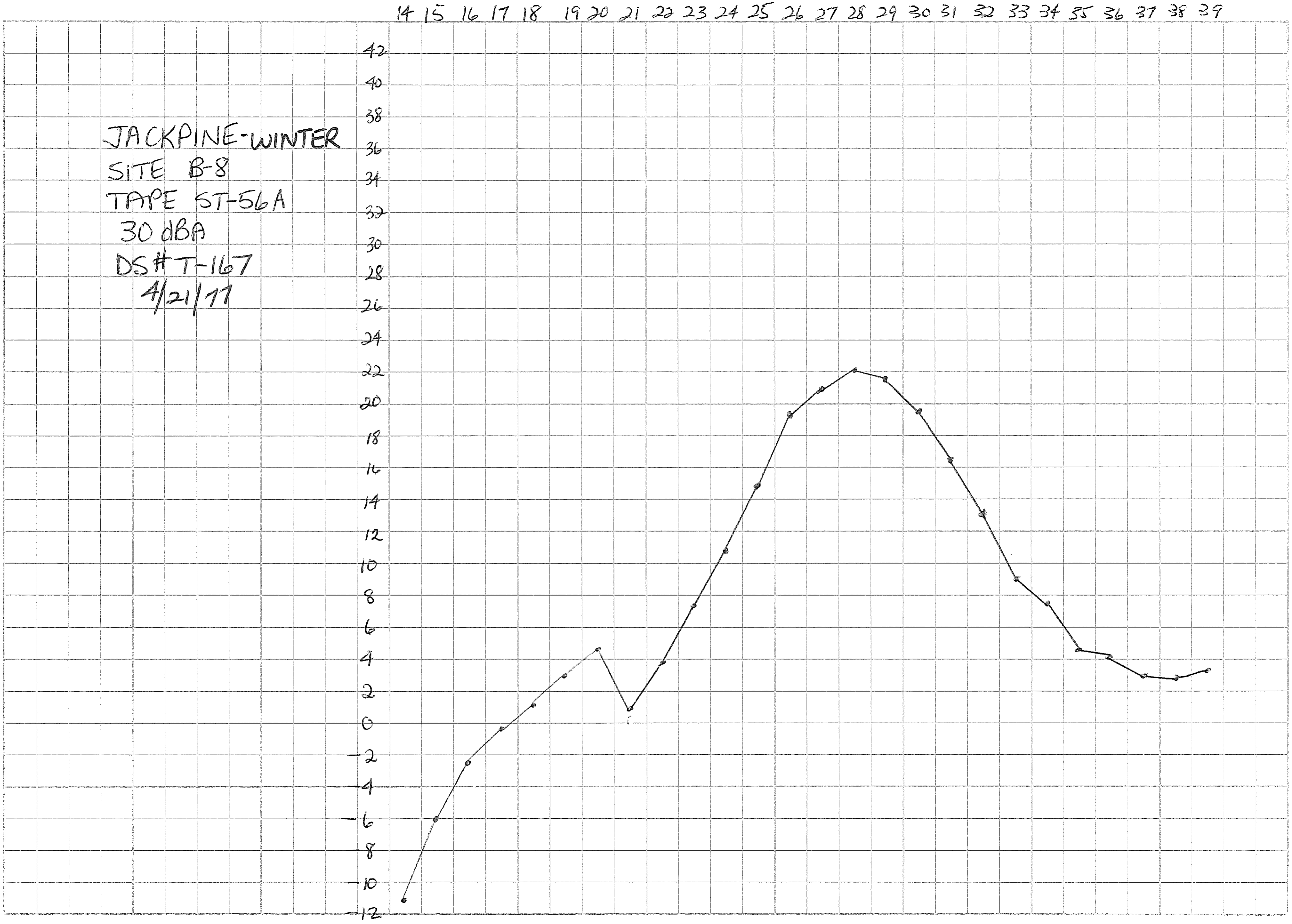




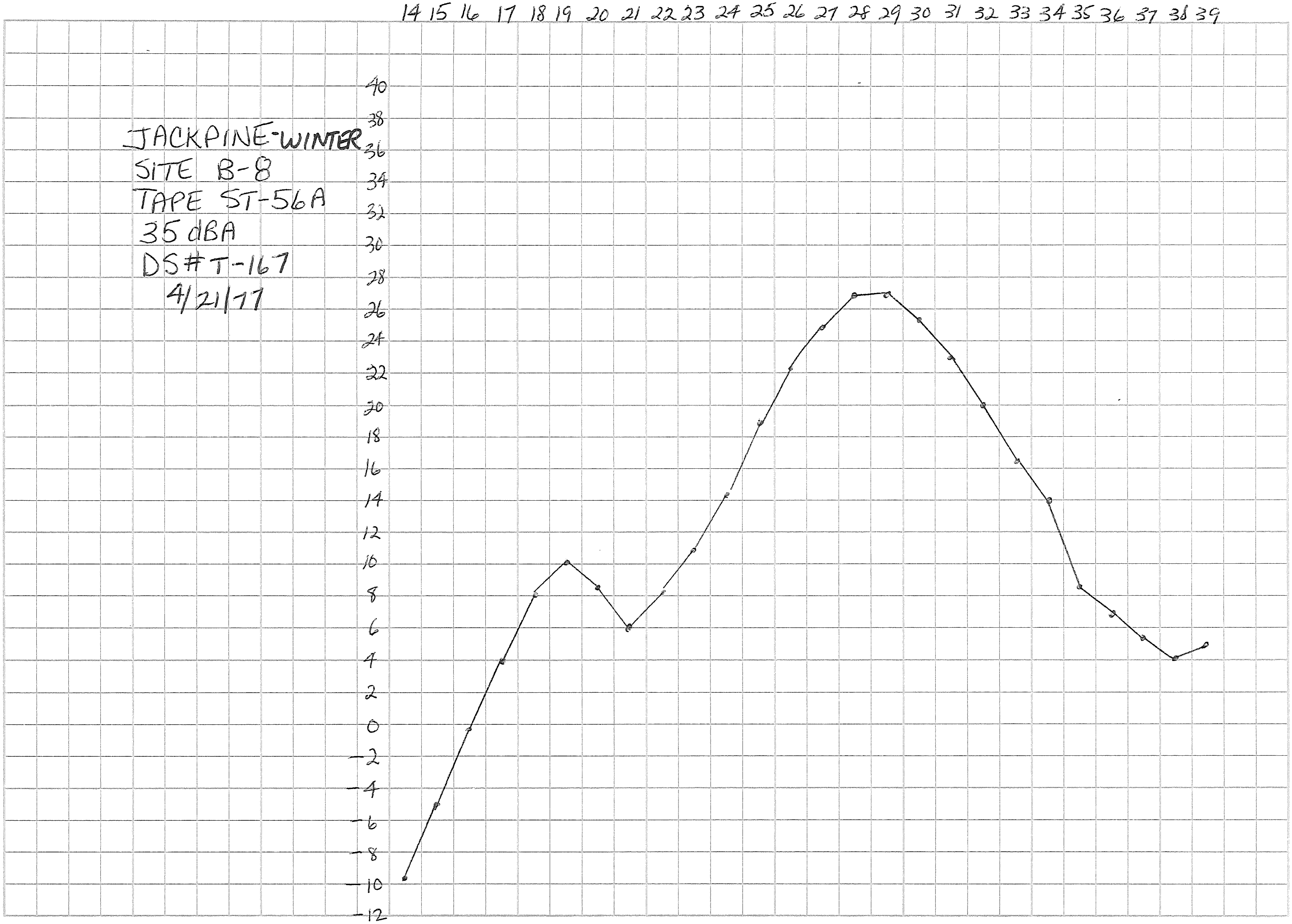
JACKPINE-**WINTER**
SITE B-8
TAPE ST-5
20 dBA
DS#T-103
1/27/77

JACKPINE-WINTER
SITE B-8
TAPE ST-56A
25 dBA
DS#T-167
4/21/77

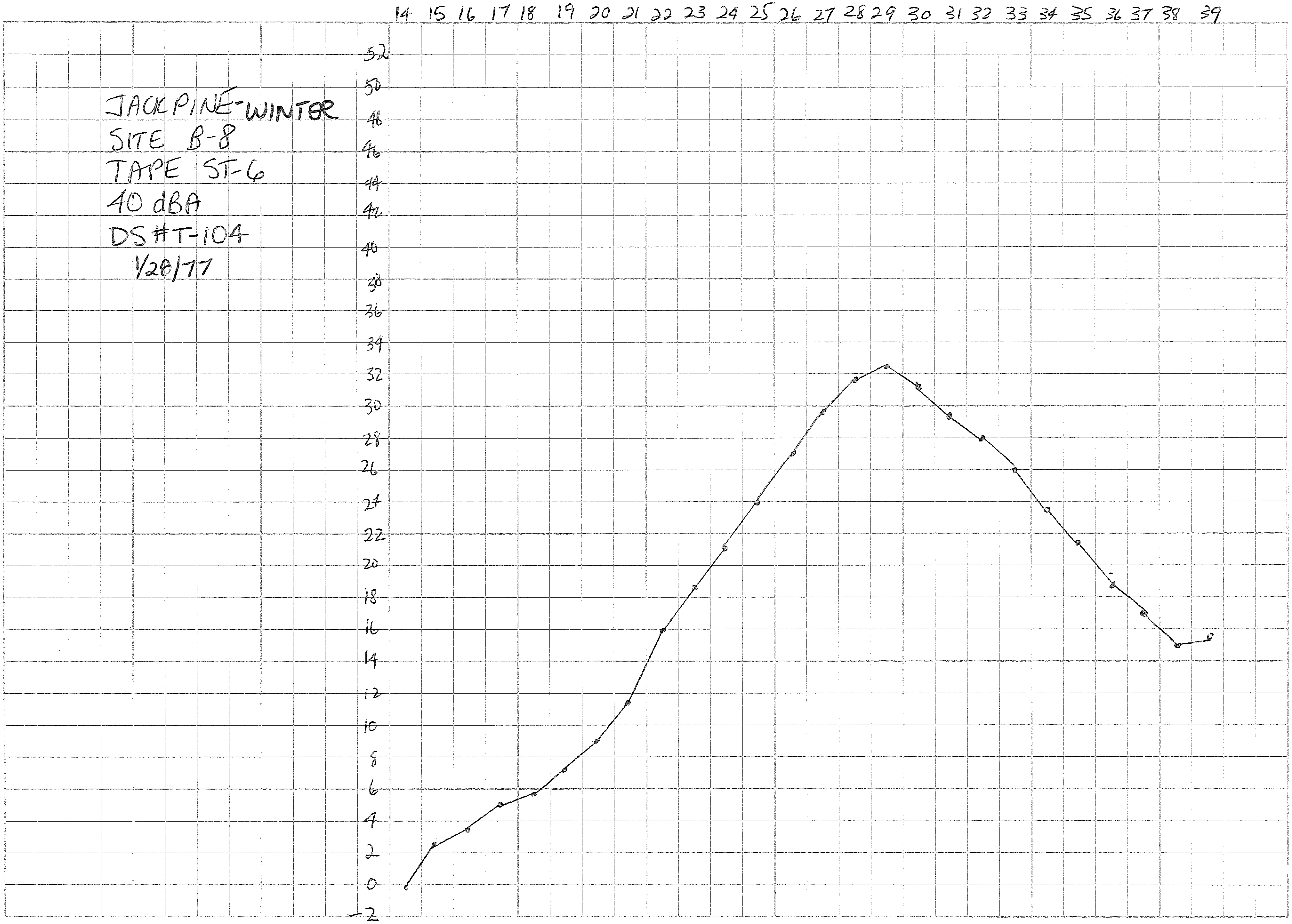




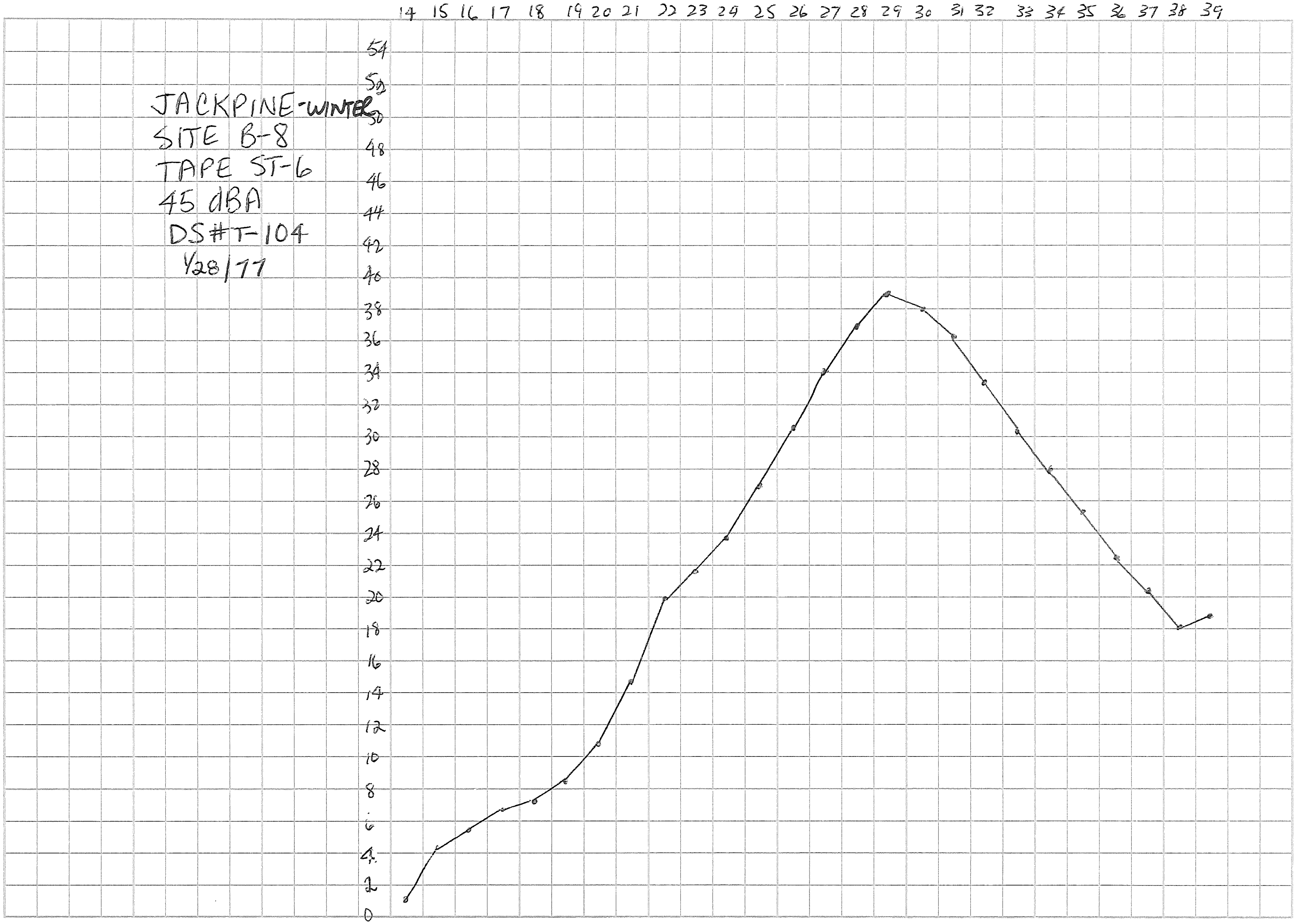
JACKPINE-WINTER
SITE B-8
TAPE ST-56A
30 dBA
DS#T-167
4/21/77



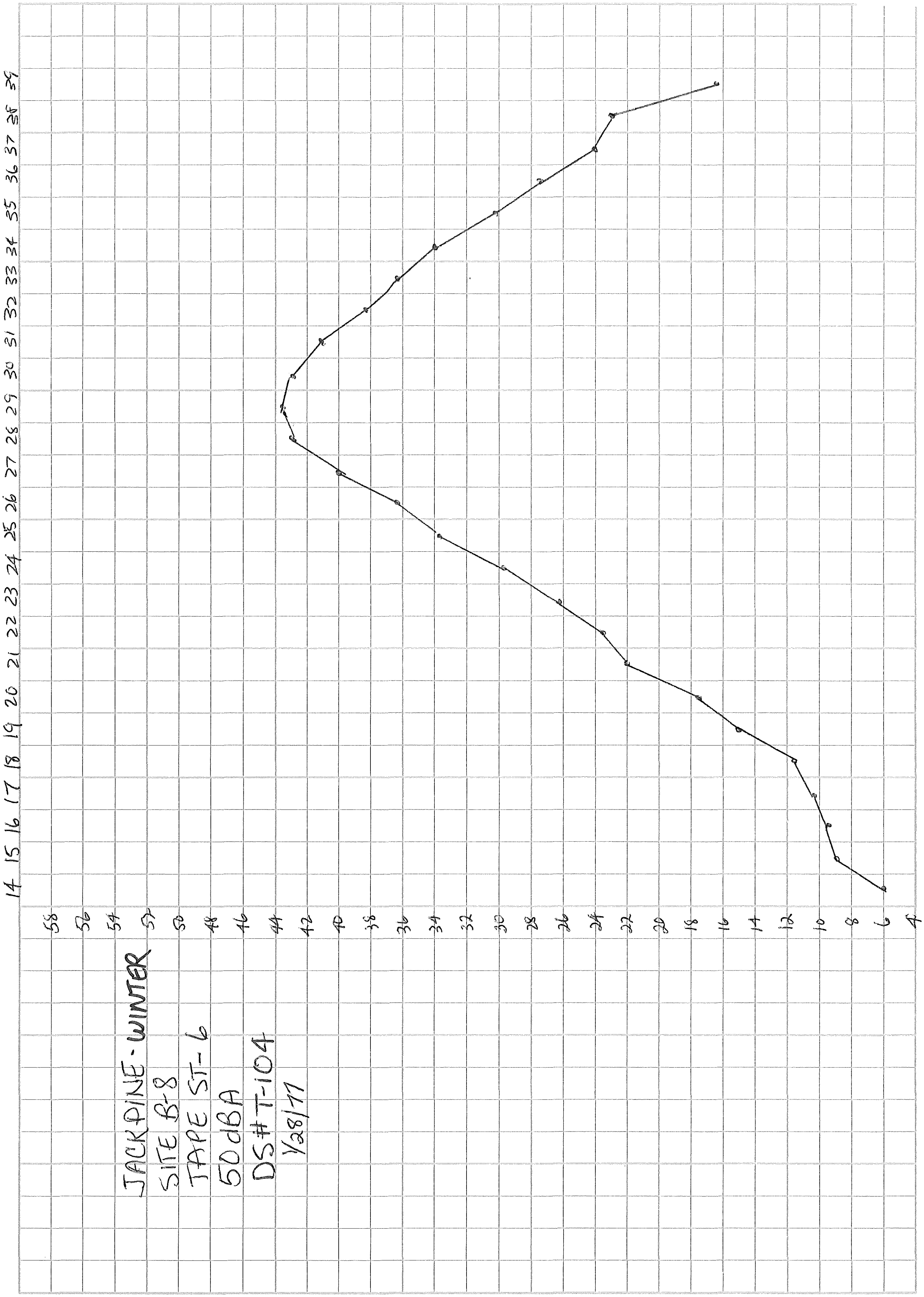
JACKPINE-WINTER
SITE B-8
TAPE ST-56A
35 dBA
DS#T-167
4/21/77



JACKPINE-WINTER
SITE B-8
TAPE ST-6
40 dBA
DS#T-104
1/28/77



JACKPINE-WINTER
SITE B-8
TAPE ST-6
45 dBA
DS#T-104
1/28/77


JACKPINE - WINTER
SITE B-8
TAPE ST-6
50dBA
DS# T-104
1/28/77
14
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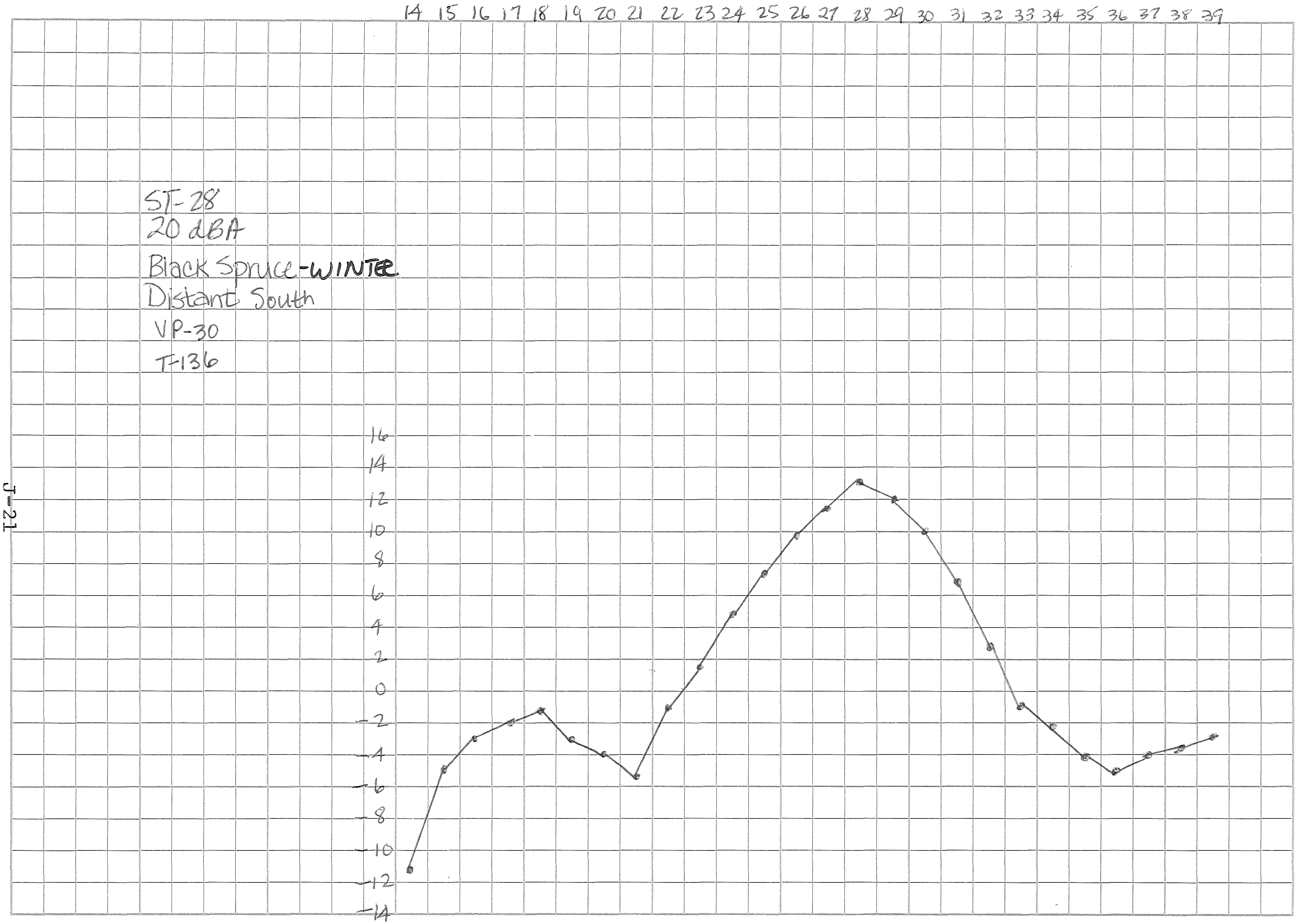
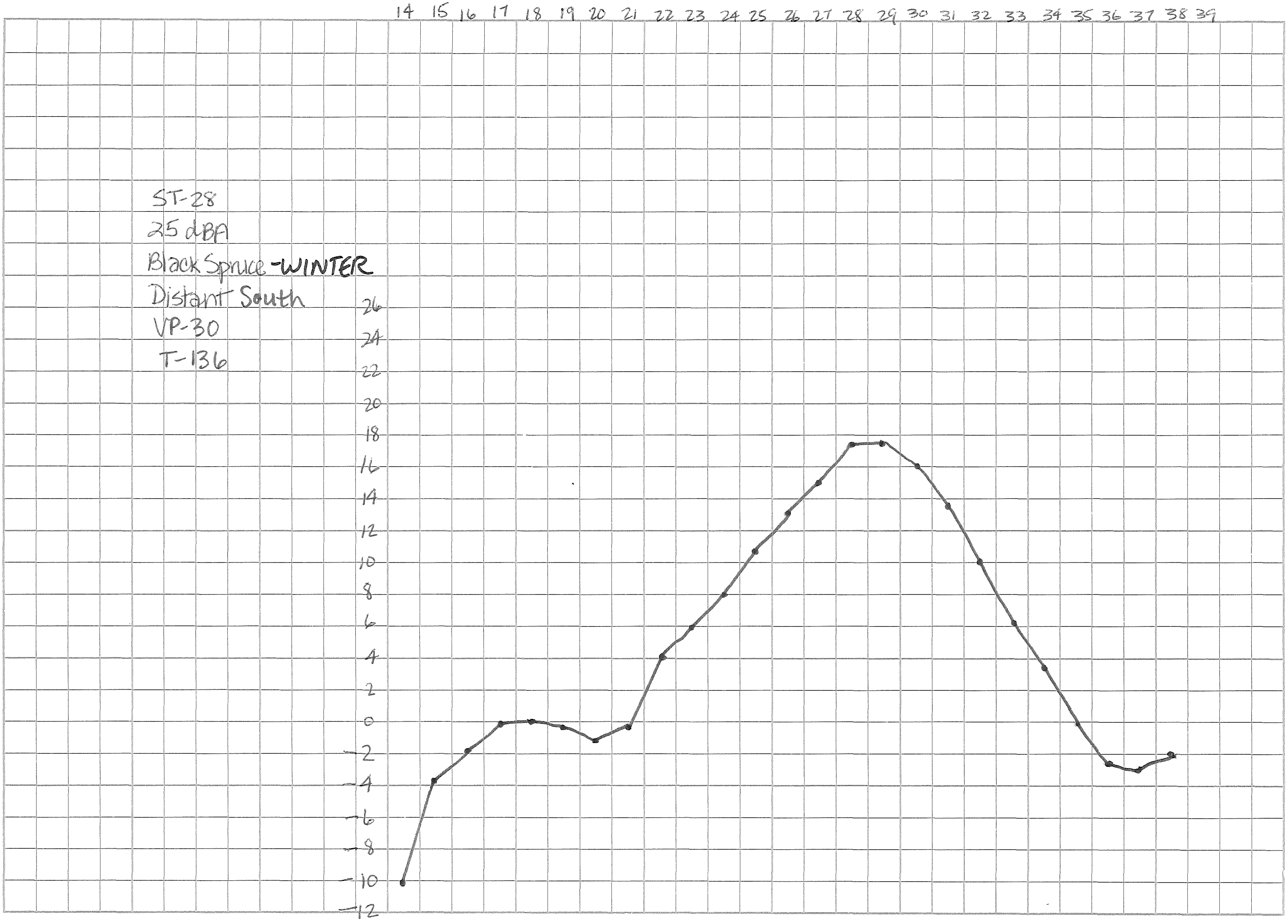
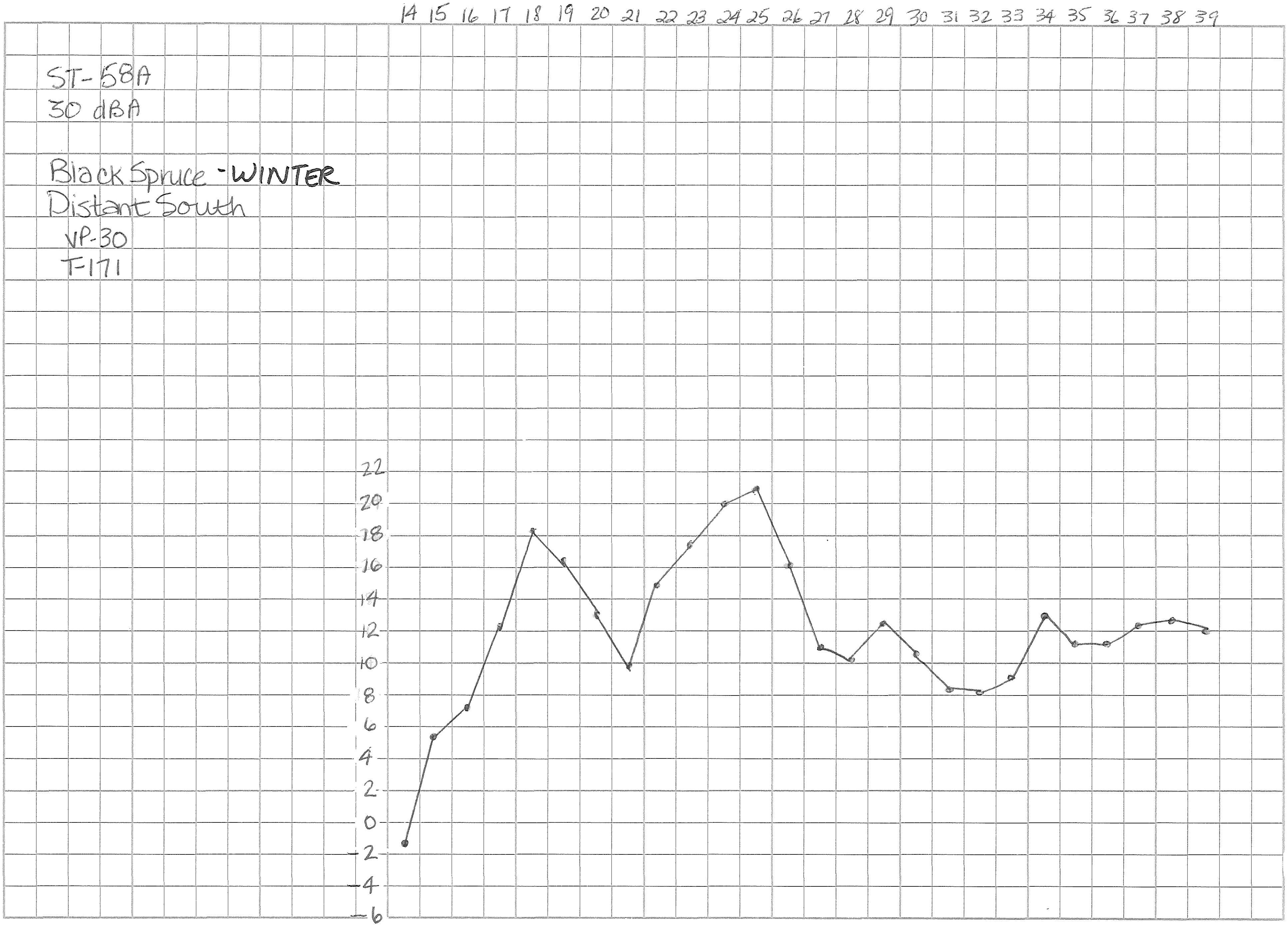


ST-28
20 dBA
Black Spruce-WINTER
Distant South
VP-30
T-136



ST-28
25 dBA
Black Spruce-WINTER
Distant South
VP-30
T-136


ST-58A
30 dBA
Black Spruce - WINTER
Distant South
VP-30
T-171
14
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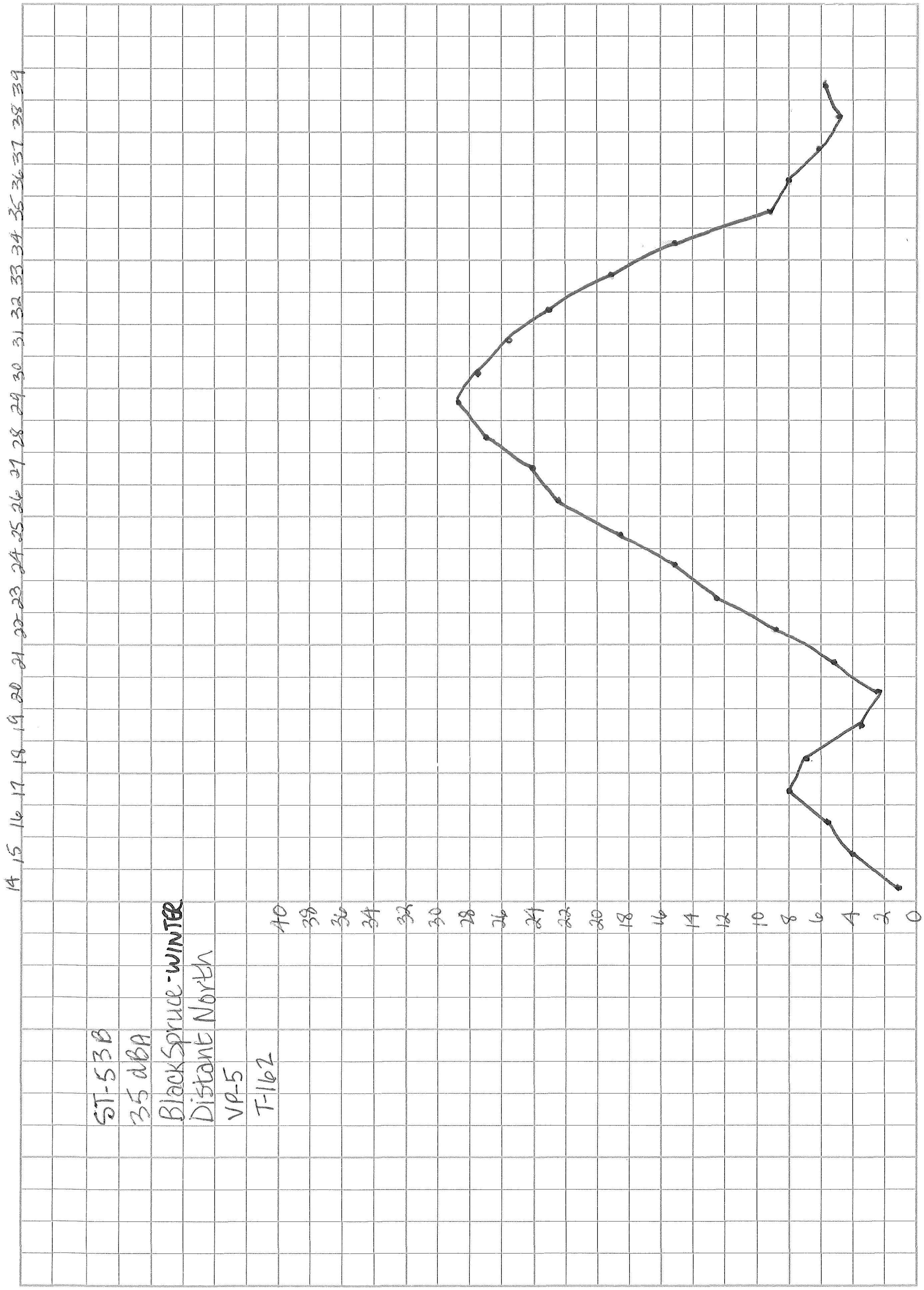
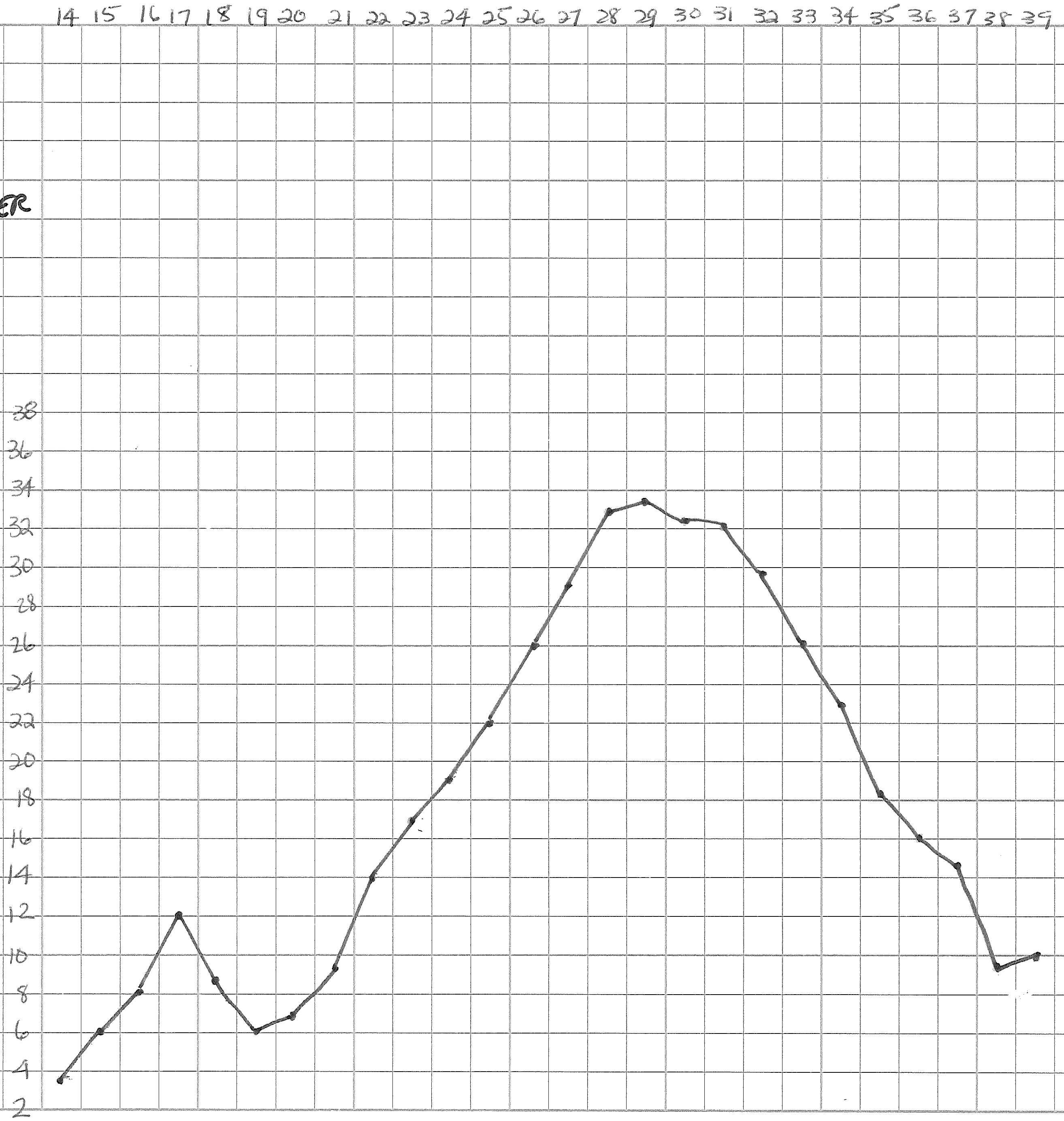


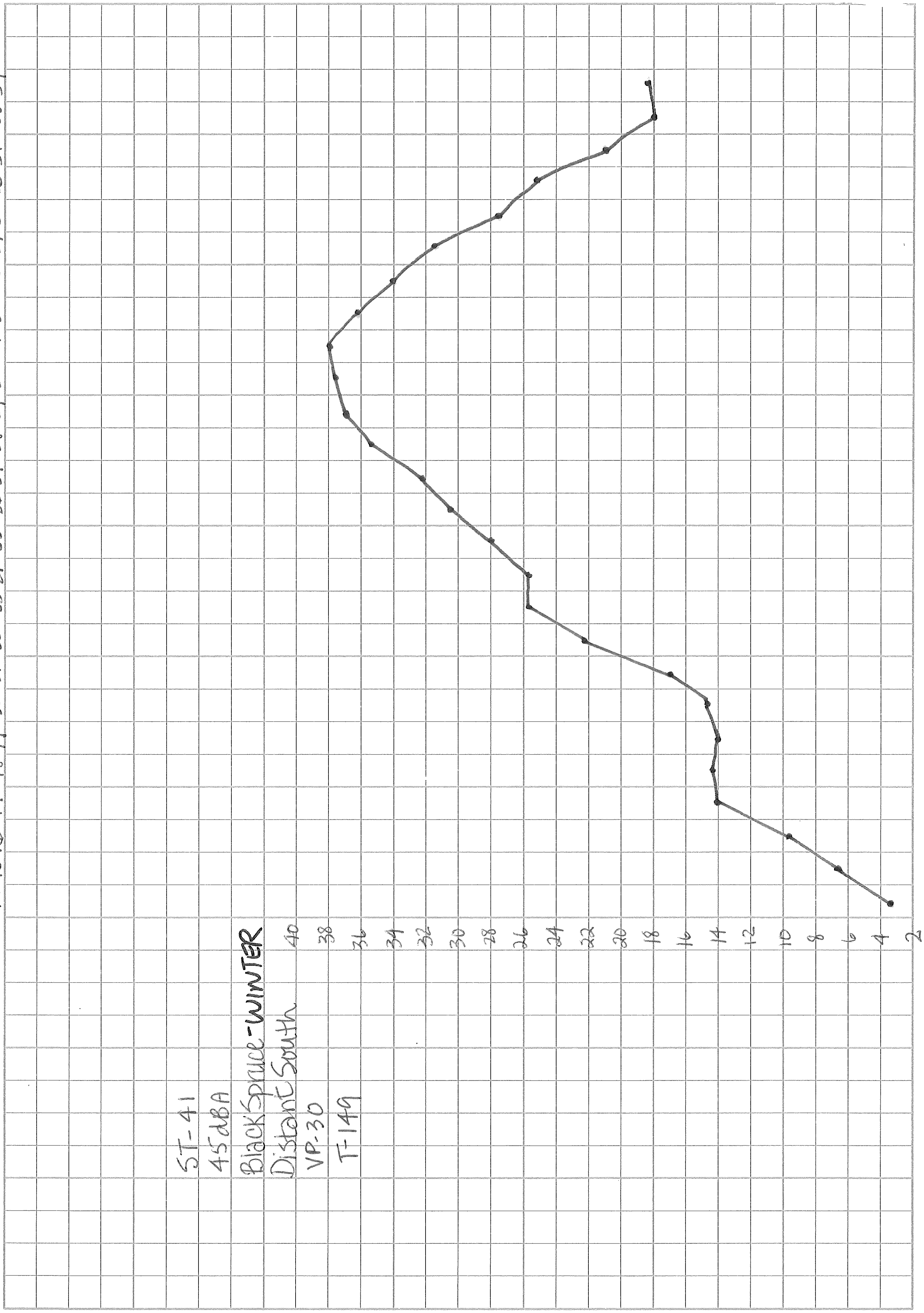
ST-53B
35 dBA
Black Spruce-**WINTER**
Distant North
VP-5
T-162

ST-53B

40 dBA

Black Spruce-**WINTER**
Distant North
VP-5
T-162




ST-41
45dBA
Black Spruce-WINTER
Distant South
VP-30
T-149
14
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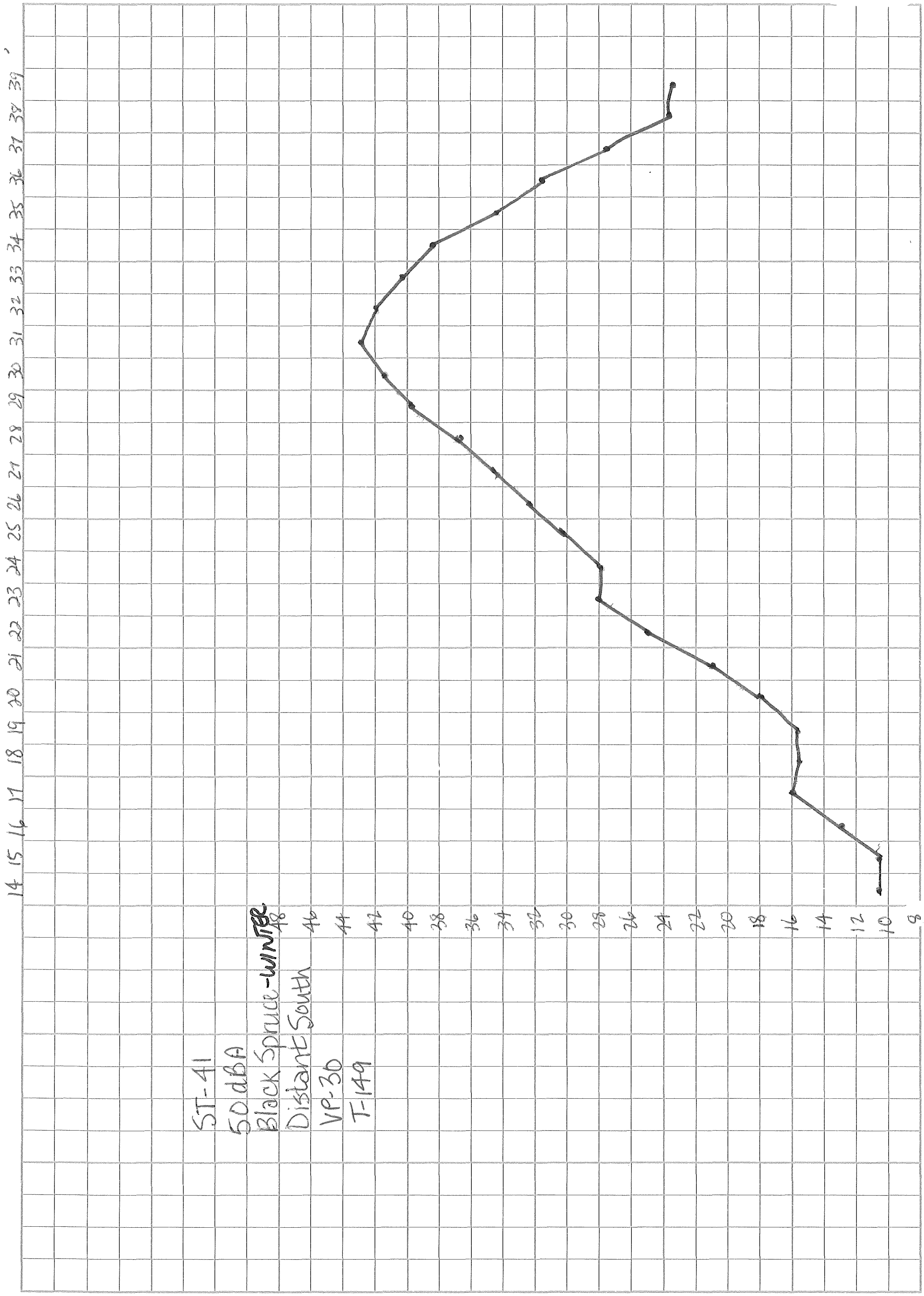
ST-41
50 dBA
Black Spruce -WINTER
Distant South
VP-30
T-149
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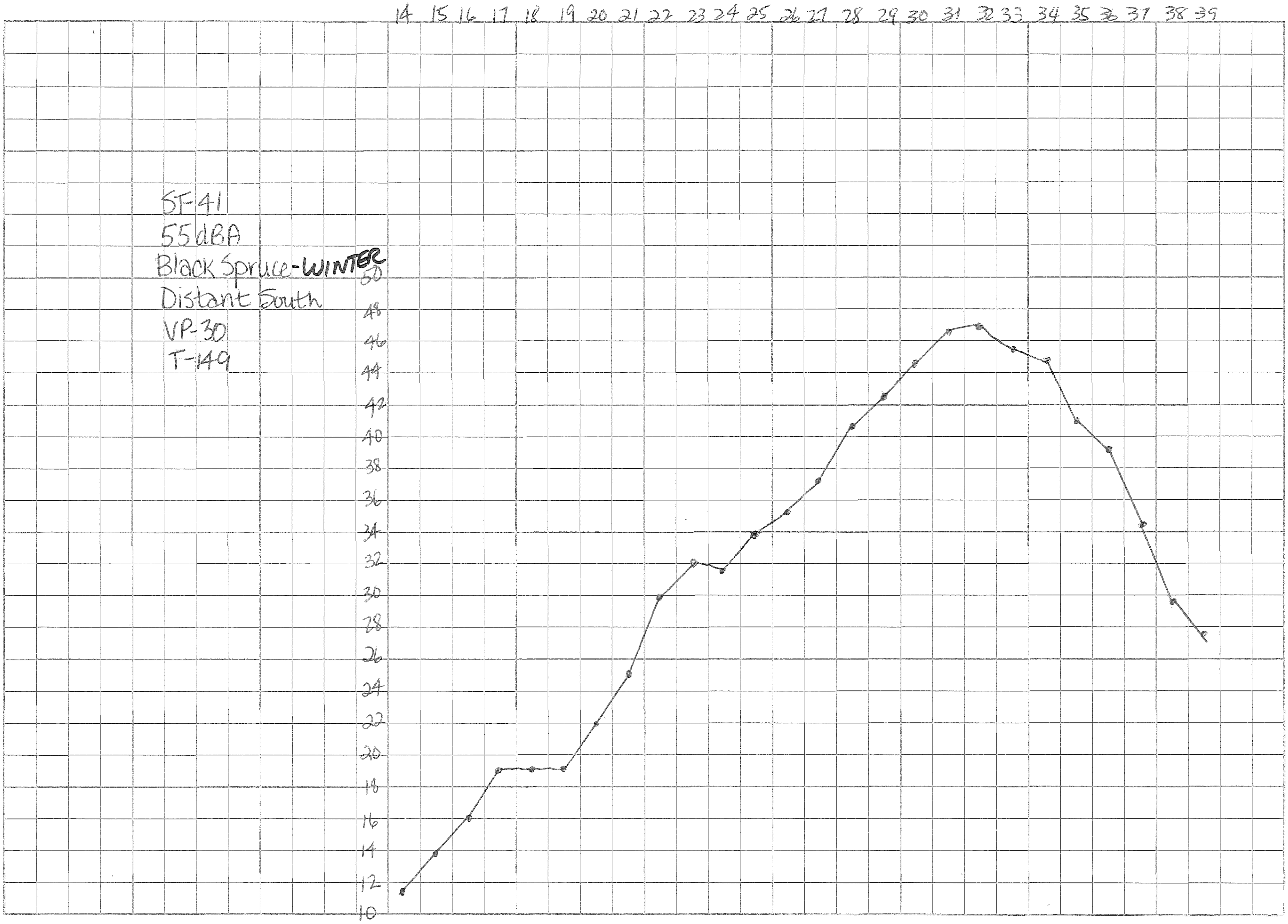
ST-41
55dBA
Black Spruce-WINTER
Distant South
VP-30
T-149
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39
50
48
46
44
42
40
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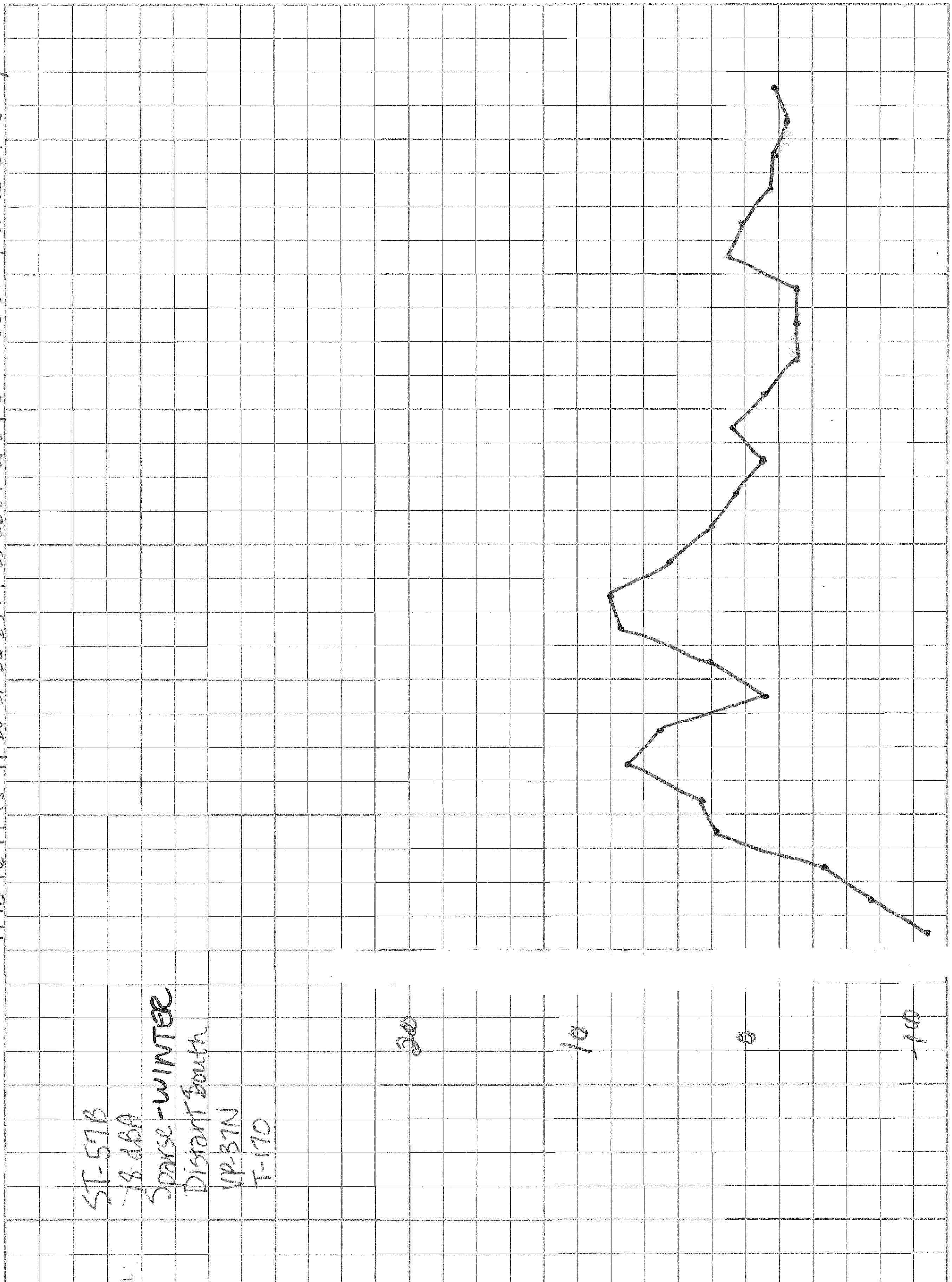
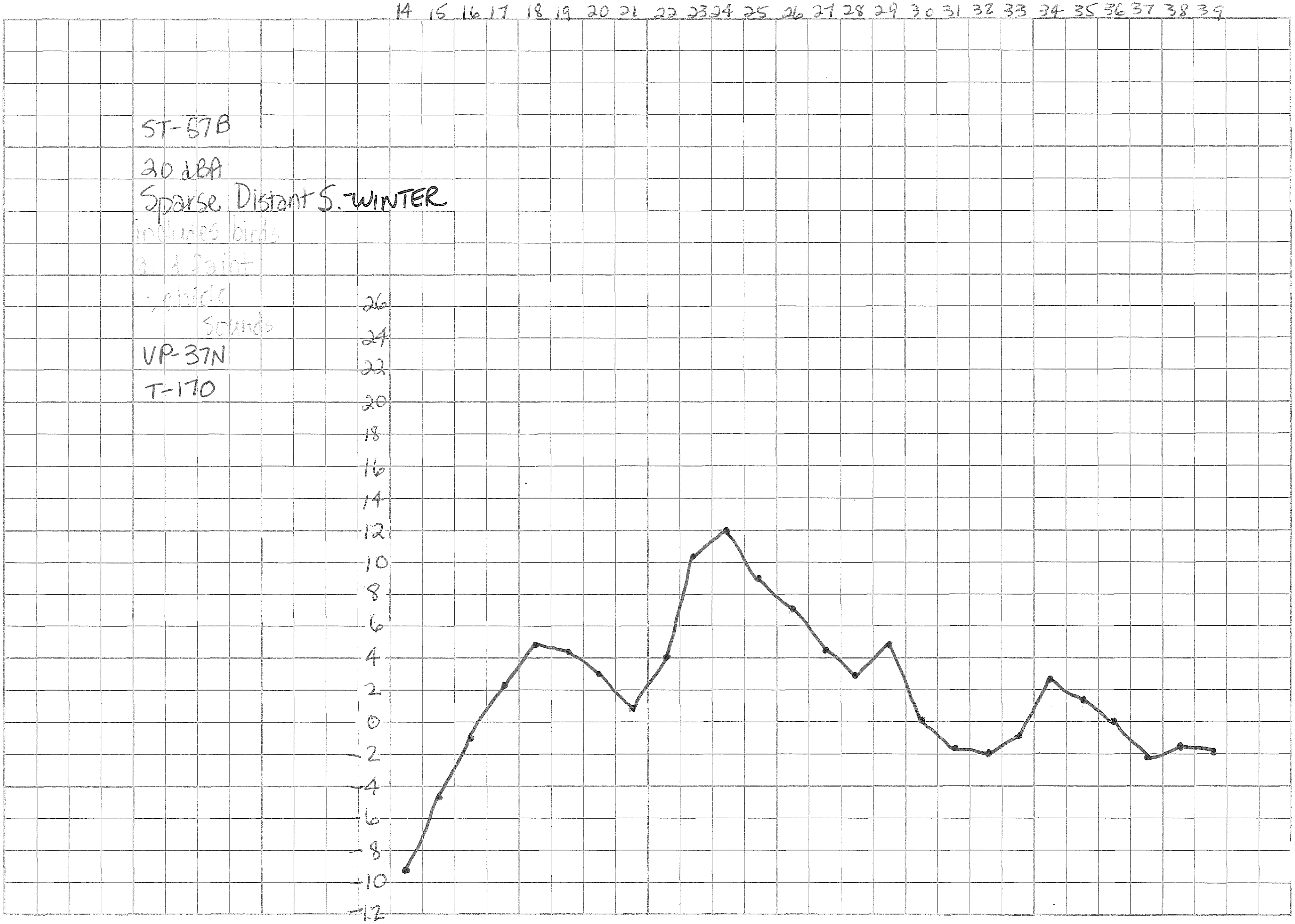
12
10


14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39
20
10
0
-10
ST-57B
-18 dBA
Sparse-WINTER
Distant South
VP-37N
T-170


ST-57B
20 dBA
Sparse Distant S.-WINTER
includes birds
and faint
vehicle
sounds
VP-37N
T-170
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39
26
24
22
20
18
16
14
12
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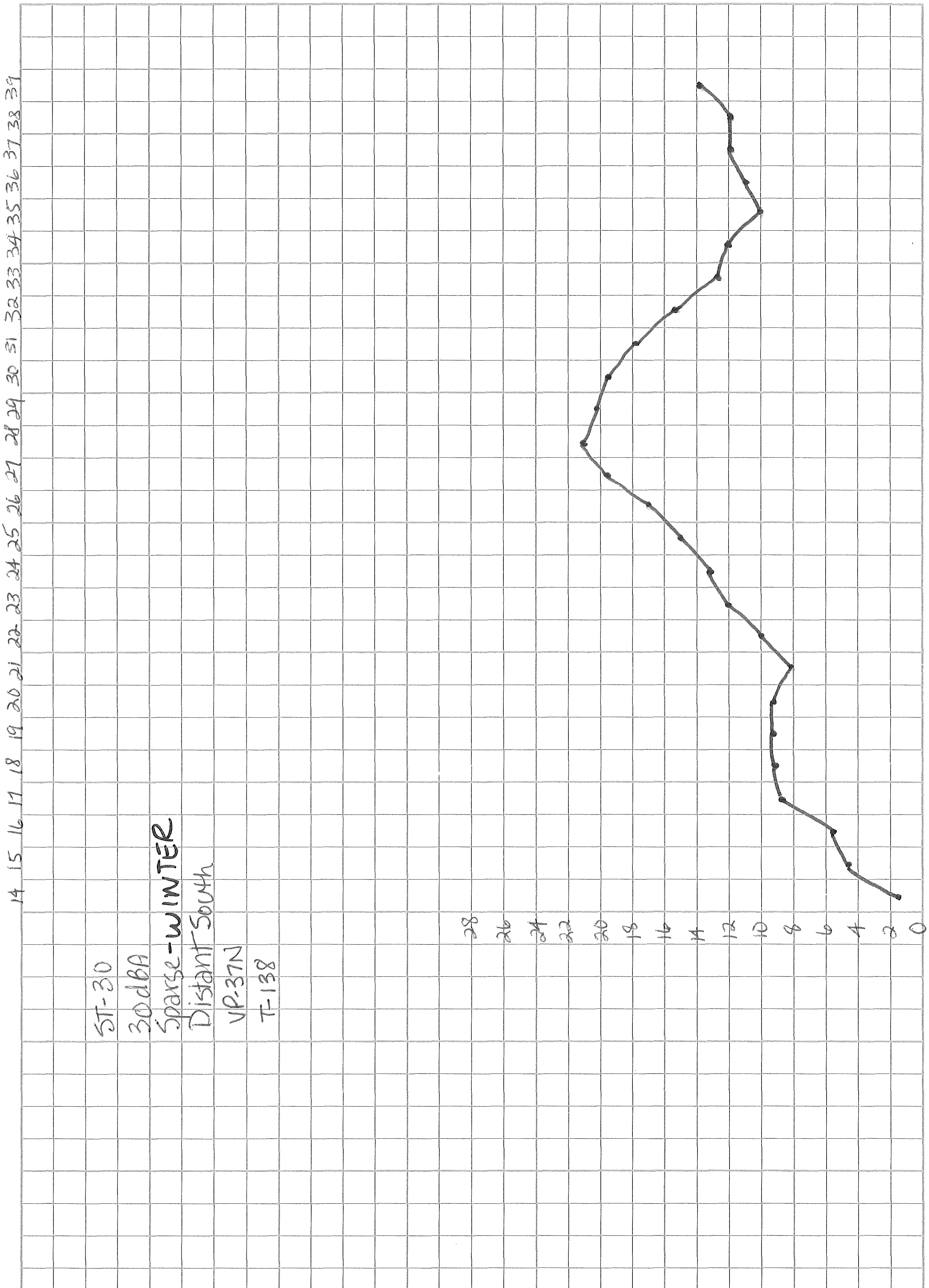
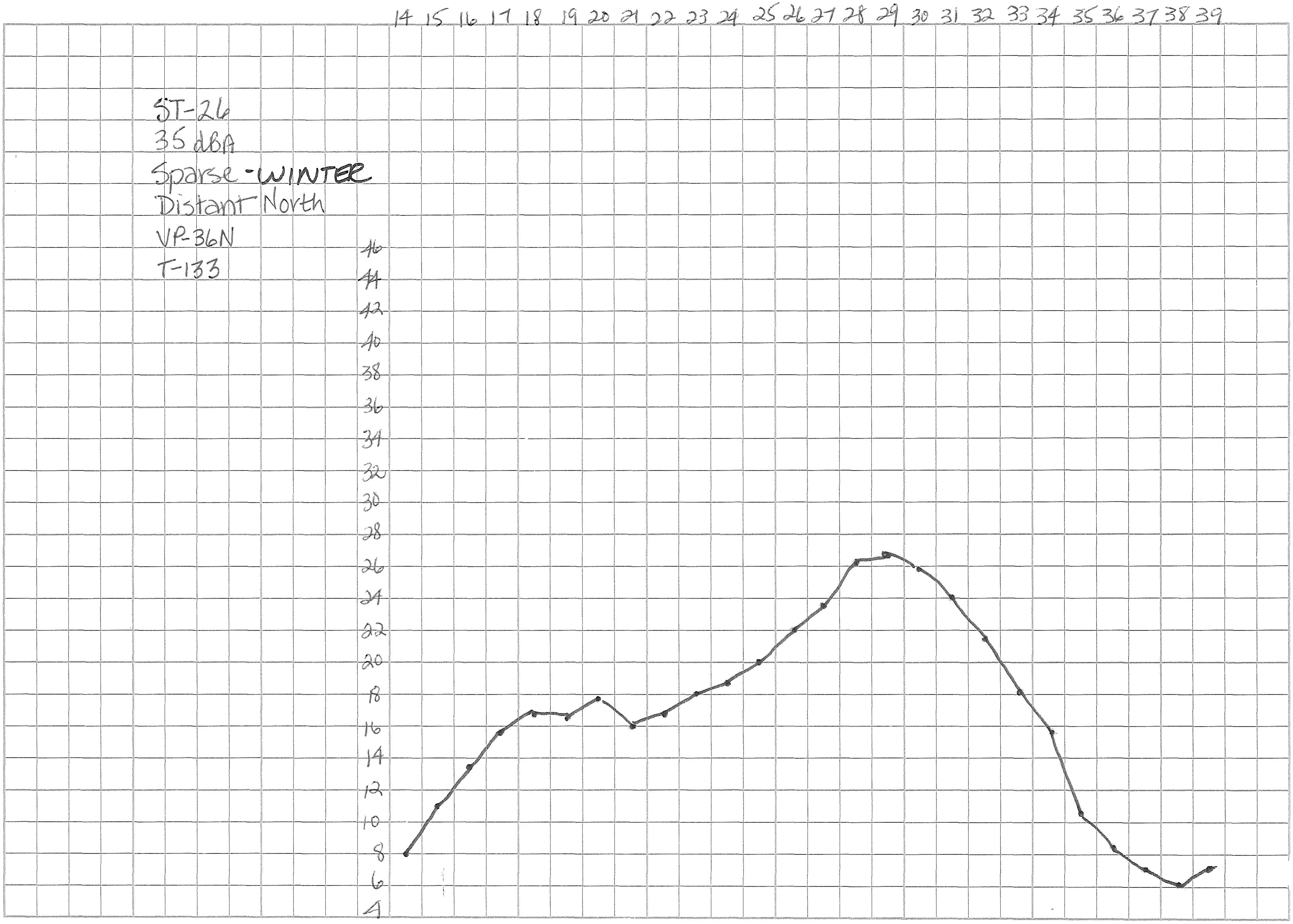
8
6
4
2
0
-2
-4
-6
-8
-10
-12



ST-30
30dBA
Sparse-WINTER
Distant South
VP.37N
T-138


ST-26
35 dBA
Sparse-WINTER
Distant North
VP-36N
T-133
14
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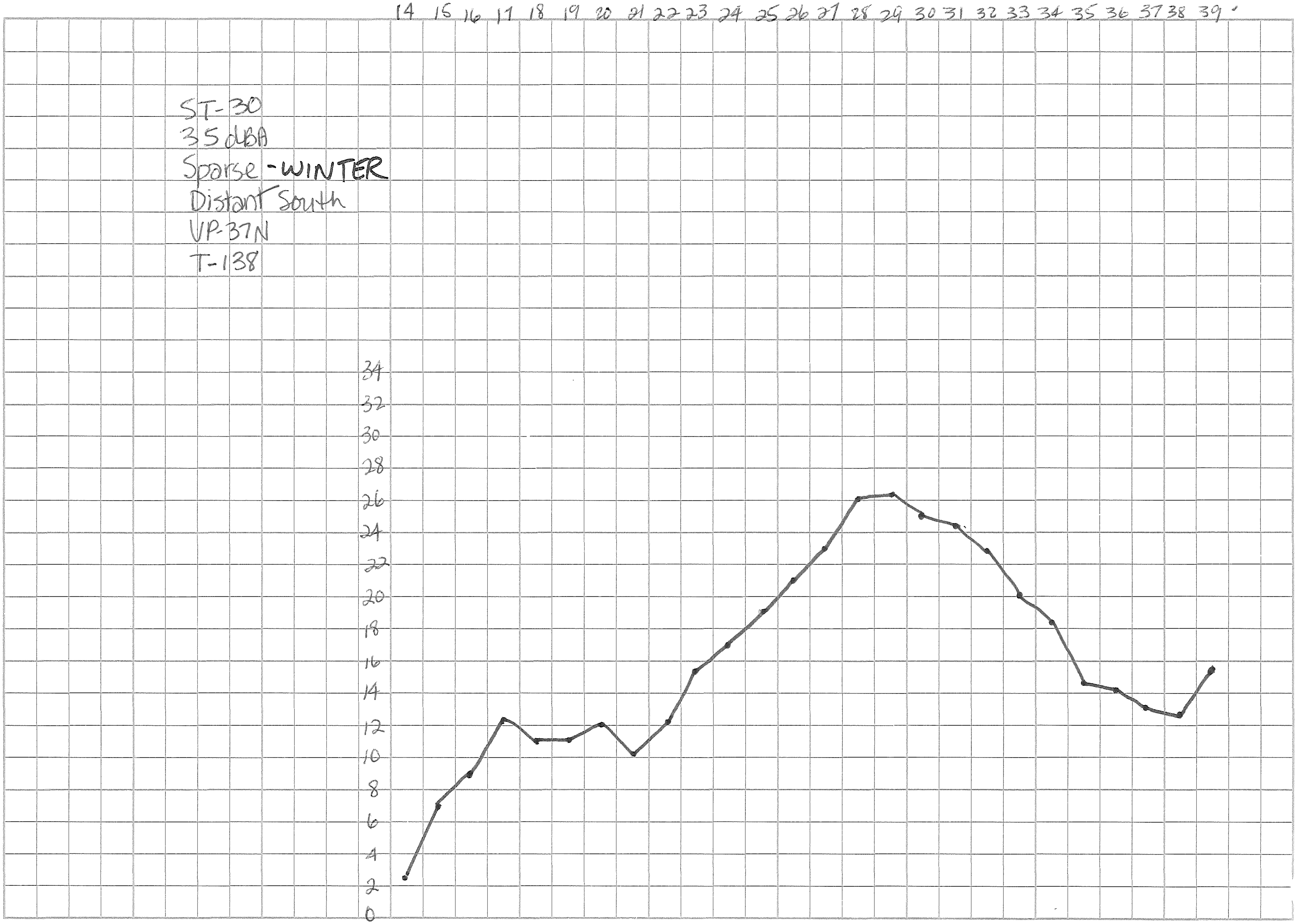
ST-30
35 dBA
Sparse-WINTER
Distant South
VP-37N
T-138
14
15
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22
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24
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39'
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6
4
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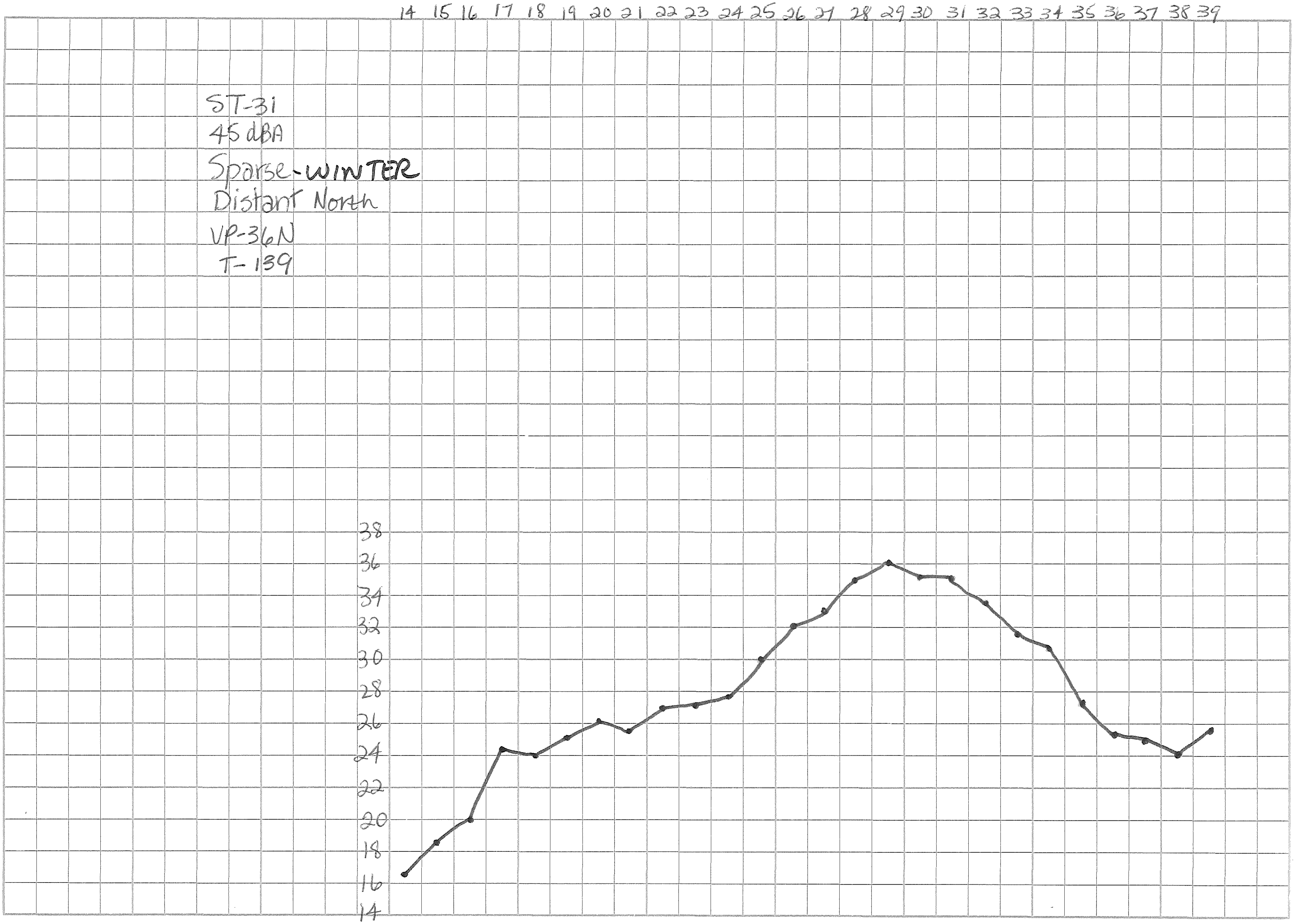
0


ST-31
45 dBA
Sparse-WINTER
Distant North
VP-36N
T-139
14
15
16
17
18
19
20
21
22
23
24
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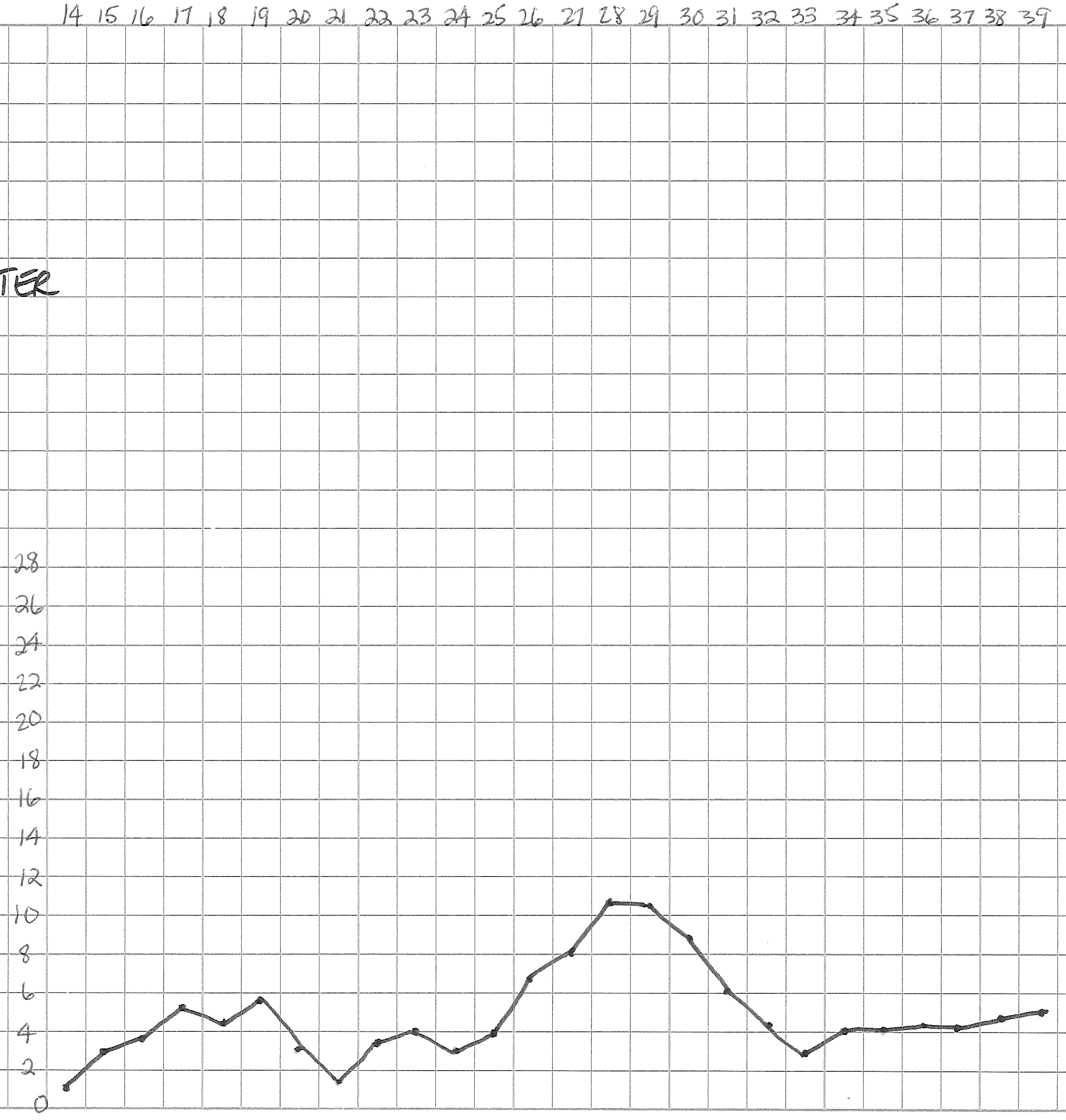
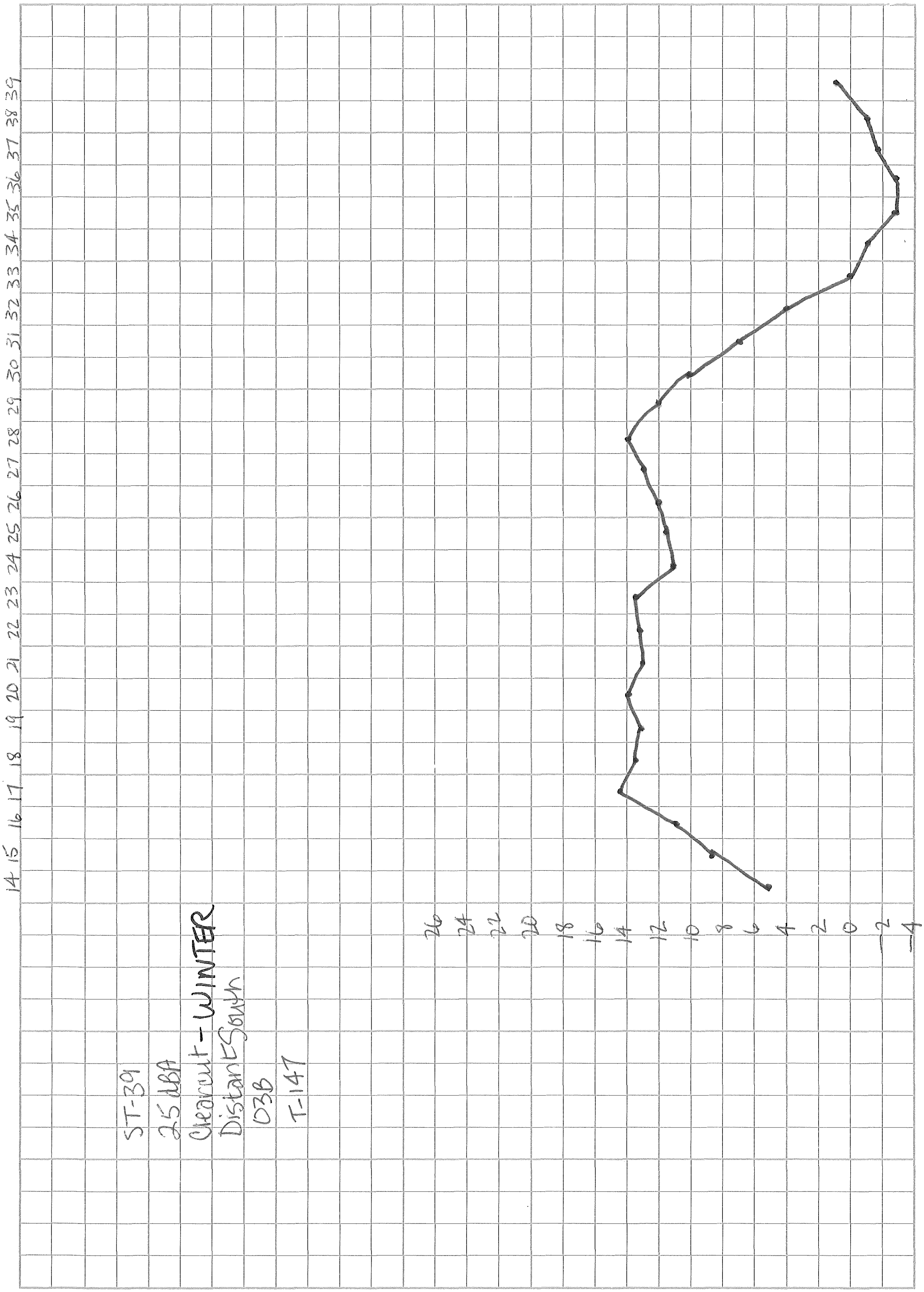
16
14

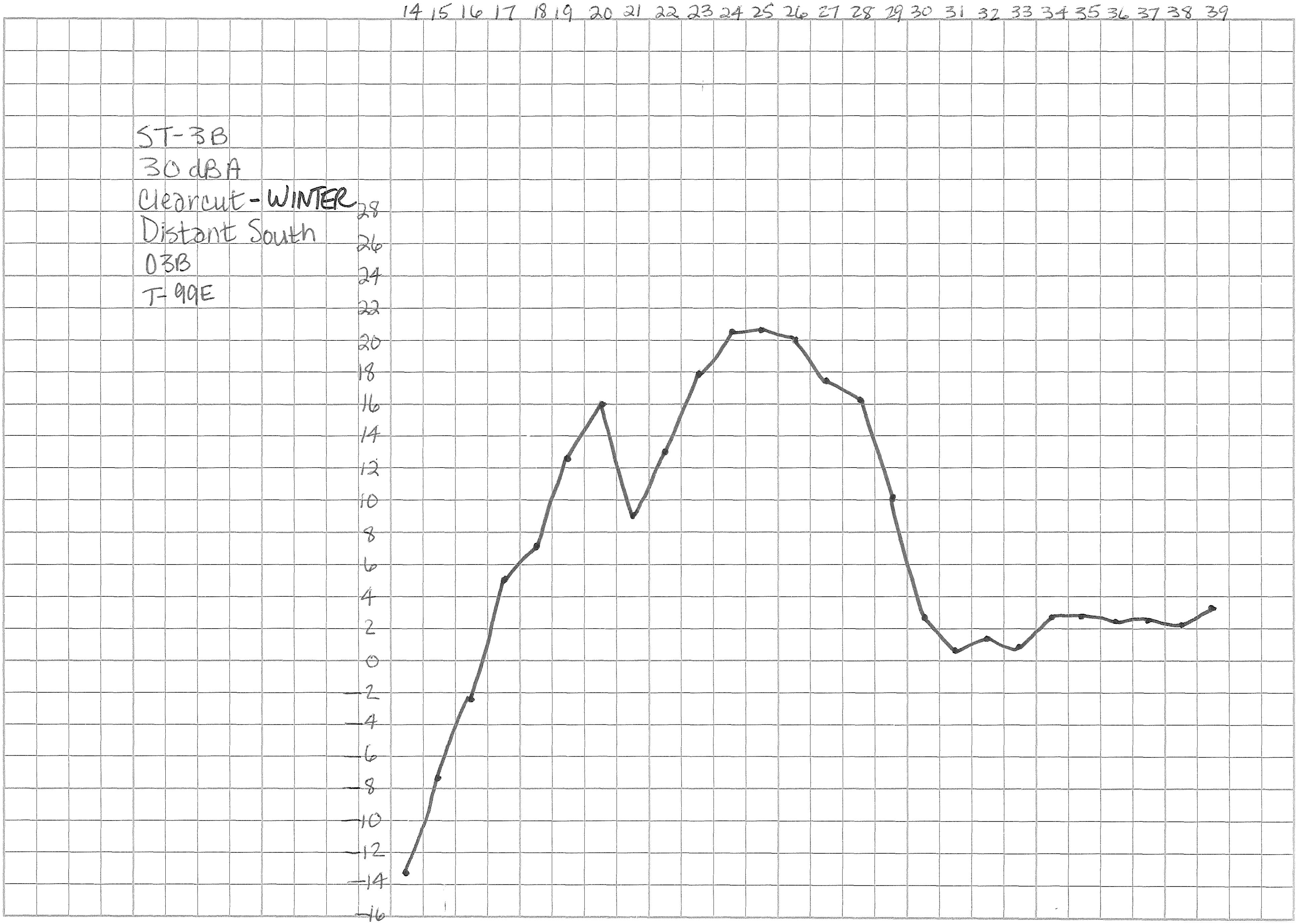
ST-4A
20dBA
Clearcut - WINTER
Distant South -
03C
T-101





ST-39
25dBA
Clearcut - WINTER
Distant South
03B
T-147

4 Squares
to the Inch


ST-3B
30 dBA
Clearcut - WINTER
Distant South
03B
T-99E
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39
28
26
24
22
20
18
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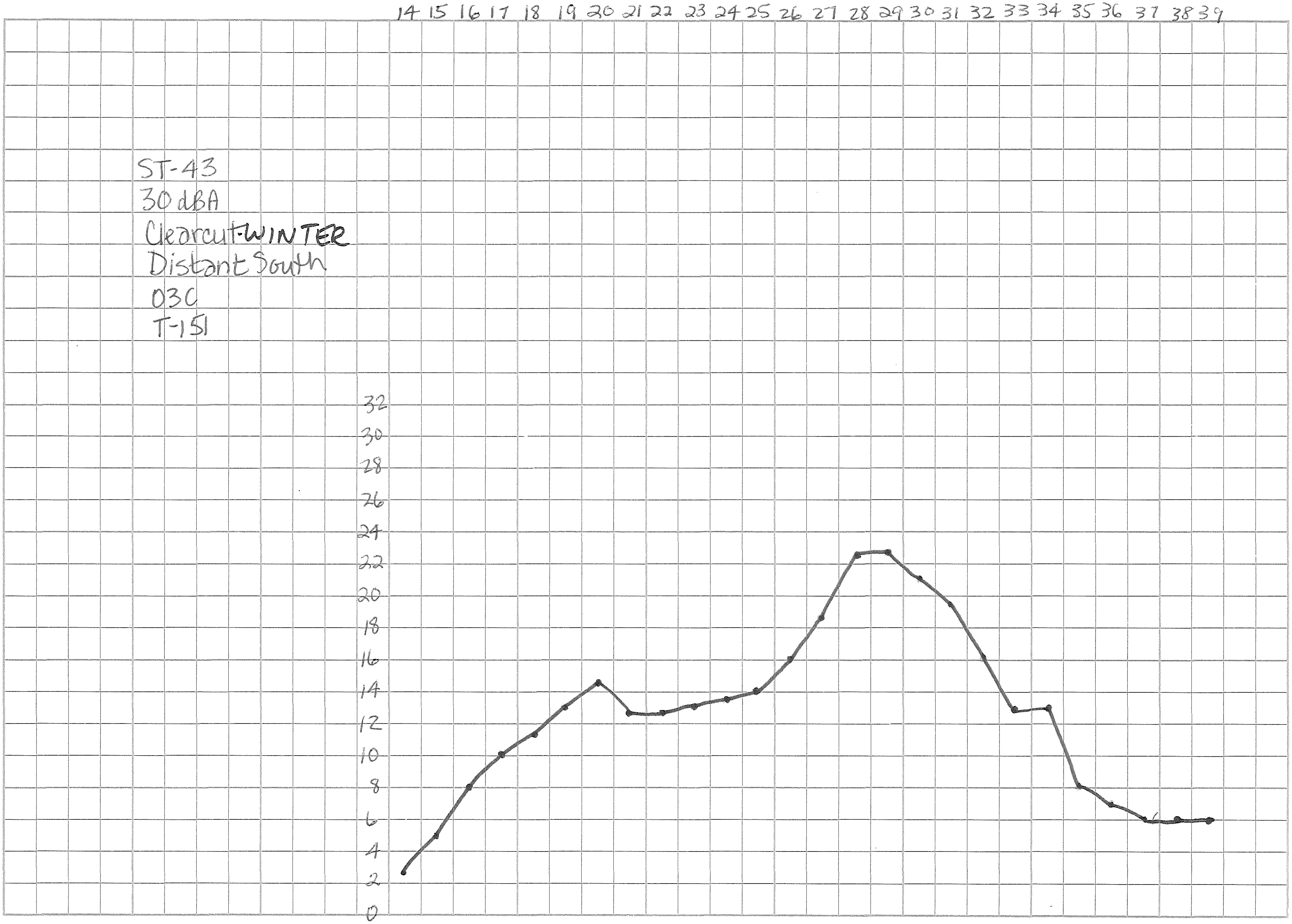
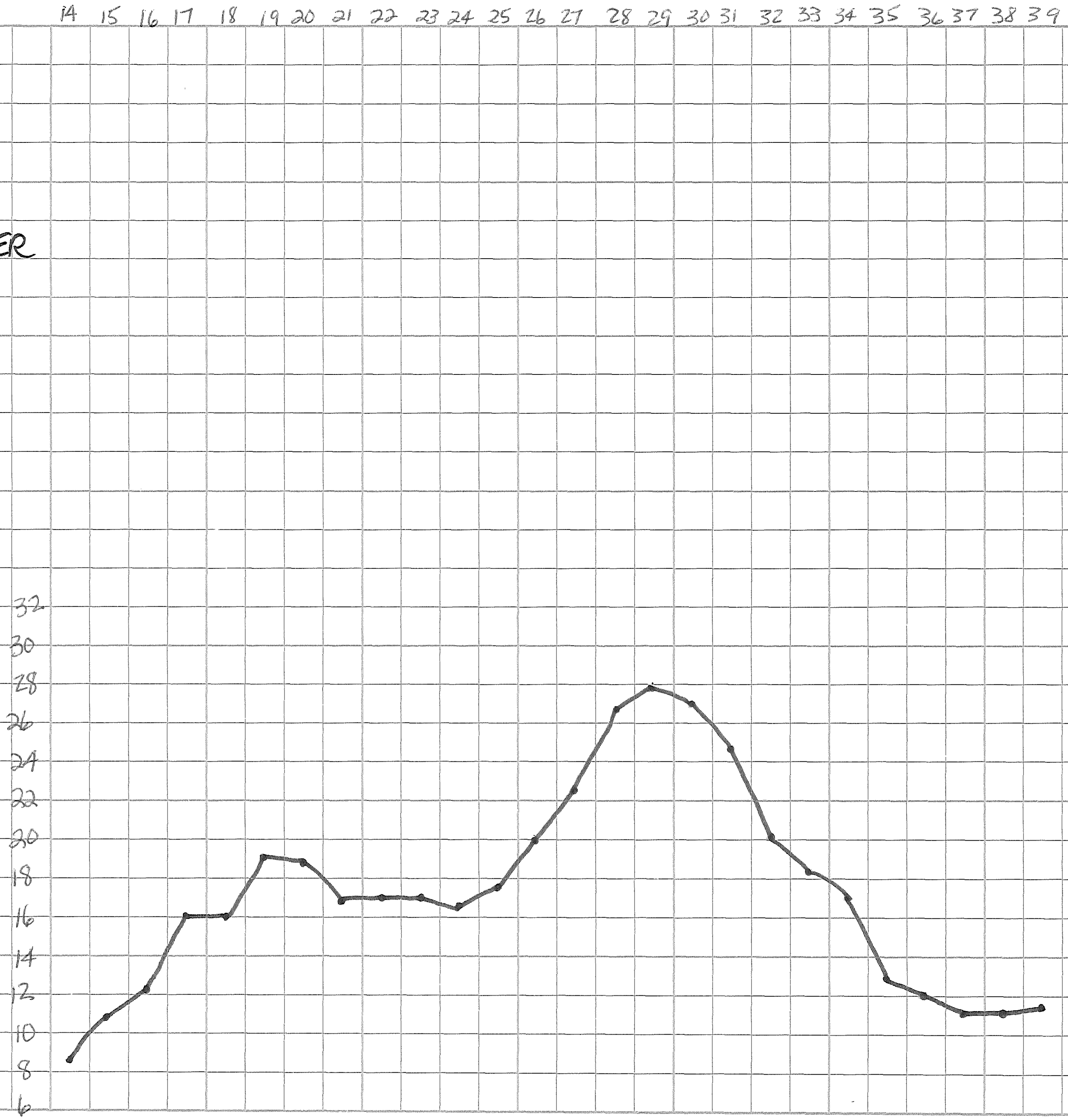
-14
-16

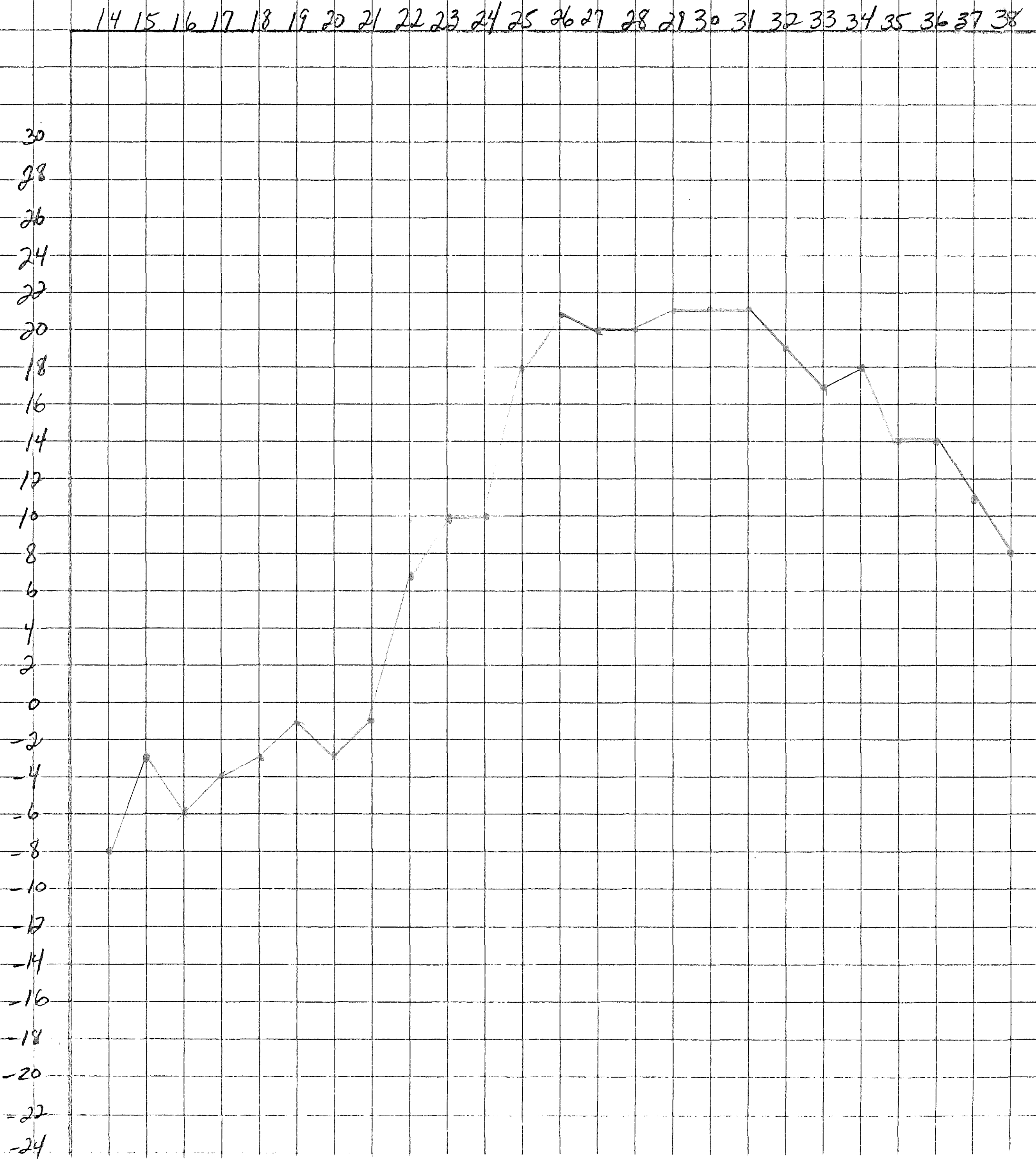


ST-43
30 dBA
Clearcut-WINTER
Distant South
03C
T-151

ST-43
35 dBA
Clearcut - WINTER
Distant South
03C
T-151

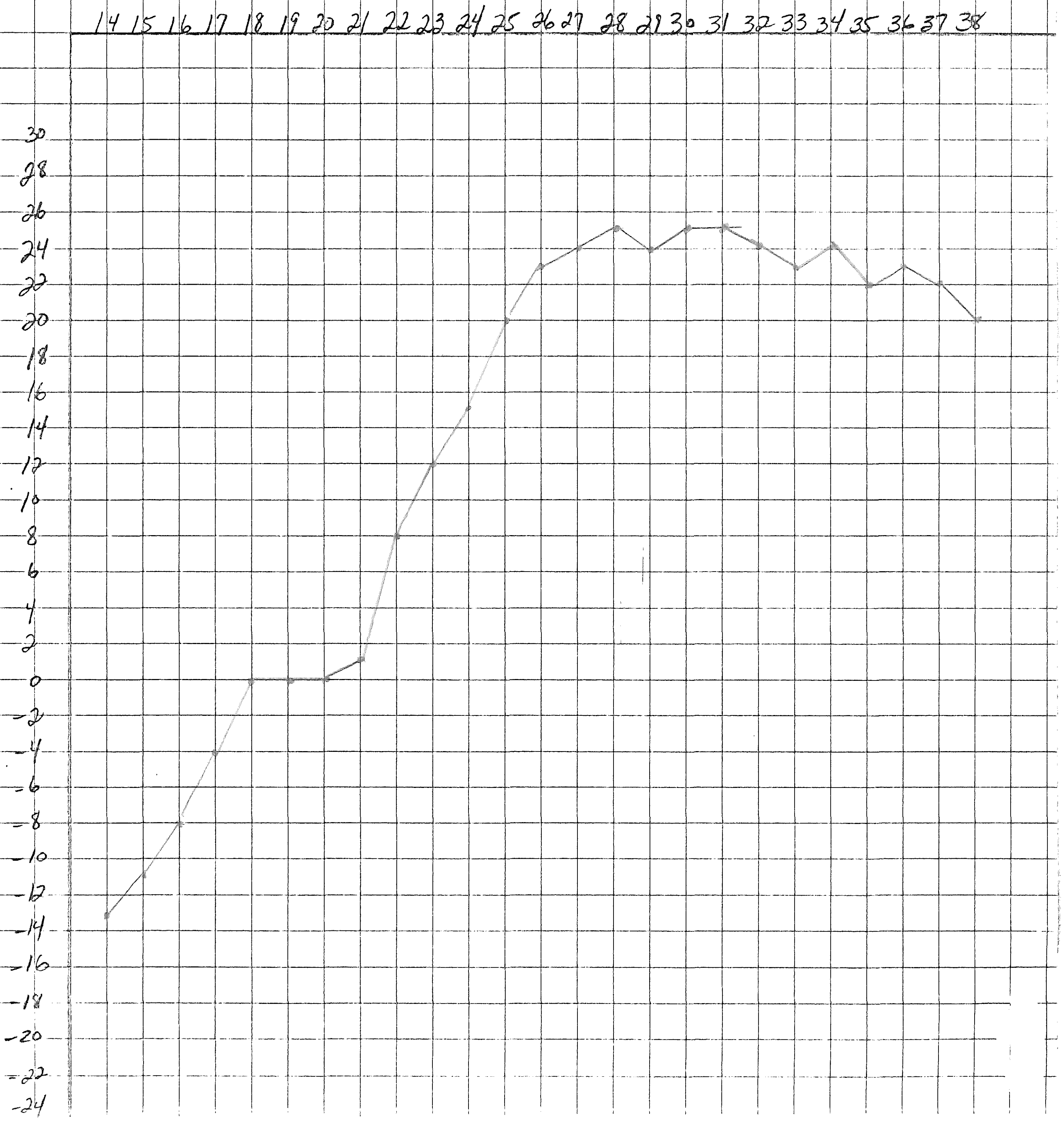


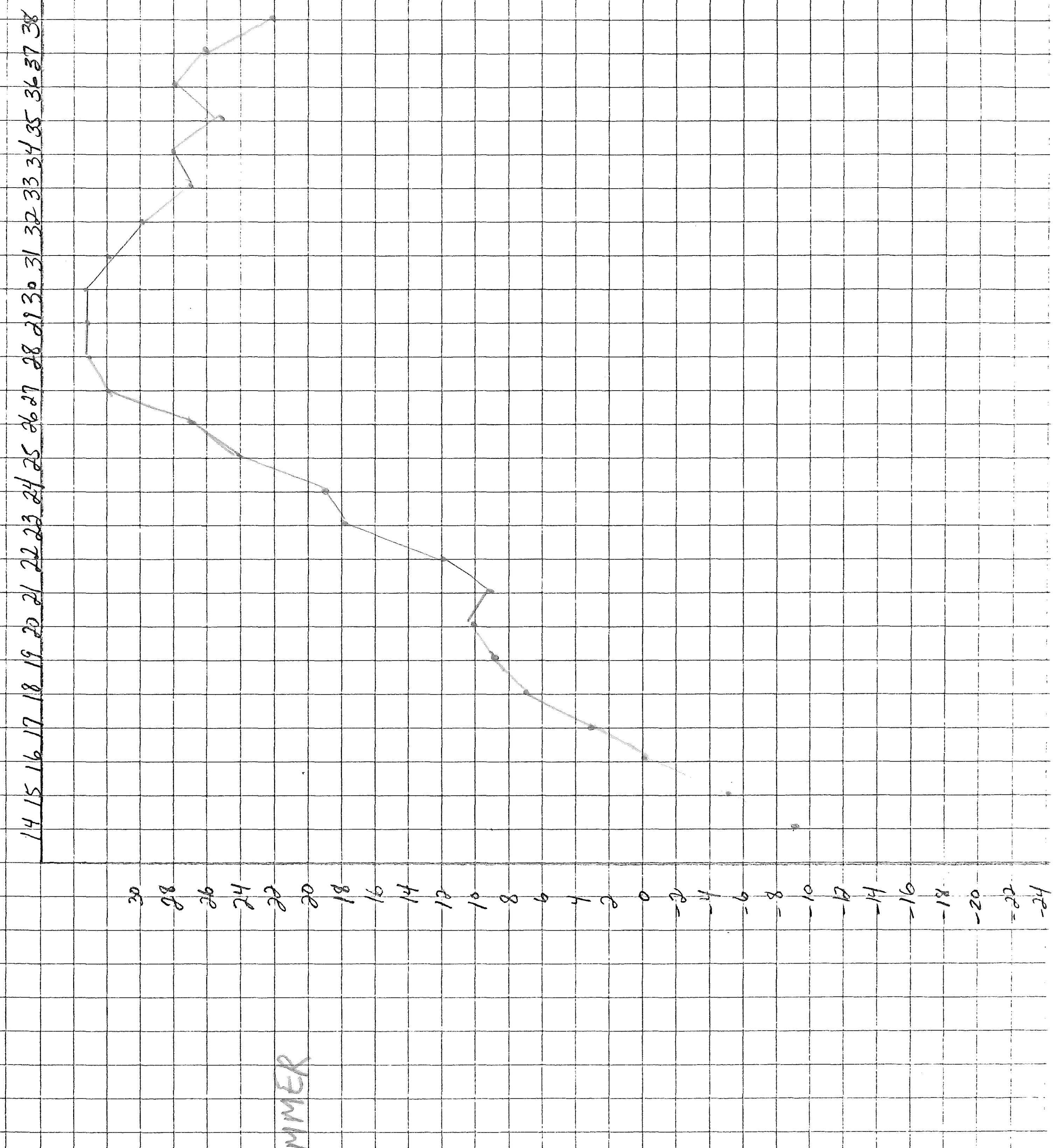
JACKPINE - SUMMER
30dBA



JACKPINE - SUMMER

25 dBA



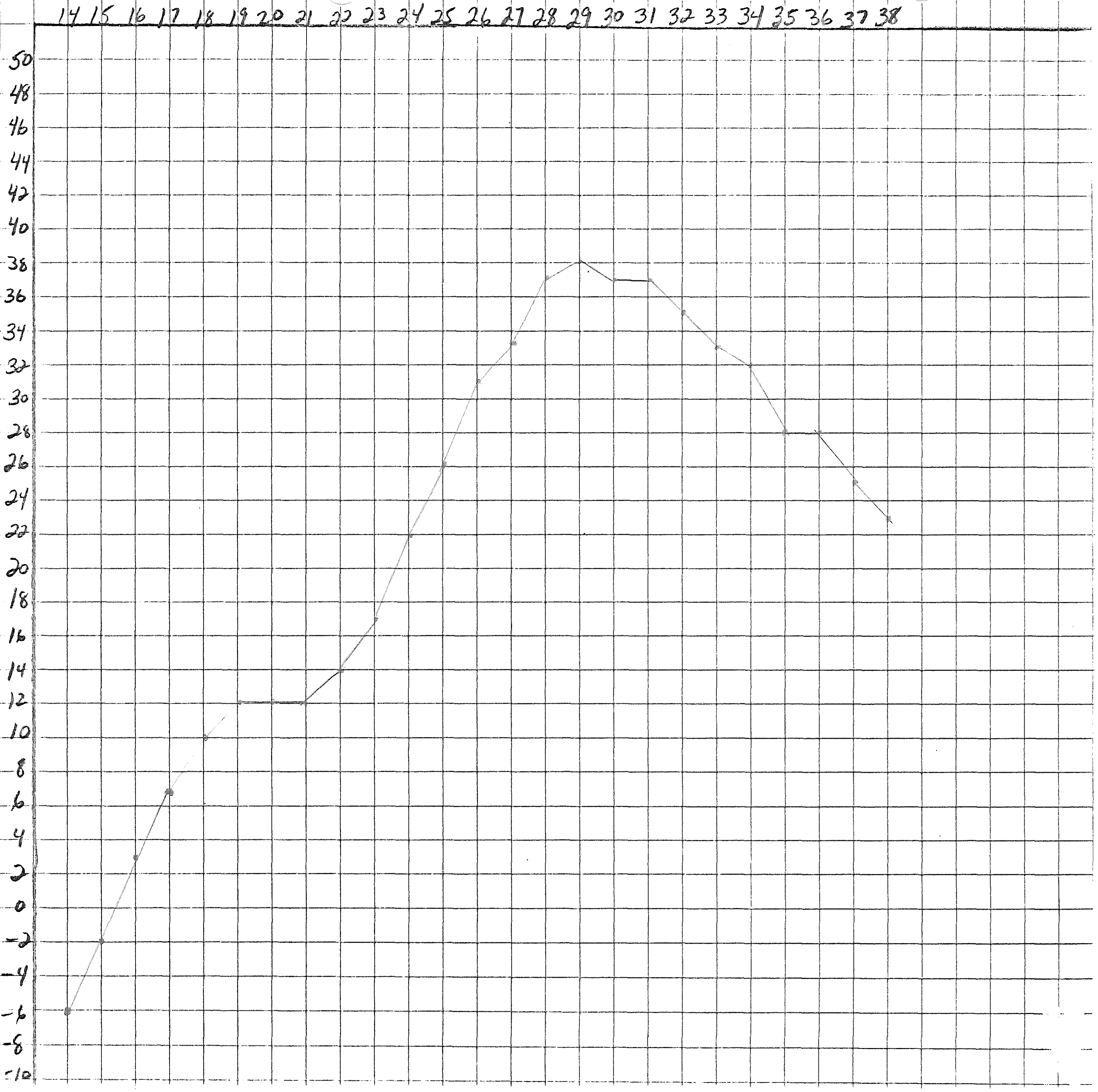


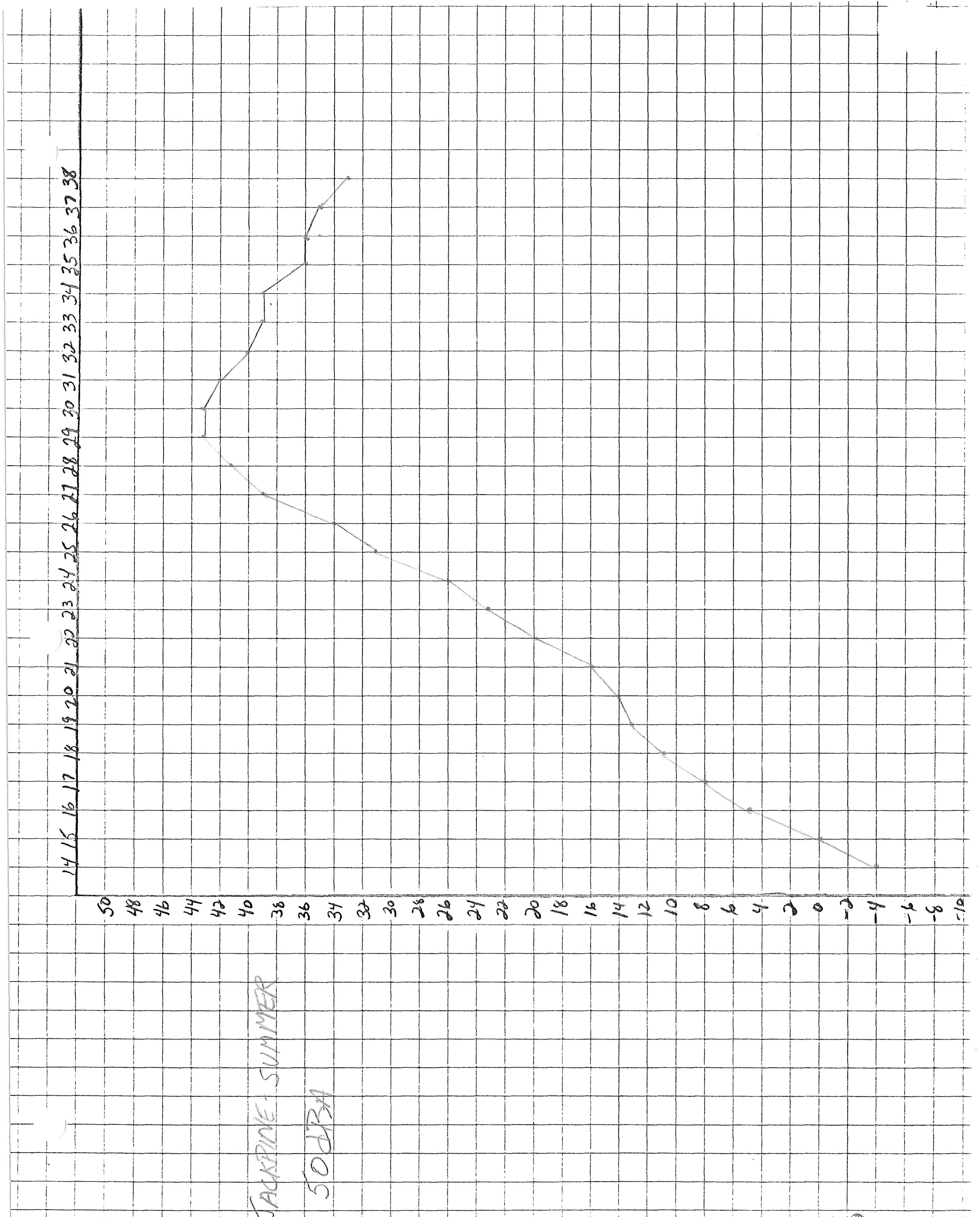
JACKPINE - SUMMER

40 dBA

JACKPINE - SUMMER

45 dBA



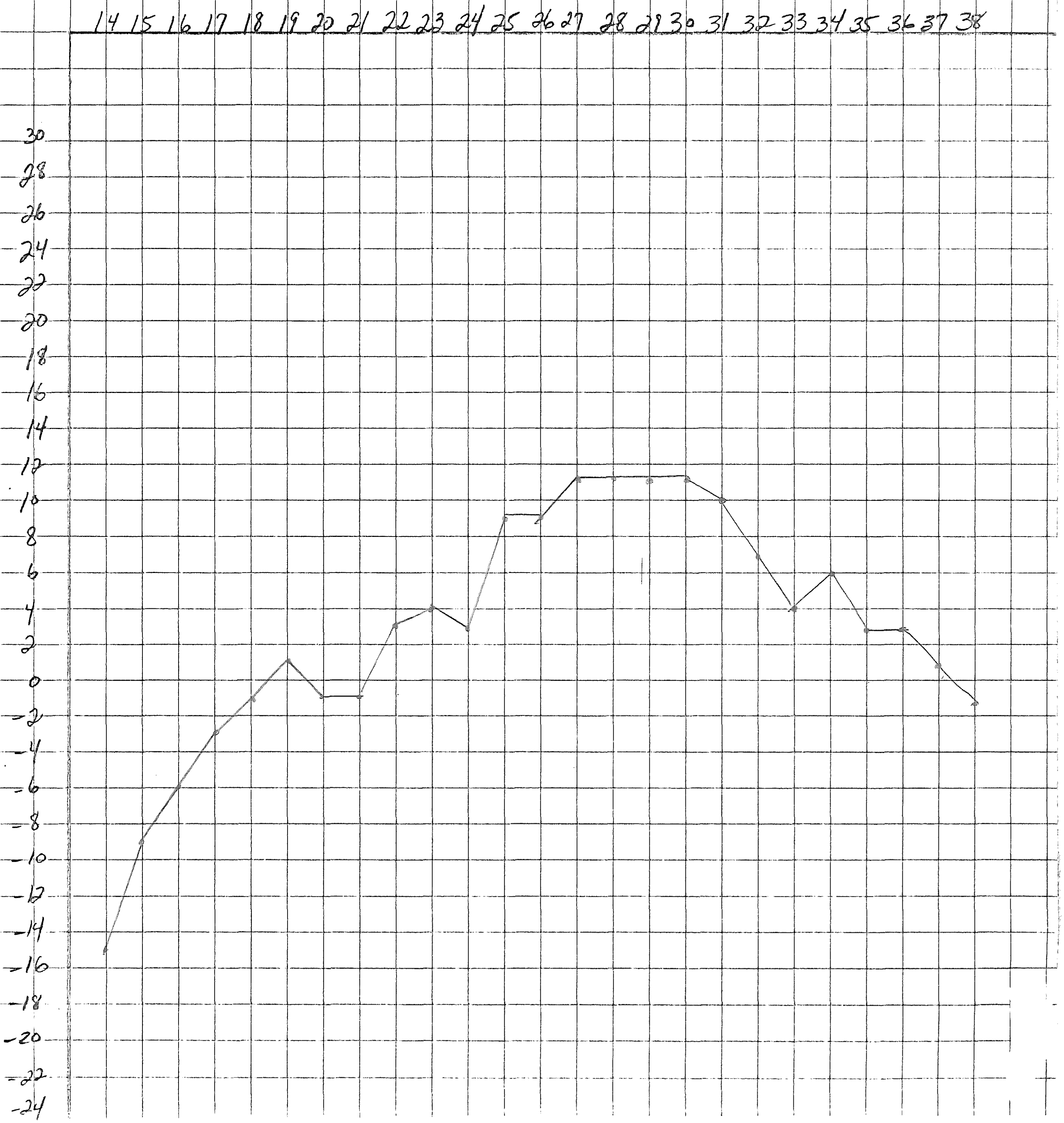


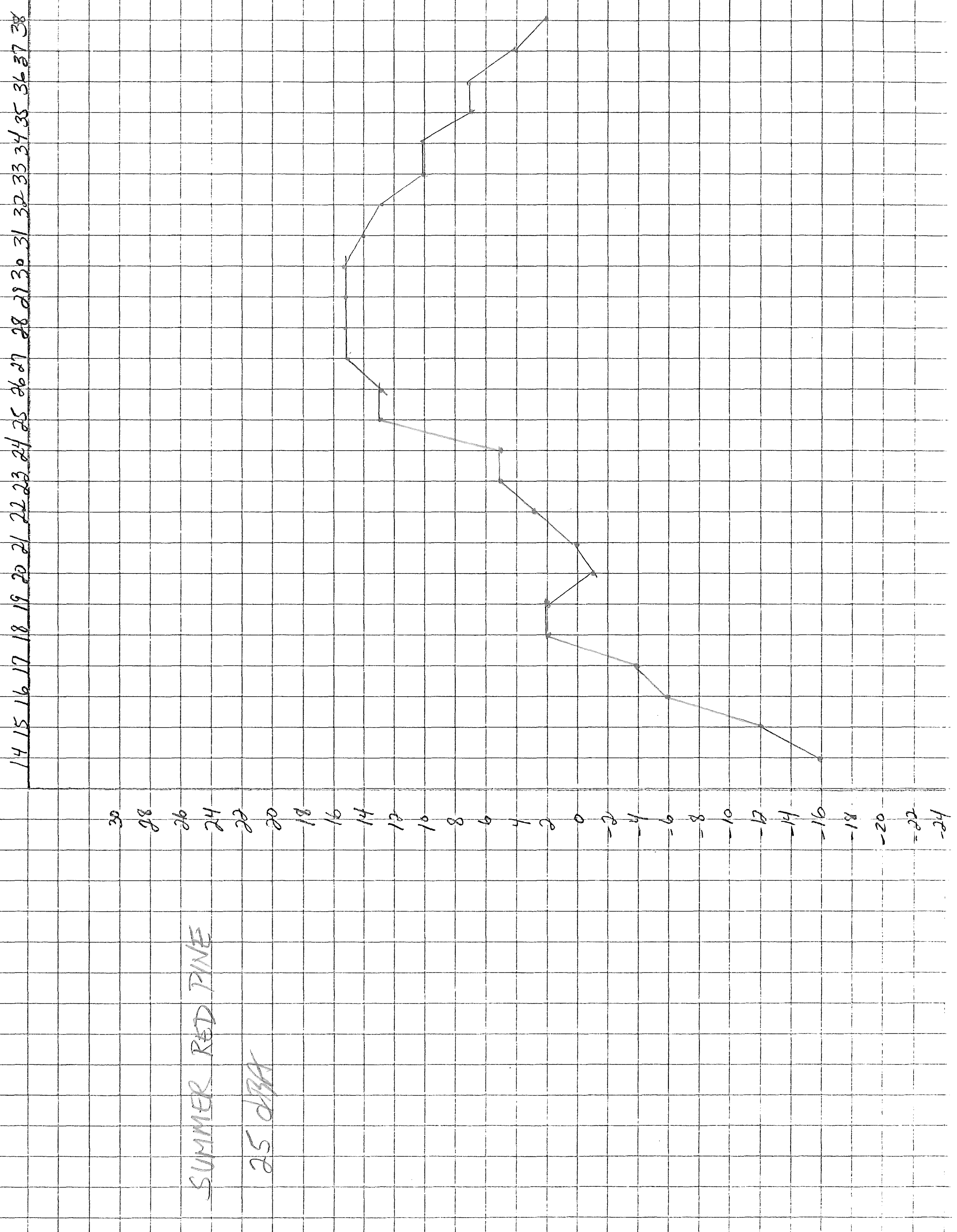
JACKPINE - SUMMER

50dBA

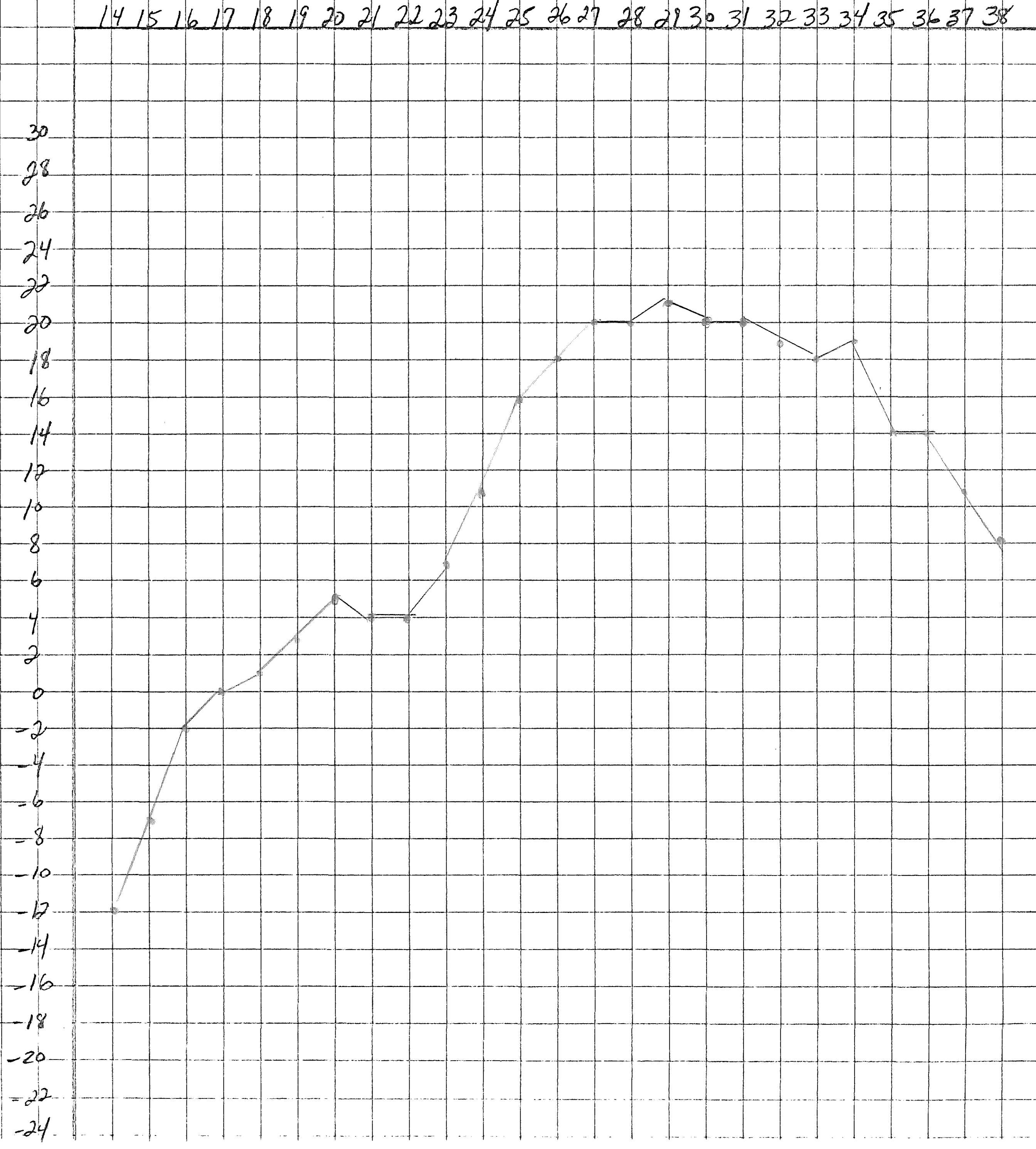
SUMMER RED PINE

20dBA



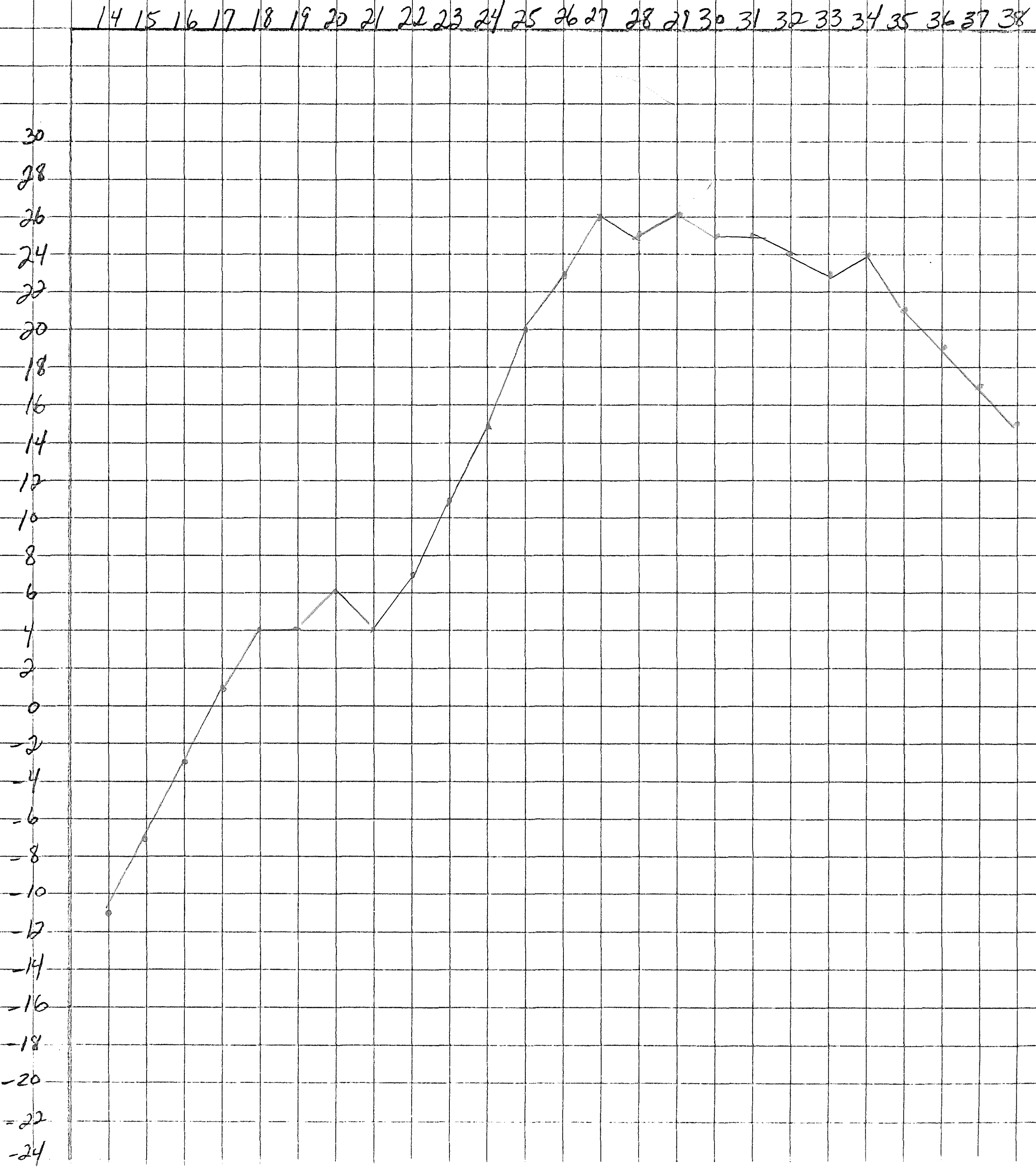

SUMMER RED PINE
25 DBH
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0 -2 -4 -6 -8 -10 -12 -14 -16 -18 -20 -22 -24

SUMMER RED PINE
30 DBA



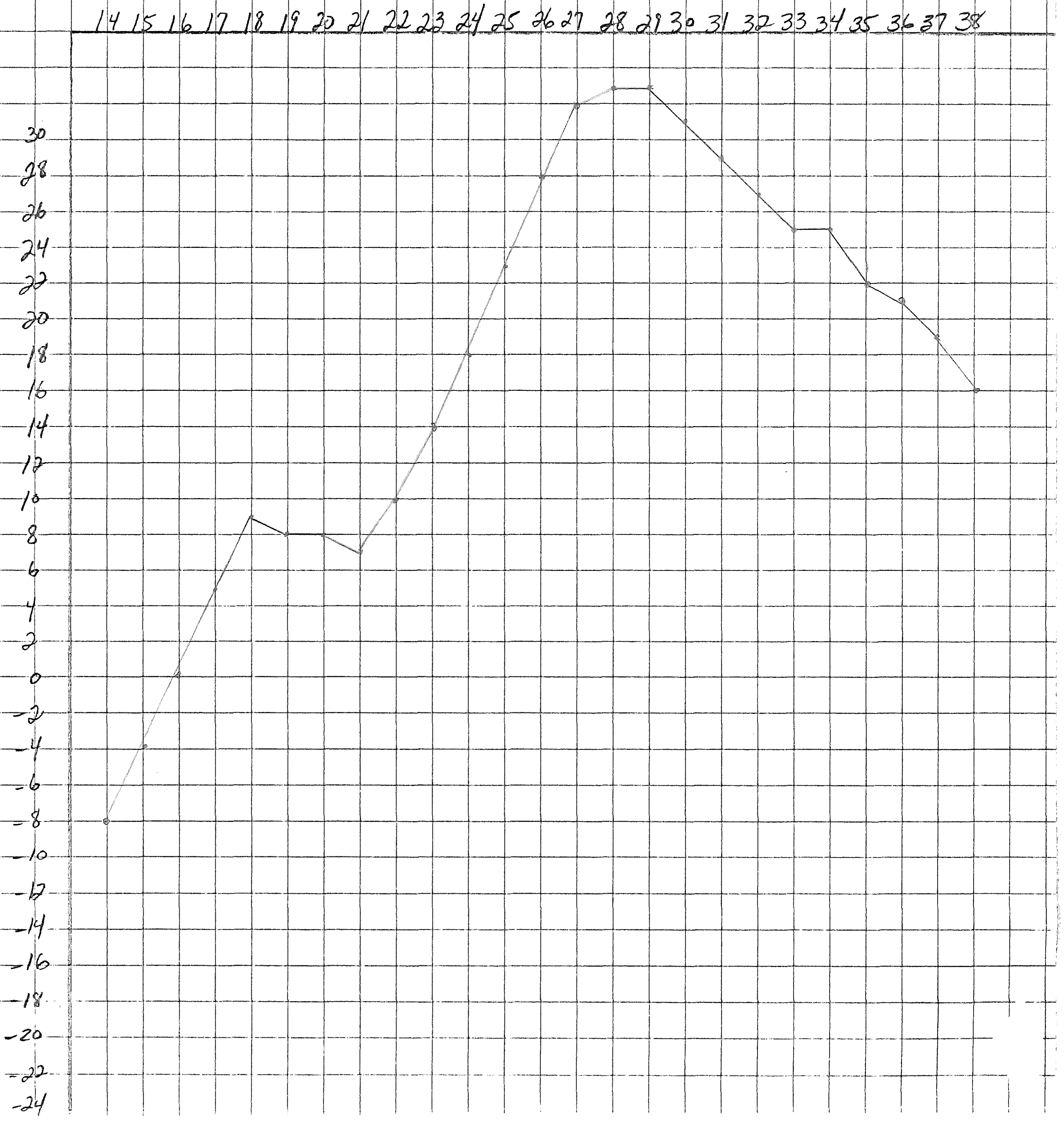
SUMMER- RED PINE

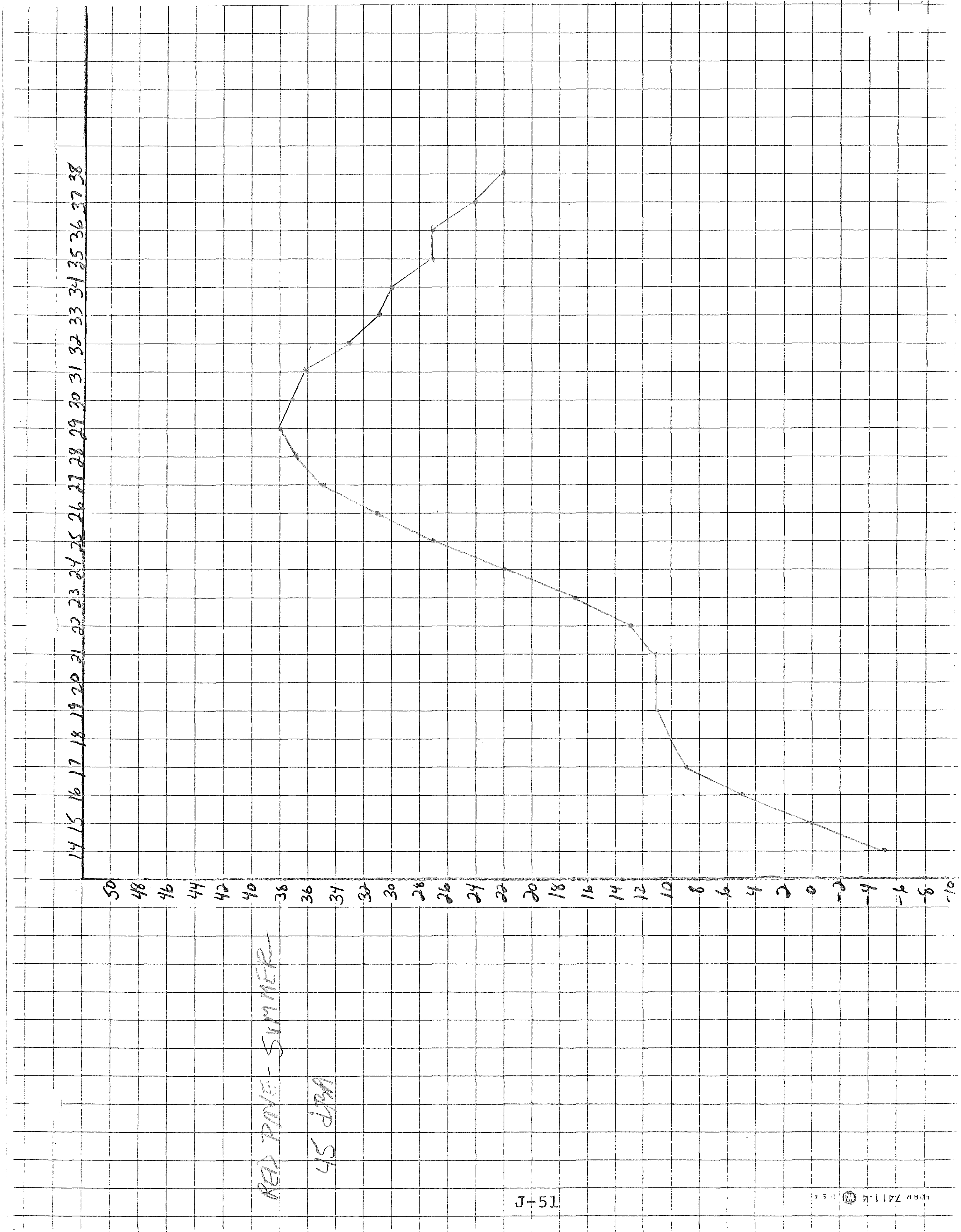
35 dBA



SUMMER - RED PINE

40 dBA

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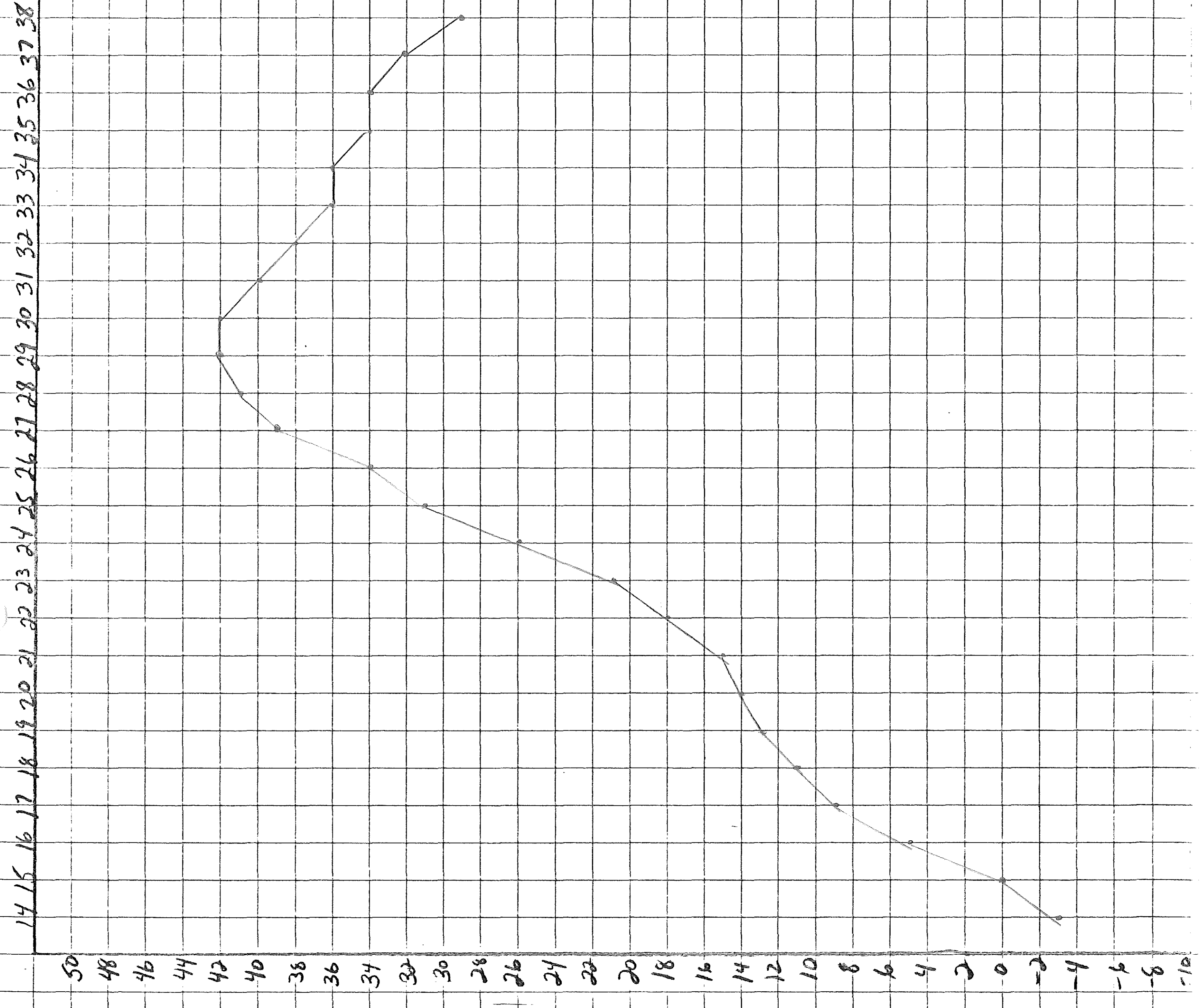
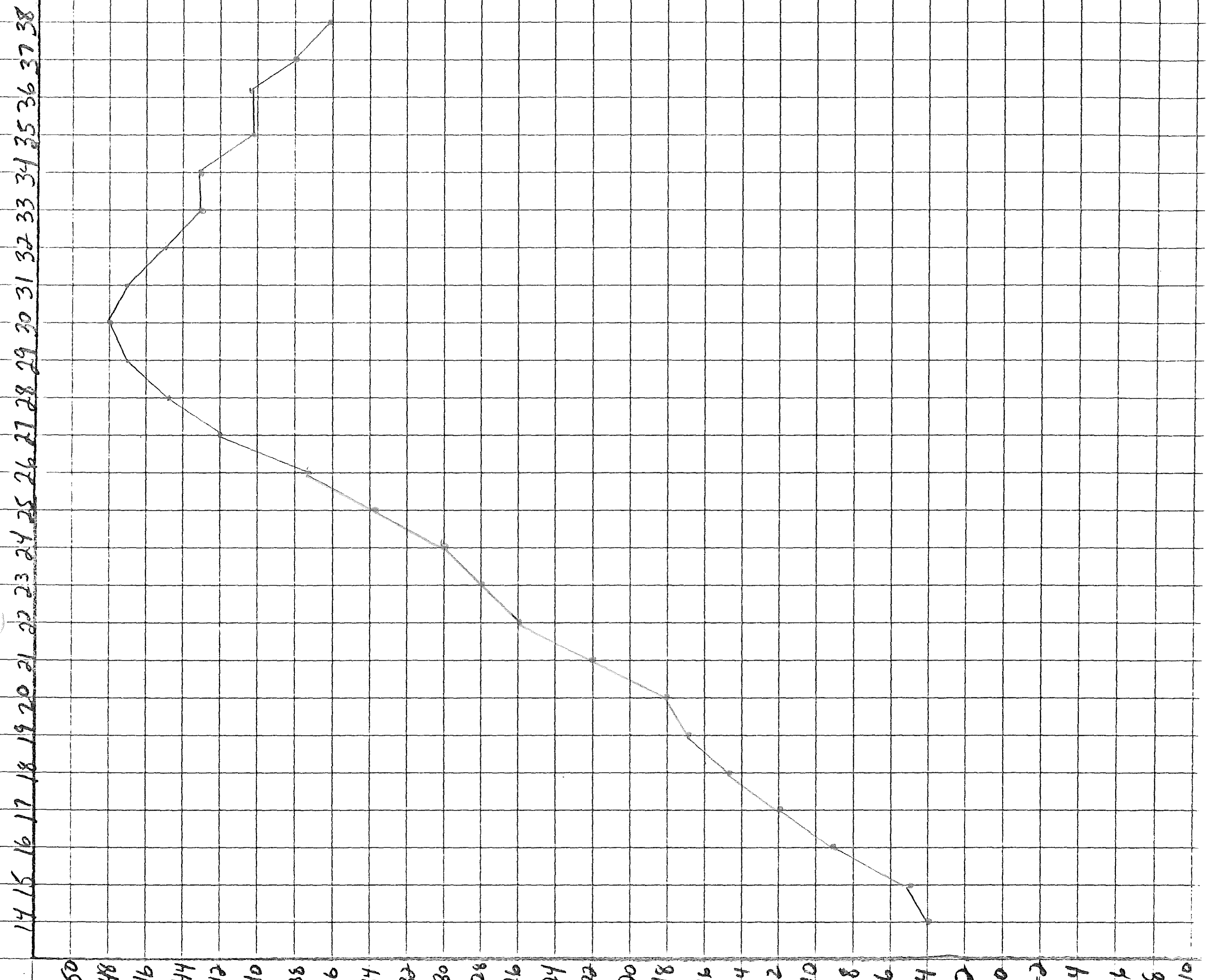
50 48 46 44 42 40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0 -2 -4 -6 -8 -10
RED PINE - SUMMER
45 DBA



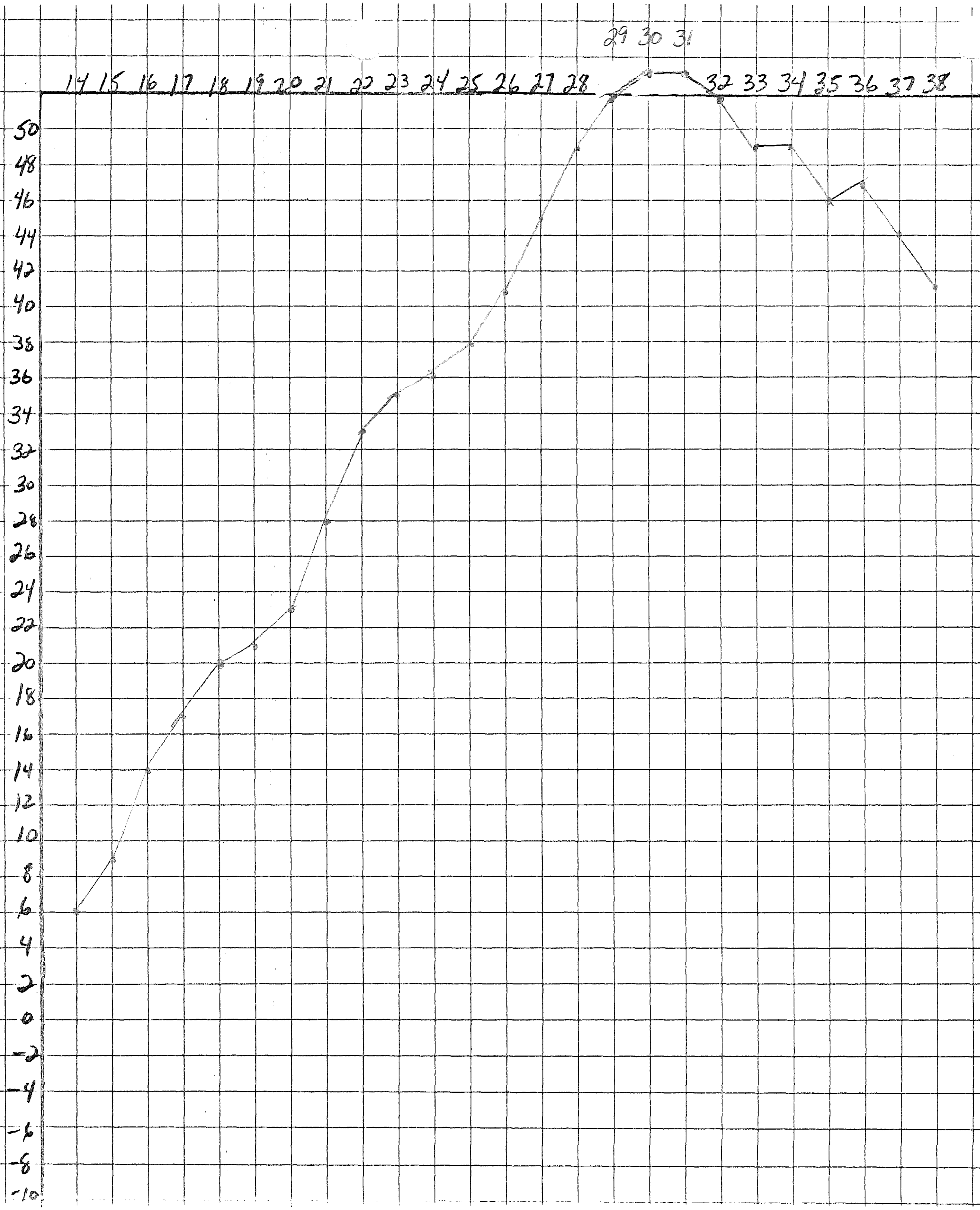
RED PINE -
500 IBA



RED PINE-SUMMER
53 [illegible]

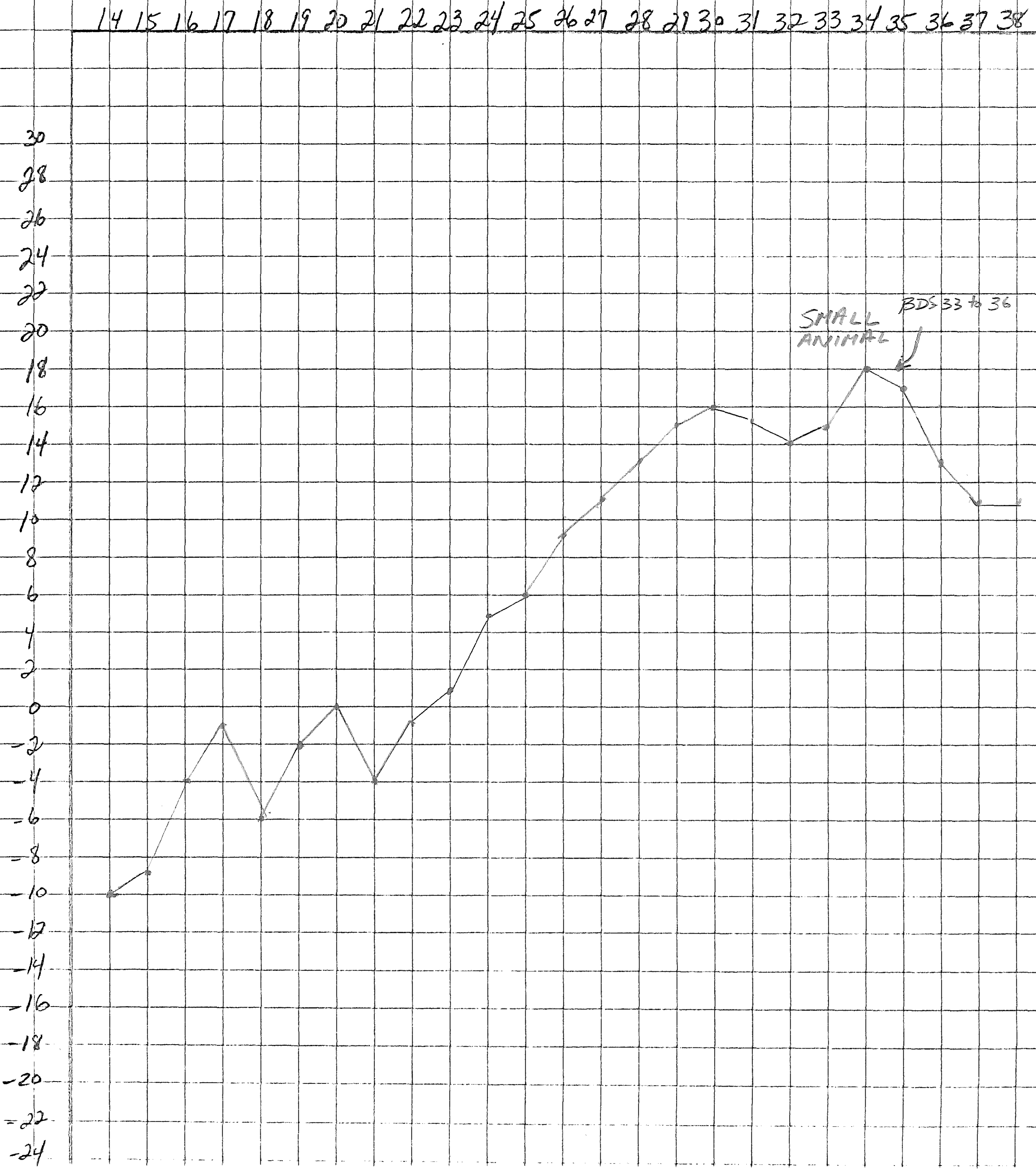
SUMMER-RED PINE

60 dBA



SUMMER- BIRCH

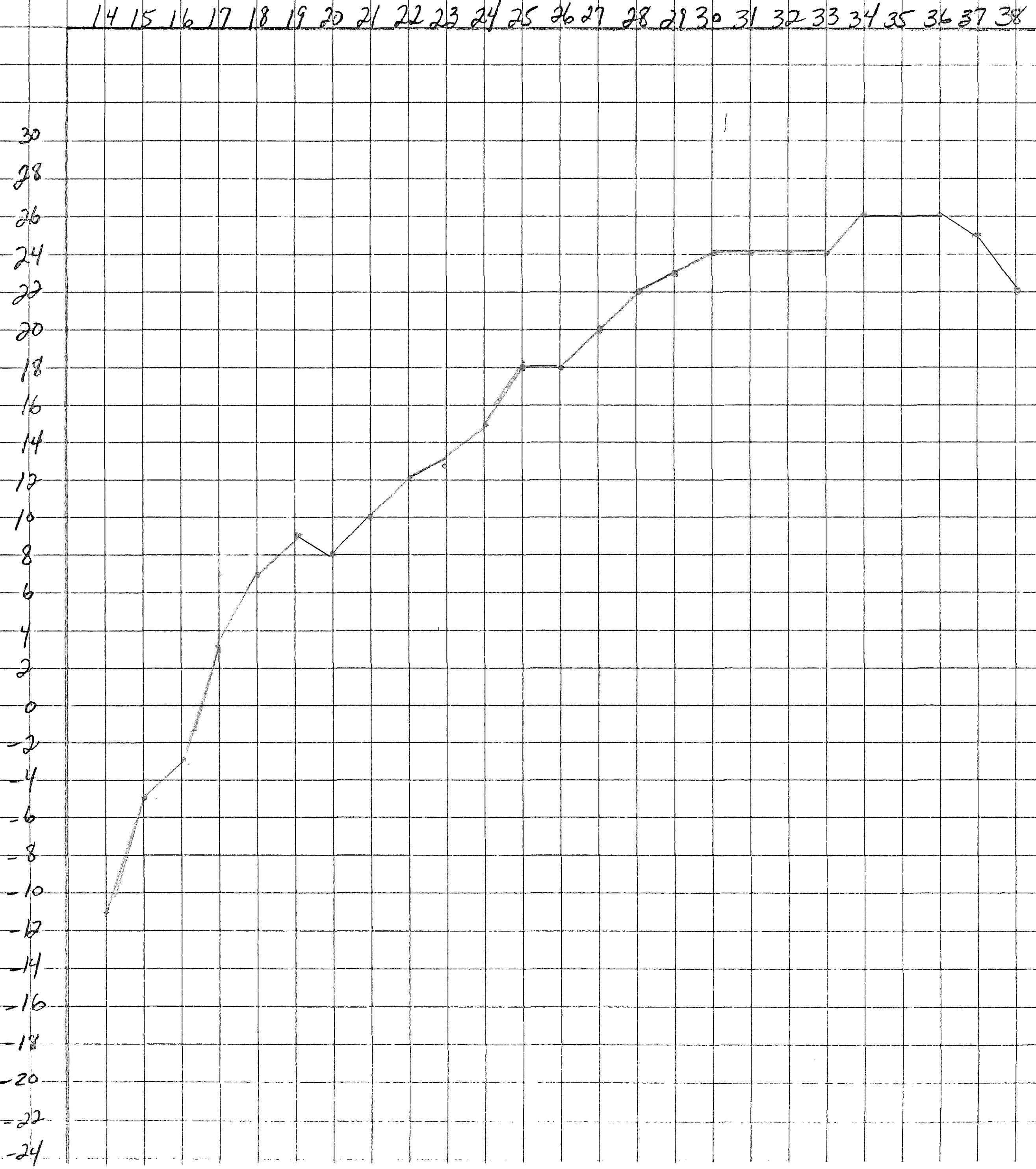
25 dBA MOSTLY
ANIMALS



SUMMER - BIRCH

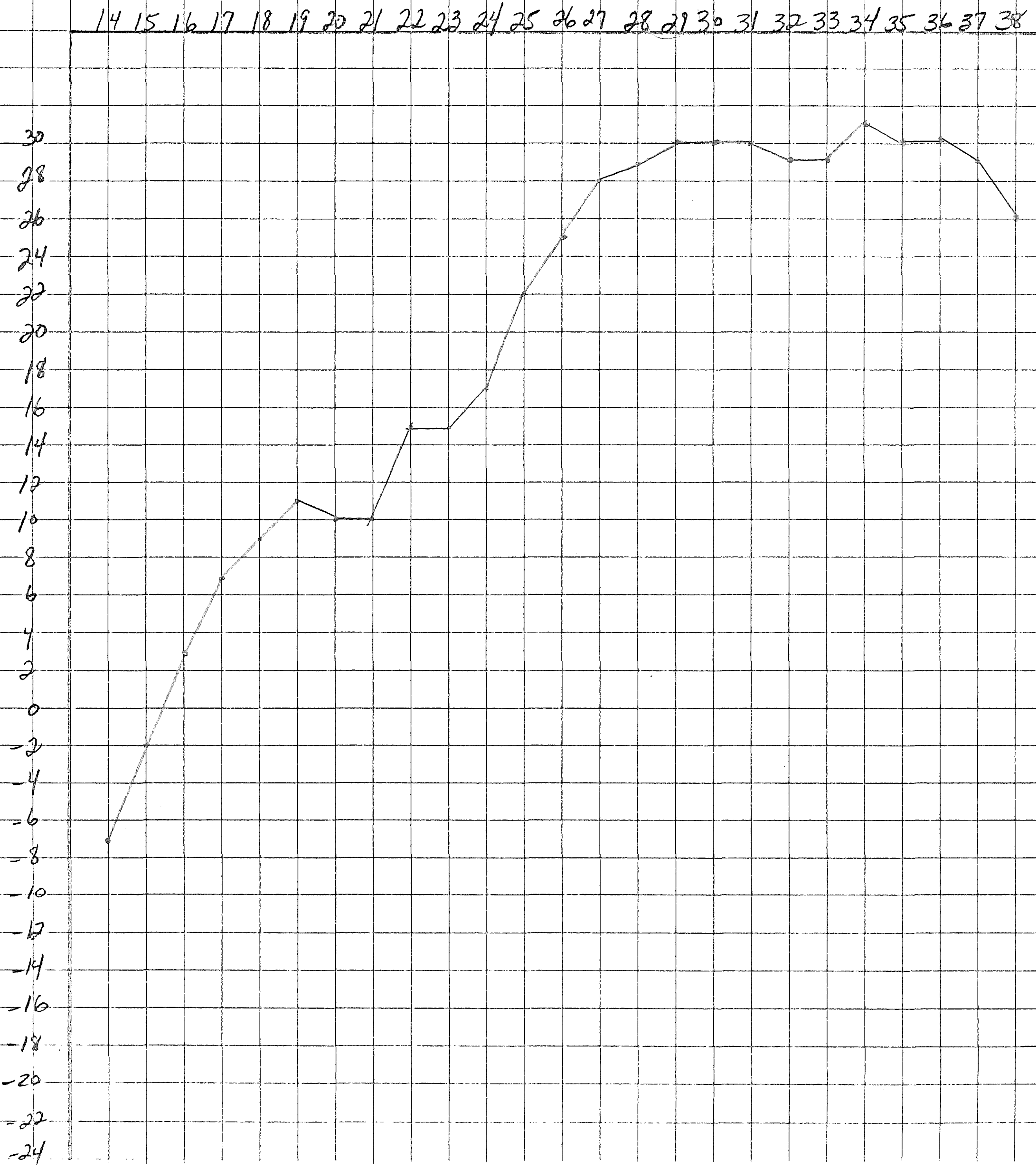
30 dBA

SUMMER - BIRCH
35 dBA

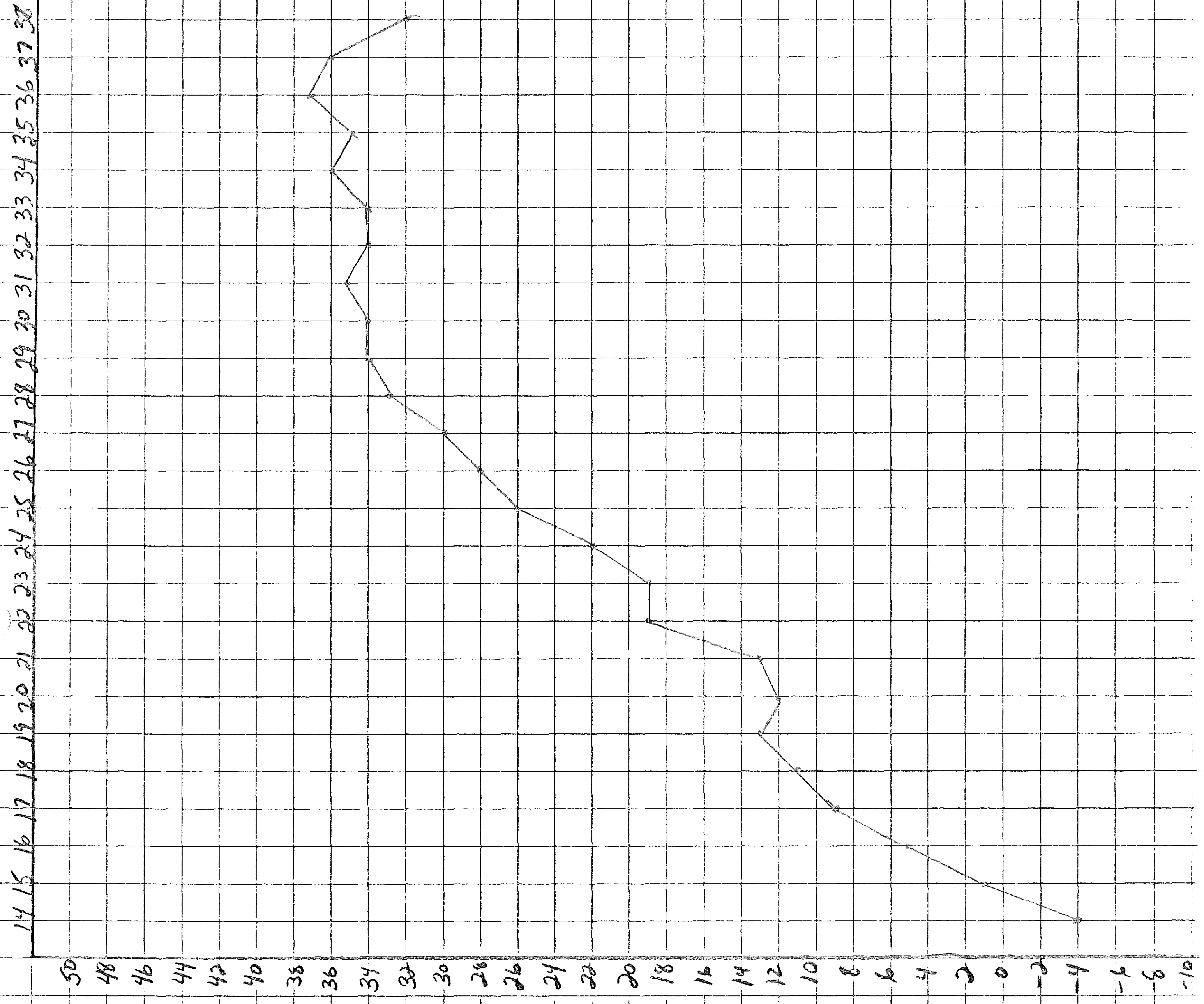


SUMMER - BIRCH

40dBA



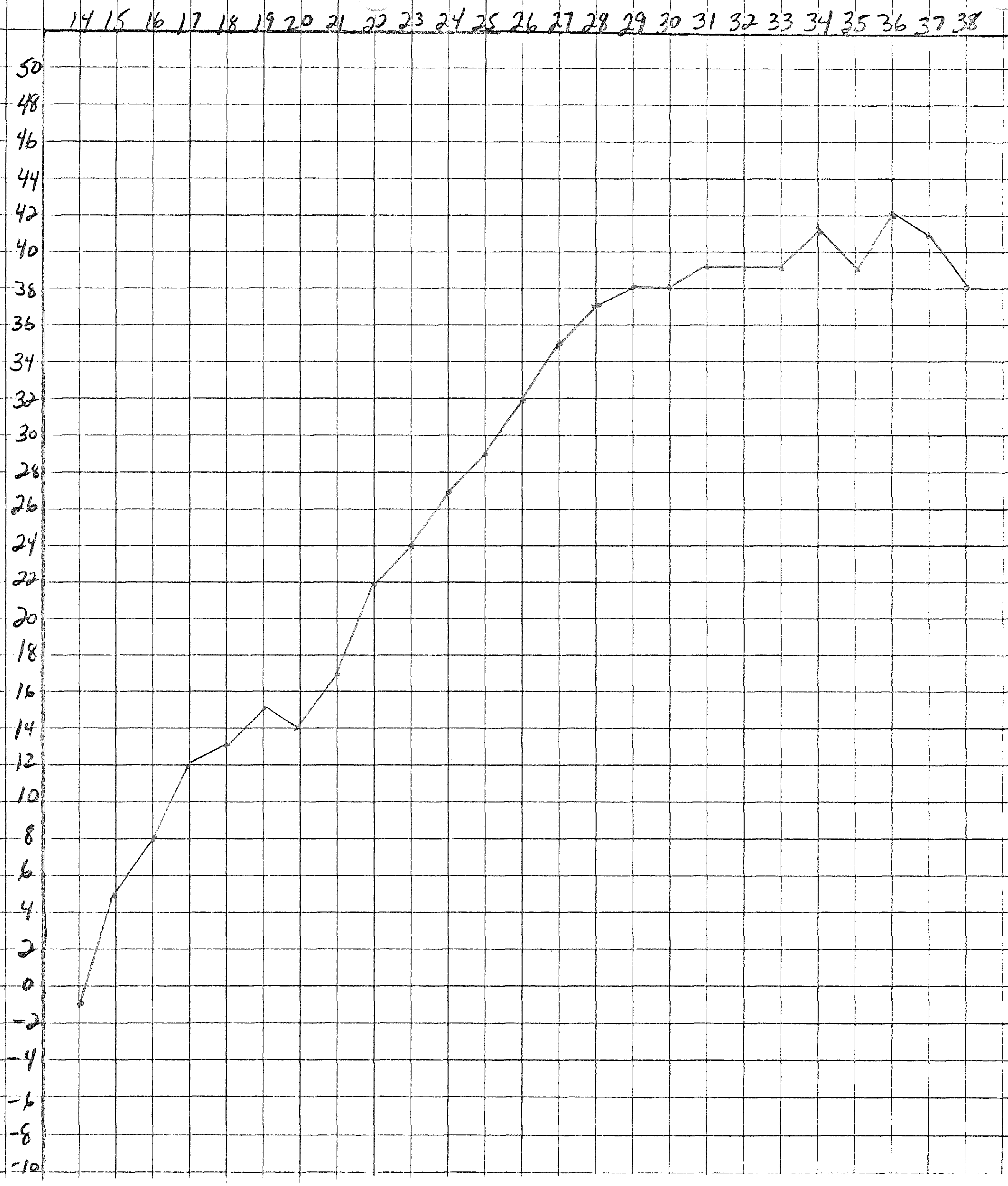
J-58



SUMMER-BIRCH

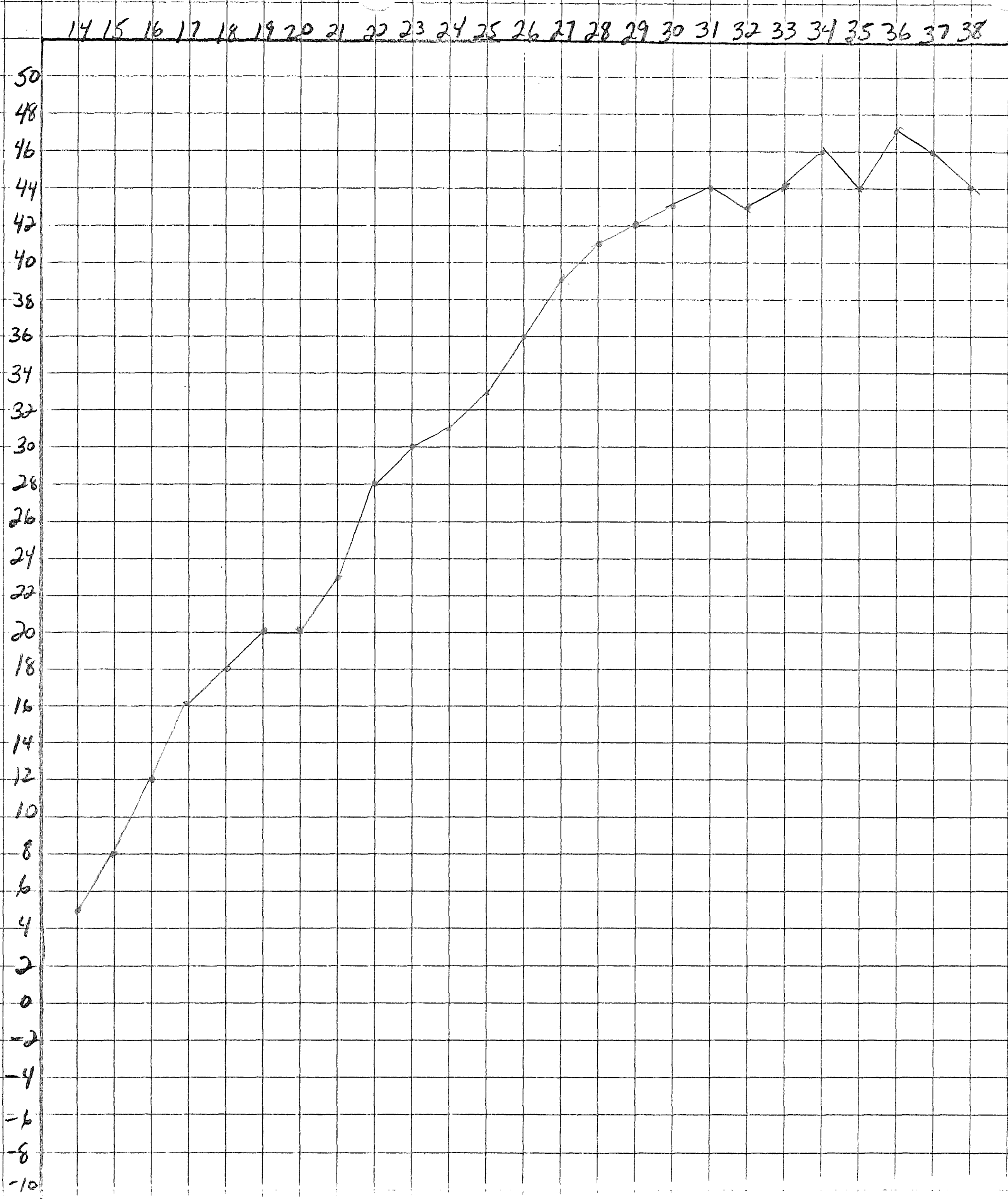
45 dBA

SUMMER-BIRCH
SOdBA

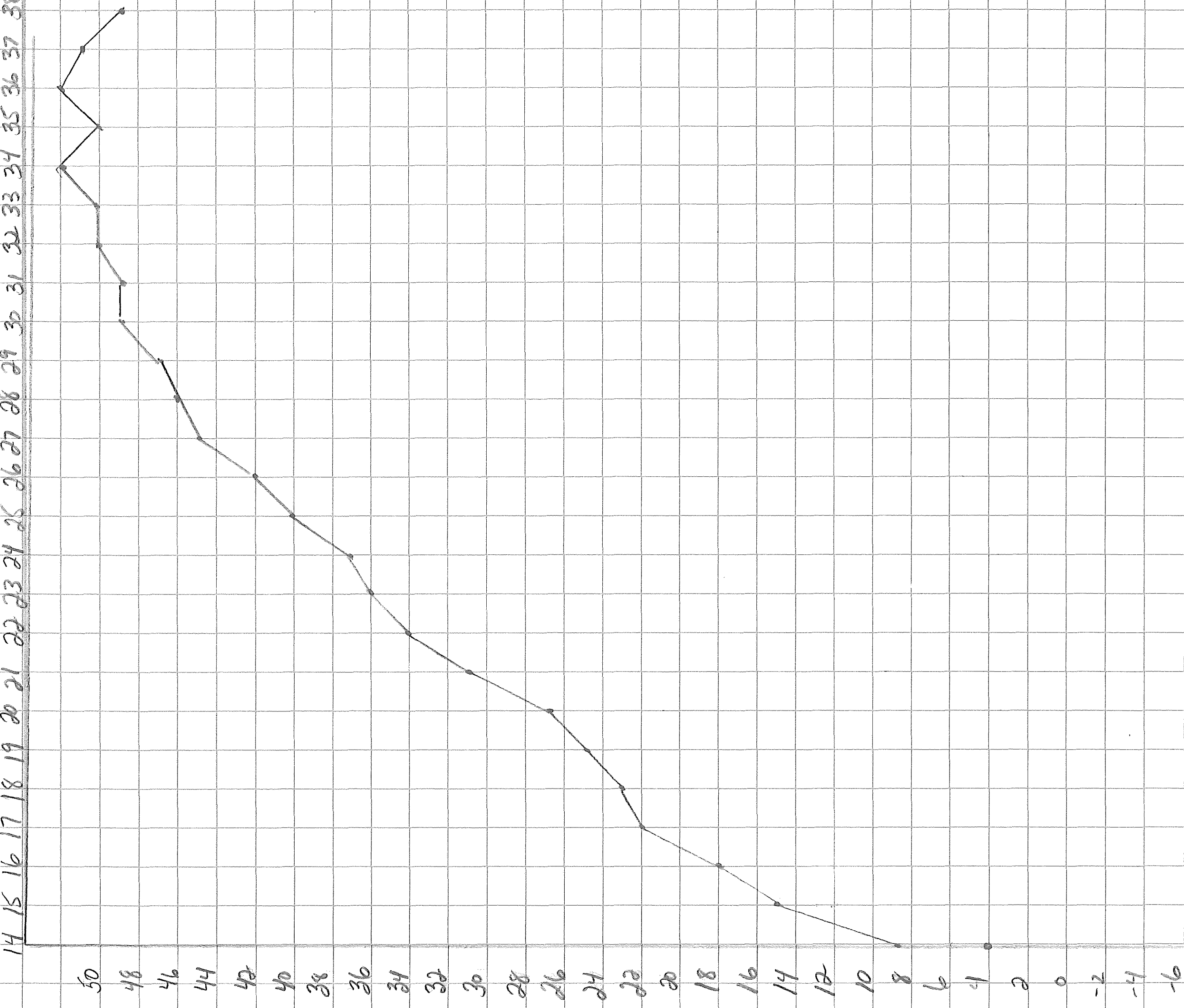


SUMMER-BIRCH

55dBA



FORM 7411-C U.S.A.

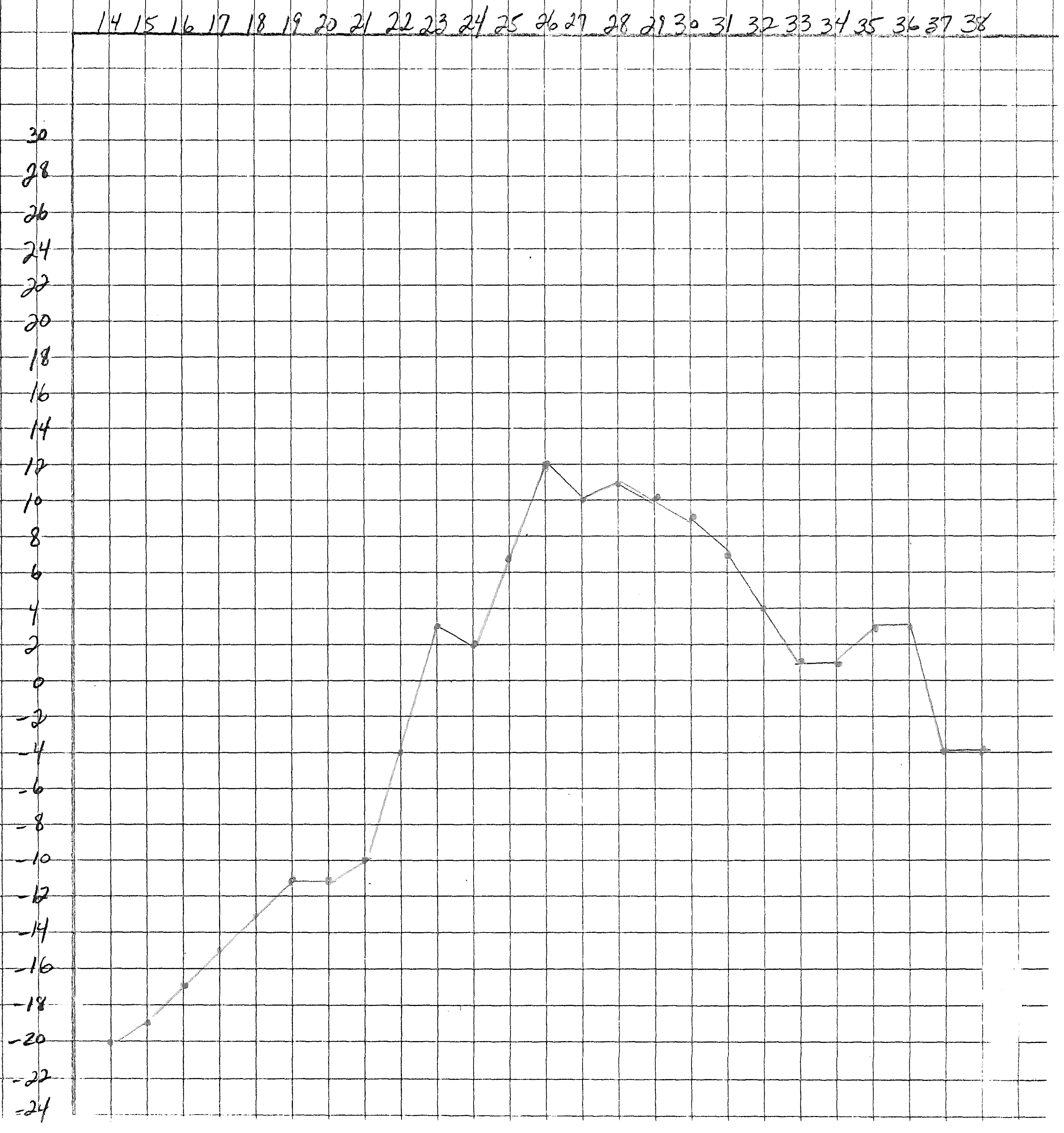


SUMMER-BIRCH-

GOOD13A

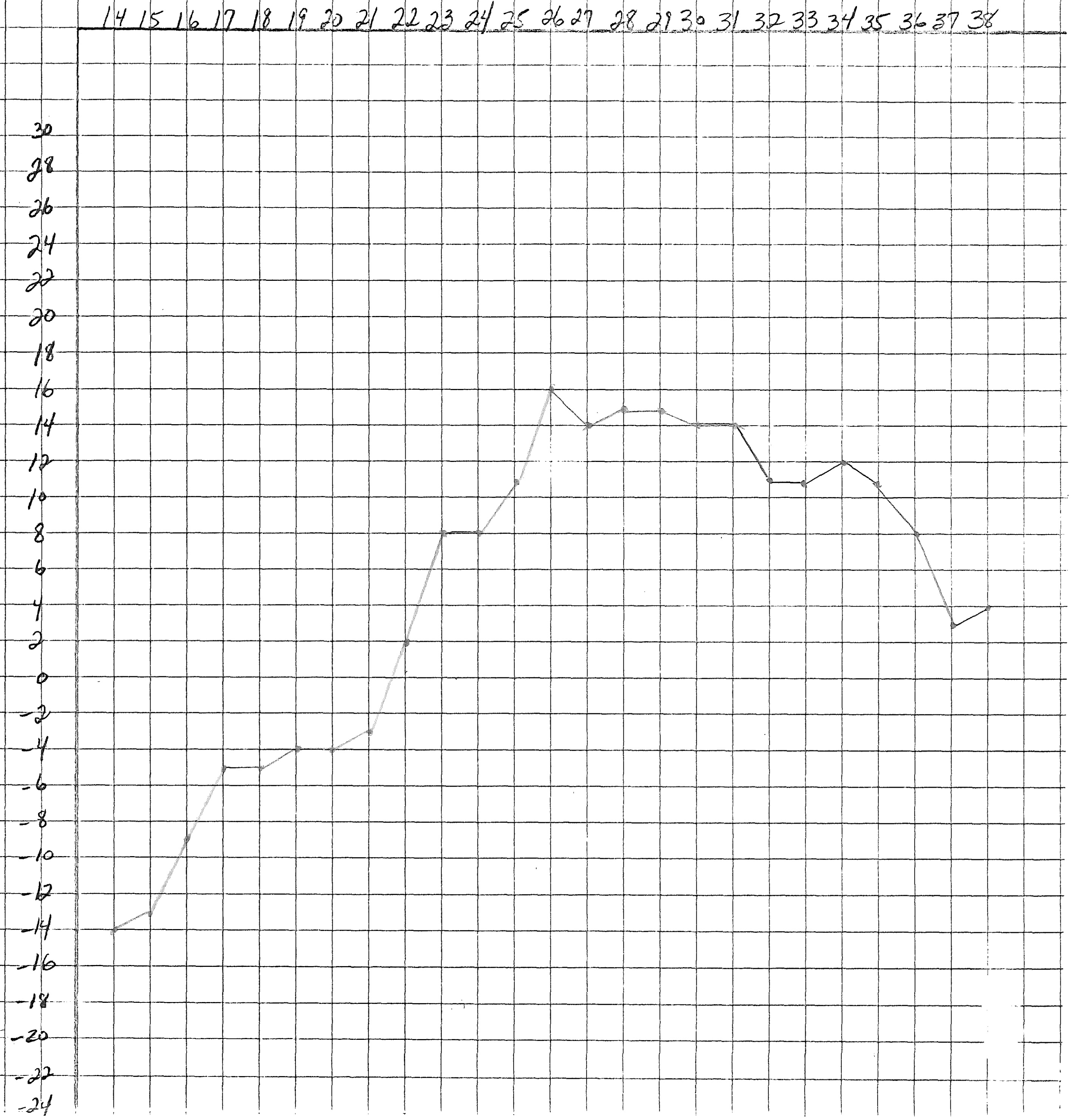
J-62

SUMMER - ASPEN
20 dBA



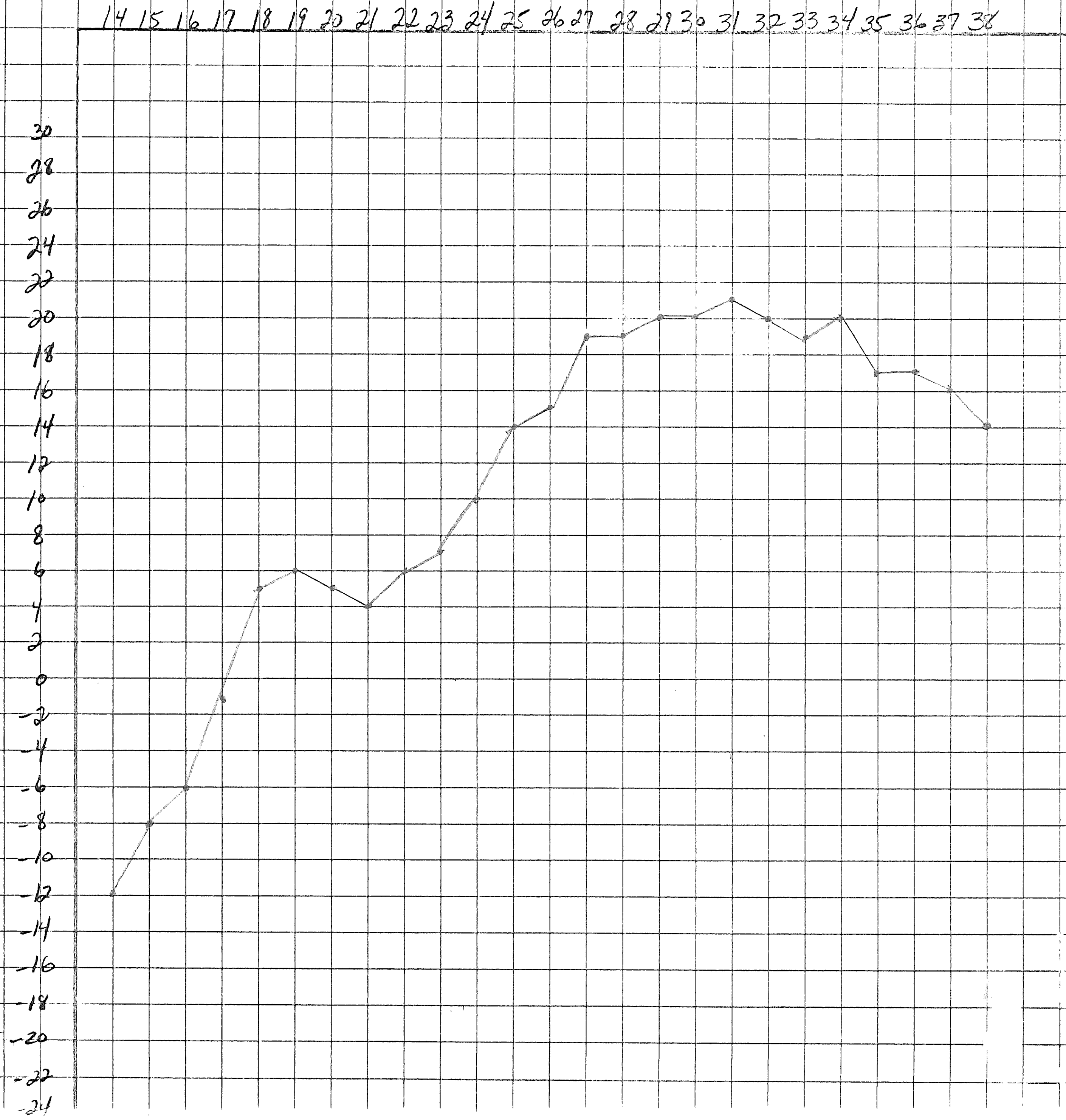
SUMMER - ASPEN

25 dBA



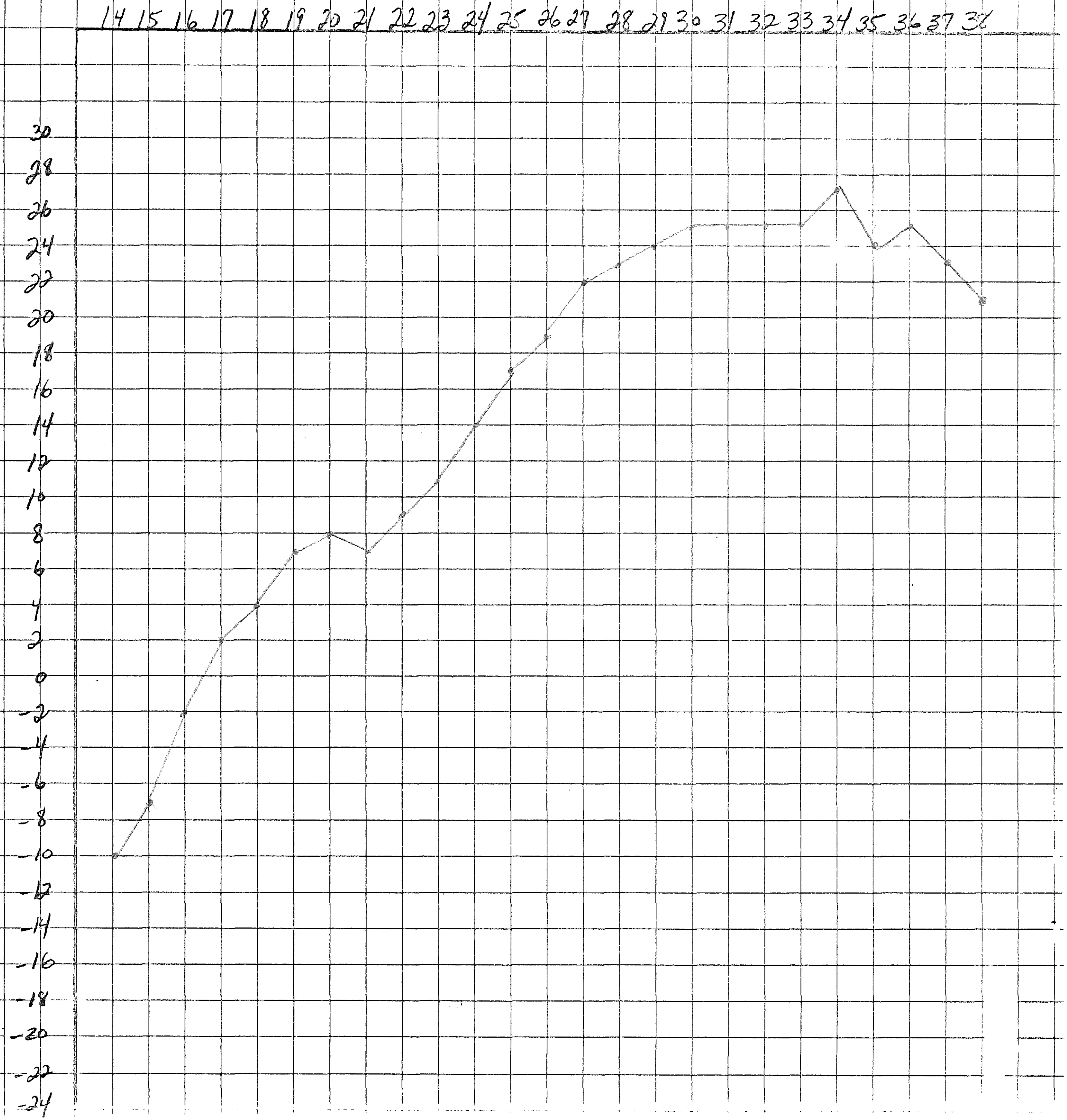
ASPEN-SUMMER

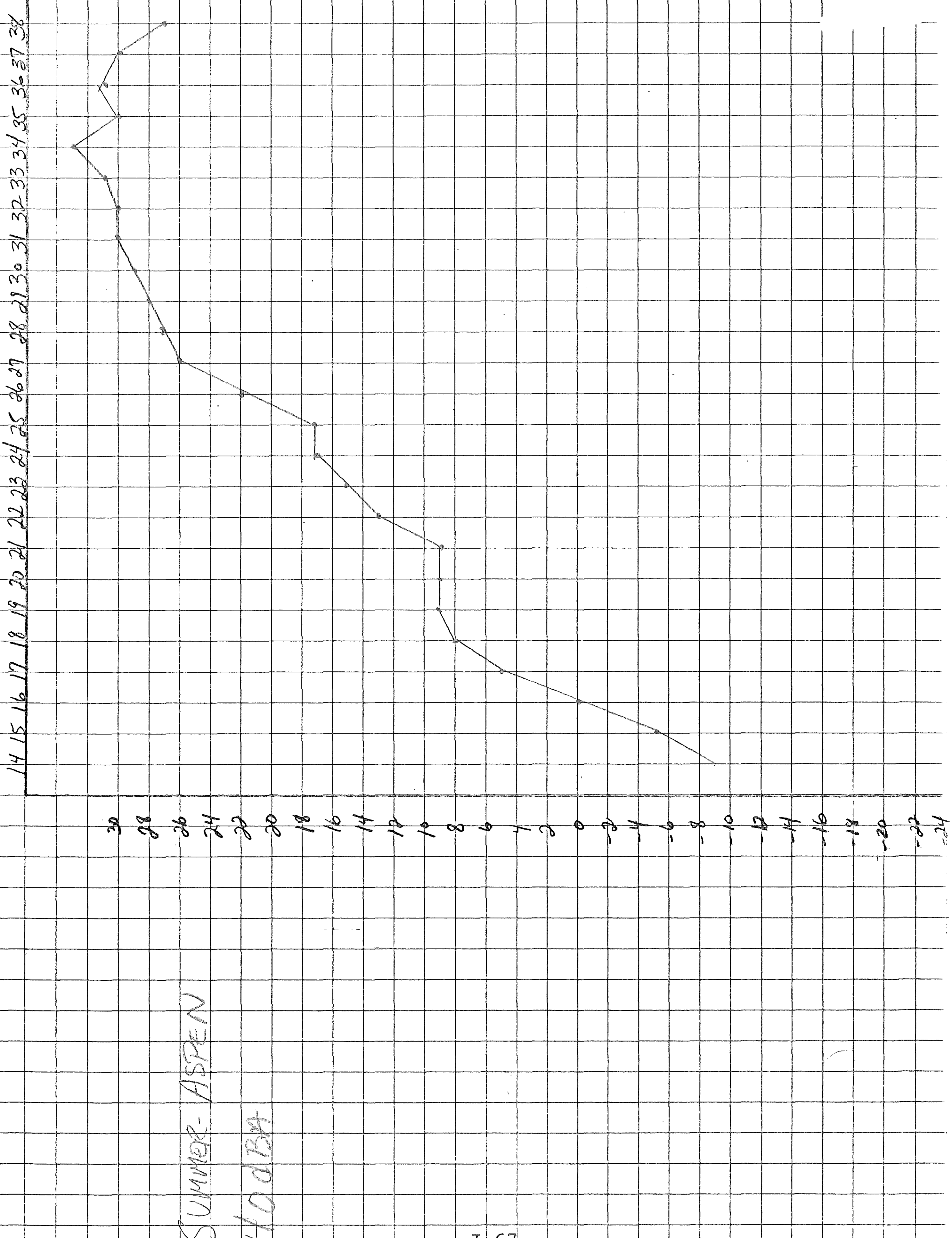
30 dBA



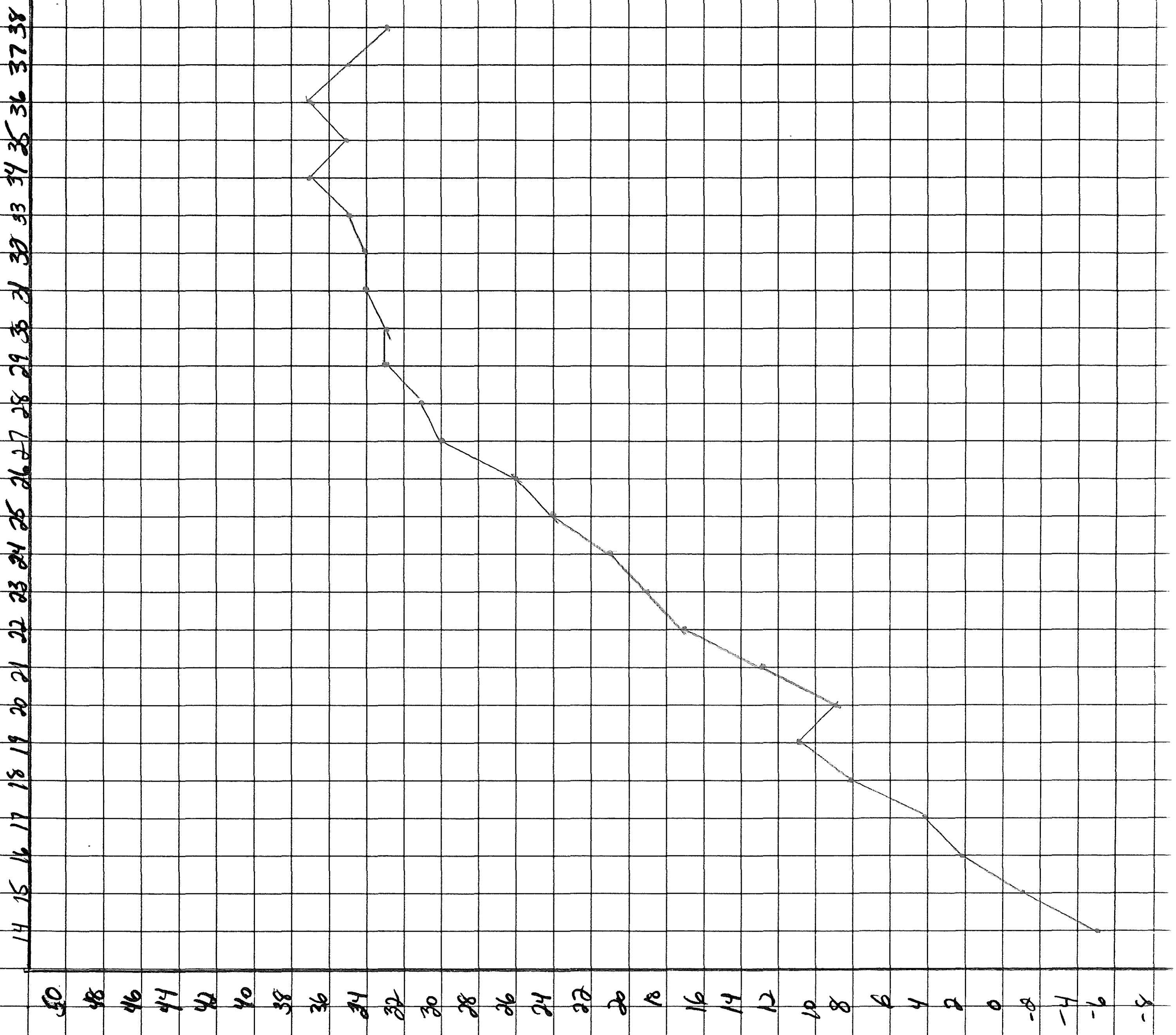
SUMMER-ASPEN

35 dBA



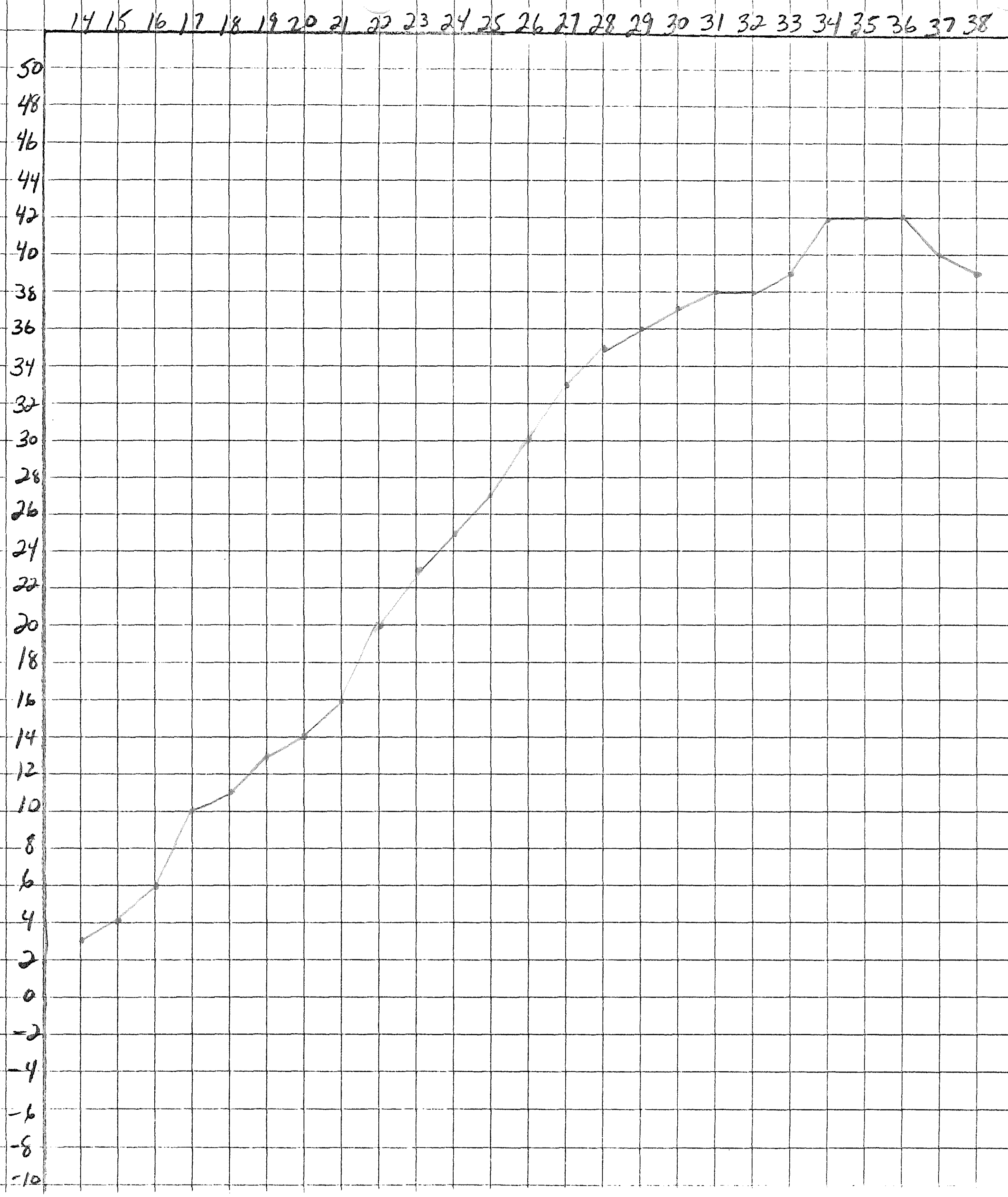

SUMMER- ASPEN
40 dBA
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0 -2 -4 -6 -8 -10 -12 -14 -16 -18 -20 -22 -24

FORM 7411 U.S.A.



45 CUBA

SUMMER-ASPEN

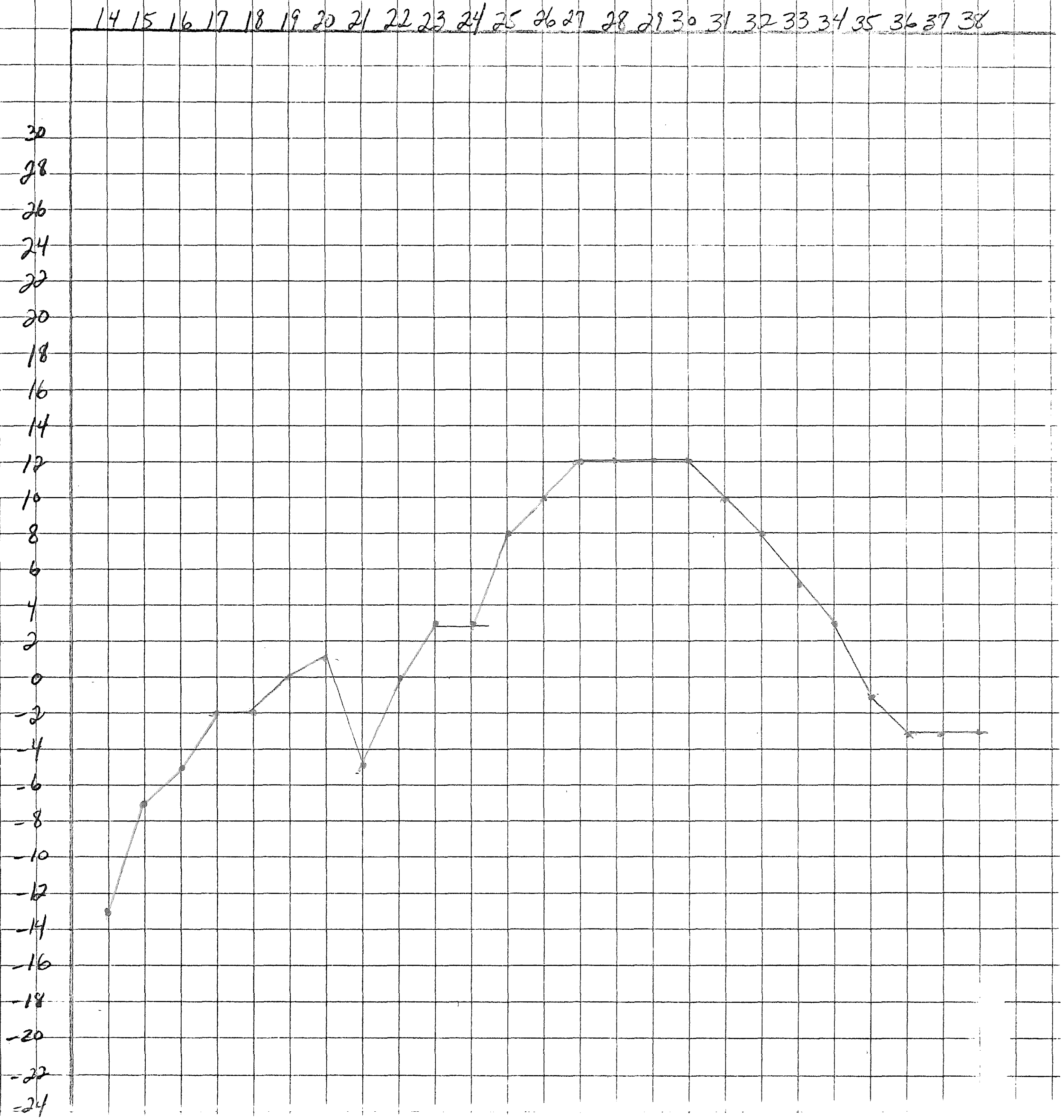


ASPEN- SUMMER

50dBA

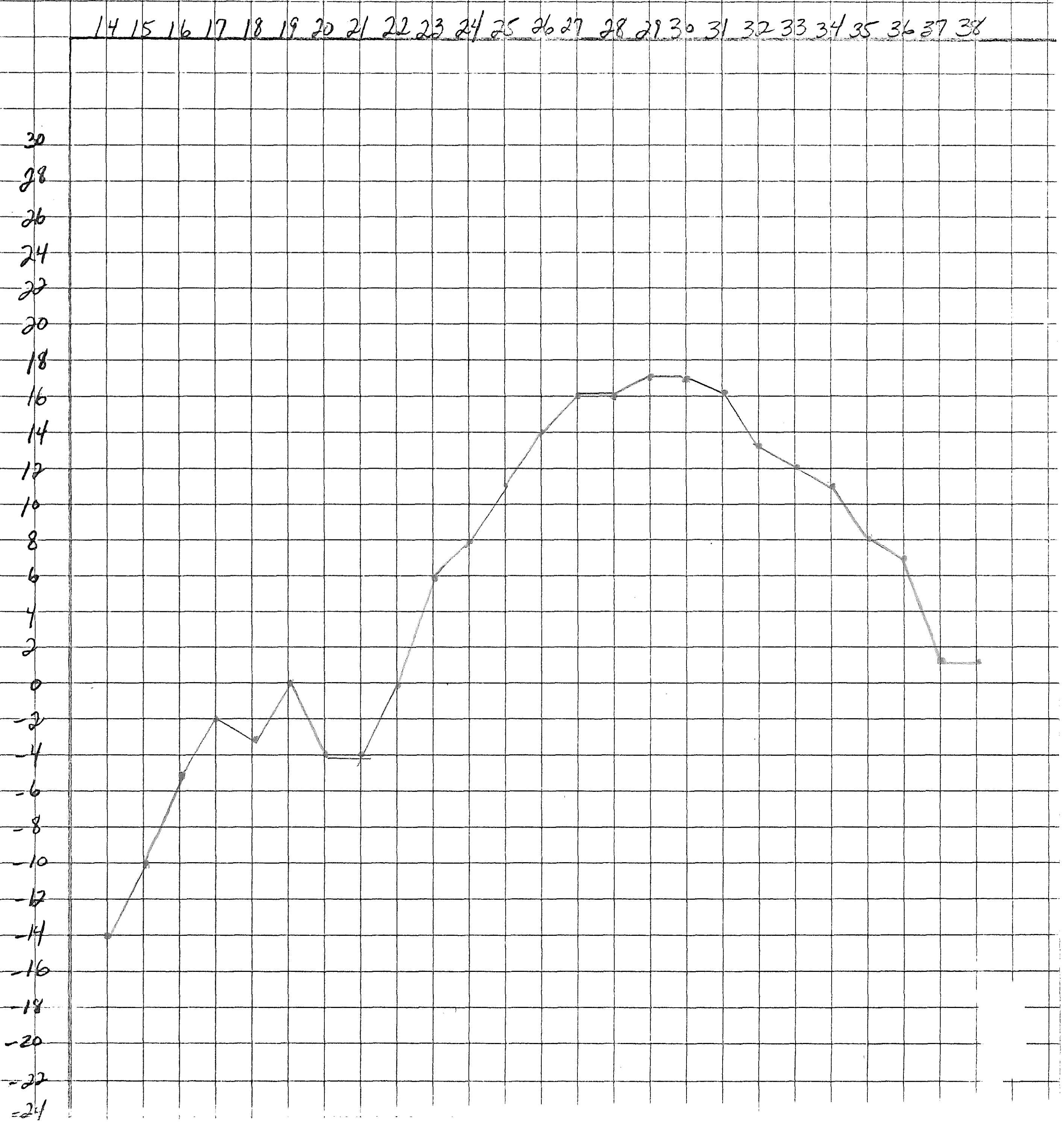
SUMMER-BLACK SPRUCE

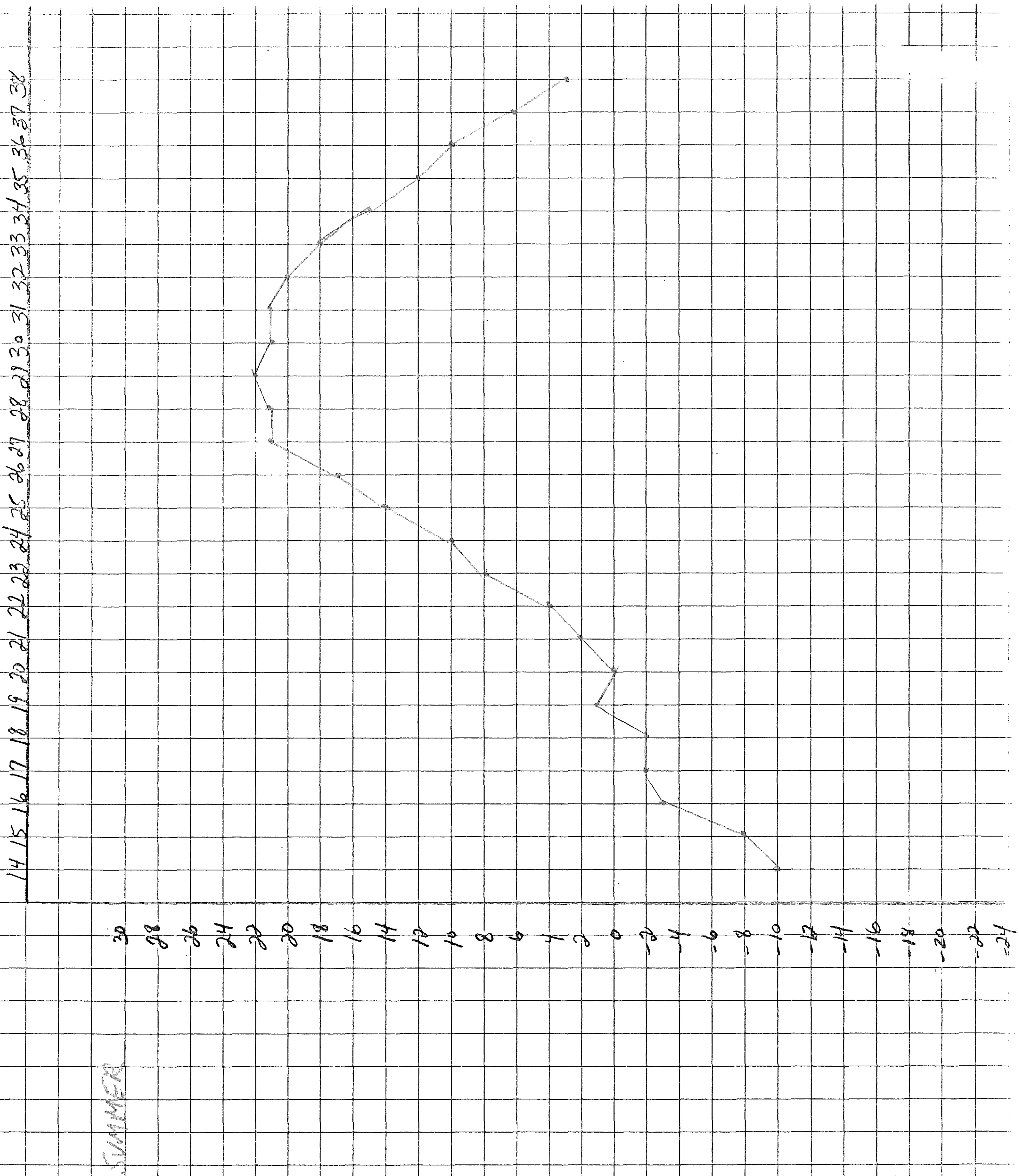
20 dBA



SUMMER-BLACK SPRUCE

25 dBA

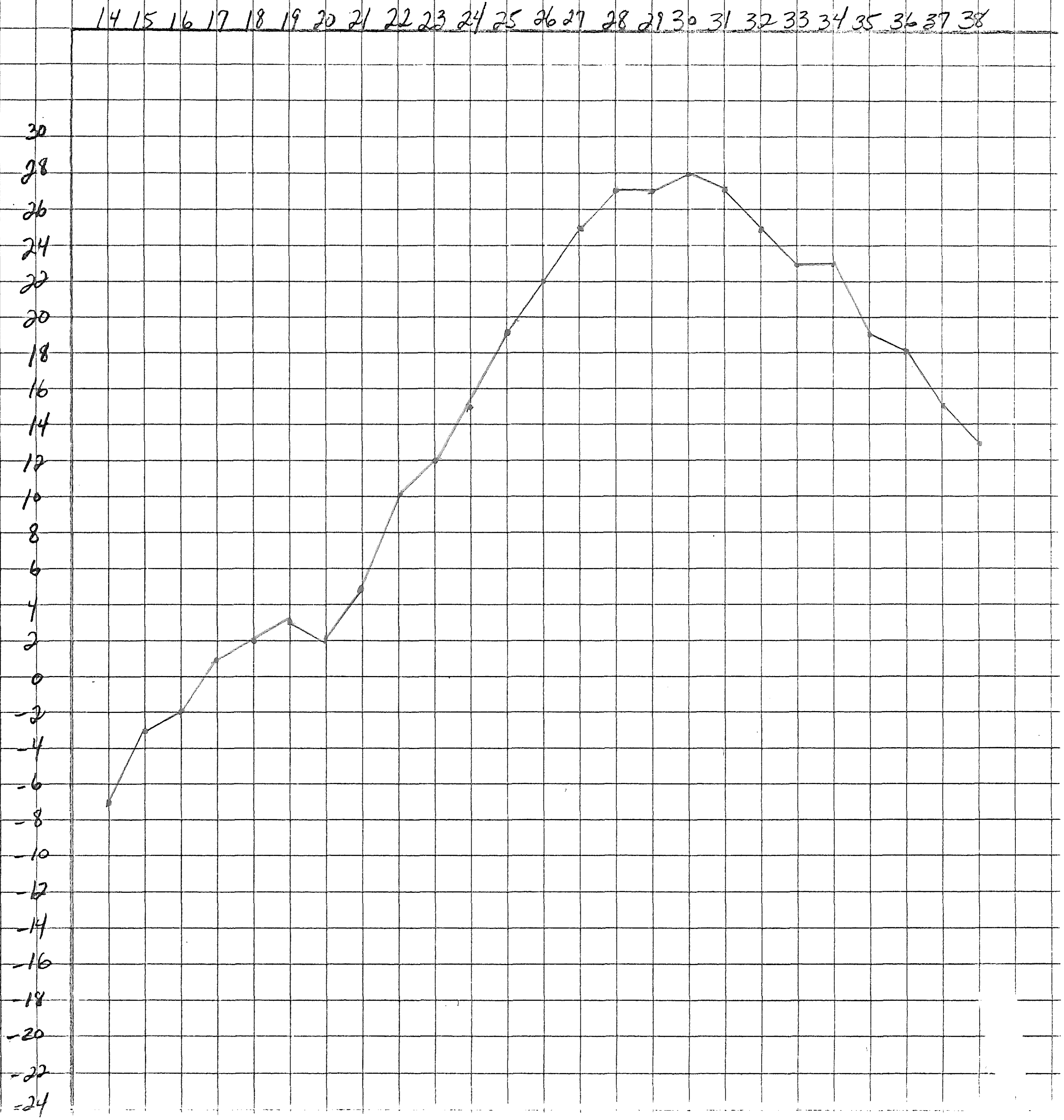




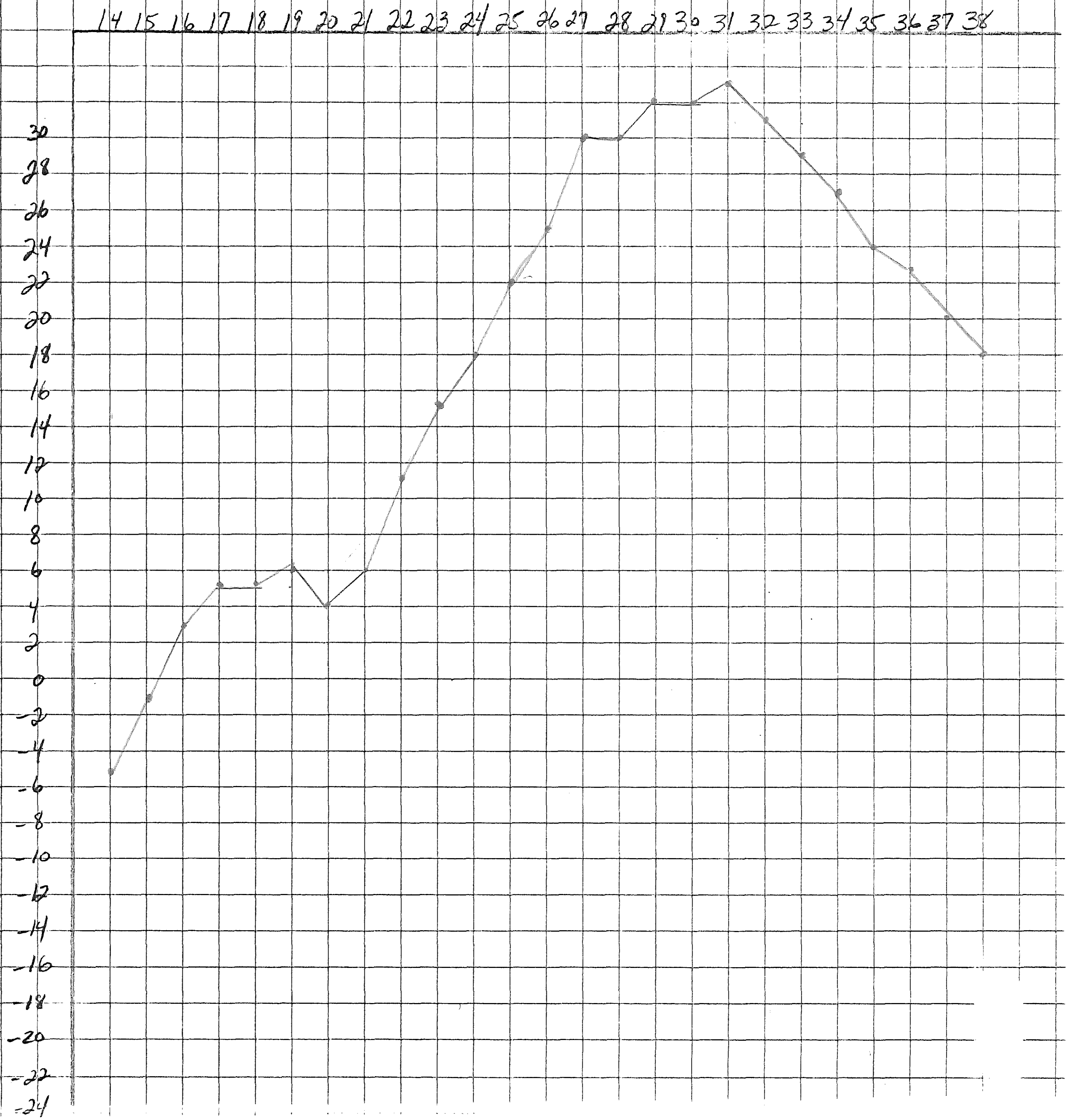
BLACK-SPRUCE-SUMMER

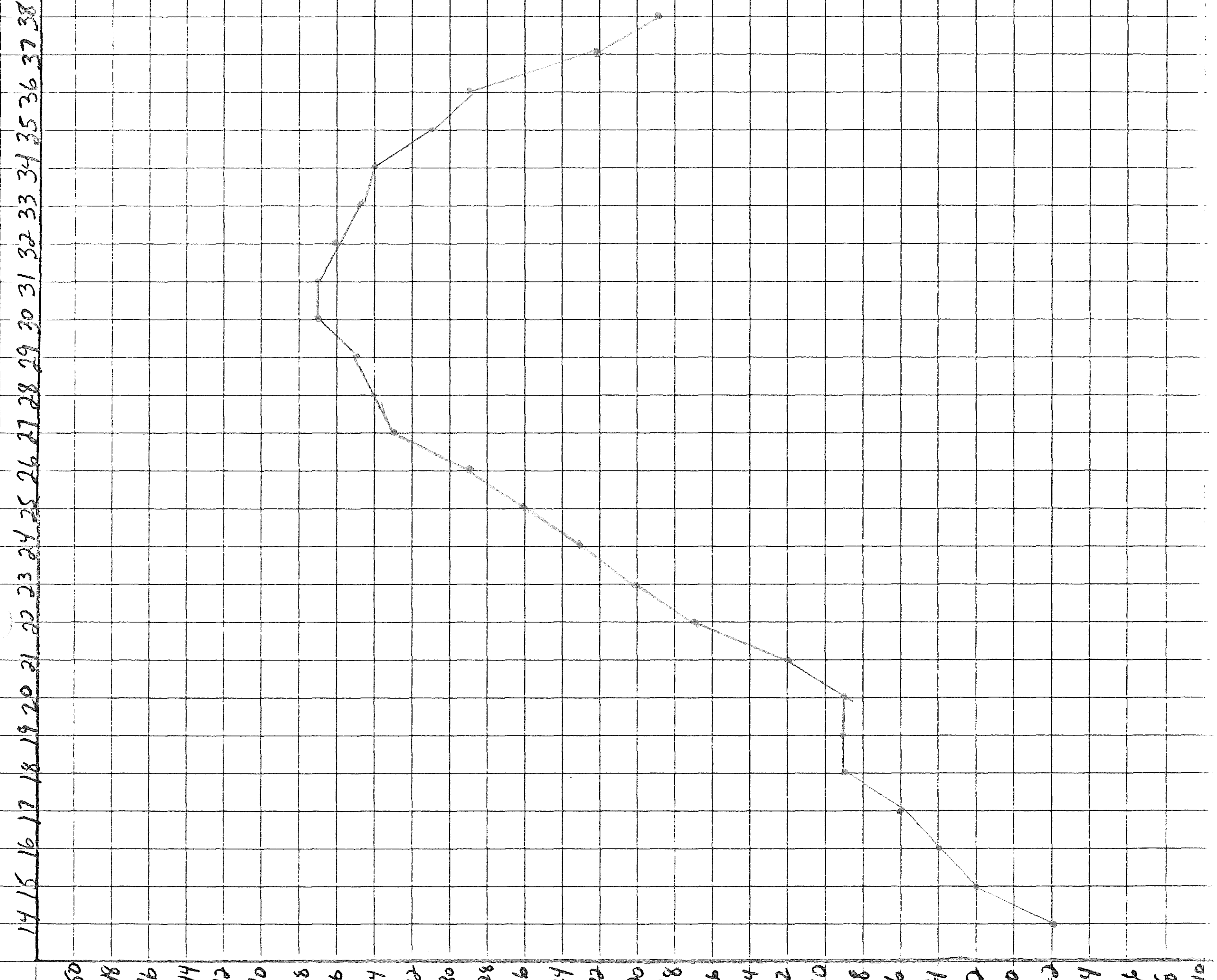
30 dBA

BLACK - SPRUCE - 35 dBA
SUMMER



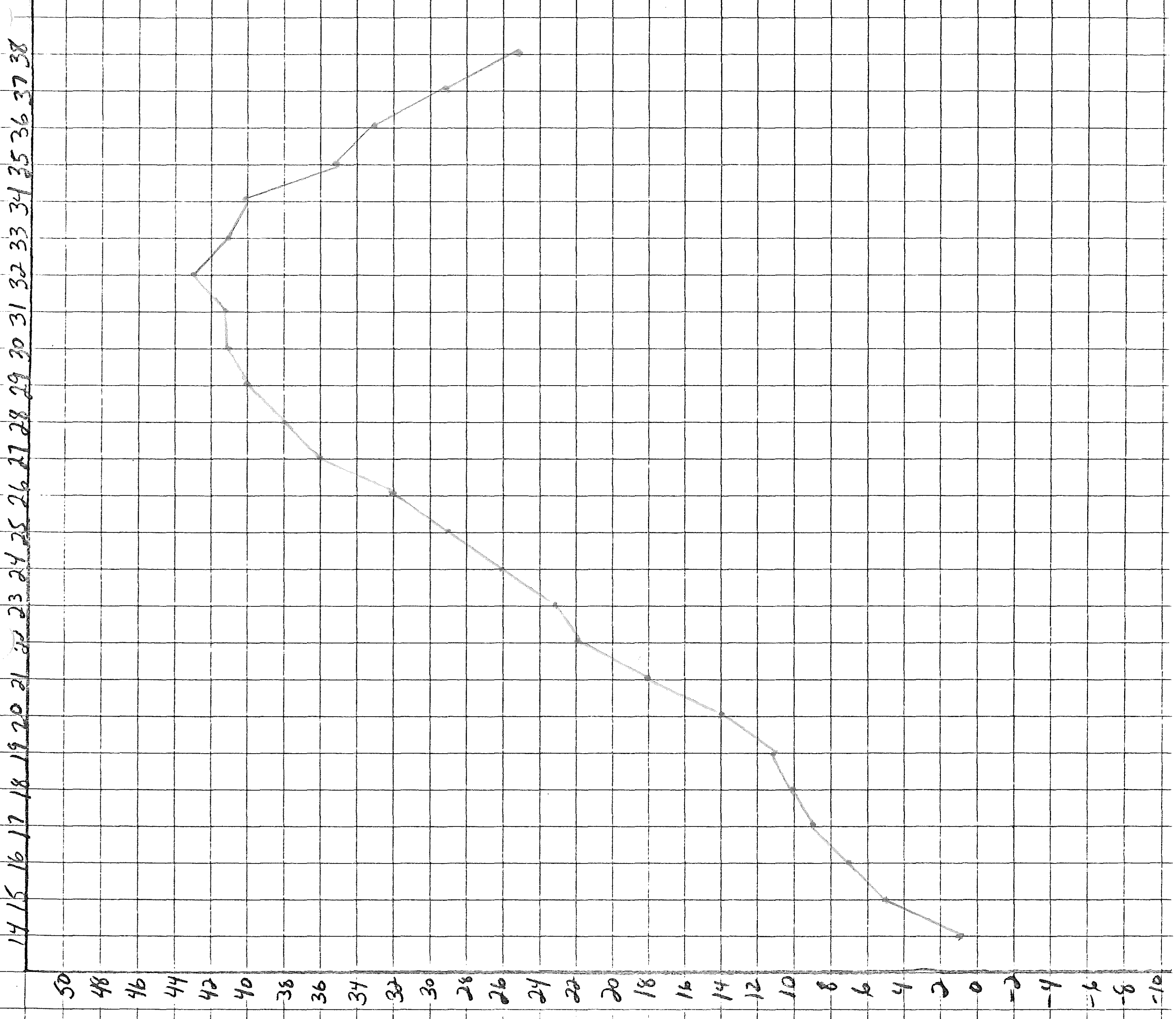
BLACK SPRUCE- SUMMER
40 dBA





BLACK SPRUCE: SUMMER

45 CH3A

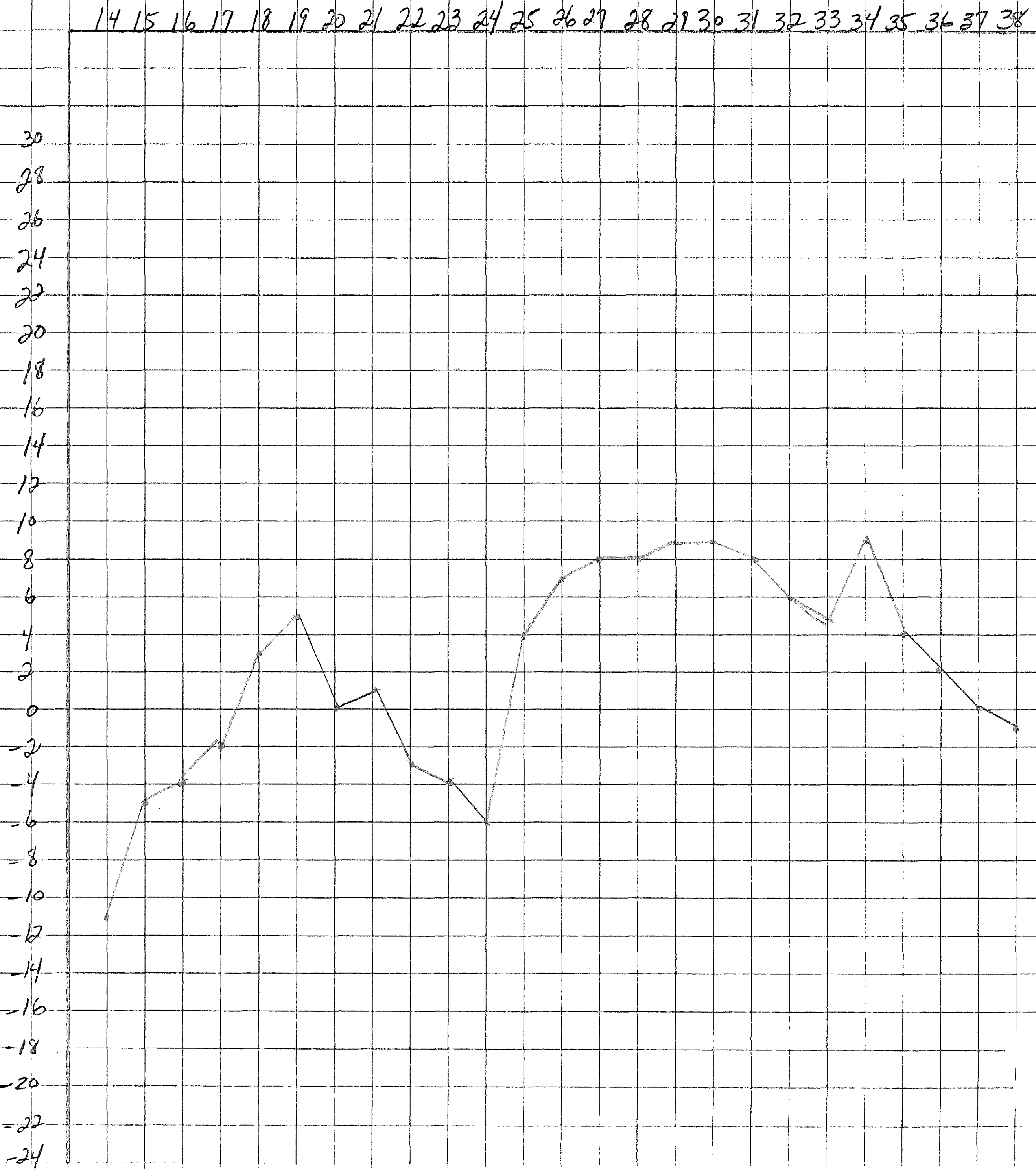


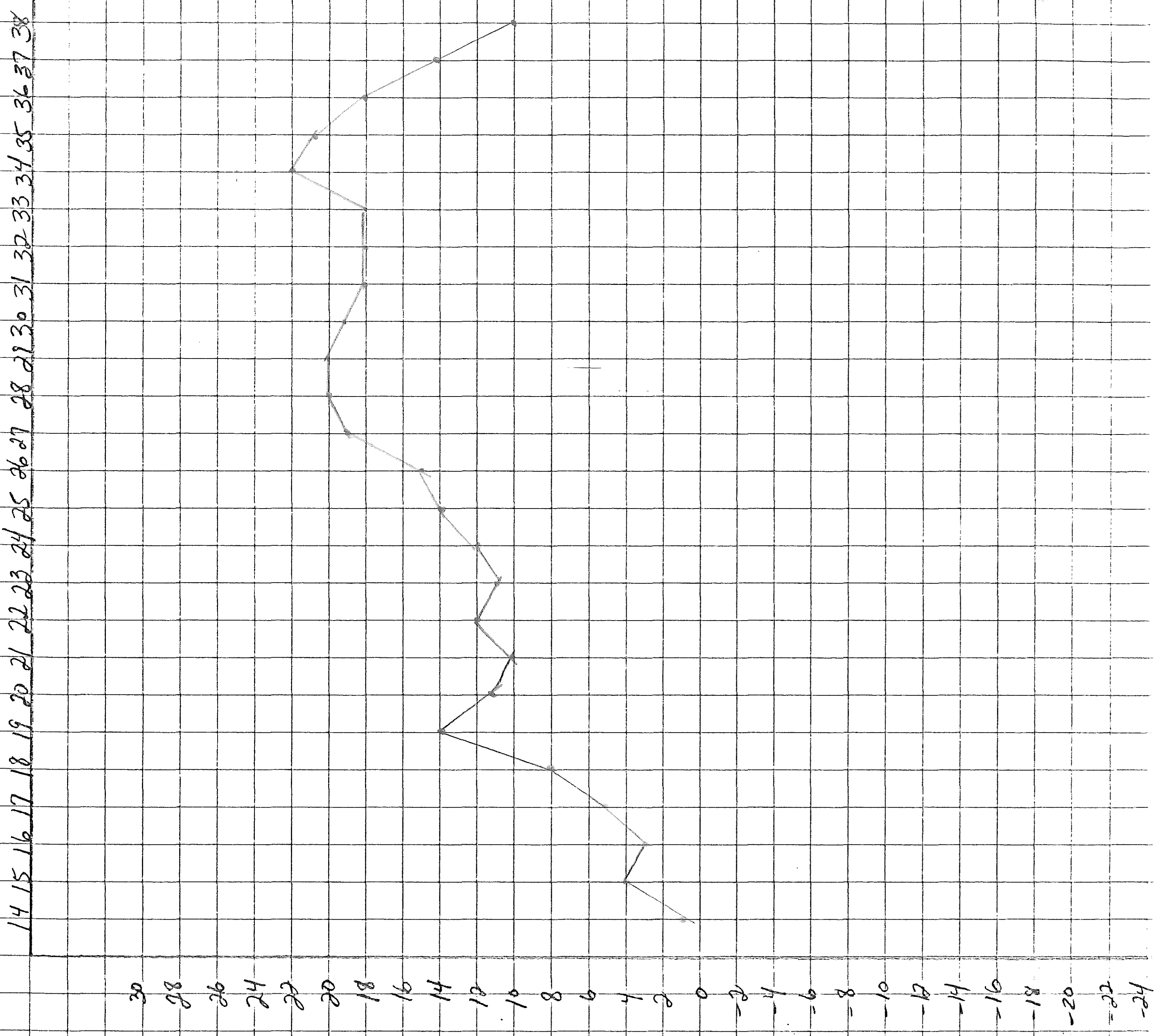
BLACK SPRUCE
SUMMER

50013A

SUMMER SAPLING ASPEN

20dBA



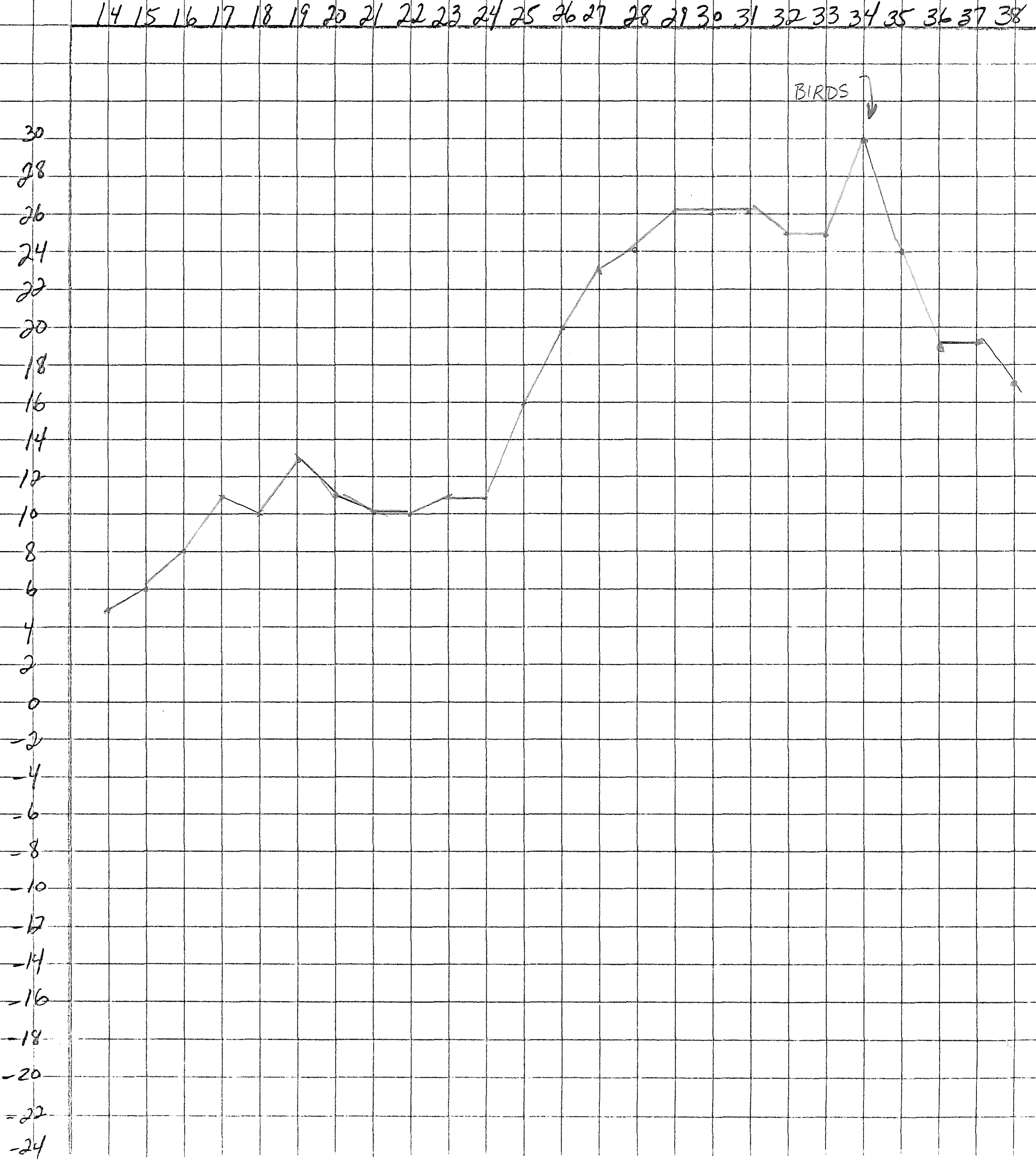


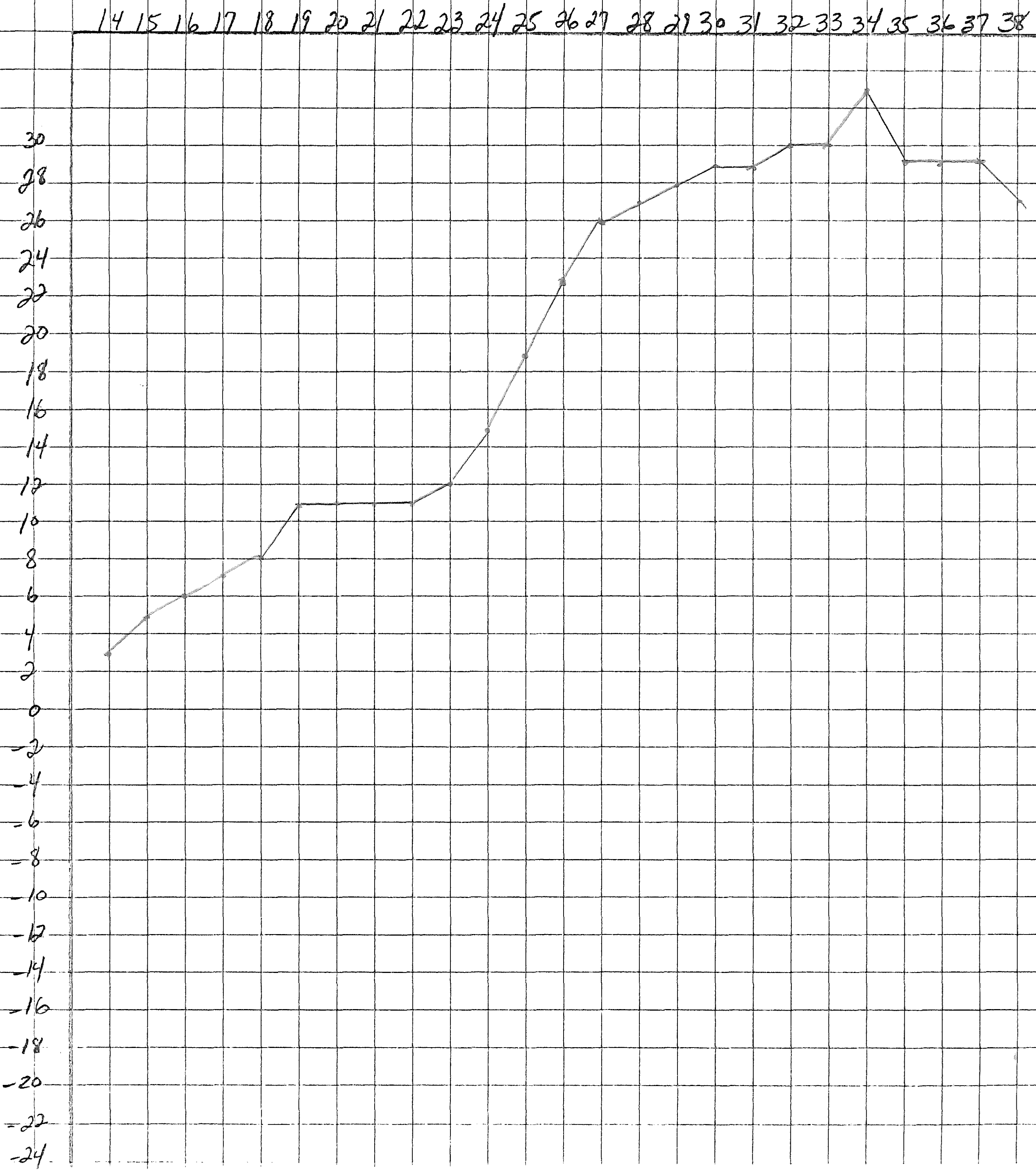
SUMMER-SAPLING ASPEN

30dTRA

J-78

SUMMER SAPLING ASPEN
35 dBA



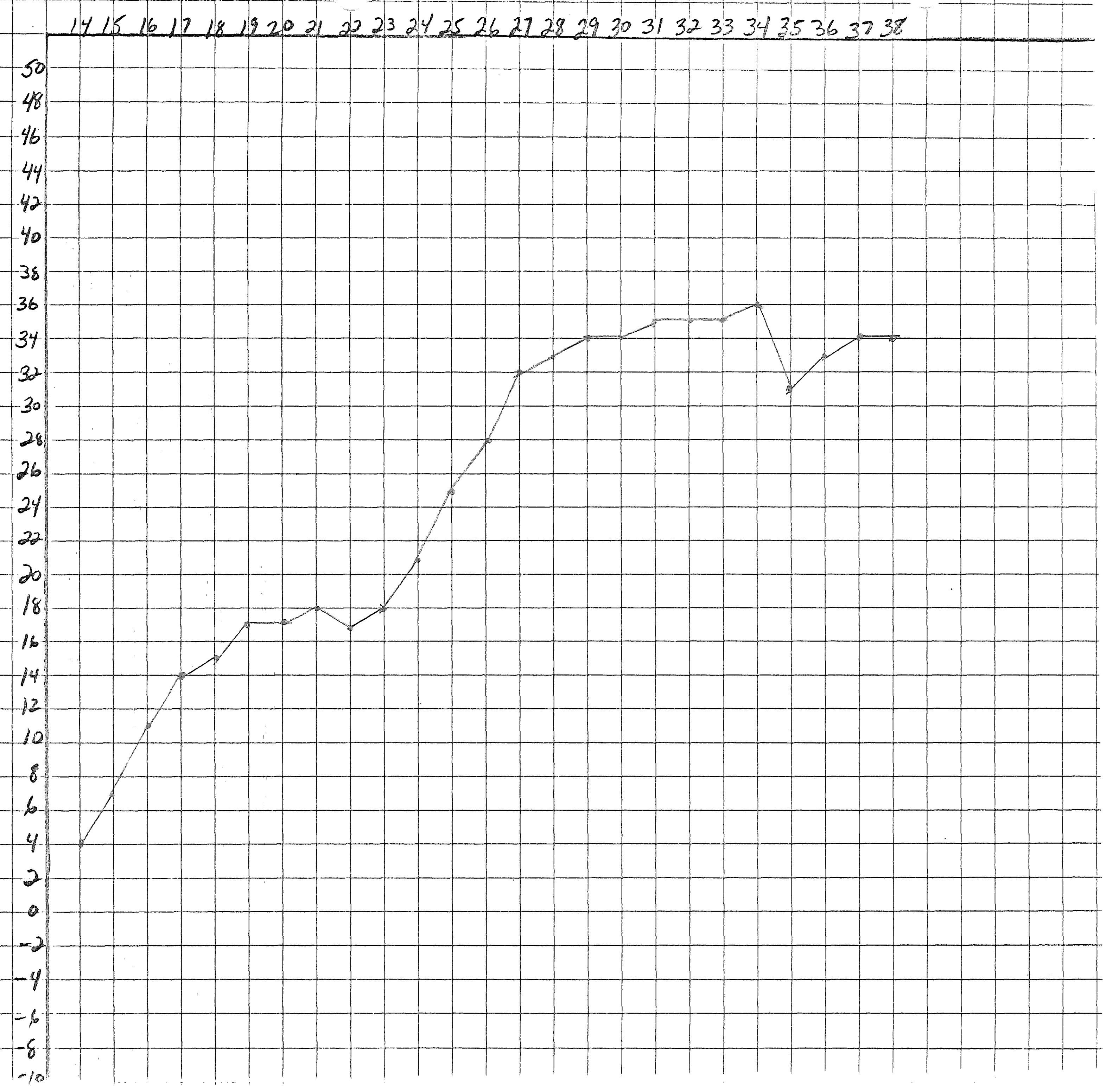


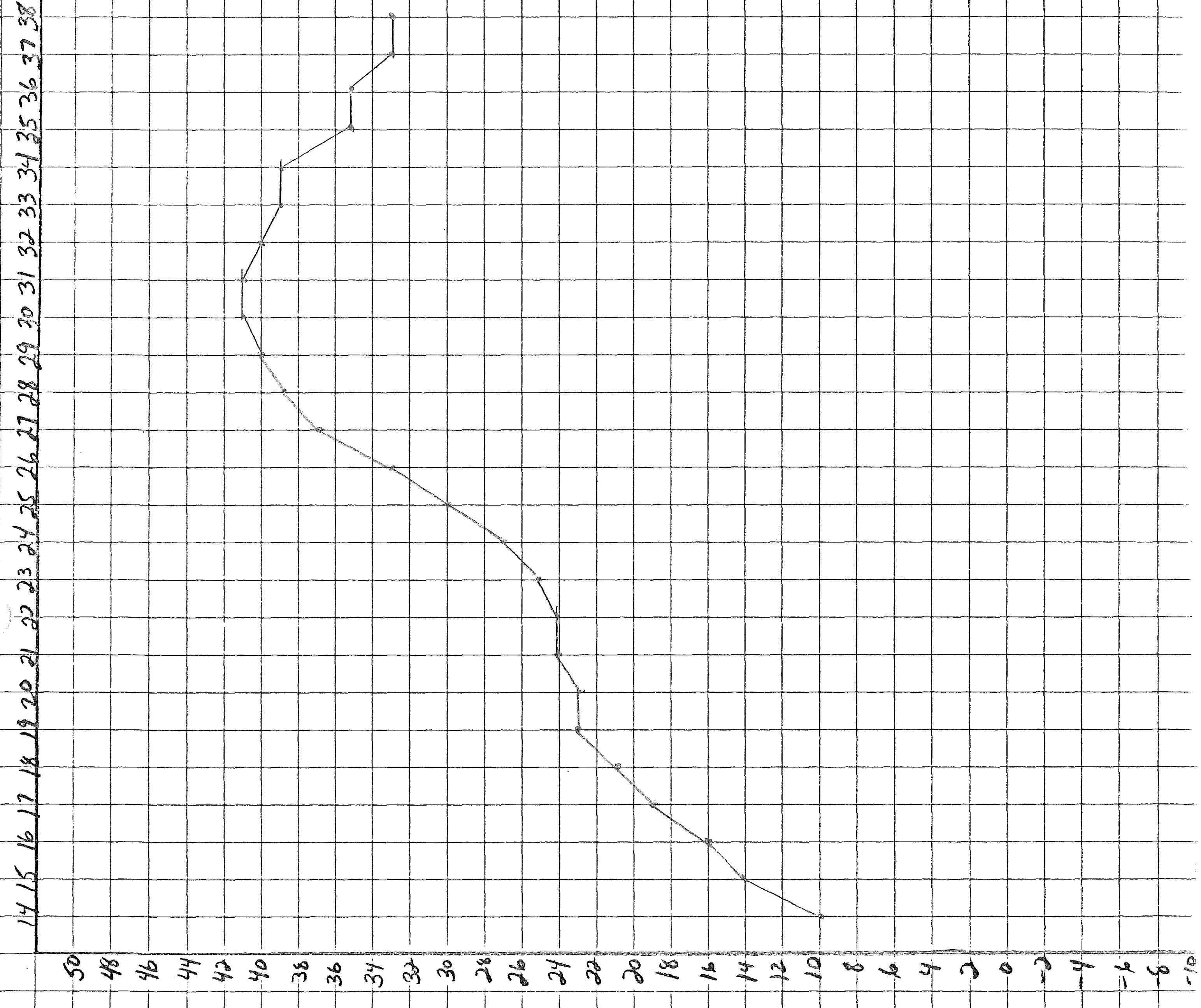
SUMMER-SAPLING ASPEN

40 dBA

SUMMER-SAPLING ASPEN

45dBA



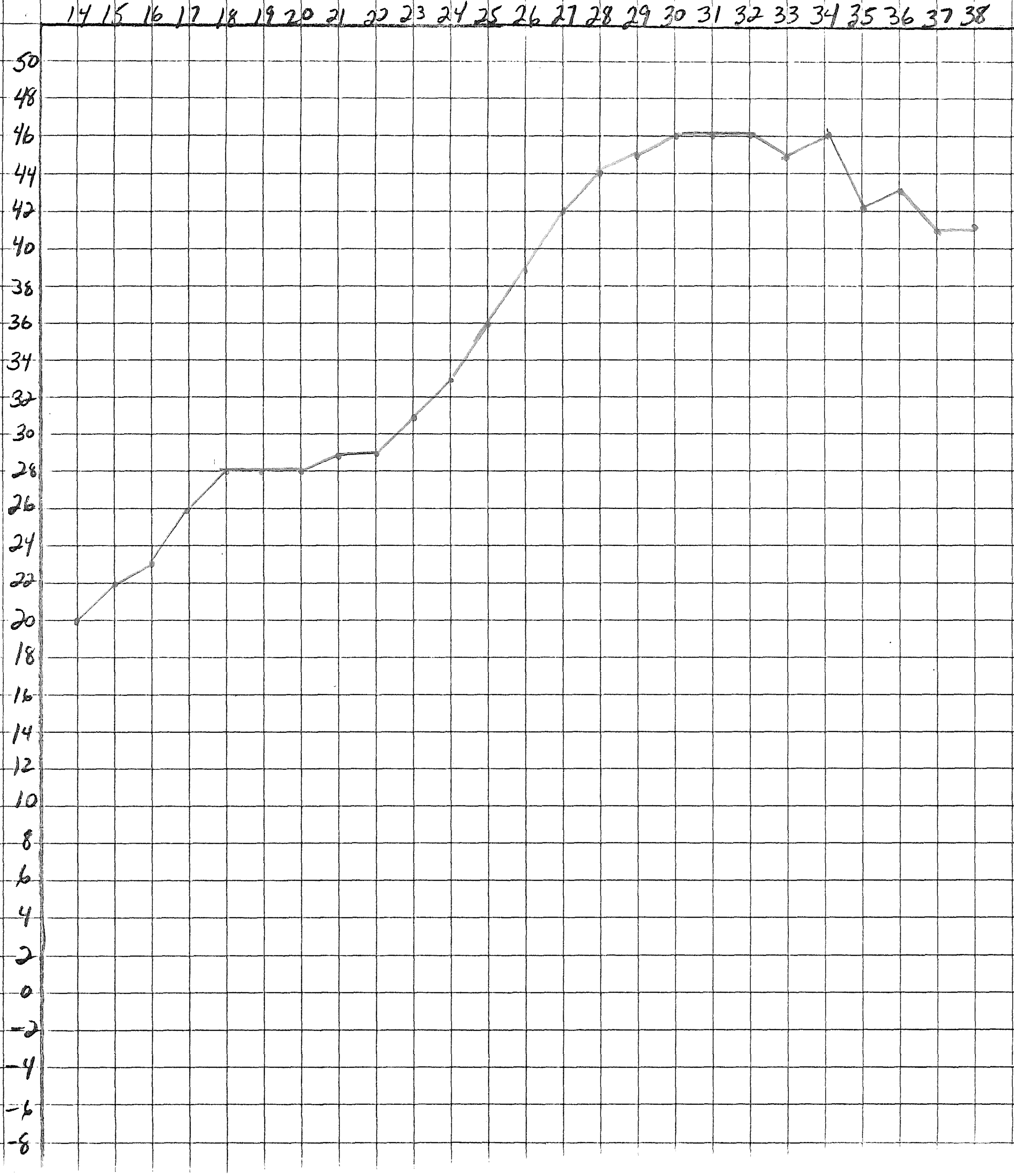


SUMMER SAPLING ASPEN

500BA

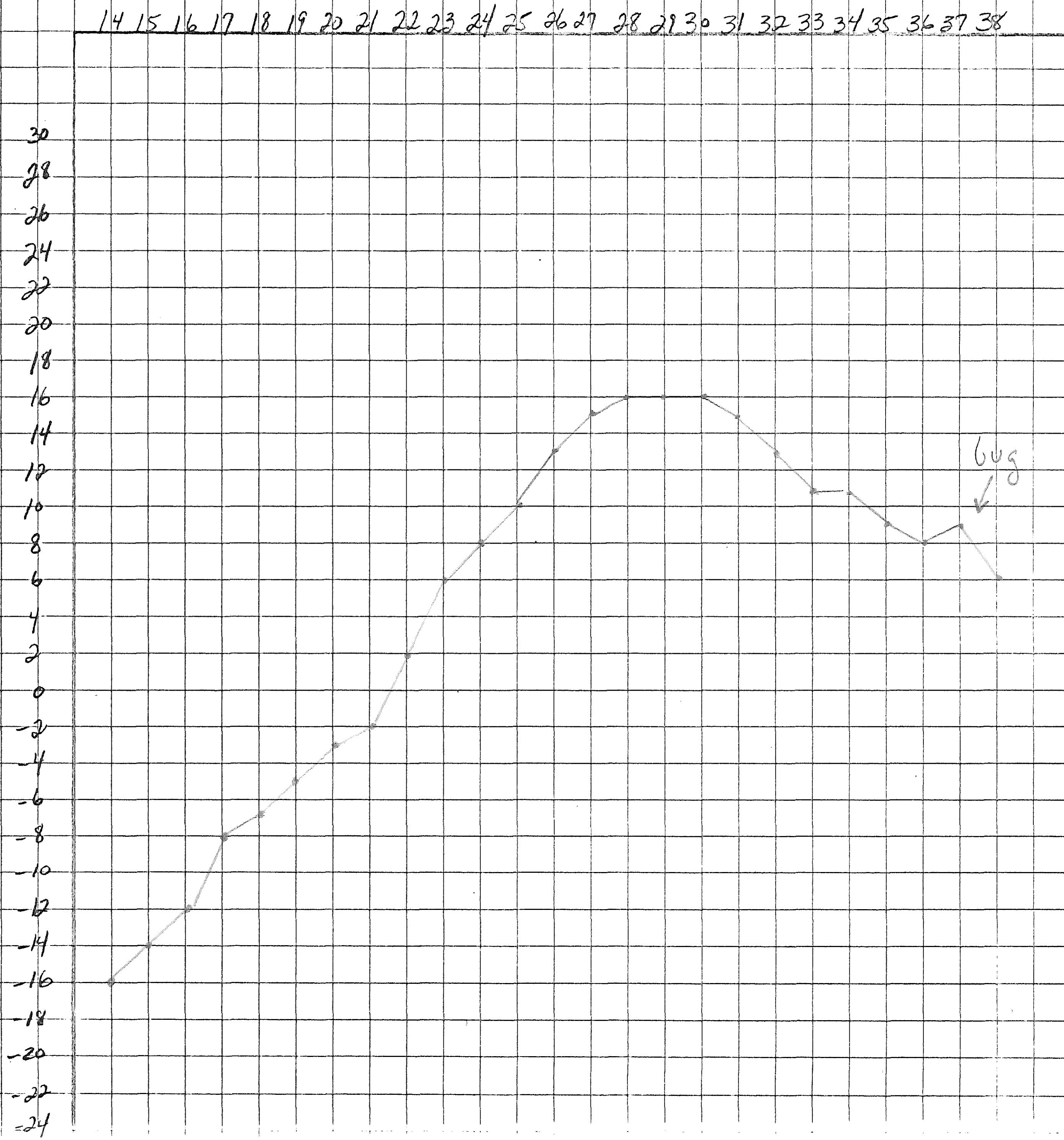
SAPLING ASPEN · SUMMER

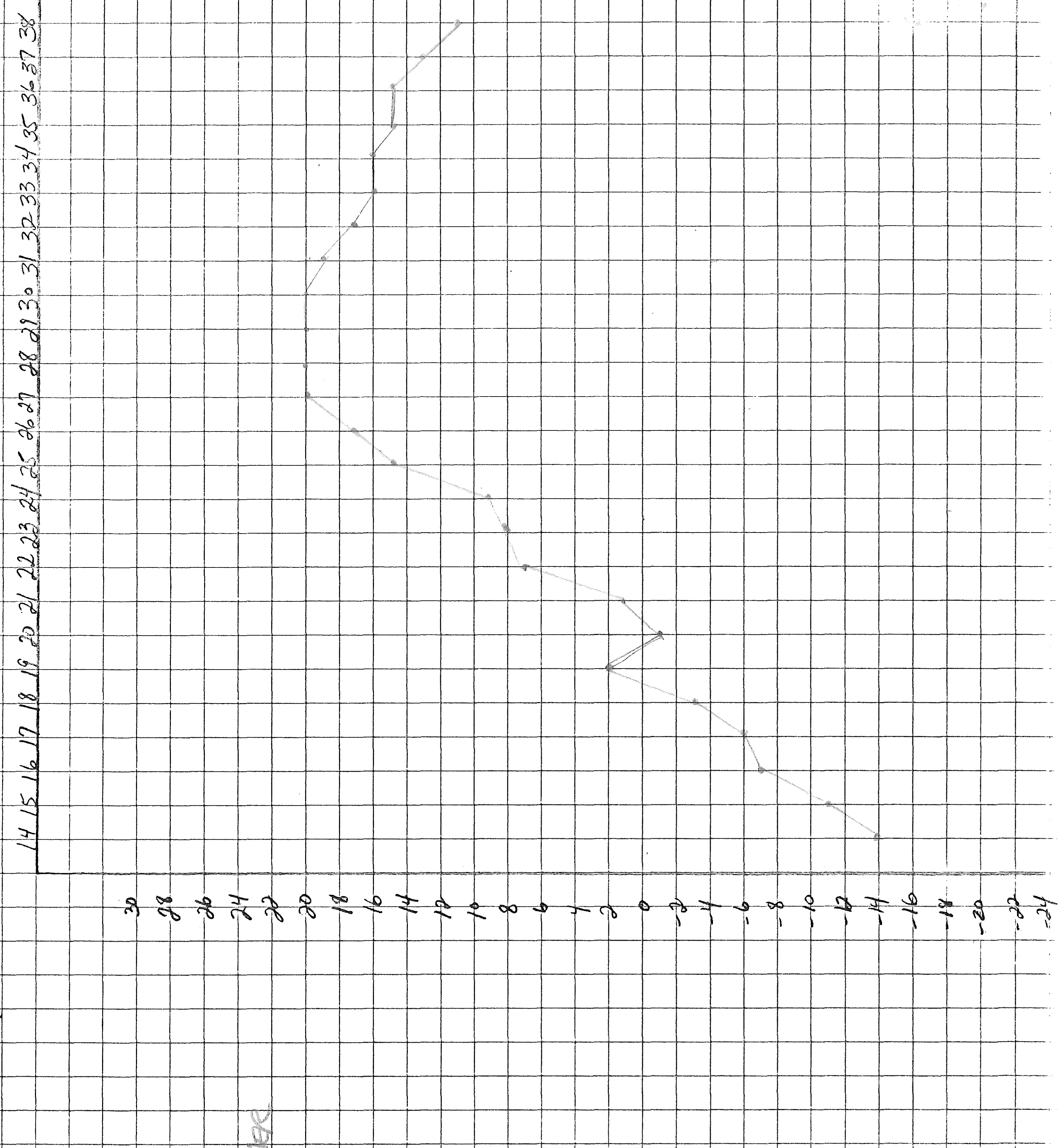
55 dBA



SPARSE - SUMMER

25 dBA

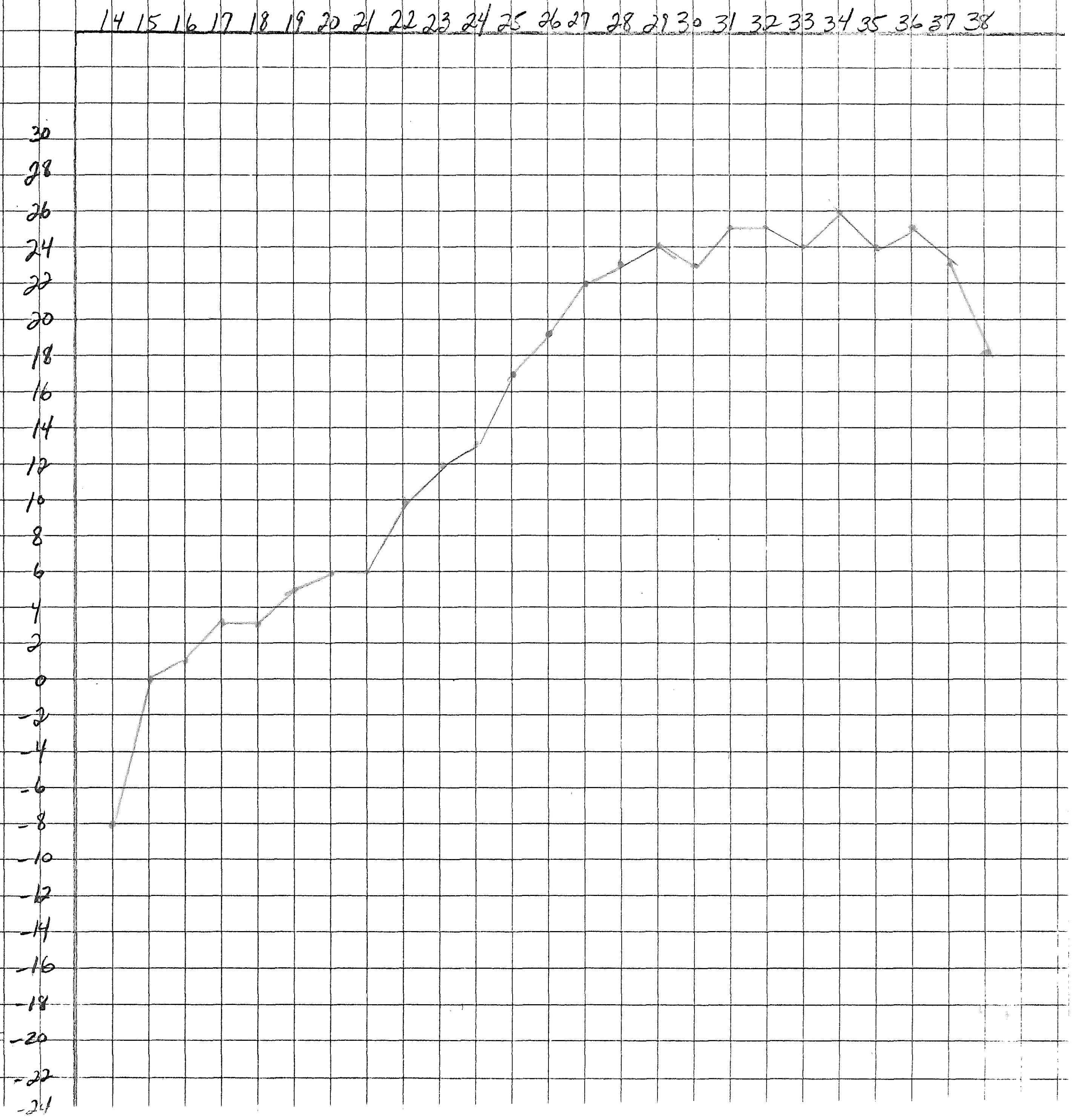


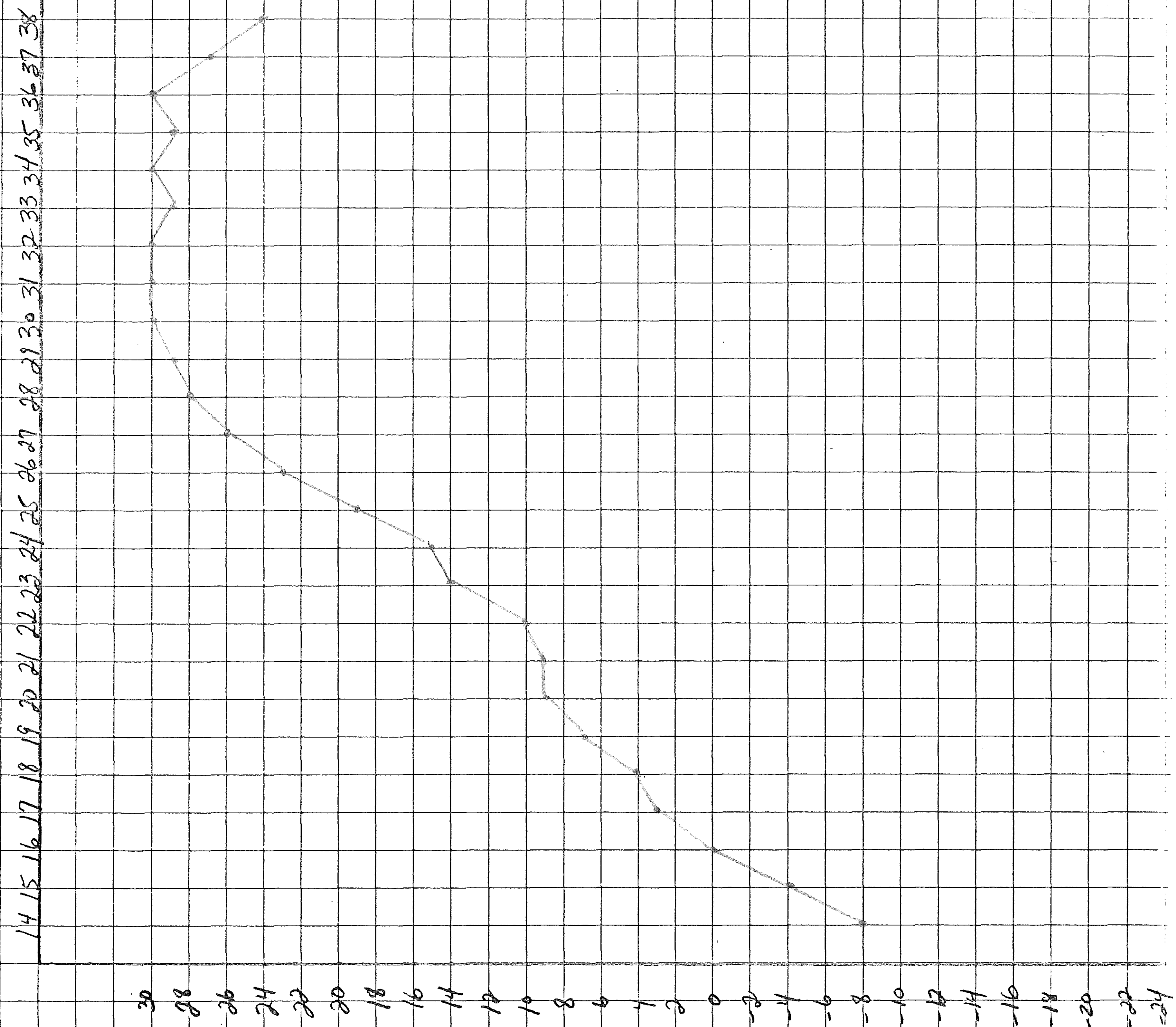


SPARSE SUMMER

30 dBA

SPARCE - SUMMER
35 dBA





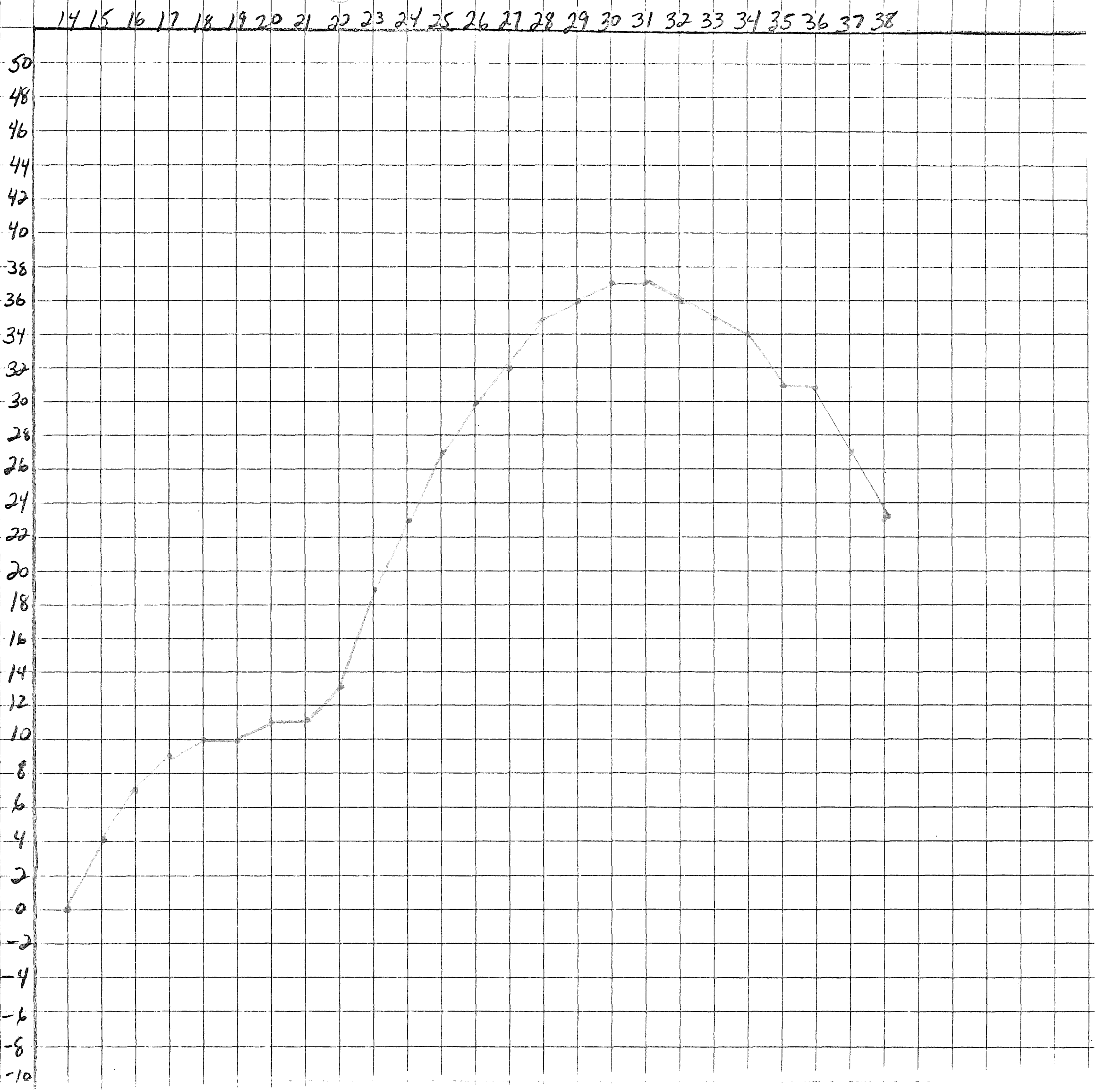
SPARSE - SUMMER

40 dBA

J-87

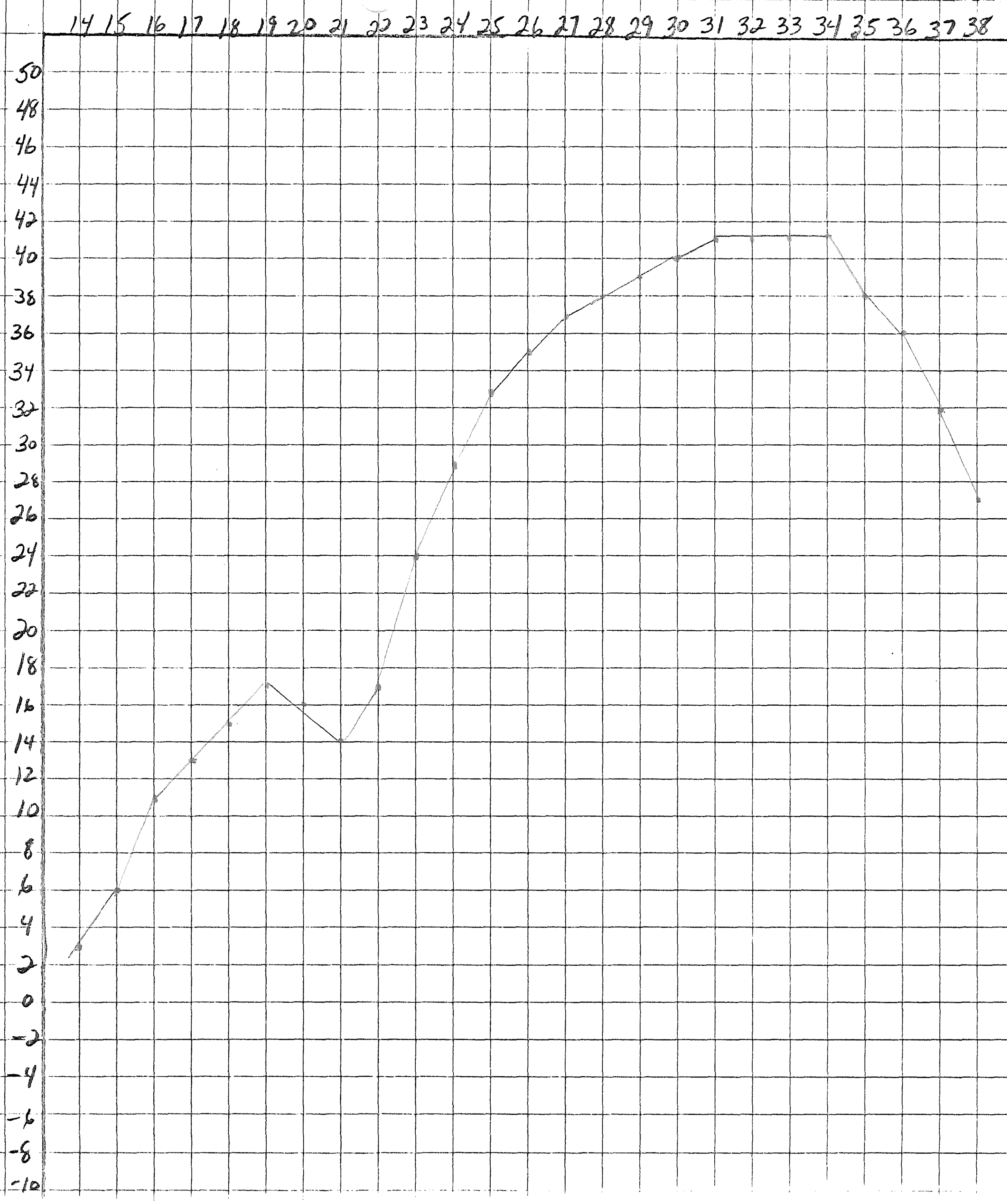
SPARSE - SUMMER

45 dBA



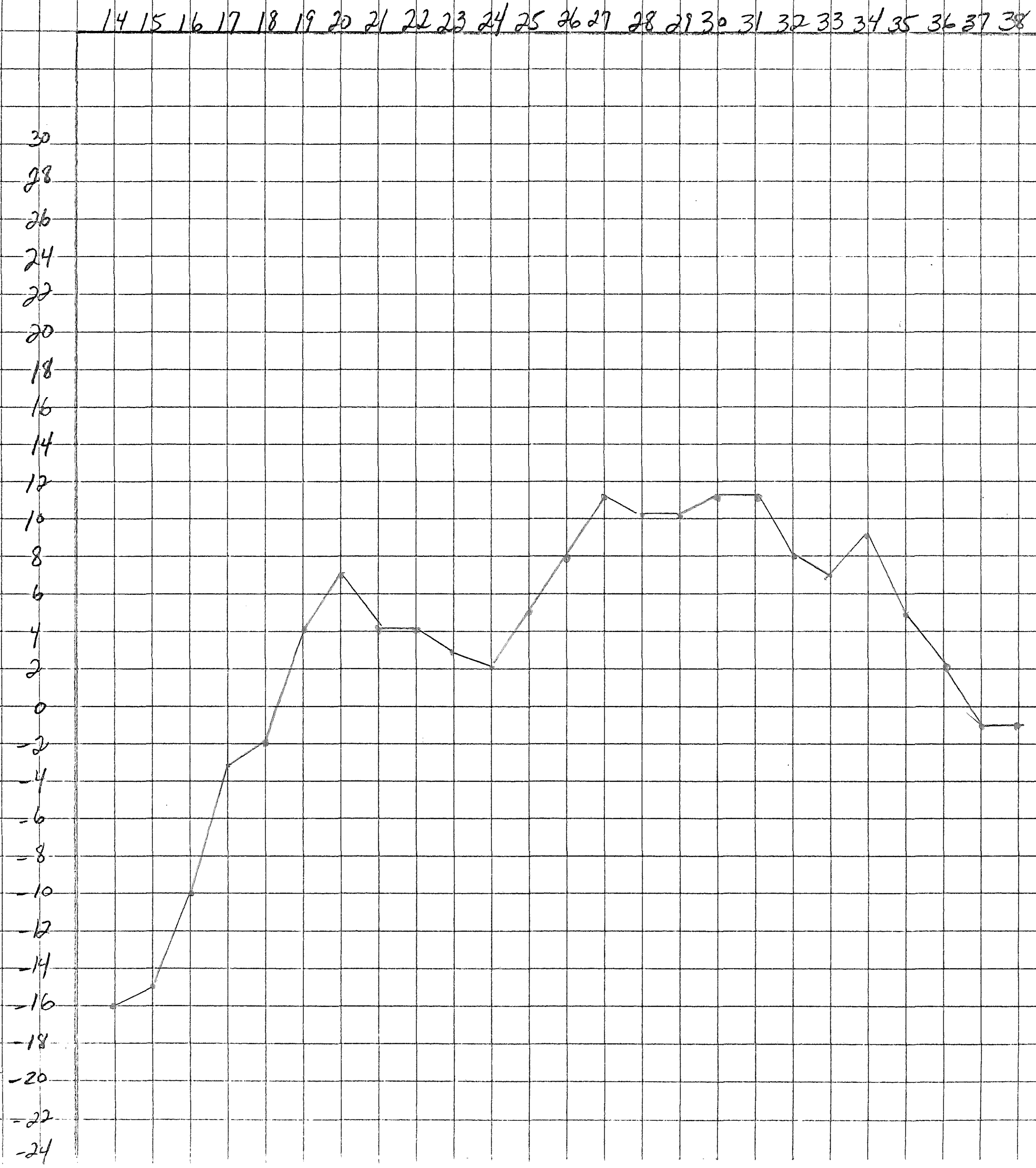
SPARSE-SUMMER

50dBA



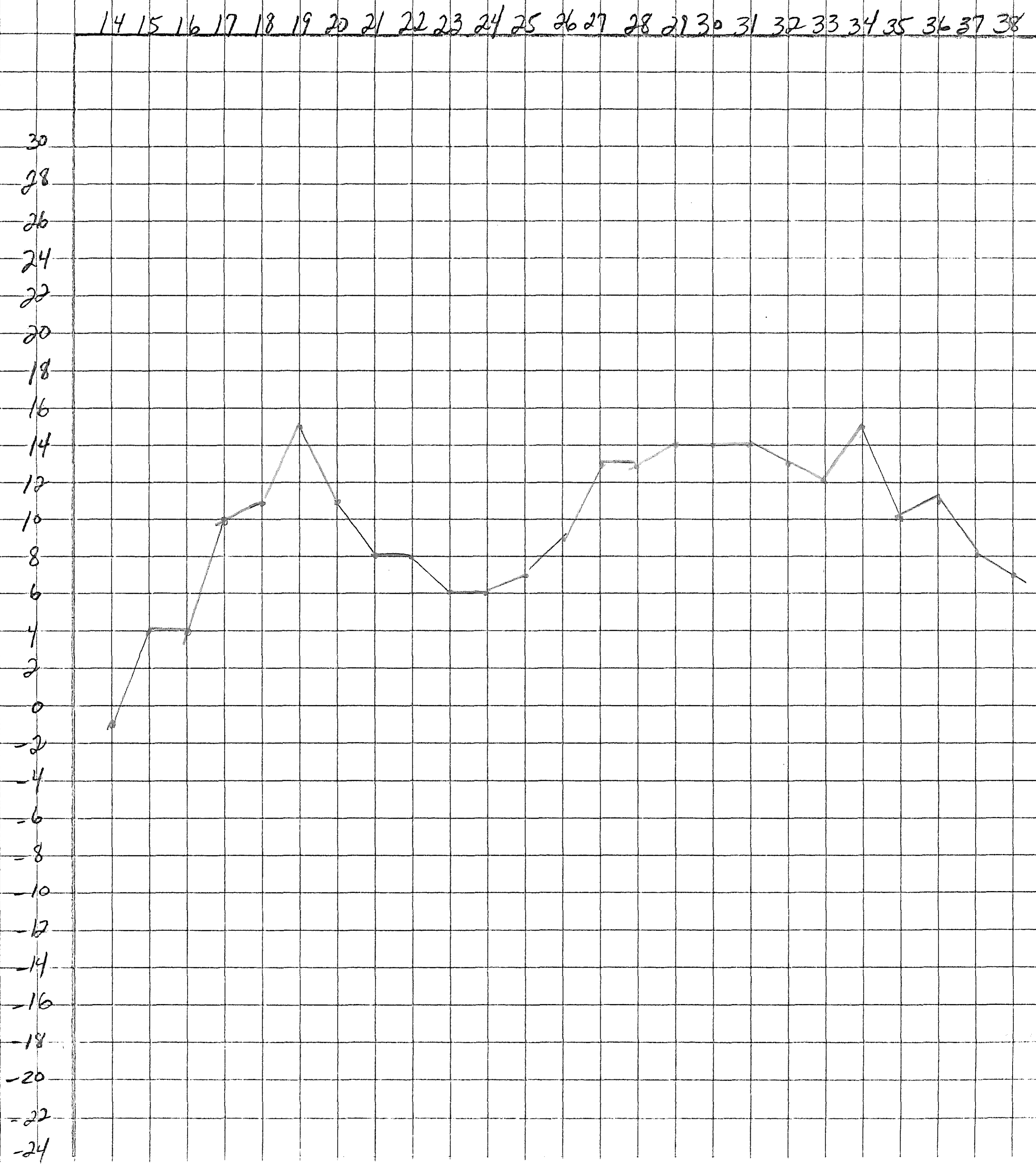
CLEARCUT - SUMMER

20 dBA



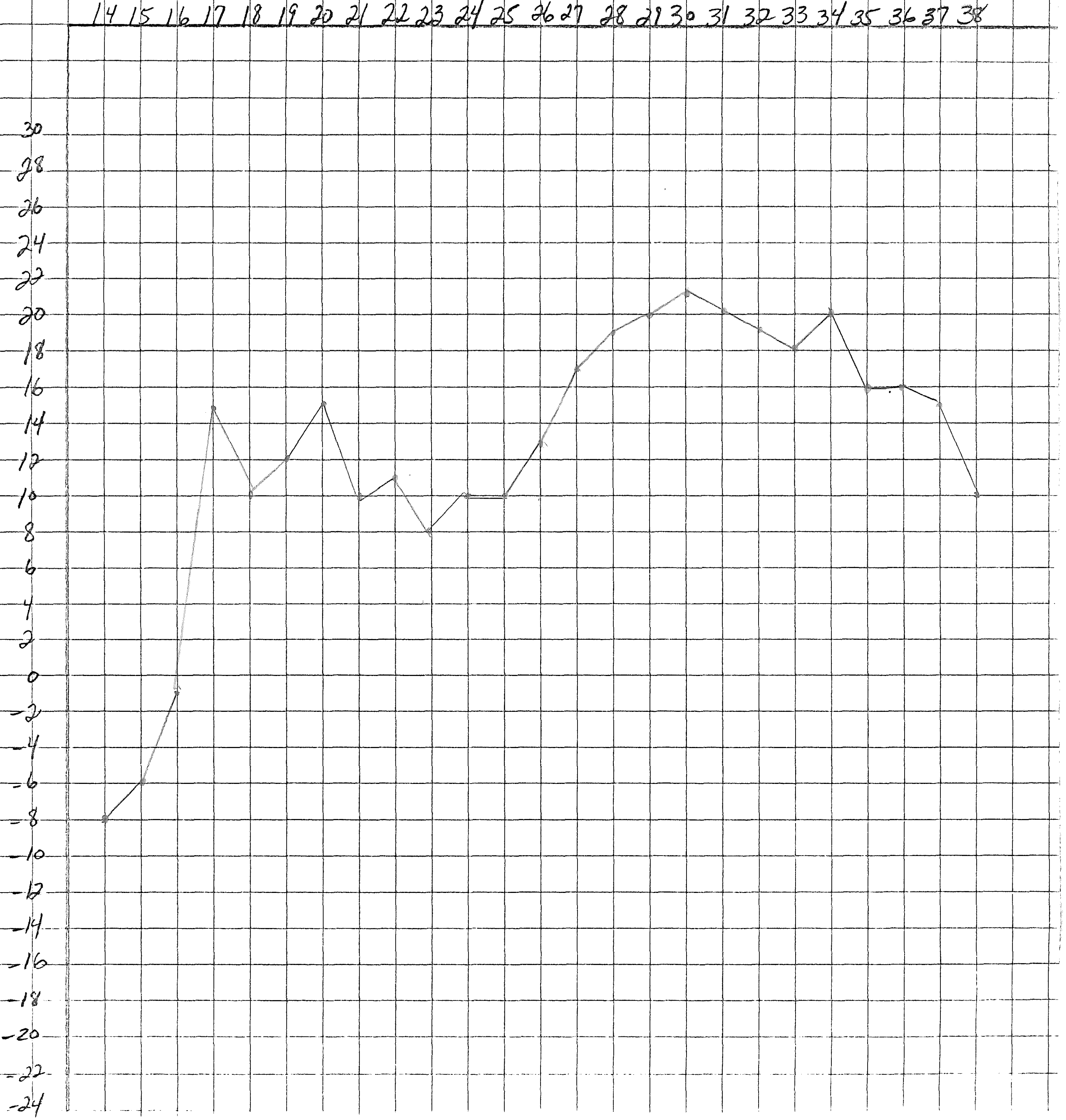
CLEARCUT· SUMMER

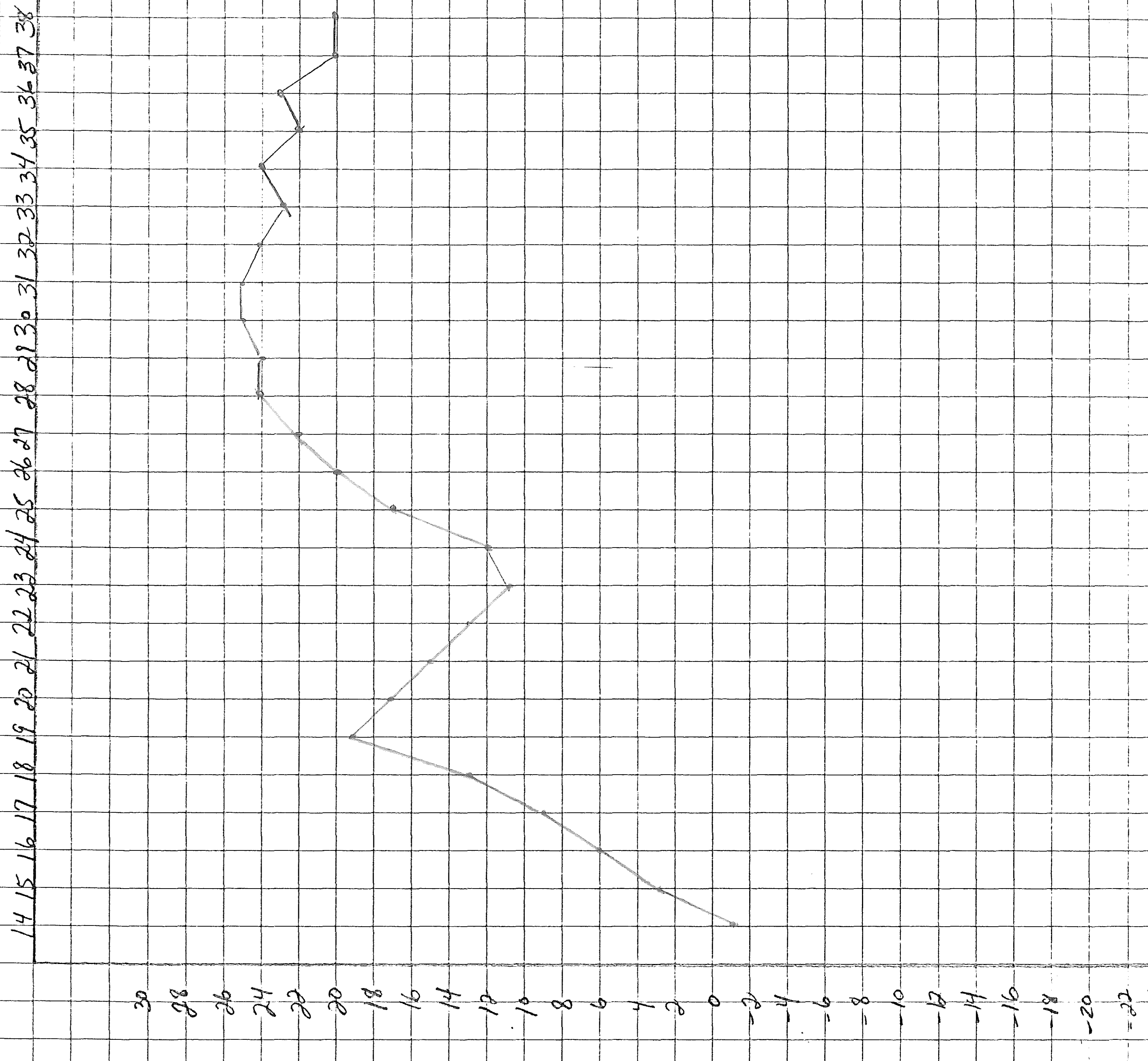
25 dBA



SUMMER-CLEARCUT

30 CKA



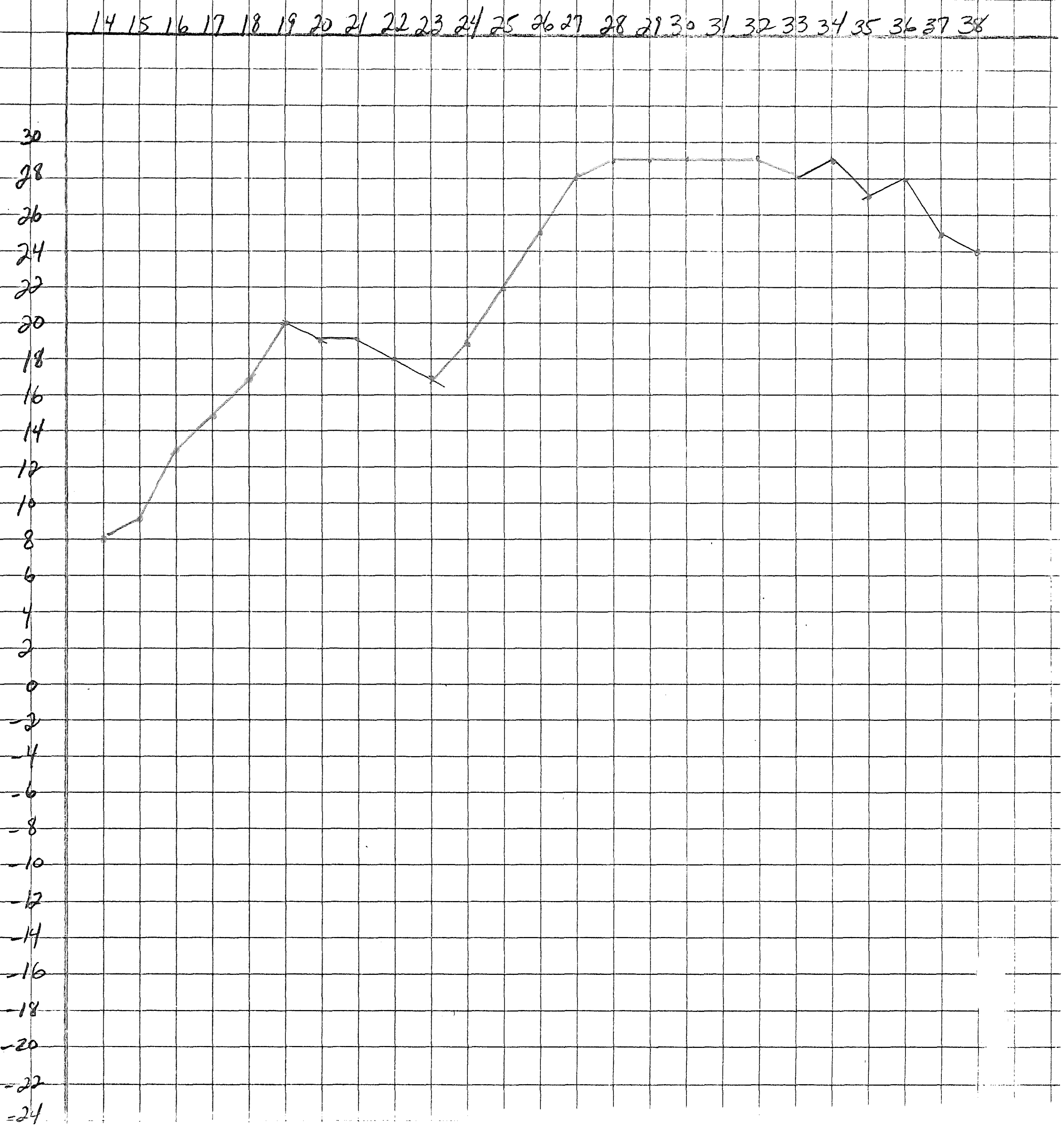


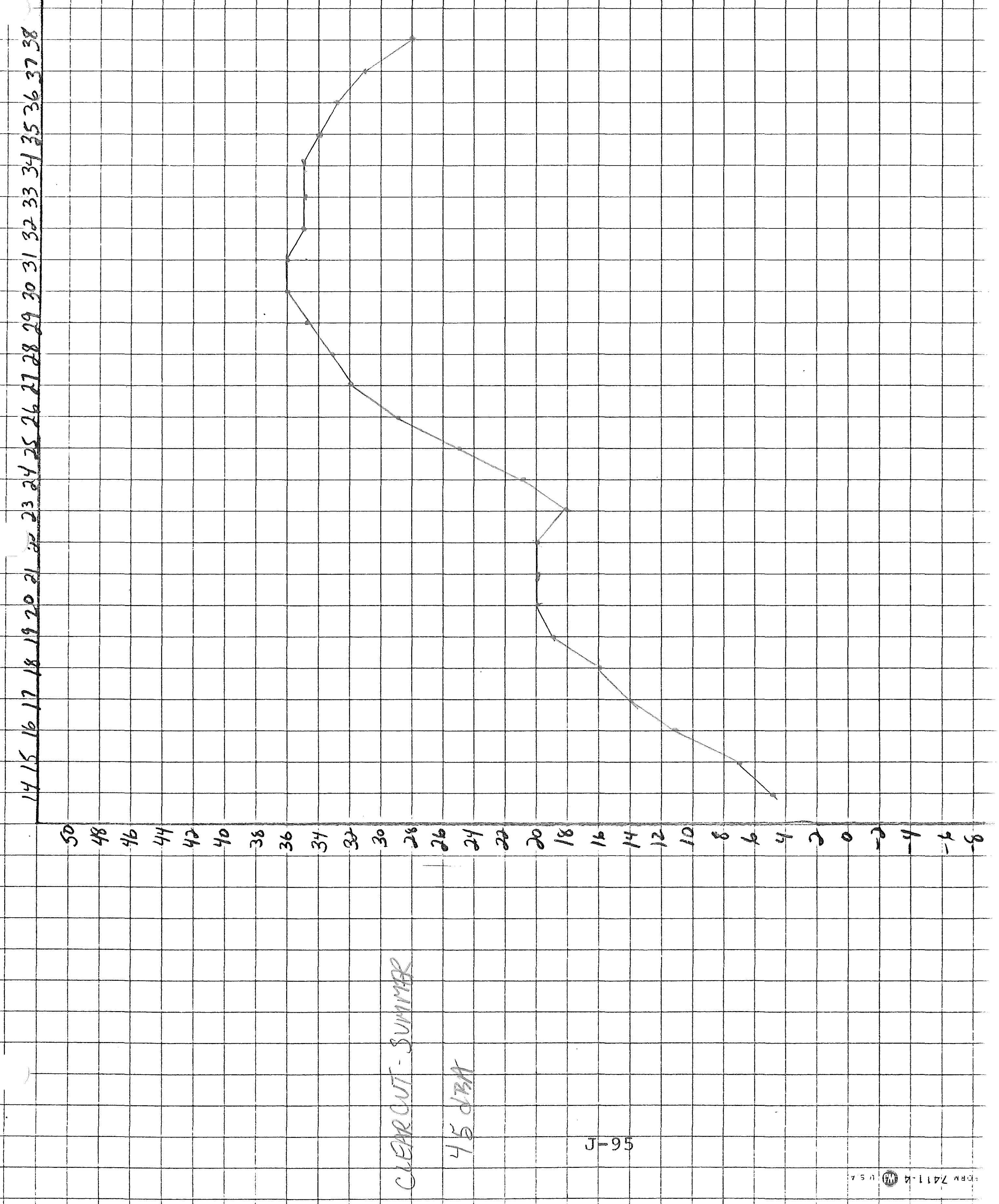
CLEAR-CUT-SUMMER

35dBA

CLEARCUT- SUMMER

40 dBA

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26
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18
16
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12
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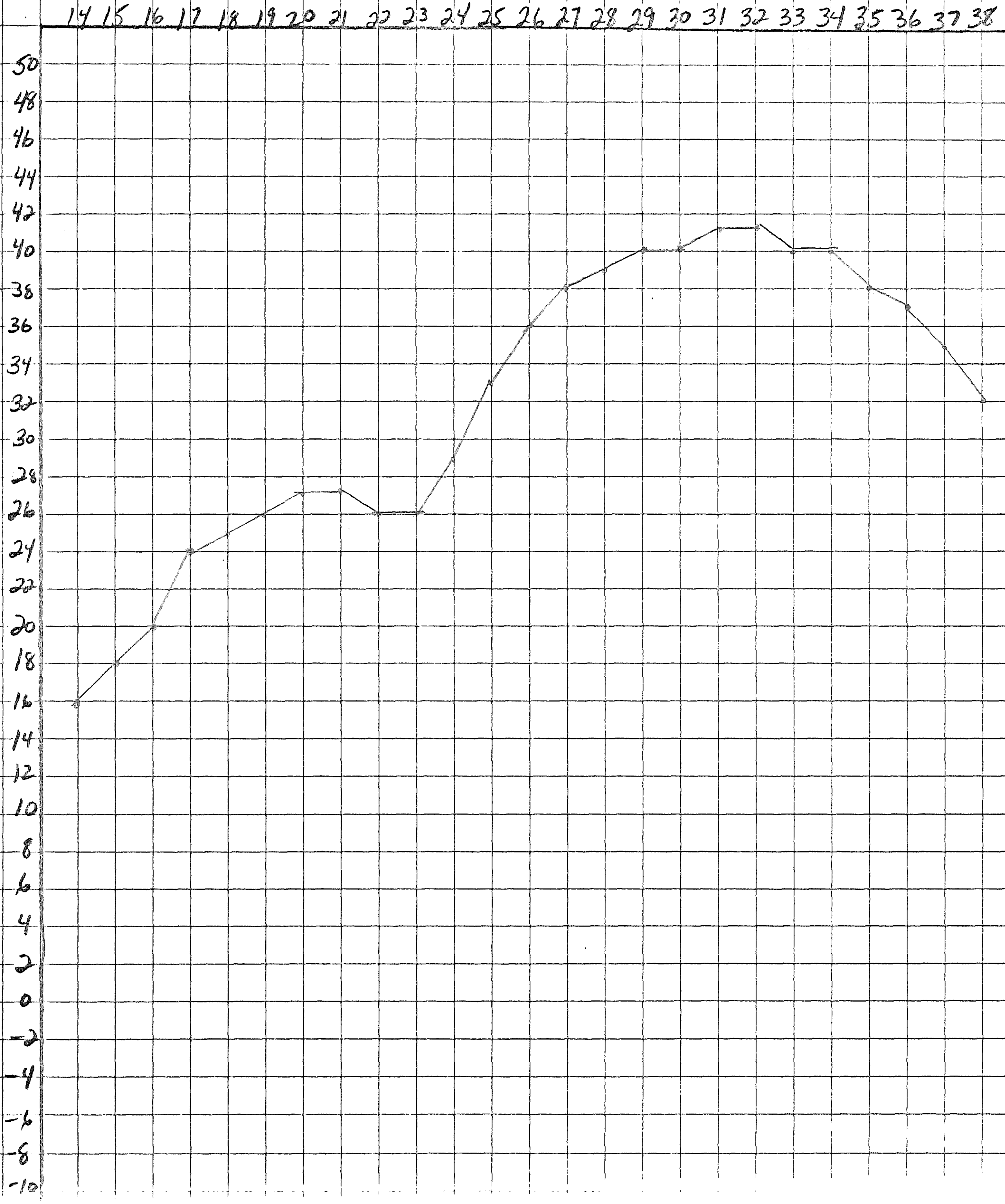
2
0
-2
-4
-6
-8
CLEARCUT - SUMMER
45 dBA

CLEAR CUT SUMMER

50-dBA



APPENDIX K

SPECTRAL PLOTS OF VARIOUS NATURAL SOUNDS

The following graphs are third octave band spectra, dBA filtered, for several natural sounds. Graphs were plotted from data obtained from field tape recordings and analyzed in accordance with Test Procedure CN-13 (See Appendix N). All plots were analyzed with an integration time of one-eighth second.

Each graph is labeled with the name of the source, the integration time, the overall dBA, and the tape number (which is a number preceded by "ST-"). The letter A or B following the tape number indicates which side of the tape was analyzed.

Third octave bands are given by their number, not center frequency. To aid in interpretation of these plots, a conversion table is given below:

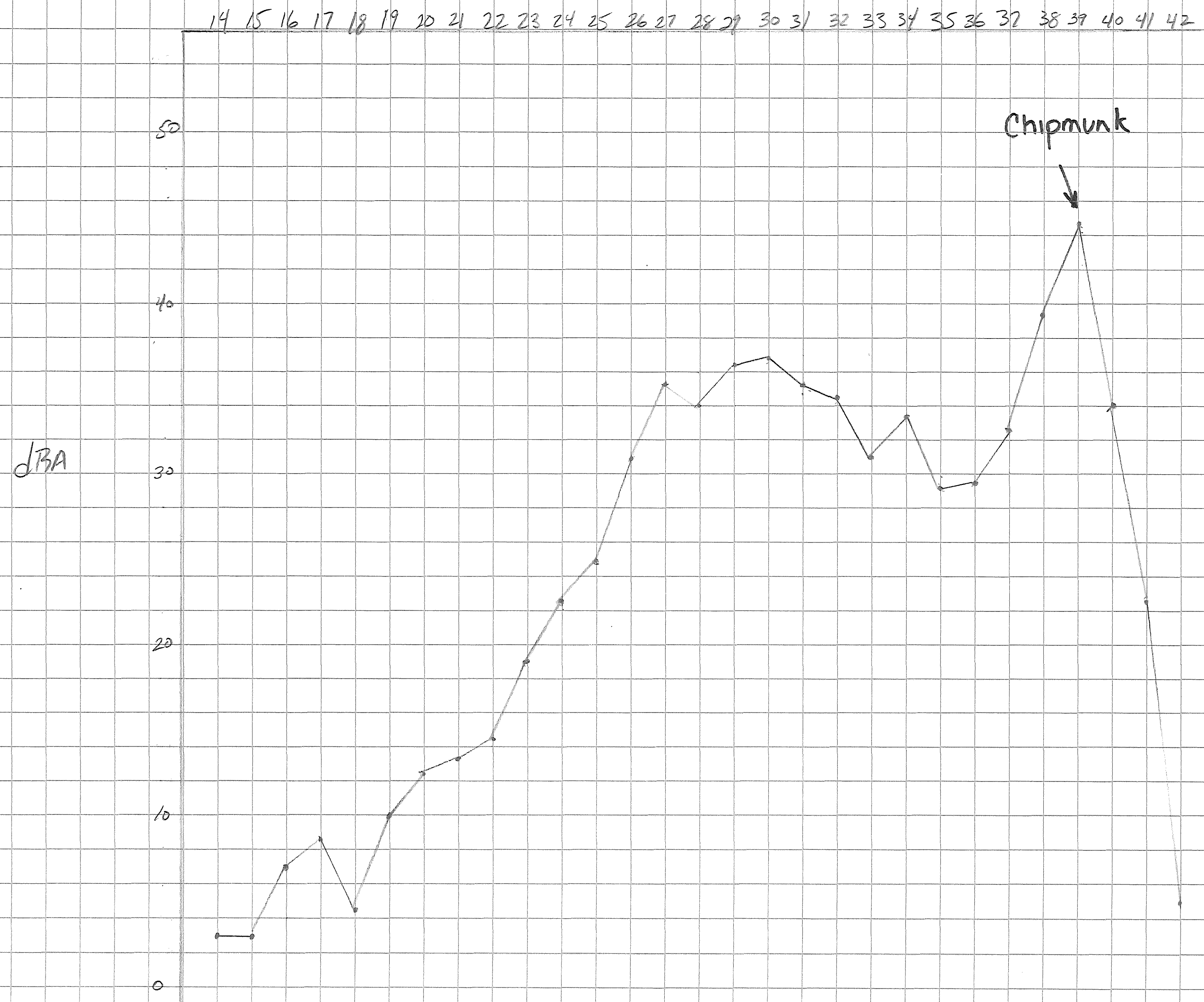
Band Number	Center Frequency (Hz)	Band Number	Center Frequency (Hz)
14	25	27	500
15	31.5	28	630
16	40	29	800
17	50	30	1,000
18	63	31	1,250
19	80	32	1,600
20	100	33	2,000
21	125	34	2,500
22	160	35	3,150
23	200	36	4,000
24	250	37	5,000
25	315	38	6,300
26	400		

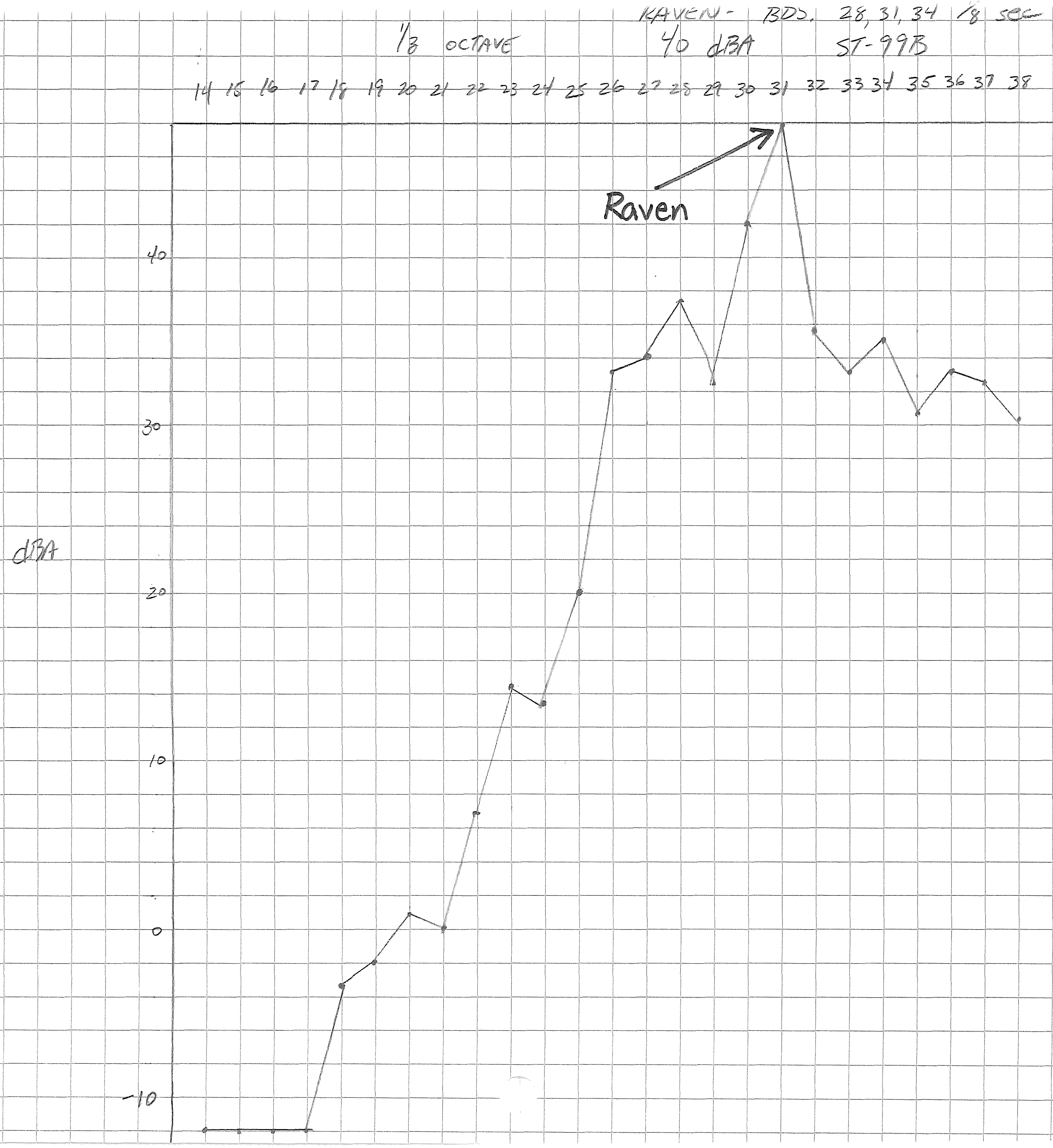
Sounds graphed in this appendix resulted from the following sources:

	Page
Chipmunk	K-2
Raven	K-3
Cricket	K-4
Flies	K-5
Thunder	K-6
Loon	K-7
Deer Snort	K-8
Insect (type unknown)	K-9
Bird (type unknown)	K-10
Robin	K-11

CHIPMUNK - BAND 37 - 18 SEC. 78 dBA

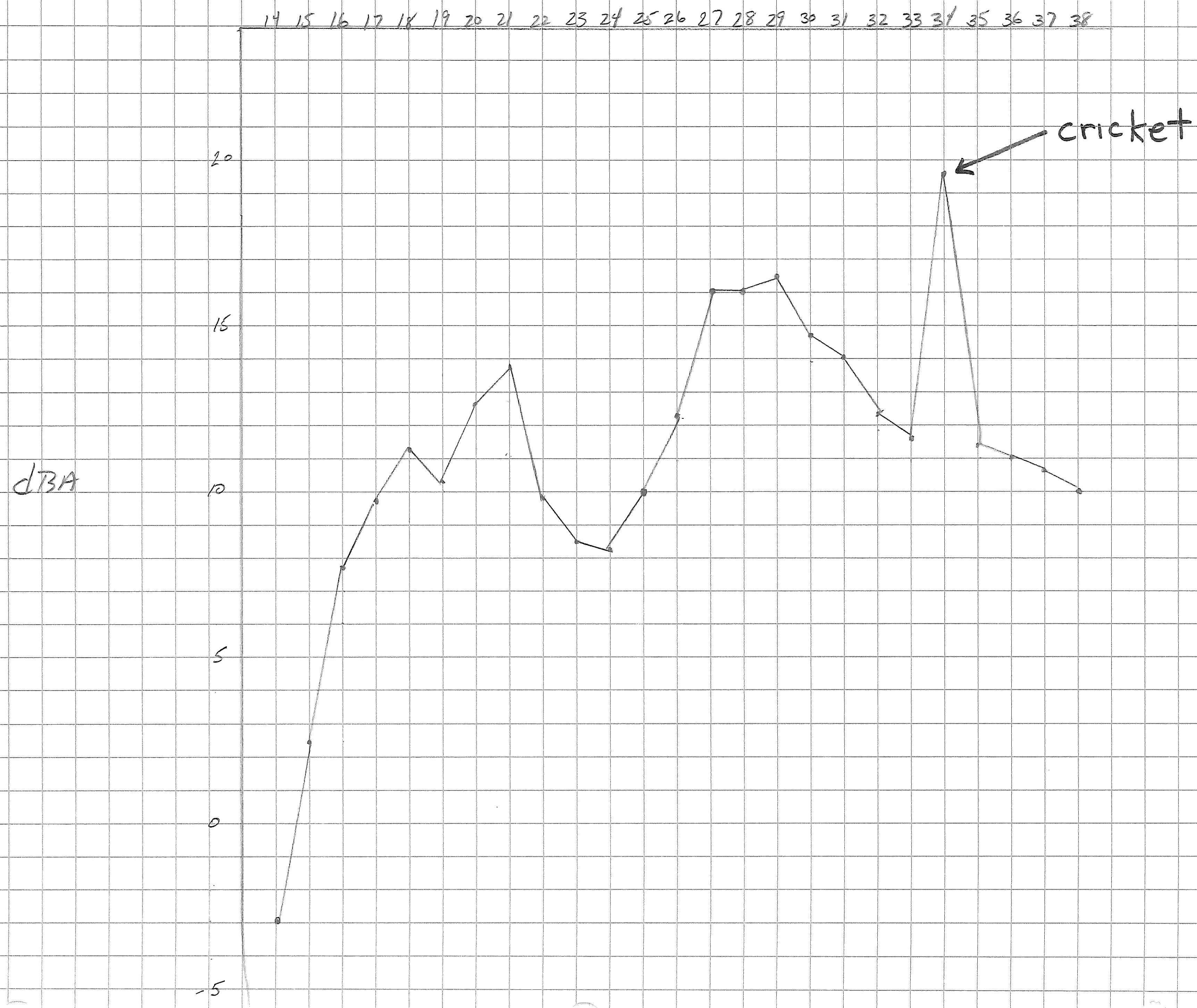
1/3 octave ST-85B




RAVEN - BDS. 28, 31, 34 1/8 sec
1/3 OCTAVE
40 dBA
ST-99B
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
Raven
dBA
40
30
20
10
0
-10

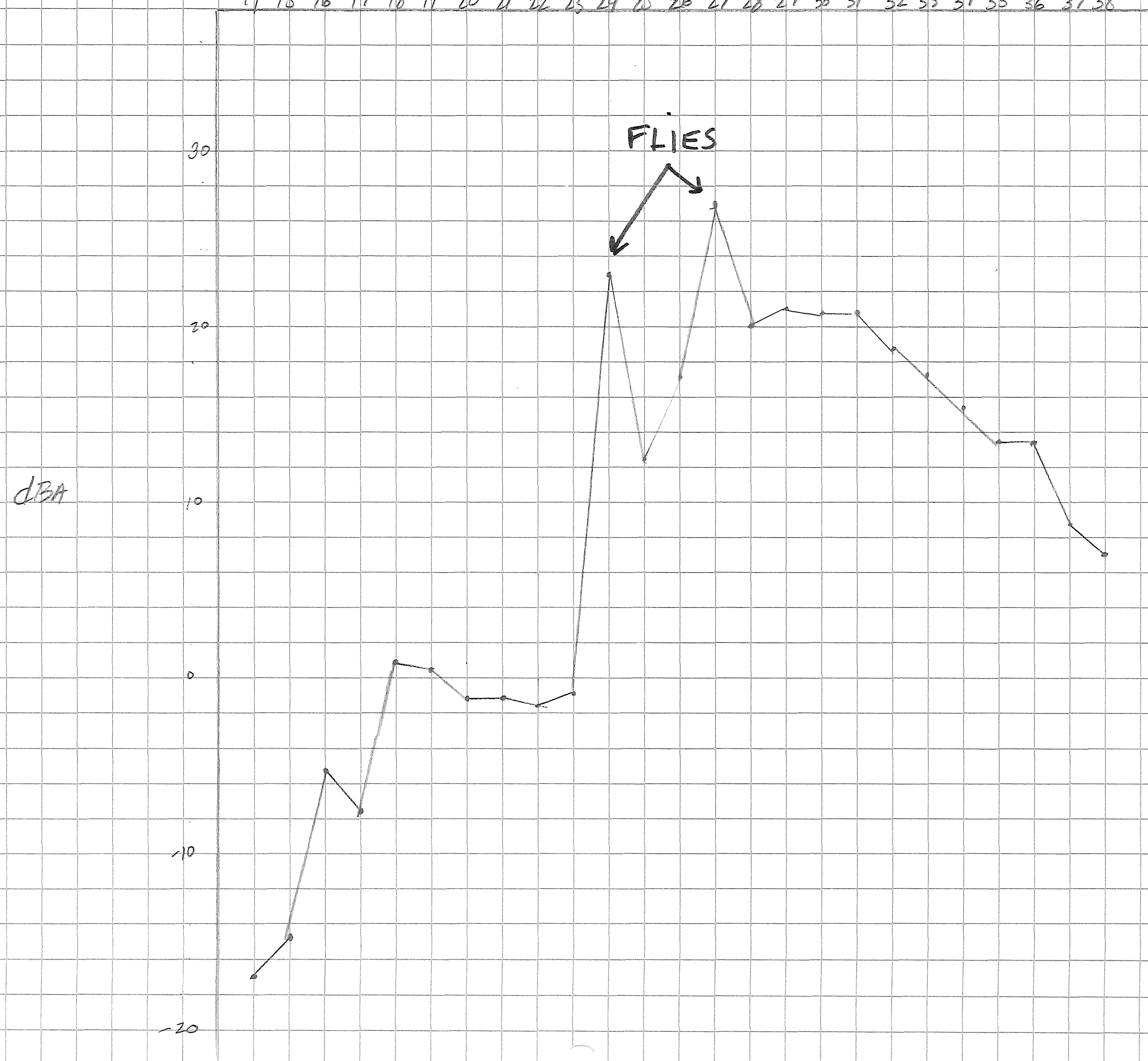
13 OCTAVE CRICKETS 18 sec 21 dBA

ST-99A BAND 34



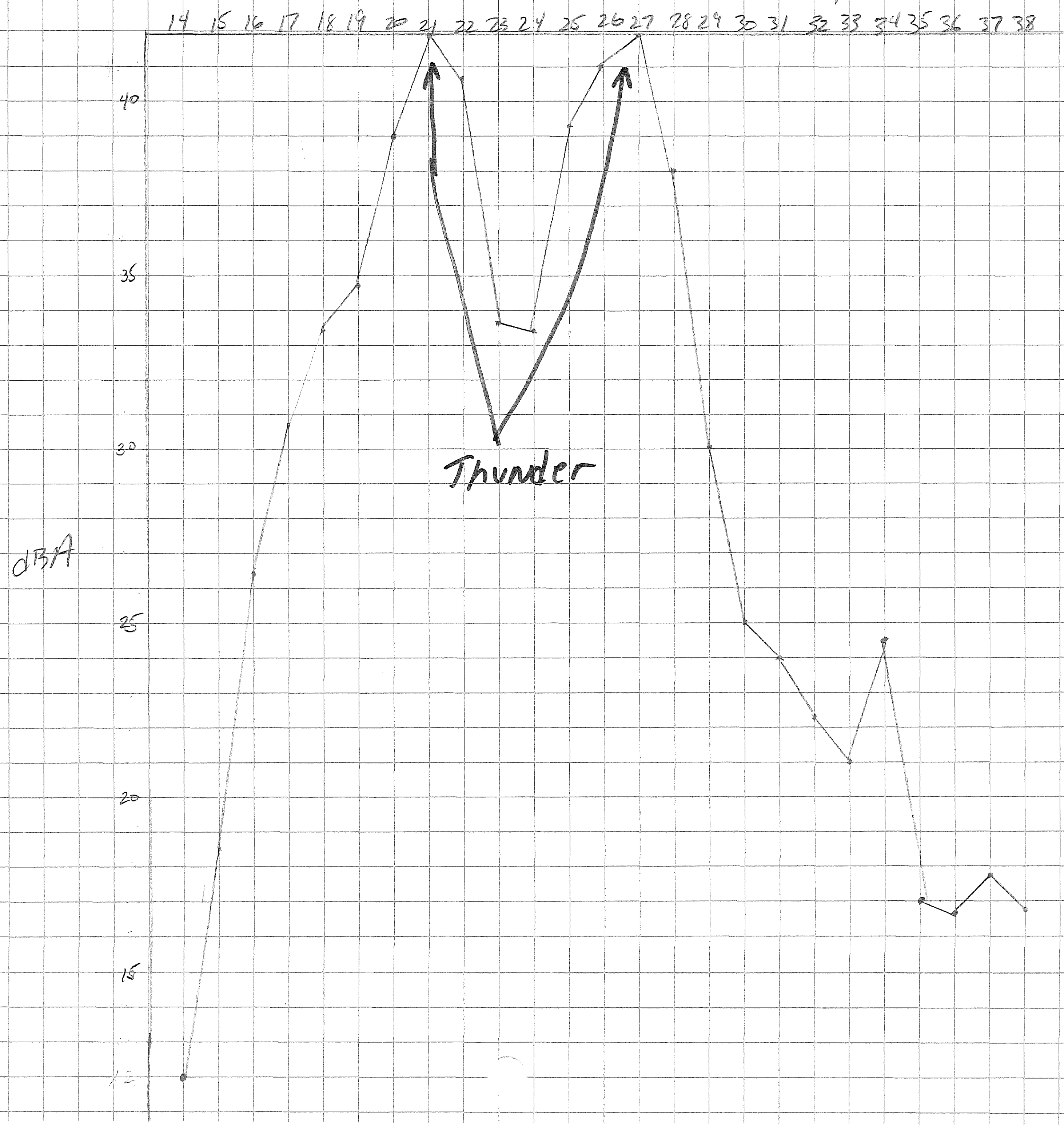
BUG (FLY) BUZZ 24, 21 1/8 sec

ST-92B 32 dBA 1/3 OCT.



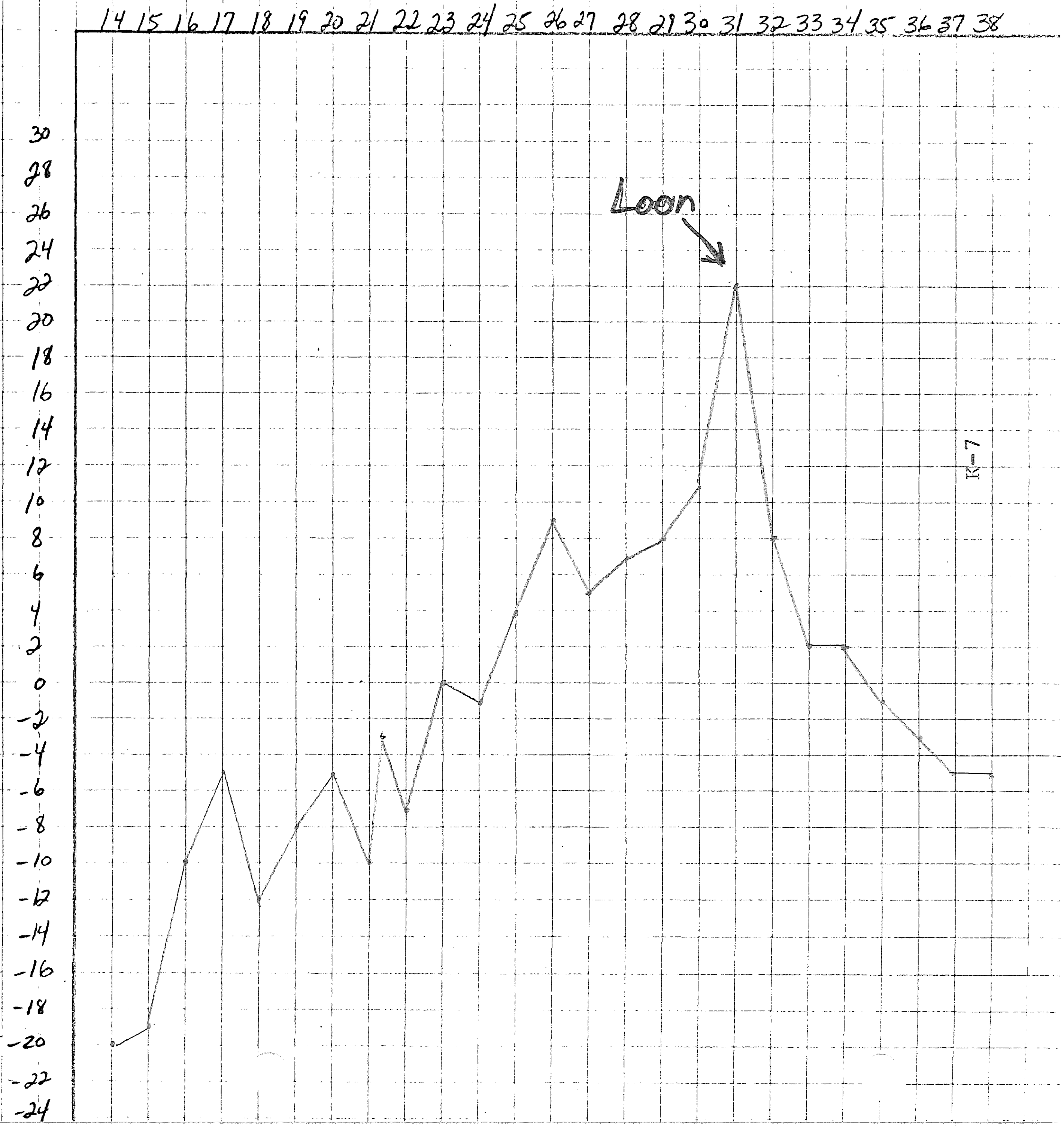
1/3 OCTAVE THUNDER 1/8 SEC 4' dish ST-81A

TWO PEAKS AT BANDS 21, 27



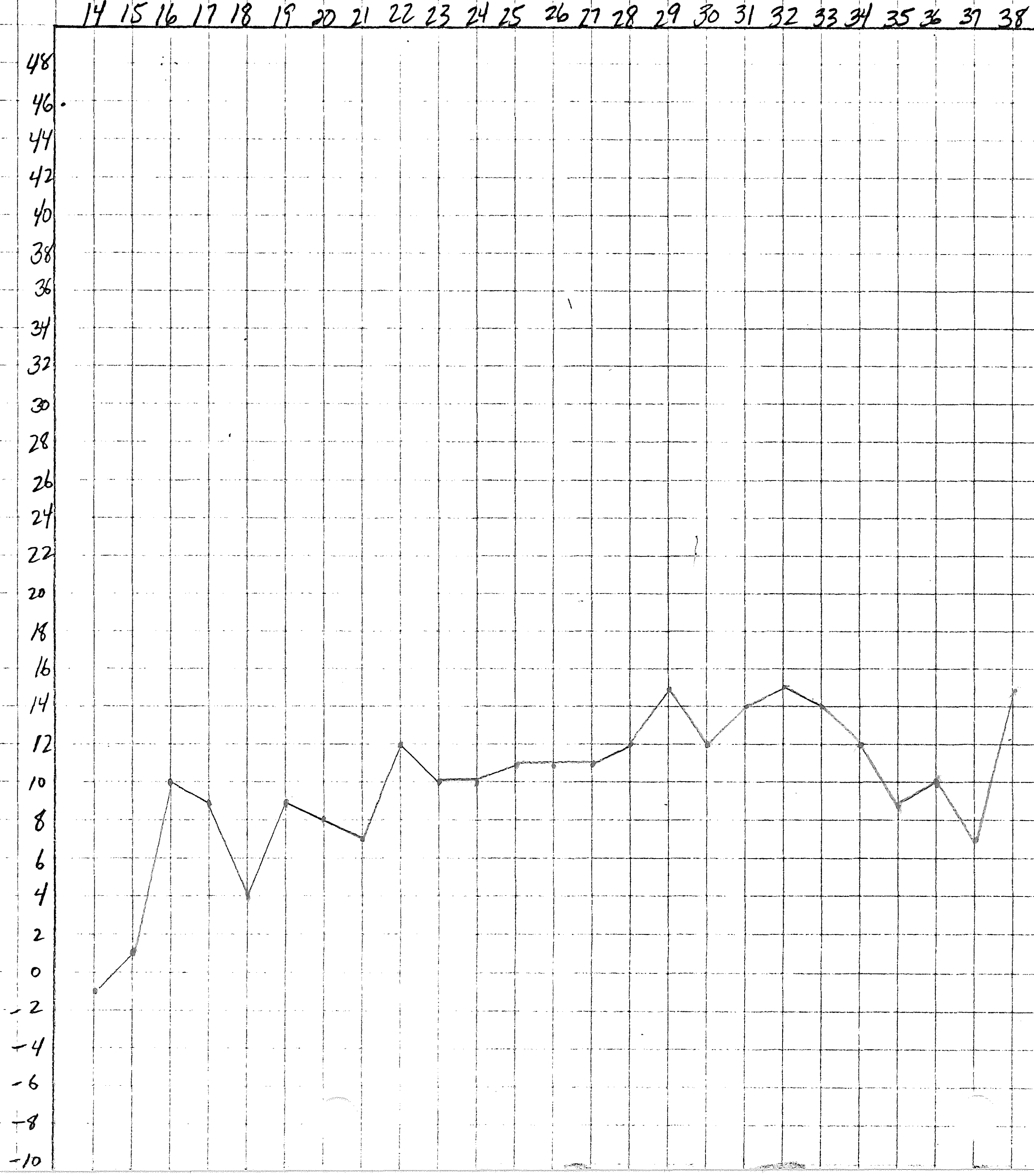
23 dBA
ST-101A
LOON - BD 31

1/8 sec

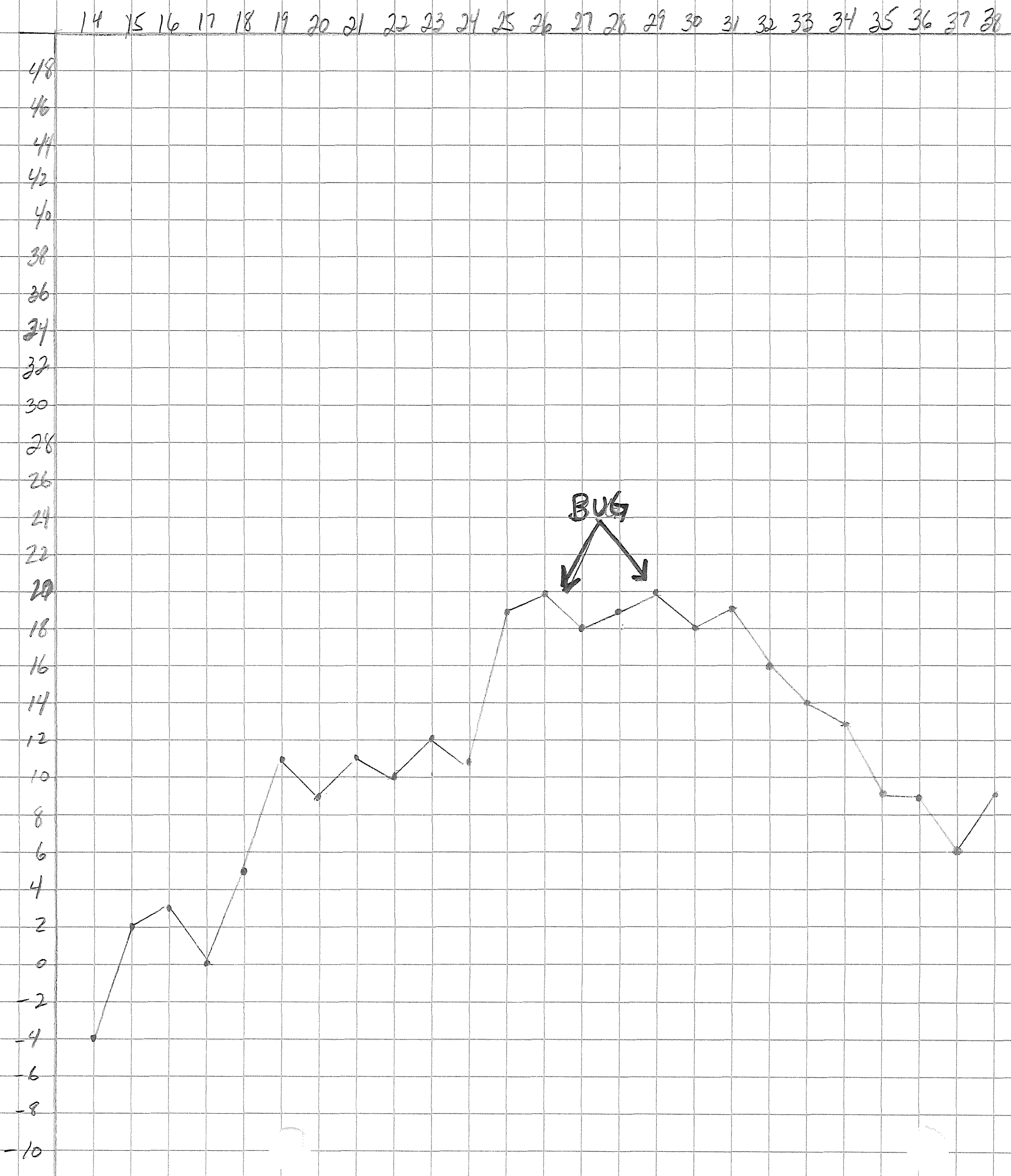


24 dBA
Loud deer snort
ST-5A 1/8 sec

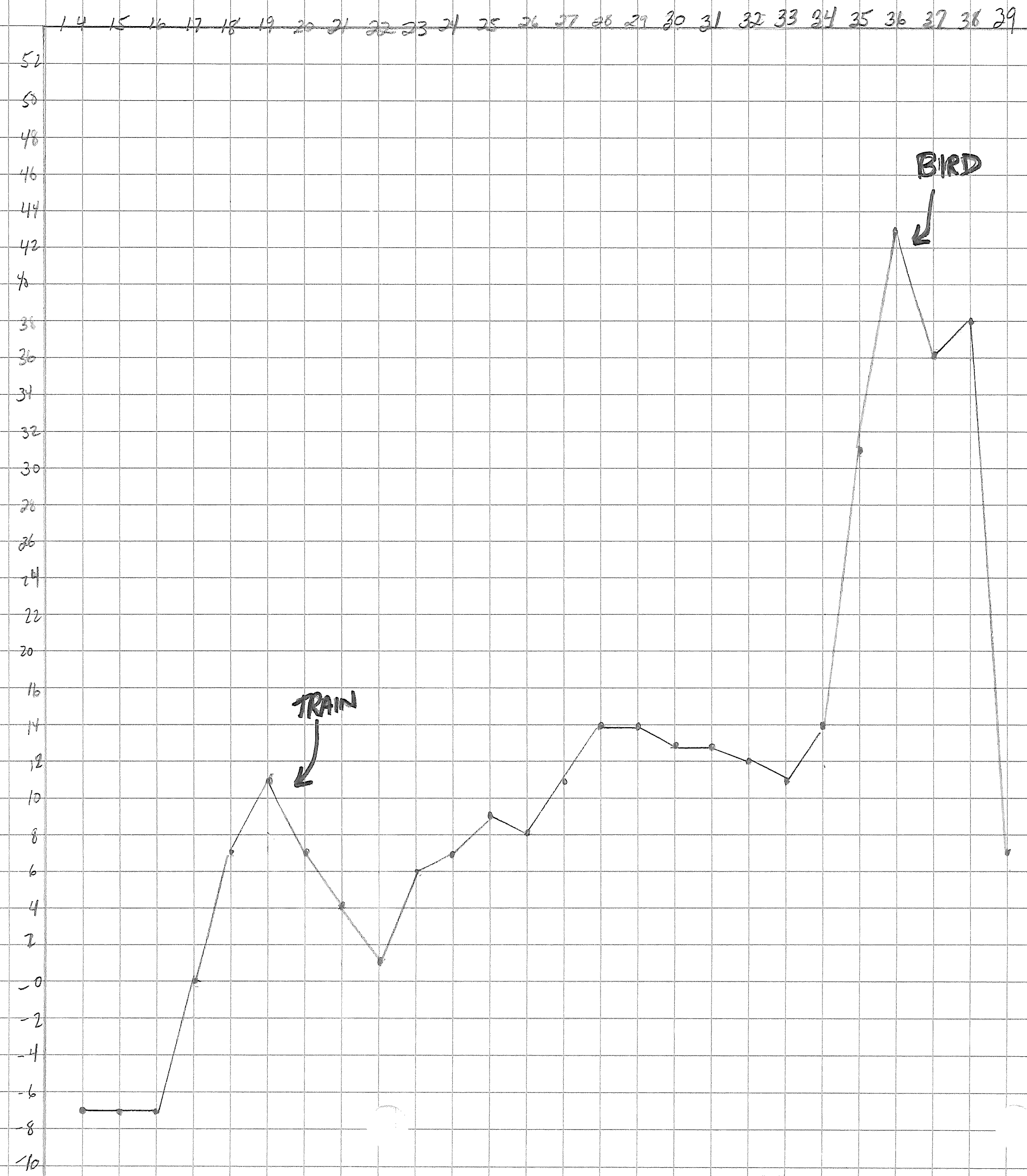
BROAD BAND



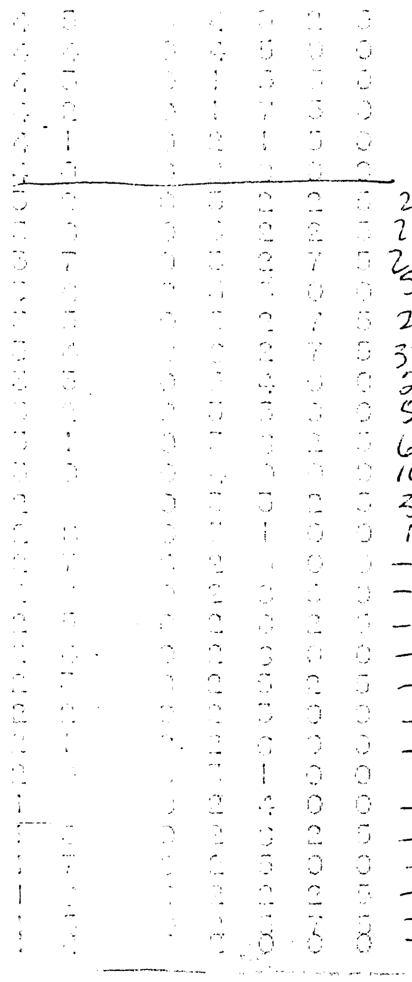
HIGH FREQ BUG BANDS 26,29
31 dBA
ST-107A 1/8 sec



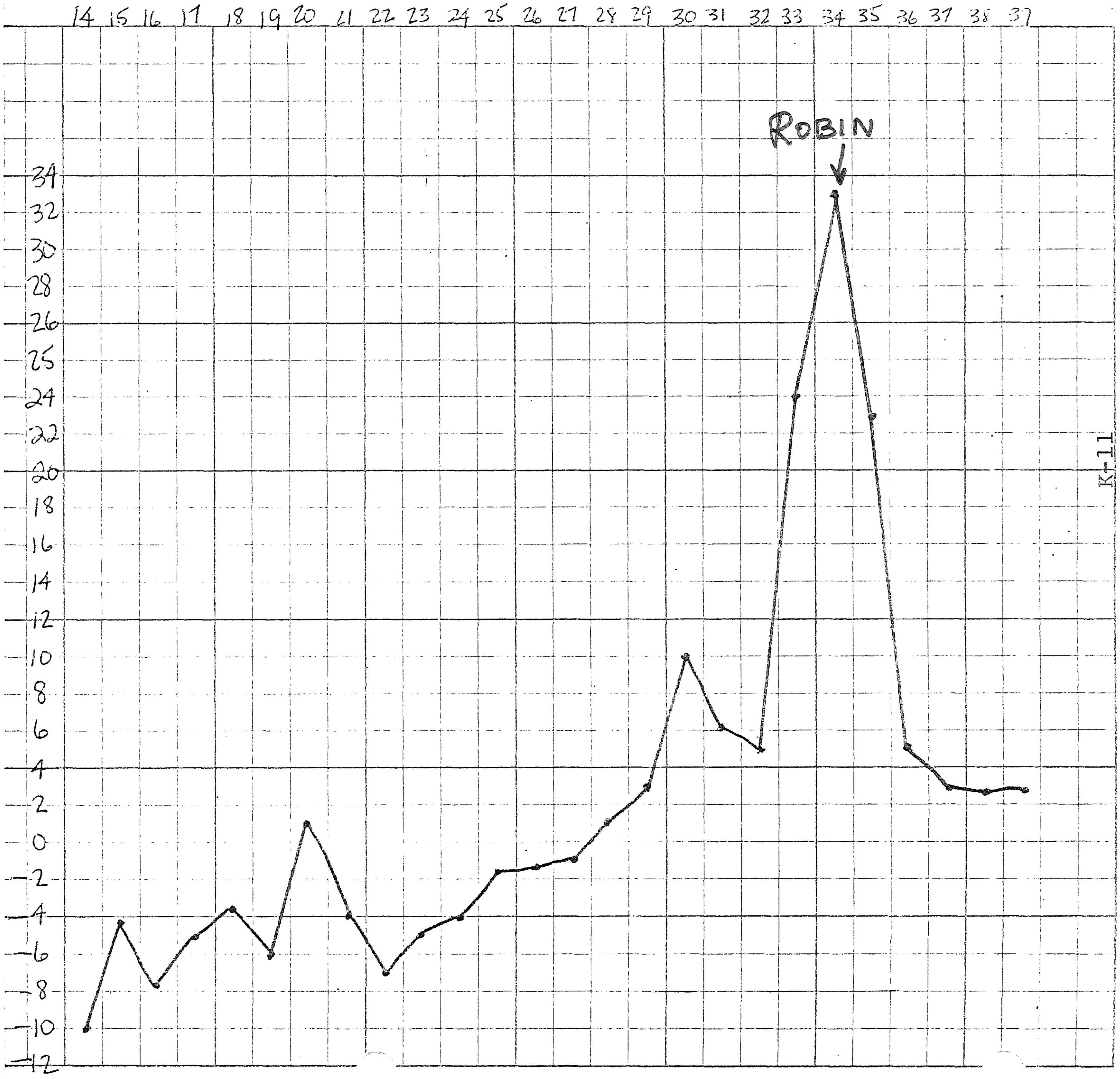
BIRD - 1/8 sec
TRAIN IN LOW FREQ
ST-102A
44 dBA



ST54A (−30)
1 sec
Robin 33 34 35



2.25
2.25
2.75
5.00
22.75
32.75
24.00
5.00
6.25
10.00
3.25
1.00
−1.00
−1.50
−1.75
−4.00
−4.75
−7.00
−4.00
1.00
−6.00
−3.75
−5.00
−7.75
−4.25
−10.00



K-11

APPENDIX L

SUMMARY OF NOISE SOURCES

As described in Section 4.30, several types of artificial noise were heard within the study area. Noise produced by at least three types of activities, mining, logging, and aircraft traffic were commonly found within a specific portion of land. The information given in this appendix summarizes the locations and amounts of use of the above noise producing activities, with the exception of mining. No attempt was made to summarize mining activities due to the fact that the mining technology staff of the Copper-Nickel Project has analyzed this subject in great detail.

Table L-1 lists the locations given in township, range, and section numbers, and equipment used for all logging sales conducted during the noise monitoring study. The thirteen sales are plotted in square mile sections on a map of the study region in Figure L-2. Square mile sections were chosen as arbitrary boundaries and do not necessarily reveal any information as to the distance over which logging noise could be heard. Because on-site logging operations are based on a number of contingencies, such as weather, there is no way of knowing exactly when each sale was operating. Usually logging takes place on a year-round basis with a shutdown in spring for winter thaw-out and equipment repair, and an acceleration of work during the summer.

Table L-3 is a summary of the amount of activities of the three local airports closest to the study region, as seen in Figure L-4. Spring and summer were clearly the busiest months at all three airports due to the influx of tourists and increased fire watches by the U.S. Forest Service.

Logging Sale and Location-Township, Range, and Section Numbers	Dates of Operation	Length of Time of Operation	Saws	Skidders	Trucks	Processors	Feller Bunchers	Bulldozers (Catapiller, D-6)	Front Loaders	Graders	Tractors	Slashers
1. T61N, R12W, Secs. 7, 8	Spring 1976	2 Mos.	6	3	1			1				1
2. Sec. 13 Sale T61N, R12W, Sec. 13	1/76-1/77	5 Mos.	2	2	1			1				
3. E. Blueberry Lake Sale T61N, R12W, Secs. 9, 10	4/76-5/76	2 Mos.	2	2	1						1	
4. Perch Lake Sale T61N, R11W, Sec. 19	4/76-6/76	4 Mos.	1	1	1							
5. T61N, R11W, Sec. 5	4/76-6/76	1 Mo.	1	1	1							
6. T60N, R12W, Sec. 11	1/76-12/76	12 Mos.	2	1							1	
7. T59N, R13W, Sec. 12	9/76-3/77	6 Mos.	6	3	3						1	
8. T57N, R14W, Secs. 28, 29	1976 1977	6 Mos.	5	2	2							1
9. T58N, R13W, Sec. 16	12/76-3/77	4 Mos.	2	1	1							
10. T58N, R13W, Sec. 26	6/77-8/77	3 Mos.	3	2			1			1		1
11. Forest Service Cutting T61N, R11W, Secs. 7, 18	9/77	1 Mo.	1		1							
12. T58N, R14W Secs. 2, 11	1/77-12/77	3 Mos.	6	3	2							
13. Baird Sale T60N, R11W, Secs. 17, 19, 20, 30, 31 T59N, R11W, Secs. 5, 6 T60N, R12W, Secs. 23, 26, 35 T59N, R12W, Secs. 2, 3, 6, 10	6/76-6/77	18 Mos.	12	12	4	1	1	2	1	1		

Table L-1. Logging sales occurring within study region at time of study - location and equipment used.

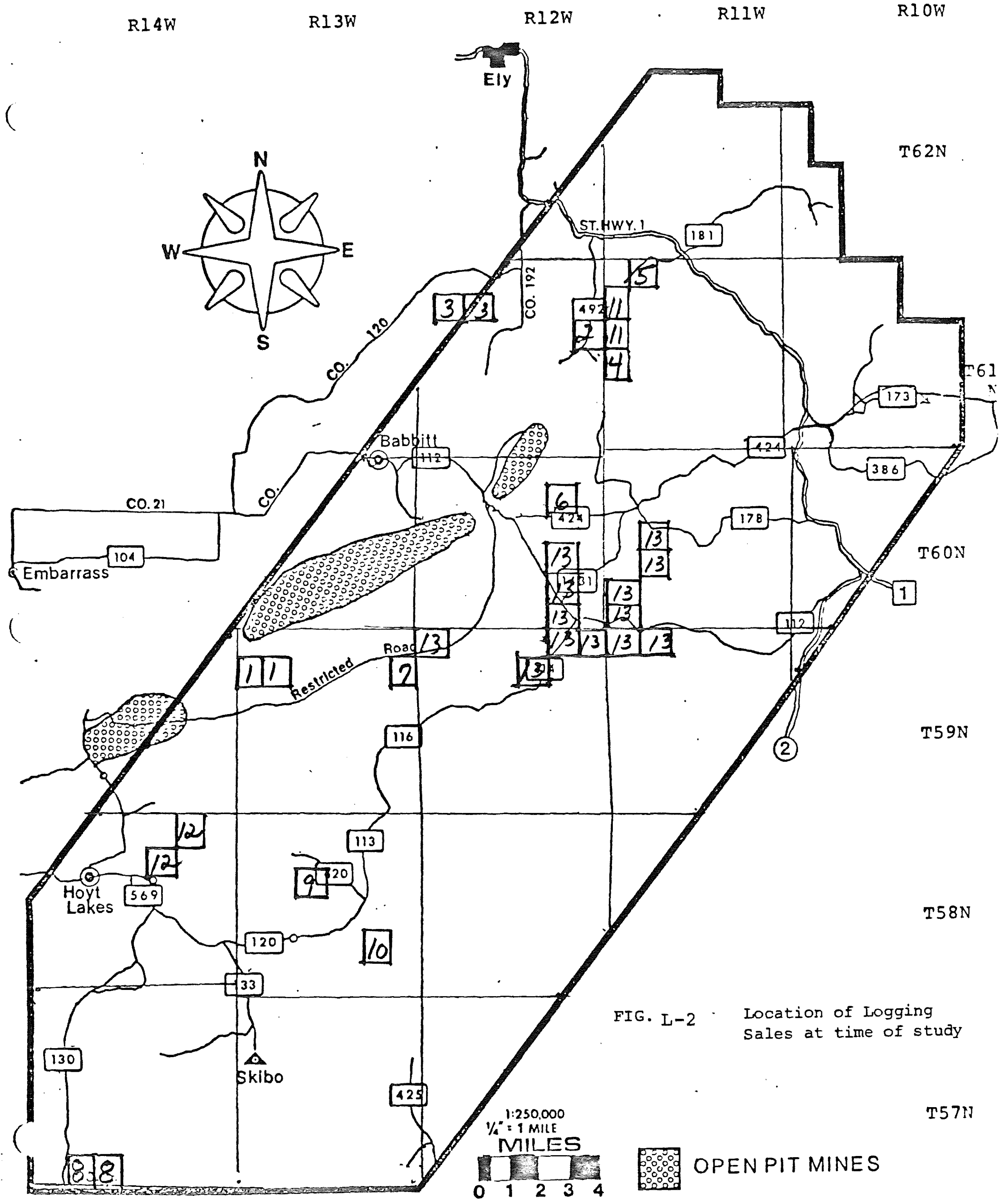


FIG. L-2 Location of Logging Sales at time of study

	Hours of Operation		# Planes/Day		% of Use				
	Winter	Summer	Winter	Summer	Cessna 172	Cessna 185	Beaver	Cessna 180	Twin-Engine Beach
Ely	Nov-Apr 1 8:00 AM-5:00 PM	Apr-Oct 31 8:00 AM-8:00 PM	4 (No Jets)	12 (1 Jet)	60-70%				
Wilderness Wings (Shagawa Lk)	Dec-Apr *	May-Sept	10	60-70	60%	20%	10%		10%
USFS (Shagawa Lk)	Oct-Apr	May-Sept	24	168			75%	25%	

Comments: Ely - 50% of planes are Mesaba Airlines; 50% private planes; 1 east-west runway; largest plane: G-12 Jet (14 pass.); smallest: Stardut 2 pass. biplane.

* Wilderness Wings - fall hours: Sept-Nov (freeze-up); Nov-Dec: all business shifted to Ely Airport until ice one foot thick. Jan-Apr: training flights; east-west take-off.

USFS - based on year from Oct, 1976-Oct, 1977.

Table L-3 Summary of aircraft traffic from the three local airports.

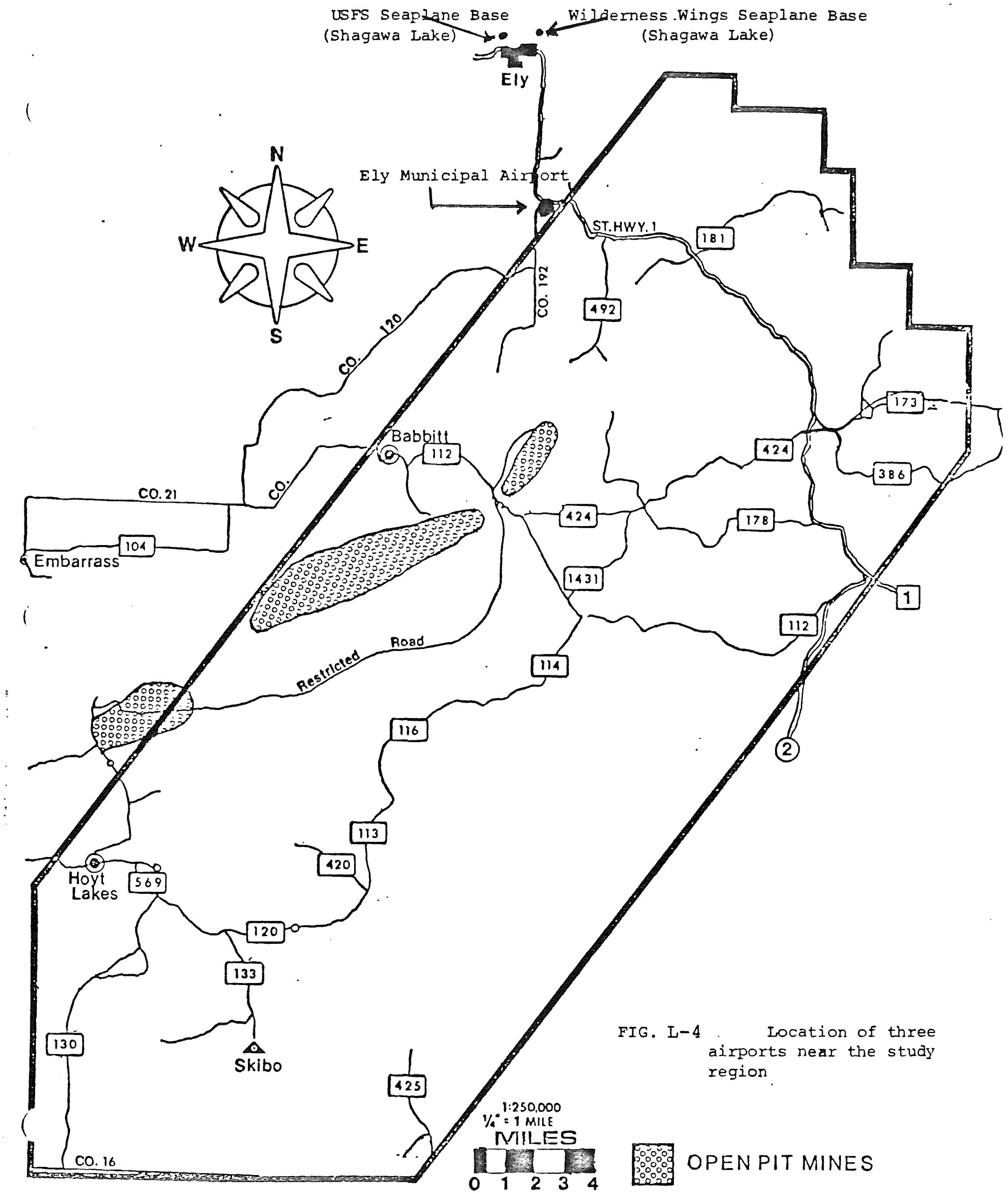


FIG. L-4 Location of three airports near the study region

APPENDIX M

SPECTRAL PLOTS OF ARTIFICIAL NOISE

This section includes third octave band plots, dBA filtered, of the most common artificial noises monitored. To emphasize peaks within certain bands, segments of background levels are superimposed over some of the graphs. (Due to time limitations it was not possible to analyze background data for all plots.) With each plot is given the tape number, ST-00, the bands at which the peaks are located, the specific noise analyzed, and the averaging time for the noise as plotted.

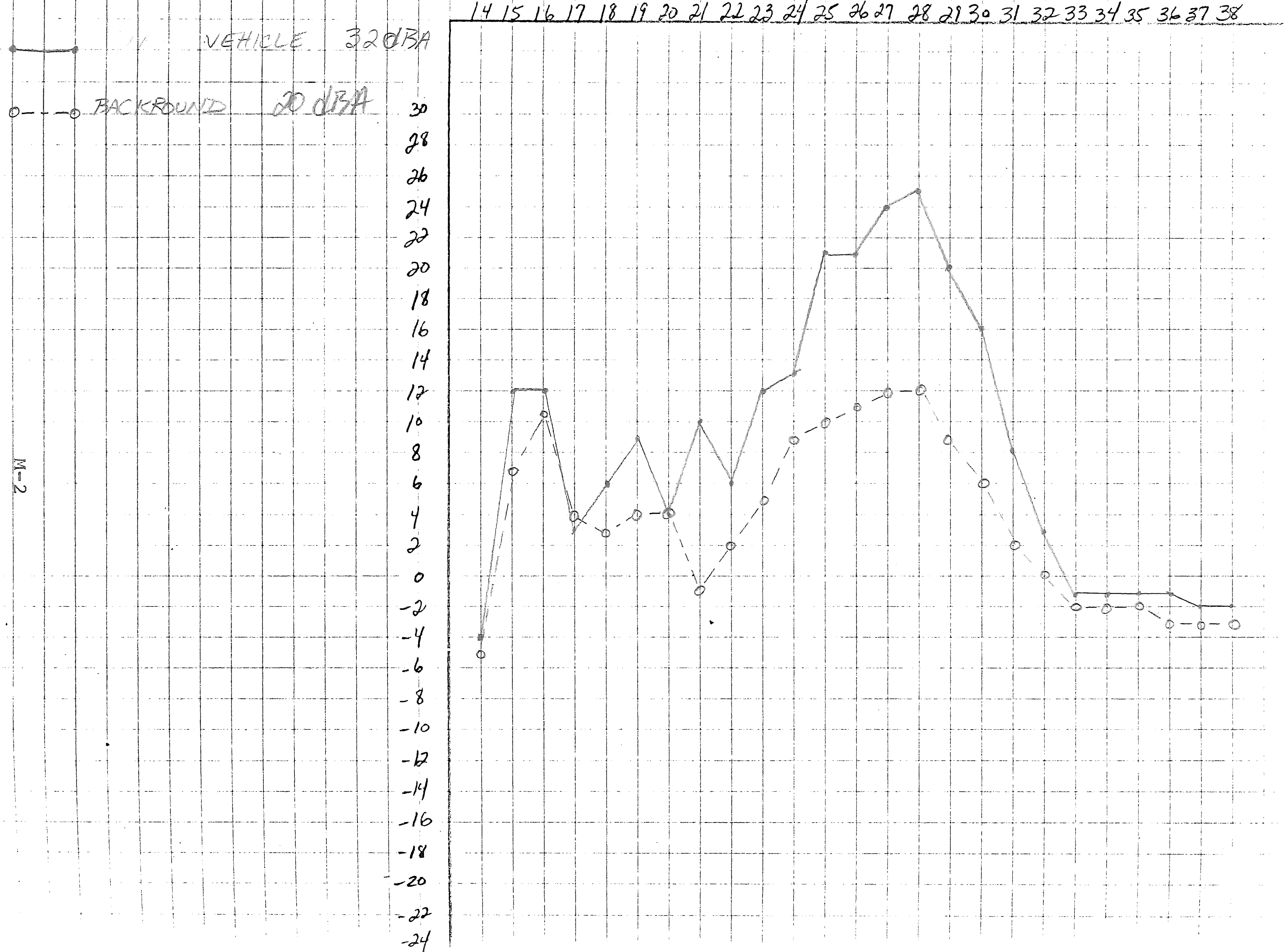
Third octave bands are given by their band number. For ease of interpretation, a conversion table is given below:

Band Number	Center Frequency (Hz)	Band Number	Center Frequency (Hz)
14	25	27	500
15	31.5	28	630
16	40	29	800
17	50	30	1,000
18	63	31	1,250
19	80	32	1,600
20	100	33	2,000
21	125	34	2,500
22	160	35	3,150
23	200	36	4,000
24	250	37	5,000
25	315	38	6,300
26	400		

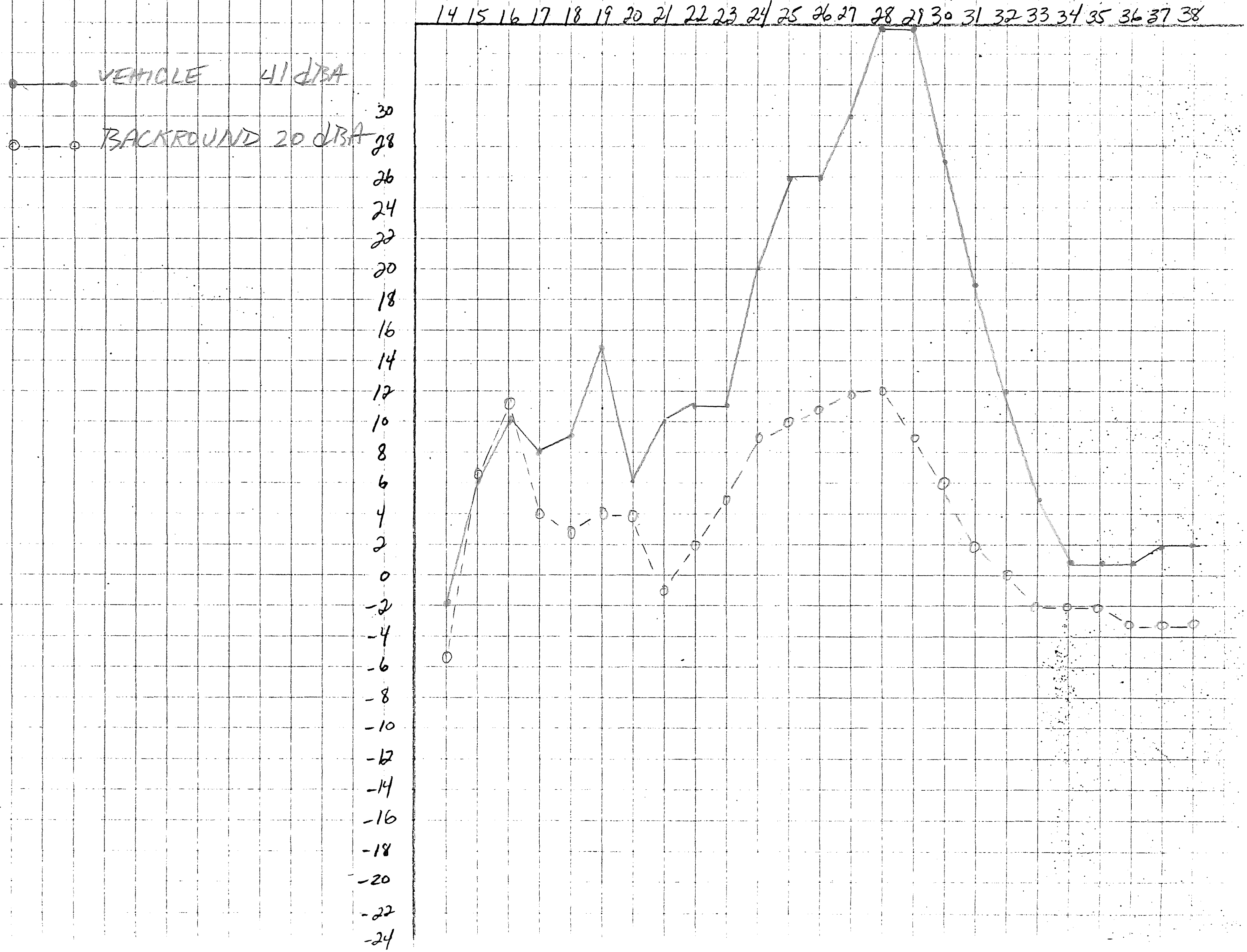
Artificial sounds plotted for third octave bands were from the following sources:

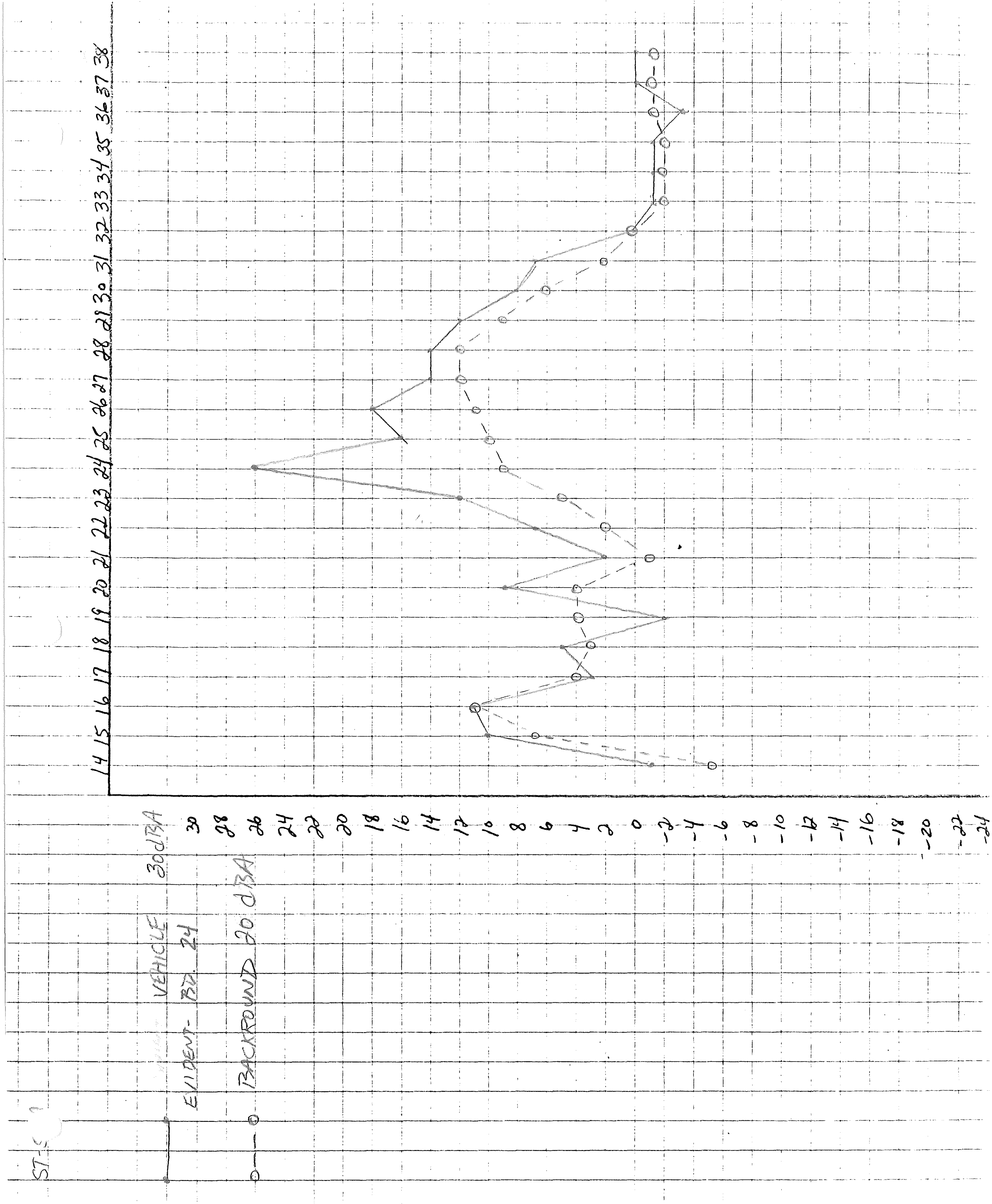
	Page
Unknown Vehicle (probably from mining activities)	M-2 - M-5
Blast	M-6
Squeaking of Brakes (probably from mines)	M-7
Logging Truck	M-8
Train Horn and Whistle	M-9;M-10
Crashing of Railroad Cars from Linde Oxygen Plant	M-11;M-12
Jet Flyover	M-13
Small Plane	M-14

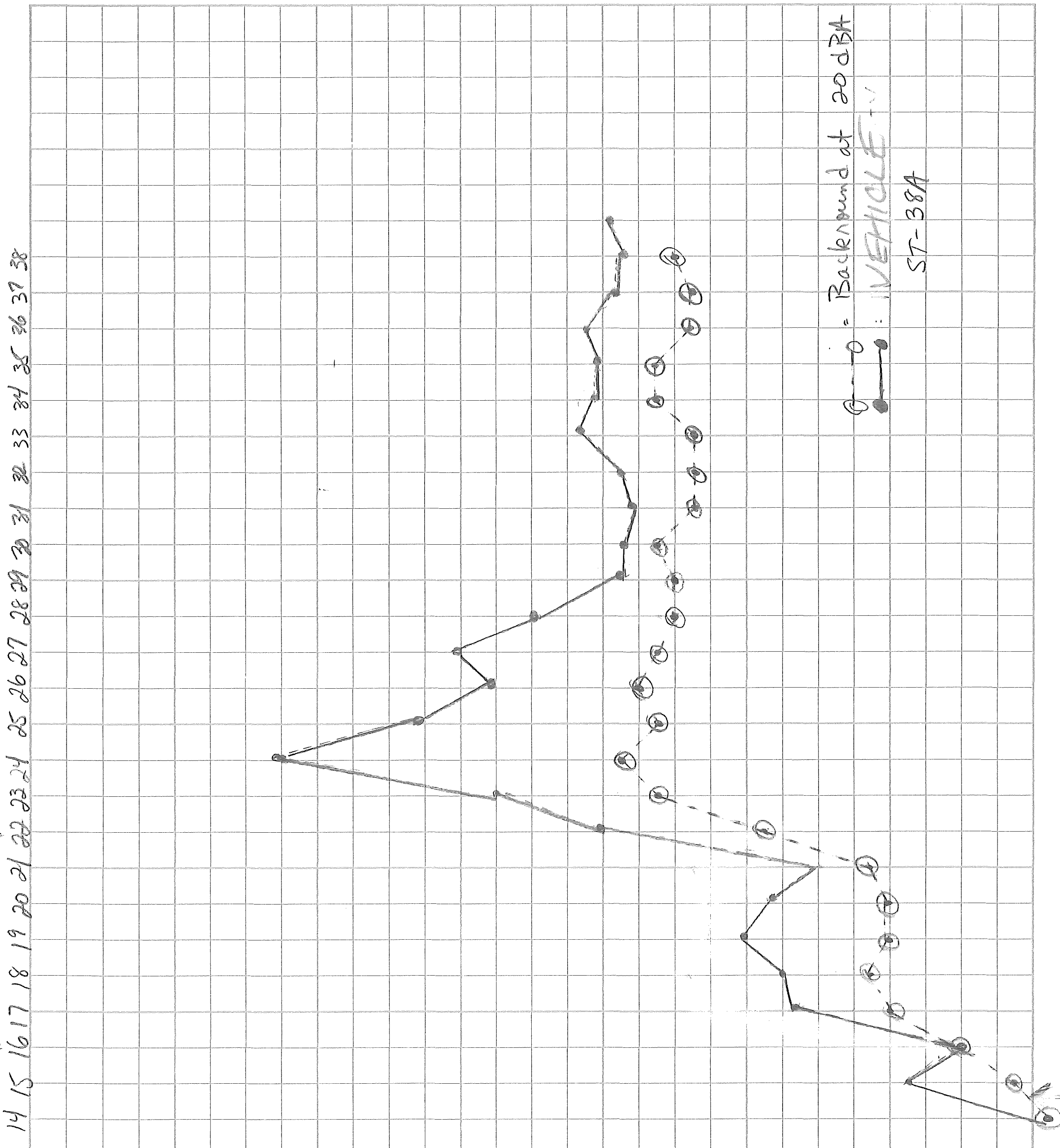
ST-5TA

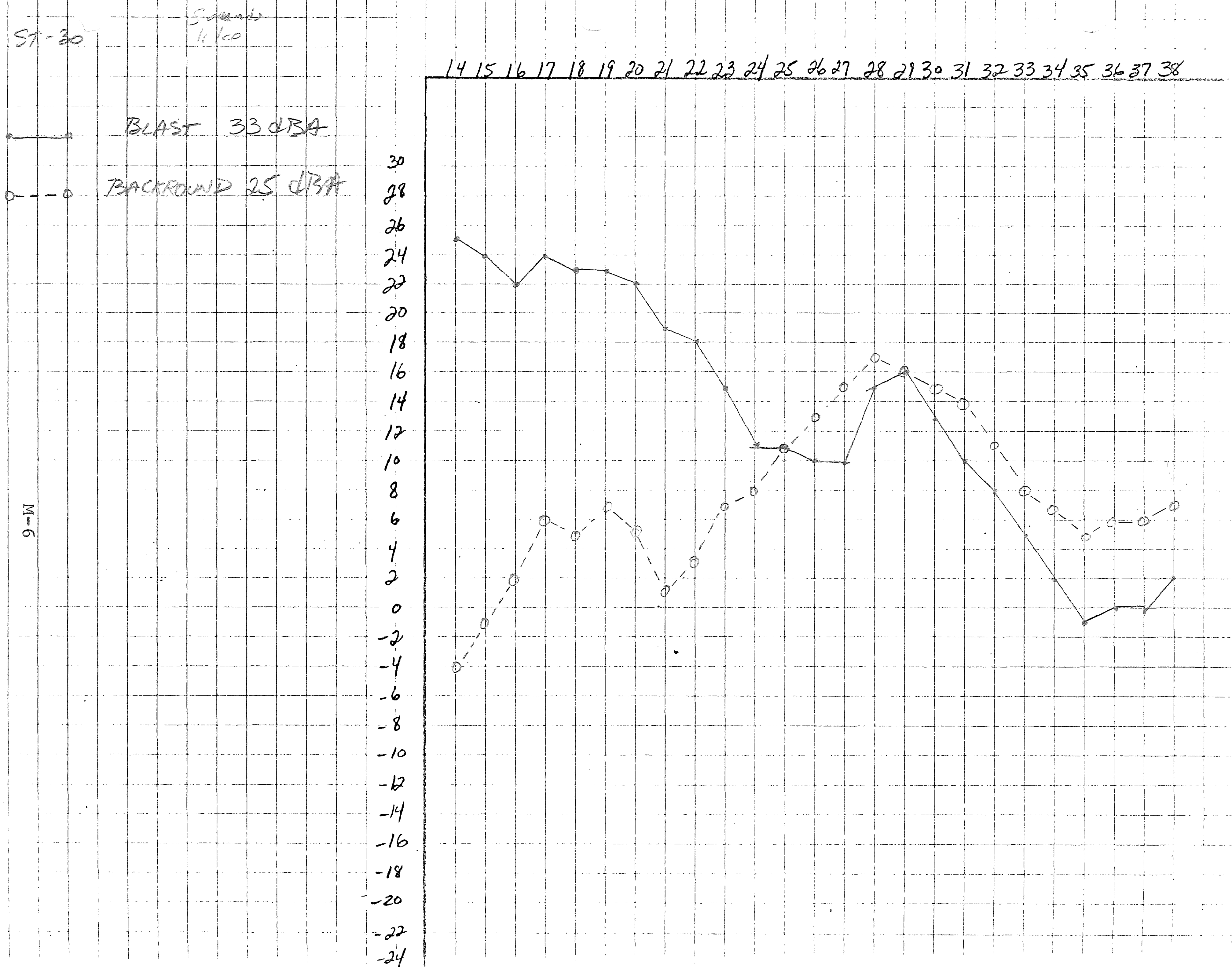

VEHICLE 32 dBA
BACKROUND 20 dBA
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38

ST-57A

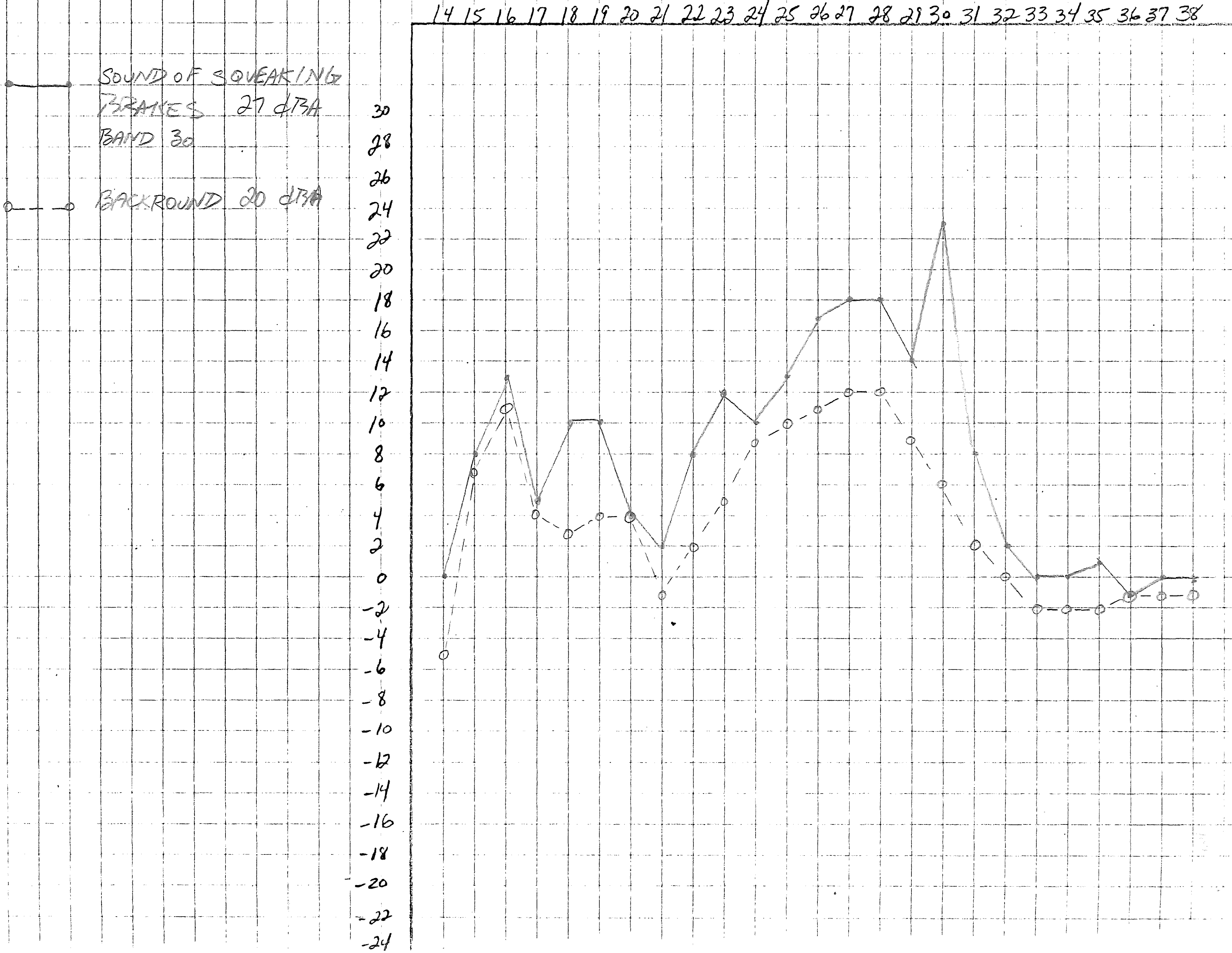

VEHICLE 41 dBA
BACKROUND 20 dBA
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24


ST-
VEHICLE 30dBA
EVIDENT - BD 24
BACKROUND 20 dBA
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38

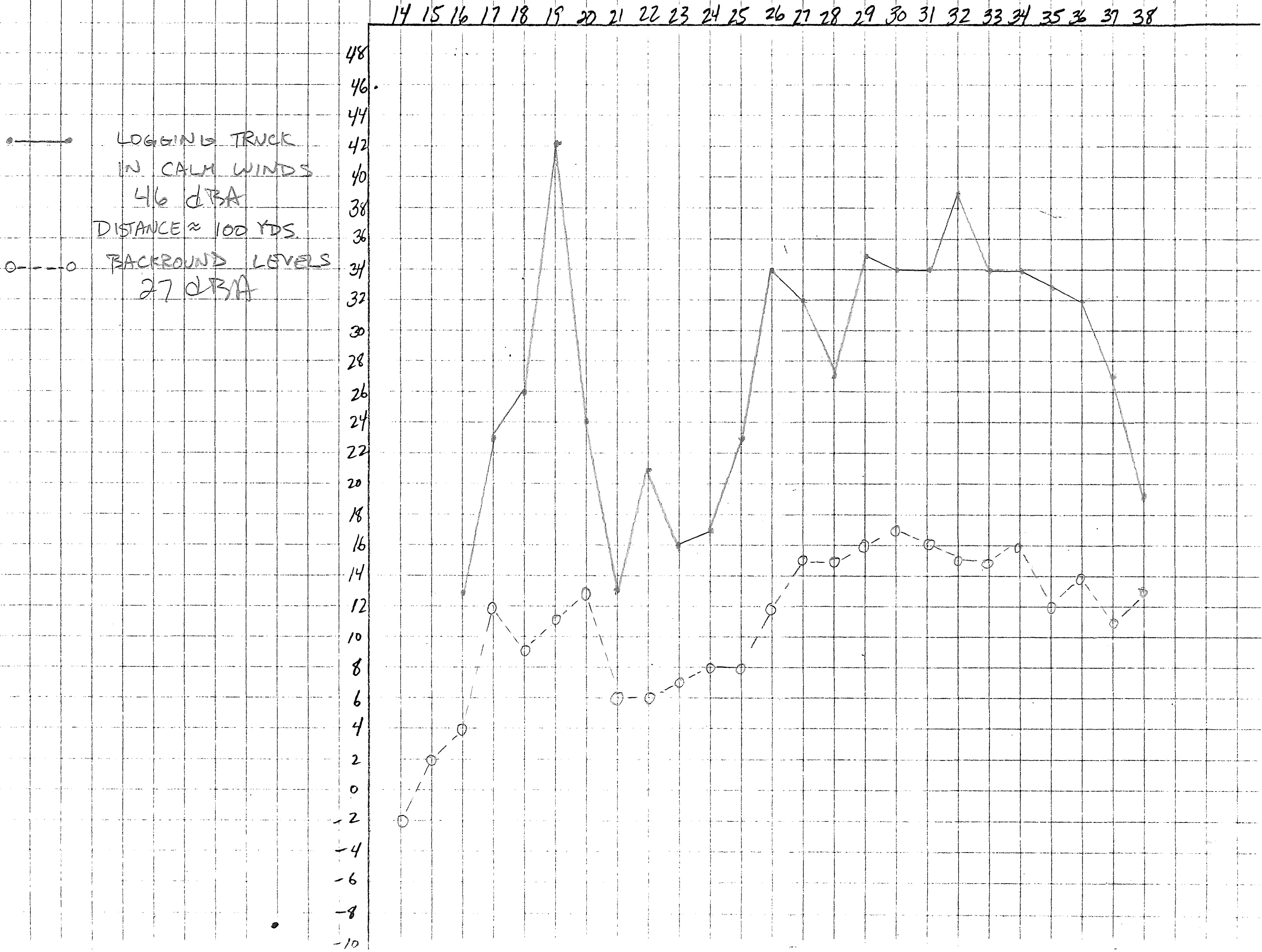

○ = Background at 20 dBA
● : VEHICLE
ST-38A
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0 -2 -4 -6 -8 -10 -12 -14


ST-30
Sands
11/60
BLAST 33 dBA
BACKROUND 25 dBA
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0 -2 -4 -6 -8 -10 -12 -14 -16 -18 -20 -22 -24

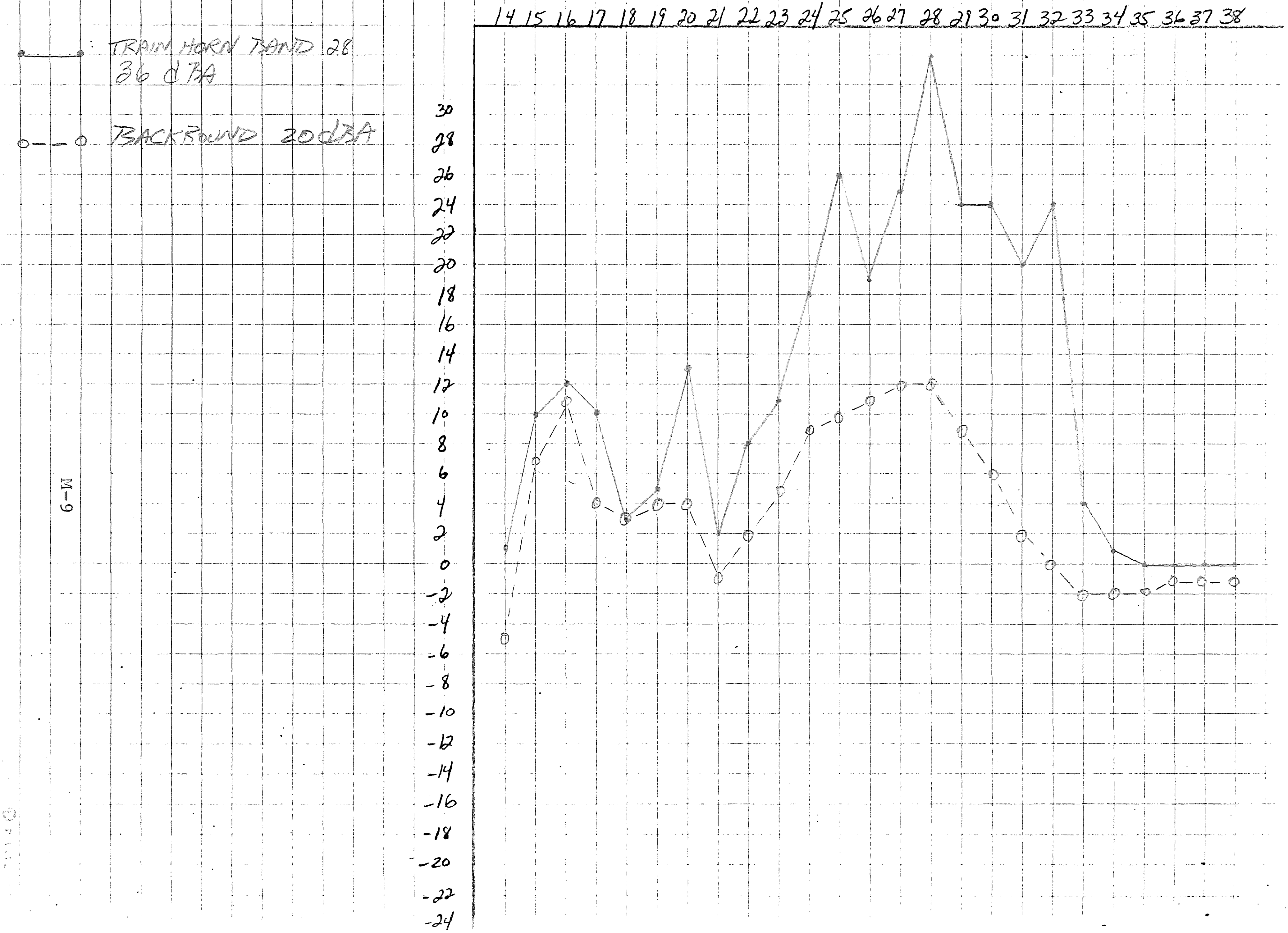
ST- 4

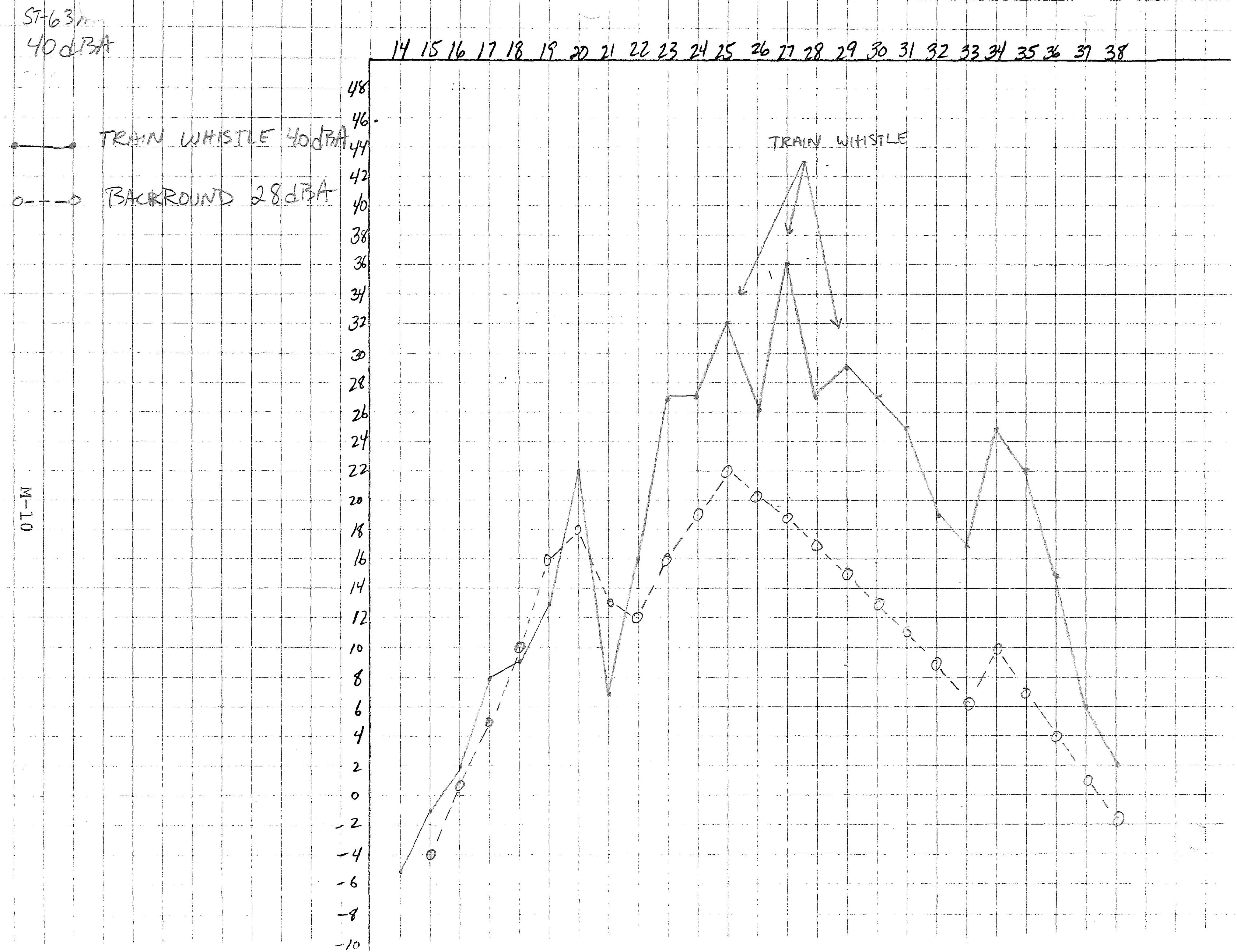

SOUND OF SQUEAKING BRAKES 27 dBA
BAND 30
BACKROUND 20 dBA
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24

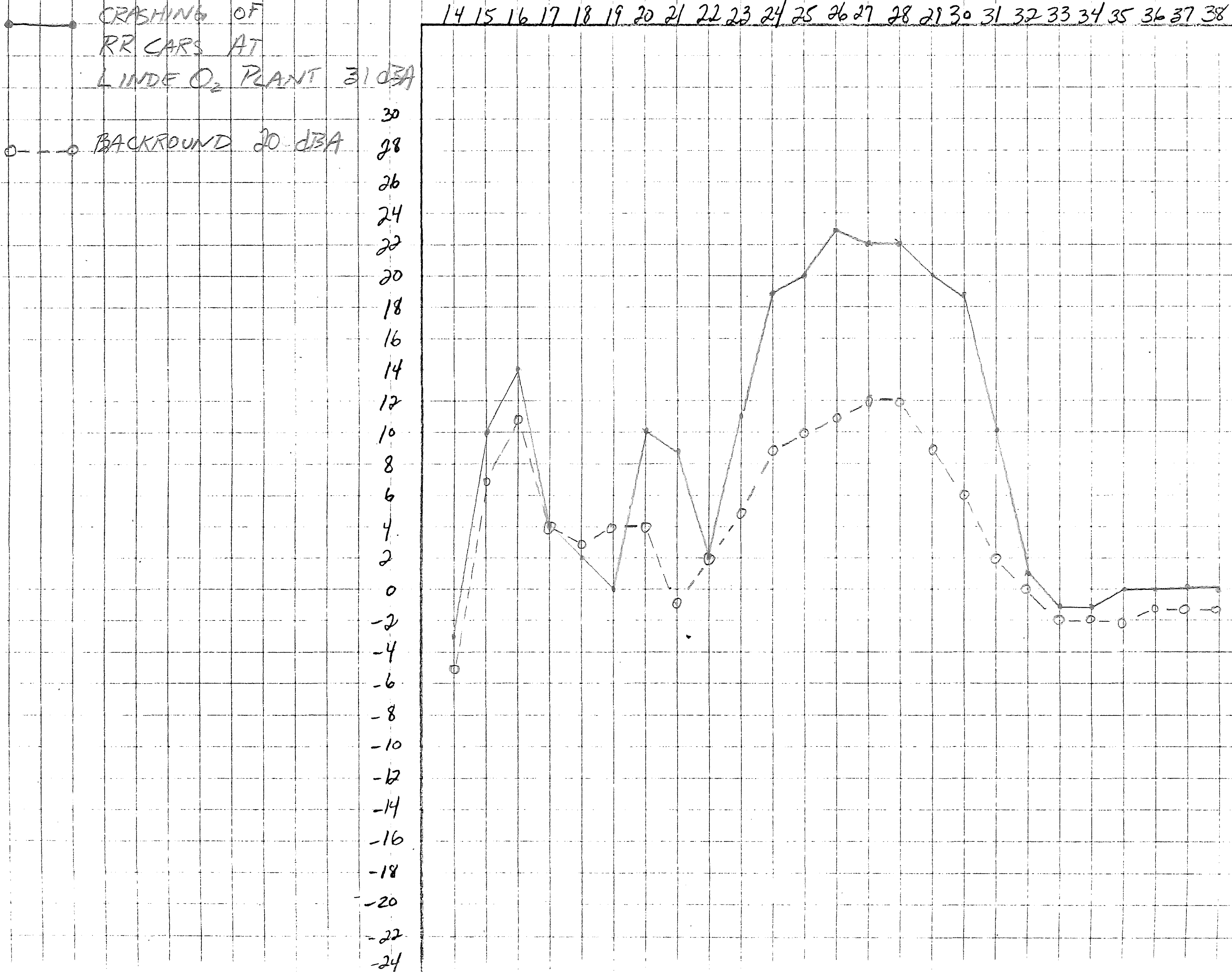
ST-74A

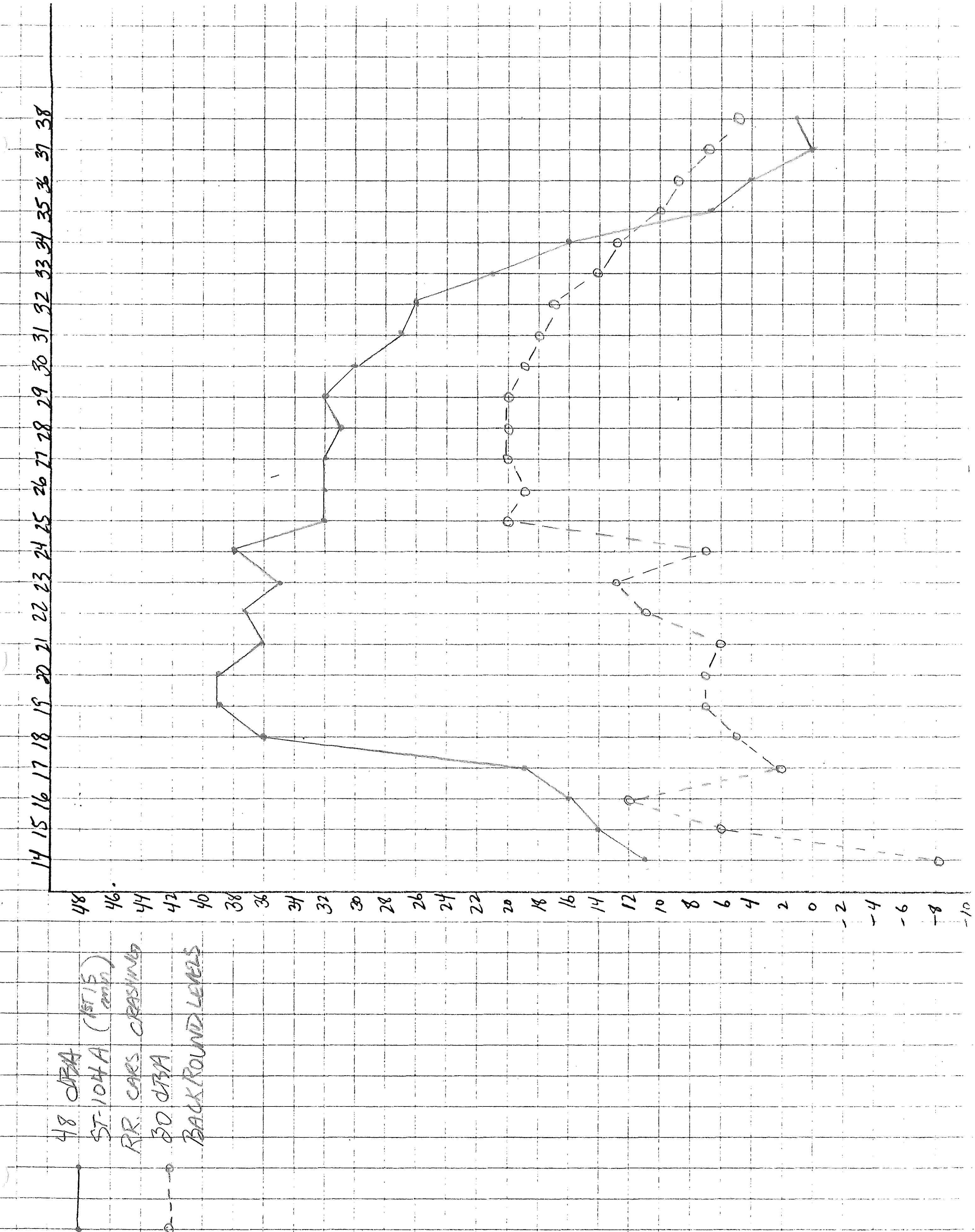

LOGGING TRUCK IN CALM WINDS 46 dBA
DISTANCE ≈ 100 YDS.
BACKROUND LEVELS 27 dBA
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10

ST-57A

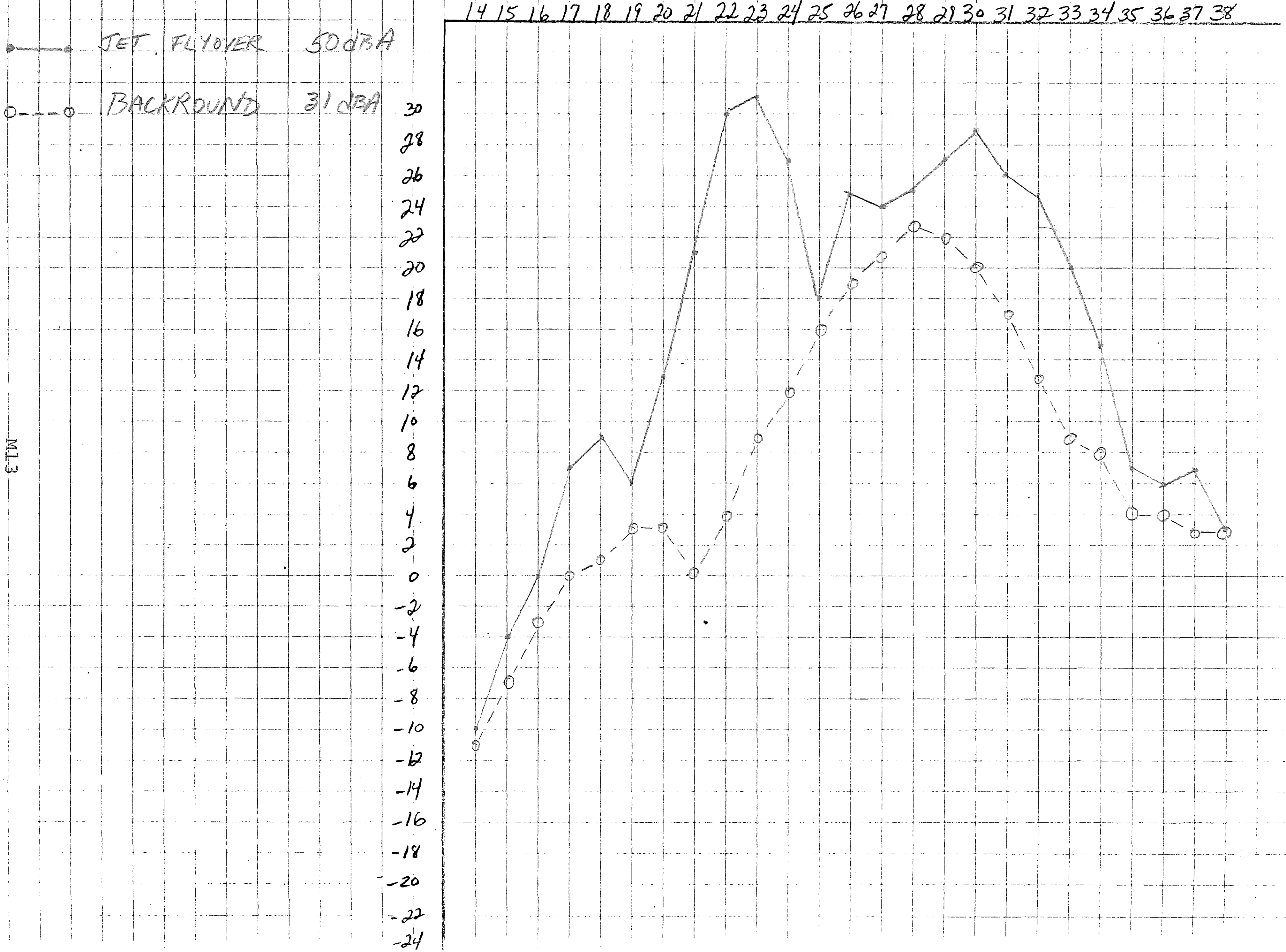

TRAIN HORN BAND 28
36 dBA
BACKROUND 20dBA
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24


ST-63A
40dBA
TRAIN WHISTLE 40dBA
BACKROUND 28dBA
TRAIN WHISTLE
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10


CRASHING OF RR CARS AT LINDE O_2 PLANT 31 dBA
BACKROUND 20 dBA
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24


48 dBA
ST-104A (1st 15 min)
RR CARS CRASHING
30 dBA
BACKROUND LEVELS
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10

ST-5

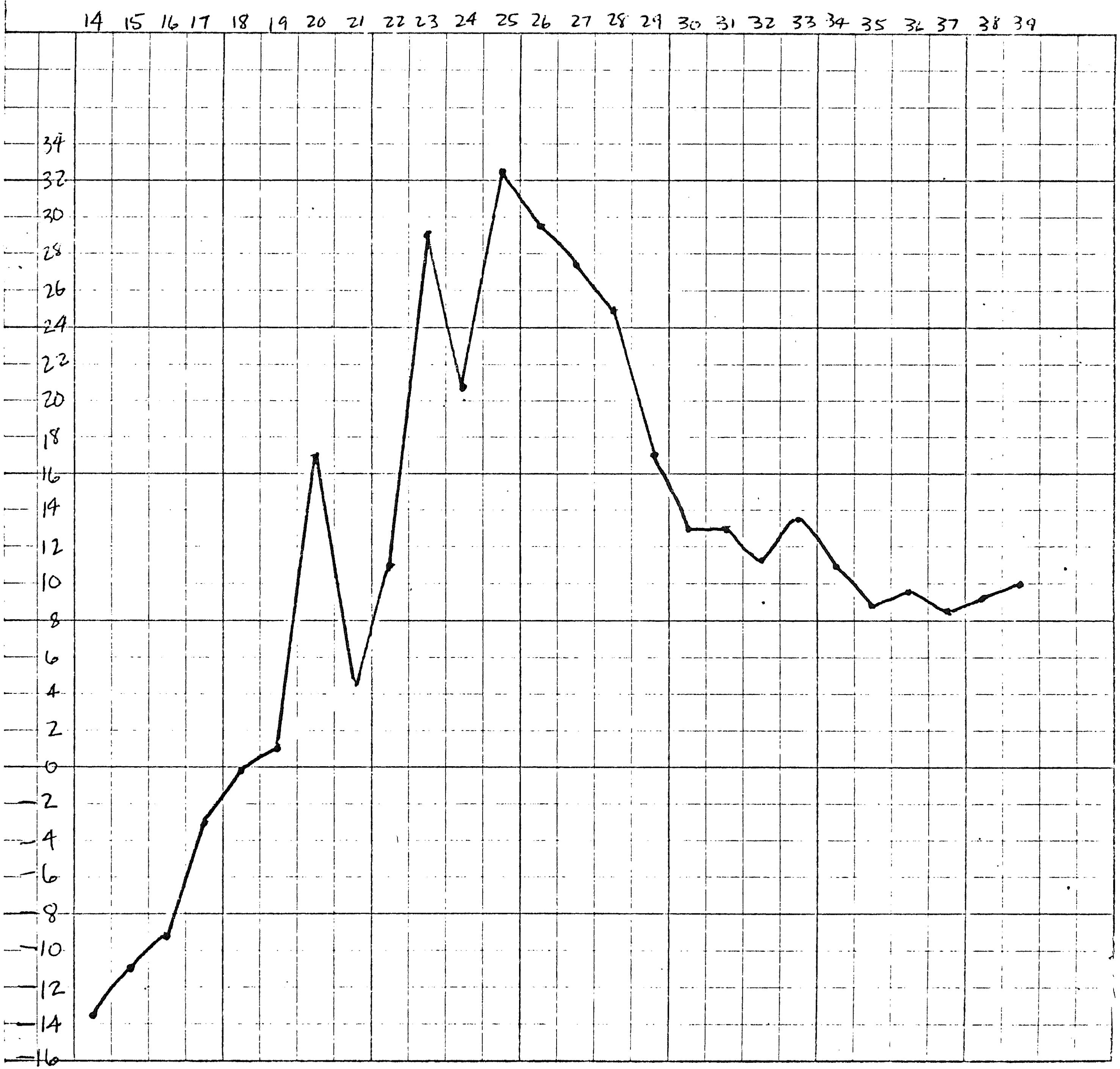

JET FLYOVER 50dBA
BACKROUND 31dBA
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24

ST38 (-30)
TC307
8 sec
Plane

5ds 20,23,252627.

M-14

10.00
9.25
8.50
9.75
9.00
11.00
13.75
11.25
12.75
12.75
17.00
24.75
27.25
29.50
32.50
20.75
29.00
11.00
4.50
17.25
1.00
.25
− 3.25
− 9.25
− 11.00
− 13.75



APPENDIX N

TEST PROCEDURES

		Page
CN-1	Metrosonic db-601 or db-602 (on single interval mode)	N-2
CN-2	General Radio Sound Level Meter 1565-C	N-5
CN-3	Nakamichi Cassette Tape Recorder	N-8
CN-4	Nakamichi Cassette Tape Recorder Plus Metrosonic db-601 or db-602 (single interval mode)-in Field	N-12
CN-5	Nakamichi Cassette Tape Recorder Plus General Radio Sound Level Meter 1565-C	N-17
CN-6	Metrosonic db-602 on Multiple Interval Mode	N-21
CN-7	Nakamichi Cassette Tape Recorder Plus Metrosonic db-601 or db-602 (single interval mode)-Analysis in Lab	N-24
CN-10	Nakamichi Cassette Tape Recorder and Teac Reel to Reel Tape Recorder	N-27
CN-11	Modified Metrosonic Wind Inhibit	N-30
CN-12	Magnetic Tape Bulk Eraser	N-32
CN-13	Real Time Analyzer-Third Octaves (in lab)	N-33

TEST PROCEDURE CN-1

OBJECTIVE

Acoustical measurement using Metrosonic db-601 Sound Level Analyzer or Metrosonic db-602 Sound Level Analyzer set on "single Interval" mode.

INSTRUMENTATION

1) Metrosonic db-601 Sound Level Analyzer, Serial #1108 with low level input or Metrosonic db-602 Sound Level Analyzer, Serial #1109 with low level input.

2) Bruel and Kjaer (B&K) 1" condenser microphone, Model #4161, Serial #55639.

3) General Radio (GR) preamplifier, Model #P42, Serial #3358.

4) B&K random incidence corrector UA0055.

5) GR multifrequency field calibrator, Model #1562-A, Serial #19045.

6) Microphone windscreens: 1 large cylindrical windscreen, 9" in diameter with a conical top and wrapped in 1/4" acoustic foam, designed for the Copper-Nickel Noise Program by Midwest Acoustics; 4" foam B&K Windscreen UA0207.

7) Remote inhibit switch to Metrosonic db-601 or db-602 to switch Metrosonic from "Normal" to "Standby" function with an extension cord of 100 feet (designed by Midwest Acoustics) (optional).

8) Psychro-dial CP-147 electric psychrometer, Serial #2014.

9) Kalt Tripod, Model #MR-913.

10) Weatherama Brass Case Barometer, Model #2-130B.

11) 100' extension cable, 3-conductor shielded, ALPHA #1521.

12) Sears stopwatch, Model #E-5.

13) Clipboard, data sheet, pen.

PRE-SURVEY EVALUATION

1) Weather conditions

-Measure temperature and relative humidity using psychrometer; record on data sheet.
-Record wind data obtained from Weather Service located in Ely and/or Isabella for given hour.
-Record atmospheric pressure from barometer.

2) Location

-Record on data sheet location of site (site listing and description) and any other observations or site conditions.

INSTRUMENT CALIBRATION

1) Switch GR P42 to "X1" and "200V" positions.

2) Replace random incidence corrector with regular microphone grid.

3) Connect all cables as shown on schematic diagram.

4) Set function switch on db-601 or db-602 to "Standby" at least one minute for warm up, input switch to "MK A" and response speed to "Fast." Turn display switch to "Sound Level."

5) Set GR calibrator at 1,000 Hz and place over microphone. Adjust calibration screw on unit by turning all the way to the right, and then gradually to the left until "113" appears in the digital readout.

6) Remove calibrator carefully to avoid damage to the microphone.

7) Note calibration tone on data sheet.

8) Mount microphone system on tripod four feet off the ground.

SURVEY PROCEDURE

1) Replace regular microphone grid with random incidence corrector, change GR P42 from "X1" to "X10" position, and place windscreens over microphone. Set microphone system 100' from Metrosonic db-601 or db-602 in pre-selected site.

2) If needed, connect remote inhibit cable into db-601 or db-602 switch remote inhibit to "Off" position (optional).

3) Turn function switch to "Clear Memory" position and press "Activate" button. Check to see if memory is cleared by turning display switch to "Test Duration." Digital readout should read "00." Turn "Display" switch off.

4) Switch function to "Normal" on db-601 or "Single Interval" on db-602. If remote inhibit switch is to be used, walk with remote inhibit to a point 100' from unit. Turn remote inhibit switch to "Analyzer" on.

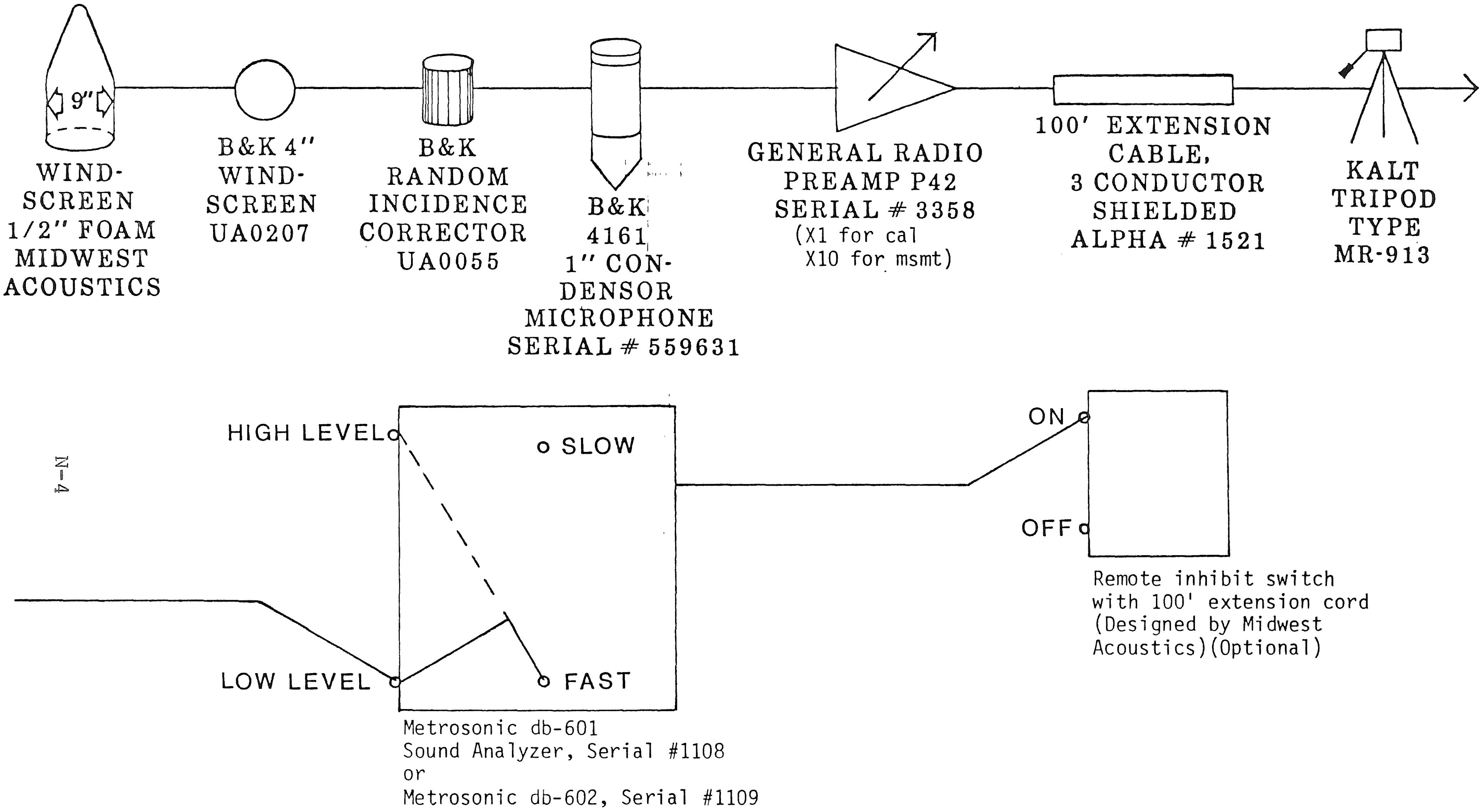
5) If remote inhibit is used, shut down system, when desired, by switching remote inhibit to "Off."

DATA LOGGING

1) After test is completed, switch function on db-601 or db-602 to "Standby" and the display switch to "L_n Compute." Record desired L values on data sheet by adjusting the "Single Interval" dials accordingly. 20 dB should be subtracted from each reading because system was calibrated on 0 dB gain, but the survey was conducted with a 20 dB gain.

2) Recalibrate, record calibration level, and disassemble system.

3) Record information from data sheet on weekly survey forms.



TEST PROCEDURE CN-1

TEST PROCEDURE CN-2

OBJECTIVE

Acoustical measurement using General Radio (GR) Sound Level Meter, Model #1565-C.

INSTRUMENTATION

1) GR Sound Level Meter, Model #1565-C, Serial #21270.

2) Bruel and Kjaer (B&K) 1" condenser microphone, Model #4161, Serial #559631.

3) GR preamplifier P42, Serial #3358.

4) B&K random incidence corrector UA0055.

5) 18 volt power supply 3 1/2x4"x5" designed by Midwest Acoustics.

6) GR multifrequency acoustical calibrator, Model #1562-A, Serial #19045.

7) Microphone windscreens: 1 large cylindrical windscreen, 9" in diameter with a conical top wrapped in 1/4" acoustic foam, designed by Midwest Acoustics; 4" B&K Windscreen UA0207.

8) 100' extension cable, 3-conductor shielded, ALPHA #1521.

9) Cables (Midwest Acoustics)

-1' 3-conductor shielded male switchcraft plugs on either end.
-1' 3-conductor shielded female switchcraft plugs on either end.

10) Psychro-dial battery powered psychrometer CP-147, Serial #2014.

11) Weatherama Brass Case Barometer, Model #2-130B.

12) Kalt Tripod, Model #MR-913.

13) Sears stopwatch, Model #E-5.

14) Clipboard, data sheet, checkmark data sheet, pen.

15) Pioneer headphones SE-305 (optional) with necessary adaptors:

-2 ended female phone plug adaptors.
-4' cable--phone plug and mini phone jack.

PRE-SURVEY EVALUATION

1) Weather Conditions

-Measure temperature and relative humidity using psychrometer; record on data sheet.
-Record barometric pressure from barometer.
-Record wind data from Weather Service located in Ely and/or Isabella.

2) Location

-Record on data sheet location of site (site listing and description) and any other observations or site conditions.

INSTRUMENT CALIBRATION

1) Assemble system as shown on schematic sketch, omitting windscreens.

2) Replace random incidence corrector with regular microphone grid.

3) Switch 18 volt power supply to "On."

4) Switch sound level meter to "On" and check battery condition by pushing "Batt" button. Indicator should fall in the "Battery-Good" range.

5) Switch preamplifier to "X1" and "200V" positions.

6) Switch sound level meter to "A" weighting and "Fast" response.

7) Switch acoustical calibrator to 1,000 Hz and place over microphone.

8) Because the B&K microphone is more sensitive than the microphone designed for the GR Sound Level Meter, the indicator should read "123" (as opposed to "113"). If not, turn calibration screw all the way to the right and gradually back to the left until the needle sits at "123." Note calibration tone on data sheet.

9) Carefully remove calibrator so as to avoid damage to the microphone.

SURVEY PROCEDURE

1) Replace regular microphone grid with random incidence corrector, switch preamplifier to X10, and place windscreen over microphone.

2) Set microphone system 100' from sound level meter.

3) Conduct a short survey to determine sound level limits on the checkmark data sheets. Label the limits.

4) Start stopwatch and record the sound level that appears every 10 seconds by placing an "X" in the appropriate box. Any unusual noise(s) can be indicated with special symbols.

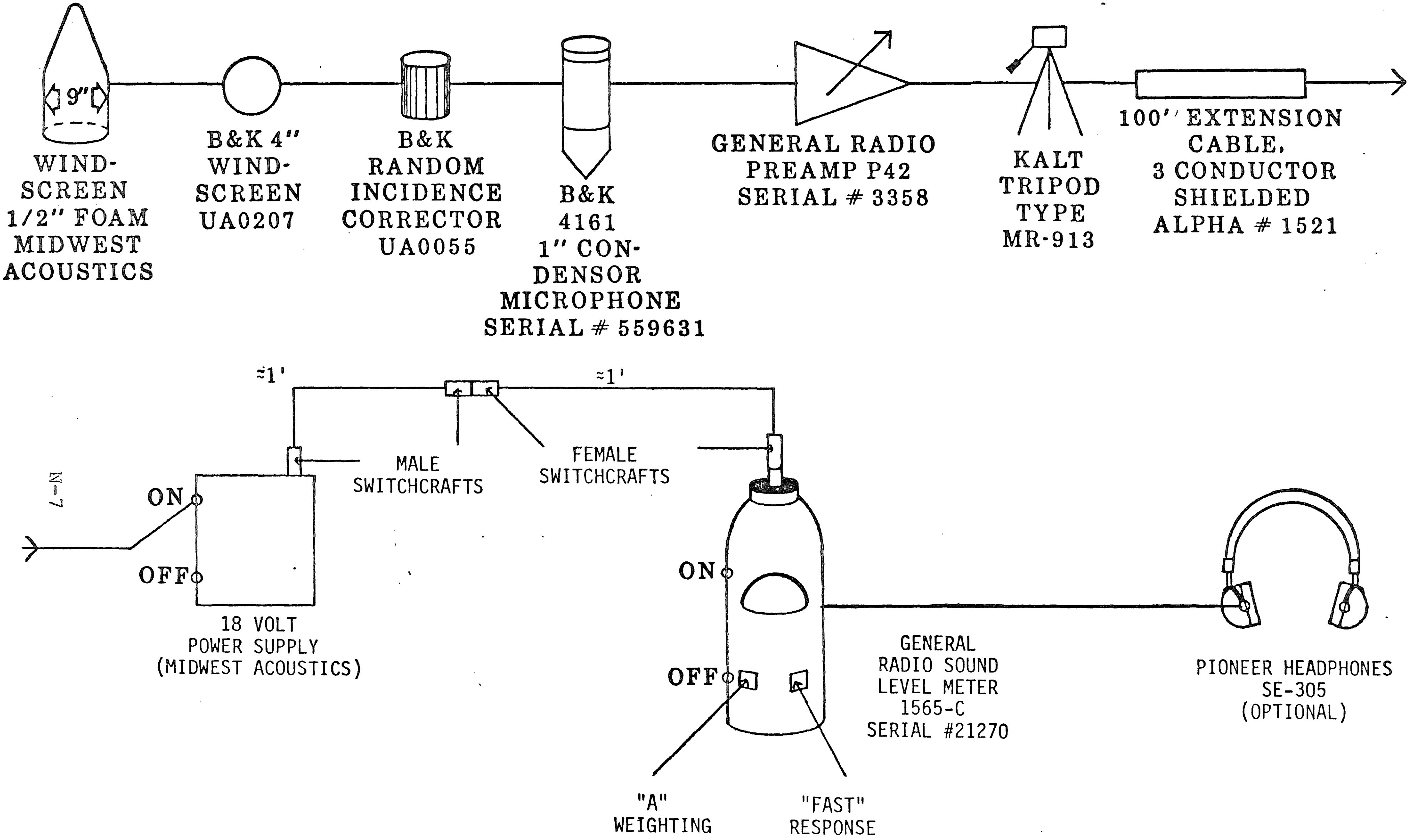
5) Note on data sheet sound sources and any comments or observations.

DATA LOGGING

1) After survey is completed, count down the appropriate percentages to compute desired L_n values. For example, if 180 readings were taken, the L_{10} would be the 18th reading, counting down from the top. Record L_n values on noise data sheets and weekly summary forms. Because system was calibrated 10 dB higher than the actual calibration tone and because test was conducted with a 20 dB gain from preamplifier, subtract 30 dB from all computed L_n values before logging data.

2) Recalibrate system and note on data sheet where indicator needle falls.

3) Disassemble system, and make sure all switches are "Off."



TEST PROCEDURE CN-2. Acoustical measurement using general radio sound level meter 1565-C.

TEST PROCEDURE CN-3

OBJECTIVE

Acoustical recording using Nakamichi 550 Magnetic Cassette Tape Recorder.

INSTRUMENTATION

1) Nakamichi 550 Cassette Tape Recorder, Serial #57714.

2) Metrosonic db-601 Sound Level Analyzer, Serial #1108 or General Radio (GR) Sound Level Meter 1565, Serial #21270.

3) 2 Bruel and Kjaer (B&K) 1" condenser microphones, Model #4161, Serial #55639 and #580385*.

4) 2 GR preamplifiers, Model #P42, Serial #3358 and #3272*.

5) 2 18 volt power supplies: 3 1/2"x4"x5" and 1 1/2"x3"x5 1/2*, designed by Midwest Acoustics.

6) 1 acoustic attenuator with a three-position attenuation switch: 0 dB, -30 dB, and -62 dB, designed by Midwest Acoustics.

7) 2* B&K random incidence correctors, Model #UA0055.

8) Pioneer headphones, Model #SE-305 (1 set).

9) 1 Maxell UD C-60 cassette tape.

10) GR multifrequency field acoustic calibrator, Model #1562-A, Serial #19045.

11) Microphone windscreens: 1 cylindrical windscreen, approximately 9" in diameter with a conical top wrapped in 1/2" acoustic foam. One cylindrical windscreen*, identical to the above described, wrapped in 1/4" acoustical foam, designed by Midwest Acoustics. Two* 4" B&K Windscreens, Model #UA0207.

12) Psychro-dial battery powered psychrometer, Model #CP-127, Serial #2014.

13) Weatherama Brass Case Barometer, Model #2-130B.

14) 2 tripod mounts: 1 Kalt, Model #MR-913; Vivitar Type 1000*.

15) 2* 100' extension cables, 3-conductor, shielded, ALPHA #1521.

16) Clipboard, data sheet, pen.

17) Nakamichi 12 volt power converter POT-64 and 12 volt power source (vehicle).

PRE-SURVEY EVALUATION

1) Weather conditions

-Measure temperature and relative humidity using psychrometer; record on data sheet.
-Record wind data obtained from Weather Service located in Ely and/or Isabella, for the given hour of data collection.
-Note atmospheric pressure from barometer.

2) Location

-Note on data sheet location of site (site listing and description) and any other observations and/or site conditions.

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* Necessary for two channel recording.

INSTRUMENT CALIBRATION

1) Assemble system as shown on schematic sketch, omitting windscreens.

2) Replace random incidence corrector with regular B&K microphone grid.

3) Switch preamplifier to "200V" position.

4) Mount microphone system on tripod four feet above ground.

5) Depress "Power" button on tape recorder making sure all other buttons are out.

6) Depress "Dolby" button.

7) If tape recorder is to be powered by its own batteries, check battery condition by pressing "Battery Check" button on the front of the recorder. The needle of the right peak meter should register "Battery-Good."

8) Open tape compartment by pushing "Stop/Eject" and insert cassette tape with tape side facing the tape heads. Close lid. Rewind tape if necessary.

9) Depress "Pause" button.

10) Depress "Play/Record" and "Record" buttons simultaneously.

11) Select one of the following six calibration procedures that is appropriate for the levels being recorded:

A-1 (most sensitive): 51 dB = 0 Vu
A (2nd most sensitive): 63 dB = 0 Vu
B (3rd most sensitive): 73 dB = 0 Vu
C (4th most sensitive): 83 dB = 0 Vu
D (5th most sensitive): 93 dB = 0 Vu
E (6th most sensitive): 103 dB = 0 Vu

12) Two steps are required in order to achieve the chosen calibration procedure: 1) taping calibration tone, and 2) taping data. Step 1 (calibration tone) consists of adjusting the preamplifier, the acoustic attenuator, and the Nakamichi input gain. Step 2 (data) consists of adjusting the preamplifier and the acoustic attenuator. Below is a chart listing the specific settings outlined for each of the two steps for each calibration procedure:

	Step 1			Step 2	
Cal Proc.	Preamp Setting	Attenuator Setting	Vu Setting	Preamp Setting	Attenuator Setting
A-1	X10	-62	0	X10	0 dB
A	X1	-30	0	X10	0 dB
B	X1	-30	-10	X10	0 dB
C	X10	-30	0	X10	0 dB
D	X1	0	0	X10	0 dB
E	X1	0	-10	X10	0 dB

13) To use the chart, select the appropriate calibration procedure. Adjust preamplifier and attenuator settings in accordance with Step 1 (e.g., for calibration A, the preamplifier is set at X1 and the attenuator at -30 dB). Switch acoustic calibrator to 1,000 Hz and place over microphone. Adjust input gain on Nakamichi for the channel being recorded to the Vu setting given on the chart (e.g., for calibration A, the Vu setting would be 0.

14) Reset index counter to "000" and release "Pause" button. Tape calibration tone until index counter reads "020." Press "Pause" to stop tape. If second channel is to be recorded, repeat process for other channel, and record calibration tone until index counter reads "040." (While the calibration tone on one channel is being taped, there should be no input to the other channel.)

15) Carefully remove calibrator from microphone.

16) After calibration tone has been set, adjust preamplifier and acoustic attenuator in accordance with Step 2 for the calibration procedure used (e.g., for calibration A, preamplifier would be set at X10 and the attenuator would be set at 0 dB).

17) Do not touch input gains during test. Note on data sheet the calibration procedure used.

18) Replace microphone grids with random incidence correctors and place windscreens over microphones.

SURVEY PROCEDURE

1) Place microphone system 100' from Nakamichi in pre-selected location.

2) Put on headphones, and adjust volume as desired. Sounds picked up by microphone(s) should now be audible in headphones. If not, check all connections and make sure all power switches are on.

3) To start recording, release the "Pause" button, noting the time on the data sheet.

4) During tape, voice commentary can be recorded on one channel, provided experimenter is 50' from the microphone that is collecting data.

5) Make notes of all sounds producing sources during recording and any other observations and comments on the data sheet.

6) If the experimenter plans to use an entire side of a tape, leave at least two minutes at the end to record the calibration tone.

DATA LOGGING

1) When survey is completed, record calibration tone, following calibration procedures used at start of test. Do not touch input gains. Note Vu setting on data sheet.

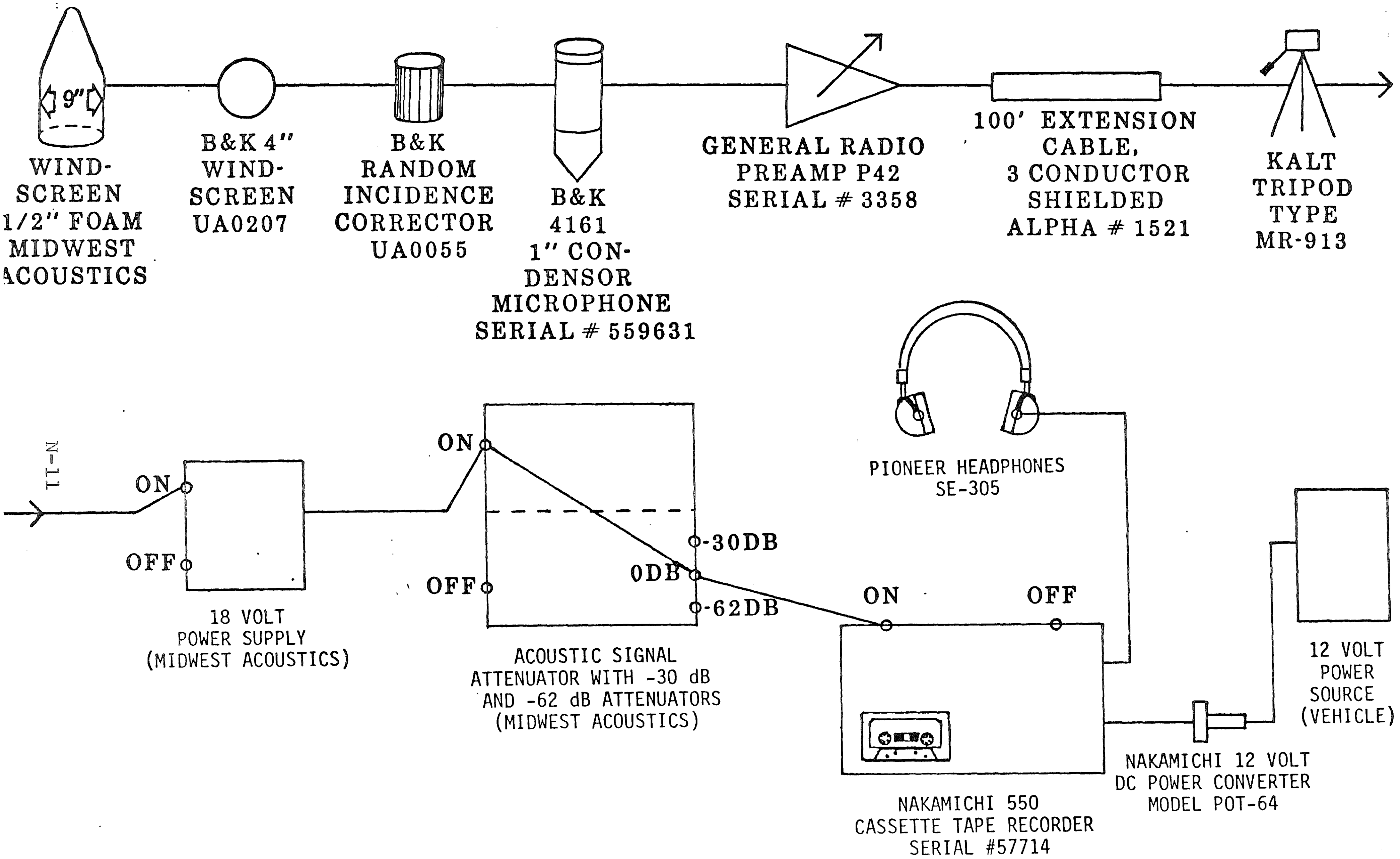
2) Note tape number and side on data sheet.

3) Note time survey has ended and disassemble system.

4) Sign and date data sheet.

5) Note on tape cover, the effective calibration tone used, time, date, and location of survey. Make sure all power switches are "Off" when survey is completed.

6) Record information on weekly survey forms.



CN-3. Acoustical Recording using Nakamichi 550 magnetic cassette tape recorder.

TEST PROCEDURE CN-4

OBJECTIVE

Simultaneous acoustical measurement and magnetic tape recording using Metrosonic db-601 Sound Level Analyzer or db-602 on "Single Interval" mode and Nakamichi 550 Cassette Tape Recorder.

INSTRUMENTATION

1) Metrosonic db-601 Sound Level Analyzer, Serial #1108 with low level input or Metrosonic db-602 Sound Level Analyzer, Serial #1109 with low level input on "Single Interval" mode.

2) Nakamichi 550 Cassette Tape Recorder, Serial #57714.

3) 2 Bruel and Kjaer (B&K) 1" condenser microphones Model #4161, Serial #55639 and #580385*.

4) 2 General Radio (GR) preamplifiers, Model #P42, Serial #3358 and #3272*.

5) Acoustical signal divider with one input and two output modes. Each output mode has a 30 dB and a 60 dB attenuator, designed by Midwest Acoustics.

6) 2* B&K random incidence correctors, Model #UA0055.

7) Pioneer headphones, Model #SE-305 (1 set).

8) General Radio (GR) multifrequency field acoustic calibrator, Model #1562-A, Serial #19045.

9) Microphone windscreens: 1 cylindrical windscreen, approximately 9" in diameter with a conical top wrapped in 1/4" acoustic foam. One cylindrical windscreen, identical to the above described, wrapped in 1/4" acoustic foam*, designed by Midwest Acoustics. 2* B&K Windscreens, Model #UA0207.

10) Psychro-dial battery powered psychrometer, Model #CP-127, Serial #2014.

11) Weatherama Brass Case Barometer, Model #CP-127.

12) 2 tripod mounts: 1 Kalt, Model #MR-913; Vivitar, Model #1000*.

13) 2* 100' extension cables, 3-conductor, shielded, ALPHA #1521.

14) Cables: (3-conductor, shielded)

-1 6" female switchcraft on either end.
-1 6" male switchcraft on either end.
-1 10" male switchcraft on one end and phone plug on other end.

15) 1 Maxell UD cassette tape C-60.

16) Nakamichi 12 volt power converter POT-64 and 12 volt power source (vehicle).

17) Clipboard, data sheets, pen.

PRE-SURVEY EVALUATION

1) Weather conditions

-Measure temperature and relative humidity using Psychrometer; record on data sheet.

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*Necessary for two channel recording.

-Record wind data obtained from Weather Service located in Ely and/or Isabella, for the given hour of data collection.

-Note atmospheric pressure from barometer.

2) Location

-Note on data sheet location of site (site listing and description) and any other observations or site conditions.

INSTRUMENT CALIBRATION

1) Assemble system as shown on schematic sketch, omitting windscreens.

2) Replace random incidence corrector with regular B&K microphone grid.

3) Switch preamplifier to "200V" position and "XI" positions.

4) Mount microphone system on tripod four feet above ground.

5) On db-601 (or db-602):

a) Set function switch to "Standby" for at least one minute for warm up, input switch to "MKA" and response speed to "Fast." Turn display switch to "Sound Level."

b) Set General Radio (GR) calibrator at 1,000 Hz and place over microphone. Adjust potentiometer screw all the way to the right and then gradually to the left until "113" appears in the digital readout.

c) Remove calibrator carefully to avoid damage to the microphone.

d) Note calibration tone on data sheet and switch calibrator to "Off."

6) On Nakamichi:

a) Depress "Power" button making sure all other buttons are out.

b) Depress "Dolby" button.

c) If tape recorder is to be powered by its own batteries, check battery condition by pressing "Battery Check" button on the front of the recorder. The needle of the right peak meter should register "Battery-Good."

d) Open tape compartment by pushing "Stop/Eject" and insert cassette tape with tape side facing the tape heads. Close lid. Rewind tape if necessary.

e) Depress "Pause" button.

f) Depress "Play/Record" and "record" buttons simultaneously.

g) Select one of the following six calibration procedures that is appropriate for levels being recorded:

A-2 (most sensitive): 53 dB = 0 Vu
A (2nd most sensitive): 63 dB = 0 Vu
B (3rd most sensitive): 73 dB = 0 Vu
C (4th most sensitive): 83 dB = 0 Vu
D (5th most sensitive): 93 dB = 0 Vu
E (6th most sensitive): 103 dB = 0 Vu

h) Two steps are required in order to achieve the chosen calibration setting: 1) taping the calibration tone, and 2) taping the data. Step 1 (calibration tone) consists of adjusting the gain of the preamplifier to either X1 or X10 position, holding in the "Attenuator" button (either -30 dB or -60 dB) corresponding to the correct output mode of the signal divider which feeds into the Nakamichi, and adjusting the input gain of the Nakamichi to the appropriate Vu setting. Step 2 consists of adjusting the input gain to X10. It is understood that during taping, no attenuation via the signal divider is necessary, i.e. the "Attenuator" buttons are activated only during Step 1. Below is a chart listing the specific settings outlined for each of the two steps for each calibration procedure:

		Step 1		Step 2
Cal Proc.	Preamp Setting	Attenuator Setting	Vu Setting	Preamp Setting
A-2	X10	-60	0	X10
A	X1	-30	0	X10
B	X1	-30	-10	X10
C	X10	-30	0	X10
D	X1	0	0	X10
E	X1	0	-10	X10

i) To use the chart, select the appropriate calibration procedure. Adjust the preamplifier and proper attenuator in accordance with Step 1. (If the attenuator setting in the chart is 0, it is not necessary to hold in either of the "Attenuator" buttons.) Switch the acoustic calibrator to 1,000 Hz and place over microphone. Adjust input gain on Nakamichi for the channel being recorded to the Vu setting given on the chart (e.g., for calibration A-2, the Vu setting would be 0). Reset index counter to "000" and press "Release" pause button. Tape calibration tone until index counter reads "010." Press "Pause" to stop tape. If second channel is to be used for recording, repeat process for that channel, and record calibration tone until index counter reads "040." (While the calibration tone on one channel is being taped, there should be no input from the other channel.)

j) Carefully remove calibrator from microphone.

k) After calibration tone has been set, release "Attenuator" button and adjust preamplifier to X10 as indicated in Step 2.

l) Do not touch input gains during test. Note on data sheet the calibration procedure used.

SURVEY PROCEDURE

1) Replace regular microphone grid with random incidence corrector and place windscreens over microphone.

2) Place microphone system 100' from Nakamichi and db-601 in pre-selected site.

3) On db-601: switch function to "normal" (or on db-602 to "Single Interval"). Note start time of survey.

4) On Nakamichi: Start recording by releasing "Pause" button. Adjust headphone volume to desired level. (If sounds are not audible in the headphones, check all connections and make sure all power switches are "On.")

5) Ring test, make notes of all sound producing sources and any observations on data sheets.

6) If the experiment plans to use an entire side of a tape, leave at least two minutes at the end to record the calibration tone.

DATA LOGGING

1) Recalibrate Metrosonic according to procedure previously described.

2) When survey is completed, record calibration tone on Nakamichi, following calibration procedures used at start of test. Do not touch input gains. Note Vu setting on the data sheet.

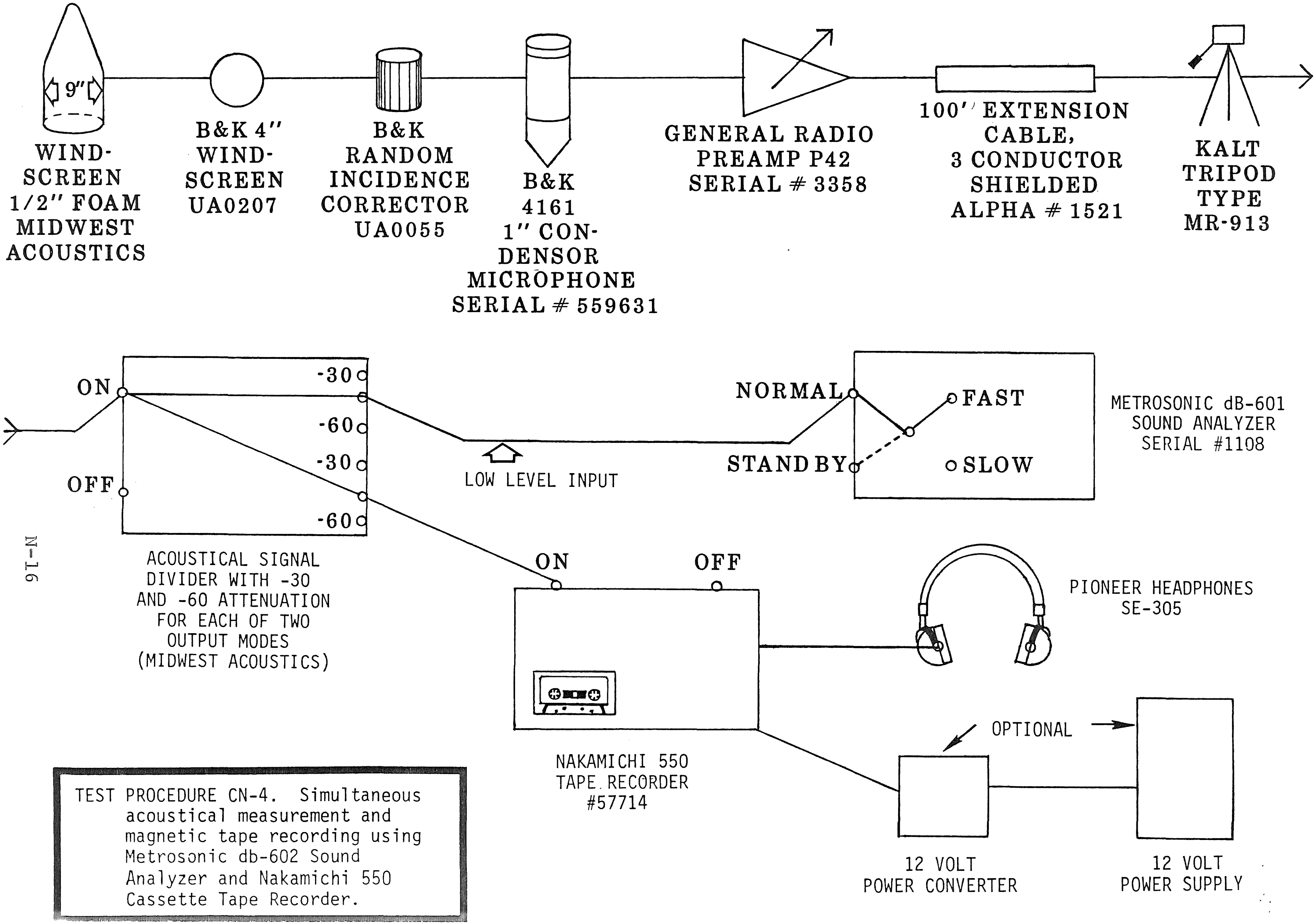
3) Note tape number and side on data sheet.

4) Note time survey has ended and disassemble system.

5) Sign and date data sheet.

6) Note on tape cover, the effective calibration tone used, time, date, and location of survey. Make sure all power switches are "Off" when survey is completed.

7) Record information on weekly survey forms.



TEST PROCEDURE CN-4. Simultaneous acoustical measurement and magnetic tape recording using Metrosonic db-602 Sound Analyzer and Nakamichi 550 Cassette Tape Recorder.

TEST PROCEDURE CN-5

OBJECTIVE

Simultaneous acoustical measurement and measurement and magnetic tape recording using General Radio (GR) Sound Level Meter 1565-C and Nakamichi 550 Cassette Tape Recorder.

INSTRUMENTATION

1) Nakamichi 550 Cassette Tape Recorder, Serial #57714.

2) GR 1565-C Sound Level Meter, Serial #21270.

3) Bruel and Kjaer (B&K) 1" condenser microphone, Model #4161, Serial #559631.

4) GR preamplifier, Model #P42, Serial #3358.

5) Acoustical signal divider with one input and two output modes, each of which contain a -30 dB and -60 dB attenuation switch, designed by Midwest Acoustics.

6) B&K random incidence corrector, Model #UA0055.

7) GR multifrequency field acoustic calibrator, Model #1562-A, Serial #19045.

8) Microphone windscreens: 1 large cylindrical windscreen, approximately 9" in diameter with a conical top, wrapped in 1/4" acoustic foam, designed by Midwest Acoustics, 1 4" B&K Windscreen UA0207.

9) 18 volt power supply (Midwest Acoustics).

10) Psychro-dial battery powered psychrometer CP-147, Serial #2014.

11) Weatherama Brass Case Barometer, Model #2-130B.

12) Maxell UD C-60 cassette tape.

13) 100' extension cable, 3-conductor, shielded, ALPHA #1521.

14) Cables (Midwest Acoustics)

-1' female switchcraft on both ends, 3-conductor, shielded to connect 18 volt power supply to input mode of acoustic signal divider.

-1' male switchcraft on both ends, 3-conductor, shielded to connect output mode of acoustic signal divider to sound level meter.

-4' male switchcraft on one end, phone plug on the other, 2-conductor, shielded to connect acoustic signal divider to cassette tape recorder.

15) Pioneer headphones, SE-305.

16) Kalt Tripod, Serial #MR-913.

17) Nakamichi 12 volt DC converter cable--POT-64 (optional if batteries are not used).

18) Sears stopwatch, Model #E-5.

19) Clipboard, noise survey data sheet, tape data sheet, pen.

PRE-SURVEY EVALUATION

1) Weather conditions

-Measure temperature and relative humidity using psychrometer, record on tape data sheet.
-Record wind data from Weather Service in Ely and/or Isabella.
-Record atmospheric pressure from barometer.

2) Location

-Record on tape data sheet location of site (zone and vegetation type) and any other observations or site conditions.

INSTRUMENT CALIBRATION

1) Assemble system as shown on schematic sketch, ommitting windscreens.

2) Replace random incidence corrector with regular B&K microphone.

3) Switch preamplifier to "X1" and "200V" positions.

4) Switch acoustical signal divider to "On."

5) Switch 18 volt power supply to "On."

6) Calibration procedures for the sound level meter are as follows:

a) Switch sound level meter to "On" and check battery condition by pushing "Batt" button. Indicator should fall in the "Battery-Good" range.
b) Switch sound level meter to "A" weighting and "Fast" response.
c) Switch acoustical calibrator to "1,000 Hz" and place over microphone.
d) Because the B&K 4161 microphone is more sensitive than the microphone supplied with the sound level meter, the indicator should read "123" (as opposed to "113"). If not, turn calibration screw on the sound level meter all the way to the right and then gradually back to the left until the indicator needle points to "123." Note calibration tone on tape data.
e) Carefully remove calibrator so as to avoid damage to the microphone.

SURVEY PROCEDURE

1) Replace microphone grid with random incidence corrector, place windscreens over microphone, and set microphone system 100' from the Nakamichi 550 and sound level meter.

2) Connect headphone to Nakamichi 550 and adjust headphone volume. During the test, the experimenter should wear the phones to note any sounds of interest.

3) On "Noise Survey" data sheet, lable the limits of the sound levels as they appear on the sound level meter.

DATA LOGGING

1) When test is completed, push the "Pause" button on the Nakamichi 550 and shut off the stopwatch.

2) Count down the appropriate percentages on the noise survey data sheet to compute the desired L_n values. For example, if 180 readings were taken, the L_{10} would be the 18th reading counting

down from the top. Because the survey was conducted on a X10 gain, and because the sound level meter was calibrated 10 dB higher than the calibration tone, subtract 30 dB from all L_n values. Note L_n values on tape data sheet. Recalibrate the sound level meter, noting the level that is indicated.

3) Record calibration tone following calibration procedures used at start of test. Do not touch input gains. Note Vu setting on data sheet.

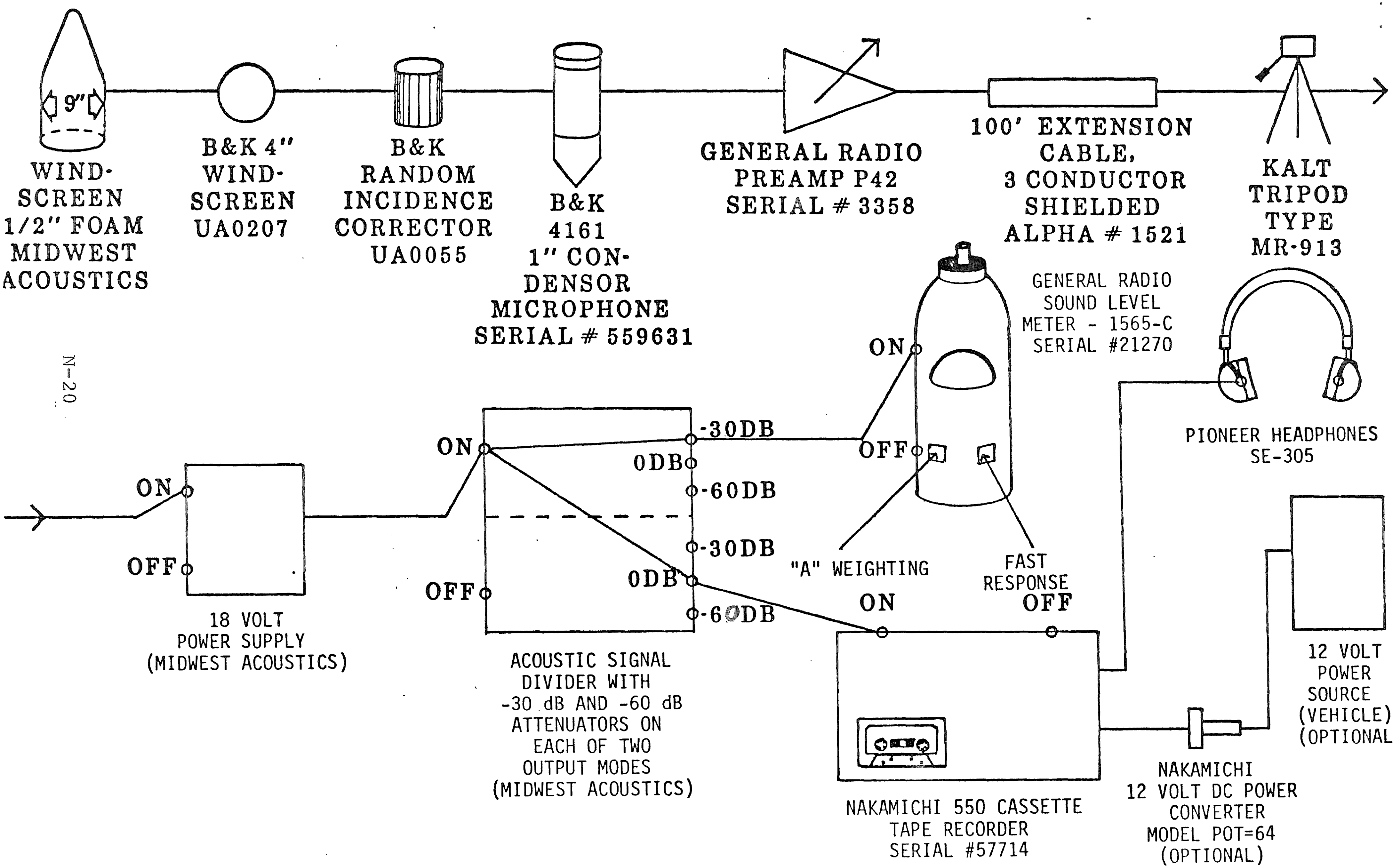
4) Note tape number and side on data sheet.

5) Note time survey has ended and disassemble system.

6) Sign and date data sheet.

7) Note on tape cover, the effective calibration tone used, time, date, and location of survey. Make sure all power switches are "Off" when survey is completed.

8) Record information on weekly survey forms.



TEST PROCEDURE CN-5

TEST PROCEDURE CN-6

OBJECTIVE

Acoustical measurement using Metrosonic db-602 Sound Level Analyzer on "Multiple Interval" mode.

INSTRUMENTATION

1) Metrosonic db-602 Sound Level Analyzer with low level input.

2) Bruel and Kjaer (B&K) 1" condenser microphone, Model #4161, Serial #55639.

3) General Radio (GR) preamplifier, Model #P42, Serial #3358.

4) B&K random incidence corrector UA0055.

5) GR multifrequency field calibrator, Model #1562-A, Serial #19045.

6) Microphone windscreens: 1 large cylindrical windscreen, 9" diameter with a conical top and wrapped in 1/4" acoustical foam, designed for the Copper-Nickel Noise Project by Midwest Acoustics; 4" foam B&K Windscreen UA0207.

7) Psychro-dial CP-147 electric psychrometer, Serial #2014.

8) Kalt Tripod, Model #MR-913.

9) Weatherama Brass Case Barometer, Model #2-130B.

10) 100' extension cable, 3-conductor, shielded, ALPHA #1521.

11) Clipboard, data sheet, pen.

PRE-SURVEY EVALUATION

1) Weather conditions

-Measure temperature and relative humidity using psychrometer; record on data sheet.
-Record wind data obtained from Weather Service located in Ely and/or Isabella.
-Record atmospheric pressure from barometer.

2) Location

-Record on data sheet location of site (site listing and description) and any other observations or site conditions.

INSTRUMENT CALIBRATION

1) Switch GR preamplifier to "X1" and "200V" positions.

2) Replace random incidence corrector with regular microphone grid.

3) Connect all cables as shown on schematic diagram.

4) Set function switch on db-602 to "Standby" for at least one minute to allow unit to warm up. Turn input switch to "MKA," response speed to "Fast," and display to "Sound Level."

5) Set GR calibrator at 1,000 Hz and place over microphone.

Adjust calibration screw on unit by turning all the way to the right and gradually back to the left until "113" appears in the window readout. Switch display to "Off."

6) Remove calibrator carefully so as to avoid damage to the microphone.

7) Note calibration tone on data sheet.

8) Mount microphone system on tripod four feet off the ground.

SURVEY PROCEDURE

1) Replace regular microphone grid with random incidence corrector, change GR preamplifier to "X10" and place windscreens over microphone. Set microphone system 100' from db-602 in pre-selected site.

2) Determine the time period in minutes in which data is to be continuously sampled. (The time interval decided upon must be a multiple on 15 minutes.) Divide the interval by 15. Dial in the result in the last two thumbwheels of the multiple interval section. For example, if data is to be sampled for one hour, intervals (60 minutes) "04" would be dialed in on the last two thumbwheels.

3) Determine the four L_n values to be tabulated for each pre-selected interval. Dial in these L_n values in the four sets of thumbwheels designated below as L_A, L_B, L_C, and L_D. (L_{00} should <u>not</u> be in the L_A column.) Make sure all four buttons for the data banks are up.

4) Turn function switch to "Clear Memory" and push "Activate" button. When survey is ready to proceed, switch from "Function" to "Multiple Interval."

DATA LOGGING

1) After test is completed, switch function to "Standby."

2) To read out data, proceed as follows:

a) Push button under the L_A data bank.

b) Switch display to L_N scan.

c) Switch toggle switch below "Activate" button to either "Manual" or "Auto Scan." If there are more than 4 or 5 L_N values to be read, switch to "Manual," otherwise "Auto Scan" can be used.

d) Push "Activate" button. If switch is on "Auto Scan," all the values for the L_N denoted in the L_a data bank will be flashed up, one per second. If the toggle switch is on "Manual, the "Activate" button should be pressed to read each value. (The unit will sometimes flash a number preceding the actual data. This number should be ignored.)

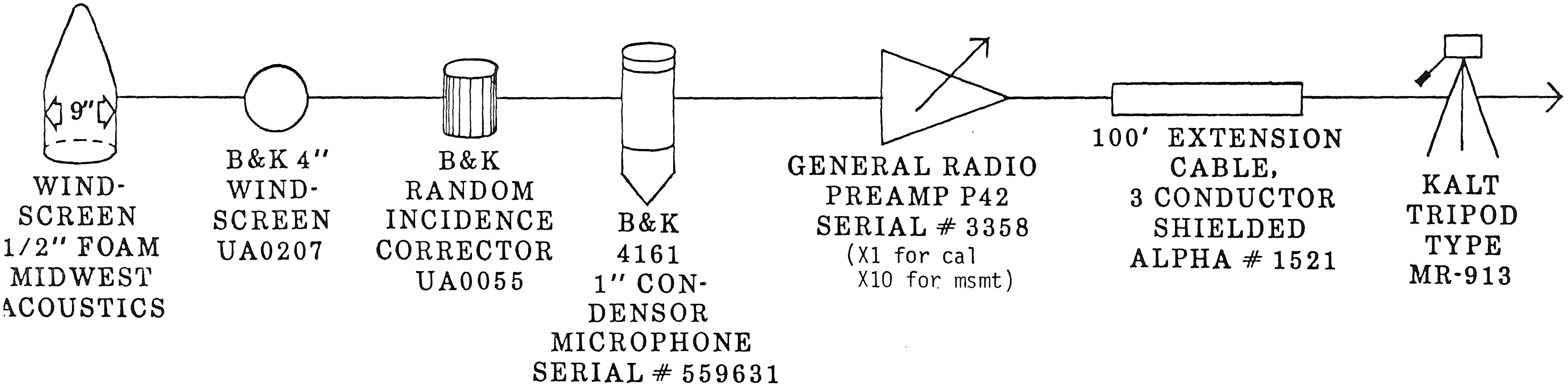
e) After all data in the L_a data bank has been read, push the button for the L_b data bank. Switch display to "Time Set Hours" and then back to L_N scan. As with the L_a data bank, push the "Activate" button to read out data.

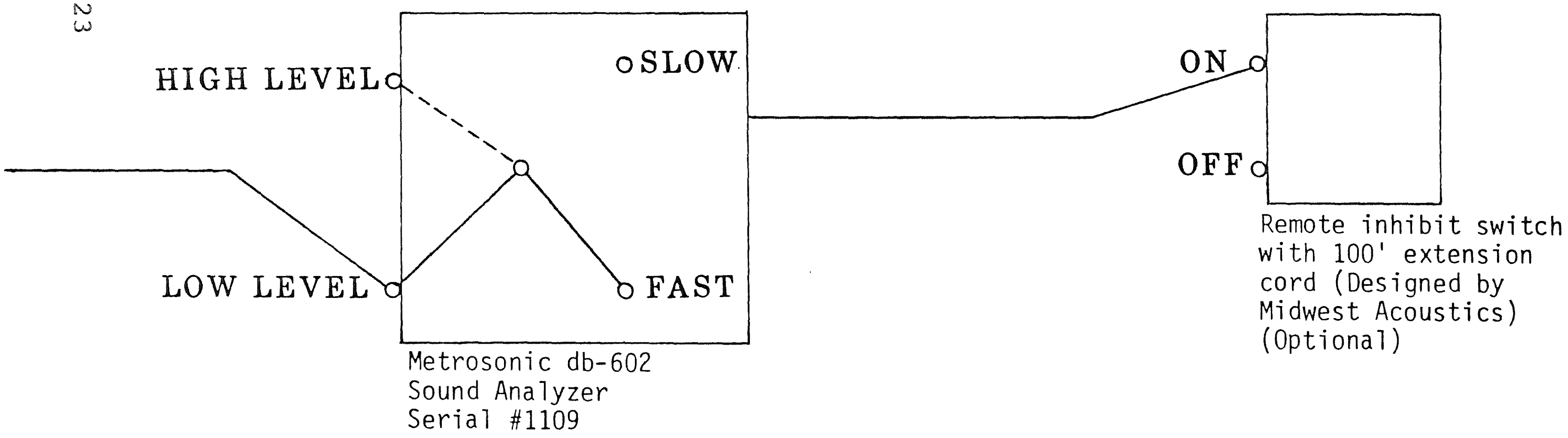
f) Proceed to the L_c data bank in the same manner.

g) All data should have 20 dB subtracted from the readout because data was sampled with a X10 gain.

h) Recalibrate, record calibration level, and disassemble system.

i) Record information from data sheet on weekly survey forms.





TEST PROCEDURE CN-6

TEST PROCEDURE CN-7

OBJECTIVE

"A" weighted acoustical analysis using Metrosonic db-601 or db-602 on "Single Interval" mode of tape recorded on Nakamichi 550 Cassette Tape Recorder (to be conducted in lab).

INSTRUMENTATION

1) Metrosonic db-601 Sound Level Analyzer, Serial #1108 with low level input or db-602 Sound Level Analyzer, Serial #1109 with low level input.

2) Nakamichi 550 Cassette Tape Recorder, Serial #57714.

3) Maxell UDC-60 cassette tape on which data was recorded.

4) Pioneer headphones, SE-305.

5) Nakamichi AD-550U AC power pack.

6) 2' cable with an RCA phone jack on one end and a male switchcraft on the other.

7) Data sheet on which survey was recorded.

8) Pen.

INSTRUMENT CALIBRATION

1) Assemble system as shown on schematic sketch. Connect output on Nakamichi of whichever channel (right or left) is to be analyzed to the low level input of the db-601 or db-602. The output jacks are located in the back of the Nakamichi.

2) Switch db-601 or db-602 to "Standby" for at least one minute to warm up. Switch input to "MKA," response speed to "Fast," and display to "Sound Level dB." Switch "function" to "Clear Memory" and push "Activate" button. Switch back to "Standby."

3) Push in "Power" and "Dolby" buttons on Nakamichi, making sure all other buttons are out.

4) Insert tape on correct side and close lid; set index counter to "000."

5) Refer to the tape for the calibration tone used. The tone will be given along with its corresponding Vu setting; for example, 63 dB-0 Vu. In this case, 63 dB is the appropriate calibration tone.

6) Push "Play" button on Nakamichi.

7) The sound level appearing in the Metrosonic digital readout window will be higher than the actual calibration tone recorded on the tape. Turn the calibration screw on the db-601 or db-602 all the way to the right and then gradually back to the left until a number appears which has the same last digit as the last digit of the calibration tone. For instance, if the calibration tone is 63, an appropriate readout on the db-601 or db-602 would be 113. Since all data appearing in the Metrosonic window is relative to the calibration tone in the window, the true data is obtained by subtracting the difference between the true calibration tone and the calibration tone appearing in the window. In the previous example, to get the true data values, 50 dB should be subtracted from all values (i.e. 113-63 = 50 dB).

8) Advance tape by pushing "FFW" button to the point where the survey began.

9) Listen in headphones. When the calibration tone stops and the survey starts, switch the db-601 function to "Normal" or the db-602 to "Single Interval." Note any observations while listening to tape.

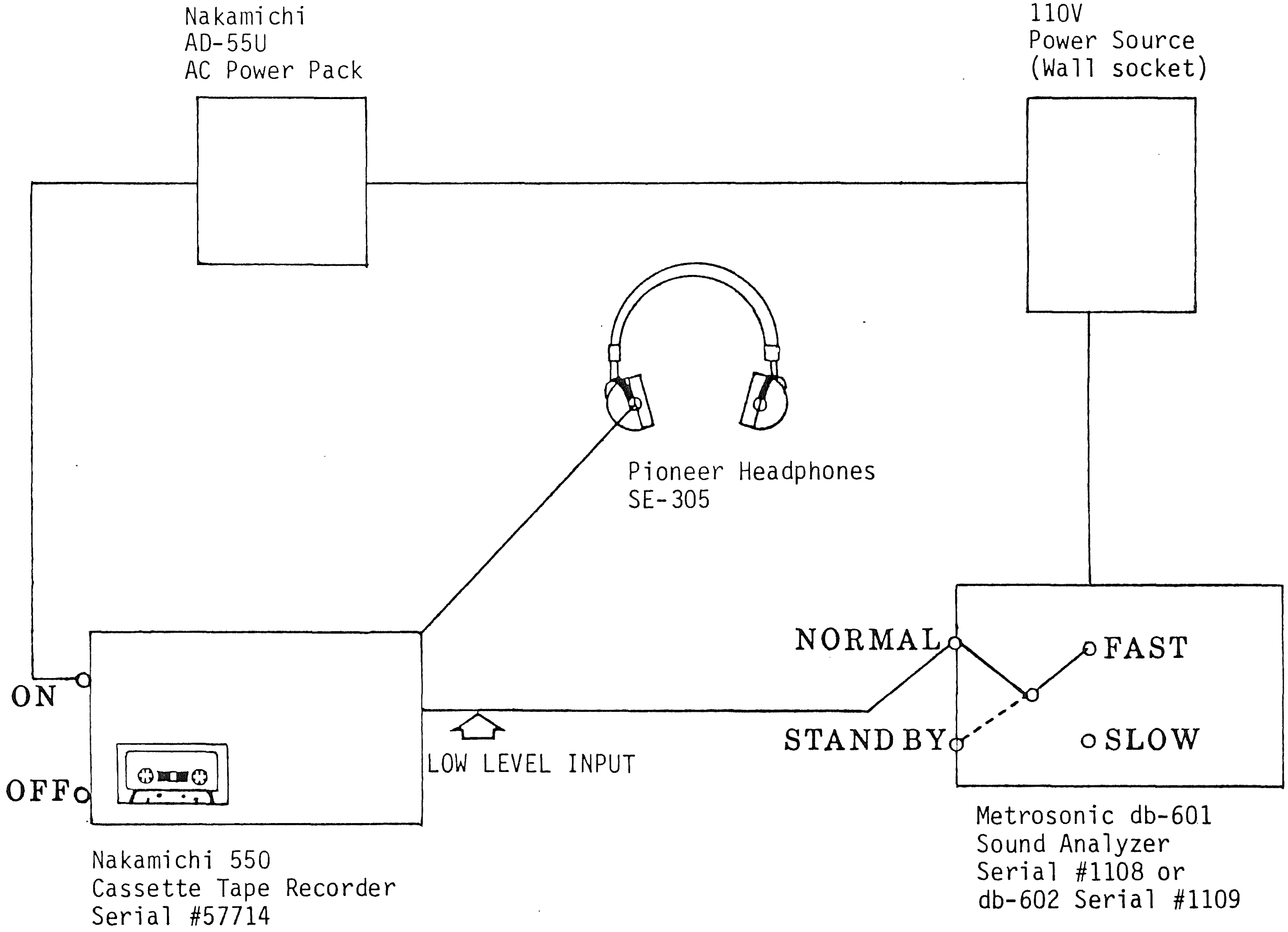
10) When survey has been completed, switch Metrosonic to "Standby" and push the "Pause" button on the Nakamichi.

11) Switch display mode on Metrosonic to "L_n Compute." Adjust dials accordingly to obtain desired L_n values. Subtract from the L_n values in the window the difference of the true calibration tone and the calibration tone in the window, as described in Step 5.

12) Switch display mode to "Sound Level dB." Release "Pause" button on the Nakamichi and note sound level that appears in the digital readout of the Metrosonic. This should be the same calibration tone as recorded prior to the survey.

13) Note all obtained data in appropriate files.

14) Disassemble system making sure all switches are "Off."



TEST PROCEDURE CN-7

TEST PROCEDURE CN-10

OBJECTIVE

Data transfer from Nakamichi 550 Cassette Tape Recorder to Teac A-2300S Reel to Reel Tape Recorder.

INSTRUMENTATION

1) Nakamichi 550 Cassette Tape Recorder, Serial #57714.

2) Teac A-2300S Reel to Reel Tape Recorder, Serial #00349673.

3) Nakamichi AC power converter AD-550U.

4) Pioneer headphones, SE-305.

5) Cables provided with Teac Recorder: two pairs of two conductor with male connectors on either end.

6) One Maxell UD reel tape 50/60 - clean.

7) One Maxell UD cassette tape C-60 with prerecorded data.

SET-UP

1) Connect system as shown on schematic sketch. Only one channel from the Nakamichi can be analyzed at a time. After determining which channel is to be analyzed, connect the output of that channel (on the Nakamichi) to the line input of the Teac--right channel. There should be no input to the left channel line input of the Teac, while the right channel is being recorded.

2) On the Nakamichi: push the "Power" switch in, push in the "Dolby" switch, and turn the output level on back of the Nakamichi to its maximum setting.

3) On the Teac: push in the "Power" switch, push the tape speed to the "High" position (out), switch the record bias and record equalization to their up positions, and switch monitor to "Source." Switch the record mode to "On" for the right channel, making sure the left channel record mode is "Off." Insert and thread a clean reel tape (Maxell UD 50/60). Wind the tape manually so that the leader has passed the recording heads. Set index counter to "0000" by pushing "Reset" button. Press "Record" and "Pause" buttons simultaneously. Plug in headphones to Teac.

4) Insert data tape into Nakamichi and rewind to the beginning. Press "Play" button on the Nakamichi. A calibration tone should now be playing.

5) On Teac: turn the microphone input level to its minimum position. Adjust the right channel line input (outer dial) to +3Vμ, the highest setting, and adjust the right ouput mode until the calibration tone is audible in the headphones. Rewind cassette tape to the beginning of the calibration tone. Play the cassette tape and immediately push the "Play" button on the Teac (▶).

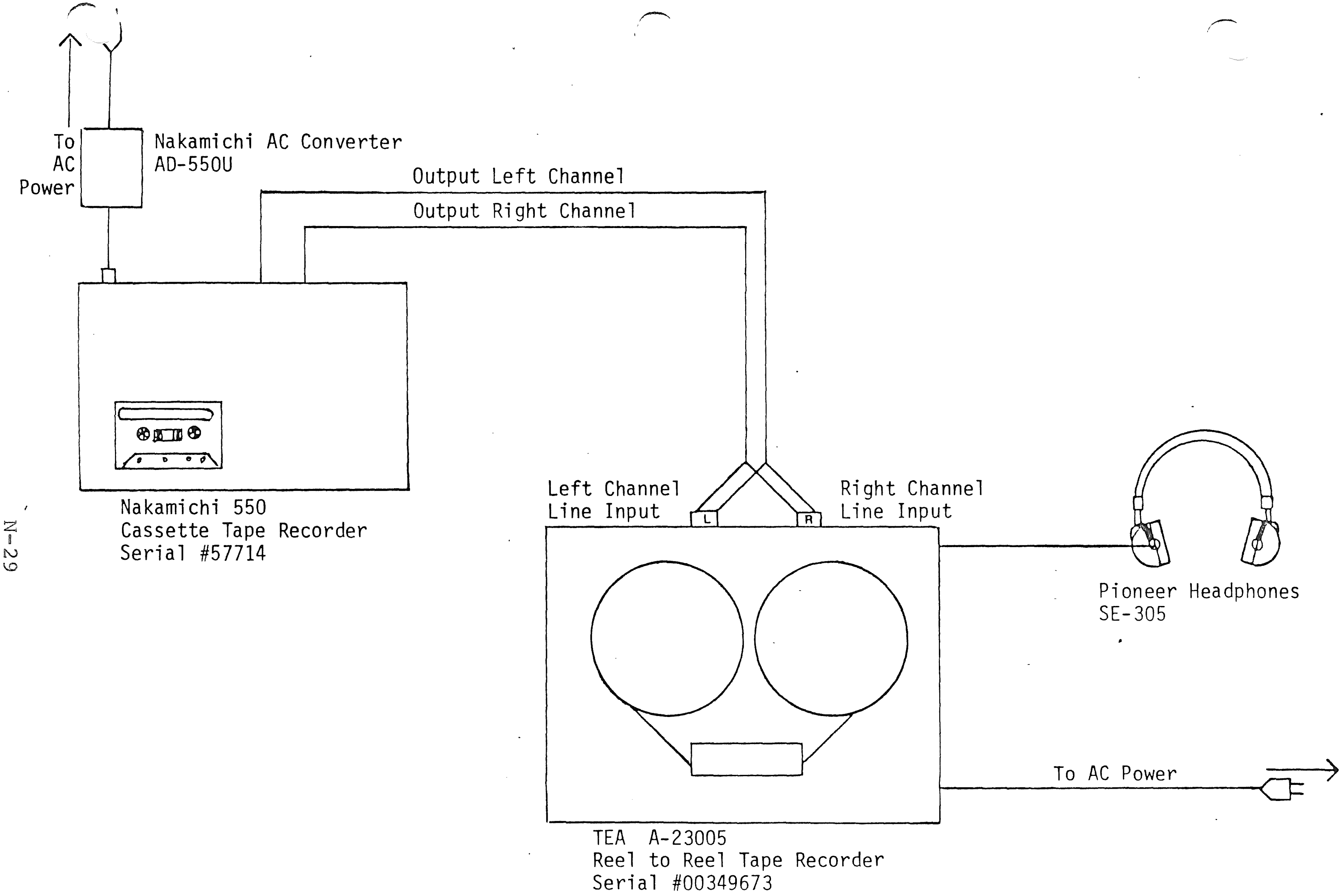
6) When the right channel of the Teac has been recorded, rewind the tape. On the back of the Teac, transfer the input connector from the right channel line input to the left channel line input. Switch the right channel record mode to "Off" and the left channel record mode to "On." Repeat the same procedure for calibration as used for the right channel. When the calibration tone from the data tape is set at +3Vμ on the Teac, record the data on the Teac's left channel as done with the right channel.

7) When data transfer has been completed, turn all power switches off and disassemble system.

8) Log the tapes in tape log book.

9) Fill out tape data transfer forms.

10) Write on reel the reel number, the cassette numbers from which the data were transferred, and the channels that correspond to the cassette numbers.



TEST PROCEDURE CN-10

OBJECTIVE

Monitoring of wind speeds using modified Metrosonic wind inhibit.

INSTRUMENTATION

1) Metrosonic wind inhibit consisting of three parts: Model #WS-601)

-Small D.C. generator.
-Three-cupped rotator
-Small extension cable with a three-pronged female army plug on one end and a male 3-conductor switchcraft connector on the other.

2) Remote readout gauge with a "Hi" and "Lo" scale designed and built by Roger Sipson, Department of Physics, Moorhead State University.

3) 150' extension cable, 3-conductor, shielded.

4) Viola Tripod, Model #3CSL.

5) Sears stopwatch, Model #E-5.

6) Clipboard, data sheet, pen.

7) 1" conduit piping 6" long to hold anemometer to tripod.

SURVEY PROCEDURE

1) Assemble system as illustrated in schematic sketch.

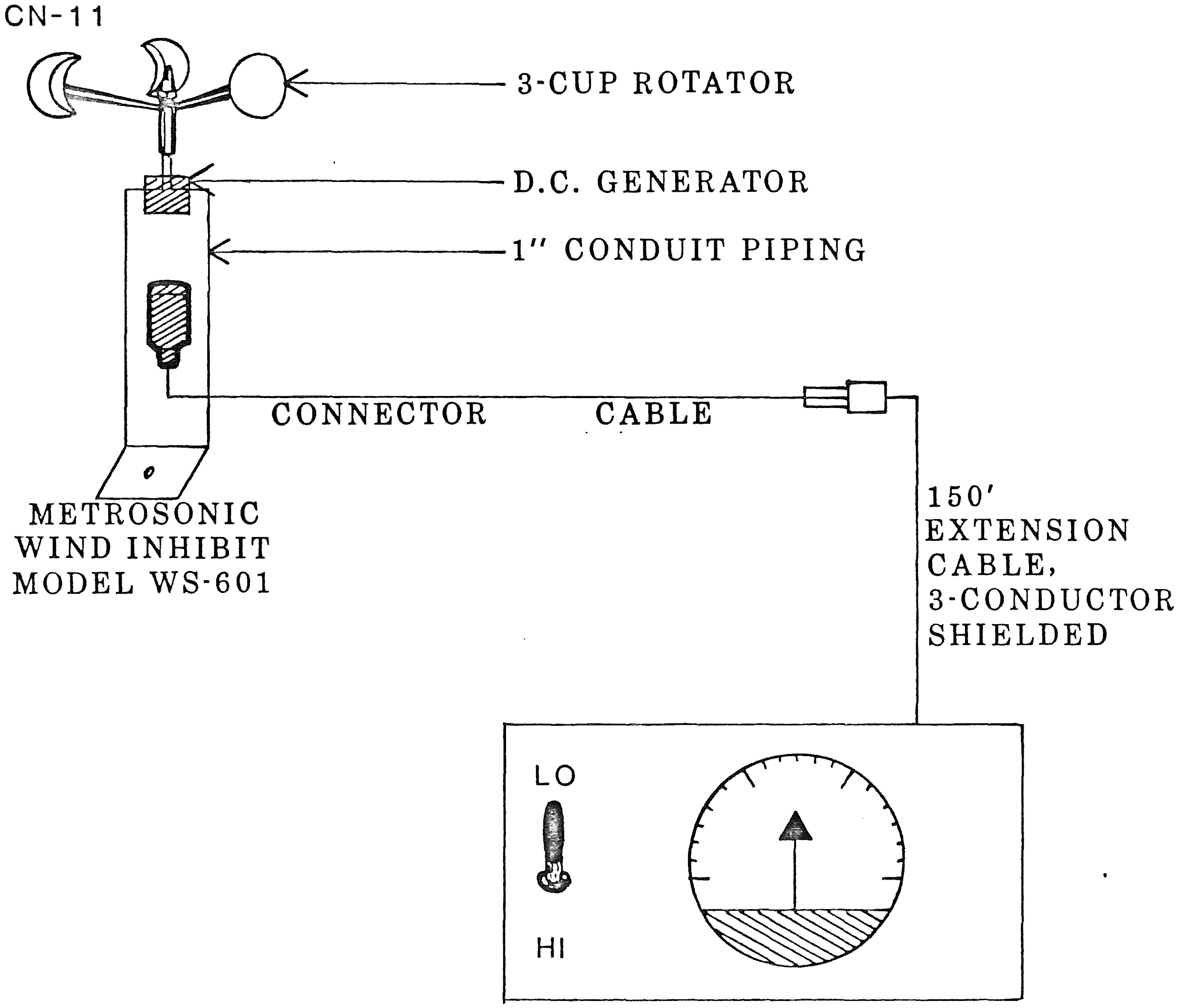
2) Place anemometer, on tripod, in desired location. If wind speeds at microphone are to be monitored, place anemometer 10 to 15 feet upwind from microphone, free from anh obstructions. Adjust anemometer height so that the cups are equal with the height of the microphone. Anemometer must be straight as possible, i.e. perpendicular to the ground.

3) On the readout gauge, switch to "Lo" if winds are 0 to 20 mph; switch to "Hi" if winds greater than 20 mph are to be monitored. The readout gauge directly reads in milliamperes. To convert to miles per hour, consult the conversion table printed on the readout gauge for either the "Hi" or "Lo" scale.

4) Record on data sheet the maximum wind gusts observed per desired time interval.

5) Practically all wind data sampled will be under 20 mph. However, if higher winds are measured and the "Hi" scale is used, such should be indicated on the data sheet.

6) When survey is completed, disassemble system and place in storage/carrying case.



REMOTE READOUT DESIGNED AND BUILT BY
DR. ROGER SIPSON, MOORHEAD STATE UNIV.

TEST PROCEDURE CN-12

OBJECTIVE

Erasure of magnetically taped data using Nortronics bulk eraser, Model #QM211.

INSTRUMENTATION

1) Nakamichi 350 Magnetic Cassette Tape Recorder, Serial #57714.

2) Nortronics bulk eraser, Model #QM211.

3) Maxell UD C-60 cassette tape with prerecorded data.

4) Pioneer headphones, SE-305.

5) Nakamichi AC power converter AD-550U (optional).

PROCEDURE

1) Plug bulk eraser into a standard 110 volt circuit.

2) Make sure all materials that might be adversely affected by a strong magnetic field, e.g., wrist watches, and Nakamichi Tape Recorder, are at least ten feet from the bulk eraser.

3) Place tape with data on a flat surface. Activate bulk eraser by depressing the switch at a distance of about two feet above the tape. Slowly approach the tape with the unit on, bringing it into direct contact with the tape.

4) Secure the tape firmly with free hand and make several passes over the tape in a circular motion. Without releasing the switch, slowly raise the bulk eraser to a distance of two feet above the tape and release the switch.

5) Turn tape over and repeat above procedure on the other side. The entire tape should now be erased.

6) Test to see if tape completely erased by placing tape in Nakamichi Recorder. Plug in headphones and listen at beginning, middle, and end of each side of tape. If any previously recorded data is observed, repeat erasing procedure.

TEST PROCEDURE CN-13

OBJECTIVE

One-third octave band analysis of acoustical data, pre-recorded on magnetic cassette tapes.

INSTRUMENTATION

1) General Radio (GR) multichannel RMS detector, Model #1926, Serial #604.

2) GR multifilter, Model #1925, Serial #983.

3) GR storage display, Model #1921-P2, Serial #B113538.

4) GR universal filter, Model #1952, Serial #614.

5) Bruel and Kjaer (B&K) microphone amplifier, Model #2604, Serial #184407.

6) Nakamichi Magnetic Cassette Tape Recorder, Model #550, Serial #3663155.

7) Hewlett-Packard digital printer, Model #561-B with interface circuitry, designed and built by Robert Munson, Moorhead State University.

8) McIntosh audio amplifier, Model #5100.

9) JBL studio monitor speaker, Model #L-200.

10) Maxell UD cassette tape with pre-recorded data.

11) Appropriate adaptors and cables.

INSTRUMENT CALIBRATION

1) Set up apparatus as described in the schematic drawing using the appropriate cables and connectors.

2) Adjust individual one-third octave attenuators as described in Appendix . This will cause all data to be "A" weighted.

3) Note from the data tape, the particular level at which the calibration tone of 1,000 Hz was recorded. Play the tone and adjust the B&K monitoring amplifier and the General Radio (GR) analyzer to coincide with the level of the calibration tone.

ANALYSIS PROCEDURES

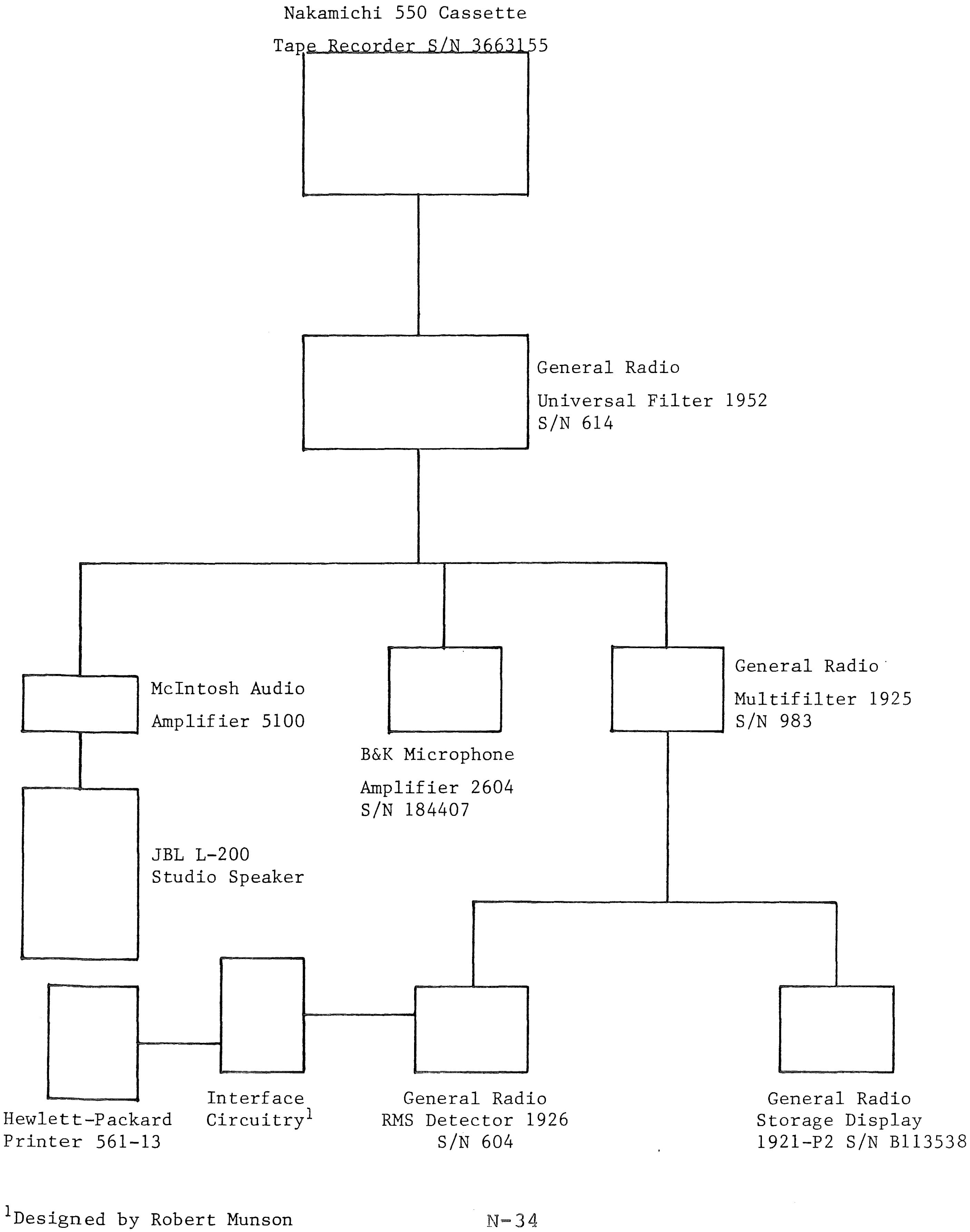
1) After the system has been calibrated in accordance with the data, play the tape until a section of interest is observed over the monitoring speaker.

2) Rewind tape to the beginning of the noted section and select an appropriate averaging time between one-eighth and thirty-two seconds on the RMS detector. Play the tape and average the segment of data over the selected interval.

3) After data has been integrated, print out bands 14 through 45 on Hewlett-Packard printer, at a speed of two bands per second. Switch the RMS detector to "Pause" until experimenter is ready to progress to the next section of data.

Test Procedure CN-13

Figure __ Diagram Showing Arrangement of Instruments



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[1] Designed by Robert Munson
Moorhead State University

APPENDIX O

ONE THIRD OCTAVE FILTER ATTENUATOR SETTINGS FOR TEST PROCEDURE CN-13

The attenuator settings for the General Radio one-third octave filter set were determined by:

1. the tape recorder record playback characteristics
2. the low frequency roll that results from using the General Radio preamplifier directly into the Nakamichi's 600 ohm input
3. the band level weighting, such as A weighting

These three things are discussed below:

The tape recordings were made in the study area using the projects's Nakamichi 550, serial #57714. For the purpose of one-third octave analysis they were played back on the Moorhead State University Nakamichi, serial #3663155. The system record play characteristics were determined by recording pink noise using the project's Nakamichi, and measuring the one-third octave levels that resulted from playing this tape back on the Moorhead Nakamichi.

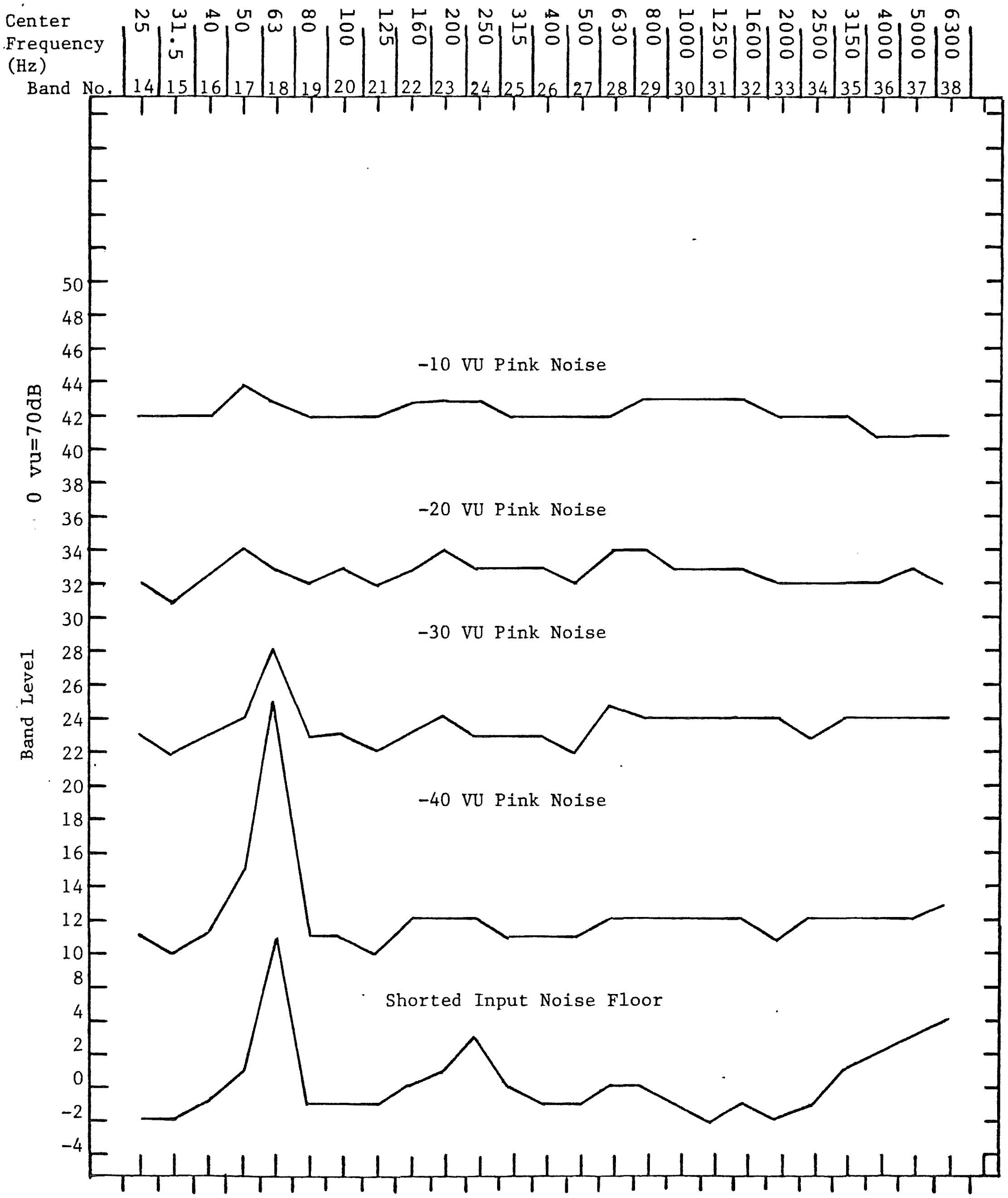
The equalization is then the attenuator settings, relative to the 1,000 Hz band, that must be used to make the display flat. The required attenuator settings depend on whether the tape was made before or after alignment of the project's Nakamichi at Moorhead, on April 25, 1977. For tapes made before alignment only data up to 8,000 Hz is taken and the settings needed are given in table O-1. Also given is a graph, figure O-2, of the equalized frequency response for four different recording levels. From this graph it can be seen that except for the 60 Hz hum in band 18 at low levels, the frequency responses are within ± 2 dB from 25 to 8,000 H2. The 60 Hz noise levels on the Field tape will be lower than those measured here since all field recordings were made with DC power in a region away from other AC powered equipment.

The required equalization settings needed after alignment are also given in table O-1. Figure O-3 gives the equalized frequency response curve for the four recording levels. After alignment, the response was usable up to band 42 (16,000 Hz) and the frequency response was correctable to ± 1 dB from 25 to 8,000 Hz.

When using the General Radio preamplifier directly into the Nakamichi there is a low frequency roll off due to the series capacitance of the output impedance of the preamplifier. The correction that this required was calculated theoretically from given circuit values and verified experimentally, the results of which are given in table O-1. This correction can be combined with the equalization curves for frequency response to give the settings needed for unweighted band levels for recordings made with the microphone directly into the Nakamichi and these are given in table O-1.

In some cases it is desireable to determine A weighted band levels. Given in table O-4 are the standard A weighting corrections and the corrections with a 20 dB over all boost. This latter form is the one that was used because of the ± 25 dB limit of the attenuators on the one-third octave filter set. The 20 dB over all boost can be easily subtracted out in data readout. The A weighting settings can be combined with the previously discussed settings to obtain A weighted band levels before and after alignment, with and without the roll off correction. The equalization settings for these weighted response curves are given in table O-4.

Figure 0-2 Equalized Frequency Response Before Allignment

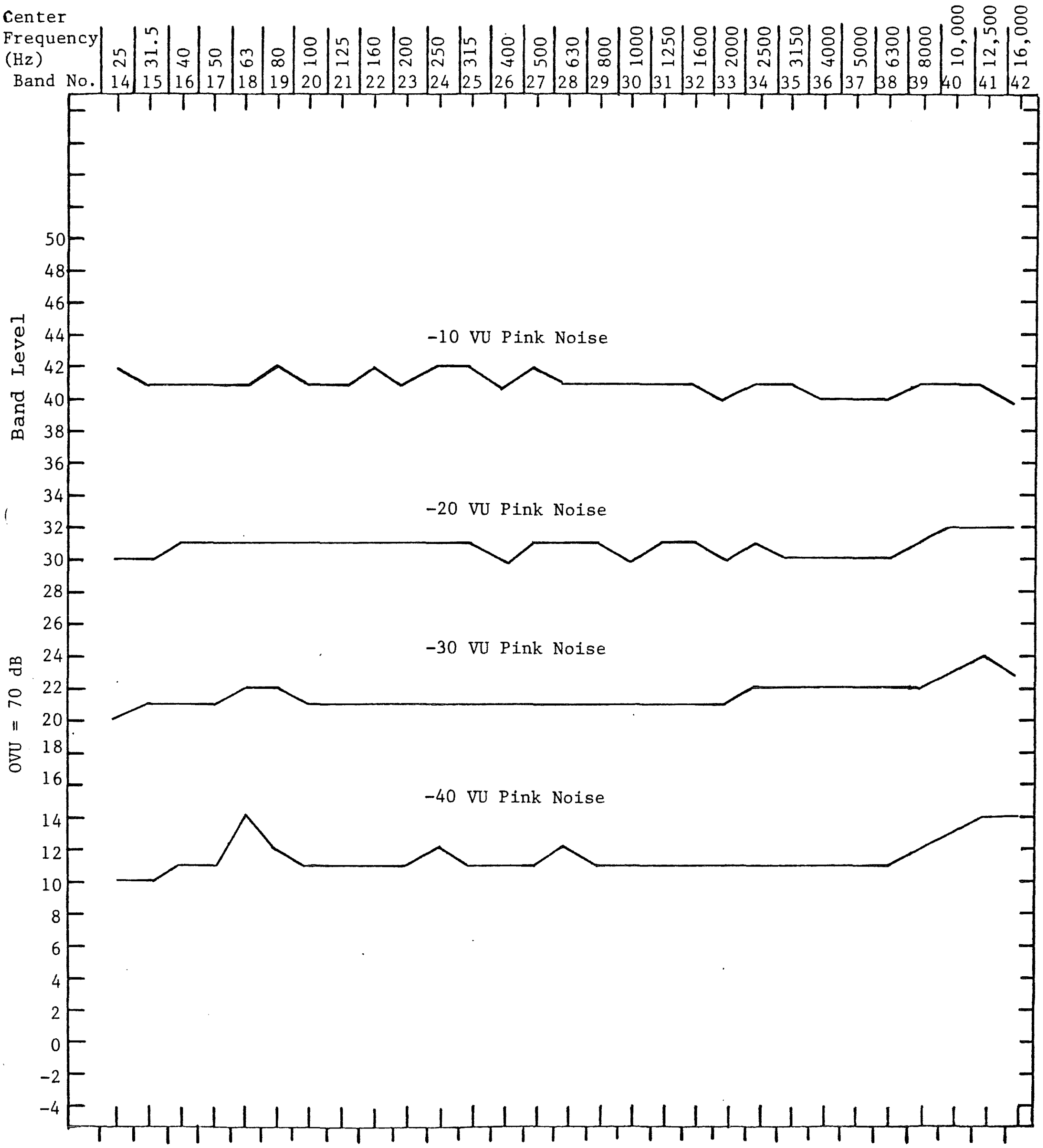


One-third Octaves Center Frequency (Hz)	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800
Band #	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
record-playback eg, before allignment	-4	-4	-4	-4	-4	-4	-4	-4	-3	-2	-2	-2	-2	-2	0	0
record-playback eg, after allignment	-3	-3	-3	-4	-3	-2	-3	-2	-2	-2	-1	-1	-1	0	0	0
low frequency roll off correction due to preamp	+10	9	7	6	4	3	2	2	1	1	0	0	0	0	0	0
before allignment including roll off correction	+6	+5	+3	+2	0	-1	-2	-2	-2	-1	-2	-2	-2	-2	0	0
after allignment including roll correction	+7	+6	+4	+2	+1	+1	-1	0	-1	-1	-1	-1	-1	0	0	0
A weighting correction factor	-43	-38	-33	-29	-25	-22	-18	-16	-13	-11	-9	-7	-5	-3	-2	-1
A weighting +20	-23	-18	-13	-9	-5	-2	+2	+4	+7	+9	41	43	45	47	48	49

One-third Octaves Center Frequency (Hz)	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000	12500	16000	20000
Band #	30	31	32	33	34	35	36	37	38	39	40	41	42	43
record-playback eg, before allignment	0	0	0	0	0	+1	+1	+2	+2	+4	not used			--
record-playback eg, after allignment	0	0	0	0	0	0	0	0	0	0	-1	-2	-3	not used
low frequency roll off correction due to preamp	0	0	0	0	0	0	0	0	0	0	0	0	0	
before allignment including roll off correction	0	0	0	0	0	+1	+1	+2	+2	+4				
after allignment including roll correction	0	0	0	0	0	0	0	0	0	0	-1	-2	-3	
A weighting correction factor	0	4	4	4	+2	+1	+1	0	0	-1	-2	-4	-6	-9
A weighting +20	20	21	21	21	22	21	21	20	20	19	18	16	14	11

Table 0-1 Equalization Settings for Test Procedure CN-13

Figure O-3 Equalized Frequency Response After Allignment



One-third Octave Center Frequency (Hz) Band #	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
A weighted, before allignment	-27	-22	-17	-13	-9	-6	-2	0	+4	+7	+9	+11	+13	+15	18	19	20	21	21	21	22	22	22	22	22	23			
A weighted, after allignment	-26	-21	-16	-13	-8	-4	-1	+2	5	7	10	12	14	17	18	19	20	21	21	21	22	21	21	20	20	19	17	14	11
A weighted, before allignment, including roll off correction	-17	-13	-10	-7	-5	-3	0	2	5	8	9	11	13	15	18	19	20	21	21	21	22	22	22	22	22	23			
A weighted, after allignment including roll off correction	-16	-12	-9	-7	-4	-1	1	4	6	8	10	12	14	17	18	19	20	21	21	21	22	21	21	20	20	19	17	14	11

Table 0-4 A weighted Equalization settings for Test Procedure CN-13

APPENDIX P

INVENTORY OF INSTRUMENTATION AND EQUIPMENT

INVENTORY OF MAJOR INSTRUMENTS

EQUIPMENT	MANUFACTURER	SERIAL #	MODEL #	DATE OF PURCHASE	SPECIFICATIONS	DATE CALIBRATED	DATE OF REPAIRS
Sound analyzer Sound analyzer	Metrosonic Metrosonic	1108 1109	db601 db602	3/2/76	Satisfy ANSI S1-4-1971 Type 2 requirements for general purpose sound level meters. Internal noise at least 10db below voltabe output by mics at their maximum sensitivity.	11/15/76	6/11/76(602) 1/14/77(602) 2/8/77(601) 5/26/77(602) 6/3/77(601)
Sound level meter	General Radio	21270	1565-C	3/15/76	30dBA to 130dBA crest factor >10dB. All-pass noise floor 24dB below maximum scale setting at minimum SLM setting.		
2 Condensor microphones 1"	B & K	559631 580385	4161	3/15/76	-58° to +140°F sensitivity -26dB re 1 $V/Nt/m^2$, capacitance: 66pF; back vented for dehumidifying	12/9/76 11/17/76 11/15/76	
1"ceramic microphone	General Radio	7653	1971-9605	3/15/76	Sensitivity -40dB rel $V/Nt/m^2$; -40° to 140°F capacitance 385pF		
Sound level meter (borrowed 3/10/76 to 6/15/76)	B & K	553832	2205	Borrowed from Al Perez, MPCA			
Preamplifiers	General Radio	902 3045 636(on loan) 3358 3272	1565-P42 1560-P42 "	4/16-8/23/76 " 8/27-9/7/76 9/7/76- present	Gain 0dB or 20dB output polarization voltage of 200V switchable on/off. Output current (signal) capability 10ma rms.	11/15/76	12/15/76 8/23/76
Pistonphone calibrator	B & K	577882	4220	3/15/76	124dB RE 20 $V/Nt/m^2$. Freq. = $250H^2$ Accuracy ±0.2dB	6/4/76 11/15/76	
Field calibrator-multifrequency	General Radio	19045	1562-A	3/15/76	113dB RE 20 $\mu N/M^2$. Freq. 125, 250, 500, 1000, 2000 $H^2 \pm 3\%$. Accuracy +0.3dB at 500Hz, +0.5dB, Others (at 25°C) **	11/15/76	
30.4 and 61dB attenuator	Midwest Accoustics	-------	--------	6/29/76			

** Although the field calibrator was specified to be 114 dB, testing prior to the field monitoring showed it to be 113 dB.

INVENTORY OF MAJOR INSTRUMENTS

EQUIPMENT	MANUFACTURER	SERIAL #	MODEL #	DATE OF PURCHASE	SPECIFICATIONS	DATE CALIBRATED	DATE OF REPAIRS
2 preamp power supplies	Midwest Accoustics						
Cassette tape recorder	Nakamichi	57714	550	3/19/76	Frequency response: 40-17,000Hz; ±3dB or better; battery life 15hrs; continuous use ; channel separation better than 35dB (1KHz 20dB); S/N ratio better than 60 dB peak level.	11/15/76	
Reel-to-reel tape recorder	Teac	00349673	A-2300	6/24/76	Frequency response ±2dB 30-16,000 Hz at 7½ips. S/N ratio 58 unweighted, 65 weighted. WOW flutter .08%. Speeds of 3-3/4, 7½ips.	11/14/76	
Signal divider	Midwest Accoustics	-------	------	6/17/76			
Anemometer	Metrosonic wind inhibit			1/7/77			
Anemometer readout meter	Roger Sipson				Two ranges: hi 0-40mph; low 0-20mph		
Bulk eraser	Notronics		QM211				
Alignment tape	Notronics	70970551	AT200	7/26/77	Tape type: BASF TP-18CrO$_2$; 15 minutes minimum; high quality standard Phillips; full track; specs on: Primary, secondary reference levels; azimuth section level; frequency response, speed and flutter, azimuth adjustment tone.		
Dynamic microphone					Low quality		

EQUIPMENT	MANUFACTURER	SERIAL #	MODEL #	DATE OF PURCHASE	SPECIFICATIONS
Wind meters(2)	Dwyer			3/5/76	Pocket size, dual range 0-10, 2-60; accuracy ±½mph (low scale) -3mph (high scale)
Navaho blanket				2/18/76	
Canoe car top carrier				6/24/76	
#2, #3 Duluth packs				6/24/76	
Small backpack				6/24/76	
Life belt (flotation for equipment)					
Compass				2/11/76	
Buck knife				2/11/76	
Stopwatch	Sears			3/4/76	
Catalytic Heater	Coleman		513A708		
12V batteries(2)			T24		
AC Power converter	Sears		7139		
Measuring tape 100'	Coast-to-Coast		302-0674		
Battery cables(2)					
Extension cables -3 conduct -or shielded					

EQUIPMENT	MANUFACTURER	SERIAL #	MODEL #	DATE OF PURCHASE	SPECIFICATIONS
2 tripods	Kalt, Vivitar		MR-913 1000	6/14/76	
Psychrometer	ETC	CP-147	2014	3/5/76	-20^{0} to $+120^{0}$F temperature range must meet Weather Bureau Spec. No. 405.8113
Pocket camera	Kodak		600		
Headphones	Pioneer		SE-305	5/3/76	
12V Power Adapter			POT 64		
2 Random incidence adapters	B & K		US-0055	4/14/76	
2-1" to ½" microphone adapters	B & K		DB0375		
Microphone dehumidifier	B & K		BA0310	3/15/76	
Brass case barometer	Weatherama		2-130B	3/5/76	27.5-31.5" mercury
Pocket calculator	Hewlett-Packard	1605A 13301	25	4/21/76	Automatic 4 memory stack; program memory of 49 steps; 8 addressable memories
½" foam large windscreen	Midwest Accoustics				
¼" foam large windscreen	Midwest Accoustics				
Volt-OHM meter	TIF	D2000	mm 240	6/21/76	
Snowshoes				2/5/76	
Parka	Eddie Bauer			2/4/76	

EQUIPMENT	MANUFACTURER	SERIAL #	MODEL #	DATE OF PURCHASE	SPECIFICATIONS
Remote inhibit cables(2)	Metrosonics				

ADAPTERS

(2) 3-prong switchcraft (male) phone plug

3-prong switchcraft (female) adapter for B & K 2205

(3) 3-prong switchcraft (female) phone plug

3-prong switchcraft (male) 2205 B & K adapter

(3) Input cables for Metrosonic dB601 and dB602

(2) Power cables for Metrosonic dB601 and dB602

(2) Phone jacks for Nakamichi tape recorder

Male small phone plug and male plug (short cable)

Small phone and phone plug (long cable)

B & K adapter calibrator

(2) Small screwdrivers

Double female phone plug

(3) Female phono and male phone

(3) Male phono and female phone

(2) General radio adapters

(2) Female switchcraft switches

TOOLS

Long nose pliers

Wire cutters

4 screwdrivers (2 regular & 2 phillips)

Soldering iron

Pliers

Stanley razor

12" crescent wrench

6" crescent wrench

Hammer

Allen wrenches (HK11)

Shovel

Extension cord

APPENDIX Q

DATA SUMMARY

FOR

CALIBRATION CHECK

OF

COPPER-NICKEL STUDY SOUND LEVEL MEASUREMENT EQUIPMENT

TO

MINNESOTA ENVIRONMENTAL QUALITY COUNCIL

COPPER-NICKEL PROJECT

FROM

MIDWEST ACOUSTICS AND ELECTRONICS, INC.

EDINA, MINNESOTA

APRIL 20, 1978

1. 1560 - P42 Preamplifiers (x10 Gain).

a. Noise levels (all in dB)
(Lin, A-wt., Octave Bands)

	S/N	3358	S/N	3272
200 Volts	Off	On	Off	On
Linear	28	37	19	39
A-wt.	5	8	4	17
31.5 Hz Octave	10	12	9	12
63 "	8	8	7	7
125 "	4	4	4	4
250 "	1	1	1	1
500 "	-1	-1	-1	-1
1k "	-4	-3	-3	-3
2k "	-5	-4	-4	-3
4k "	-5	-2	-4	-1
8k "	-3	1	-2	3
16k "	0	5	0	9
31.5k "	2	18	3	22

b. Frequency REsponse

10Hz - 20kHz	±0.1 dB	±0.1 dB

c. Gain (20Hz, 1kHz, 10kHz, 20kHz)

Gain Setting x 1	0dB ±0.1dB	0dB ±0.1dB
Gain Setting x10	20.3dB ±0.1dB	20.3dB ±0.1dB

d. Input voltage clipping level

Gain Setting x 1	4.72V	4.33V
Gain Setting x10	0.407V	0.433V

2. Signal Splitter designed by MAE

a. Input Impedance: 3.7 k ohm.

b. System noise at outputs with GR1560-P42 preamp S/N 3358, Gain: x10, (all in dB)

200V	Left Channel		Right Channel	
	Off	On	Off	On
Linear	17	34	19	34
A-wt.	6	7	6	7
31.5 Hz Octave	8	11	10	11
63 "	7	9	8	8
125 "	4	4	4	4
250 "	1	1	1	1
500 "	-1	-1	-1	-1
1k "	-3	-3	-3	-3
2k "	-3	-3	-3	-3
4k "	-2	-1	-2	-1
8k "	1	2	1	2
16k "	0	7	3	8
31.5k "	3	13	6	14

c. Input Voltage Clipping Level	4.46V	4.35V
d. Attenuator Attenuation (1kHz)		
Setting: 30dB	30.1dB	30.0dB
Setting: 60dB	60.0dB	59.8dB
e. Frequency Response (with 1560-P42 Preamp S/N 3272)		
10Hz - 20kHz	Flat ±4.0dB	Flat ±4.0dB
31.5Hz - 20kHz	Flat ±0.9dB	Flat ±0.9dB
125 Hz - 20kHz	Flat ±0.1dB	Flat ±0.1dB

3. Attenuator Designed by MAE with 1560-P42 preamps.

Frequency	Atten. Setting	Observed Attenuation into 600 ohm Load	
		S/N 3358	S/N 3272
125Hz	30.4	30.3	30.3
250Hz	"	30.4	30.4
500Hz	"	30.4	30.4
1k HZ	"	30.4	30.4
2k Hz	"	30.4	30.4
125Hz	62	62.0	62.0
250Hz	"	62.0	62.0
500Hz	"	62.0	62.0
1 kHz	"	62.0	62.0
2 kHz	"	62.0	62.0

4. Nakamichi 550 Tape Recorder S/N 57714

a. Noise Level Relative to OVU (shorted input) Dolby ON)

Input Gain Control		Full CW				1/2 CW			
Input		Line		Mic.		Line		Mic.	
Channel		L	R	L	R	L	R	L	R
Noise Level in dB Re: OVU for A-wt. and Octave Bands:									
A-wt.		-59	-59	-50	-52	-58	-59	-58	-59
31.5Hz	Octave	-71	-71	-69	-71	-69	-71	-70	-70
63Hz	"	-61	-68	-61	-67	-61	-68	-61	-68
125Hz	"	-65	-67	-64	-66	-64	-67	-65	-67
250Hz	"	-60	-60	-62	-60	-61	-60	-62	-60
500Hz	"	-67	-67	-63	-65	-67	-67	-67	-67
1kHz	"	-68	-68	-62	-64	-68	-68	-68	-68
2kHz	"	-68	-67	-60	-62	-68	-68	-68	-68
4kHz	"	-67	-67	-57	-59	-66	-66	-66	-67
8kHz	"	-63	-63	-54	-56	-63	-63	-63	-64
16kHZ	"	-58	-59	-48	-53	-58	-59	-58	-60

4. b. Nakamichi 550

Frequency Response (Dolby ON, Line Input)

VU Setting	Tolerance (dB)	Left Channel	Right Channel
-20VU	±1dB	60Hz- 6kHz	50Hz - 2kHz
-20VU	±2dB	50Hz-10kHz	40Hz - 16kHz
-20VU	±3dB	50Hz-13kHz	30Hz - 16kHz
-40VU	±1dB	50Hz- 6kHz	50Hz - 12kHz
-40VU	±2dB	50Hz- 8kHz	50Hz - 14kHz
-40VU	±3dB	30Hz-10kHz	30Hz - 14kHz

c. Frequency Stability ±0.07%

d. Frequency Response (Mic input, 1560-P42 preamp, S/N 3358, Dolby ON, Right Channel -20VU).

Tolerance (dB)	Frequency Range:
±1dB	90Hz-12kHz
±2dB	70Hz-13kHz
±3dB	70Hz-17kHz

Nakamichi 550 System noise with GR 1560-P42 Preamp. mic. input.

(65dB calibration signal recorded at 0VU with P42 on x1 Gain. P-42 then changed to x10 gain and a 66 pf. dummy microphone placed on the preamp. The effective sound level in dB is given for A-wt. and Octave bands.)

	1560-P42 S/N 3272				1560-P42 S/N 3358			
	200V off		200V on		200V off		200V on	
	L	R	L	R	L	R	L	R
A-wt.	10	4	14	7	11	5	11	6
31.5 Hz Octave	-7	-1	-5	-1	-5	2	-5	3
63 "	-2	10	-2	11	0	6	0	6
125 "	0	3	0	4	1	5	1	6
250 "	0	2	0	2	1	3	1	3
500 "	0	0	-2	0	0	1	-1	1
1k "	1	-3	-3	-3	1	-2	-2	-1
2k "	3	-4	-3	-3	3	-3	-2	-2
4k "	3	-4	1	-3	4	-3	2	-3
8k "	3	-2	8	1	4	-1	7	0
16k "	7	1	18	7	7	1	14	5

5. Metrosonics Analyzers

a. Frequency Response

Analyzer	dB601		dB601		dB602	
S/N	X001		1108		1119	
Input Frequency	Mic A (dB)	Hi Level (dB)	Mic A (dB)	Hi Level (dB)	Mic A (dB)	Hi Level (dB)
Hz						
10	-65	0	-63	-1	-64	-1
16	-56	0	-51	-1	-53	-1
20	-51	0	-48	-1	-49	-1
31.5	-41	0	-38	0	-39	0
125	-17	0	-16	0	-17	0
250	- 9	0	- 9	0	- 9	0
500	- 4	0	- 3	0	- 4	0
1k	0	0	0	0	0	0
2k	+ 1	0	+ 1	0	+ 2	0
4k	0	0	0	0	+ 1	0
8k	- 4	-1	- 4	-1	- 4	-1
12k	- 8	-2	- 7	-1	- 7	-1
16k	-13	-2	-11	-1	-10	-1
20k	-20	-3	-14	-1	-12	-1

b. System Noise Floor (66 pf. dummy mic. P-42 preamp, with and without signal splitter).

Analyzer	601	601	602
S/N	X001	1108	1119
P42 S/N 3358 (x10)	8dBA	6dBA	1dBA
P42 S/N 3358 (x10) with splitter	7dBA	6dBA	1dBA
P42 S/N 3272 (x10)	5dBA	6dBA	1dBA
P42 S/N 3272 (x10) with splitter	5dBA	6dBA	2dBA

5. c. Display Linearity

dB 601 (S/NX001) - linear ±0.5 dB over 95dB range *

dB 601 (S/N1108) - linear ±0.5dB over 95dB range *

dB 602 (S/N1119) - linear ±0.5dB over a 90dB range *

*down to the noise limits of the measurement equipment

d. Input Attenuator Accuracy

dB 601 (S/N X001) ±0.1 dB for all settings except for the 60 range which has a broken connecting wire to the switch.

dB 601 (S/N 1108) ±0.1dB for all settings

dB 602 (S/N 1119) ±0.1dB for all settings

e. Duration Clock Accuracy

The duration clock was checked for durations of 30 min. and one hour. Accuracy on all three units was ±1 seconds over one hour.

f. LN Calculation Accuracy

A test tape was made and the tape output fed to the analyzer units, a fast-responding strip chart recorder and a B & K 4426 analyzer. All metrosonic analyzers computed LN values correctly within ±0.5dB.

g. Analyzer Fast and Slow Response.

Fast Response - All units showed an overshoot when tested with a series of 0.2 sec. long tone burst pulses at 1kHz. None of the units were found to meet ANSI Fast.

Slow Response - All units showed an inability to rise to within the level specified for ANSI slow. None met this ANSI Standard.

5. h. Microphone Preamp Power Supply Voltage

Analyzer	dB 601	dB 601	dB 602
S/N	x001	1108	1119
Voltage, No load	20.2V	18.3V	19.3V
Voltage, P-42 load (Battery only)	10.8V	9.6V	9.8V
Voltage, P-42 Load (110 VAC Power)	12.3	12.1V	13.0V

i. Multiple Interval Mode of dB602

A test tape was run into the dB602 high level input and the multiple interval calculation was checked. The multiple interval LN values agreed with the continuous LN values within 1dB for L10, L50, L90 and L99.

6. General Radio Sound Level Calibrator

Type 1562-A S/N 19045

Compared with B & K 4220 Pistonphones S/N 577882 and S/N 407987 in place on B & K microphone type 4145 S/N 573630 with a sound level of 124.0dB at 200 Hz.

Frequency	125Hz	250Hz	500Hz	1kHz	2kHz
Sound level (dB)	113.6	113.0	113.1	112.8	112.1

7. Power Supplies Designed by MAE

	S/N:	CU-101	CU-102
a. Voltage - unloaded		19.4	19.3
- loaded (P-42)		19.8	19.8

b. Noise Floor

A comparison was made of both power supplies using preamplifier P-42 S/N 3272. Results showed an identical noise floor for each power supply. See Section 1.a., for P-42 S/N 3272 noise floor with power supply CU-101.

8. Comments

Metrosonics Frequency Response - The analyzers meet ANSI type 2 and very nearly meet ANSI type 1.

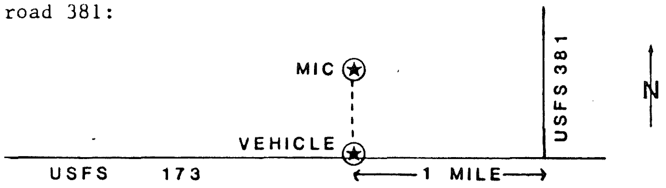
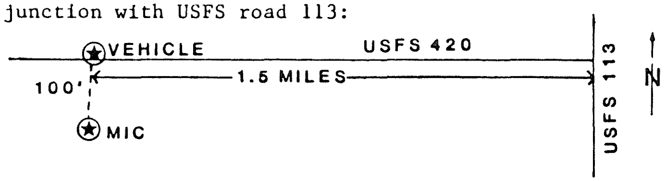
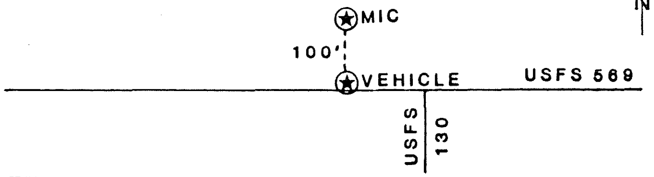
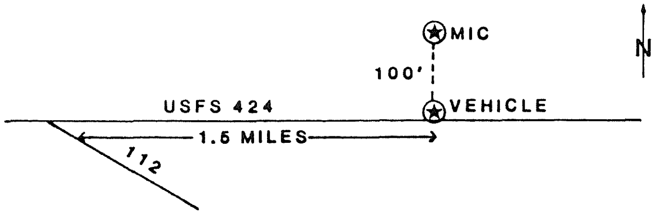
Metrosonics FAST and Slow Response - The analyzers did not meet the ANSI Fast and Slow required response over a pulse dynamic range greater than 50dB. Over a dynamic range of 30dB, the analyzers met the ANSI Fast response test. In a comparison test with an analyzer that meets ANSI Fast and Slow, the statistical Slow response analysis of a tape loop of noise bursts showed close agreement between the two analyzers.

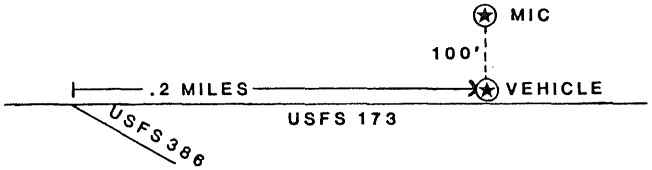
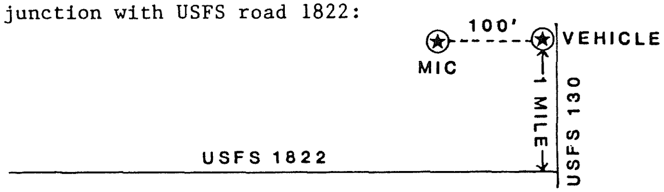
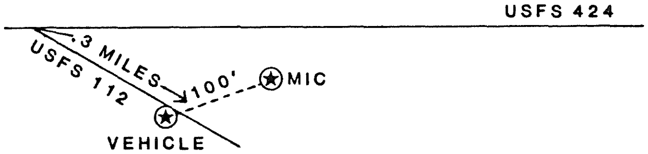
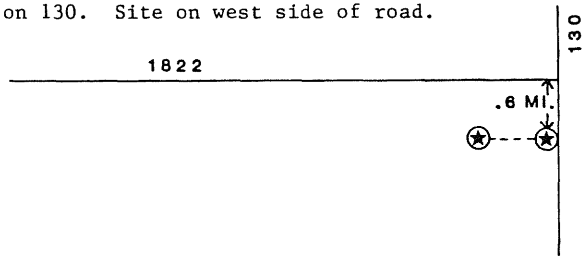
For field measurements having a restricted dynamic range such as that encountered in the Copper-Nickel study, it is our opinion that the analyzers will give correct and reliable data.

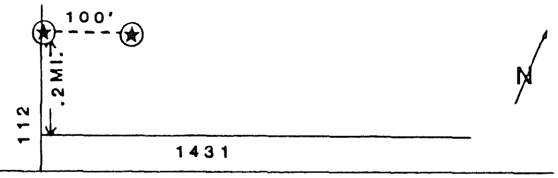
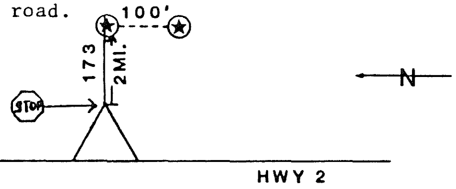
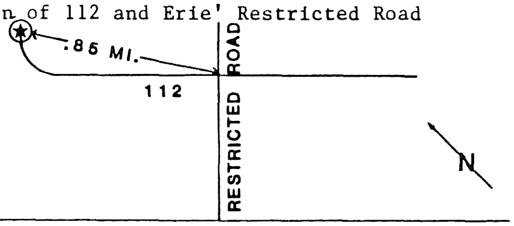
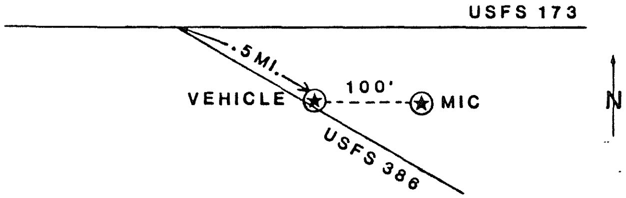
APPENDIX R

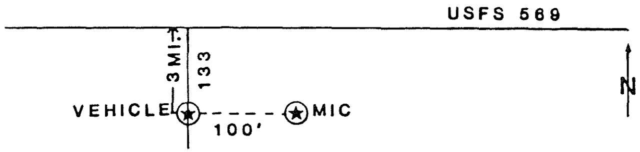
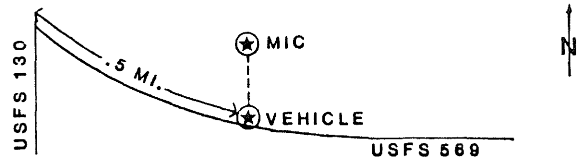
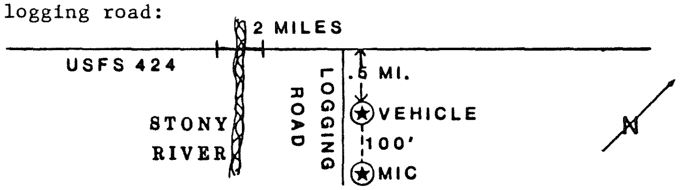
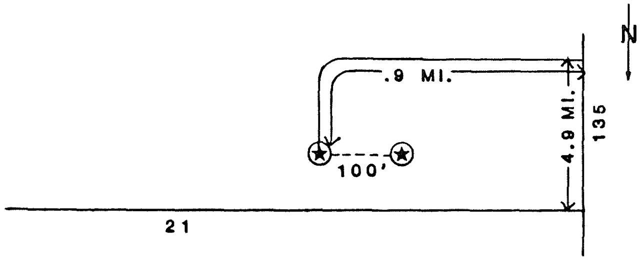
SITE DESCRIPTIONS AND LOCATIONS

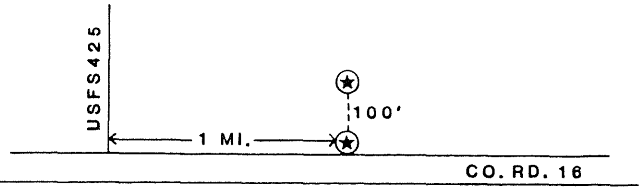
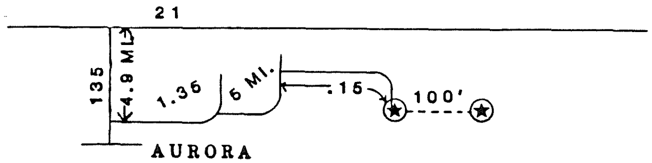
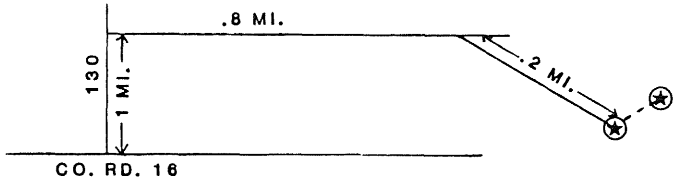
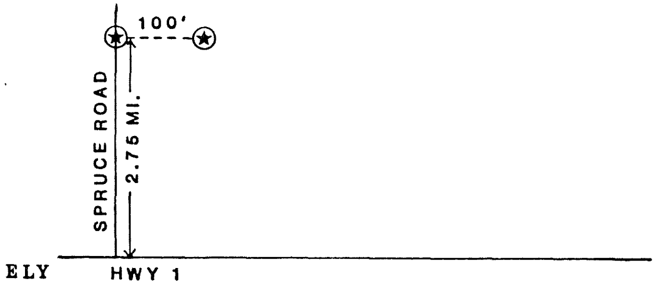
SITE DESCRIPTIONS FOR PERIOD 1/77-END OF PROJECT

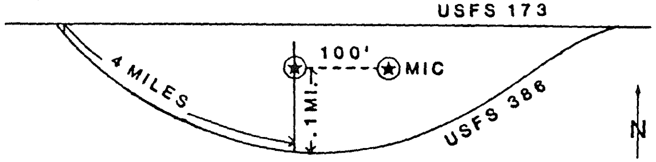
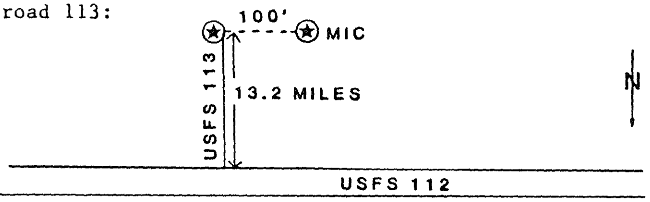
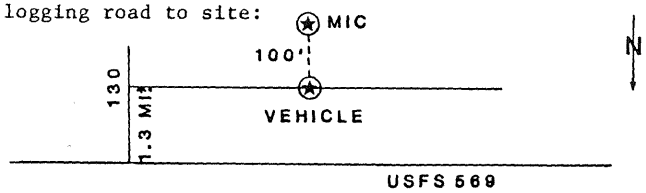
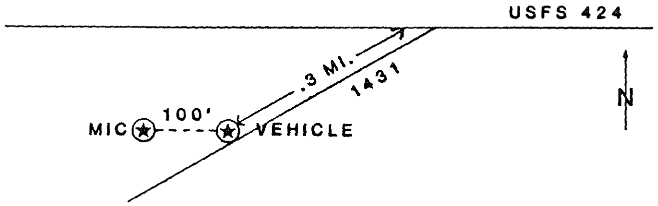
SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAP (ORIENTED NORTH)
VP-5 Distant North	Mature Black spruce	Jackpine, Red pine, Surrounding site	North side of USFS road 173, 1 mile west of USFS road 381: 
VP-30 Distant South	Mature Black spruce	Alder swamp across road (420) with other surrounding mixed sparse vegetation	South of USFS road 420, 1.6 miles northwest of junction with USFS road 113: 
B-24 Distant South	Black spruce		North side of USFS road 569 at junction of USFS road 569 and USFS road 130: 
VP-16 Close	Mid-aged tamarack and black spruce co-cominant	Tamarack, Black spruce	North side of USFS road 424, 1.5 miles east of junction with USFS road 112: 

SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAP (ORIENTED NORTH)
B-8 Distant North	Mature Jackpine	Jackpine, Red pine, Black spruce, Sporadic aspen	North side of USFS 173, .2 miles west of junction with USFS road 386: 
VP-2 Distant South	Mature Jackpine	Jackpine, Alder shrubs, Birch, Aspen	West side of USFS road 130, 1 mile north of junction with USFS road 1822: 
B-9 Close	Mature Jackpine	Sparse Black spruce, Tamarack, and treated aspen to the west. Jackpine on all other sides.	Northeast side of USFS road 112, .3 miles southeast of junction with USFS road 424: 
B-20 Distant South	Red pine plantation, some young aspen	Mid-aged aspen	.6 miles south of intersection of 130 and 1822 on 130. Site on west side of road. 

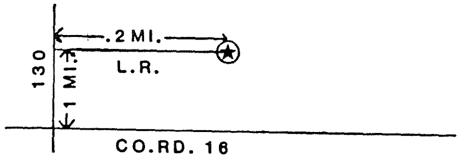
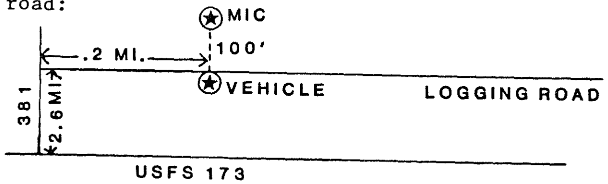
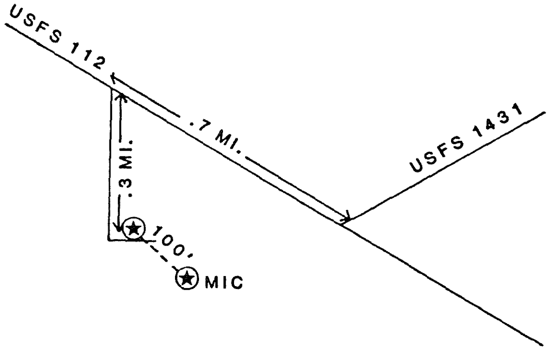
SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAP
B-3 Close	Red pine	Mixed aspen	Site .2 miles west of intersection of 1431 and 112 on 112. Located on north side of 112. 
NS-8 Distant North	Red pine	Mid-age aspen, Birch, Jackpine	Site 2 miles north of the stop sign at the intersection of Lk Isabella Rd. and 173 on 173 on east side of road. 
NS-2 Close	Birch, some mid-aged aspen		Site located .85 miles northwest of the intersection of 112 and Erie' Restricted Road on 112. 
VP-9 Distant North	Mid-aged trembling aspen/paper birch	Fir, Paper birch	Northeast side of USFS road 386, .5 miles southeast of junction with USFS road 569: 

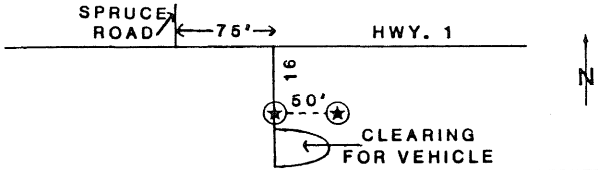
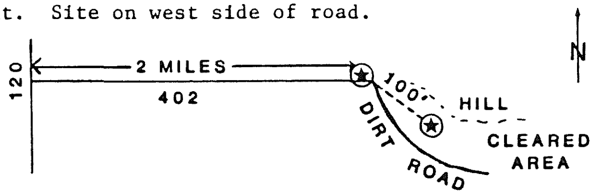
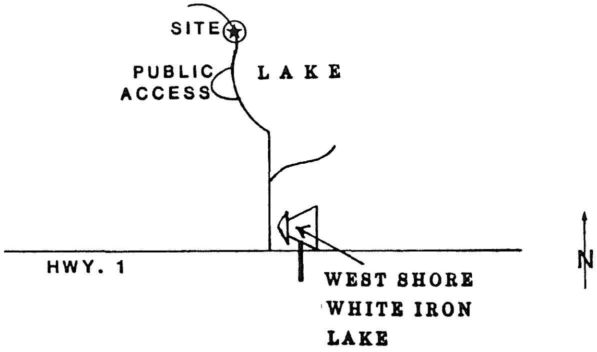
SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAP
VP-8 Distant South	Mature Paper birch	Fir, Paper birch	East side of USFS road 113, ∿3 miles south of junction with USFS road 569: 
B-23 Distant South	White birch		North side of USFS road 569, .5 miles southeast of junction with USFS road 130: 
VP-7 Close	Mature Paper birch	Fir, Aspen, Birch	2 miles northeast of Stony River on USFS road 424 to logging road, .5 miles southeast on logging road: 
NS-3 Close	Aspen, Mid-aged fir understory		

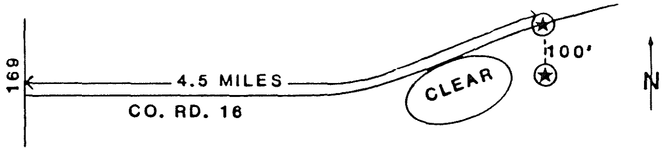
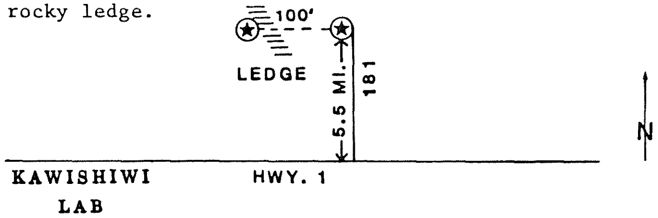
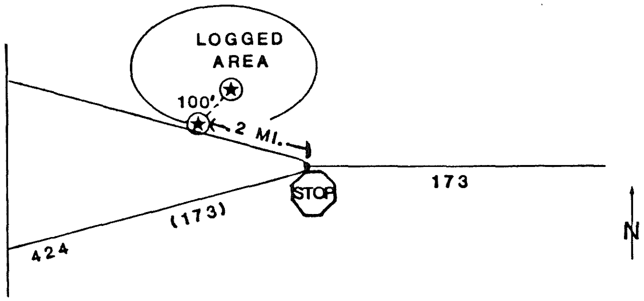
SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAP (ORIENTED NORTH)
G-12 Distant South	Mid-aged Aspen with some spruce and fir mixed in	Ash, Spruce, Shrubs, Aspen	
NS-5 Close	Sapling aspen, Sparse mature birch and popple		
NS-6 Distant South	Sapling aspen		
NS-9 Distant North	Sparse-mixed	Mid-age aspen, Black spruce, Jackpine	

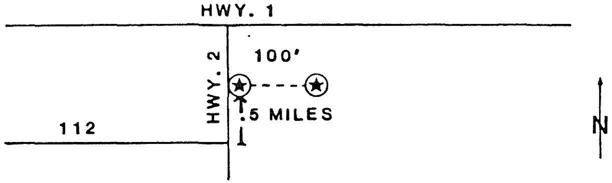
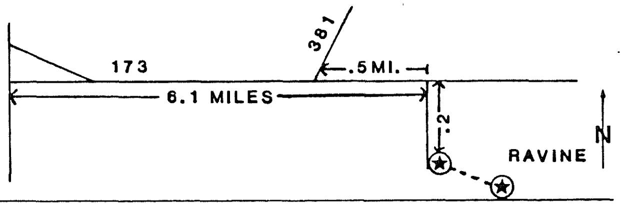
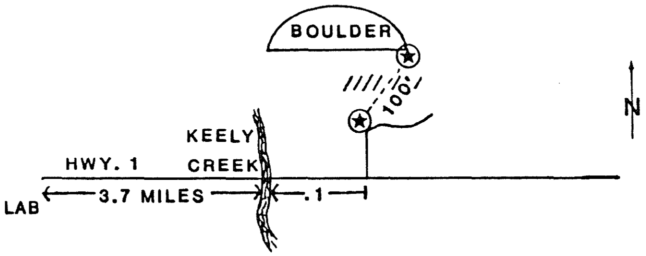
SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAP
VP-36N* Distant North	Sparse mixed vegetation, shrubs and young red pine	Sparse mixed vegetation with sporadic mid-aged to mature red pine, mid-aged aspen on southside of USFS 386	4 miles southeast of USFS road 173 on USFS road 386 to logging road, .1 mile north on logging road to site: 
VP-37N* Distant South	Sparse mixed vegetation, black spruce, young jackpine, and 6' alder	Same as site: some sporadic aspen	13.2 miles south of USFS road 112 on USFS road 113: 
VP-35N* Distant South	Sparse vegetation, young red pine plantation	Shrubs, Young red pine	1.3 miles south from USFS road 569 on USFS road 130 to logging road, .2 miles west on logging road to site: 
R-25 Close	Sparse vegetation: mostly alder shrubs		West side of USFS road 1431, .3 miles south of junction with USFS road 424: 

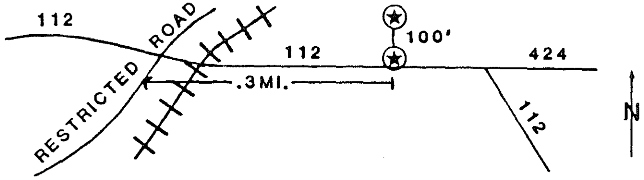
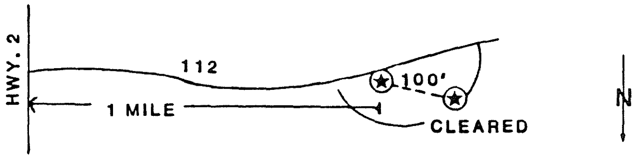
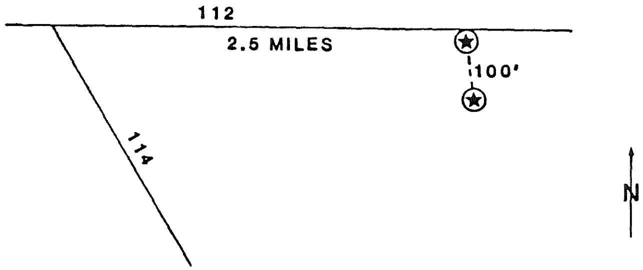
*Not a terrestrial plot

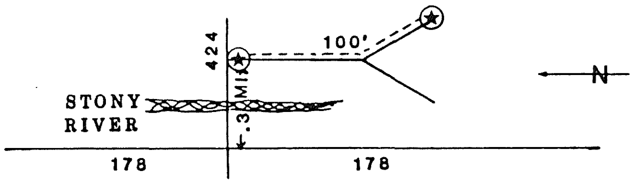
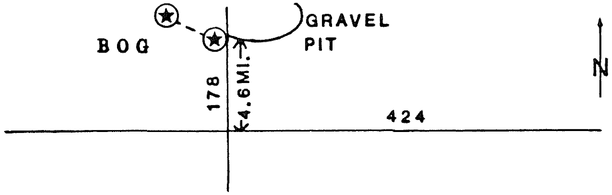
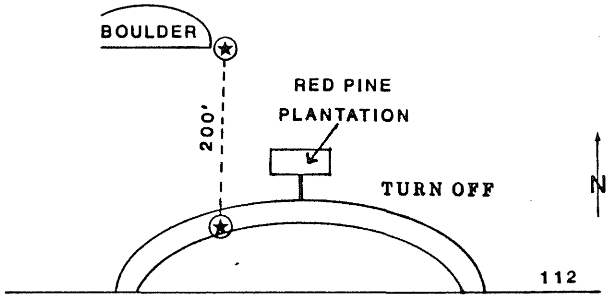
SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAP (ORIENTED NORTH)
NS-7 Distant South	Clear cut	Aspen	North on 130 one mile from intersection with Co Rd 16. East on logging road .2 miles to site. 
VP-31 Distant North	Clear cut ~40-60 acres	Black spruce	2.6 miles north of USFS road 173 on USFS road 381 to logging road, .2 miles east on logging road: 
3B Close	Clear cut ~40 acres	Black spruce, Red pine	.7 miles northwest of USFS road 1431 on USFS road 112 to logging road, south on logging road .3 miles to site: 

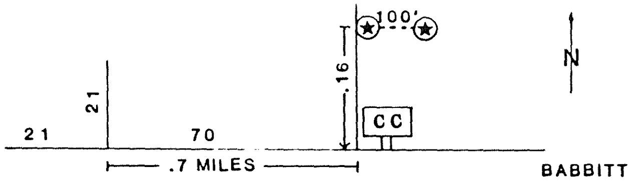
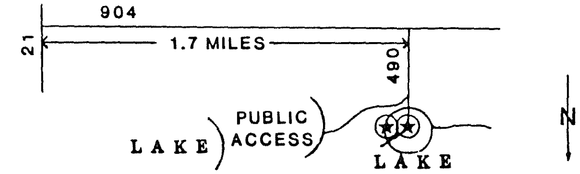
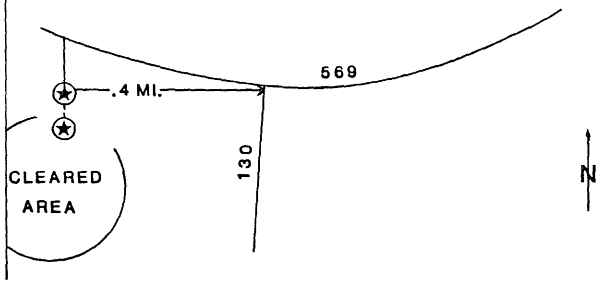
SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAPS
WH Control	Coniferous, Fir, Spruce, White pine, Red pine		Southeast on Hwy 1 (∿11 miles from Ely), past Spruce Rd Sign 75', turn right on 16, sign "S. Kawishiwi Summerhomes," follow .2 miles. 
WH 100	Mixed, mostly Jack-pine, some Spruce, birch, Alder	Cleared	End of Co Rd 402 ∿2 miles from 120. Site marked where 402 ends and dirt road turns right. Site on west side of road. 
WH 200	Ash spruce		New house on site: ∿300' past public access, ∿1 mile from Hwy 1. 

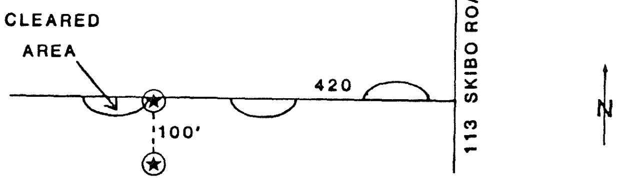
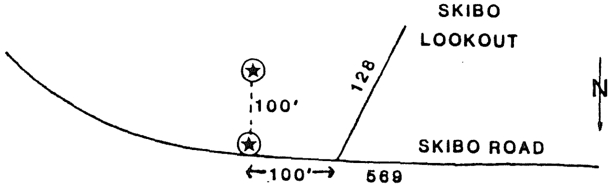
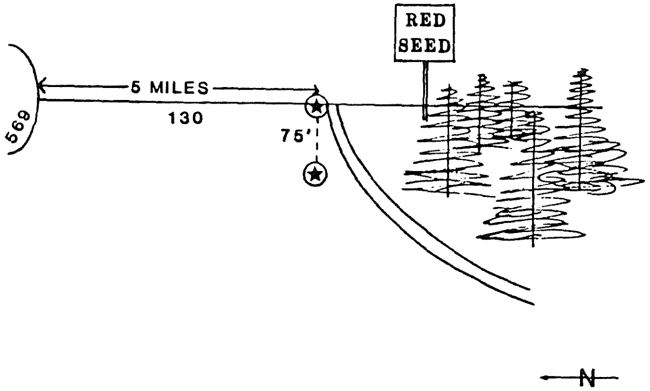
SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAPS
WH 300	Mixed: Fir, Birch, Aspen	Partially cleared	East on Co Rd 16 (NE of Ely) ∿4.5 miles. Site on south side of road. 
WH 400	Sparse mixed: Young birch, White pine, Spruce, Shrubs	Same	North on USFS 181 (Spruce Rd.) ∿5.5 miles at top of hill, narrow semi-cleared area on west side of rd. MIC site 100' west just past small rocky ledge. 
DV Control	Logged; 4' alder, few young Red pine and Spruce		Hwy 1 to Lake Isabella Road, .2 miles from stop sign at intersection of Tomahawk Rd. (173 north of Hwy 1). 

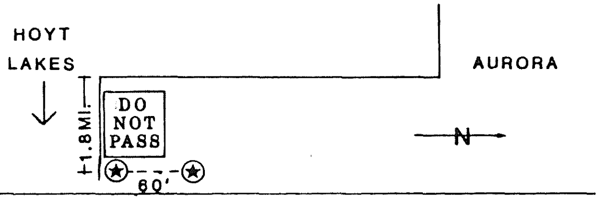
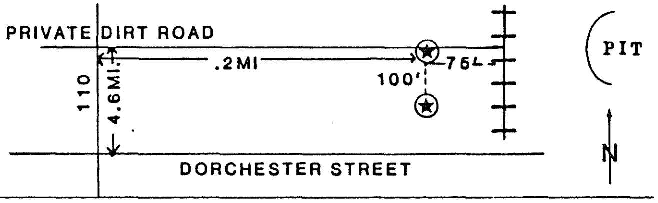
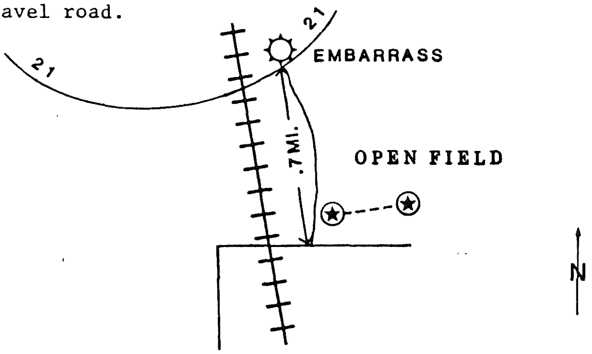
SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAPS
DV 100	Red pine, White pine, Birch		.5 miles from intersection of Hwys 2 and 112 on 2 going north. Site on east side of road ~100' north of plantation sign. 
DV 200	Red pine, Jack pine		6.1 miles east on 173 from Jct. of Lake Isabella Rd. and 173, turn right on unmarked dirt road .5 miles past 381, .2 miles to site. Site on east side of road. Follow ravine south to MIC site 100'. 
DV 300	Mixed: Jackpine, Spruce, Birch	Same	Intersection of Hwy 1 and Keeley Creek 3.7 miles SE of Kawishiwi Lab. Turn north .1 miles past Keeley Creek sign. There is cleared area to park vehicle. MIC site 100' up rocky incline 15' into shrubby vegetation. 

SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAPS
BR Control	Mixed: Black spruce, Jackpine, 3M Alder		100' in off 112 .3 miles from intersection with restricted road. Turn in to park vehicle. 
BR 100	Mostly Red pine, some White pine, Fir, Birch/Aspen		On USFS road 112, 1 miles south of Hwy 2, site on west side of road near small clearing. 
BR 200	Mostly Spruce and Fir, some Birch		2.5 miles from intersection of 112 and 114 on east side of road. 

SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAPS
BR 300	Young Jackpine, 5m Alder, a few Birch		East on USFS Rd 424 .3 miles past USFS 178 intersection, site on south side of road near old road, road forks 50' from 424. 
BR 400	Black spruce bog, Jackpine, Birch/Aspen		North on 178 from 424 4.6 miles. Site on left side of road opposite small gravel pit. 
BR 500	Red pine plantation	Same	North side of 112 .9 miles from intersection with 70. Turnoff: Superior National Forest sign: Birch Lake Plantation. Site 200' from road by large boulder: 

SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAP
BR 600	Jackpine, very young Red pine		.7 miles from 21 on 70 towards Babbitt, turn left at Country Club sign, site .5 miles on right (east). 
BR 700	Birch/Aspen, sporadic Jackpine		East on Co. Rd. 904 to Co. Rd. 490. North on 490 to turn-around at top of small hill just past public access sign. Site on west side of circle; MIC site 75' west of road site: 
SL Control	Cleared	Birch/Aspen A few Spruce	.4 miles west of USFS 130 on 569, site 1st road on south side. MIC site in center of cleared area. 

SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAP
SL 200	Sparse: young Red pine and Spruce	Aspen, Spruce, Tamarack	Third truck turn-out on 420: 
SL 300	Birch, Fir, Spruce	Birch, Spruce	Site 100' east of intersection of 569 and 128 on 569 
SL 400	Cleared: young Red pine plantation	Birch/Aspen	5 miles south of 569 on 130 to plantation sign reading "Red Seed" on south side of road: 

SITE	VEGETATION	SURROUNDING VEGETATION	LOCATION AND MAP
SL 500	6-8' Alder	Black spruce, Birch	Site north side of 110 1.8 miles from Aurora towards Hoyt Lakes. Alder marked near "Do Not Pass" sign. MIC 60' north of road just past cleared strip for telephone poles. 
SL 600	Partially cleared: Shrubs, Tamarack (?), Mixed	White pine, Birch/Aspen, Spruce, Alder	4.6 miles north of Dorchester Street (Hoyt Lakes) on Co. Rd. 110 to private road. Site 75' from railroad track on south side of road. 
SL 700	Open field short grass 500' x 1000'	Mixed young coniferous and Birch, Alder	.75 miles south of Hwy 21 out of Embarrass on gravel road. 

The sites described in this section were monitored during the summer of 1976. These sites were derived from Workplan II.

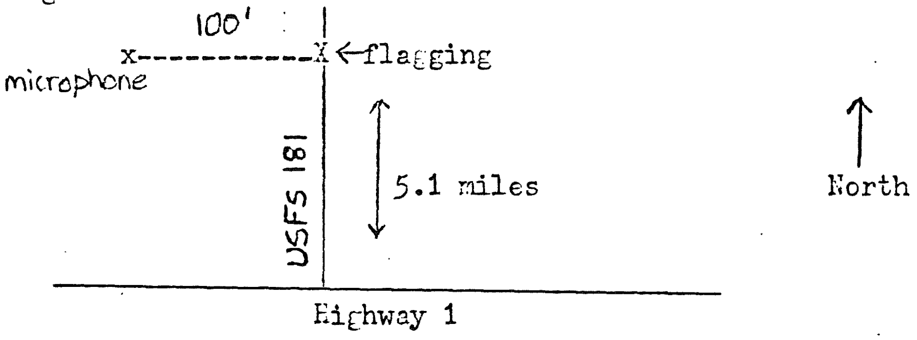
I. Site 01A

A) Description

Fairly dense young aspen with mixed coniferous vegetation. Site is bordered by

B) Location

5.1 miles north of Highway 1 on USFS 181 (Spruce Road). Site is about 100' due west of 181. Microphone is set up in a small clearing:



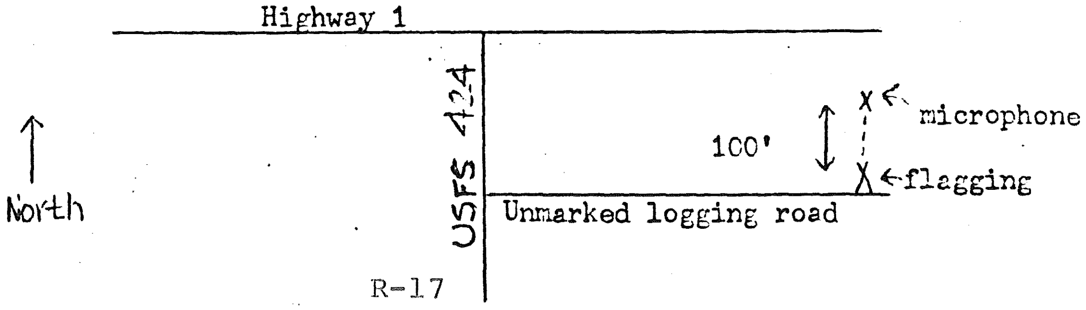
II. Site 01B

A) Description

Mature paper birch stand with little surrounding coniferous vegetation.

B) Location

5.2 miles south of Highway 1 on USFS road 424 to unmarked logging road on east side of 424. 1 mile on logging road to site marker. Microphone is set up 100' north of site marker:



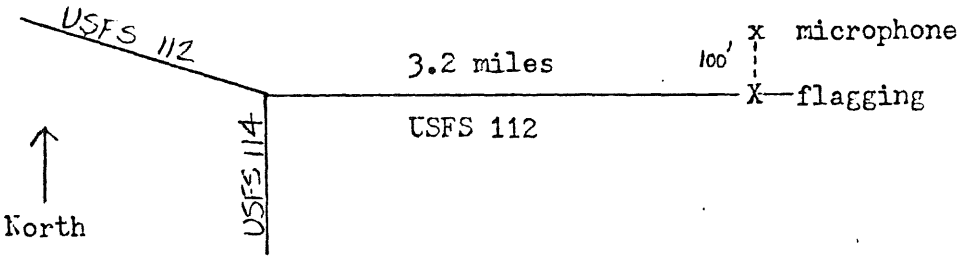
III. Site 01C

A) Description

Mature to mid-aged white birch with little coniferous vegetation mixed in. Site is bordered by

B) Location

3.2 miles east of USFS road 114 on USFS 112. Site is marked on north side of 112 and microphone is set up 100' north of site marker:



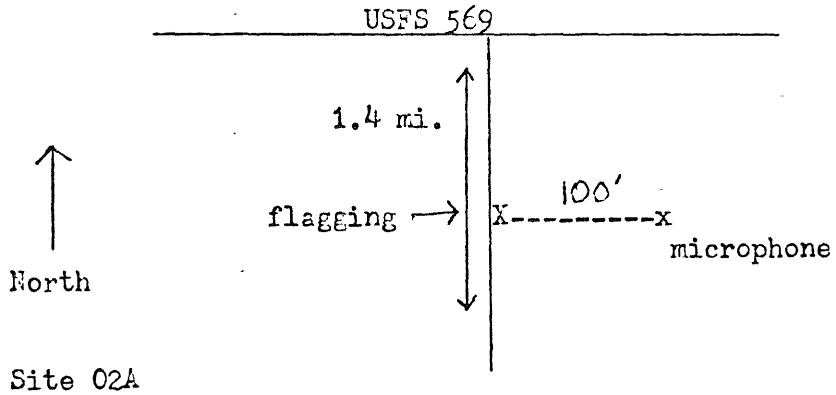
IV. Site 01D

A) Description

Paper birch mid-aged to mature with some mixed coniferous vegetation. Site is bordered on the north by alder shrubs.

B) Location

1.4 miles on USFS road 569. Site is marked on east side of 133 with microphone placed 100' east of flagging:



V. Site 02A

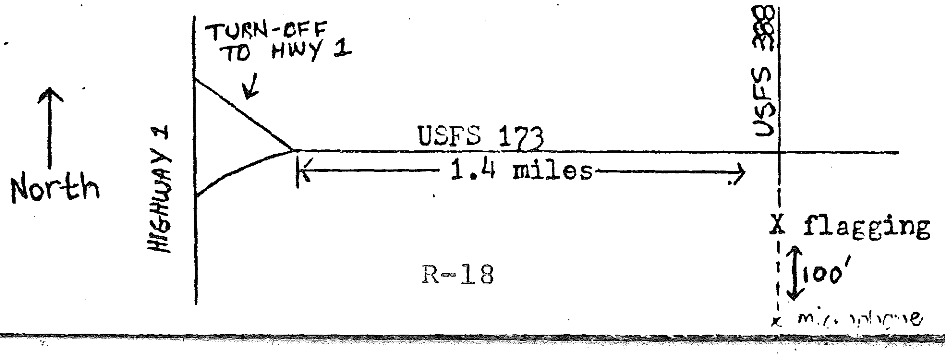
A) Description

Site is a mix of

Site is flanked by hills approximately 20' high.

B) Location

1.4 miles north on USFS road 173 from turn-off to Highway 1 to unmarked logging road directly south of intersection of USFS 173 and USFS 388. .1 Mile south on logging road to flagging. Microphone placed 100' south of flagging on logging road:



VI. Site 02E

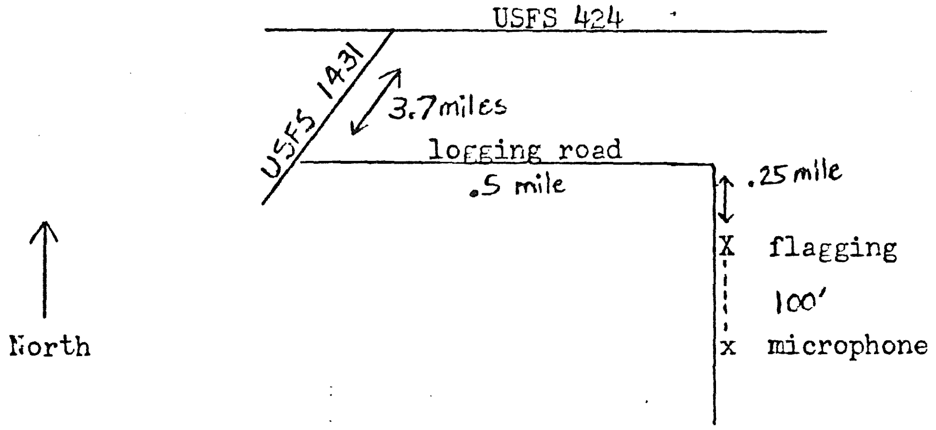
A) Description

Site is mixed with JACK PINE, SPRUCE, AND SCATTERED BIRCH

Some alder shrubs are also present.

B) Location

3.7 miles southwest of USFS road 424 on USFS road 1431 to unmarked logging road on east side of 1431. .5 miles on logging road to fork in road. Right fork for .25 miles to flagging. Microphone is set up 100' south of flagging on road:



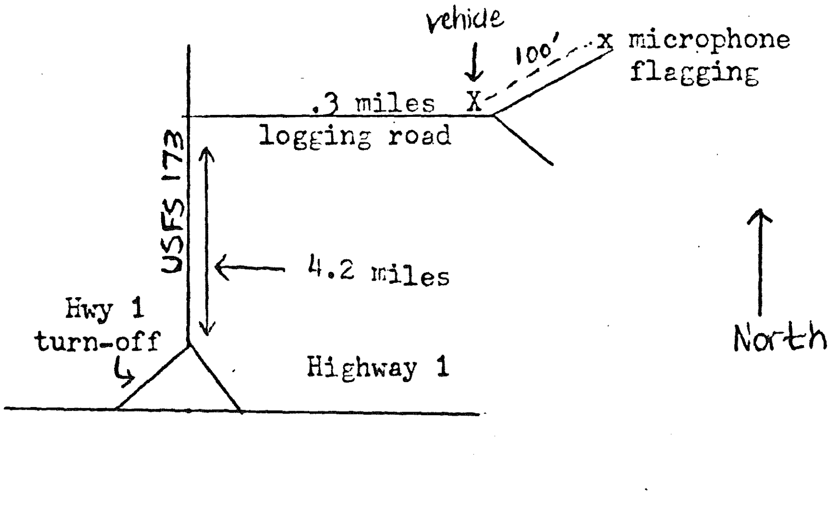
VII. Site 02C

A) Description

Site is mixed with

B) Location

4.2 miles north of turn-off to Highway 1 on USFS road 173 to unmarked logging road on east side of 173. .3 miles to a fork in the road. Microphone is set 100' down the left fork from the intersection. Flagging indicates placement of microphone:



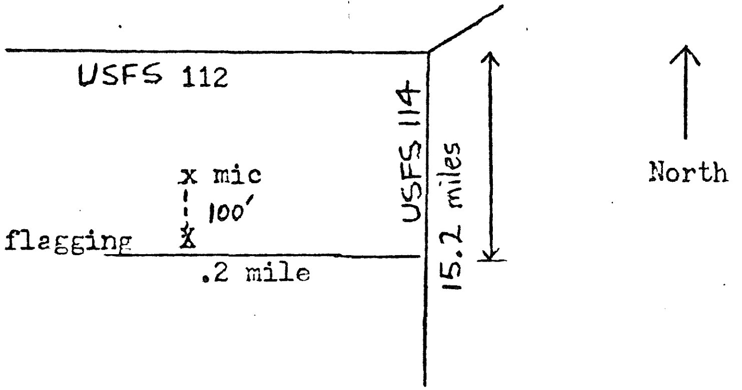
VIII. Site 02D

A) Description

Site is mixed with

B) Location

15.2 miles south of USFS road 112 to USFS road 420. .2 miles west on 420 to marker on north side of 420. Microphone is placed 100' north of marker:



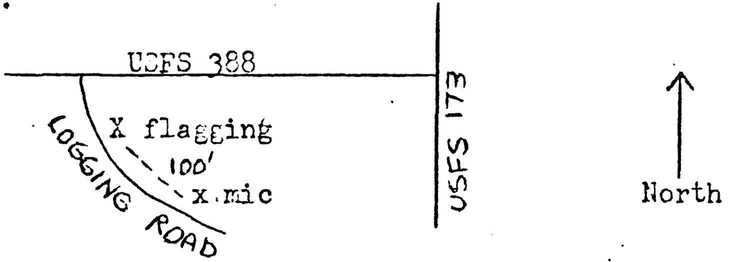
IX. Site 03A

A) Description

Large clear cut with high elevation. Some young red pine planted about ten years ago plus sporadic young aspen and shrubs are the predominant vegetation.

B) Location

3.4 miles north of USFS road 173 on USFS road 388 to unmarked logging road on south side of 388. .2 miles on logging road to site marker. Microphone is set 100' southeast of site marker:



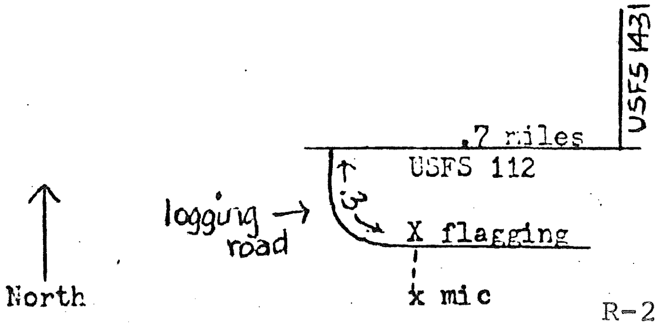
X. Site 03B

A) Description

Site is a recent clear cut about 40-60 acres. Most vegetation is shrubs and weeds. Site is bordered by RED PINE. A FEW STANDING DEAD TREES.

B) Location

.7 miles northwest on USFS road 112 from USFS road 1431 to unmarked logging road. .3 miles on logging road to site marker. Microphone is set 100' south of flagging:



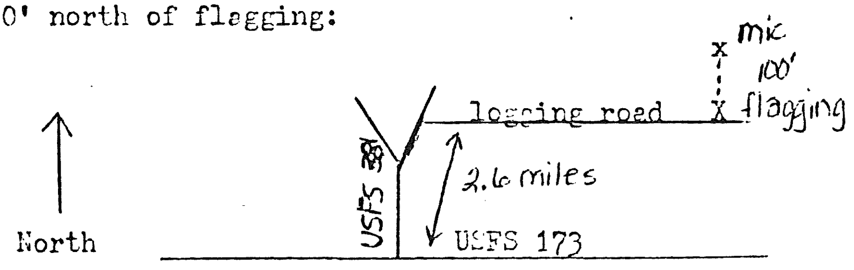
XI. Site 03C

A) Description

Recent clear cut about 40-60 acres. Most vegetation is shrubs and weeds. Clear cut is bordered by black spruce on all sides.

B) Location

6 miles north on USFS road 173 to USFS road 381. 2.6 miles north on 381 to unmarked logging road east side of 381. .2 miles on logging road to site marker. Microphone is set 100' north of flagging:



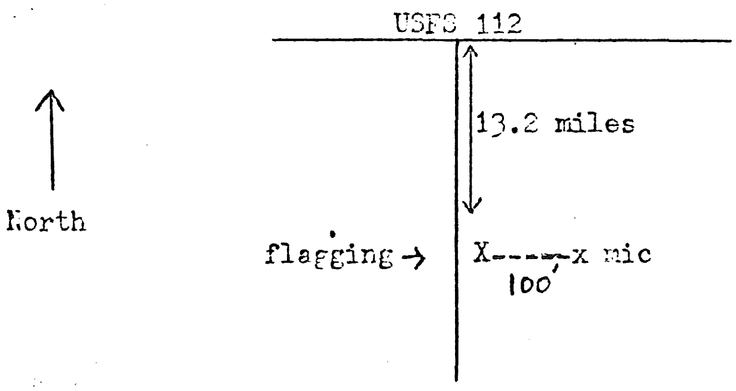
XII. Site 03D

A) Description

This site is very small lowland clearcut about 20-30 acres, surrounded by

B) Location

13.2 miles south of USFS road 112 on USFS road 114. Marker denotes site. Microphone is placed 100' east of flagging:



APPENDIX S

DETAILED DESCRIPTIONS OF WORKPLAN I

Workplan I actually consists of two sequential workplans, noted in this appendix as parts A and B. Both parts were developed by Midwest Acoustics and Electronics Inc. of Minneapolis, Minnesota and were used during the initial data collection phases of the Copper-Nickel Noise Monitoring Project.

SUMMARY REPORT
ON PROPOSED
NOISE MONITORING AND ANALYSIS WORK PLAN
FOR THE
REGIONAL COPPER-NICKEL
ENVIRONMENTAL IMPACT STATEMENT

WORKPLAN I (Contains two parts- A and B)

Prepared for the
Minnesota Pollution Control Agency

by
Midwest Acoustics and Electronics, Inc.
Edina, Minnesota

October 17, 1975

WORKPLAN I (A)

SUMMARY WORK PLAN

NOISE MONITORING AND ANALYSIS PROGRAM

for

REGIONAL COPPER-NICKEL EIS

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NOISE IMPACT ANALYSIS 10

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- Analysis of Alternatives 11
- Criteria Development 11

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- Timing 13
- Divided-Time Program 15
- Full-Time Program 17

RECOMMENDATIONS 18

SUMMARY

A summary work plan is presented for the noise monitoring and analysis aspects of the regional copper-nickel EIS.

Quietude is recognized as an essential characteristic of the Boundary Waters Canoe Area as it exists today and as an important feature of seasonal and permanent residences and resorts in the area.

Three topics are important in evaluating the noise impact of copper nickel development alternatives:

- Monitoring information -- required to provide data on the present noise environment within the region.
- Criteria development -- required to permit judgment of noise impact and for decisions on acceptable alternatives.
- Modeling and analysis -- required to predict the noise levels due to development alternatives for a variety of environmental and terrain conditions.

A program is recommended that will provide the required monitoring information,criteria development and analysis at a total cost of $129,800.

The recommended program utilizes two professionals dividing their time in an optimum way between the monitoring and analysis criteria efforts. This means that the program will provide the required level of effort on each topic at a near-optimum cost/benefit ratio.

Timing is recognized as one of the critical factors--an early start is essential to obtaining sufficient monitoring hours. To begin monitoring in February 1976, funding must be released by December 15, 1975.

BACKGROUND

Copper-nickel resources in northern Minnesota are drawing increasing attention as being potentially economic. The Minnesota Environmental Quality Council (MEQC) has required that a comprehensive study be made of the possible consequences of developing these resources. This study is taking the form of a regional Environmental Impact Statement (EIS).

The copper-nickel resource area of greatest economic interest lies in a region abutting the Boundary Waters Canoe Area (BWCA) and extending southwest to just north of Hoyt Lakes. Mining of the copper-nickel minerals will be by means of open-pit or underground mining. Where feasible, open-pit mining is considered to be more economical.

The noise impact of copper-nickel mining is one of the factors considered to be important in the regional EIS.

Facets of the noise impact that require attention are:

- Present noise levels throughout the region
- Potential impact of anticipated mining operations
- Criteria by which noise levels can be judged.

The region presently supports several open-pit taconite mines, accompanying beneficiation operations and a rail system for ore transportation. Noise sensitive areas include residential sites already under some impact by existing noise sources, the BWCA wilderness area, resorts and seasonal homes and other residential areas and farms.

A map showing the region is given in Figure 1. The outlined area is the primary study region; noise impact will be considered over an area extending approximately 4 miles beyond the region and along remote transportation routes.

NOISE SOURCES

The region presently supports open-pit taconite mining, gravel pits, lumbering operations, railroads, highways and a snowmobile trail. In addition, overflights of the area are made by aircraft landing at Ely and by military aircraft on training missions.

A map showing the existing noise sources is given in Figure 2. Future noise sources associated with copper-nickel mining may be located throughout the enclosed region--these could include open-pit mines, underground mines, beneficiation plants, transportation systems, and possibly a smelter.

The proposed International Nickel Company (INCO) site is shown in the northern most corner of the region--the edge of the proposed open-pit being approximately one mile from the BWCA boundary.

Transportation routes will affect areas remote from the mining area and will be considered when the potential routes are more clearly defined.

NOISE SENSITIVE AREAS

Noise sensitive areas within the region include the BWCA wilderness area, those areas that may presently be impacted and sensitive to further noise intrusion, seasonal resort and residence areas, recreation areas, residences, schools, farms and wildlife refuges.

The identified noise sensitive areas within and abutting the region are shown in Figure 3. When transportation routes are more clearly defined, these routes should be examined for the existence of remote noise sensitive areas adjacent to them.

The BWCA is considered a noise-sensitive area that must be given special consideration.

NOISE MONITORING

The purpose of the noise level monitoring effort is directed toward obtaining a clear picture of the present noise environment in order to assess change, to provide a basis for predicting noise impact and to provide guidance for operational and post operational monitoring.

DATA REQUIRED

Noise is often described best in statistical terms. For an area containing relatively few sound sources, a statistical form of data presentation clearly provides the best vehicle for appraising the noise environment.

The statistical noise descriptors that will be measured and recorded in this case are (all levels measured in dBA with a fast response over a one-hour period):

- L_{max} - the maximum noise level
- L_{10} - the level exceeded 10 percent of the time
- L_{50} - the level exceeded 50 percent of the time
- L_{90} - the level exceeded 90 percent of the time

Blasting represents a significant source of noise and vibration of duration typically less than a second. Special efforts will be taken to record the levels and the propagation phenomena associated with blasting noise and vibration.

Some question exists as to the State department responsible for vibration control. Vibration may prove to have a serious impact on the region and will be evaluated briefly in order to estimate the impact.

METHODOLOGY

The region has been broken down into seven zones, each of which contains a control point that will serve as a reference, correlating with other points in the zone.

Figure 4 shows the region as divided into zones with all the desirable noise level sampling sites shown. Priorities have been attached to the sampling sites as indicated on Figure 4. All sites shown are accessed by road with the exception of several along railroad lines and several others along old trails in the BWCA. The notation "OPEN" indicates that section of road is kept open in the winter.

The basic monitoring effort will gather data from all the priority 1 and 2 sites. Other sites may be added during the monitoring program as indicated by a need at the time.

Three automatic statistical analyzers will be used to obtain the data. All data will be taken in groups within a specific zone and the control point will be monitored continuously while the other points are being sampled on a one-hour basis each. The control points will accumulate approximately 6 hours of data for each hour of data at other points. Thus, statistically significant amounts of data will accumulate at the seven control points and, through correlation with the other points, provide high-confidence data for all points.

Sampling of noise levels will be made under three foliage and ground conditions:

- No foliage, with snow
- Full foliage
- No foliage, no snow

A minimum of 24 hours of data for each of the 52 sampling points will be obtained over the monitoring period of nearly two years. Each of the 7 control points will be monitored for a total of 150 or more hours.

Blasting noise data will be obtained by coordinating with blasting operations at the present Erie and Reserve mines. Special instrumentation will be required; equipment rental is included for this purpose. Blast monitoring will be particularly important due to the high sound level and potential long-distance impact of both the blast noise and vibration.

EQUIPMENT

The following is a list of the equipment required listed by generic name with current prices for satisfactory equipment presently available.

EQUIPMENT LIST

QUANTITY	ITEM	COST
1	Statistical Analyzer with storage	$ 3,600
2	Statistical Analyzer	5,000
2	Calibrators	700
3	Microphone Systems (1 all-weather)	1,700
1	Sound Level Meter	500
1	Portable Tape Recorder	700
20	Tapes	100
1	Anemometer	150
1	Temperature/Humidity Gauge	50
1	2-Way CB Radio	300
2	Walkie/Talkie (5 watt)	220
2	Winter and Camping Gear (coats, gloves, snowshoes, tent, etc.	600
	Miscellaneous	700
		$14,320

In addition to the equipment required for measurements establishing the baseline noise levels in the area, special equipment will be required to monitor the levels and propagation characteristics of blasting noise. This special equipment will be rented on a short-term basis to minimize the costs.

NOISE IMPACT ANALYSIS

Noise Impact Analysis for the region being studied will consist of essentially two component studies. First will be the development of a model of noise generation and propagation that is adequate to predict the noise levels due to the different existing sources and potential sources within the study area. This will include modeling of the source (source noise levels and frequency distribution), and propagation through the atmosphere and over the ground to given receiver locations. The second component will be an analysis of the different development alternatives for the area in terms of their noise impact. This alternative analysis will consider the noise ramifications of such details as open-pit versus underground mining, one kind of mining equipment versus another, etc.

MODEL DEVELOPMENT

The development of a noise analysis model will have to consider the source of the sound, the path over which the sound travels, the statistical occurrence of the sound (whether it occurs frequently or infrequently and for how long) and finally, computerization of the mathematical formulae describing the source, the path, and the statistics of the noise.

Description of the different noise sources within the study region will require a certain amount of measurement of source levels of the existing noise sources such as the open-pit mines, blasting, the ore trains, and the highways and lumber roads that serve as paths for trucking within the area. The existing open-pit mines will provide an invaluable source for data on typical noise levels due to ensembles of electric shovels, drills, ore trucks, over-the-road trucks, crushing and other milling facilities that process the ore before it is shipped. Measurements that will be necessary to develop the model are: sound power level measurements where possible, sound pressure levels at reference distances from specific sources (trucks, trains, cranes, open-pits), the time history of the sound, and the frequency content of the noise from the different sources.

Consideration of the path followed by the noise as it is radiated outward from a source to some receiver location will be important. The effects of foliage on the propagation of the noise are somewhat known and are a function of the particular kinds of trees and brush that populate an area. Snow and the various changes in terrain (the existence of swamps and hills) will also be factors in the propagation of noise. In addition, atmospheric effects, wind gradients, thermal gradients and wind direction will all have effects on the noise level at a particular location. The purpose of considering the path is to develop a practical means of realistically predicting noise levels.

Over many parts of the region the noise levels will be best described in terms of the level exceeded for a given percentage of the time. Blasting, a relatively short-term but rather high magnitude source of noise for the region, is a transient type sound and will probably best be described in terms of L_{max}, the maximum noise level reached in a given period of time. It will be important to develop a suitable mathematical means of providing statistical noise information for sources that occur on an infrequent basis.

Computerization of the model is important from the point of view of economy of time and in terms of being able to handle the large number of calculations and parameters that contribute to the noise level at a given location throughout such a large region as this. The goal for the computer model of the noise sources within a region will be to provide a means for taking the total number of sources and their sound characteristics and to predict (within plus or minus 4 decibels) the noise level at any given point that would exist on a long-term statistical average due to those sources. To our knowledge, such a model that adequately describes the noise level over a period of time, does not exist today. Such a computerized model will be invaluable in future planning efforts in the State of Minnesota and will provide significant insight into the impacts of various noise sources and various alternatives, both in this region and elsewhere.

ANALYSIS OF ALTERNATIVES

Once the noise model has been completed, analysis of the various alternatives for development of the area will be considered from the point of view of noise impact. Alternatives that the noise model will be capable of considering will include the effects of:

- Different types of mining operations, such as open-pit versus underground mining
- Various transportation routes to and from the mining area
- Differing blasting techniques (e.g., different total pounds of powder per delay)
- Alternative equipment selection
- Numbers of particular pieces of equipment used in any given area
- Mine location.

CRITERIA DEVELOPMENT

One of the great unknowns in evaluating the impact of noise in an area such as the Boundary Waters Canoe Area Wilderness Region will be the selection of criteria for judging the noise impact on such an area. To a lesser degree but still a significant problem, will be the establishment of criteria for noise impact on seasonal resort or residential homes that in part owe their attractiveness as vacation areas to quietude.

Minnesota currently has a set of noise standards defined as being required in order to safeguard the health and welfare of the public. These noise standards represent upper-bounds for noise intrusion within the urban environment. A great deal of serious research has taken place over the last 30 years on the effects of noise on people and the reactions of communities to noise. It has been found that two significant factors in the reactions of communities to noise are: one, their prior experience with noise in general, and; two, their prior experience with the specific intruding noise in particular. Thus, in a wilderness type area where land use depends greatly on quietude, a significantly different criteria (from urban noise standards) should be expected to be applied in judging the impact of noise. The question of the effect of noise on wildlife is an important one and will have a bearing on the noise level criteria for the region.

It is regarded as one of the key tasks of the noise impact study to provide some basis for judgment of the impact of different noise levels on the study region. Of special importance, the BWCA wilderness area and the tolerable noise levels within that area must be examined very carefully and a thoughtfully considered judgment made of the allowable noise degradation within such a preservation.

Recommendations as to the acoustic or noise criteria to be applied to the different kinds of areas that make up this region will be offered to the State of Minnesota. As an aid in developing perspective for the judgment of the impact of different levels of noise, a goal of this program is to prepare tape recordings illustrating the background noise levels that typically exist in sample areas of the region, specifically the BWCA, some of the residential areas, and some of the seasonal resort type areas, together with superimposed noise levels of various strengths that might be generated by noise sources intruding in the area due to mining operations. By listening to the actual superposition of differing intruding noise on the background noise, it is hoped that a qualified and confident judgment can be made by those officials responsible for making a final·decision on this matter.

PROPOSED PROGRAM OPTIONS

The personnel and timing aspects of the program are discussed. Two program options are presented. The essential details and estimated costs of each are given below.

PERSONNEL

As in most programs, the people doing the work will be the key to success. In the two noise program options presented farther on, the important people in the program are identified as "equivalent to PCS-II." This implies college training and the capability to carry through routine procedures with little or no supervision. Sound judgment will be required in performing measurements and making program decisions while on-site in northern Minnesota.

In the program options proposed, it has been assumed that the noise monitoring and analysis personnel were to be based at the PCA office where Mr. Alfonso Perez could maintain day-to-day supervision. Should the decision be made to house these people elsewhere, the person brought in to perform the analysis function will be given responsibility for day-to-day program management, and a higher cost will result.

As discussed under the proposed program options, significant care will need to be exercised in selecting a person to handle both the monitoring and analysis aspects of the program.

Supervision and provision of technically mature leadership are factors that will influence the program outcome. Present commitments at the MPCA limit the available time of MPCA senior noise staff to approximately ten percent or 1.2 months per year. For this reason, it is considered vital to have the input of a senior level acoustical consultant for the training stages and the model development.

Training is critical. The person conducting the measurements must be well versed in good noise measurement practices,the capabilities and limitations of the equipment being used, the Minnesota noise standards and the overall program objectives. A period of two weeks of training and orientation will be needed in the Twin Cities and this will be followed by two additional weeks of training and assistance by the training consultant on-site in the study region.

TIMING

Timing is another important factor in the successful launching of the noise effort. Neither the necessary equipment nor the trained personnel are available immediately. A lead time of 45 days must be allowed before initiating the training program and monitoring effort. This is required to complete the hiring process and to order and receive the required equipment.

Thus, for the training and monitoring effort to begin on February 1, 1976, sufficient funds for the first stages of the program (equipment, personnel, consultant) must be released by December 15, 1975.

DIVIDED TIME OPTION

Two year cost of $129,800.

In this option, two full-time professionals are utilized from the inception of the program and divide their time in an optimum way between the monitoring and analysis/modeling/criteria (analysis) efforts. At times when two people are needed for monitoring work (in the winter months) the analyst works with the field measurement person. At other times, the field person works in analysis.

The field person will be stationed permanently in the study area for the duration of the two-year program. In this way, travel expenses will be minimized. A consultant is scheduled to be involved in developing a training program and in development of the noise model--a programmer is also provided for on a part-time basis.

It is estimated that the following will result:

Data hours per non-control point	27 hours
Data hours per control point	161 hours
Monitoring cost	$76,600
Cost per non-control data hour	$ 55

Furthermore, a total of 3306 hours will be devoted to analysis, at a cost of $16 per hour.

The detailed, estimated costs for each year of the divided-time program are shown below. The cost table was prepared assuming the people involved were based at the PCA and subject to day-to-day supervision by PCA senior noise staff. Should the program staff be officed elsewhere, an additional cost of 13 percent should be added to the cost--this will provide for hiring an analyst with sufficient experience to be able to manage the program with only occasional supervision.

DIVIDED-TIME PROGRAM

Monitoring			Modeling/Analysis/Criteria		
	Man-Months	Cost $		Man-Months	Cost $
Year 1					
Supervision	0.6	1,200	Supervision	0.6	1,200
Equiv. of PCS II (A)	11.0	13,200	Equiv. of PCS II (A)	1.0	1,200
Equiv. of PCS II (B)	4.0	4,800	Equiv. of PCS II (B)	8.0	9,600
Consultant (acoustic)	1.0	4,800	Consultant (acoustic)	2.0	9,600
Office costs		2,400	Programmer	1.0	3,500
Expenses		1,500	Office costs		1,600
Relocation allowance		800	Expenses		800
Equipment purchase		14,300	Computer time		1,000
Blast monitoring equip. rental		1,500			
Vehicle cost		2,400			
Year 1 Total		46,900	Year 1 Total		28,500
Year 2					
Supervision	0.6	1,300	Supervision	0.6	1,300
Equiv. of PCS II (A)	12.0	15,600	Equiv. of PCS II (A)	---	--
Equiv. of PCS II (B)	2.0	2,600	Equiv. of PCS II (B)	10.0	13,000
Office costs		2,600	Consultant (acoustic)	1.0	4,900
Expenses		1,400	Programmer	0.3	1,000
Relocation allowance		800	Office costs		1,700
Miscellaneous Equip. Purchase		500	Expenses		800
Equip. Maint. Calibration		1,000	Computer time		1,500
Instrument rental (blast)		1,000	Reporting costs		500
Vehicle cost		2,400			
Reporting costs		500			
Year 2 Total		29,700	Year 2 Total		24,700
Two Year Total		76,600	Two Year Total		53,200

Two-Year Program Total $129,800

FULL-TIME OPTION

Two-year cost of $150,400.

In this option, two full-time professionals and one technician are utilized. One professional and the technician are used full time for the monitoring effort. The other professional is applied full time to the modeling/analysis/criteria (analysis) effort. In this case, the analyst is hired approximately 6 months into the first program year. A consultant is provided for to assist with training and modeling. A part-time programmer has also been included.

It is estimated that this option will yield the following:

Data hours per non-control point	30 hours
Data hours per control point	180 hours
Monitoring cost	$95,700
Cost per non-control point data hour	$ 61

In addition, a total of 3785 hours will be devoted to analysis at a total cost of $14.50 per hour.

Should the program staff be officed other than at the PCA, an additional 15 percent should be added to the total cost. This reflects the additional cost of hiring an analyst capable of managing the program under minimal supervision.

The detailed, estimated costs for this option are given below:

FULL-TIME PROGRAM

Monitoring	Man-Months	Cost $	Modeling/Analysis/Criteria	Man-Months	Cost $
Year 1					
Supervision	0.6	1,200	Supervision	0.6	1,200
Equiv. to PCS II	12.0	14,400	Equiv. to PCS II	6.0	7,200
Equiv. to PCS I	12.0	11,700	Consultant (acoustic)	2.0	9,600
Consultant (acoustic)	1.0	4,800	Programmer	1.0	3,500
Office costs (field)		2,400	Office costs		2,300
Expenses		1,000	Expenses		800
Relocation allowance		1,600	Computer time		1,000
Equipment purchase		14,300			
Blast monitoring equip. rental		1,500			
Vehicle cost		2,400			
Year 1 Total		55,300	Year 1 Total		25,600
Year 2					
Supervision	0.6	1,300	Supervision	0.6	1,300
Equiv. to PCS II	12.0	15,800	Equiv. to PCS II	12.0	15,800
Equiv. to PCS I	12.0	12,900	Consultant (acoustic)	1.0	4,900
Office costs		2,400	Programmer	0.6	2,000
Expenses		1,000	Office costs		2,300
Relocation allowance		1,600	Expenses		800
Misc. Equipment purchase		500	Computer time		1,500
Equip. Maintenance, calib.		1,000	Reporting costs		500
Instrument Rental (blast)		1,000			
Vehicle cost		2,400			
Reporting costs		500			
Year 2 Total		40,400	Year 2 Total		29,100
Two Year Total		95,700	Two Year Total		54,700

Two-Year Program Total $150,400

RECOMMENDATIONS

It is recommended that the following steps be taken:

- The Divided-Time Program be funded at a cost of $129,800.
- The First-Year funds of $75,450 be released by December 15, 1975 at the latest to permit training to begin by February 1, 1976.

	FY 76	FY 77	FY 78	TOTAL
SALARIES	$ 500	$11,000	$17,000	$28,500
COMPUTER TIME	500	2,000	3,000	5,500
CONTRACTS	3,000	30,000	4,000	37,000
EQUIPMENT/SUPPLIES	500	1,000	500	2,000
TRAVEL	500	500	500	1,500
TOTAL	$5,000	$44,500	$25,000	$74,500

FIGURE 9

NOISE IMPACT ANALYSIS BUDGET

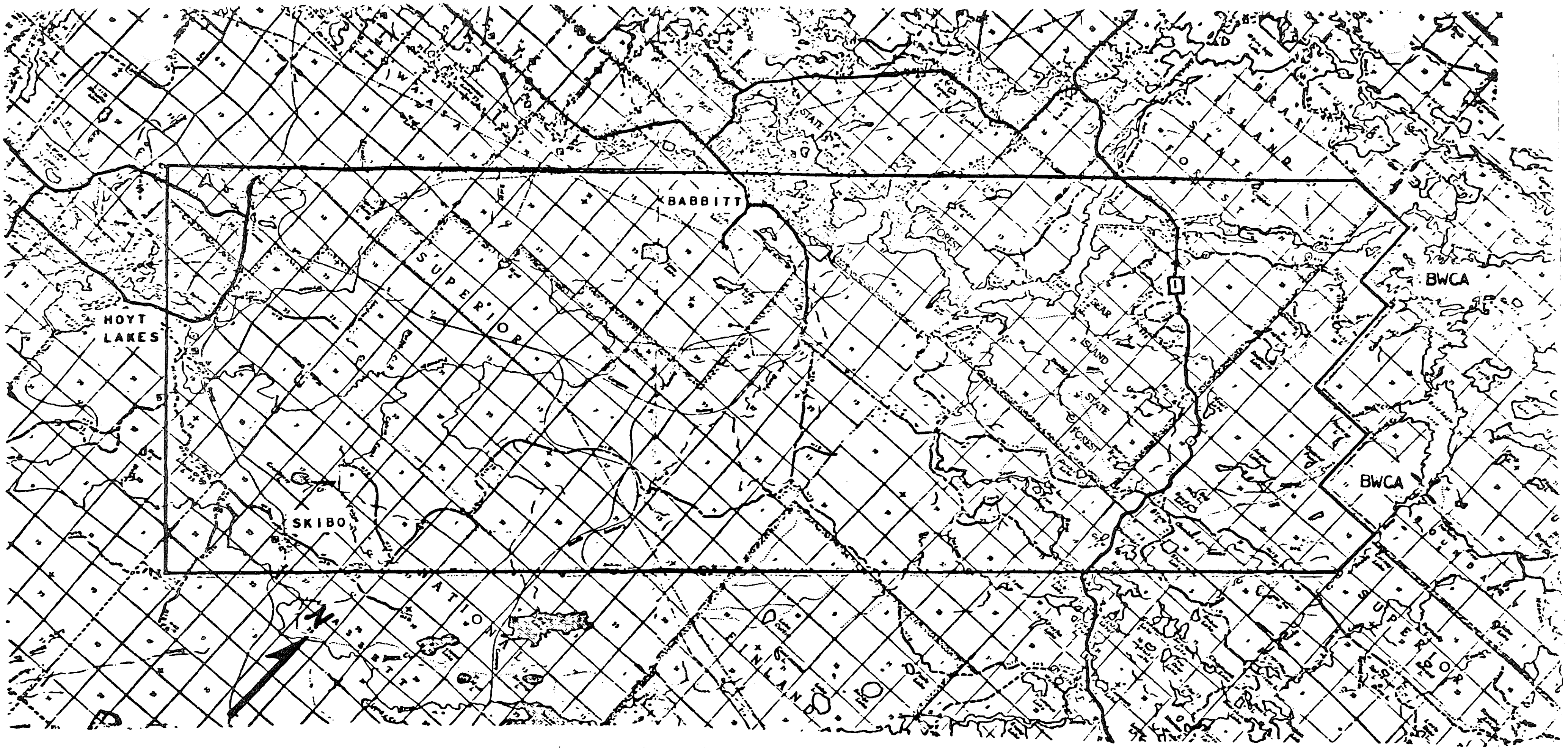

FIGURE I

STUDY AREA

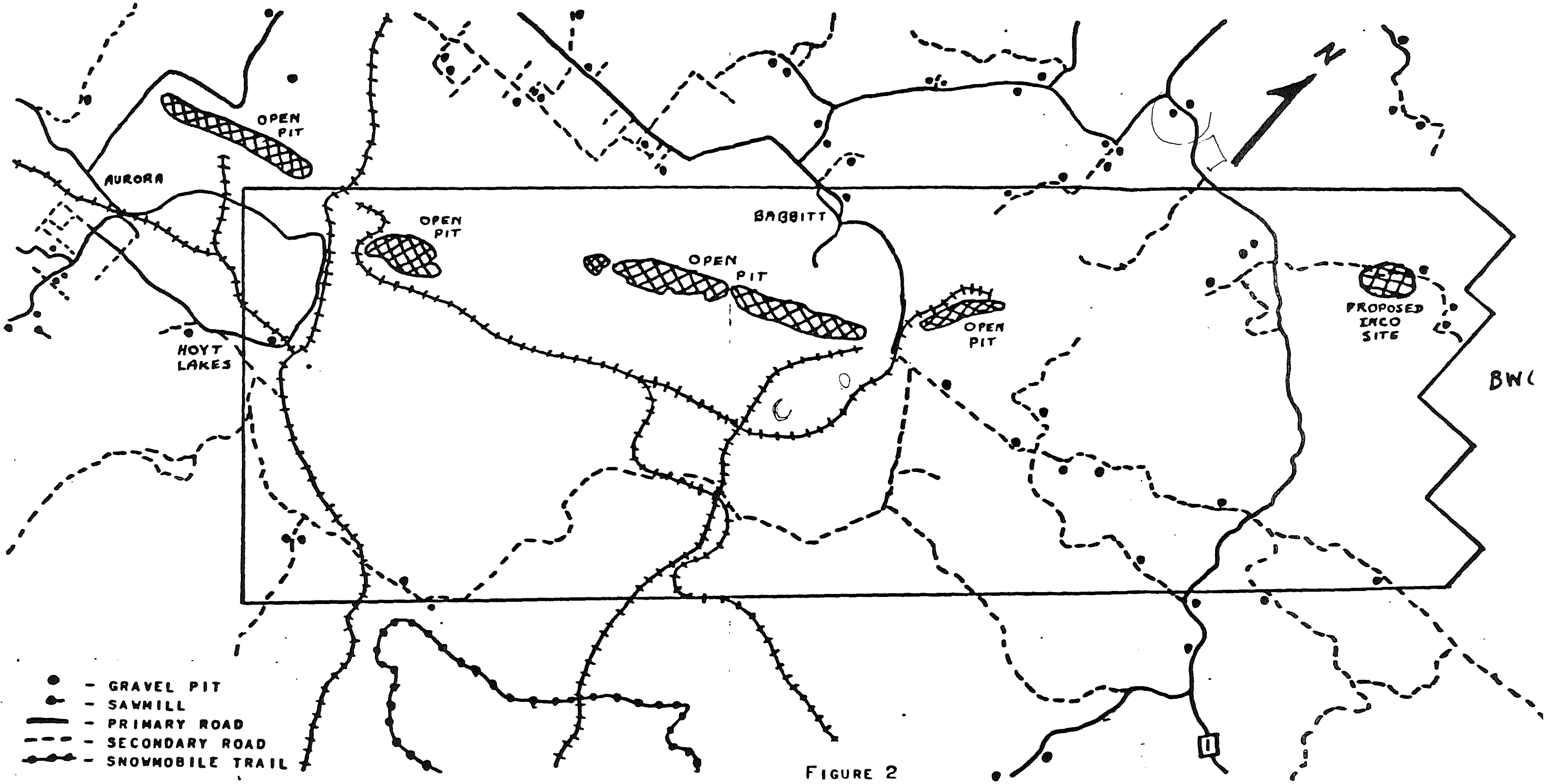

FIGURE 2

NOISE SOURCES

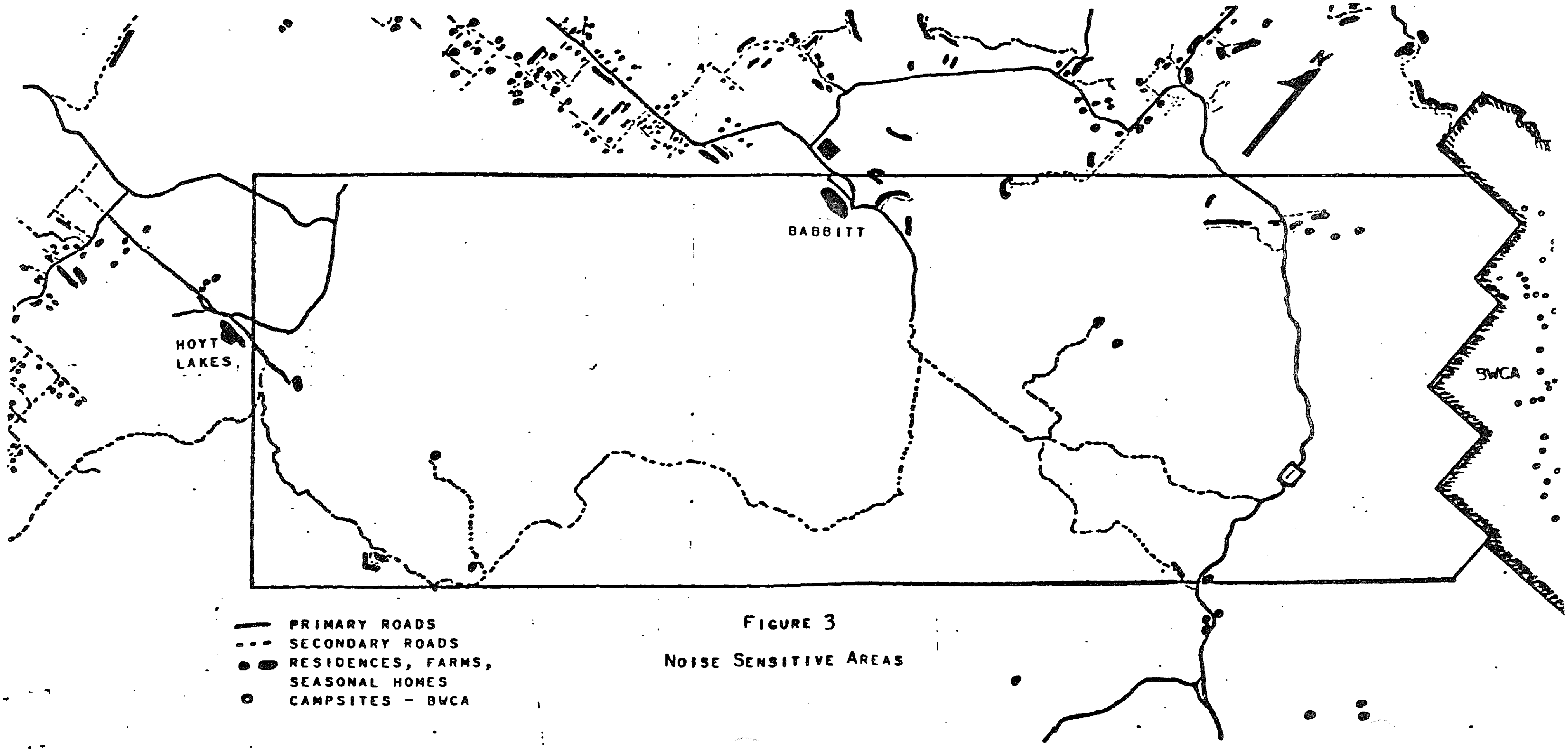

FIGURE 3

NOISE SENSITIVE AREAS

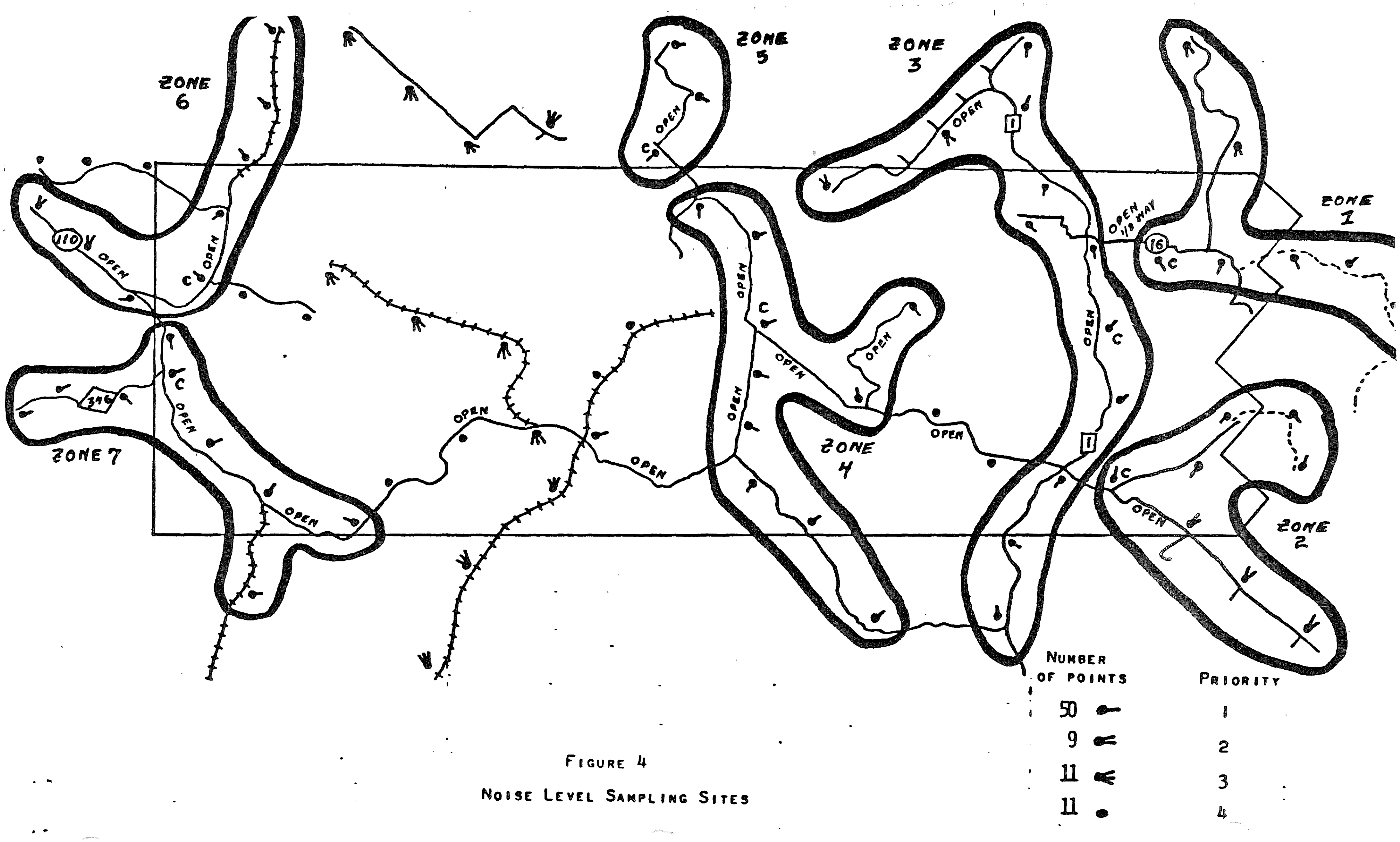

FIGURE 4

NOISE LEVEL SAMPLING SITES

S-23

WORKPLAN I (B)

DETAILED
NOISE MONITORING WORK PLAN
and
RECOMMENDED NOISE IMPACT ANALYSIS WORK PLAN
for the
REGIONAL COPPER-NICKEL
ENVIRONMENTAL IMPACT STATEMENT

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SUMMARY

A detailed work plan is presented for the noise monitoring aspects of the regional copper-nickel EIS. The MPCA has agreed to carry out these monitoring aspects.

A recommended detail work plan is presented for the noise impact analysis aspects of the regional copper-nickel EIS. Responsibility for carrying out the impact analysis has not been assigned to the MPCA and the program itself is still in the process of definition. The recommended work plan can serve as a guide in developing the final noise impact analysis effort.

Quietude is recognized as an essential characteristic of the Boundary Waters Canoe Area as it exists today and as an important feature of seasonal and permanent residences and resorts in the area.

Three topics are important in evaluating the noise impact of copper nickel development alternatives:

- Monitoring information -- required to provide data on the present noise environment within the region.
- Criteria development -- required to permit judgment of noise impact and for decisions on acceptable alternatives.
- Modeling and analysis -- required to predict the noise levels due to development alternatives for a variety of environmental and terrain conditions.

BACKGROUND

Copper-nickel resources in northern Minnesota are drawing increasing attention as being potentially economical. The Minnesota Environmental Quality Council (MEQC) has required that a comprehensive study be made of the possible consequences of developing these resources. This study is taking the form of a regional Environmental Impact Statement (EIS).

The copper-nickel resource area of greatest economic interest lies in a region abutting the Boundary Waters Canoe Area (BWCA) and extending southwest to just north of Hoyt Lakes. Mining of the copper-nickel minerals will be by means of open-pit or underground mining. Where feasible, open-pit mining is considered to be more economical.

The noise impact of copper-nickel mining is one of the factors considered to be important in the regional EIS.

Facets of the noise impact that require attention are:

- Present noise levels throughout the region
- Potential impact of anticipated mining operations
- Criteria by which noise levels can be judged.

The region presently supports several open-pit taconite mines, accompanying beneficiation operations and a rail system for ore transportation. Noise sensitive areas include residential sites already under some impact by existing noise sources, the BWCA wilderness area, resorts and seasonal homes and other residential areas and farms.

A map showing the region is given in Figure 1. The outlined area is the primary study region; noise impact will be considered over an area extending approximately 4 miles beyond the region and along remote transportation routes.

NOISE SOURCES

The region presently supports open-pit taconite mining, gravel pits, lumbering operations, railroads, highways and snowmobile trails. In addition, flights over the area are made by aircraft landing at Ely and by military aircraft on training missions.

A map showing the existing noise sources is given in Figure 2. Future noise sources associated with copper-nickel mining may be located throughout the enclosed region--these could include open-pit mines, underground mines, beneficiation plants, transportation systems, and possibly a smelter.

The proposed International Nickel Company (INCO) site is shown in the northern-most corner of the region--the edge of the proposed open-pit being approximately one mile from the BWCA boundary.

Transportation routes will affect areas remote from the mining area and will be considered when the potential routes are more clearly defined.

NOISE SENSITIVE AREAS

Noise sensitive areas within the region include the BWCA wilderness area, those areas which may presently be impacted and sensitive to further noise intrusion, seasonal resort and residential areas, recreational areas, residences, schools, farms and wildlife refuges.

The identified noise sensitive areas within and abutting the region are shown in Figure 3. When transportation routes are more clearly defined, these routes should be examined for the existence of remote noise sensitive areas adjacent to them.

The BWCA is a noise sensitive area that requires special attention. The BWCA is classified as a wilderness area and as such, criteria for intrusive noise and vibration must be carefully considered.

NOISE MONITORING WORK PLAN

The purpose of the noise monitoring effort is directed toward obtaining a clear picture of the present noise environment in order to assess change, to provide a basis for predicting noise impact and to provide guidance for operational and post operational monitoring.

DATA REQUIRED

Noise is often described best in statistical terms. For an area containing relatively few sound sources, a statistical form of data presentation clearly provides the best vehicle for appraising the noise environment.

The statistical noise descriptors will be referenced to a one-hour period; those that will be measured and recorded in this case will include (all levels measured in dBA with a fast response):

- L_{max} - the maximum level (or L_1 or L_2)
- L_{10} - the level exceeded 10 percent of the time
- L_{50} - the level exceeded 50 percent of the time
- L_{90} - the level exceeded 90 percent of the time

Blasting represents a significant source of noise and vibration of duration typically less than a second. Special efforts will be taken to record the levels and the propagation phenomena associated with blasting noise and vibration.

Some question exists as to the State department responsible for vibration control. Vibration may prove to have a serious impact on the region and will be evaluated briefly in order to estimate the impact.

METHODOLOGY

Figure 4 shows the region as divided into zones with all the desirable noise level sampling sites shown. Priorities have been attached to the sampling sites as indicated in Figure 4. All sites shown are accessed by road with the exception of several along railroad lines and several others along old trails in the BWCA. The notation "OPEN" indicates that section of road that will probably be kept open in the winter.

The basic monitoring effort will gather data from the priority 1 and 2 sites. Other sites may be added during the monitoring program as indicated by a need at the time.

Automatic analyzers will be used to obtain the data. Initially, two analyzers will be used; a third may be purchased later if the benefits of the third unit appear to be significant. The automatic analyzers will compute the statistical noise descriptors at the site.

The data points throughout the region are broken into seven zones. Each zone contains one control point. All data within the zone will be correlated with simultaneous data taken at the control point. In this way, the noise statistics throughout a zone will be tied to the noise statistics at the zone control point.

Data will be taken using a procedure similar to that described below. A storage-type analyzer that computes the statistical descriptors of interest over a set period of time will be placed at the control point. This storage analyzer automatically computes the noise statistics for a predetermined period of time and then stores the data. The device then resets and repeats the process for the second period, and so on. While the data is being taken automatically at the control point, another analyzer will be used to obtain the noise statistics at the other data points throughout the region. The second analyzer will be moved from point-to-point while the control point analyzer remains fixed throughout the measurements within that zone that day. In this way, approximately 6 hours of control point data will be gathered for each hour of data at a non-control point.

Thus, statistically significant amounts of data will accumulate at the seven control points and, through correlation with the other points, provide high-confidence data for all points.

Sampling sites will be chosen in the approximate locations shown in Figure 4. Sites will be at least 100 feet from adjacent roads or railroads.

It is anticipated that a minimum of 24 hours of data for each of the 52 sampling points will be obtained and that each of the 7 control points will be monitored for a total of 150 or more hours over the monitoring period of nearly two years.

Sampling of noise levels will be made under three foliage and ground conditions:

- no foliage, with snow
- full foliage
- no foliage, no snow

Blasting noise data will be obtained by coordinating monitoring with blasting operations at the present Erie and Reserve mines. Special instrumentation will be required; equipment rental is included for this purpose. Blast monitoring will be particularly important due to the high sound levels and potential long-distance impact of both the blast noise and vibration.

EQUIPMENT

Figure 5 lists the equipment required by generic name with the current prices for satisfactory equipment presently available.

TIMING

The project timing is broken down into timing for sub-areas. The sub-areas are discussed below and the overall project timing is shown in Figure 6.

Equipment

This task involves the selection, ordering and qualification of the project equipment.

Fine Details - Procedures

This task will result in a project workbook containing brief but complete descriptions of the overall monitoring guidelines, the seasonal summary report contents and format, data reporting and logging procedures, and the methodology details. The workbook will provide the common basis for carrying out the monitoring and will insure adequacy of the data and data reduction to meet the program requirements. The workbook will be modified as needed throughout the program.

Site Work

This task includes selection of sites, 24-hour baseline monitoring and routine monitoring.

Data Reduction

This task includes the preliminary reduction performed on-site and the analysis required to prepare the information for formal reporting.

Propagation Experiments

These experiments will provide basic information relating to sound propagation in the northern Minnesota environment--this will include propagation over snow and through foliage.

QUANTITY	ITEM	COST
1	Statistical Analyzer with storage	$ 4,140
1	Statistical Analyzer	3,050
2	Calibrators	790
3	Microphone Systems	1,800
1	Sound Level Meter	450
1	Portable Tape Recorder	700
20	Tapes	100
1	Anemometer	110
1	Temperature/Humidity Gauge	90
1	2-Way CB Radio	300
2	Winter and Camping Gear (coats, gloves, snowshoes, tent, etc.	600
	Miscellaneous	1,170
	Vehicle Costs	3,000
		$16,300

FIGURE 5

EQUIPMENT LIST

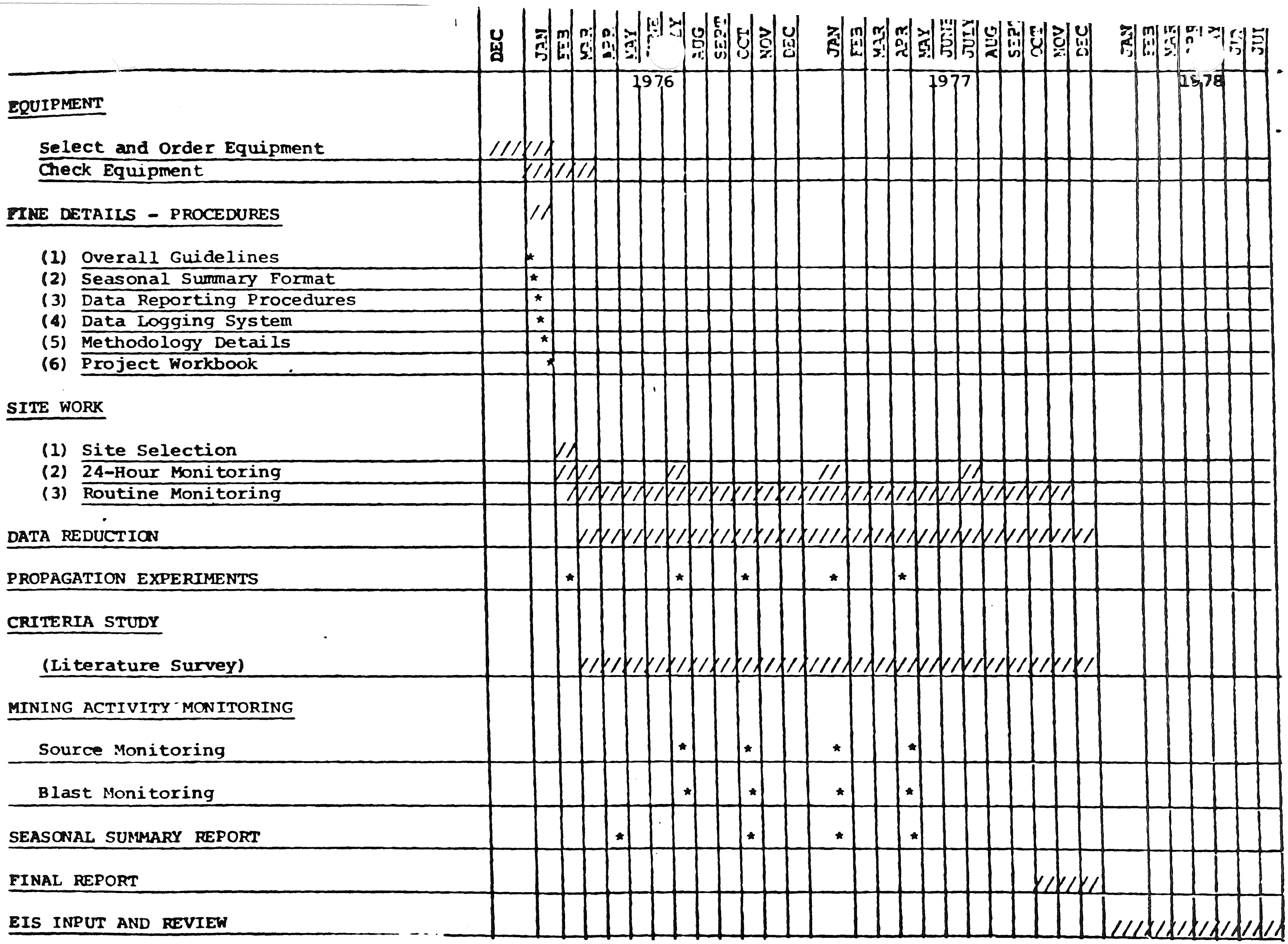

FIGURE 6
NOISE MONITORING TIMING

Criteria Study

A certain percentage of the days will not be useable for gathering outside acoustical data. These days will be devoted to data reduction and analysis and to review of the literature on noise criteria for similar wilderness/rural areas.

Source Monitoring

This task will provide information on the noise levels and frequency spectra of existing sources in the area. The data will be useful in the impact analysis.

Blast Monitoring

This task includes monitoring of blasting operations in the area for both sound and vibration. The data will be useful for establishing the present-day levels and for the prediction of the impact of new sources.

Reports

A status report discussing financial and technical project status will be submitted quarterly. In order to preserve the data in immediately useful form, seasonal summary reports will be prepared summarizing the data for the preceding season. The final report will review and report the entire monitoring effort and the findings.

PERSONNEL

As in most programs, the people doing the work will be the key to success. The important person in the program is identified as "equivalent to PCS-II." This implies college training and the capability to carry through routine procedures with little or no supervision. Good judgment will be required in performing measurements and making program decisions while on-site in northern Minnesota.

Supervision and provision of technically mature leadership are factors that will influence the program outcome. Present commitments at the MPCA limit the available time of MPCA senior noise staff to approximately five percent or 0.6 months per year. For this reason, it is considered vital to have the input of a senior level acoustical consultant for the training stages and the site work.

Training is critical. The person conducting the measurements must be well versed in good noise measurement practices, the capabilities and limitations of the equipment being used, the Minnesota noise standards and the overall program objectives. A period of two weeks of training and orientation will be needed in the Twin Cities and this will be followed by two additional weeks of training and assistance by the training consultant on-site in the study region.

BUDGET

The budget necessary for implementation and completion of this program is shown in Figure 7. The budget shown in Figure 7 is that approved and recommended by the EQC. The total for FY 77 and FY 78 is adequate BUT should be distributed differently--FY 77 should have a total budget of $25,000 and FY 78 a total of $15,000. This rearrangement will provide adequate funding for the level of effort required to complete the monitoring and reporting; also, to provide input and review for the EIS itself.

	FY 76	FY 77	FY 78	TOTAL
SALARIES	$15,600	$22,800	$ 6,300	$44,700
EQUIPMENT/SUPPLIES	16,300	1,000	500	17,800
TRAVEL/LODGING	1,200	1,200	200	2,600
ANALYSIS/CONTRACTS	7,400	5,000	3,000	15,400
TOTAL	$40,500	$30,000	$10,000	$80,500

FIGURE 7

NOISE MONITORING BUDGET

RECOMMENDED NOISE IMPACT ANALYSIS WORK PLAN

Noise Impact Analysis for the region being studied will consist of essentially two component studies. First will be the development of a model of noise generation and propagation that is adequate to predict the noise levels due to the different existing sources and potential sources related to mining activities within the study area. This will include modeling of the source (source noise levels and frequency distribution), and propagation through the atmosphere and over the ground to given receiver locations. The second component will be an analysis of the different development alternatives for the area in terms of their noise impact. This alternative analysis will consider the noise ramifications of such details as open-pit versus underground mining, one kind of mining equipment versus another, etc.

To our knowledge, a computerized model capable of realistically and economically predicting the noise statistics of a large number of sources over a region such as this is not in existence today. Such a computerized model will be invaluable in future planning efforts in Minnesota. It will provide significant insight into the impacts of various noise sources, technologies and alternatives, both in this region and elsewhere.

MODEL DEVELOPMENT

The development of a noise analysis model will have to consider the source of the sound, the path over which the sound travels, the statistical occurrence of the sound (whether it occurs frequently or infrequently and for how long) and finally, computerization of the mathematical formulae describing the source, the path, and the statistics of the noise.

Description of the different noise sources within the study region will require a certain amount of measurement of source levels of the existing noise sources such as the open-pit mines, blasting, the ore trains, and the highways and lumber roads that serve as paths for trucking within the area. The existing open-pit mines will provide an invaluable source for data on typical noise levels due to ensembles of electric shovels, drills, ore trucks, crushers and other milling facilities that process the ore before it is shipped. Measurements that will be necessary to develop the model are: sound pressure levels at reference distances from specific sources (trucks, trains, cranes, open-pits), the time history of the sound, the frequency content of the noise from the different sources and possibly source directivity. Sound power levels can be estimated from sound pressure levels measured over a surface enclosing a noise source. The directivity, the frequency spectrum and the sound power level or reference sound pressure level are important for the prediction of the noise level at some distance and direction from the source. The time history of the sound will affect the statistical nature of the noise.

Consideration of the path followed by the noise as it is radiated outward from a source to some receiver location will be important. The effects of foliage on the propagation of the noise are somewhat known and are a function of the particular kinds of trees and brush that populate an area. Snow and the various changes in terrain (the existence of swamps and hills) will also be factors in the propagation of noise, and their influence is not well documented. In addition, atmospheric effects, wind gradients, thermal gradients and wind direction will all have effects on the noise level at a particular location. The purpose of considering the path is to develop a practical means of realistically predicting noise levels.

Over many parts of the region the noise levels will be best described in terms of the level exceeded for a given percentage of the time. Blasting, a relatively short-term but rather high magnitude source of noise for the region, is a transient type sound and will probably best be described in terms of L_{max}, the maximum noise level reached in a given period of time. It will be important to develop a suitable mathematical means of providing statistical noise information for sources that occur on an infrequent basis.

Computerization of the model is important from the point of view of economy of time and in terms of being able to handle the large number of calculations and parameters that contribute to the noise level at a given location throughout such a large region as this. The goal for the computer model of the noise sources within a region will be to provide a means for taking the total number of sources and their sound characteristics and to predict (within plus or minus 4 decibels) the noise level at any given point that would exist on a long-term statistical average due to those sources. The goal of ±4 dB sound level prediction accuracy (in the mean) was chosen for two reasons. First, for most people, a 3 dB change in a sound level is just perceptible and a 5 dB change clearly perceptible; a 4 dB change then can be identified as a perceptibility criteria. The second reason is that ±4 dB average accuracy is a fairly realistic target without becoming unduly cumbersome.

A major check and guide for the model development will be the comparison of computed levels with those measured due to real-world sources in the field. Measured data will be obtained in part from the monitoring program and in part from experiments conducted strictly as a check on the model.

A report summarizing the essential assumptions, the basic algorithms, the computer program and the observed accuracy should be prepared. This will insure the long term utility of the model.

FORECASTING OF SOURCE PROPERTIES

As part of the alternatives analysis, the potential noise sources, their acoustical properties and their probable locations will need to be forecasted. This step will be highly dependent upon input from the group setting up the basic alternative matrix.

Acoustic properties that will need to be forecasted are those listed earlier in the paragraph describing characterization of noise sources.

ANALYSIS OF ALTERNATIVES

Once the noise model has been completed, analysis of the various alternatives for development of the area will be considered from the point of view of noise impact. Alternatives that the noise model will be capable of considering will include the effects of:

- Different types of mining operations, such as open-pit versus underground mining
- Various transportation routes to and from the mining area
- Differing blasting techniques (e.g., different total pounds of powder per delay)
- Alternative mining equipment selection
- Numbers of particular pieces of equipment used in any given area
- Mine location.

CRITERIA EVALUATION

One of the key unknowns in evaluating the impact of noise in an area such as the Boundary Waters Canoe Area Wilderness Region will be the selection of criteria for judging the noise impact on such an area. To a lesser degree but still signficant, will be the establishment of criteria for noise impact on seasonal resort or residential homes that in part owe their attractiveness as vacation areas to quietude.

Minnesota currently has a set of noise standards defined as being required in order to safeguard the health and welfare of the public. These noise standards represent upper bounds for sound levels within three different noise area classifications. A fourth noise class, undeveloped areas, does not yet have standards defined; it is recognized that such areas require attention but satisfactory criteria have not yet been determined.

The Minnesota Noise Standards are intended to be upper bounds only. The development of the standards clearly indicates that these standards do not imply the right to create noise levels up to the standards in areas that previously enjoyed lower levels. The 1974 proposal of NPC-3 (anti-degradation) clarifies and strengthens this awareness.

The Minnesota Noise Standards address the major question of health and welfare but do not address the question of annoyance to infrequent intrusive noises, property value erosion or aesthetic value of "quiet" areas.

Thus, in areas that have present-day noise levels well below the Minnesota Standards, the upper-bound imposed by the Standards should not be assumed to be acceptable. Other criteria must be developed for the purpose of judging the impact of intrusive sound.

Criteria evaluation should also consider the effect of noise on wildlife. This question is an important one and will have a bearing on the noise level criteria for the region. Some work has been reported in the literature in recent years on animals and noise; a review of this literature will provide the information necessary to assess noise and wildlife criteria.

It is regarded as one of the key tasks of the noise impact study to provide some basis for judgment of the impact of different noise levels on the study region. Of special importance, the BWCA wilderness area and the tolerable noise levels within that area must be examined very carefully and a thoughtfully considered judgment made of the allowable noise degradation within such a preservation.

Recommendations as to the noise criteria to be applied to the different kinds of areas that make up this region will be offered to the State of Minnesota. As an aid in developing perspective for the judgment of the impact of different levels of noise, a goal of this program is to prepare tape recordings illustrating the background noise levels that typically exist in sample areas of the region, specifically the BWCA, some of the residential areas, and some of the seasonal resort type areas, together with superimposed noise levels of various strengths that might be generated by noise sources intruding in the area due to mining operations. By listening to the actual superposition of differing intruding noise on the background noise, it is hoped that a qualified and confident judgment can be made by those officials responsible for making a final decision on this matter.

TIMING

The project timing is broken down into sub-areas or tasks. The sub-areas were discussed previously. The overall project timing is shown in Figure 8.

PERSONNEL

Development of an adequate noise model will require application of a fairly high level of mathematical and programming sophistication together with a good knowledge of acoustics and noise. In addition, provision must be made for regular supervision on the part of senior MPCA noise staff.

The model development step is basically short-term, roughly a year Thus, hiring a competent person to perform the model development would be difficult and expensive (to entice a properly qualified person for a one year period). It is therefore recommended that outside contracts be utilized for the development of the regional noise model. It is also recommended that a member of the state staff be allocated on a full-time basis in January 1977

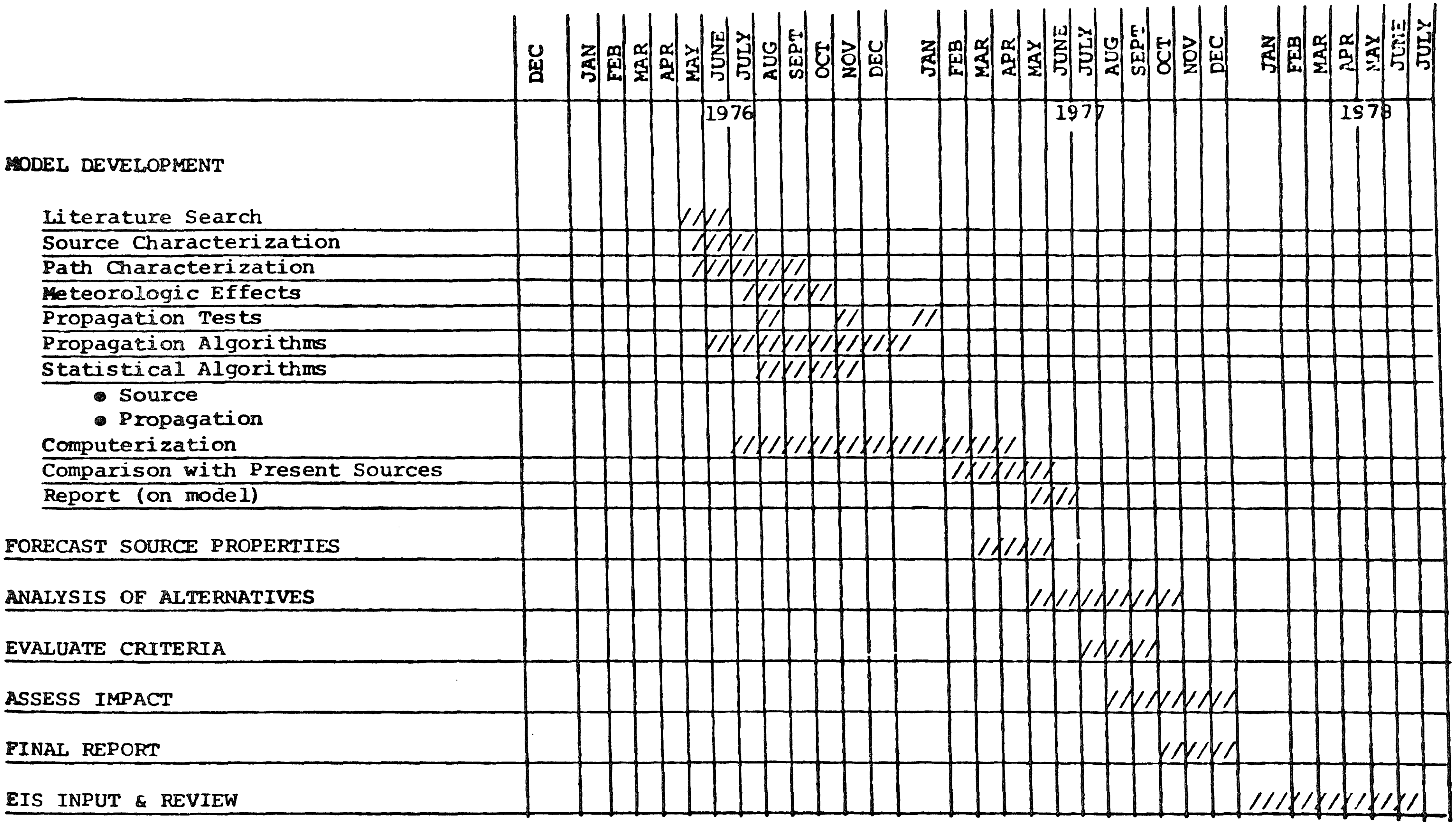

FIGURE 8

NOISE IMPACT ANALYSIS TIMING

to perform the alternatives study using the model developed under contract. This person or another would be switched to one-half time or less beginning in January 1978. It is anticipated that some outside contractual assistance will be important, particularly in the initial phases of the alternatives analysis.

It is considered imperative that the modeling effort be under the supervision of senior MPCA noise staff at a level of at least one day per month.

BUDGET

The budget necessary for carrying out the noise impact analysis effort is shown in Figure 9. The budget reflects approximately one day per month of senior MPCA staff and utilization of other staff and contractual work as described under the personnel discussion.

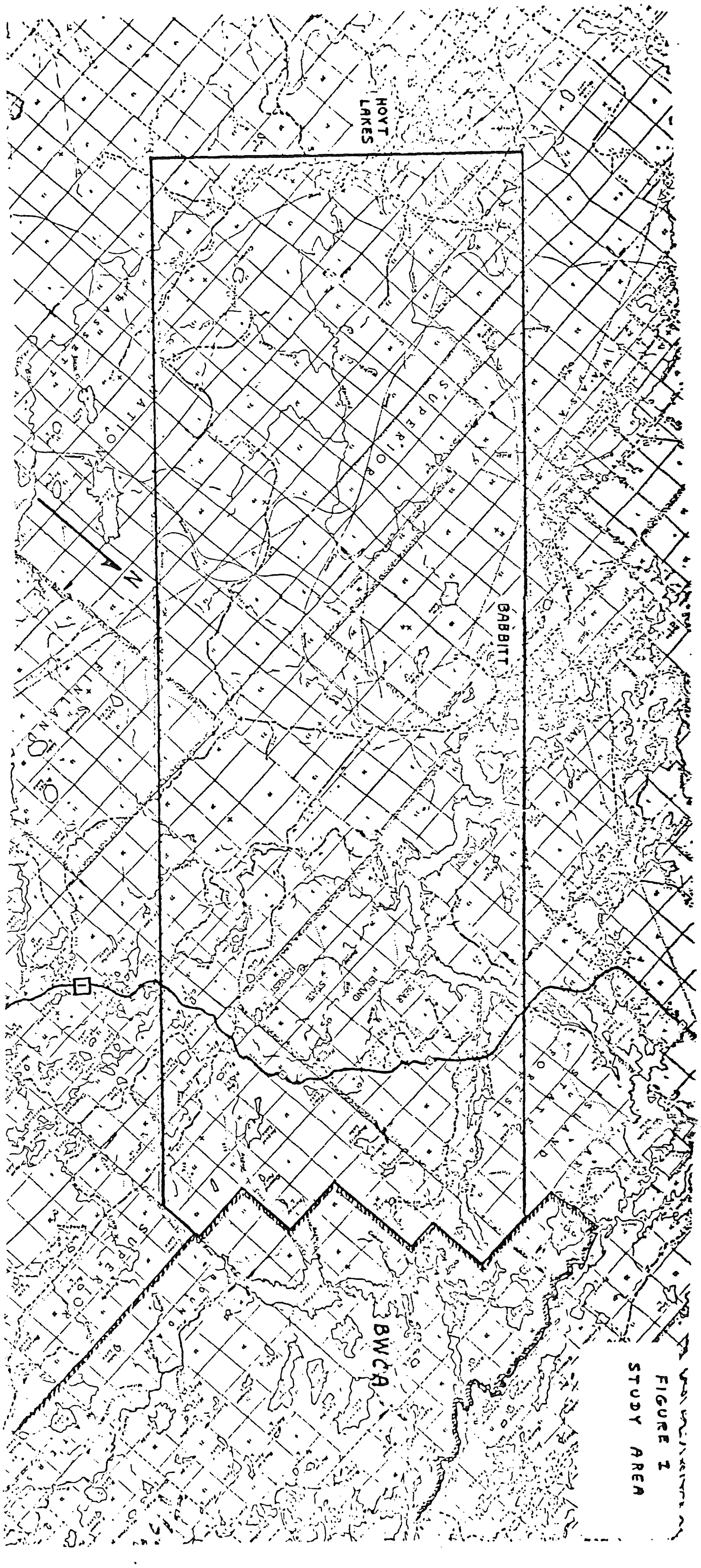

FIGURE 1
STUDY AREA

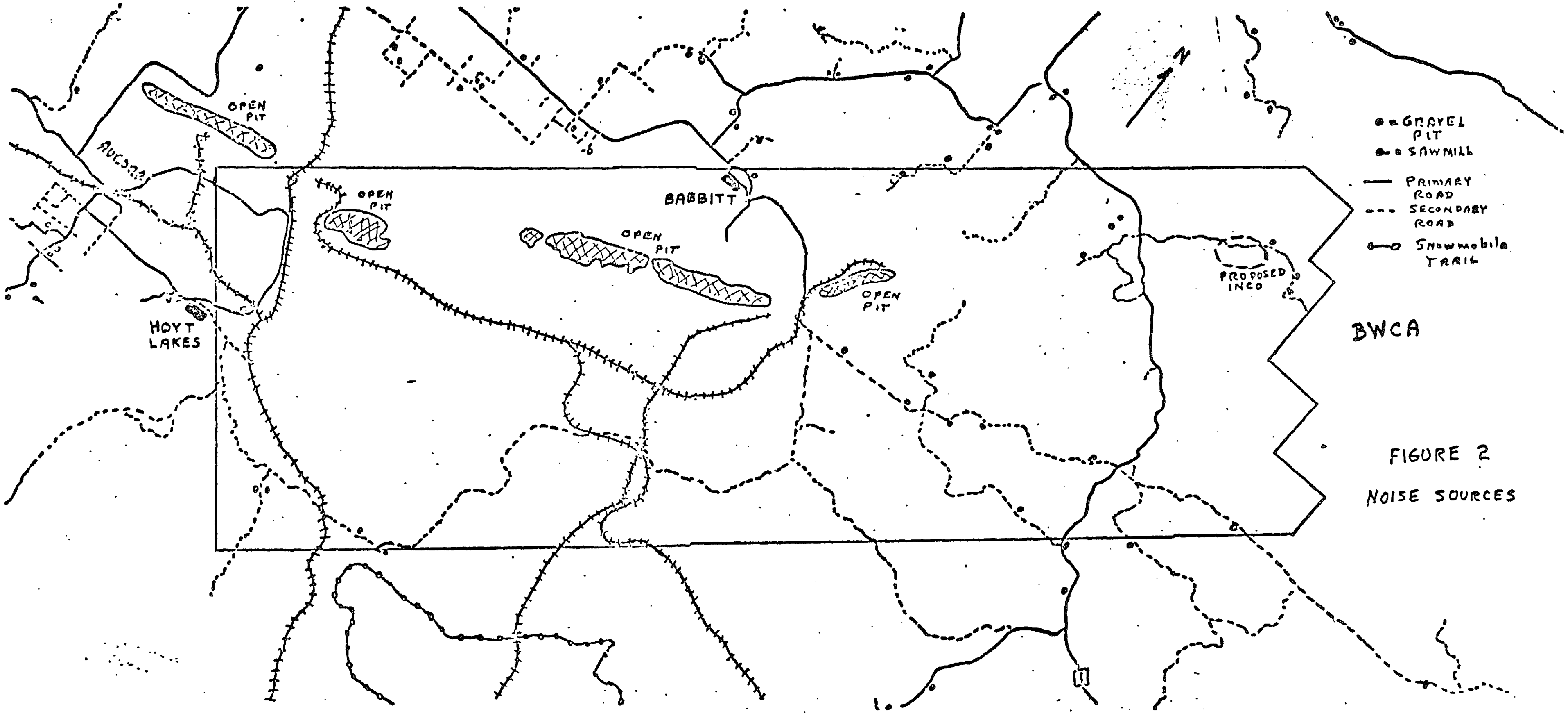

FIGURE 2

NOISE SOURCES

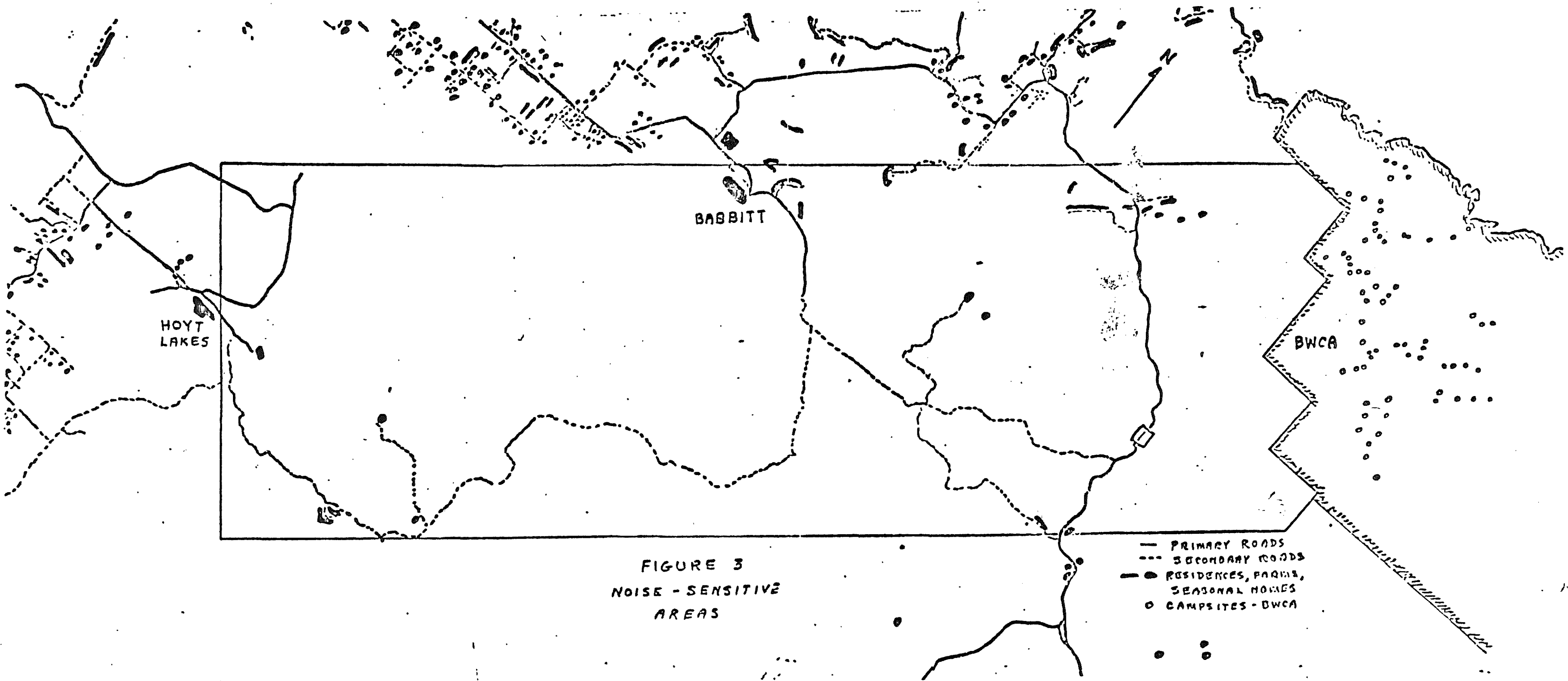

FIGURE 3
NOISE - SENSITIVE
AREAS

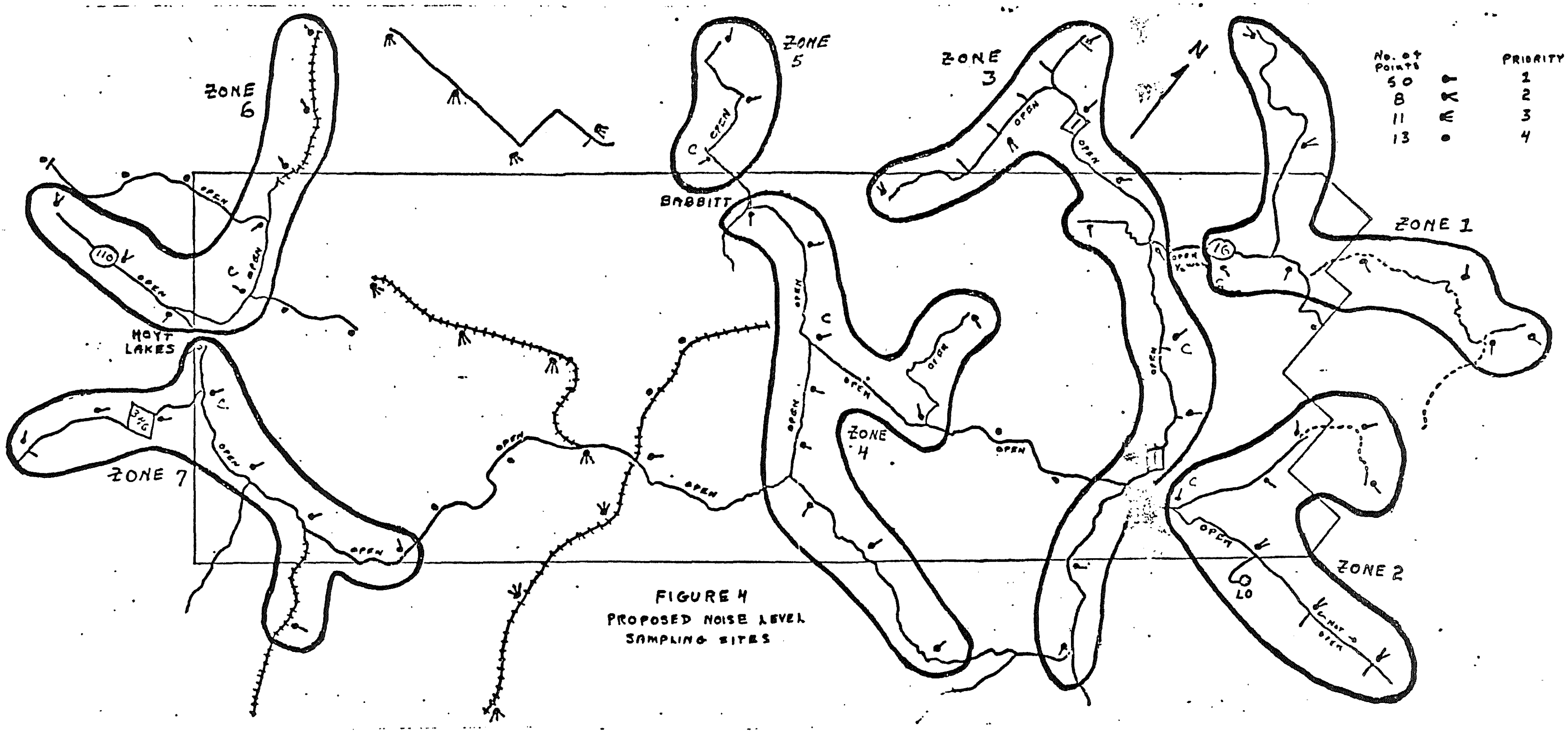

FIGURE 4
PROPOSED NOISE LEVEL
SAMPLING SITES

APPENDIX W

GLOSSARY OF TERMINOLOGY AND UNIT CONVERSIONS

1. artificial noise--any man-made sound heard and/or measured during the course of the Copper-Nickel Noise Monitoring Project.

2. background sounds--total of all sounds other than artificial noise heard and/or measured during the course of the Copper-Nickel Noise Monitoring Project.

3. band pass filter--type of acoustical filter which allows only a certain specified frequency range to pass.

4. coniferous vegetation--vegetation which keeps its foliage year-round.

5. dBA--a measurement of acoustical signals passed through the "A" weighted network.

6. deciduous vegetation--vegetation which loses and regrows its foliage on a yearly basis.

7. hertz--measure of frequency of acoustical signals or cycles per seconds.

8. knots--measure of velocity, used in Copper-Nickel Noise Monitoring Study to measure wind speeds. 1 knot=1.15 mph

9. least squares fit--statistical procedure used to quantify the correlation of an independent and dependent variable.

10. natural sound--any acoustical signal heard and/or measured during the Copper-Nickel Noise Monitoring Study, which was produced by any source naturally found within the study area.

11. probability paper--graph paper on which sound levels are plotted as a function of the percent of time exceeded.

12. rayl--a measure of flow resistance. 1 rayl=1 dynel cm^3 per second.

13. real time analyzer--analyzer of acoustical signals which measures frequency components in the same time sequence as it originally occurred.

14. residual sound--sound produced by wind interaction with various vegetation types as heard and/or measured during the Copper-Nickel Noise Monitoring Project.

15. rms averaging--method of averaging decibels.

16. sound level--any "A" weighted acoustical signal as compared to a specified reference.

17. standard error of estimate (δ)--a goodness of fit parameter used in the least squares fit procedure.

18. third octave bands--a specific grouping of acoustical frequency ranges which divides octave band into three. (Octave bands are separated by a frequency ratio of two.)