PPWB DESIGN WIND PROGRAM

USER'S MANUAL

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ENVIRONMENT CANADA

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Preface

Phase II of the Prairie Provinces Water Board (PPWB) design wind project was divided into parts A and B. Part A was completed in December 1988 and represented a significant enhancement to the utility of the data provided in Phase I (see PPWB Report No. 90, December 1986). However, the Committee on Hydrology (COH) requested that a user's manual be prepared together with a number of program modifications.

For completeness, the documentation from Part A and the User's Manual from Part B are combined in this report. The Part A documentation is included as an Addendum to the User's Manual because most of the information is superseded by the User's Manual. There are a few references to Part A in the text of the User's Manual, but otherwise the manual can stand alone.

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PPWB DESIGN WIND PROGRAM
Phase II, Part B

BACKGROUND

In 1986, the agencies of the Prairie Provinces Water Board (PPWB) asked the Atmospheric Environment Service (AES) of Environment Canada to develop a proposal to update the design wind study conducted by McKay (1966). A proposal was submitted by AES and three separate contracts have been completed as follows:

December 31, 1986 -	Phase I - Data Assembly	
November 30, 1988 -	Phase II, Part A - Software development for design wind rose plots.	
January 31, 1991 -	Phase II, Part B - Software modification and user's manual.	

This user's manual marks the completion of this project. Any future updates to the software are expected to be of a trivial nature, but corrections to the data files and the anemometer histories may be required from time to time. It is possible to obtain updated date files for sites of critical importance, but there will be a $95 minimum charge in accord with the current (January 1991) AES fee schedule. That fee would entitle the user to up to four (4) stations of updated data. The software will handle up to 50 years of data so it will require modification after the year 2002. When running the program on updated files, the user should ensure that the anemometer history is current (i.e. no change in anemometer height or exposure since December 1986). Recent changes in anemometer heights are mainly in forested areas and more changes are expected as AES introduces its 10 m tilt-down towers in those areas.

The software is quite versatile and should not require significant changes. It is designed to access a number of directory or parameter files which can be modified without having to recompile the software. Also, the software supports a wide variety of equipment. For processors, it supports IBM compatibles (XT, AT, 286 or 386). It is recommended for use on machines with coprocessors, but it will run on machines without one, albeit much more slowly. Generating a design wind rose is very computationally intensive and can require up to 10 minutes on an old XT without a coprocessor. The program supports a host of standard output devices, but does not take advantage of the new VGA monitor standard. Users with a VGA monitor should select IBM EGM if they want high quality graphics displayed on the VGA monitor. The program will produce an acceptable graphic on a dot matrix printer, but for report quality, a plotter or laser printer is recommended.

Software support and advice will be provided by the author at (306) 780-5739.

TECHNICAL SPECIFICATIONS

Computers: IBM XT, IBM AT, IBM PS2, 80286, 80386 or compatibles using DOS 2.0 or higher.

Output Devices: EPSON - all dot matrix
IBM Graphics or Proprinter
HP laserprinter
HP plotters
IBM CGA
IBM EGA
Others - see menu in program

Line Printer LPT1: It is assumed that a standard printer or laser printer is attached to parallel port 1. If no device is attached, no data tables or return period tables will be produced, but the program will still run.

Coprocessor: 8087, 80287, 80387 recommended, but not necessary.

Execution Times: (Polar diagram) to Epson dot matrix printer.

		with coprocessor
XT	7m 10s	1m 12s
80286	3m 11s	28s
80386-SX	2m 20s	not tested

Memory: 256K

Disk Drives: Recommend configuration
- Floppy 5 1/4" or 3 1/2" drive **A** for data diskettes
- Hard drive **C** or **D** with DESNWIND subdirectory as the current directory for program and associated files (space required 248K).

NOTE: Data diskettes **MUST** be in drive **A**.

Alternatives
- One floppy drive **A** - will run but have to change diskettes and it is somewhat slower.
- Two floppy drives - data diskettes must be in drive **A** and current drive must be the other drive where the program diskette resides.

Data Diskettes: The files of monthly extreme winds for hourly and other durations are found on diskettes
PPWBWIND1 to PPWBWIND10
and
IWDWIND1 to IWDWIND5.

The files xxxxDIR.DAT on the program diskette provide a directory to the data diskettes and will prompt the user to enter the correct data diskette for the selected station.

Files on Program Diskette:

SASKDIR.DAT	- directory to Saskatchewan stations
ALTADIR.DAT	- directory to Alberta stations
MAN_DIR.DAT	- directory to Manitoba stations
ONT_DIR.DAT	- directory to Ontario stations
NWT_DIR.DAT	- directory to Northwest Territories stations
GUSTDIR.DAT	- directory to gust stations
DSWIND.EXE	- executable design wind program
ANHISTORY.DAT	- station anemometer histories
DNAME.DAT	- output device names supported by this program package
PORTMODL.DAT	- default IOPORT and model specifications corresponding to devices in DNAME.DAT
PORTS.DAT	- alternate IOPORTs
DSCOPY.BAT	- batch file to make directory DESNWIND and copy files to this directory on your hard drive, C.

Programming Language:

The source code for the design wind program uses the FORTRAN 77 standard and was compiled used Microsoft FORTRAN V 4.1. The graphical outputs make extensive use of PLOT88 Version 18 (Plotworks, Inc.), which is linked to the machine code following compilation. Licensed copies of both commercial software packages are retained by the AES office in Regina.

ASSUMPTIONS

1. **Homogeneity** - It is assumed that the station wind data are homogeneous in time except for changes in anemometer height, and that the latter can be corrected by a power law adjustment of all years to a common reference level.

   Changes in instruments, exposure and observing practices are known to have occurred at many sites. Stations with long periods of no changes will come closest to producing a homogeneous record.

2. **Anemometer Histories** - It is assumed that the anemometer history has been well documented and is reflected accurately in the ANHISTORY.DAT file.

   This is not a trivial matter because AES station inspection reports have varied in quality and some significant changes have not been documented. Some anemometer histories may be in error, but a review of the graph of monthly extremes and anemometer height produced by the design wind software can reveal anomalous changes not corresponding to a significant change in anemometer height.

3. **Data Integrity** - It is assumed that all data derived from the Canadian Climate Centre's Digital Archive of Canadian Climatological Data have been subjected to a rigorous quality control process and are error free.

   Quality control procedures are used for all data in the archive, but errors have been made. For example, Regina's one-hour extreme wind was 142 km/h which was supposed to have occurred on October 14, 1959. This was 46% higher than the second highest values. A check of the original records for the day revealed relatively light winds. That error is in the file YQR.PRO on the data diskette PPWBWIND4 originally supplied with this project. A corrected file is found on your program diskette. It is known that there is an error in the file SCOTT.PRO for SCOTT CDA, but the archive has not been corrected yet.

4. **Independent Stationary** - For the purpose of the statistical analysis, it is assumed that the annual extremes for the specified period (month, season, annual) are independent and that there are no trends.

   The first assumption is reasonably good because we are sampling a single hour from each year out of a possible 8760 hours. Some climatological variations of the order of years to a decade, leading to an altered storm track pattern over successive years, may weaken this assumption slightly.

5. **Gumbel Extremal Distribution** - It is assumed that the annual extremes fit the Gumbel extremal distribution. The sample of annual extremes should have a skew close to 1.13 for this to be true.

   It can be shown that the annual extremes for most stations approach a Gumbel distribution, but outliers can cause significant errors.

6. **Representative** - Only stations with at least 15 years of data were selected for the design wind data assembly except in data sparse areas. It is assumed that 15 years of data will provide an adequate sample of the total population.

   The longer the record, the greater the assurance that the sample is representative and stations based on a full 33 years (1953-85), barring significant outliers, should yield a stable estimate of return period wind speeds. As the record length of the digital archive increases, even better estimates of design winds will be possible in the future.

Extreme winds arise from a variety of causes: intense synoptic scale storms, chinooks, thunderstorm gust fronts (down drafts), tornadoes, and hurricanes. The first three are probably well represented in the station records, but the fourth is much rarer and is not meaningful except for the gust duration. All sites are sufficiently far removed from tropical waters, that hurricane winds are not possible. Although moisture from such systems can reach the southern prairies on rare occasions, the wind system associated with the hurricane degenerates rapidly over land because the source of energy is removed, and the increased friction over land results in a rapid loss of kinetic energy from the storm system.

At some time, a segregation of wind types may be warranted to separate extremes associated with synoptic storms and thunderstorms such as might be done with runoff extremes due to snowmelt or rainfall events. Such an analysis would be significant to short duration winds (gust to less than 1 hour).

Chinook and katabatic winds are only of concern in mountainous areas or east of the Rockies and Mackenzie mountains. Lethbridge provides an example of extreme winds dominated by chinooks.

7. **Power Law Wind Dependency** - It is assumed that the wind speed increases with height according to a power law relationship

$$u_1 = u_o \ (Z_1/Z_o)^P$$

due to the affect of surface friction where p is dependent on surface roughness. The values used for the powers are empirically derived and are attributable to Davenport (1960) and used by McKay (1966) in the predecessor to this project.

On average, this "law" gives a good representation of the change in wind speed with height above ground, but it must be recognized that on very short time scales (e.g. gusts), the turbulent structure of the atmosphere will depart significantly from this. When adjusting gust data, careful examination of data is required to adjust for different anemometer heights.

Great care must be exercised in choosing the appropriate power. The program suggests a default value of 0.154 which is appropriate to a well exposed prairie (airport) location well removed from all local obstructions. The power should be chosen to minimize discontinuities in the extreme wind due to differences in anemometer height. This program displays the adjusted data set so one can visually assess the impact of the adjustment. The roughness parameter can be specified for individual directions.

The powers used by McKay in transfer of data to a reservoir may be too high. The power must be appropriate to the boundary conditions in which the anemometer is located, and which is continuous for 5 km upwind. Airport locations near a city or in a forest clearing may demonstrate a transitional behaviour. Although the program permits numerous options, the directional powers must be tested on the station data set to check the appropriateness of the chosen powers. **This should be attempted ONLY by knowledgeable users!**

8. **Extrapolation to Reservoirs** - There are very few wind records from an over water environment so it is necessary to extrapolate land winds to the water environment. A fetch of 6 km over water is required to achieve full adjustment of the wind profile to the over water environment. Thus, the program assumes large reservoirs or lakes, but even small narrow reservoirs may have one axis which approaches 6 km but directional data for the cross reservoir direction should be reduced to reflect the transitional state.

   For example, data quoted by McKay (1966) may be used as a guide, as follows:

Fetch (km)	Ratio (water/land)
0.8	1.08
1.6	1.13
3.2	1.21
6.4	1.28
9.6	1.31
12.9	1.31

   McKay used a simplified version of the following equation:

$$u_w = u_l \, (Z_{gl}/R_f)^{P_l} \,/\, (Z_{gw}/10)^{P_w}$$

   where
   - u_w - over water wind at 10 m
   - u_l - over land wind at height R_f (m)
   - Z_{gl} - height (m) of the gradient wind level over land
   - Z_{gw} - height (m) of the gradient wind level over water
   - P_l - power over land
   - P_w - power over water
   - R_f - reference height (m) of land anemometer.

   This program solves the above equation explicitly. The estimates for the gradient wind levels Z_g are those quoted by McKay (1966) from Davenport (1960).

The extrapolation is very sensitive to the choice of power and associated gradient wind level. For example, for the default power, 0.154, the adjustment ratio is 1.16 given a reference level of 10 m for the land based anemometer. For a power of 0.286, the adjustment ratio is 1.99! The program adjusts all design winds at the reservoir to the 10 m level.

The prominent topographic features should be similar at the reservoir site to those at the land location. For example, a station in a pronounced east-west valley would not provide a good estimate of the design winds over a reservoir located in a north-south valley.

9. **Period Selection** - The program will permit a monthly design wind analysis but the sample size over 31 days (744 hours) may not always be sufficient to provide an extreme wind for all directions. It is recommended that a minimum of three months be used to provide a sufficient sample.

SETUP

Hard Drive

The program diskette supplied should be copied as a back-up and the copy used for the following instructions.

The diskette contains a batch file which will copy all the files to a subdirectory - DESNWIND on the C drive. It assumes that diskette is in drive **A** and that the desired hard drive is drive **C**. If that is not the case, use an editor to modify DSCOPY.BAT to the desired drive settings. Then type

A:DSCOPY

This will create subdirectory DESNWIND if it does not already exist, and copy the files required to run the program to the DESNWIND subdirectory.

If you have diskette PPWBWIND4, you should overwrite YQR.PRO with the revised file of the same name supplied on the updated data diskette. As an added bonus, the Regina file has been updated to include 1988 data. You may want to run the DSWIND program on both files and compare the results. Except for southeast, the changes are very slight. As already noted, the error in the old file drastically affected the calculated return period winds from the southeast direction. Similarly, copy YQR12.PRO onto diskette PPWBWIND10, CONTWOY6.PRO onto IWDWIND1, YEV3.PRO and YEV6.PRO onto IWDWIND5 and WBK3.PRO, WBK6.PRO and YZF12.PRO onto IWDWIND5. All diskettes have sufficient room to accept the revised files.

Floppy Drives

To run from a floppy drive, no set up is required, but you should make a backup copy of the program diskette and use the backup copy as your working copy. Just copy over the *.DAT and *.EXE files to your working copy.

All Drive Systems

Leave the write-protect tag on for your original program diskette. Also, it is recommended that write protect tags be added to all data diskettes.

NEW FEATURES

DSWIND replaces program FWINDOW and DWPLOT developed in phase II, Part A of this project. The program FWINDOW calculated the return period wind speeds and created a file which was used as input to DWPLOT. DWPLOT produced the design wind rose on a limited number of output devices.

DSWIND accomplishes all this without the need for an intermediate file. The code for DWPLOT was made into a subroutine to FWINDOW and the whole package renamed to DSWIND for design wind. All outputs (tables and plots) identify the design wind duration (gust, one hour, two hour, three hour or six hour). A cautionary note has been added to the design wind plot to advise against interpolation between the standard eight (8) directions.

A significant change has been the addition of all output devices supported by Version 18 of PLOT88. This was accomplished by a series of parameter files which the program accesses before generating each plot.

Not only are many more devices supported, but a host of communications options have been included to suit unusual serial port data transfer protocols. For the author's own system, the HP plotter is connected to COM2 so the alternate port file has been tested to some extent. This is accomplished through a new subroutine DEVICE which replaces a much more limited selection of devices previously coded into subroutines VIEW and DWPLOT (now DWOUT).

The greatest programming change related to the request to specify directional roughness parameters and to calculate the over water design winds. Subroutine MODIFY was upgraded to permit directionally dependent roughness parameters. Minor changes were made to the output table in subroutine GETOUT and the design wind plotting subroutine DWOUT to indicate the powers used for specific directions. A new subroutine TRANSPOSE was written to calculate the reservoir return period wind speeds and call DWOUT in an alternate mode.

While it is possible to calculate directional return period winds over the lake by applying directional ratios directly to the directional return period wind over land, the non-directional design wind speed estimates may become inconsistent with the directional data. In TRANSPOSE, the directional ratios are applied to the respective annual directional extremes and the non-directional extreme determined from the maximum of resultant values. Then the subroutine GUMBEL is applied to the modified extreme wind array to compute the return period wind speeds over the lake and 50% error confidence limits.

The calculation of directional over water to over land ratios has been improved from McKay's (1966) study in that the ratio is explicitly calculated in its unsimplified form. For a power of 0.154, the new and old ratios are 1.16 and 1.13 respectively.

The subroutine VIEW permits one to examine the impact of the directional power (roughness) selection before the design wind calculation. All data must be adjusted to a common reference level or TRANSPOSE will be bypassed. This is to force the user to view the adjusted data. A transparent straight edge placed over the monthly extreme wind diagram is very useful for visually assessing the appropriateness of the wind power across changes in anemometer height. Too high a wind power will over adjust winds from a high anemometer height whereas too small a power will be noticeable in the opposite direction. The power can be tuned to yield a relatively homogeneous data set provided the anemometer history is correct and other influences are minor. Another useful technique is to overlay the raw and adjusted plots on a light table. This will also reveal over or under adjustment.

Note that all winds transposed to a reservoir or lake are at a reference height of 10 m regardless of the reference height at the land station.

In summary, all changes or improvements to the program which were specified in the work schedule for this final portion of the design wind project have been incorporated into the software DSWIND. The program has been tested and run on a wide variety of industry standard IBM microcomputer or compatibles and many standard output devices.

EXAMPLES

a) Uniform Anemometer History - Outlook PFRA

A few stations have a continuous wind record at a standard height of 10 m. One such station is Outlook PFRA which was established in November 1962. There has been no change in instrumentation - a 45B anemometer has been used throughout the observing period.

A design wind rose for the site can be produced without adjustment, but to transpose the data to a reservoir, one must choose an adjustment. In this case, there is no impact on the site specific design winds because all data are already at 10.0 m, but the appropriate power for the local roughness must be determined to transpose the data to a water environment.

Figure 1 shows the monthly one-hour wind extremes for all directions in raw form. Table 1 shows the annual extreme winds for the selected period (Jan-Dec). Adjusting the data has no impact on the site specific design wind. The design winds for Outlook are shown in Figure 2 and Table 2. The transposed design winds for a hypothetical large reservoir (fetch greater than 6 km) are shown in Figure 3 and Table 3.

All directional data have been adjusted by the same ratio for the reservoir design winds so the non-directional return period wind speeds are also adjusted by the same ratio.

Despite the constant anemometer height at Outlook, it is apparent that this record is not perfectly stationary. The extremes in the first few years tend to be a little higher than in the last 15 years.

b) Changes in Anemometer Height - Regina A

At most airports, the anemometer history is complex and Regina A is no exception to that. Documentation of anemometer relocations is not always clear and more recent investigations by the author have revealed that the information in PPWB Report No. 90 which is based on AES Station Information System is not accurate.

As far as this project is concerned, the winds up to October 1960 were measured with a 45B anemometer on the old terminal building at 20.4 m above ground. Both 45B and U2A anemometers were installed at 26.8 m above ground on the new control tower. In November 1962, a U2A anemometer on a 10 m tower was established adjacent to the runway. There is a conflict in the height of the anemometer at this point. One source quotes a height of 9.1 m until March 1973, but that appears to be the height of the tower whereas the Regina Annual Summary quotes 34 feet (about 10 m) beginning in November 1962. With several anemometers in place in the 1960's, it is not clear which data appear in hourly wind speed file. However, the author has concluded the 10 m U2A wind beginning in November 1962 is the source of data in the hourly wind speed in the archive. Thus, the anemometer history information in the file ANHISTRY.DAT has been altered to reflect the discussion above.

Figure 4 illustrates the raw hourly non-directional wind extremes for Regina A with the revised anemometer history. Note that mean extremes are during the period 1960 to 1962 when the anemometer was at 26.8 m. Also note that the entire period 1953 to 1988 is displayed illustrating the capability of the software to handle updated records past 1985. Figure 5 shows the adjusted data. While the 1960 to 1962 data are more in line with the latter part of the record, the information prior to October 1960 may be over adjusted, reflecting, in part, the change in instrument as well as location. The data measured at 10 m (November 1962 to present) was unchanged by the adjustment process. The design wind rose based on this adjusted data (Figure 6) indicates that southwest, west and northwest directions yield the strongest design winds at Regina. Figure 7 extends this information to a hypothetical large lake environment. The reservoir design wind diagram is similar to Figure 6 except all values have been increased by 16% (see Tables 4 and 5).

c. Directional Roughness - Regina A

This is for illustrative purposes only. A northeast wind at Regina A would mean that the wind is blowing across the entire city, but then there is at least one kilometre of relatively flat unobstructed terrain between the edge of the current city and the anemometer site. Thus, for the northeast direction, the boundary layer is in a transitional state between fully developed urban turbulence structure and open prairie environment to which is adjusting.

Figure 8 plots the unadjusted northeast wind extremes for the period of record. Worth mentioning are the two zero values which actually represent a complete lack of northeast winds in two months, rather than any missing data. Figure 9 shows the adjusted time series from northeast winds. The plot suggests that the data are over adjusted (i.e. the power chosen is too high), but for the purposes of this example, it was retained.

Table 6 demonstrates that the impact of the adjustment on the site specific design winds is small (compare to Table 4). However, Table 7 and Figure 10 show a very marked impact on the over water design winds. Obviously, the power chosen for northeast is not appropriate and leads to fictitious results! Instead of a 16% increase applied to other directions, the northeast winds are adjusted by 51%. Clearly, the choice of directional roughness must be warranted and the use of the time series plot may provide some clues as to the appropriate power/roughness which should be used.

The above example was provided to illustrate that the choice of directional roughness must be justified in the data set and, if it is not, misleading design winds will be the result. The impact on the site specific wind rose may be modest depending on the percentage of the record being adjusted, even if the choice is not correct. The program DSWIND provides the capability to specify the directional roughness parameter through the choice of power. The impact on the reservoir design wind is drastic. **It is up to the user to use this feature responsibly!**

d) Gust Design Wind - Regina A

Extreme gust (instantaneous) winds are available for a limited number of stations as specified in Phase I of this project. The data are not available by direction so only a non-directional analysis is possible, and no design wind diagram is produced by the design wind program. However, a data table is output (see Table 8) as well as a return period table. It is also possible to view the monthly extreme gusts through the subroutine VIEW. The direction of the annual maximum gust is shown in Table 8, but program suppresses the directional analysis.

Figures 11 and 12 graph the raw and adjusted monthly extreme gusts. Because the program automatically scales the ordinate axis, the two graphs are not directly comparable, but one can see that the early part of the record (before 1962) is modified downward with respect to the period since 1962.

Table 9 provides the non-directional return period gusts for Regina at 10 m. Table 10 shows the transposed gusts to a reservoir.

The use of the power low for gust data is questionable. The power law describes the average change in wind speed with height whereas a gust by definition is a significant departure from the average. Thus, one should use the gust analysis with caution.

e. Other Durations for Extreme Winds

For a selected number of stations (two per province), data was assembled for other durations, namely gust, 2-hour, 3-hour, 6-hour and in some cases 12-hour durations. The AES utility program GRP124 can be set to select the maximum average wind speed in a month by direction for any duration from one to 24 hours. For wind mileage from the old 45B anemometers the data are true hourly average winds (e.g. Weyburn), but for most first order stations (e.g. Regina A), the winds are one minute or two-minute samples taken close to the hour. However, it would be incorrect to assign a one-minute duration to the so-called hourly winds. For the purpose of this analysis, the observed one-minute winds on the hour are assigned a one-hour duration. There is no good source of data between the gust and the one-hour duration. Perhaps the advent of the data logger will fill that gap in the future. For this analysis, it was assumed that a gust had a duration of the order of a few seconds (.001 hours).

Table 11 records the non-directional return period winds by duration based on runs of the DSWIND on the files for Regina A. It is possible to plot these data directly as shown in Figure 13 and then interpolate to the required duration along the return period of interest. An alternate approach is to normalize the winds with respect to one-hour duration. In Figure 14, the 25-year return period curve is plotted, but as one will note from Table 12, the ratios for different return periods are virtually identical.

Because only a very limited number of stations were specified for winds of other durations in this project, it is necessary to extrapolate the ratios shown in Table 12 and Figure 14 to other sites in the same region. However, the ratios derived here were for full-year design winds are very similar to open water 'average' found in McKay's study for Winnipeg. Hence, given the one-hour design winds for any site in a given region, one can apply the ratios from the nearest appropriate site where winds of other duration are included in the data set of this project.

One glitch was revealed in this example which involved the 12-hour duration data. There was a problem in the data file YQR12.PRO which arose in the "clean-up" processing in Phase I. (Although the author has tested the design wind software extensively, not all processed wind files have been accessed.) The "CLEANUP" program from Phase I proved incapable of handling data sets which identified no 12-hour duration data for an entire year for a particular direction. For Regina, northeast winds are not very common so there are often months when there are no instances of northeast winds persisting for 12 hours. In some years such as 1963, there were no 12-hour winds from the northeast in any month, so the "CLEANUP" program reacted in a strange, but until this point, undetected manner. A new copy of YQR12.PRO is on the program disk and should be copied to PPWBWIND10.

OPERATING INSTRUCTIONS

a. <u>Running From Hard Drive C or D</u>

This is the recommended configuration with the program DSWIND and associated directory and parameter files on subdirectory DESNWIND. Type

```
CD C:\DESWIND
DSWIND
```

and follow the instructions in the program. If you wish to break out of the program, use Ctrl-C. Occasionally, an illegal response to one of the questions will cause the program to cease with a run-time error. If this happens, just restart the program and enter a number in the form requested.

All data diskettes are accessed through floppy drive A. When you are done just type

```
CD C:\
```

to return to your root directory.

b. Running From a Floppy Drive

Make the floppy drive into the current drive by

```
   A:
or B:
```

Insert the program diskette into the current drive and type DSWIND. If running from drive A, you will have to swap diskettes to read the data in from the data diskette and then swap back to access the other files needed from the program diskette.

When you are finished, you can return to your normal mode of operation by typing

```
C:
```

if you have a hard drive.

Note that DSWIND may be run as many items as you need design wind information for different stations or durations.

GUIDELINES FOR APPLICATION

1. Choose a meteorological station close to your site of interest and appropriate to the ecozone.

2. Bring the hourly data to a common reference height and review the time series for each direction. This can be done quickly by directing the output to the monitor. Make sure you choose the power corresponding to the appropriate roughness description.

3. For very knowledgeable users, select directional powers if warranted. Note that the winds transposed to a reservoir are very sensitive to the choice of power, so review the time series closely.

4. Print the return period table and plot the corresponding design wind diagram. The return period table is printed automatically on LPT1:. You choose the output device and port parameters to suit your output device(s).

5. If you want the results transposed to a large water body, the program insists that all data be modified to a common reference height first. The program will produce a table of reservoir design winds as well as a plot of the same information.

6. If data of some other duration is needed, a ratio such as shown in Figure 14 may be applied to the hourly design wind data.

7. Although the software can be used to analyze monthly data, it is not recommended because the sample size for extremes is not very large. **A minimum of a three month season is recommended to ensure an adequate sample size.** This becomes even more important at longer durations (e.g. six or 12 hours)!

8. If the software produces strange results or there is a problem with one of the data files, contact the author at (306) 780-5739 for assistance.

THE FUTURE

This program can be used for up to 50 years of data with no change to the software. The changes required to accept even longer records mainly involve changing the size of some arrays in the program and some do-loop parameters.

AES has plans to put its data on optical disk over the next few years. When hourly wind data is available in this form, a program similar to the utility GRP124 could be used to extract the data needed as input for this program. Thus, it will probably be possible to avoid another major data assembly like Phase I of this project.

The data sets can be expanded to include other stations, but the directory and anemometer history files would need to be modified. This can be done without recompiling the program. To include other provinces, the program would have to be modified, but the changes are minor.

Because anemometer heights are subject to change, particularly in forested areas, a thorough updating of the anemometer history file will be needed to extend the useful life of the program. When wind data becomes readily available on optical disk, it would be advisable to update the anemometer histories. For airport sites like Regina, the current anemometer history may serve for many years, so no changes would be needed to take advantage of a longer data set. If users are particularly concerned about a particular station, an updated data file and anemometer history can be provided on a cost recovery basis.

The source code (MS FORTRAN 4.1) is provided so that updates are possible even if the author is no longer available to provide them. The software has proven upward compatible with the new 80386 based microcomputers so it should be applicable for a number of years (at least five years) to come. If a major upgrade to the software is to be made, a change to the 'C' programming language should be considered for application on many different computing platforms. However, the current software is ideal for the micro-computer environment and may not lend itself to mainframe or mini-computer.

This project was initiated prior to the introduction of AES's private sector meteorology policy. Although AES is available to fix any minor problems with the current software or data files, AES would not be in a position to undertake a major upgrade to the software unless a private sector supplier could not be found. AES could provide updated anemometer histories on a cost recovery basis because it is doubtful that any private sector company would have access to the necessary information.

REFERENCES

Davenport, A.G., 1960: Rationale for determining design wind velocities. Proceedings ASCE, Structural Division. 86: ST5, pp 39-68.

McKay, G.A., 1966: Design Winds for reservoirs in southern Manitoba. Regina Prairie Farm Rehabilitation Administration, Met. Report No. 20, 25 p.

APPENDIX A - TABLES

LIST OF TABLES

ANNUAL EXTREME WIND SPEEDS (km/h) FOR OUTLOOK PFRA 1 HOUR

ANALYSIS PERIOD IS FROM Jan TO Dec

YEAR	N	NE	E	SE	S	SW	W	NW	ALL	FLAG
1963	48.	53.	53.	68.	61.	58.	58.	56.	68.	0
1964	51.	51.	43.	50.	43.	48.	50.	53.	53.	0
1965	58.	39.	45.	56.	47.	72.	60.	64.	72.	0
1966	45.	34.	43.	51.	47.	51.	50.	50.	51.	0
1967	40.	45.	48.	51.	45.	53.	60.	60.	60.	0
1968	39.	42.	45.	55.	40.	66.	61.	56.	66.	0
1969	43.	58.	55.	47.	31.	53.	61.	48.	61.	0
1970	37.	40.	39.	56.	35.	50.	53.	48.	56.	0
1971	34.	32.	39.	48.	40.	56.	50.	61.	61.	0
1972	27.	34.	40.	50.	32.	45.	50.	51.	51.	0
1973	39.	53.	45.	51.	51.	56.	56.	56.	56.	0
1974	37.	48.	42.	50.	37.	51.	47.	50.	51.	0
1975	31.	43.	42.	45.	26.	53.	47.	58.	58.	1
1976	34.	45.	39.	56.	34.	53.	63.	72.	72.	1
1977	37.	42.	47.	45.	39.	51.	60.	50.	60.	0
1978	34.	35.	42.	50.	43.	48.	45.	61.	61.	0
1979	37.	42.	34.	43.	37.	58.	53.	50.	58.	0
1980	39.	29.	51.	47.	39.	64.	47.	50.	64.	0
1981	37.	48.	45.	43.	43.	48.	47.	61.	61.	0
1982	31.	35.	35.	53.	37.	43.	43.	51.	53.	0
1983	42.	48.	42.	66.	39.	55.	55.	63.	66.	0
1984	37.	39.	39.	55.	45.	60.	61.	66.	66.	0
1985	34.	40.	39.	45.	34.	60.	58.	60.	60.	0

***DATA HAVE BEEN ADJUSTED TO AN ANEMOMETER HEIGHT OF 10.0m
POWER FOR DIRECTION ALL IS .154

VALID FOR ONE HOUR WIND SPEEDS UNLESS NOTED OTHERWISE

Table 1: Annual one-hour extreme winds (km/h) for Outlook PFRA. Although this table indicates the data are adjusted, no change has occurred because the data are already at 10 m.

**RETURN PERIOD WIND SPEEDS AND 50% CONFIDENCE LIMITS (km/h) FOR
OUTLOOK PFRA 1 HOUR

NUMBER OF VALID YEARS = 23
RECORDS BEGAN IN 1963 AND END IN 1985
ANALYSIS PERIOD IS FROM Jan TO Dec

	RETURN PERIOD (YEARS)								
DIRECTION	2	5	10	15	20	25	30	50	100
N	37.6	43.7	47.7	50.0	51.6	52.8	53.8	56.6	60.3
+/-	.9	1.5	2.0	2.3	2.6	2.7	2.9	3.3	3.8
NE	41.2	47.8	52.1	54.6	56.3	57.6	58.7	61.7	65.8
+/-	1.0	1.6	2.2	2.5	2.8	3.0	3.1	3.5	4.1
E	42.3	46.9	50.0	51.7	52.9	53.8	54.6	56.7	59.5
+/-	.7	1.1	1.5	1.8	1.9	2.1	2.2	2.5	2.9
SE	50.3	56.0	59.7	61.8	63.3	64.4	65.4	68.0	71.4
+/-	.8	1.4	1.9	2.2	2.4	2.5	2.7	3.0	3.5
S	39.0	45.5	49.9	52.3	54.0	55.3	56.4	59.4	63.4
+/-	1.0	1.6	2.2	2.5	2.7	2.9	3.1	3.5	4.1
SW	53.3	59.4	63.4	65.6	67.2	68.4	69.4	72.2	75.9
+/-	.9	1.5	2.0	2.3	2.5	2.7	2.9	3.2	3.8
W	52.7	58.1	61.7	63.8	65.2	66.3	67.2	69.7	73.0
+/-	.8	1.3	1.8	2.1	2.3	2.4	2.6	2.9	3.4
NW	55.2	61.0	64.9	67.0	68.5	69.7	70.6	73.3	76.9
+/-	.8	1.4	1.9	2.2	2.4	2.6	2.7	3.1	3.6
ALL	59.2	64.7	68.4	70.4	71.9	73.0	73.9	76.4	79.8
+/-	.8	1.4	1.8	2.1	2.3	2.5	2.6	3.0	3.4

***DATA HAVE BEEN ADJUSTED TO AN ANEMOMETER HEIGHT OF 10.0m
POWER FOR DIRECTION ALL IS .154

***DATA REQUIREMENTS WERE RELAXED TO PERMIT ONE MISSING MONTH PER SEASON
2 SEASONS WERE INCLUDED WITH THIS CRITERION

VALID FOR ONE HOUR WIND SPEEDS UNLESS NOTED OTHERWISE

Table 2: Return period one-hour wind speeds (km/h) for Outlook PFRA. In this case, adjusted data are the same as the raw data because the anemometer was at 10 m. The adjustment process enables the transposition process to a water environment.

*** R.E.S.E.R.V.O.I.R ***

**RETURN PERIOD WIND SPEEDS AND 50% CONFIDENCE LIMITS (km/h) BASED ON OUTLOOK PFRA 1 HOUR

NUMBER OF VALID YEARS = 23
RECORDS BEGAN IN 1963 AND END IN 1985
ANALYSIS PERIOD IS FROM Jan TO Dec

	RETURN PERIOD (YEARS)								
DIRECTION	2	5	10	15	20	25	30	50	100
N	43.7	50.7	55.4	58.0	59.9	61.3	62.5	65.7	70.0
+/-	1.0	1.7	2.3	2.7	3.0	3.2	3.3	3.8	4.4
NE	47.8	55.4	60.5	63.4	65.4	66.9	68.2	71.7	76.4
+/-	1.1	1.9	2.5	2.9	3.2	3.4	3.6	4.1	4.8
E	49.1	54.4	58.0	60.0	61.4	62.5	63.4	65.8	69.1
+/-	.8	1.3	1.8	2.1	2.3	2.4	2.5	2.9	3.4
SE	58.4	65.0	69.3	71.8	73.5	74.8	75.9	78.9	83.0
+/-	1.0	1.6	2.2	2.5	2.8	2.9	3.1	3.5	4.1
S	45.3	52.9	57.9	60.7	62.7	64.3	65.5	69.0	73.6
+/-	1.1	1.9	2.5	2.9	3.2	3.4	3.6	4.1	4.7
SW	61.9	68.9	73.6	76.2	78.1	79.5	80.6	83.8	88.2
+/-	1.0	1.7	2.3	2.7	3.0	3.1	3.3	3.8	4.4
W	61.2	67.5	71.7	74.0	75.7	77.0	78.0	80.9	84.8
+/-	.9	1.6	2.1	2.4	2.7	2.8	3.0	3.4	3.9
NW	64.1	70.8	75.3	77.8	79.6	80.9	82.0	85.1	89.2
+/-	1.0	1.7	2.2	2.6	2.8	3.0	3.2	3.6	4.2
ALL	68.7	75.1	79.4	81.8	83.5	84.8	85.8	88.7	92.7
+/-	.9	1.6	2.1	2.5	2.7	2.9	3.0	3.4	4.0

***VALUES HAVE BEEN ADJUSTED TO AN ANEMOMETER HEIGHT OF 10.0 m
POWER FOR DIRECTION ALL IS .154 BOUNDARY LAYER HT = 305. m

***DATA REQUIREMENTS WERE RELAXED TO PERMIT ONE MISSING MONTH PER SEASON
2 SEASONS WERE INCLUDED WITH THIS CRITERION

VALID FOR ONE HOUR WIND SPEEDS UNLESS NOTED OTHERWISE

Table 3: Reservoir return period one-hour wind speeds (km/h) based on Outlook PFRA. The directional and non-directional design winds have all been adjusted by 1.16 to an over water environment (see Table 2).

**RETURN PERIOD WIND SPEEDS AND 50% CONFIDENCE LIMITS (km/h) FOR
REGINA A 1 HOUR

NUMBER OF VALID YEARS = 36
RECORDS BEGAN IN 1953 AND END IN 1988
ANALYSIS PERIOD IS FROM Jan TO Dec

	RETURN PERIOD (YEARS)								
DIRECTION	2	5	10	15	20	25	30	50	100
N	50.4	58.3	63.5	66.5	68.5	70.1	71.4	75.0	79.9
+/-	.9	1.6	2.1	2.4	2.7	2.8	3.0	3.4	3.9
NE	46.7	53.4	57.9	60.4	62.2	63.6	64.7	67.8	72.0
+/-	.8	1.3	1.8	2.1	2.3	2.4	2.6	2.9	3.4
E	54.7	60.7	64.7	66.9	68.5	69.7	70.7	73.5	77.2
+/-	.7	1.2	1.6	1.8	2.0	2.2	2.3	2.6	3.0
SE	59.0	64.0	67.3	69.2	70.5	71.5	72.3	74.6	77.6
+/-	.6	1.0	1.3	1.5	1.7	1.8	1.9	2.1	2.5
S	47.5	52.8	56.4	58.4	59.8	60.9	61.8	64.2	67.5
+/-	.6	1.1	1.4	1.6	1.8	1.9	2.0	2.3	2.7
SW	58.2	67.5	73.6	77.1	79.5	81.4	82.9	87.1	92.8
+/-	1.1	1.8	2.5	2.8	3.1	3.3	3.5	4.0	4.6
W	69.6	77.8	83.2	86.3	88.4	90.0	91.4	95.1	100.2
+/-	1.0	1.6	2.2	2.5	2.7	2.9	3.1	3.5	4.1
NW	65.9	74.4	80.1	83.3	85.6	87.3	88.7	92.6	97.9
+/-	1.0	1.7	2.3	2.6	2.9	3.1	3.2	3.7	4.3
ALL	73.0	80.8	85.9	88.8	90.8	92.4	93.6	97.2	101.9
+/-	.9	1.5	2.1	2.4	2.6	2.8	2.9	3.3	3.9

***DATA HAVE BEEN ADJUSTED TO AN ANEMOMETER HEIGHT OF 10.0m
POWER FOR DIRECTION ALL IS .154

VALID FOR ONE HOUR WIND SPEEDS UNLESS NOTED OTHERWISE

Table 4: Return period one-hour wind speeds for Regina A using a uniform directional adjustment.

*** R.E.S.E.R.V.O.I.R ***

**RETURN PERIOD WIND SPEEDS AND 50% CONFIDENCE LIMITS (km/h) BASED ON
REGINA A 1 HOUR

NUMBER OF VALID YEARS = 36
RECORDS BEGAN IN 1953 AND END IN 1988
ANALYSIS PERIOD IS FROM Jan TO Dec

	RETURN PERIOD (YEARS)								
DIRECTION	2	5	10	15	20	25	30	50	100
N	58.5	67.7	73.8	77.2	79.6	81.4	82.9	87.1	92.8
+/-	1.1	1.8	2.4	2.8	3.1	3.3	3.5	3.9	4.6
NE	54.2	62.0	67.2	70.2	72.2	73.8	75.1	78.7	83.6
+/-	.9	1.5	2.1	2.4	2.6	2.8	3.0	3.4	3.9
E	63.5	70.5	75.1	77.7	79.5	81.0	82.1	85.3	89.6
+/-	.8	1.4	1.9	2.1	2.3	2.5	2.6	3.0	3.5
SE	68.5	74.3	78.1	80.3	81.8	83.0	83.9	86.6	90.1
+/-	.7	1.1	1.5	1.8	1.9	2.1	2.2	2.5	2.9
S	55.1	61.3	65.5	67.8	69.4	70.7	71.7	74.6	78.4
+/-	.7	1.2	1.7	1.9	2.1	2.2	2.3	2.7	3.1
SW	67.6	78.4	85.5	89.5	92.3	94.5	96.3	101.2	107.8
+/-	1.3	2.1	2.9	3.3	3.6	3.8	4.0	4.6	5.4
W	80.8	90.3	96.6	100.1	102.6	104.6	106.1	110.5	116.3
+/-	1.1	1.9	2.5	2.9	3.2	3.4	3.6	4.1	4.7
NW	76.5	86.4	93.0	96.7	99.3	101.4	103.0	107.5	113.7
+/-	1.2	2.0	2.6	3.1	3.3	3.6	3.7	4.3	5.0
ALL	84.8	93.8	99.7	103.1	105.4	107.2	108.7	112.8	118.3
+/-	1.0	1.8	2.4	2.8	3.0	3.2	3.4	3.8	4.5

***VALUES HAVE BEEN ADJUSTED TO AN ANEMOMETER HEIGHT OF 10.0 m
POWER FOR DIRECTION ALL IS .154 BOUNDARY LAYER HT = 305. m

VALID FOR ONE HOUR WIND SPEEDS UNLESS NOTED OTHERWISE

Table 5: Reservoir return period one-hour wind speeds (km/h) for Regina A using a uniform directional adjustment.

**RETURN PERIOD WIND SPEEDS AND 50% CONFIDENCE LIMITS (km/h) FOR
REGINA A 1 HOUR

NUMBER OF VALID YEARS = 36
RECORDS BEGAN IN 1953 AND END IN 1988
ANALYSIS PERIOD IS FROM Jan TO Dec

DIRECTION	RETURN PERIOD (YEARS) 2	5	10	15	20	25	30	50	100
N	50.4	58.3	63.5	66.5	68.5	70.1	71.4	75.0	79.9
+/-	.9	1.6	2.1	2.4	2.7	2.8	3.0	3.4	3.9
NE	46.0	52.7	57.2	59.7	61.5	62.8	63.9	67.0	71.2
+/-	.8	1.3	1.8	2.1	2.3	2.4	2.5	2.9	3.4
E	54.7	60.7	64.7	66.9	68.5	69.7	70.7	73.5	77.2
+/-	.7	1.2	1.6	1.8	2.0	2.2	2.3	2.6	3.0
SE	59.0	64.0	67.3	69.2	70.5	71.5	72.3	74.6	77.6
+/-	.6	1.0	1.3	1.5	1.7	1.8	1.9	2.1	2.5
S	47.5	52.8	56.4	58.4	59.8	60.9	61.8	64.2	67.5
+/-	.6	1.1	1.4	1.6	1.8	1.9	2.0	2.3	2.7
SW	58.2	67.5	73.6	77.1	79.5	81.4	82.9	87.1	92.8
+/-	1.1	1.8	2.5	2.8	3.1	3.3	3.5	4.0	4.6
W	69.6	77.8	83.2	86.3	88.4	90.0	91.4	95.1	100.2
+/-	1.0	1.6	2.2	2.5	2.7	2.9	3.1	3.5	4.1
NW	65.9	74.4	80.1	83.3	85.6	87.3	88.7	92.6	97.9
+/-	1.0	1.7	2.3	2.6	2.9	3.1	3.2	3.7	4.3
ALL	73.0	80.8	85.9	88.8	90.8	92.4	93.6	97.2	101.9
+/-	.9	1.5	2.1	2.4	2.6	2.8	2.9	3.3	3.9

***DATA HAVE BEEN ADJUSTED TO AN ANEMOMETER HEIGHT OF 10.0m
POWER FOR DIRECTION NE IS .222
POWER FOR DIRECTION ALL IS .154

VALID FOR ONE HOUR WIND SPEEDS UNLESS NOTED OTHERWISE

Table 6: Return period one-hour wind speeds (km/h) for Regina A applying a different adjustment for northeast winds. The impact of the power selected for northeast winds is small (compare with Table 4).

*** R.E.S.E.R.V.O.I.R ***

**RETURN PERIOD WIND SPEEDS AND 50% CONFIDENCE LIMITS (km/h) BASED ON
REGINA A 1 HOUR

NUMBER OF VALID YEARS = 36
RECORDS BEGAN IN 1953 AND END IN 1988
ANALYSIS PERIOD IS FROM Jan TO Dec

	RETURN PERIOD (YEARS)								
DIRECTION	2	5	10	15	20	25	30	50	100
N	58.5	67.7	73.8	77.2	79.6	81.4	82.9	87.1	92.8
+/-	1.1	1.8	2.4	2.8	3.1	3.3	3.5	3.9	4.6
NE	70.1	80.4	87.2	91.1	93.8	95.8	97.5	102.2	108.5
+/-	1.2	2.0	2.7	3.1	3.4	3.7	3.9	4.4	5.1
E	63.5	70.5	75.1	77.7	79.5	81.0	82.1	85.3	89.6
+/-	.8	1.4	1.9	2.1	2.3	2.5	2.6	3.0	3.5
SE	68.5	74.3	78.1	80.3	81.8	83.0	83.9	86.6	90.1
+/-	.7	1.1	1.5	1.8	1.9	2.1	2.2	2.5	2.9
S	55.1	61.3	65.5	67.8	69.4	70.7	71.7	74.6	78.4
+/-	.7	1.2	1.7	1.9	2.1	2.2	2.3	2.7	3.1
SW	67.6	78.4	85.5	89.5	92.3	94.5	96.3	101.2	107.8
+/-	1.3	2.1	2.9	3.3	3.6	3.8	4.0	4.6	5.4
W	80.8	90.3	96.6	100.1	102.6	104.6	106.1	110.5	116.3
+/-	1.1	1.9	2.5	2.9	3.2	3.4	3.6	4.1	4.7
NW	76.5	86.4	93.0	96.7	99.3	101.4	103.0	107.5	113.7
+/-	1.2	2.0	2.6	3.1	3.3	3.6	3.7	4.3	5.0
ALL	85.8	95.1	101.3	104.8	107.2	109.1	110.7	114.9	120.7
+/-	1.1	1.8	2.5	2.9	3.1	3.3	3.5	4.0	4.7

***VALUES HAVE BEEN ADJUSTED TO AN ANEMOMETER HEIGHT OF 10.0 m
POWER FOR DIRECTION NE IS .222 BOUNDARY LAYER HT = 366. m
POWER FOR DIRECTION ALL IS .154 BOUNDARY LAYER HT = 305. m

VALID FOR ONE HOUR WIND SPEEDS UNLESS NOTED OTHERWISE

Table 7: Reservoir return period one-hour wind speeds (km/h) for Regina A applying a different adjustment for northeast winds. Demonstration of directional adjustment on reservoir design winds.

ANNUAL EXTREME WIND SPEEDS (km/h) FOR REGINA A - GUST

ANALYSIS PERIOD IS FROM Jan TO Dec

YEAR	DIR	MAX	FLAG
1957	N	98.	0
1958	W	95.	0
1959	W	120.	0
1960	NW	108.	0
1961	NW	113.	0
1962	W	131.	0
1963	W	135.	0
1964	SE	137.	0
1965	NW	122.	0
1966	W	122.	0
1967	W	100.	0
1968	W	108.	0
1969	E	101.	0
1970	NW	101.	0
1971	W	117.	0
1972	NW	100.	0
1973	NW	114.	0
1974	N	93.	0
1975	W	98.	0
1976	W	127.	0
1977	SW	137.	0
1978	W	124.	0
1979	SE	126.	0
1980	W	98.	0
1981	W	117.	0
1982	NW	117.	0
1983	NW	85.	0
1984	W	109.	0
1985	NW	109.	0

***DATA HAVE BEEN ADJUSTED TO AN ANEMOMETER HEIGHT OF 10.0m
POWER FOR DIRECTION ALL IS .154

VALID FOR ONE HOUR WIND SPEEDS UNLESS NOTED OTHERWISE

Table 8: Annual maximum wind gusts (km/h) for Regina A. Note that the winds prior to 1963 have been adjusted.

**RETURN PERIOD WIND SPEEDS AND 50% CONFIDENCE LIMITS (km/h) FOR
REGINA A - GUST

NUMBER OF VALID YEARS = 29
RECORDS BEGAN IN 1957 AND END IN 1985
ANALYSIS PERIOD IS FROM Jan TO Dec

	RETURN PERIOD (YEARS)								
DIRECTION	2	5	10	15	20	25	30	50	100
ALL	110.2	122.7	131.0	135.7	138.9	141.5	143.5	149.2	156.9
+/-	1.6	2.7	3.7	4.3	4.7	5.0	5.2	6.0	7.0

***DATA HAVE BEEN ADJUSTED TO AN ANEMOMETER HEIGHT OF 10.0m
POWER FOR DIRECTION ALL IS .154

VALID FOR ONE HOUR WIND SPEEDS UNLESS NOTED OTHERWISE

Table 9: Return period wind gusts for Regina A (non-directional).

*** R.E.S.E.R.V.O.I.R ***

**RETURN PERIOD WIND SPEEDS AND 50% CONFIDENCE LIMITS (km/h) BASED ON REGINA A - GUST

NUMBER OF VALID YEARS = 29
RECORDS BEGAN IN 1957 AND END IN 1985
ANALYSIS PERIOD IS FROM Jan TO Dec

	RETURN PERIOD (YEARS)								
DIRECTION	2	5	10	15	20	25	30	50	100
ALL	127.9	142.5	152.1	157.5	161.3	164.2	166.6	173.3	182.2
+/-	1.9	3.2	4.3	5.0	5.4	5.8	6.1	6.9	8.1

***VALUES HAVE BEEN ADJUSTED TO AN ANEMOMETER HEIGHT OF 10.0 m
POWER FOR DIRECTION ALL IS .154 BOUNDARY LAYER HT = 305. m

VALID FOR ONE HOUR WIND SPEEDS UNLESS NOTED OTHERWISE

Table 10: Reservoir return period wind gusts (km/h) based on Regina A.

Table 11: Return period wind speeds (km/h) for durations from gusts to to 12 hours at Regina A (non-directional).

Duration (hours)	Return Period (years)				
	2 yr	10 yr	25 yr	50 yr	100 yr
0.001	110.2	131.0	141.5	149.2	156.9
1	73.0	85.9	92.4	97.2	101.9
2	70.5	82.1	88.0	92.3	96.6
3	68.9	80.0	85.6	89.7	93.8
6	65.0	75.7	81.1	85.1	89.1
12	59.0	69.3	74.4	78.3	82.1

Table 12: Duration analysis for durations from gusts to 12 hours based on Regina A. Ratios are calculated with respect to the one-hour winds.

Duration (hours)	Return Period (years)				
	2 yr	10 yr	25 yr	50 yr	100 yr
0.001	1.51	1.53	1.53	1.53	1.54
1	1.00	1.00	1.00	1.00	1.00
2	0.97	0.96	0.95	0.95	0.95
3	0.94	0.93	0.93	0.92	0.92
6	0.89	0.88	0.88	0.88	0.87
12	0.81	0.81	0.81	0.81	0.81

APPENDIX B - FIGURES

LIST OF FIGURES

Figure 1: Extreme one-hour winds for Outlook PFRA

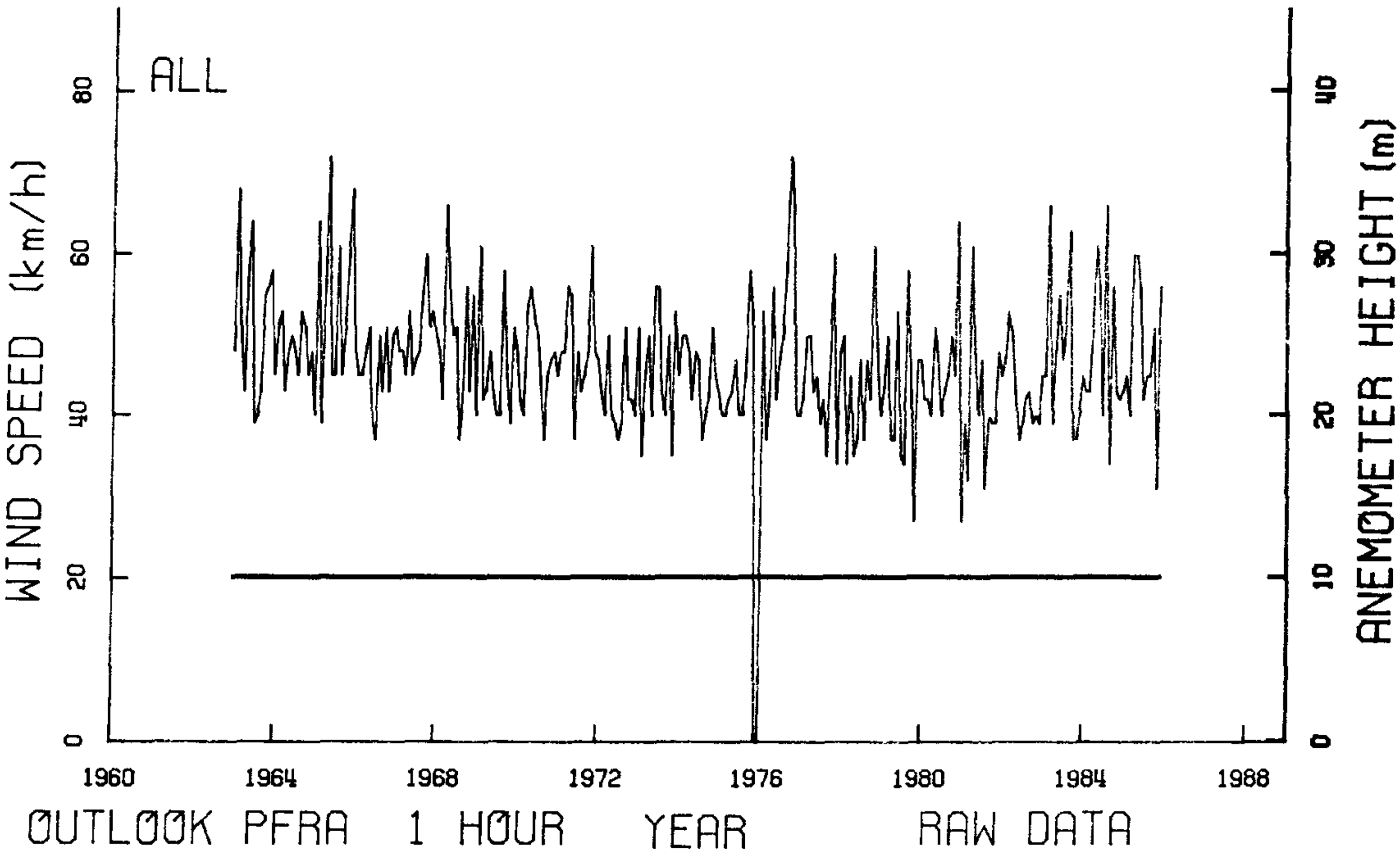


Figure 2: Example of unadjusted design wind rose plot. For this station, the adjusted data are exactly the same because the anemometer height of 10 m has remained unchanged.

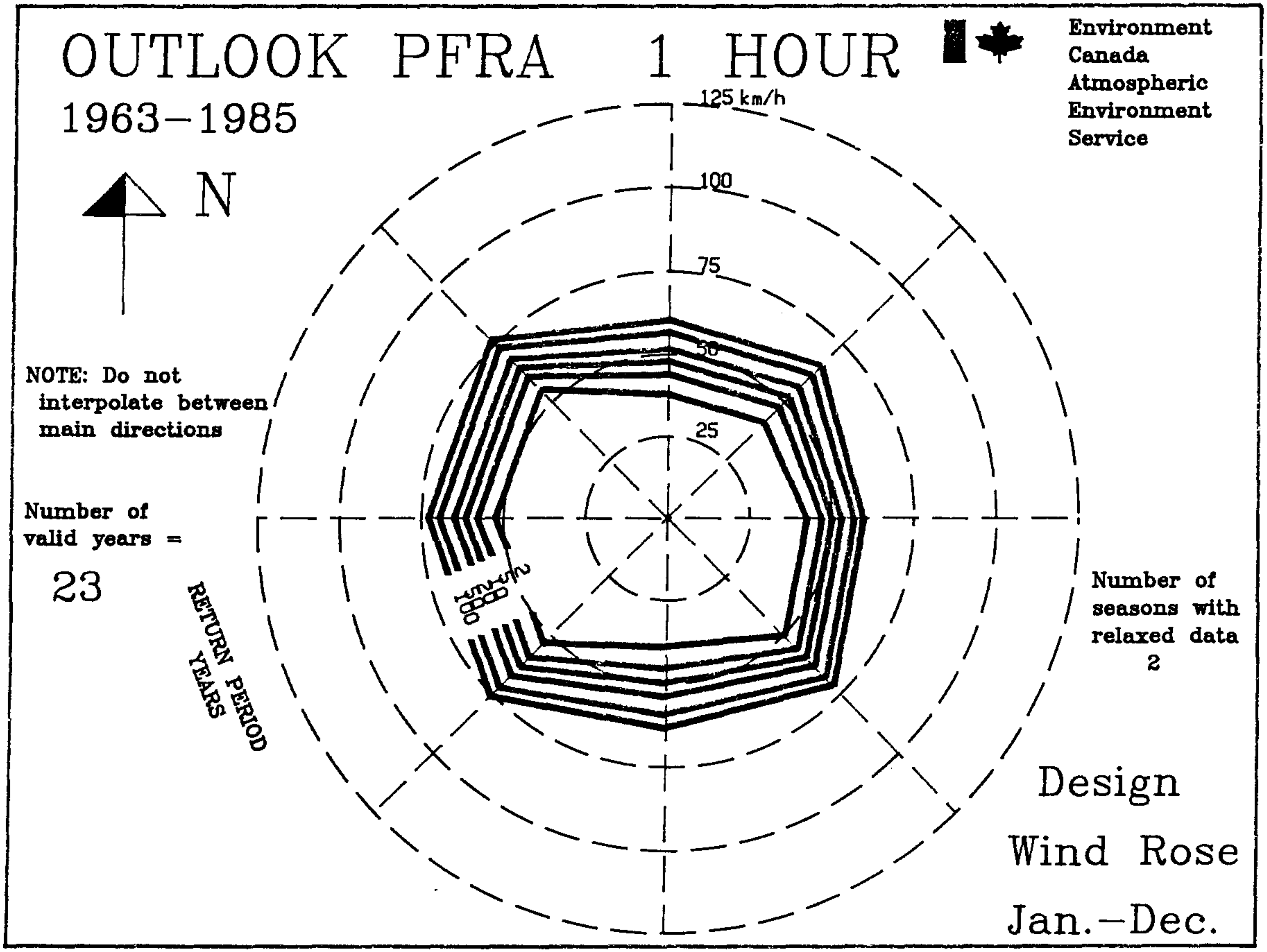


Figure 3: Transposed design wind rose based on Outlook PFRA. All directions were adjusted by same ratio.

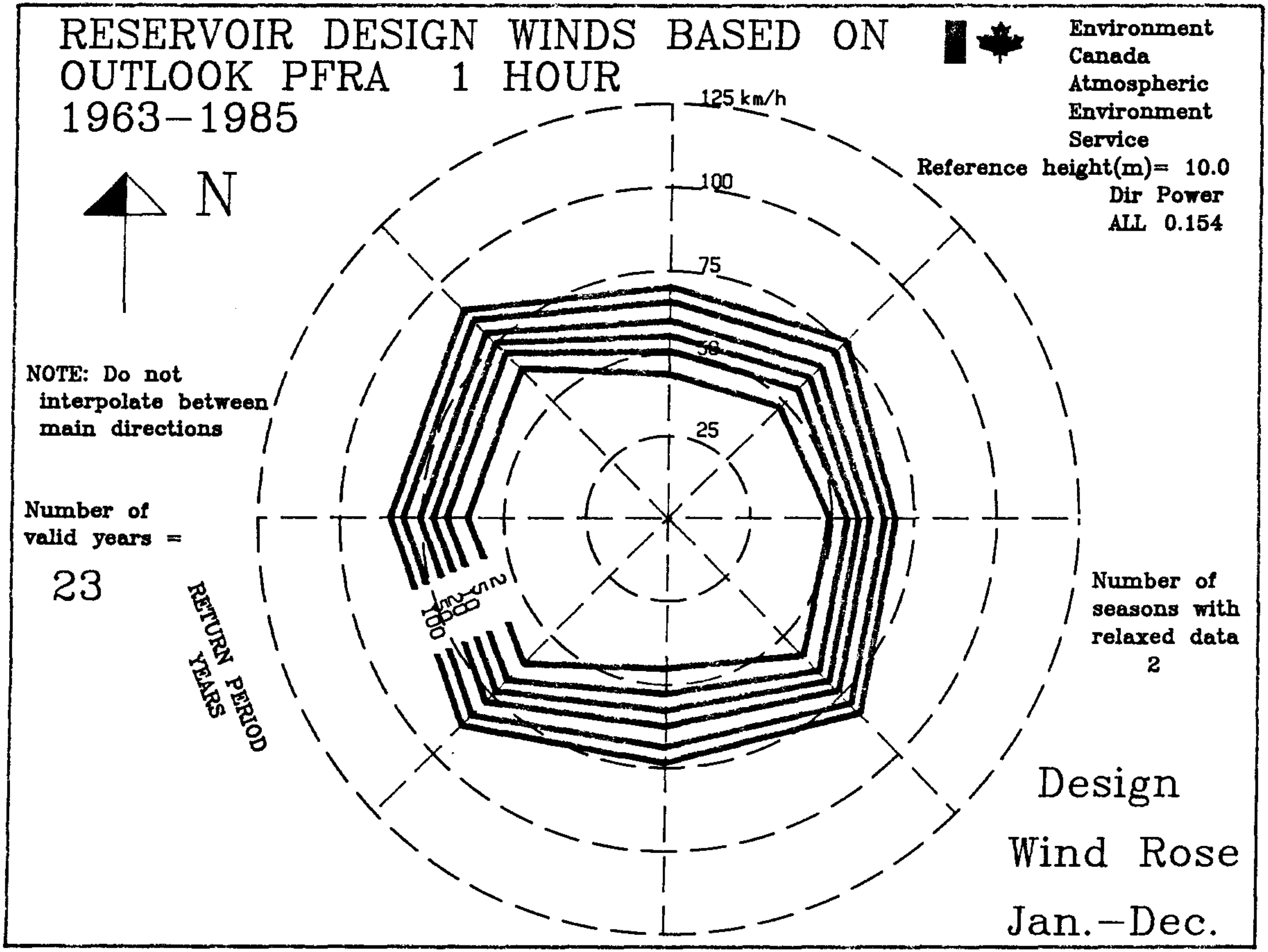


Figure 4: Raw hourly wind extremes for Regina A.

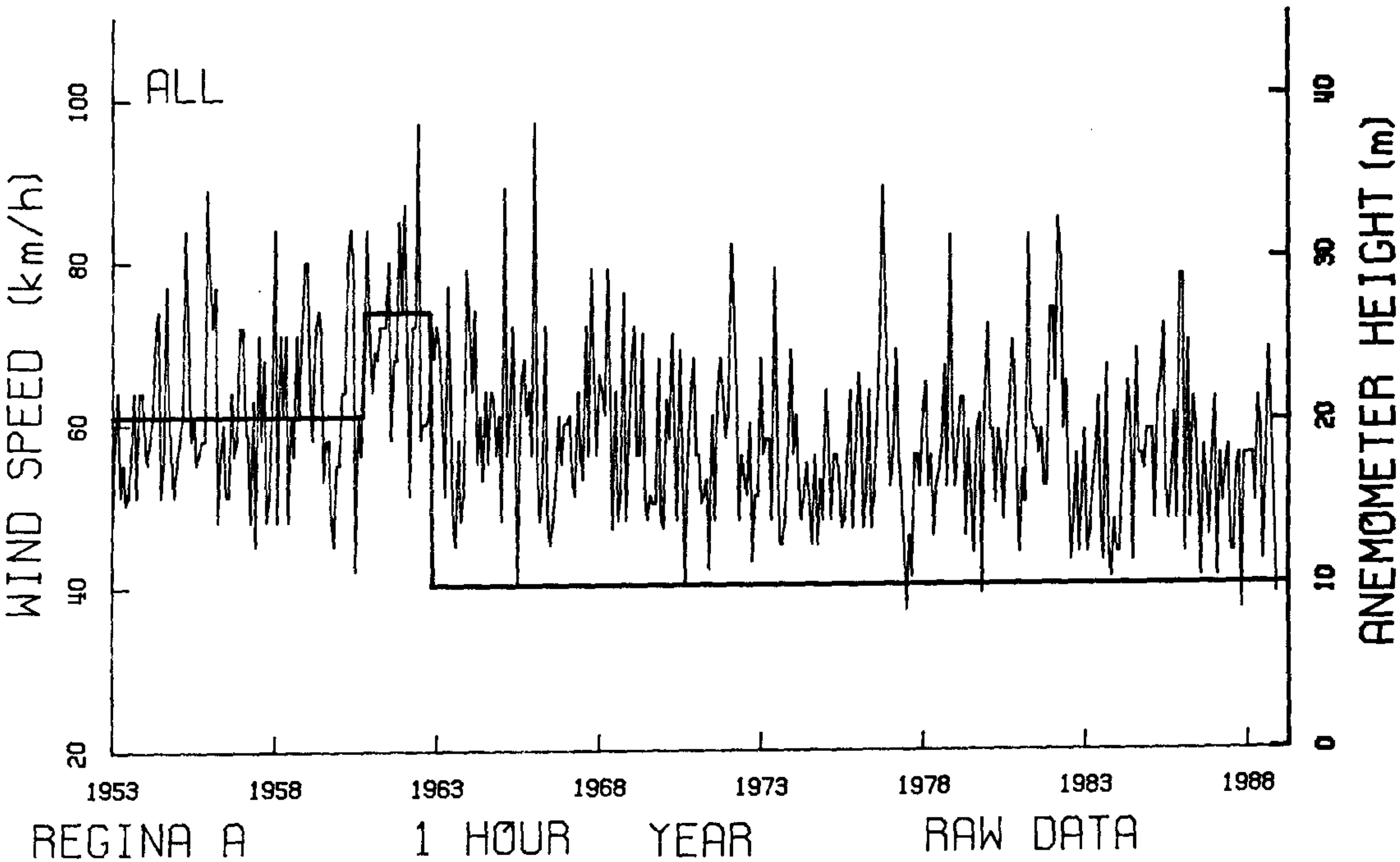


Figure 5: Adjusted data for Regina. Note data already at 10 m remains unchanged.

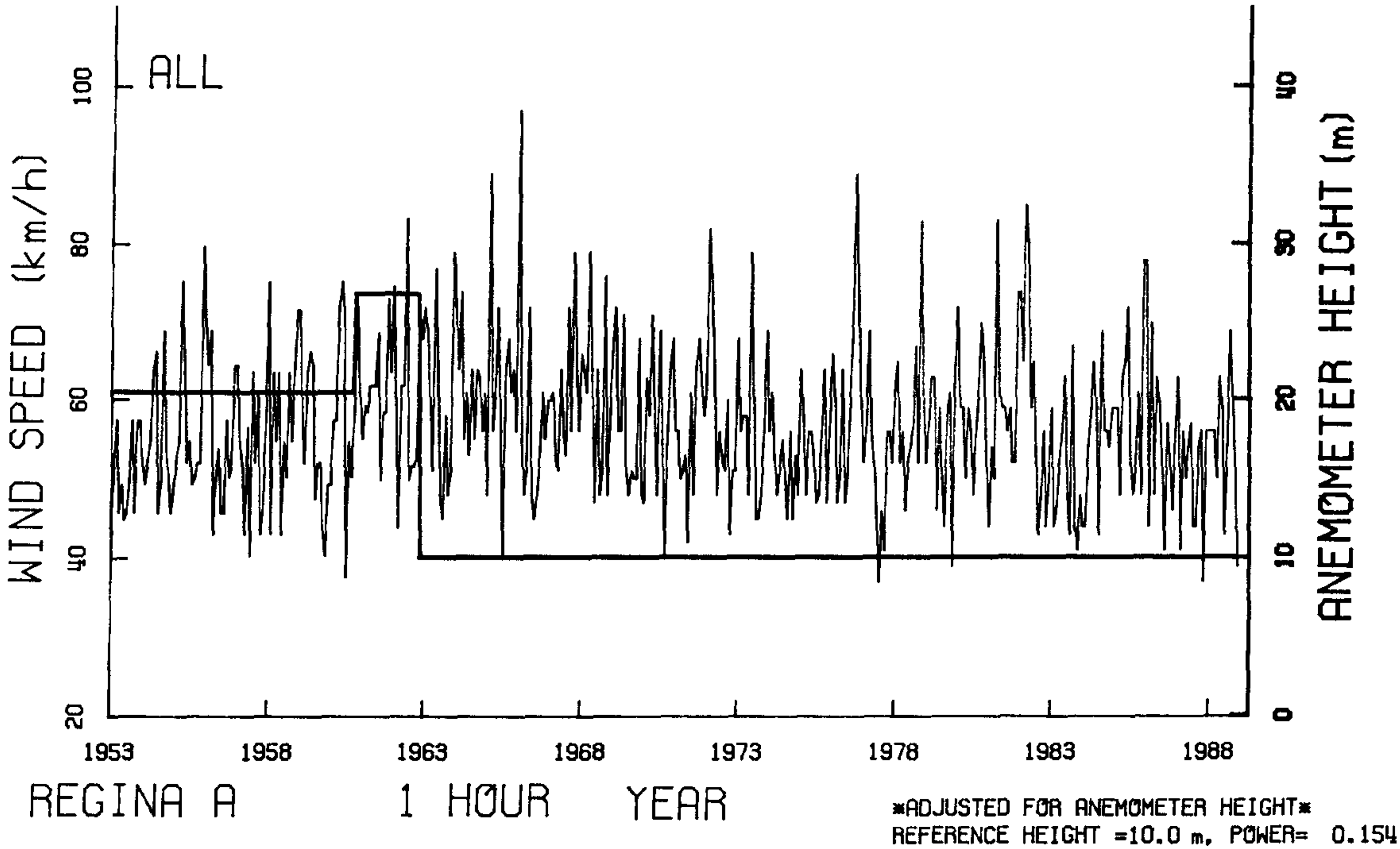


Figure 6: Site specific design wind rose for Regina.

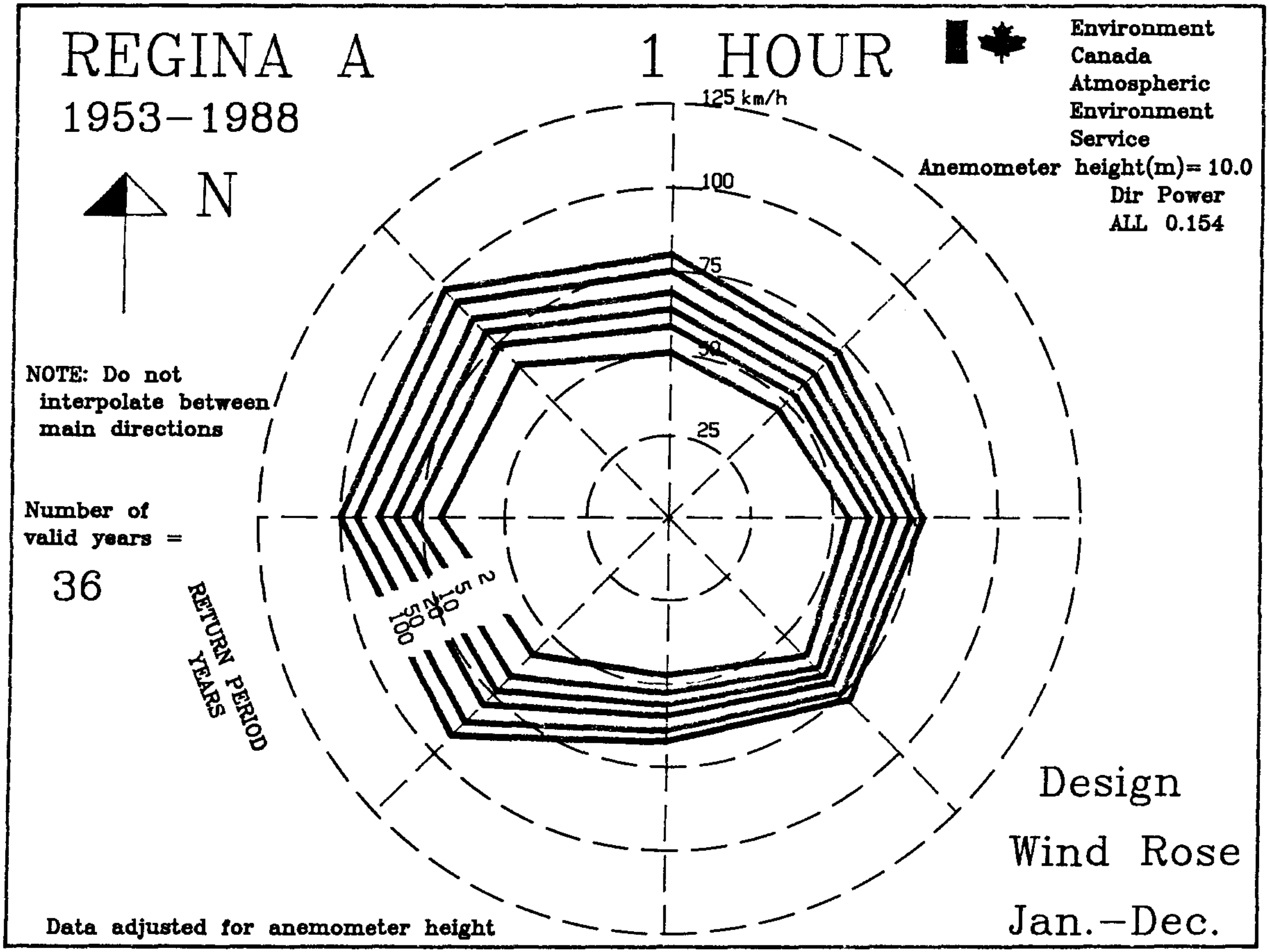


Figure 7: All values from Figure 6 have been increased by 16%. Note that these values are for large lakes (fetch greater than 6 km).

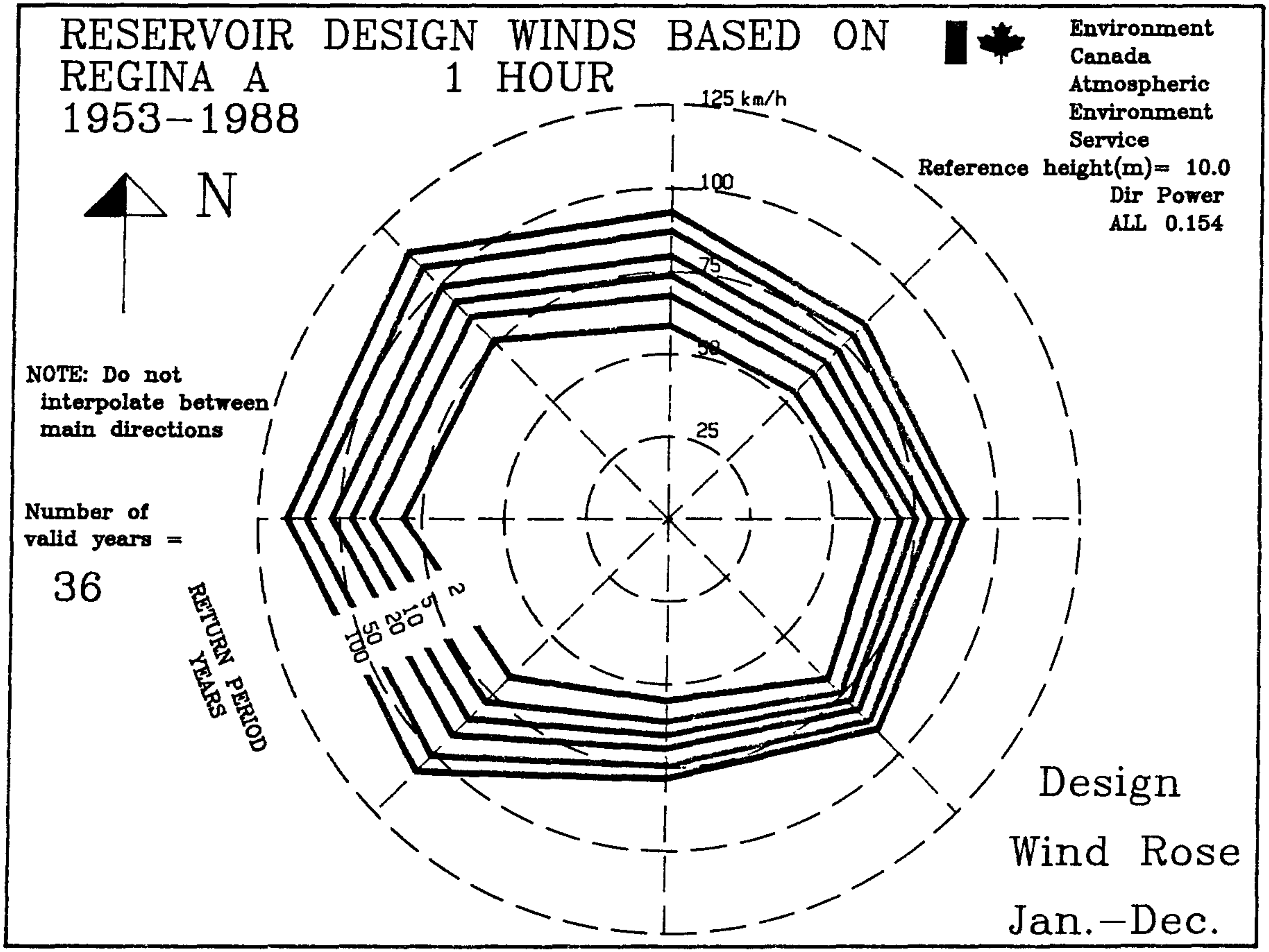


Figure 8: Extreme hourly northeast winds in raw form.

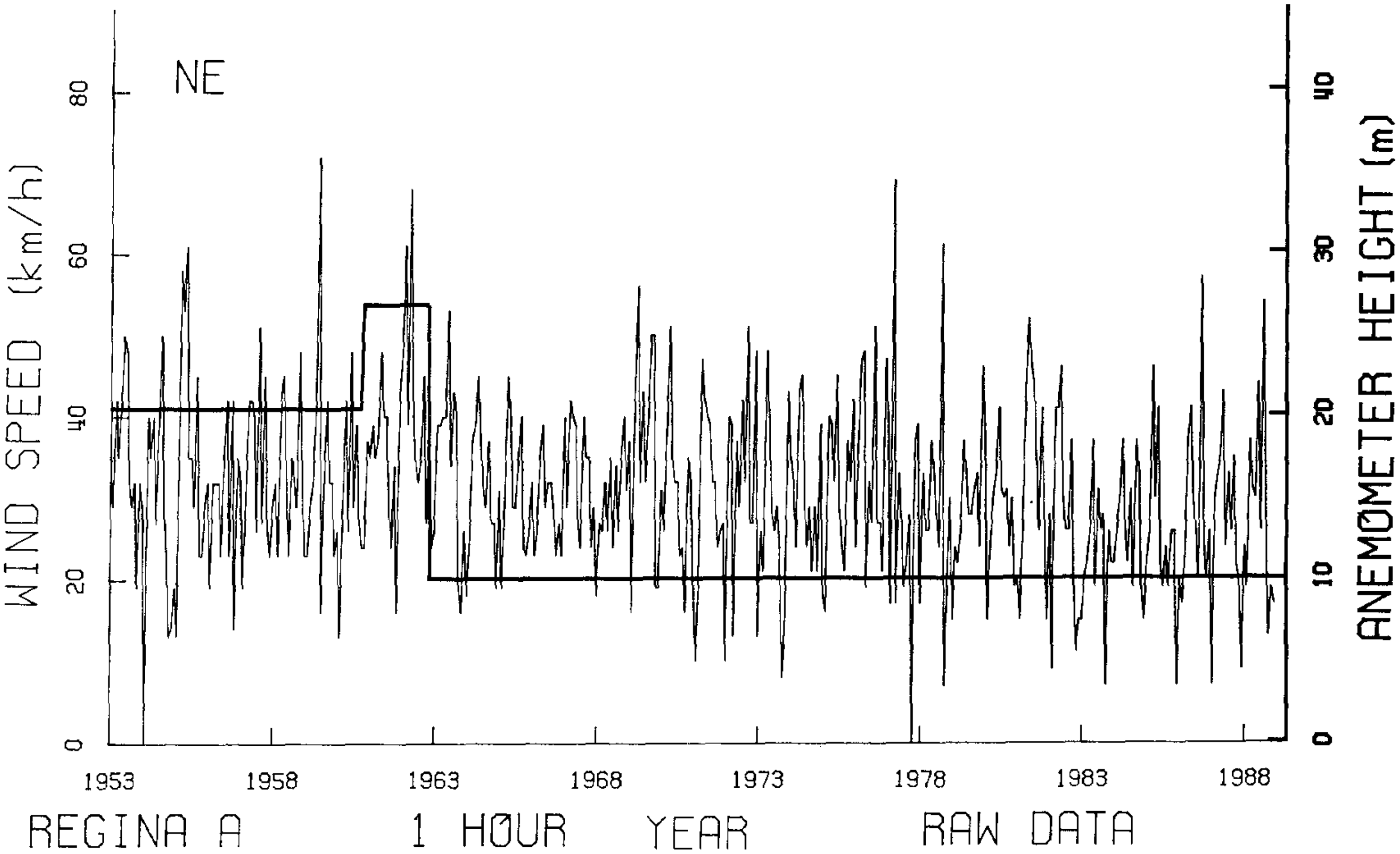


Figure 9: Adjusted extreme hourly time series for northeast winds at Regina A.

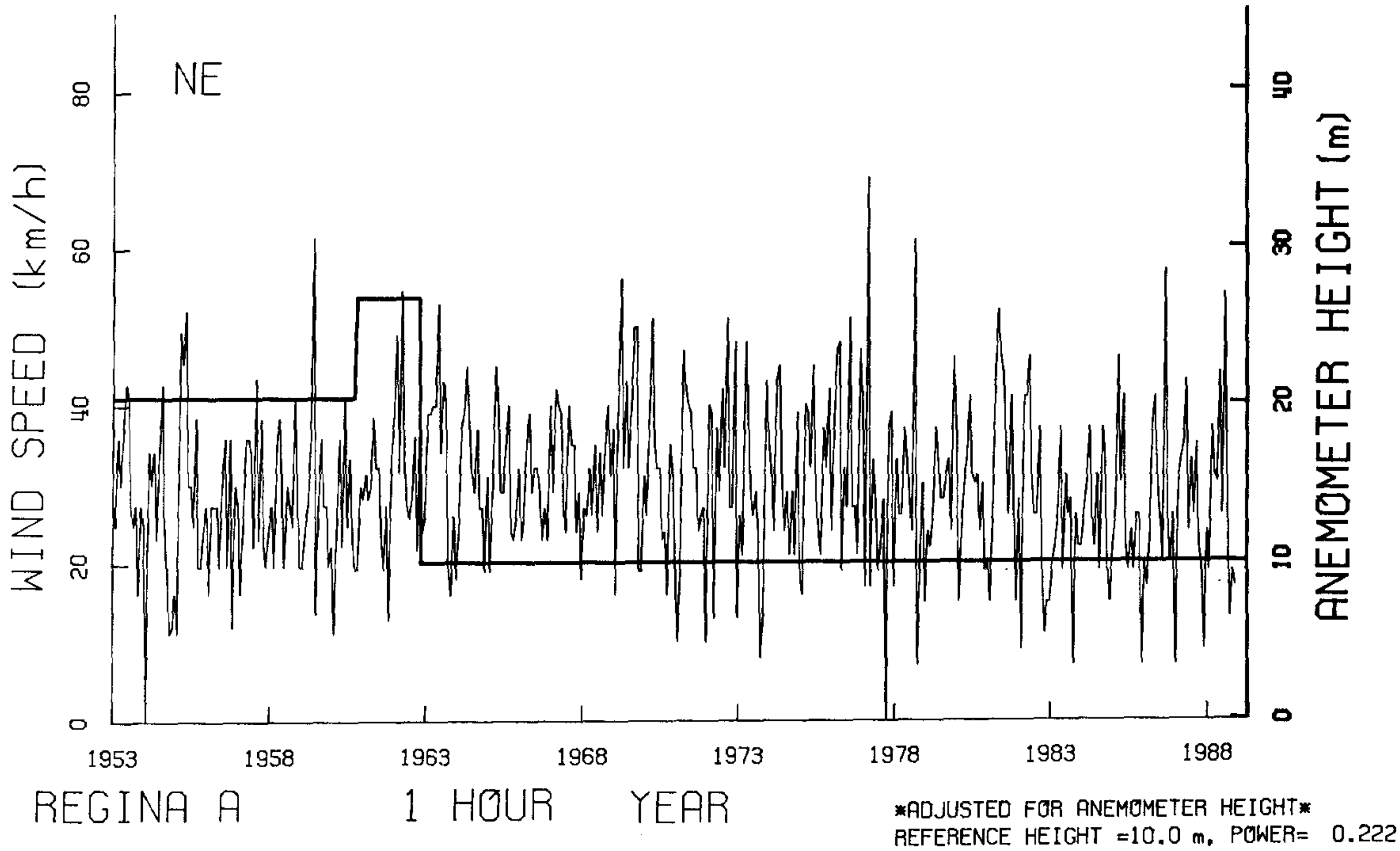


Figure 10: Demonstration of impact of unsuitable roughness applied to northeast winds. Compare to Figure 7.

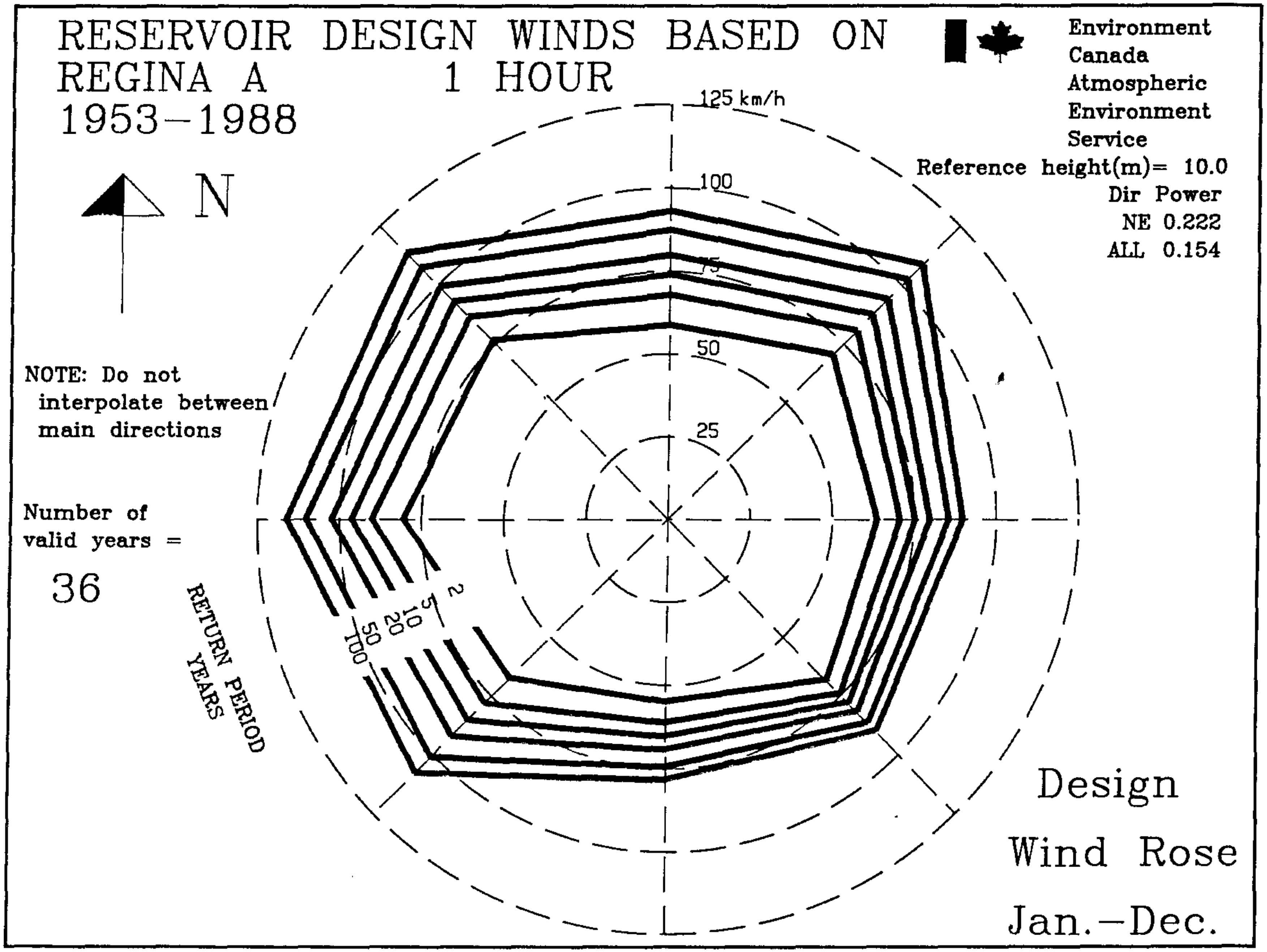


Figure 11: The program will provide a graph of the monthly extreme gusts. This is unadjusted data for Regina A.

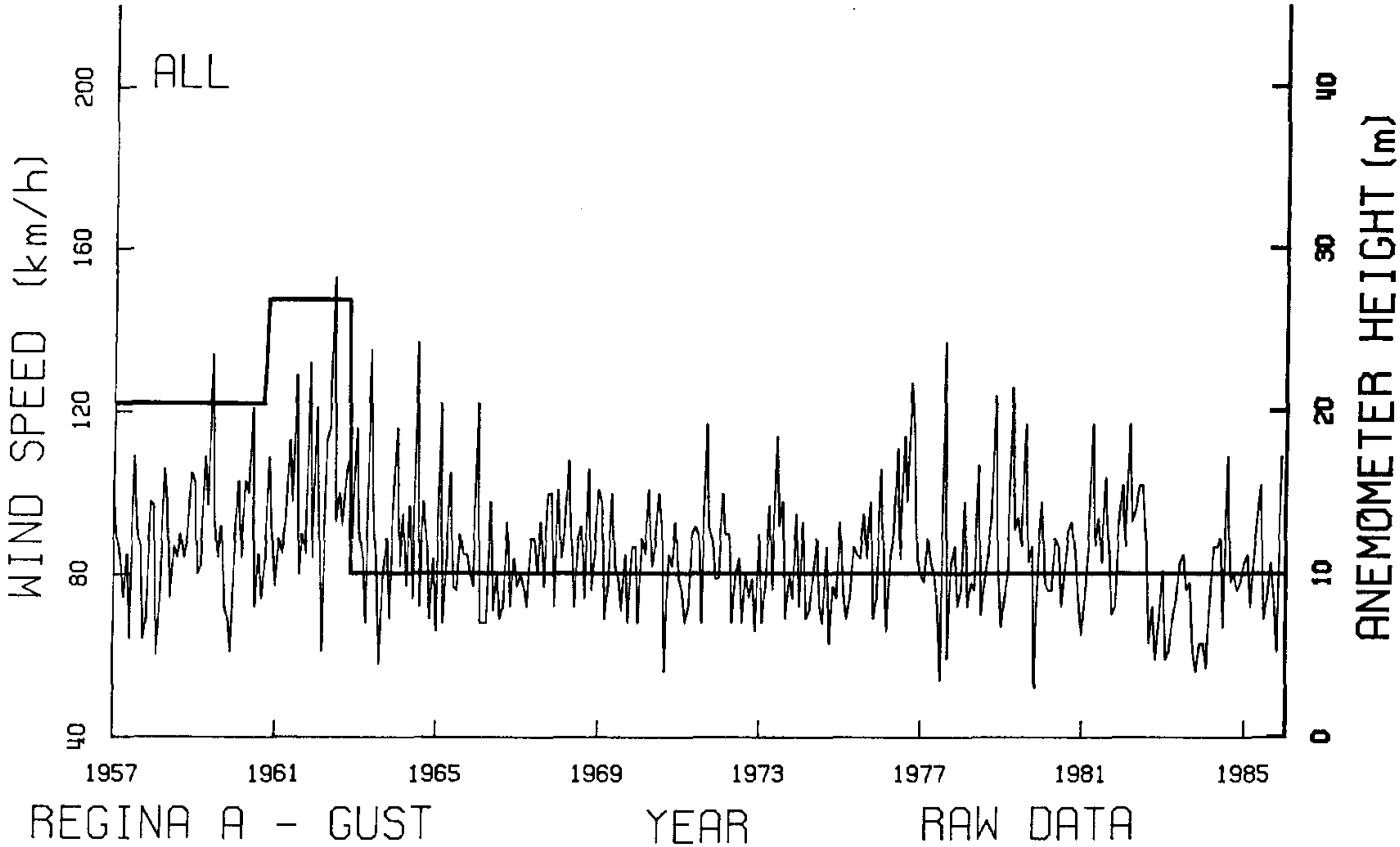


Figure 12: Because of a change in scaling, the adjusted data set is not directly comparable with Figure 11.

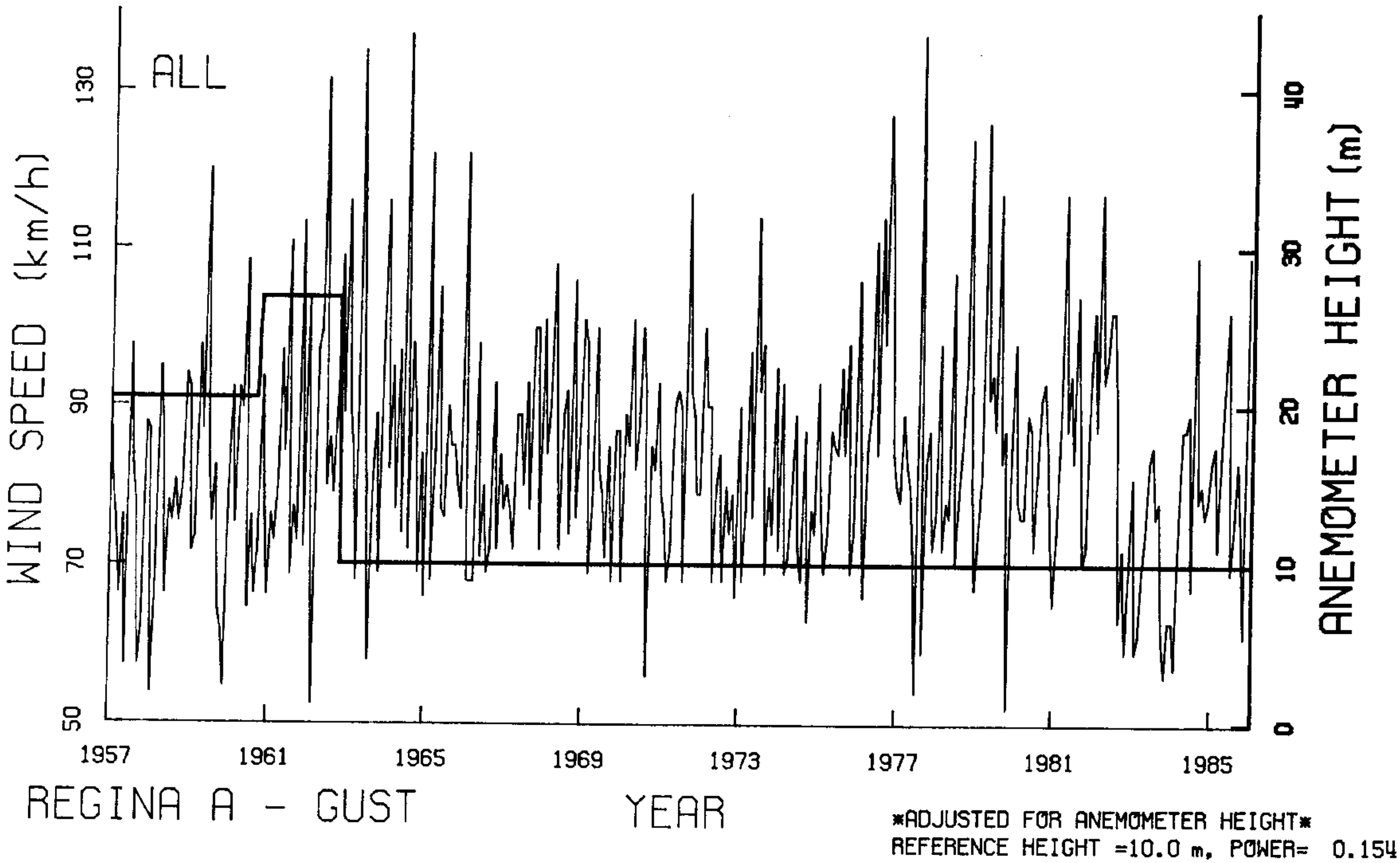


Figure 13: Graph of actual wind speeds for different durations and return periods.

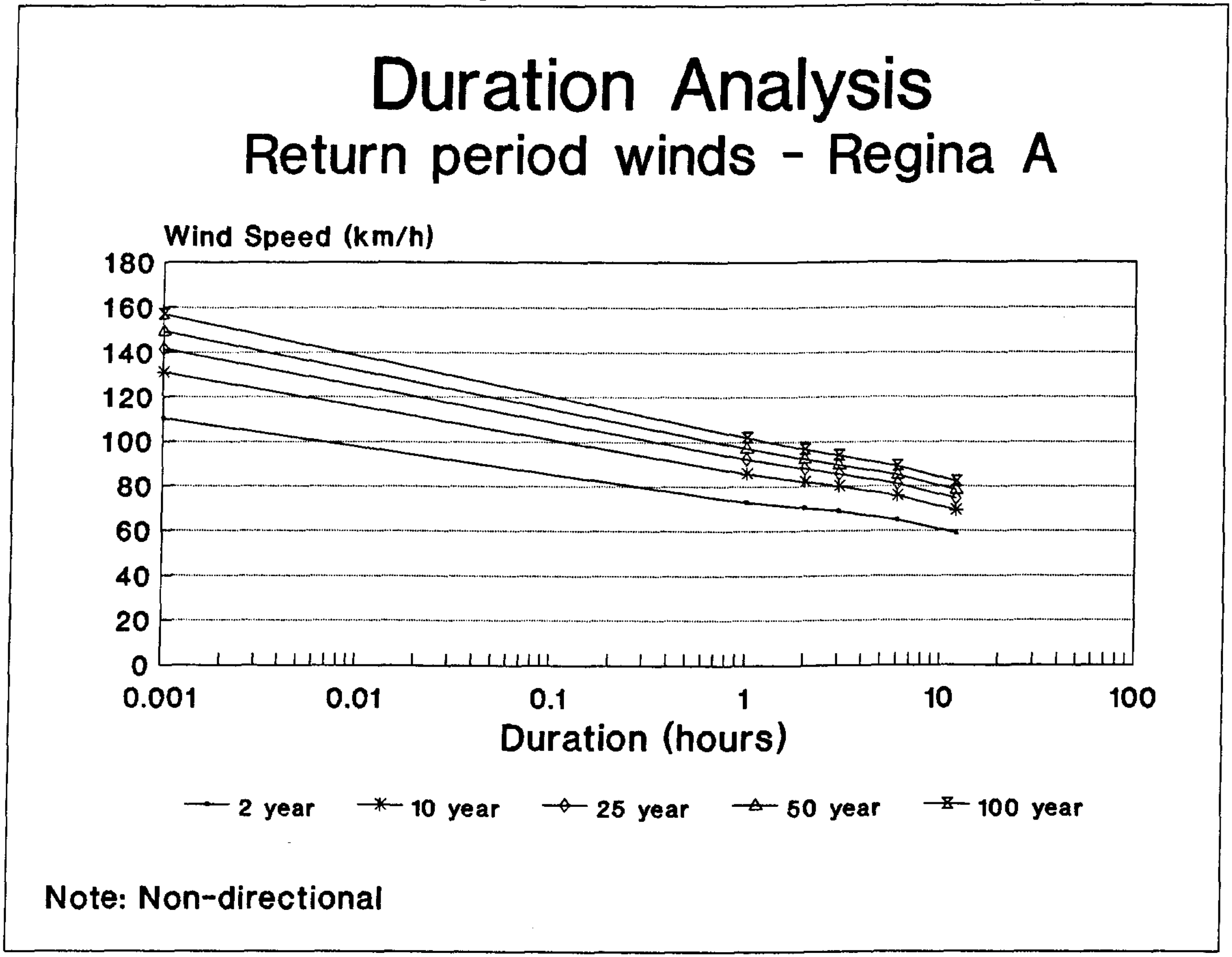
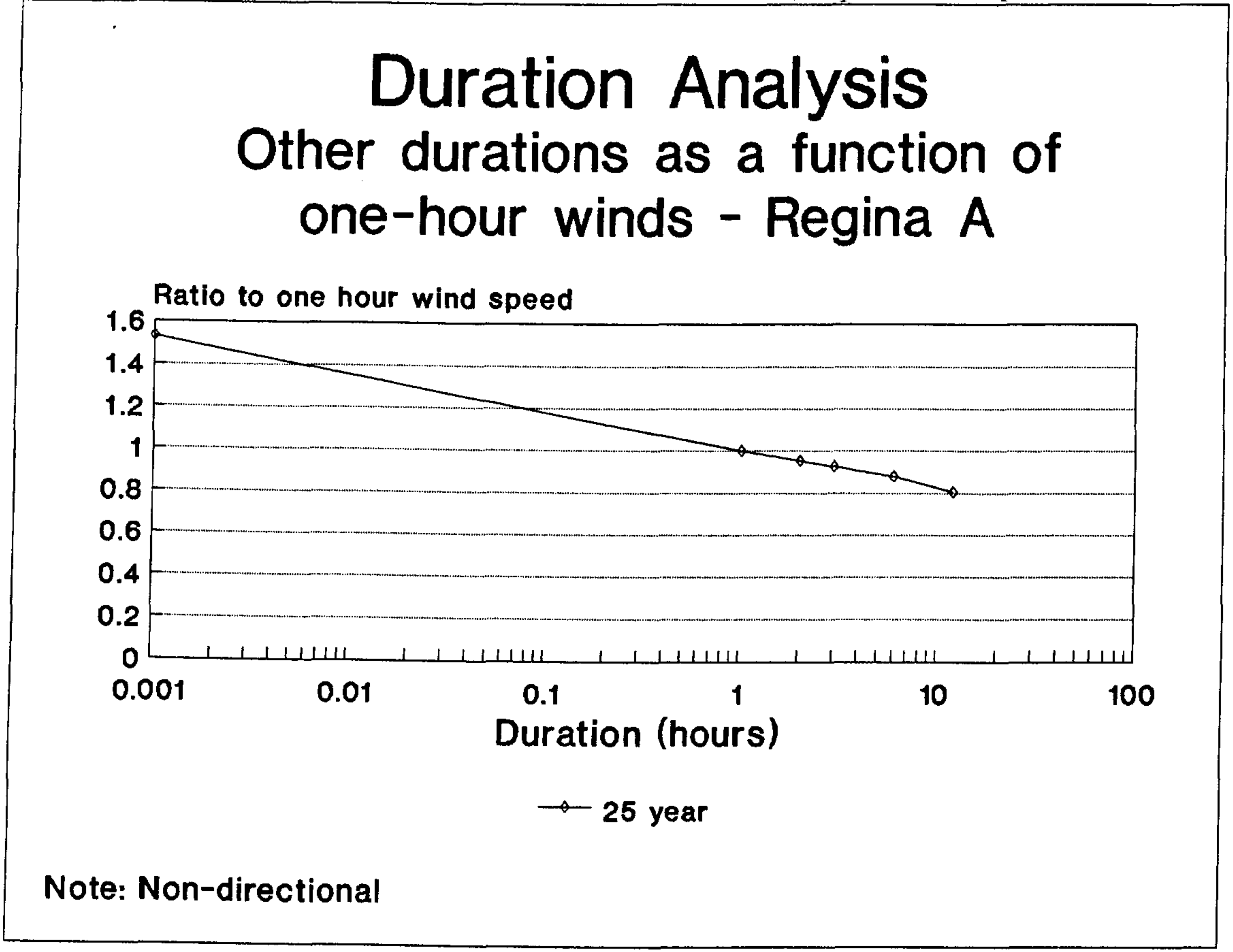


Figure 14: Ratio of other durations to one hour winds (25 year return period).



ADDENDUM

PPWB DESIGN WIND PROJECT

PHASE II, PART A

PPWB DESIGN WIND PROJECT
PHASE II, PART A

by
R.F. Hopkinson

ATMOSPHERIC ENVIRONMENT SERVICE
ENVIRONMENT CANADA

The first phase of the PPWB Design Wind Study was completed in December 1986. It was basically the data assembly portion of the project and was documented in PPWB Report No. 90. In addition, a program GUMBEL was supplied which allowed a determined user to compute the return period wind speeds by direction for an individual station.

Part A of phase II was initiated to develop software which would permit use of the station anemometer heights to adjust the data to a common base and to plot a design wind rose which could be used in publications.

The programs WINDOW and GUMBEL from phase I were reworked in FORTRAN and integrated into a new program, FWINDOW which accomplishes all the goals stated in Schedule A, Memorandum of Understanding, between the Prairie Provinces Water Board (PPWB) and the Atmospheric Environment Service (AES). A copy of Schedule A is included in Appendix A. The actual plotting of the design wind roses is done by a second program, DWPLOT. Both FWINDOW and DWPLOT were written in Microsoft FORTRAN 4.1 and use PLOT88 by PLOTWORKS INC.. The latter is a versatile package which is highly recommended as it supports a wide variety of output devices, including most dot matrix printers. FWINDOW and DWPLOT offer the option to output plots to a number of devices - printers, plotters and the monitor itself.

The programs and supporting files are supplied on two diskettes, DESIGNWIND1 and DESIGNWIND2. These programs and data files must be loaded on your hard drive. A batch file DW.BAT on diskette DESIGNWIND1 can be used to set-up the directory DESNWIND and copy the files to drive C. If your hard drive is not C, then you should use EDLIN on DW.BAT and change the drive specification. Then type

```
A:DW.BAT
```

with diskette DESIGNWIND1 in the A drive. Then type

```
A:DW2.BAT
```

with diskette DESIGNWIND2 in drive A.

Source listings of FWINDOW.FOR and DWPLOT.FOR are also on diskette DESIGNWIND2 and may be listed by using the TYPE command as follows

TYPE A:FWINDOW.FOR>LPT1:

which will provide a listing on your printer connected as LPT1:.

Data files that were on the diskette PPWB-PROGRM in phase I have been moved to PPWDWIND10 and IWDWIND5. Copies of these diskettes will be required to access data files previously on the phase I program diskette.

Then whenever you wish to process extreme wind data, just enter the design wind sub-directory

CD C:\DESNWIND

and type

FWINDOW

Thereafter everything is menu driven. A sample session is included along with several examples of the output (see Appendix B).

FWINDOW concludes by writing the necessary information to a file for input to DWPLOT. FWINDOW supplies the name of the file (e.g. YQR.PRN). To run DWPLOT simply type

DWPLOT<filename.PRN

where filename is provided by FWINDOW (e.g. YQR). Eventually you will accumulate many filename.PRN files and you can clean these off within the DESNWIND sub-directory by

ERASE *.PRN

FWINDOW will overwrite the previous .PRN file if one with the same filename already exists, so you need not erase .PRN files until you are completely finished with a particular station.

FWINDOW is fairly fast on most XT-compatible machines even those without a co-processor. However DWPLOT can take about 15 minutes to generate the temporary plotting files on machines lacking a co-processor and plotting on a dot matrix printer. Over 30 minutes of execution time are required to generate a plot for the HP laserjet printer with an ordinary IBM-XT with no co-processor. Both programs will sense the presence of a co-processor and use it if present. Running time of DWPLOT on machines equipped with a co-processor is typically around 1 or 2 minutes. Because the both programs generate temporary plotting files, they will need free space on your hard drive. For this reason they should be run from your hard drive and not from a floppy drive.

To remove the software and data files from your system, type

```
CD C:\DESNWIND
ERASE *.*
CD C:\
RMDIR DESNWIND
```

You can always restore your design wind software at a future time using DW.BAT an DW2.BAT as described earlier.

For those with access to the IWDWIND diskettes only, Ontario and Alberta stations may be accessed through the NWT menu in FWINDOW.

The programs have been tested on a variety of machines and output devices, but if your situation is unique, please call Ron Hopkinson at (306) 780-5739 for assistance.

APPENDIX A

SCHEDULE A

MEMORANDUM OF UNDERSTANDING

FOR

PPWB DESIGN WIND STUDY
PHASE II, PART A

SCHEDULE A - WORK REQUIRED

1. Enter anemometer history data for stations identified in the attached list into machine readable files.

2. Modify the program WINDOW to access the above anemometer history files.

3. Modify the program WINDOW to include the options to adjust all extreme winds data to (i) 10 metres above ground; (ii) the present height of the anemometer or (iii) another height as specified, using a power law relation.

4. Adapt a plotting routine to process return period data from the program GUMBEL.

5. Ensure that both the WINDOW and GUMBEL computer programs can be run on an IMB-PC/XT and the plots can be generated on an EPSON or EPSON compatible dot matrix printer.

6. Write a brief letter report outlining the operation procedures for programs WINDOW and GUMBEL.

7. Upon completion of Task 1 to 6 inclusive, make the information available to the PPWB Committee on Hydrology.

APPENDIX B

SAMPLE RUNS AND OUTPUT

FROM PROGRAMS FWINDOW AND DWPLOT

a) REGINA A - 3 hour - sample session and dot matrix printer output

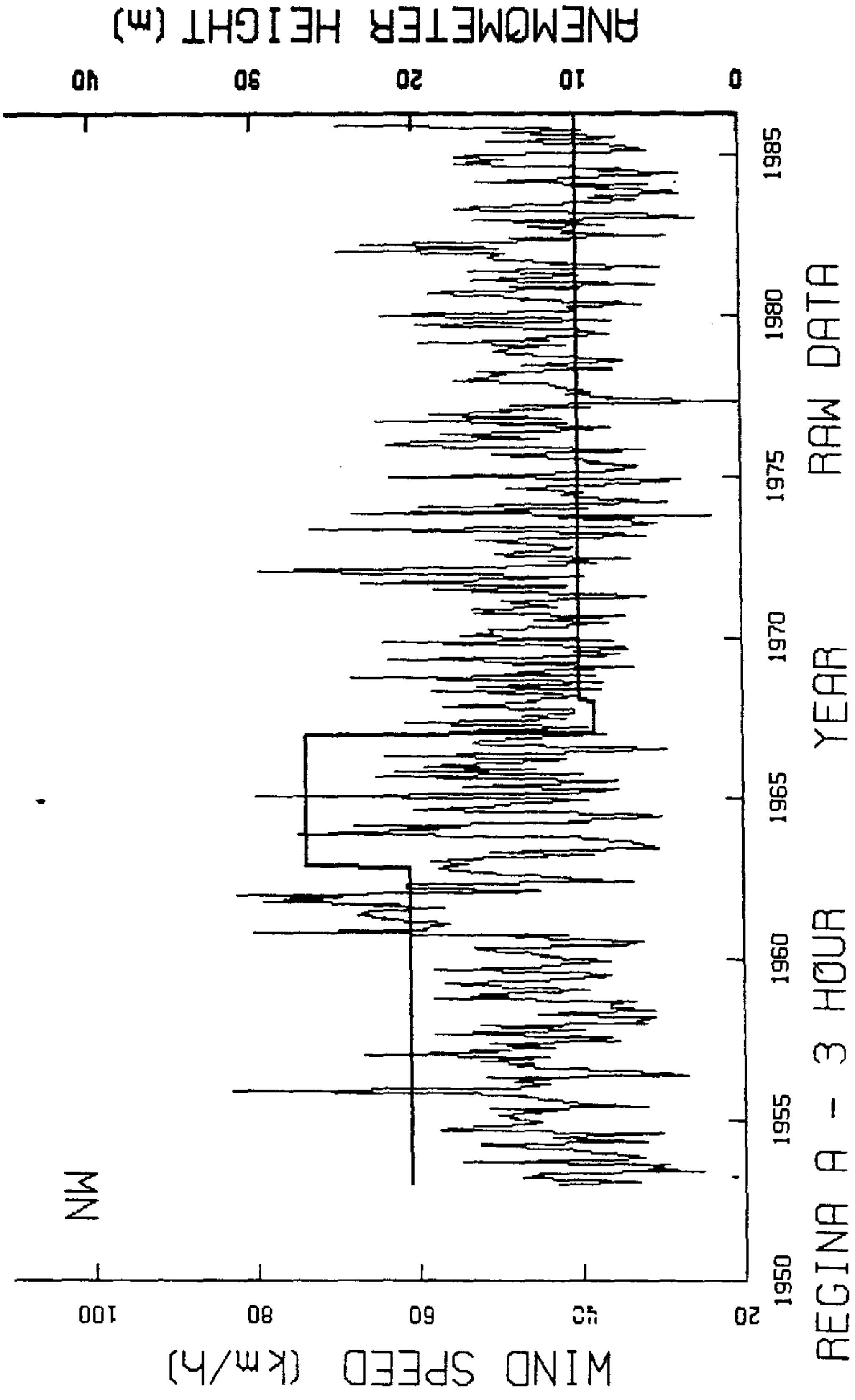
b) IQALUIT A - output from HP Colorpro Plotter

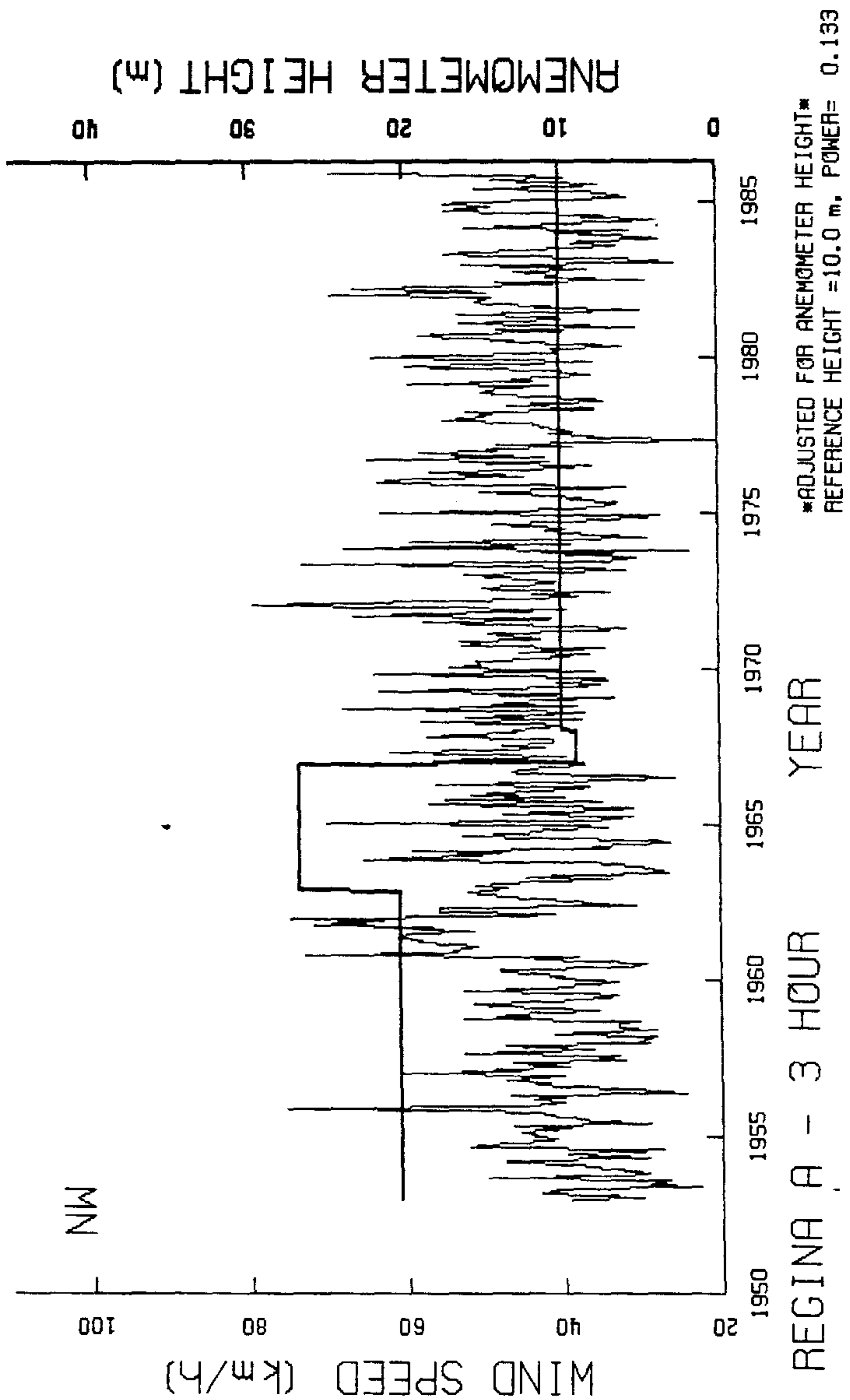
c) WRIGLEY A - dot matrix output with warning re inadequate sample.

Sample session with CTRL PRTSC invoked. Manual Entries are surrounded by a box.
This was run using a COMPAQ 286 with co-processor and Panasonic printer in IBM Graphics Mode.

```
FWINDOW
SELECT NUMBER CORRESPONDING TO AREA
1=ALBERTA
2=SASKATCHEWAN
3=MANITOBA
4=ONTARIO
5=NORTHWEST TERRITORIES
6=GUST DATA
ENTER NUMBER ( 1 TO 6 )==> 2
 1 = REGINA A                     2 = SASKATOON A
 3 = KINDERSLEY KY                4 = BROADVIEW
 5 = BUFFALO NARROWS A            6 = COLLINS BAY
 7 = CREE LAKE                    8 = ESTEVAN A
 9 = HUDSON BAY A                10 = INDIAN HEAD PFRA
11 = ISLAND FALLS                12 = LA RONGE A
13 = MEADOW LAKE A               14 = MELFORT CDA
15 = MOOSE JAW A                 16 = NIPAWIN A
17 = NORTH BATTLEFORD A          18 = OUTLOOK PFRA
19 = PRINCE ALBERT A             20 = ROCKGLEN (AUT)
21 = SCOTT CDA                   22 = SWIFT CURRENT A
23 = URANIUM CITY A              24 = WASKESIU LAKE
25 = WEYBURN                     26 = WYNYARD
27 = YORKTON A                   28 = EASTEND (AUT)
29 = ELBOW                       30 = REGINA A - 2 HOUR
31 = REGINA A - 3 HOUR           32 = REGINA A - 6 HOUR
33 = REGINA A - 12 HOUR          34 = PRINCE ALBERT-2 HOUR
35 = PRINCE ALBERT-3 HOUR        36 = PRINCE ALBERT-6 HOUR
SELECT DESIRED STATION BY NUMBER ==> 31
STATION SELECTED IS REGINA A - 3 HOUR    , IS THAT CORRECT(Y OR N)==> Y
***** INSERT DISKETTE   PPWBWIND9

PRESS ENTER(CR) TO CONTINUE

*****  WRONG DISKETTE *****
***** INSERT DISKETTE   PPWBWIND9

PRESS ENTER(CR) TO CONTINUE
       1953         1985

SELECT WIND DIRECTION FOR DATA REVIEW
1 = N
2 = NE
3 = E
4 = SE
5 = S
6 = SW
7 = W
8 = NW
9 = non-directional (ie extreme without regard for direction)

SELECT OPTION ( 1 to 9 ) ==> 8

SELECT OUTPUT DEVICE BY NUMBER
1=IBM GRAPHICS PRINTER,EPSON(MX-80,RX-80,FX-100,etc.),OKIDATA(92,182,192) LPT
2=IBM COLOR GRAPHICS ADAPTER(MONITOR)
3=IBM EGA (MONITOR)
4=HERCULES GRAPHICS CARD (MONITOR)
5=HP COLOR-PRO PLOTTER AND MOST OTHER HP PLOTTERS (COM1)
6=HP PLOTTERS (COM2)
7=HP LASERJET PRINTER (LPT1)

ENTER SELECTION==> 1
```

```
DO YOU WANT ANOTHER PLOT (Y OR N)==>N

DO YOU WANT TO ADJUST THE DATA TO A COMMON ANEMOMETER HEIGHT(Y OR N)==>Y
REFERENCE WIND LEVEL IS 10.0m, IS THIS OK(Y OR N)==>Y

 CHOOSE PROPER POWER FOR ADJUSTMENT OF WIND DATA
1 = .118 -VERY SMOOTH (eg.LARGE EXPANSE OF OPEN WATER)
2 = .133 -LEVEL (eg. PRAIRIE GRASSLAND OR TUNDRA )
3 = .154 -**DEFAULT** - LEVEL TO SLIGHTLY ROLLING FARMLAND
          WITH FEW TREES OR BUILDINGS
4 = .182 -GENTLY ROLLING OR LEVEL WITH LOW OBSTRUCTIONS
5 = .222 -ROLLING OR LEVEL WITH NUMEROUS OBSTRUCTIONS
6 = .286 -ROLLING OR LEVEL SURFACE COVERED WITH LARGE
          OBSTRUCTIONS (eg. FOREST OR PARKLAND )
7 = .333 -VERY BROKEN SURFACE WITH LARGE OBSTRUCTIONS
          (eg TOWNS,SUBURBS)
8 = .500 -SURFACE BROKEN BY EXTREMELY LARGE OBSTRUCTIONS
          (eg. CENTRE OF CITIES)
9 = OWN CHOICE
10= RETURN TO UNADJUSTED ( RAW DATA ) STATE

ENTER SELECTION (1 TO 10)==>2

SELECT WIND DIRECTION FOR DATA REVIEW
1 = N
2 = NE
3 = E
4 = SE
5 = S
6 = SW
7 = W
8 = NW
9 = non-directional (ie extreme without regard for direction)

SELECT OPTION ( 1 to 9 ) ==>8

SELECT OUTPUT DEVICE BY NUMBER
1=IBM GRAPHICS PRINTER,EPSON(MX-80,RX-80,FX-100,etc.),OKIDATA(92,182,192) LPT1
2=IBM COLOR GRAPHICS ADAPTER(MONITOR)
3=IBM EGA (MONITOR)
4=HERCULES GRAPHICS CARD (MONITOR)
5=HP COLOR-PRO PLOTTER AND MOST OTHER HP PLOTTERS (COM1)
6=HP PLOTTERS (COM2)
7=HP LASERJET PRINTER (LPT1)

ENTER SELECTION==> 1
```


REGINA A - 3 HOUR RAW DATA
YEAR
1950
1955
1960
1965
1970
1975
1980
1985
WIND SPEED (km/h)
20
40
60
80
100
ANEMOMETER HEIGHT (m)
0
10
20
30
40
NW


REGINA A - 3 HOUR
YEAR
1950
1955
1960
1965
1970
1975
1980
1985
WIND SPEED (km/h)
20
40
60
80
100
ANEMOMETER HEIGHT (m)
0
10
20
30
40
NW
ADJUSTED FOR ANEMOMETER HEIGHT
REFERENCE HEIGHT =10.0 m, POWER= 0.133

DO YOU WANT ANOTHER PLOT (Y OR N)==> N

DO YOU WISH TO TRY A DIFFERENT ADJUSTMENT(Y OR N)==> N

SELECT ANALYSIS PERIOD
1=ONE MONTH - NOT RECOMMENDED
2=SUMMER (APR - OCT)
3=FULL YEAR (JAN - DEC)
4=DEFINE OWN SEASON
SELECTION==> 3

DO YOU WANT TO RELAX DATA REQUIREMENTS TO PERMIT
ONE MISSING MONTH DURING THE ANALYSIS PERIOD(Y OR N)==> Y

1953	36.	44.	43.	54.	36.	46.	57.	50.	57.	0
1954	31.	42.	64.	51.	41.	46.	68.	52.	68.	0
1955	38.	54.	64.	51.	50.	73.	81.	75.	81.	0
1956	44.	35.	60.	62.	38.	47.	63.	48.	64.	0
1957	35.	43.	54.	54.	43.	40.	61.	61.	61.	0
1958	36.	40.	55.	58.	40.	61.	68.	53.	68.	0
1959	38.	62.	59.	54.	38.	56.	69.	53.	69.	0
1960	42.	36.	43.	53.	54.	73.	68.	73.	73.	0
1961	56.	39.	50.	64.	55.	58.	63.	72.	72.	0
1962	56.	50.	48.	62.	40.	51.	61.	75.	75.	0
1963	50.	42.	43.	48.	50.	54.	56.	66.	66.	0
1964	51.	37.	48.	50.	42.	39.	53.	59.	59.	0
1965	40.	37.	41.	52.	41.	52.	68.	70.	70.	0
1966	33.	28.	39.	52.	31.	33.	72.	56.	73.	0
1967	51.	40.	52.	63.	37.	37.	76.	62.	76.	0
1968	53.	36.	62.	62.	43.	34.	73.	68.	73.	0
1969	50.	48.	63.	49.	42.	53.	72.	64.	72.	0
1970	41.	47.	50.	57.	37.	57.	70.	54.	70.	0
1971	46.	43.	46.	51.	49.	45.	60.	67.	67.	0
1972	44.	43.	54.	56.	38.	43.	59.	79.	79.	0
1973	38.	46.	54.	57.	55.	46.	65.	73.	73.	0
1974	41.	42.	45.	50.	37.	49.	48.	59.	59.	0
1975	37.	39.	56.	48.	34.	43.	58.	63.	63.	0
1976	60.	46.	51.	59.	36.	42.	86.	65.	86.	0
1977	49.	64.	50.	46.	43.	39.	55.	49.	64.	0
1978	45.	56.	64.	61.	38.	41.	75.	55.	75.	0
1979	45.	39.	49.	59.	37.	44.	59.	60.	60.	0
1980	47.	33.	46.	66.	50.	39.	63.	64.	66.	0
1981	40.	47.	53.	56.	51.	76.	71.	53.	80.	0
1982	53.	44.	64.	65.	41.	55.	78.	69.	80.	0
1983	43.	34.	43.	53.	36.	44.	60.	55.	60.	0
1984	56.	34.	53.	58.	38.	46.	66.	55.	66.	0
1985	52.	40.	55.	52.	40.	54.	70.	69.	71.	0

DO YOU WANT A TABLE OF RETURN PERIOD VALUES(Y OR N)==>

Y

**RETURN PERIOD WIND SPEEDS AND 50% CONFIDENCE LIMITS (km/h) FOR REGINA A - 3 HOUR

NUMBER OF VALID YEARS = 33
RECORDS BEGAN IN 1953 AND END IN 1985
ANALYSIS PERIOD IS FROM Jan TO Dec

	RETURN PERIOD (YEARS)								
DIRECTION	2	5	10	15	20	25	30	50	100
N	43.5	50.2	54.7	57.2	59.0	60.3	61.4	64.5	68.6
+/-	.8	1.4	1.9	2.1	2.4	2.5	2.6	3.0	3.5
NE	41.5	48.5	53.1	55.7	57.6	59.0	60.1	63.3	67.7
+/-	.9	1.4	1.9	2.2	2.5	2.6	2.8	3.1	3.7
E	50.8	57.3	61.6	64.0	65.7	67.0	68.1	71.0	75.0
+/-	.8	1.3	1.8	2.1	2.3	2.4	2.5	2.9	3.4
SE	54.7	59.4	62.6	64.4	65.7	66.6	67.4	69.6	72.5
+/-	.6	1.0	1.3	1.5	1.7	1.8	1.9	2.1	2.5
S	40.8	46.5	50.2	52.3	53.8	54.9	55.8	58.4	61.9
+/-	.7	1.2	1.6	1.8	2.0	2.1	2.2	2.5	2.9
SW	47.2	56.7	63.0	66.5	69.0	70.9	72.4	76.8	82.6
+/-	1.2	1.9	2.6	3.0	3.3	3.5	3.7	4.2	4.9
W	64.5	71.9	76.8	79.6	81.5	83.0	84.3	87.6	92.2
+/-	.9	1.5	2.1	2.4	2.6	2.8	2.9	3.3	3.9
NW	60.6	68.2	73.2	76.1	78.1	79.6	80.9	84.4	89.1
+/-	.9	1.6	2.1	2.4	2.7	2.9	3.0	3.4	4.0
ALL	68.4	74.7	78.9	81.3	83.0	84.3	85.3	88.2	92.1
+/-	.8	1.3	1.8	2.0	2.2	2.4	2.5	2.8	3.3

***DATA HAVE BEEN ADJUSTED TO AN ANEMOMETER HEIGHT OF 10.0m
***USING A POWER LAW WITH A POWER OF .133

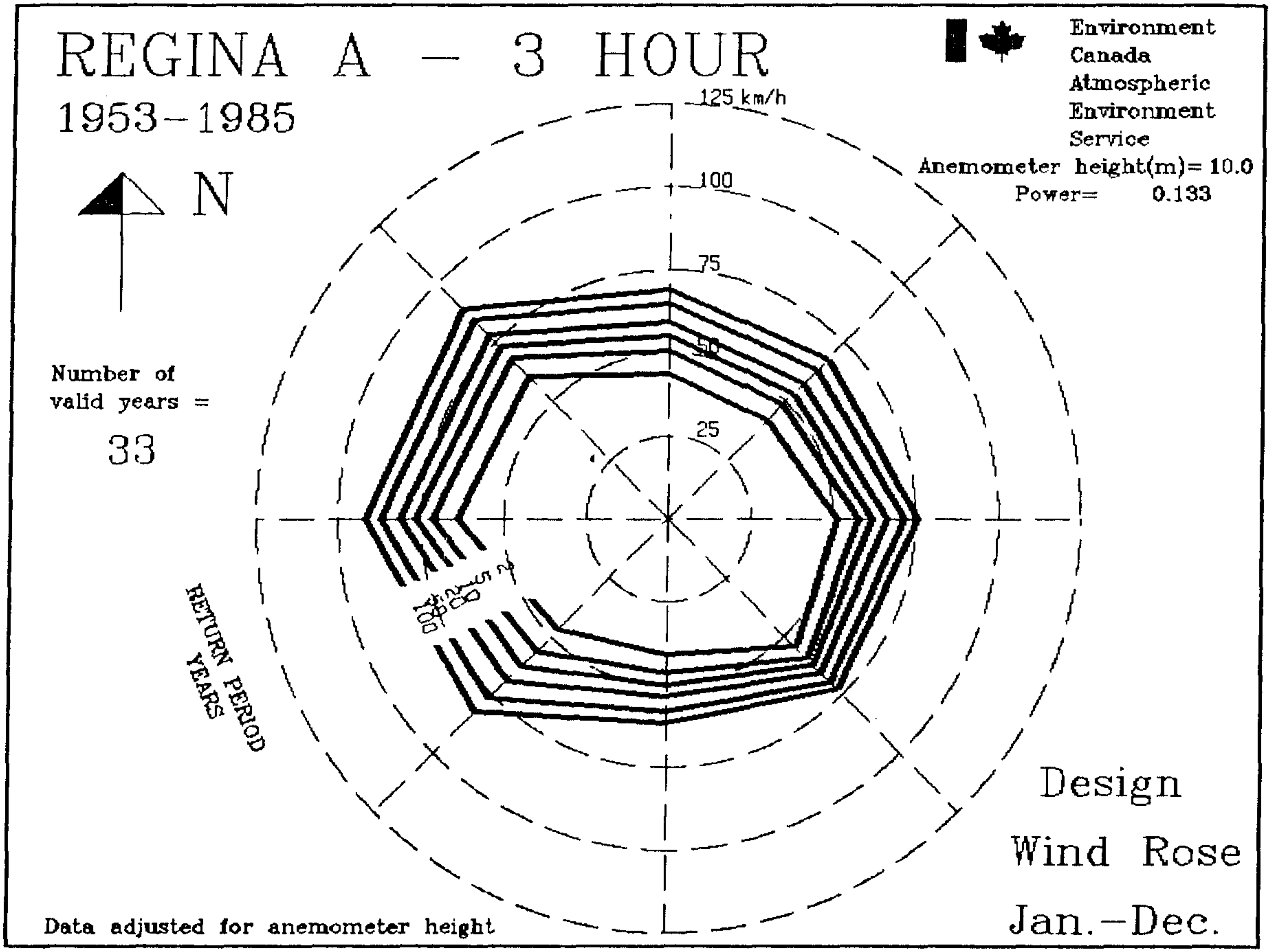
SELECT OUTPUT DEVICE BY NUMBER
1=IBM GRAPHICS PRINTER,EPSON(MX-80,RX-80,FX-100,etc.),OKIDATA(92,182,192) LPT
2=IBM COLOR GRAPHICS ADAPTER(MONITOR)
3=IBM EGA (MONITOR)
4=HERCULES GRAPHICS CARD (MONITOR)
5=HP COLOR-PRO PLOTTER AND MOST OTHER HP PLOTTERS (COM1)
6=HP PLOTTERS (COM2)
7=HP LASERJET PRINTER (LPT1)

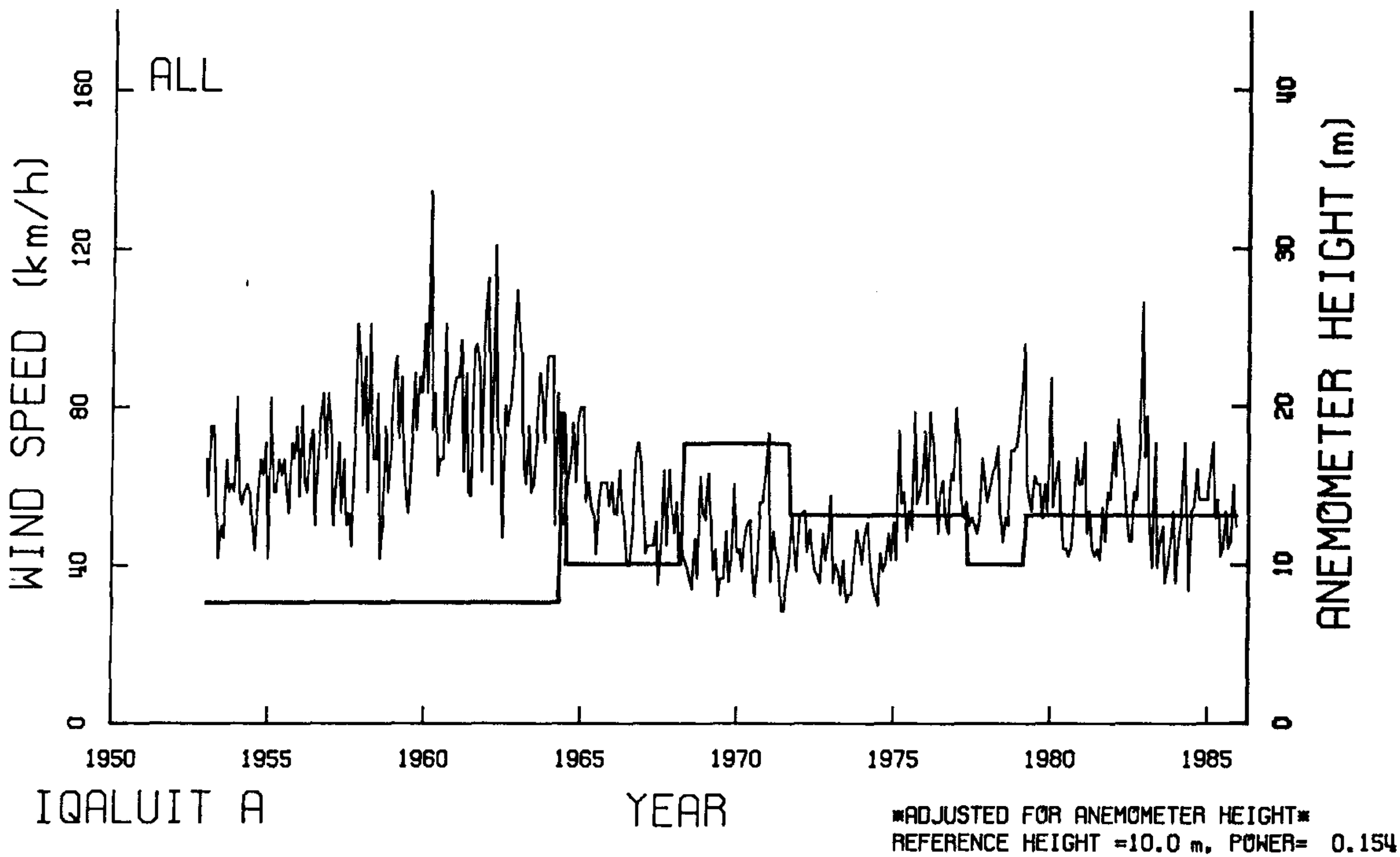
ENTER SELECTION==> 1

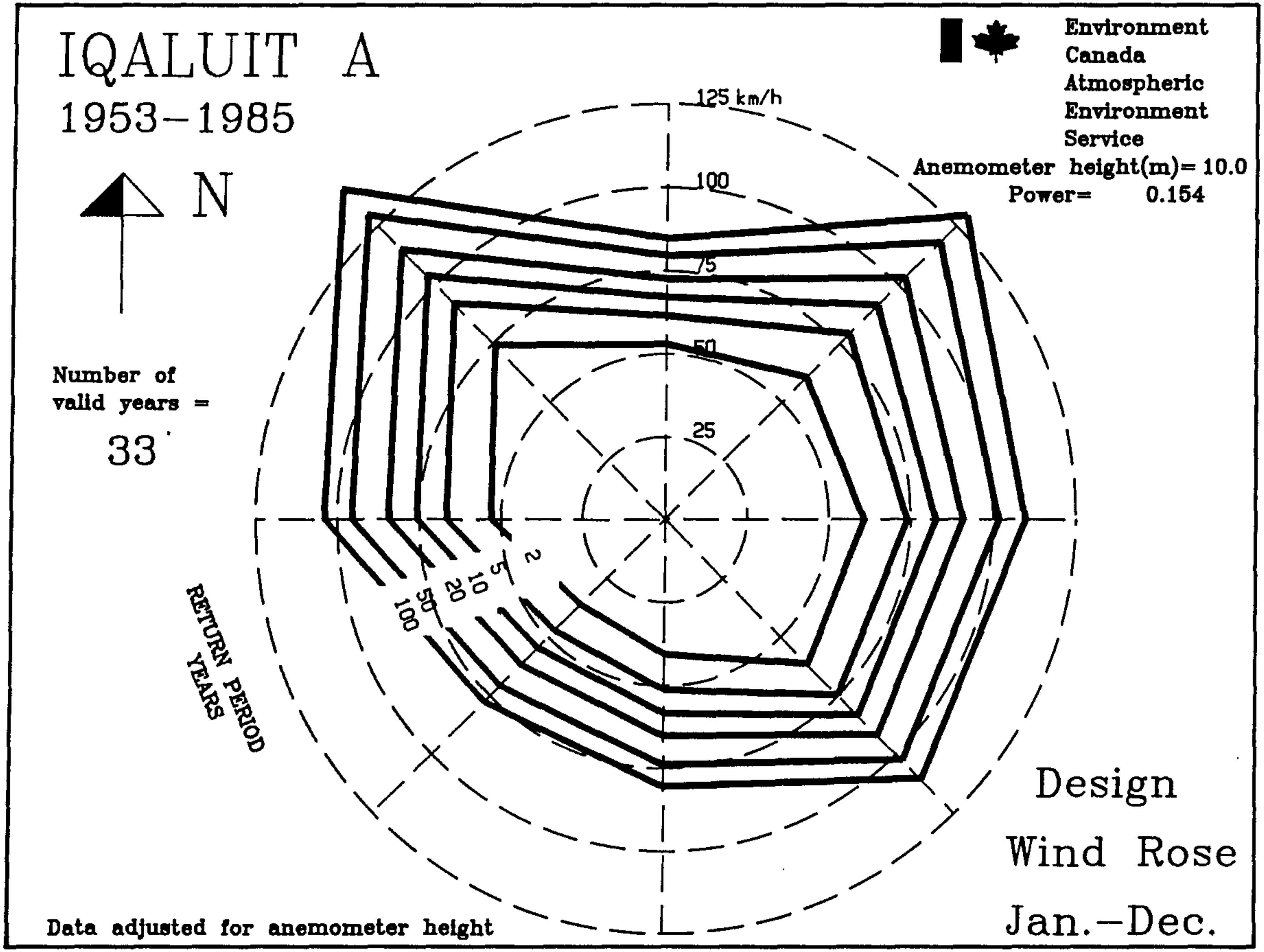
** RUN DWPLOT USING FILE NAME **** YQR3.PRN *****
Stop - Program terminated.

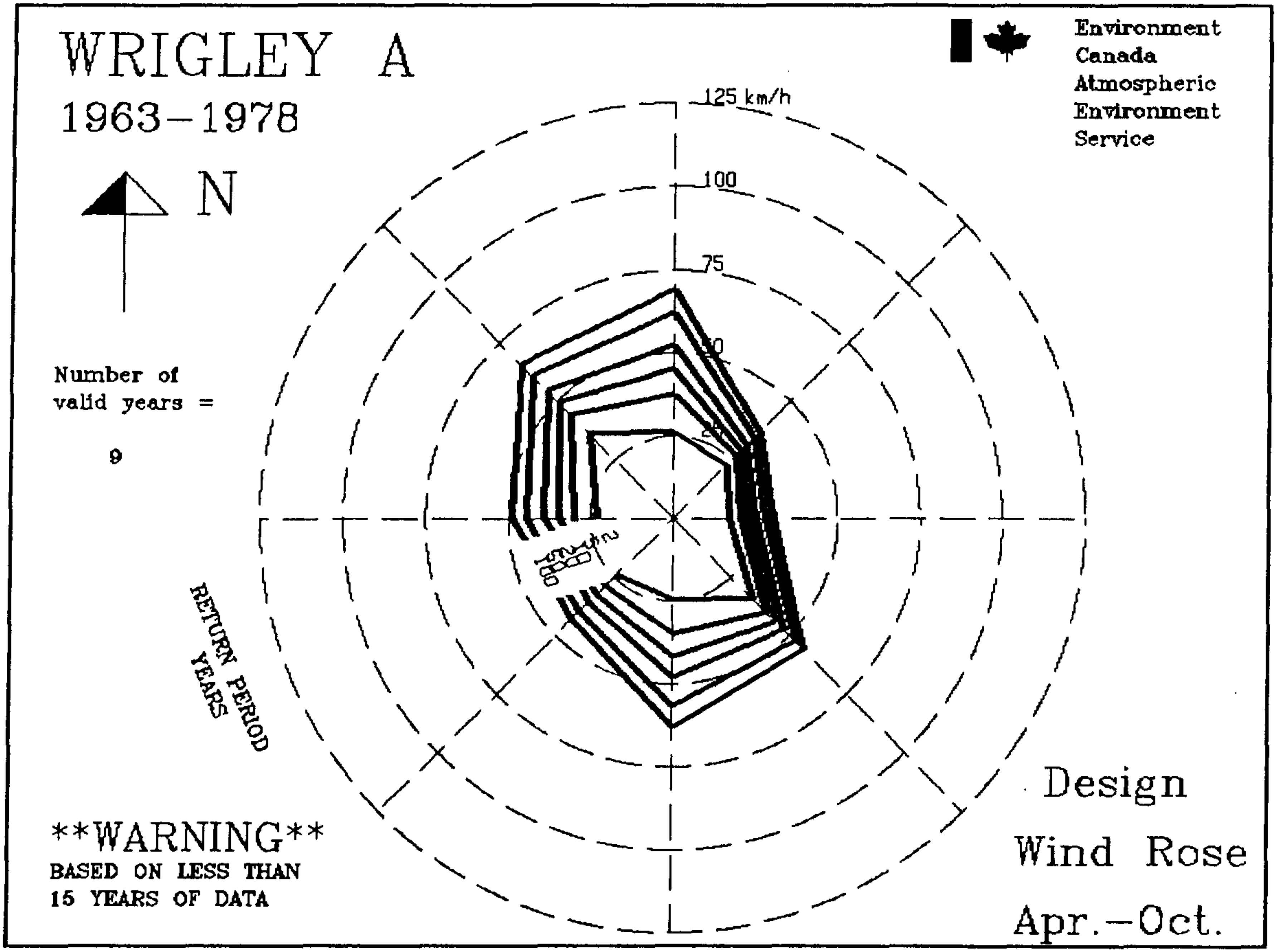
C:\DESNWIND>DWPLOT <YQR3.PRN
ENTER IOPORT, MODEL, AND FACTOR >
ENTER STATION NAME>
ENTER Return Period BY DIRECTION AS PROMPTED

```
   2     5    10    15    20    25    30    50   100 YEARS
  N NE  E SE  S SW  W NW AL ENTER VALID YEARS (eg 1951-1980) >
ENTER MONTH,SEASON OR ANNUAL AS APPROPRIATE
ENTER NUMBER OF VALID YEARS
ENTER MADJ,ANEMOMETER HT(m),POWER,#YEARS DATA RELAXED
WORKING
```


REGINA A - 3 HOUR
1953-1985
N
Environment
Canada
Atmospheric
Environment
Service
Anemometer height(m)= 10.0
Power= 0.133
125 km/h
100
75
50
25
Number of
valid years =
33
RETURN PERIOD
YEARS
2
5
10
20
50
100
Design
Wind Rose
Jan.-Dec.
Data adjusted for anemometer height


ALL
WIND SPEED (km/h)
0
40
80
120
160
ANEMOMETER HEIGHT (m)
0
10
20
30
40
1950
1955
1960
1965
1970
1975
1980
1985
YEAR
IQALUIT A
ADJUSTED FOR ANEMOMETER HEIGHT
REFERENCE HEIGHT =10.0 m, POWER= 0.154


IQALUIT A
1953–1985
N
Environment
Canada
Atmospheric
Environment
Service
Anemometer height(m)= 10.0
Power= 0.154
125 km/h
100
75
50
25
Number of
valid years =
33
2
5
10
20
50
100
RETURN PERIOD
YEARS
Design
Wind Rose
Jan.–Dec.
Data adjusted for anemometer height


WRIGLEY A
1963–1978
N
Environment
Canada
Atmospheric
Environment
Service
125 km/h
100
75
50
25
Number of
valid years =
9
RETURN PERIOD
YEARS
WARNING
BASED ON LESS THAN
15 YEARS OF DATA
Design
Wind Rose
Apr.–Oct.