Digitized seismic data from analog recordings from the spring of 1980 at Mount St. Helens volcano

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In the spring of 1980 Mount St. Helens volcano in Washington State went through an intense seismic swarm, starting on March 20, that culminated in a major eruption on May 18, 1980. The Pacific Northwest Seismic Network (at the time called the Washington Regional Seismic Network) operated a telemetered short-period, analog network of stations and, along with the US Geological Survey, installed and operated a set of portable, analog, tape-recording seismic stations in the vicinity of Mount St. Helens. The telemetered network data were recorded on film and digitized by a brand new event triggered computer system. Triggered events were processed off-line by hand to generate catalogs of a small subset of the many events that originated at the volcano. The vast majority of events were not processed or even recorded digitally. Most publications based on seismic data from this early period at Mount St. Helens are based on either visual records or the triggered digital records and thus are quite incomplete. (See the bibliography at the end of this report for a list of publications).

In recent years waveforms from the analog magnetic tapes from the portable instruments and those from a small subset of telemetered stations have been digitized to provide semi-continuous digital records starting on March 22, 1980 and ending on June 15, 1980. These digital data are being archived at the IRIS Data Management Center in standard SEED format. Because of the nature of the original data and the difficulty of accurate recovery the data quality is far lower than most DMC archived data. In particular the response information is very poorly known and the time stamps can be minutes off. Nevertheless this data set provides a unique and more complete and valuable record of the early parts of the 1980 Mount St. Helens eruption sequence.

As of September, 2014 all of the continuous telemetry data have been digitized and loaded into the DMC. Most of the portable station data have been digitized and the laborious process of checking and time-stamping is complete and the recoverable data are now at the DMC. This report details the background, data recovery efforts and nature of the data at the DMC. These data can be found under the Virtual Network page (http://www.iris.edu/vnets) with network name: _STHELENS-1980.

BACKGROUND

On March 20, 1980 an earthquake of Mag=~4.2 took place near Mount St. Helens (MSH). Within an hour of the event the staff at the Pacific Northwest Seismic Network (PNSN) had located the event putting it right under the north side of the mountain. At the time there was only one station, SHW, operating within 50 km of the volcano. Plans were made immediately to add stations to the network to help interpret any subsequent seismicity. Over the following week several portable, three-component, 5-day, tape recording stations (called *5-day stations* after this) were installed plus a few telemetry stations. Within ten days of the first earthquake ten new stations were added to the region around Mount St. Helens. Because of the remote location and winter snow cover access close to the mountain was difficult. The staff and students of the PNSN and our U.S. Geological Survey (USGS) colleagues spent long hours under difficult and dangerous conditions to install and maintain these stations. After the first minor eruption on March 27 USGS interest increased to the point that funds were available for the use of helicopters on a routine basis.

Craig Weaver of the USGS and I took responsibility for the decisions regarding station installation and maintenance and for analysis and interpretation. With help and financial support from the USGS I have taken responsibility for the recovery of data from the analog tapes. Figure 1 shows a timeline of when stations were operational and what data are now available from digitizing their analog tapes.

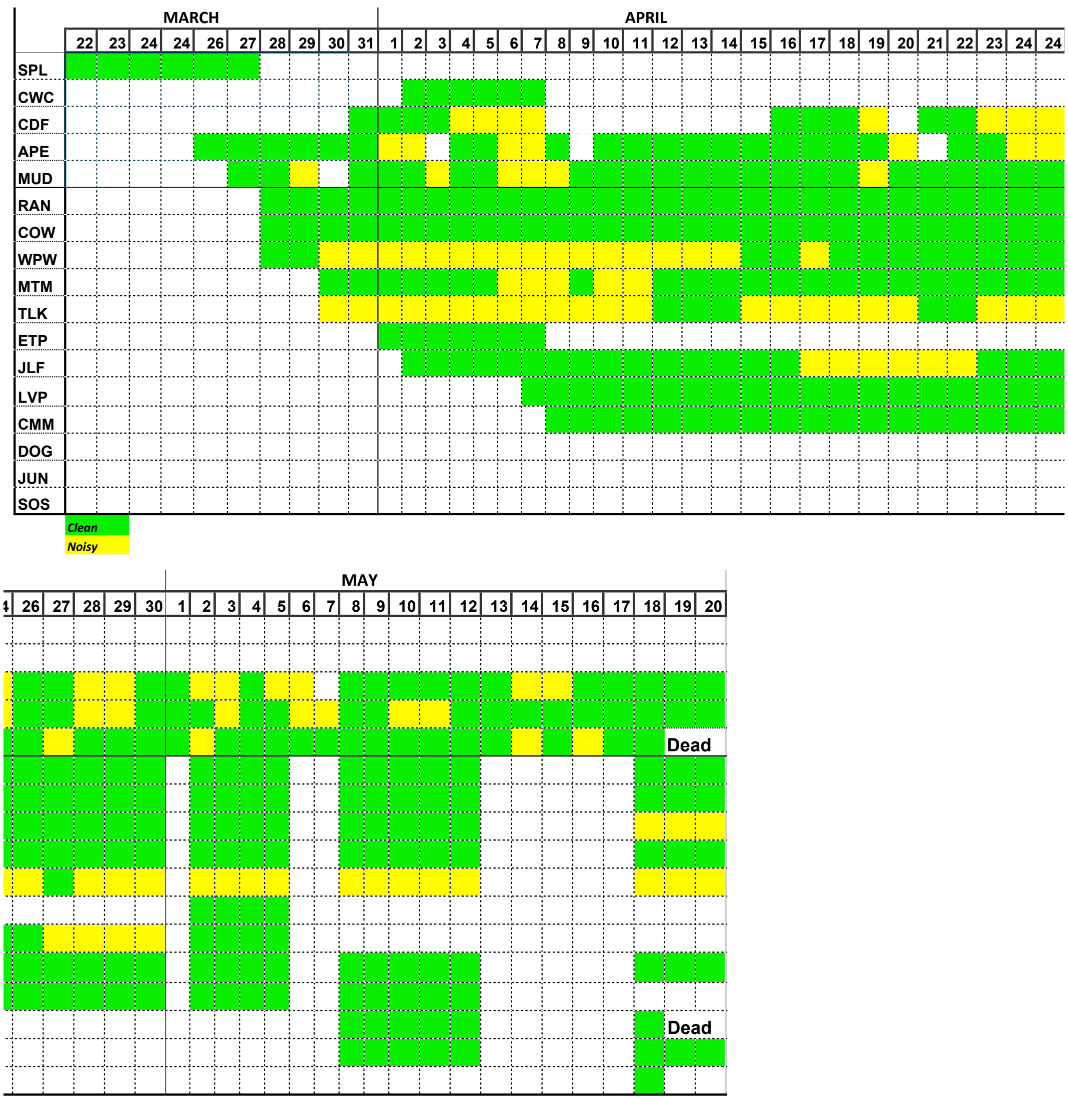

Figure 1. Timeline of station-days with digitized data. Green: good data, Yellow: noisy data, White: no data. The data character marked as colors are just approximate for that day; average quality. Some days marked green are missing short periods of data or have short noisy periods and those days marked yellow may have some part of the day with good quality data. This summary terminates on May 20, shortly after the big eruption. Some data from a few stations for short intervals are available after that date but no data from the analog tapes have been recovered after June 15, 1980.

Table 1 is a list of the station coordinates and basic parameters. An astrix (*) marks telemetered stations.

		Table 1 -	Stations			
Name	**Delta**	**Date on**	**Lat**	**Lon**	**Elevation**	**Note**
DOG*	1	May 1	46.20600	-122.17621	2.317	Lost in eruption
SHW*	5	1972	46.19347	-122.23630	1.425	Still operating
SOS*	6	May 16	46.24386	-122.13787	1.270	Lost in eruption
JUN*	7	May 8	46.14706	-122.15243	1.049	Still operating
JLF*	8	Mar. 25	46.14650	-122.15421	1.049	Closed 5/9/1980
SPL	8	Mar. 22	46.26583	-122.15367	0.991	Closed 5/1/1980
CWC	10	Mar 24	46.27917	-122.27800	0.683	Lost in eruption
MUD	12	Mar 27	46.17669	-122.04096	0.488	Damaged in eruption
APE	12	Mar 24	46.09946	-122.20750	0.579	Closed 7/10/1980
CDF	13	Mar. 30	46.11689	-122.04623	0.756	Became telemetered
MTM*	17	Mar. 28	46.02533	-122.21287	1.121	Still operating
LVP*	24	Apr. 4	46.06595	-122.40193	1.130	Still operating
RAN*	33	Mar. 24	46.40817	-121.86481	1.620	Closed 10/31/1981
COW*	34	Mar. 27	46.49083	-122.01332	0.305	Closed 04/10/1989
CMM*	35	Apr. 7	46.43511	-122.50705	0.620	Closed 10/02/2004
TLK*	54	Mar. 31	45.96206	-121.58536	0.756	Closed 05/08/1980
WPW*	72	Mar. 31	46.69864	-121.53734	1.280	Still operating
ETP*	239	1974	46.46469	-119.06012	0.250	Still operating

With an evolving seismic sequence underway and the outcome unknown, efforts were necessarily divided between acquiring seismic data and its near realtime analysis and interpretation. Frequent reports on the seismic activity and our interpretations were made to the US Forest Service (USFS, land mangers for the Mount St. Helens area), USGS geologists and volcanologists who showed up in increasing numbers at the USFS offices in Vancouver, WA., and to the State Emergency Management Department (EMD) who had the overall responsibility for public safety. These reports were primarily related to the number and size of earthquakes at MSH and our best estimates for their locations. Seismicity rates were generated by scanning visual (helicorder) records of key stations and determining times and rough durations of events with an estimate of the event type (Type-A, Type-B or other). See Endo et. al., (1980) for details. Location parameters were more difficult. Because the computer triggering and recording system was brand new there was no effective computer based analysis available. Thus arrival time picks were made from the telemetry stations by playing out the triggered digital records on strip charts and timing them by hand. Data from the *5-day stations* were handled in much the same way though, analog tapes had to be searched by hand in order to match events from the triggered telemetry data. This process was very time consuming meaning that only a very small fraction of the many earthquakes counted from the visual records were actually timed and located and usually at least a day or more after they occurred.

After selected events from the *5-day station* analog tapes were played back the tapes were placed in storage. Over the following couple of years several researchers used selected data from these tapes for special studies, but much of the data were never looked at, and the tapes languished in storage almost being forgotten until recently.

Almost as an after thought a 14-channel, 1” analog tape system that just happened to be available at the UW was connected up to the analog signals from some of the telemetered stations. These tapes lasted only two days each and were changed at irregular intervals as time permitted. Because of a tape shortage old tapes and tapes of unknown quality were sometimes used. Because this effort was seen as very low priority during a very busy time (many individuals were spending 24 hours of some days at the lab or in the field) there are many gaps in this otherwise continuous record. Like the *5-day station* tapes, these telemetry data tapes saw only very limited additional use in subsequent years and ended up in a storage location, also nearly forgotten.

While no special care was taken for storing all of these tapes they, fortunately were kept in a relatively stable environment with cool temperatures and relatively dry conditions.

DATA RECOVERY

In 2005, because of a need to clean out the storage location, the *5-day* tapes were “rediscovered”, and I decided to try and recover the original continuous seismic data and save them to a digital format for permanent archiving. This process has been interrupted several times because of higher priority tasks and the difficulty of finding old tape play-back equipment and the time consuming nature of both processing and determining appropriate response parameters for the digital data. After my retirement in the fall of 2007 I spent more time with the recovery effort yet still it has taken over six more years to complete the task. Figure 2 illustrates the several steps these data have gone through to get into the IRIS DMC. The two different types of data tapes have been handled quite differently though there are some parts of the processing that share common software.

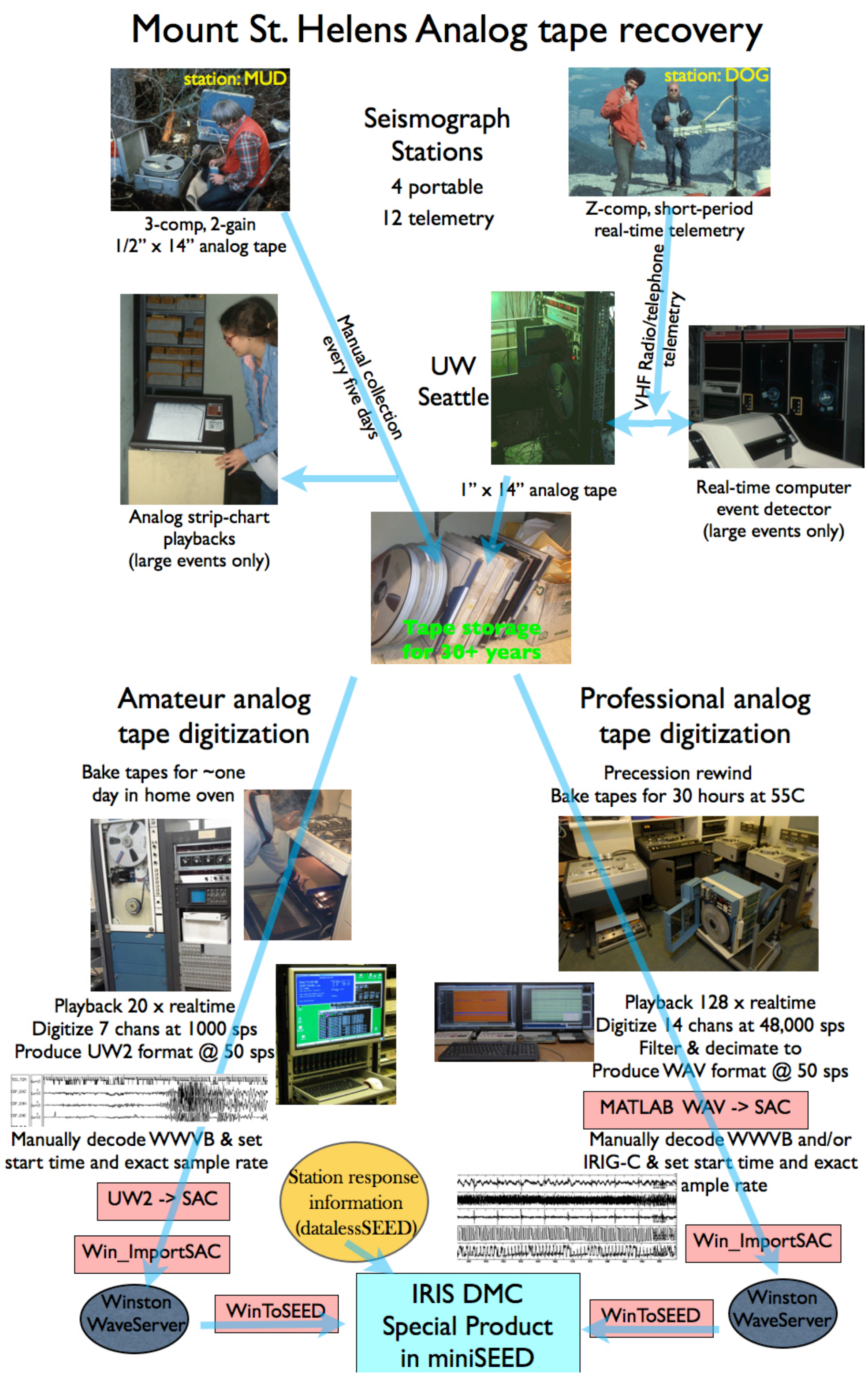

Figure 2. Path from recording to IRIS DMC for both 5-day Stations and Telemetry Stations.

5-DAY STATIONS

In 2005 the only 1/2" analog tape playback unit I knew about was at the USGS offices in Menlo Park. Its effective playback speed was 20 times that of the original recording speed of the *5-day station* recorders. I modified a standard "earthworm" digitizing computer system to digitize seven channels at 1000 samples per second (sps) per channel and save the resulting data in 10 minute long batches. This high sample rate meant that the effective sample rate of the original data was at 50 sps, and each batch of data was then 200 minutes (~3.3 hours) long.

Experiments on several *5-day station* tapes indicated that tape deterioration resulted in oxide rapidly building up on the playback heads degrading the data quality to useless. To try to alleviate this problem I experimented with baking the tapes at low temperature for different time periods in my home electric oven. It seemed that a temperature of about 150F (65C) for a day resulted in minimal shedding of oxide and fairly good data recovery. Even then some tapes would still degrade over the course of their playback resulting in very noisy or useless data for latter parts of the tape.

Arrangements were made with personnel at the USGS offices in Menlo Park, CA, and I spent several days setting up and testing the digitizing computer system and tape playback unit and developed a relatively simple procedure that could be done by someone else. Once a tape was mounted it would be rewound and then played back at the same time the digitizing system would be run. Each 10 minute file was automatically written in UW2 trace data format and then transferred to a computer at the University of Washington (UW) in Seattle via the Internet. Since it took 6 hours to playback a 5-day tape (playback was 20 times recording time) it took more than one work day to digitize two tapes. Thus an operator would start a tape first thing in the morning, check data quality three hours later and possibly clean the tape heads. Then a new tape would be started near the end of the day and run into the evening stopping after the tape ran out. USGS staff in Menlo Park kindly performed this operation for most of the 50 tapes digitized. See Appendix 1 for the instruction document provided to the digitizing staff.

The data files at UW were periodically checked and backed up onto digital tape. If a problem was found the USGS staff person was contacted to try and redo a specific tape. Because the process of running these old tapes through the playback machine further deteriorated the data quality (oxide sloughing off) these "redos" only generated improved data quality in the rare case when there had been a problem with the digitizer. In no case could the data be improved when the tape quality was already bad. Testing and development of the procedures and the processing of a few tapes were done in Dec. 2005 while production digitizing of all the rest of the tapes was done in Nov. 2006 through Jan. 2007. All analog tapes were discarded after it was determined that no improved data quality was possible.

Each tape produced about 35 UW2 trace data files, each representing 10 minutes of digitizing time or 200 minutes of recorded time. Because the data header timestamps and digitizing rate for these UW2 files were for the playback times rather than recorded time, each file had to have its header changed to represent the parameters at recording time. To do this the WWVB time-code recorded on one of the channels was used to both determine the original start time of each file and its exact digitizing rate. This was nominally 50 sps, but, because of tape speed variations either during recording or playback, this rate could vary between 49.2 and 50.1 sps. To assist with this time-stamping process a WWVB reading program, *timecode* written by Tony Qamar, was used to try and automatically determine the time and digitizing rate. The results of this program were reviewed by hand using the picking program, *xped* and/or WWVB was decoded by eye, and the file start-time and equivalent digitizing rate were set in the file header.   Because WWVB would often fade or the tape quality would make reading it impossible I would sometimes need to search through a whole file by hand to try and find a good signal to read by eye. Even then there are a number cases where the time could be set only based on the ending time of the previous file and the digitizing rate set to that of the previous file. Figure 3 shows an example of the WWVB (and some seismic traces) where the program, *timecode*, could not successfully decode WWVB but I could do so by eye. Thus the time stamps in the archived data can be off by up to many minutes in the worst cases. Appendix 2 is a README of the detailed procedures for time stamping. Because the original data files only had generic channel names in the header these were also changed using the program, *correctd,* to match the station and channel codes for the particular tape.

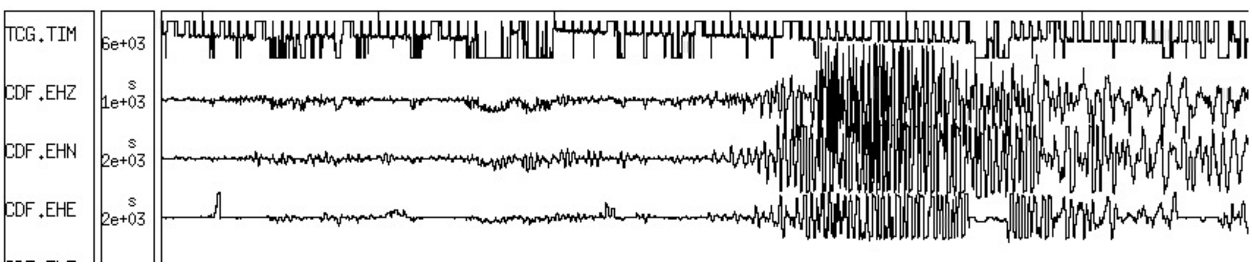

Figure 3. Example of WWVB time-code that could not be automatically read but could be interpreted by eye.

The process of time/rate-stamping each 5-day tape was very labor intensive and could take as much as seven hours per tape if the quality of the WWVB channel was poor much of the time. When WWVB was of good quality a tape could be processed in less than two hours.

Once all of the tapes for a given station had been processed in this way, the UW2 data files were converted to SAC format using the program, *uw2sac* at first and then a *CORAL* module in MatLab for production. Then they were loaded into a Winston wave-server using the java method that comes with Winston. Local review and research are usually done using data from the Winston.

Miniseed files for archiving at IRIS were generated using the *winstonclient* application from the seisFile package written by Philip Crotwell. In some cases adjustments to Station-Channel-Network-Location (SCNL) was done using the routine, *mseedmod*. Miniseed files were sent via *FTP* or *miniseed2dmc* to the IRIS Data Management Center where they were loaded into their archive database.

TELEMETRY STATIONS

At the time the 1" x 14" tapes were "rediscovered" in 2009 I knew of no tape playback system with the proper speeds and discriminators. A search of the Internet for commercial tape recovery operations came up with only three possibilities. Two of these were primarily for recovering old music master tapes and had little or no experience with seismic or scientific waveform-type data. They did recommend to me the third option, Richard Hess of Aurora, Ontario, Canada, who when contacted seemed to know something about these sorts of old seismic data. Arrangements were made for a test of three tapes to be done by Richard and paid for with internal UW funds. The results were quite promising, and a proposal was submitted to the USGS data preservation fund by Seth Moran of the Cascade Volcano Observatory, USGS on my behalf. The proposal was eventually funded, and the remaining 22 tapes were shipped to Canada for processing. Complete details of the digitizing process is covered in a document provided by Richard Hess and included in Appendix 3.

Files were provided to me via ftp in "*.wav*" format by channel-tape with equivalent recorded sampling of 50 sps. Of the 14 channels on the tape two were time code (radio WWVB and a local Time-code Generator producing an IRIG-C slow code). Up to 9 other channels had different seismic channels at different times. Appendix 4 contains a table of channel number to station mapping with on-off dates for each tape. Because notes related to channel assignments for these tapes from when they were recorded have been lost, the channel mapping had to be reverse engineered, in some cases by matching up waveforms from the original triggered event computer files with waveforms from these tapes. Because of the high seismicity it was easy to find events with characteristic waveforms to use for this purpose though it was quite time consuming.

Processing these tapes to properly time and rate stamp the digital files was somewhat similar to that used for the *5-day stations.* In this case a builtin MatLab function to read *.wav* files was used to input the time-code channels and display them for manual decoding. All channels were then written out in SAC format using a function from the Coral package with exactly the same starting times, sample rates and lengths. These SAC files were then loaded into a Winston from which miniSEED files were generated to ship to IRIS.

RESPONSE INFORMATION

For waveform data to be archived at the IRIS DMC channel response information (dataless-SEED) must be included. Since these data are from analog instruments with poorly known characteristics and going through a number of steps with unknown gains determining accurate response information is not possible. Dataless-SEED volumes have been generated with our best guesses as to the appropriate parameters. For the telemetered data the responses are the same as used for these station in the triggered digital data but with the gain adjusted to approximately match. For the *5-day stations* generic responses for the L4C-3 seismometers and an approximate low-pass filter for the tape recorder have been used with gains some what arbitrarily adjusted to be consistent with other data. However, in all cases the user of these data should NOT put any trust in the response information (and similarly in the time-stamps).

DATA USAGE

While the quality of these recovered data are generally poor, the hope is that their unique origin makes them a valuable record of the beginning of the 1980 Mount St. Helens eruption. Anyone interested in volcano seismology is welcome to look at and use these data for any purpose. If this document doesn't contain enough information for some purpose or any questions come up in their use please contact me for help.

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APPENDIXES

Appendix 1.

5-Day tape digitizing procedures

1. Check to see if all is finished. If tape is still going and/or SUN (lower right) window does NOT say "*Data collecting has terminated normally*" then wait some until it does. It should not go much more than 6 hours.
2. Remove full tape from lower reel and put it in its box.
3. Put new tape on bottom reel, feed tape to top reel not over heads and push "REV". Then slowly switch the "TAPE SPEED SELECTOR" up to 240. step by step
4. After all tape is on top reel switch "TAPE SPEED SELECTOR" back to 3 3/4. . Clean tape heads and guides.
5. Thread tape back onto bottom reel over heads, winding it several times and press "FORWARD".
6. On SUN lower right window type "*start SSSddd-ddd*" where *SSS* is the station name (CDF, APE SPL) and *ddd-ddd* is the starting and ending days of the tape.
7. It may take a couple of minutes to see good date on PC console using "wave_viewer". To start, double click "Shortcup to fast wave_viewer" icon; to stop it click upper-right X, (go to most recent data by clicking on "-| "symbol and "groups" "ALL").
8. Log Tape name and start time (UTC) on tape log sheet

Other info and what is going on.
If PC doesn't seem to be working you can use "Shortcut to fast autostart" icon or try typing, *startstop* in the lower right (pigia) window. If PC needs rebooting, login as "eworm", get terminal window by clicking "cygwin" icon, cd fastrun/params; startstop.
The PC to left of tape drive is running earthworm digitizer at 1000 sps /chan into a wave_server. It is always running even if the tape drive is not producing anything. The SUN computer has a shell script that runs every 10 minutes at 2, 12, 22, 32, 42, 52 minutes to get the previous 10 minutes of data from the PC wave_server into UW2 data files and then copy them to a computer at UW. When all tapes are finished you can type '*quit*' in the lower right (pigia) window to stop the earthworm digitizer or on the PC console window.

For any questions at any time call me (office: 206-685-3811, cell: 206-419-9711)
Molto grazie. Steve Malone <steve@ess.washington.edu>

Appendix 2

Time stamping procedures

The raw data files are in UW2 format and have a start time of when the digitizing was done (based on the computer clock). The sample rate of the data is the digitizing sample rate and thus, along with the starting time needs to be changed to be useful. To do this there is a script in each tapes directory (that have been done) called 'tim', which used the program timecode, xped and correctd and config file correctd.STA. ch maps channel numbers into station-channel names.   One should know the approximate starting time of the tape when 'tim is first run. Syntax is:

   tim MMDDHHMM file_nameW

The first argument is used as the approximate starting time of the data. The slow-code reading program, timecode is used to try and decode the first channel on the tape. It spits out lots of information about its parameters for getting the time for you to use to estimate the more accurate starting time of the data. Xped is used to display the slow code for you to try and decode or check by hand. The program then asks for you to input the sample rate (timecode may be successful in determining this, but a value of 49.6 is probably pretty close). It then asks for the exact starting time in format:

  MMDDHHMMSS.ss

The name of the data file (and created pickfile) are changed to match this new time and the original raw file is backed up in a subdirectory called, BAK. When using this it’s a good idea to recheck the time by using xped on the corrected file and also to determine what time the end of the file is for use in processing the next file in the sequence.
Each file is about 3 hours and 25 minutes of recorded time.

APPENDIX 3

Introduction

The author (Richard L Hess) was contacted by Dr. Steve Malone based on information that it was possible for us to transfer IRIG 1-inch, 14-track tapes. We have several Honeywell 101 tape machines in various configurations. We first agreed to a three-tape pilot project, followed by the digitization of 22 additional tapes, for a total of 25.

Dr. Malone indicated that 50 s/s files were adequate and the low end bandwidth of about 0.1 Hz as that was the high-pass on the input amplifiers when the recordings were made and the seismometers were “1 Hz” devices.

Tape Condition

The tapes arrived in boxes and cans on precision metal reels. There were many different tape types and it was difficult to identify each one as the tapes were not necessarily in their original boxes nor on their original reels. Roughly a third of the tapes were back-coated, later-generation tapes.

Tape Preparation

Since all of the tapes were provided “tails out” they needed to be rewound prior to playing. The instrumentation recorder does not have a mechanism for winding tape without it being in contact with the tape heads, so it did not make sense to use that. All rewinding was done on a Sony APR-16[1] which is a 16-track audio recorder adjustable for both one-half-inch and one-inch tape. It has “tape lifters” which hold the tape away from the heads during spooling. We rewound the tapes at a slow speed of about 60 in/s—it took roughly the same time to rewind as it did to capture the data from the tapes.

We selected several reels of tape which were back-coated for immediate baking and those performed flawlessly after baking for 60 or more hours in a food dehydrator at about 55 °C. We watched closely during the first few minutes of winding to see if there was any buildup of debris that looked like baking would be needed. At first, we did not think that tapes 095, 099, and 123 needed baking, but there was some sticky shed components. These tapes were also baked and performed satisfactorily, but had more (dry) shedding during playback than the others.

There were other minor pieces of damage which were repaired as noted in a few “Tape Notes” text files in the archive file for each tape.

Equipment setup

We set up the Honeywell recorder to run the tapes at 60 in/s (inches per second, aka “i.p.s.”) and used a 5 kHz low-pass filter on the reproduce channels.

This was connected to a pair of RME Multiface II audio analog-to-digital converters. The odd channels were connected to one converter and the even channels to a second converter. In that way, slight sample shifts between the converters would not degrade the accurately timed odd/even channel sets and would simply add to the already somewhat ambiguous odd-even timing jitter.

- Playback was at 60 in/s (1524 mm/s) which was 128 x the record speed.

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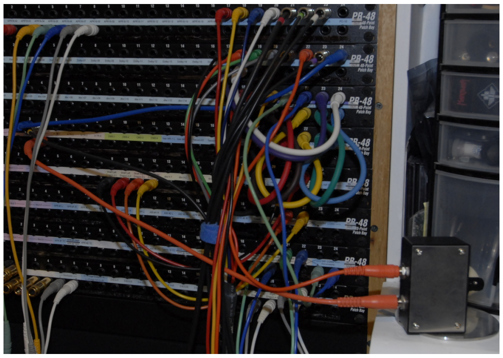
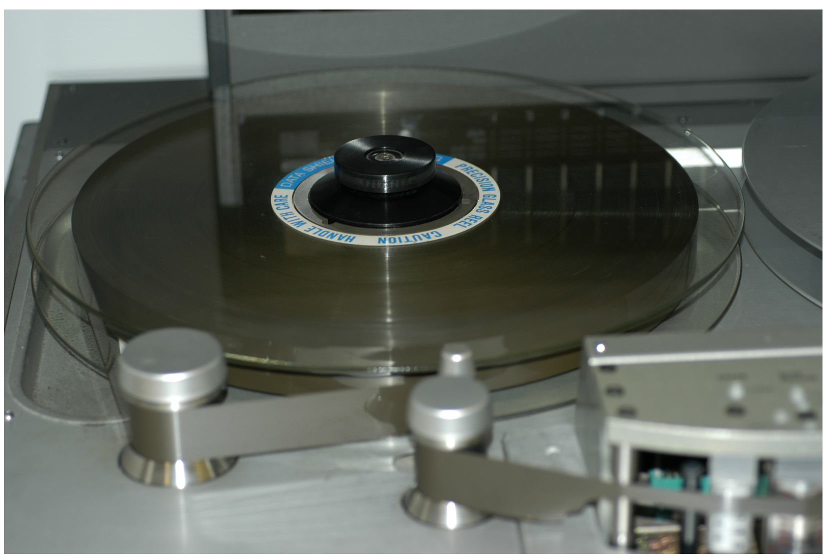
1 This APR-16 is believed to be the only one ever made. It was a trade-show concept machine, made from modified APR-24 (two-inch, 24-track) machine components. It came with 1/2-inch 4- and 8-track heads and one-inch 8- and 16-track heads. I have had 1/2-inch 7-track IRIG and 16-track audio heads mounted for use on it since I obtained it in 2004.

- Initial digitization was at 48,000 samples per second (s/s), 24 bits.
- On-board FM demodulation was used for all channels except the IRIG time code one, which had a direct card installed. A 5 kHz filter was used.
- The native low-frequency response of the Multiface II is flat to about 10 Hz and within 3 dB to 7 Hz.
- The tapes were recorded at 15/32 in/s (11.91 mm/s)
- The effective bandwidth was from 0.08 Hz to 39 Hz, with some data passing through both above and below those points.
- The initial transfers captured signals out to approximately 172 Hz, with a sample frequency of 375 s/s in real (tape) time.
- The files were decimated by a factor of 7.5 to 50 s/s which limited the upper bandwidth to approximately 24 Hz, lower than the 39 Hz (plus) delivered by the recorder and substantially lower than the 172 Hz brick wall in the initial digitization. This however appears to be the standard for analysis.
- The high-bandwidth files are the files as they were recorded. The 50 s/s files that Dr. Malone worked on for the main submission did have level adjustments, especially in the time code channels.
- The IRIG timecode was recorded both with its native 100 Hz carrier and when it was discovered that this would not pass through the 50 s/s files, this signal was demodulated (retrospectively for some tapes and simultaneously for the balance) and stored as a 15th track.
- When it was noticed that there was energy above the ~24 Hz cutoff of the decimated files, it was decided that preserving these additional data may be useful in some as-of-yet unknown analysis. Since these data already existed, it was decided to retain them.
- Full deviation of the IRIG machine FM output corresponds to 2.82 V peak-to-peak (p-p). The full-scale input to the RME Multiface II converters is 19.5 V p-p. This means that the full-scale signal is about 16.09 dB below clipping.
- The useable dynamic range of the digital signals is about 80 dB, assuming the -16 dB level is the maximum used. The noise floor on the digital side is better than –96 dBFS.

Equipment layout-blue machine is Honeywell 101, machine to its left and rear with doors open is the Sony APR-16 which was used for winding the tapes. Below is a view of the custom demodulator “black box” (lower right) connected into the studio patchfield.



A view of the operating area (above)
Use of precision glass reels (and some tape damage, below).



APPENDIX 4

Mon/Day	JDay	TAPE NUM	Tape OFF	Tape ON	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5	14 track analog tape recovery channels Chan 6	Chan 7	Chan 8	Chan 9	Chan 11	Chan 12
										14 track analog tape recovery channels					
Mon/Day	JDay	TAPE NUM	Tape OFF	Tape ON	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5	Chan 6	Chan 7	Chan 8	Chan 9	Chan 11	Chan 12
03/28	88	**088**		03/28-09:09		RAN 09:09-	COW 09:09-	WPW 19:02-						IRIG	WWVB
03/29	89														
03/30	90	**090**	- 03/30-02:42	03/30-02:56 -		RAN	COW	WPW	*TLK 00:02-*	MTM 01:20-					
03/31	91														
04/01	92	**092**	- 04/01-06:04	04/01-06:44 -		RAN	COW	WPW	*TLK*	MTM					
04/02	93				JLF -00:30 -						ETP?? 00:36-				
04/03	94		- 04/03-09:48												
04/04	95	**095**		04/04-02:37 -	JLF	RAN	COW	WPW	TLK	MTM	ETP??				
04/05	96														
04/06	97	**097**	- 04/06-08:32	04/06-15:13 -	JLF	RAN	COW	WPW	TLK	MTM	ETP??		LVP 15:13-		
04/07	98														
04/08	99	**099**	- 04/08-16:45	04/08-16:57 -	JLF	RAN	COW	WPW	TLK	MTM	CMM 05:57-		LVP		
04/09	100														
04/10	101														
04/11	102	**102**	- 04/11-11:11	04/11-15:14 -	JLF	RAN	COW	WPW	TLK		CMM	MTM	LVP		
04/12	103														
04/13	104	**104**	- 04/13-15:53	04/13-16:02 -	JLF	RAN	COW	WPW	TLK		CMM	MTM	LVP		
04/14	105														
04/15	106	**106**	- 04/15-19:06	04/15-19:40 -	JLF	RAN	COW	WPW	TLK		CMM	MTM	LVP		
04/16	107				04/16-19:17 -										
04/17	108														
04/18	109	**109**	- 04/18-09:15	04/18-09:25 -	JLF	RAN	COW	WPW	TLK		CMM	MTM	LVP		
04/19	110														
04/20	111				-bad data-										
04/21	112	**112**	- 04/21-03:36	04/21-06:33 -	JLF	RAN	COW	WPW	TLK		CMM	MTM	LVP		
04/22	113				-04/22-03:00										
04/23	114	**114**	- 04/23-09:38	04/23-17:53 -	JLF	RAN	COW	WPW	TLK		CMM	MTM	LVP		
04/24	115														
04/25	116		- 04/25-21:17												
04/26	117	**117**		04/26-02:53	JLF	RAN	COW	WPW	TLK		CMM	MTM	LVP		
04/27	118				04/27-01:34 -										
04/28	119	**119**	- 04/28-03:43	04/28-04:56 -	JLF	RAN	COW	WPW	TLK		CMM	MTM	LVP		
04/29	120				-bad data-										
04/30	121		- 04/30-14:08		- 04/30-14:08										
05/01	122														
05/02	123	**123**		05/02-18:54 -	JLF	RAN	COW	WPW	TLK	ETP??	CMM	MTM	LVP		
05/03	124														
05/04	125	**125**	- 05/04-19:20	05/04-19:33 -	JLF	RAN	COW	WPW	TLK	ETP??	CMM	MTM	LVP		
05/05	126														
05/06	127		- 05/06-22:36		-06:22 JLF										

										14 track analog tape recovery channels					
Mon/Day	**JDay**	**TAPE NUM**	**Tape OFF**	**Tape ON**	**Chan 1**	**Chan 2**	**Chan 3**	**Chan 4**	**Chan 5**	**Chan 6**	**Chan 7**	**Chan 8**	**Chan 9**	**Chan 11**	**Chan 12**
05/07	128														
05/08	129	**129**		05/08-07:22 -	JUN 07:22 -	RAN	COW	WPW	TLK	ETP -17:56- LVP	CMM	MTM	LVP -17:56- DOG		
05/09	130														
05/10	131	**131**	- 05/10-10:44	05/10-17:04 -	JUN	RAN	COW	WPW	TLK	LVP	CMM	MTM	DOG		
05/11	132														
05/12	133		- 05/12-:20:46								-20:46 CMM				
05/13	134														
05/14	135														
05/15	136														
05/16	137														
05/17	138	**138**		05/17-23:43 -	JUN	RAN	COW	WPW	TLK	LVP	SOS 23:43-	MTM	DOG		
05/18	139	**139**	- 05/18-18:43	05/18-18:59 -	JUN	RAN	COW	WPW	TLK	LVP	-15:32 SOS	MTM	-15:32 DOG		
05/19	140							-23:37 WPW							
05/20	141	**141**	- 05/20-06:55	05/20-08:01 -	JUN ->RAN	RAN->COW	COW->JUN	LVP 08:01-	-06:55 TLK	LVP -08:00- MTM	OCP 08:01-	OBC 08:01-	OFK 08:01		
05/21	142														
05/22	143	**143**	- 05/22-06:17	05/22-06:29 -	RAN	COW	JUN	LVP		MTM	OCP	OBC	OFK		
05/23	144														
05/24	145	**145**	- 05/24-09:31	05/24-15:04 -	RAN	COW	JUN	LVP	ELK 15:04-	MTM	OCP	OBC	OFK		
05/25	146														
05/26	147		- 05/26-18:22						-18:21 ELK						
05/27	148	**148**		05/27-06:25 -	RAN	COW	JUN	LVP		MTM	OCP	OBC	OFK		
05/28	149														
05/29	150		- 05/29-09:33								-09:33 OCP	-09:33 OBC	-09:33 OFK		
05/30															
06/13		**165**		06/01-01:18	RAN	COW	JUN	LVP	SHW 01:18-	MTM			CMM 01:18-		
06/14															
06/15			06/03-04:16												
06/16															