National Transportation Safety Board
Internal Inspection Factual
Bellingham, Washington
Accident DCA99-MP008

Appendix 3 OPS consultant report

SMART PIG DATA ANALYSIS
Final Report

Olympic Pipeline Company Gasoline Pipelines
16" Cherry Point to Ferndale
16" Ferndale to Allen
16" Allen to Renton
20" Allen to Renton

By
H. Noel Duckworth
January 24, 2000

Overview:

Subsequent to Olympic Pipe Line Company's 16" pipeline failure and the resulting release of refined product in Bellingham, Washington, the Department of Transportation, Office of Pipeline Safety, Western Region has tasked Oak Ridge National Laboratories to provide technical support associated with OPS' oversight of certain of Olympic's related efforts. ORNL has engaged my services as a consultant in electronic pigging systems for the purpose of providing an analysis of the prior employment of such devices by Olympic and the utilization of those services to maintain the integrity of their pipeline system at the highest possible level.

Procedure:

Seek as much operational history on the pipeline facilities and their operation as possible from all sources available, especially the pipeline operator. Investigate the inspection equipment that was previously utilized so as to: 1) confirm that the proper equipment was chosen for the surveys, 2) confirm that the equipment was set up properly, and 3) confirm that the equipment was still functioning properly at the end of the survey. Evaluate the survey logs and determine whether or not the data was analyzed properly in accordance with industry-accepted standards. Make recommendations to OPS-Denver regarding actions to be taken prior the pipelines being returned to their normal state of operation. Recommend additional surveys to be performed in 1999 that may be appropriate for a better understanding of the integrity of the pipelines.

Pre-Analysis Discovery

Operational history on the pipelines was limited in first hand availability due to the extenuating circumstance that possible criminal action was pending due to the incident. Thus, the most knowledgeable individuals at Olympic were not available for discussion upon their lawyers' advice. Records were made available to us through legal counsel and we were allowed to talk to one corrosion engineer which was not extremely helpful since he did not have first hand knowledge of most of the issues that were important relative to the operating history and electronic pigging of the pipelines. We were, however, able to finally attain a reasonable understanding of the pipelines and their operating characteristics from the records.

Inspection Equipment:

Tuboscope's Linalog equipment chosen for the **1991** and **1996** surveys was adequate in all respects for detecting and displaying the types of three dimensional, metal loss, anomalies that one could reasonably expect to find in this pipeline. According to the records made available by Tuboscope, the instruments were properly set up and calibrated prior to insertion into the pipeline and they were functioning properly after they were removed from the pipeline.

The caliper equipment provided by Enduro for the inspection for mechanical deformation in **1997** was limited in terms of resolution and thus, was limited in its usefulness as a complete deformation evaluation system. The most limiting element is the recording and presentation of the data on a scale of **1** inch of log equals 250 feet of pipe. At this scale, it is reasonable to conclude that visual, human interpretation **will** resutt in omissions and errors from time to time when analyzing miles and miles of data over a long period of time. Another limiting element is circumferential resolution. The sensor array detects deformation of a polyurethane cup at the rear of the pig (which is deformed due to physical pipe deformation) and the most severe deformation at any instant in time is recorded on a single channel. The newer Enduro equipment, which was not available in **1997,** contains several sensors in an array (depending on pipe diameter) and records data from each separately as it traverses the pipeline. ***Also,*** the data can be displayed on a much larger scale allowing for better resolution linearly along the pipeline as well as circumferentially. The Enduro equipment employed in the 1997 survey was set up properly and it did function properly (within its limited capability as described above) throughout the entire length of the pipeline.

An analysis of the **1991** and **1996 LINALOG** MFL survey logs on these sections of pipeline was made and my conclusion is that the sensitivity of the **1991** survey is quite high. The data reflects that the indications are at least 25% higher than they should be which results in interpretation of data at a very conservative level (defects **look** much worse than they actually are). The sensitivity was adjusted down for the **1996** survey by **a** substantial amount and the results still prove to be on the conservative side. In the event that the pipeline contained anomalies with substantial penetration such as in the range of 50% to 90% then you would **lose** the capability to distinguish the more serious indications **from** each other due to signal saturation. High sensitivity is acceptable in this case since there are not any indications in the upper range that require analysis. The Enduro equipment was set so that the sensitivity was optimum for these pipeline parameters.

The log analysis procedures at Tuboscope require that only those signals typical of metal loss such as corrosion be called as a "Defect" (**D1, D2,** etc). Another category of reporting is called 'Features" and it includes all identifiable features in the pipeline such as valves, tees, taps, bends, casing ends, etc. These items are those items that the pipeline operator installed in or on the pipeline, he knows they are there, and they quite often are valuable reference/correlation points. This category named "Features", in this case, also includes some unknown signals that the analyst has concluded is neither corrosion nor natural pipeline elements. Their character is such that the analyst is compelled to bring them to the attention of the client. There are comments attached to the each of these that describes why the analyst chose to report it. Examples used in these pipelines are "Possible Dent", "Possible Wrinkle Bend", "Possible Mash", "Possible Attachment", and 'Possible Mill/Mechanical Anomaly". The word "Possible" proceeding each one clearly states that the analyst doesn't know for sure what they are but he/she is rendering an opinion on what it might be. No matter how accurate these opinions are they are clearly attempts on the part of the analyst to bring these items to the client's attention for further evaluation. This is a poor and ineffective method to communicate with the client on a sensitive subject since very pertinent information is mixed in with all of the multitudes of nondefect type "Features". These important issues warrant a category of their own.

Data Analysis:

A complete and thorough data analysis of the **1991** and **1996** Linalog MFL Surveys and the **1997** Enduro Caliper Survey was made on the 37.4-mile section containing the origin of failure (Ferndale to Allen). On the other three sections, the most recent MFL survey logs were reviewed in their entirety. It was my intention to refer back to the prior survey at locations where an area of importance was missed or improperly graded by the log analyst. However, this situation did not occur and the earlier surveys were not utilized.

16" Cherry Point to Femdale:

This very short, **5.12** mile line was found to be in excellent condition. Special emphasis was given to the possibility that there might be some intemal corrosion due to a prior operating condition. There were no indications found that might represent intemal corrosion. The three indications found were extremely light and were typical of insignificant mill origin surface anomalies normally found on the inside of the pipe or very light isolated extemal corrosion. There were no defects included in the "Features" category.

16" Ferndale to Allen:

This **37.4** mile section has a few indications in it but there is very little corrosion. As shown in the table in Appendix B, there were **20** locations **(D1 - D20)** selected by the Tuboscope analyst to represent three dimensional, metal loss type defects. Twelve of these **(D1, D4, D5, D6, D10, D11, D14, D15, D16, D17, D18,** and **D19)** are typical of mill origin defects and will most likely prove to be very small and on the internal surface of the pipe. Another two are the same type signals and were called as a 'FEATURE'' by the analyst. These are located at WC **661**0' **9.2"** and WC **71**75' **3.9" (WC** = Linalog odometer wheel count). There were eight locations **(D2, D3, D7, D8, D9, D12, D13,** and **D20)** that were called as three dimensional, metal loss type defects and they are unique because they are all in the immediate vicinity of the girth weld. This is a common problem caused by deterioration **of** the field joint coating that was applied during construction in the area of the circumferential girth weld. These will most likely prove out to be very small extemal corrosion pitting and probably will be found to be inactive corrosion since there does not appear to be any measurable progression between **1991** and **1996** on any of them. The cathodic protection levels expressed by OPL and stated in the documentation made available to me also support this observation.

There are six locations found on the 1996 Linalog, MFL survey logs that were not called by Tuboscope and they are designated as **HND1** through **HND6.** Three of these **(HND1, HND2,** and **HND5)** are light in nature and appear to be probable external corrosion located in the immediate vicinity of the girth weld as discussed above. **HND3** is the onty group of signals in the entire pipeline section that has a long-length extemal corrosion pattern and even though it falls below the minimum reportable level, it will be valuable to understand their source. **HND4** is in the next joint downstream from **HND3** and has a unique corrosion-type signal character also. The signals are contained in a much smaller area, are low in amplitude and high in frequency. **HND6** is at a repair area where a sleeve was installed over an intemal defect found during the 1991 survey and it appears that the sleeve does not cover the entire defect.

There are four anomalies reported by Enduro as a result of their Caliper Survey in **1997** and they are specified in Table **1.** as E l through **E4.** The first one (E1) is at approximate station number 0+14 and is in a TEE and the source of the signal is thought to be associated with alignment of the pig bars in the throat of the tee. The second (S2) is at approximate station **843+69** and is near the origin of failure and will be discussed later. The third **(E3)** is at approximate station number **847+54** and is in a bend downstream of the origin of failure. It appears that this signal is derived **from** misalignment typically found when forged fittings are trimmed to provide a lesser angle. This misalignment is commonly the result of a slight miter generated in the trimming process or, it is due to the thicker metal **on** the trimmed end not being "back beveled" so as to provide a good lineup without "Hi-Lo" prior to welding. The fourth (E4), very similar to **E3,** is at approximate station number **1973+54** and is located in a bend very near the trap location at the Allen Station. I am of the opinion that **E3** and **E4** should be reevaluated from a structural point of view consideting that the welding procedures at the time of initial construction probably were not as advanced as they are now as relates to these types of problems. This is especially important with the operating history of the pipeline with so many pressure surges due to rapid valve closures. I understand that they did uncover E4 and performed compression wave ultrasonic tests and the results showed the bend to be thicker than the pipe as you would expect. Radiography would be required to properly evaluate the weld as per the **1104** code.

We did not find any areas in this section of pipeline on the survey logs that would be indicative of mechanical damage caused by an outside force with the exception of that at and near the origin of failure. It is my understanding that **HND3** was, in fact, minor mechanical damage that appeared to be inflicted by 'tracks" on a dozer or hoe and then coated over by a repair coating different from the coating applied to the pipeline on original construction. The signal was very low and thus did not present a classic deformation waveform. Regardless, I have been informed that it was removed from the pipeline along with **HND4** as is appropriate. **HND6** must be removed from the pipeline, in my opinion, due to the presence of a fillet weld associated with a sleeve over an intemal mill defect.

16" Allen to Renton:

There are **37** indications in this **75.61** mile section that were graded as metal loss defects and **7** of them were marked as "Possible MilVMechanical Related". In addition, there were **29** indications marked as "Features" that were clearly defect-type features as opposed to pipeline element-type features. I agreed with the interpretation made by the analyst and I did not find any indications that were missed in this section. The records provided by OPL indicated that all items of significance were previously dug and either eliminated or repaired.

20" Allen to Renton:

There are **167** indications in this **76.03** mile section of the pipeline that were graded as corrosion-type, metal loss defects and **10** of them were marked as "Possible MilUMechanical Related". (Please note that there is an error in the database for some versions of Linalog Plus for this section wherein defect **D113** is counted **15** times – **D114** through **D127** are the same as **D113** and should be thrown out.) In addition, there were 31 indications marked as "Features" that were clearly defect-type features as opposed to pipeline element-type features. I agreed with the interpretation made by the analyst and I did not find any indications that were missed in this section. The records provided by OPL indicated that all items of significance were previously dug and either eliminated or repaired.

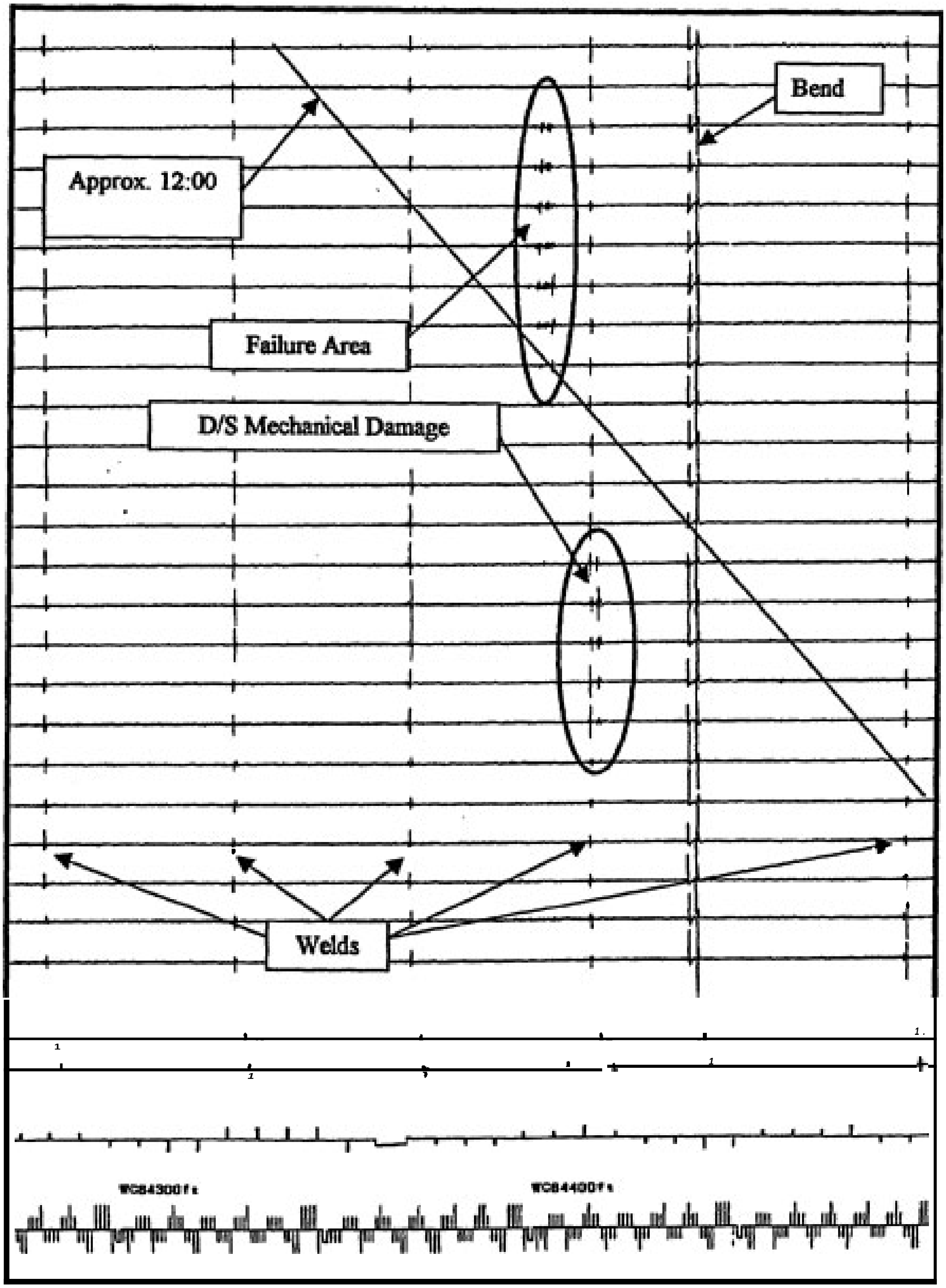
Origin of Failure:

Figure **1.** is a scanned graphic of the **1996** Linalog log at an area described by others as the origin of failure which is contained within an area on the **log** centered at approx. wheel count WC 84404. I added all annotations to the graphic for clarification purposes except the wheel count (WC) at the bottom that is a permanent part of the original log presentation.

It is impossible to establish a precise log correlation to each of the gouges in the area of the origin of failure due to the presence of corresponding denting at each point **of** damage. The physical resultant on the log is a series of predominantly low frequency, low amplitude signals indicative of denting over a large area with several higher amplitude, higher frequency signals present throughout the area. Physical movement of the transducer assembly in toward the central axis of the pipe as it passes over a dent causes a **low** frequency signal to be be generated. Thus, it is an indicator that deformation is present. It is not always as prevalent as is shown here and that is a function of the abruptness of the dent. These impact origin dents are usually quite abrupt as compared to a dent caused from the pipe resting on a rock or a skid. Also this same movement causes poor correlation to three dimensional, metal-loss defects due to the additional variables introduced. The prominent variables are; **loss** in sensitivity to flux leakage due to sensor proximity (lift off), flux leakage pattems normal to the deformed pipe surface instead of normal to straight pipe, and spurious signals generated as a result of sensor assembly bounce.

As a general statement, the signals in the area containing the origin of failure are less th[illegible] the [illegible] in amplitude and are not [illegible] proper waveform to be considered as metal loss. The Tuboscope analysts did, however, recognize the area as one of some potential importance and chose to

Figure 1.



bring it to the attention of OPL by annotating it as a "Possible Wrinkle Bend". I bring it to the attention of OPL by annotating it as a "Possible Wrinkle Bend". I cannot take exception to this procedure because a series of dents does look like the pattem you would expect from a wrinkle bend. In the next joint downstream and just 1.5' downstream from the upstream weld, the analyst called a high frequency, relatively high amplitude signal as a "Possible Mill/Mechanical" with a "Possible Mash" immediately downstream of that. We have seen pictures of this specific location taken from the inside of the pipe after it was removed and the Possible Mash appears to be a quite abrupt dent. Since there are no pictures or any other input relating to the outside of the pipe at that location, we have to assume that the high frequency signal is derived from a gouge associated with the dent. For the record, the analyst has called the bend immediately downstream as a repair sleeve. He observed excess metal type signals only 2 feet in length and called it a sleeve and we now know it to be a bend (which also has excess metal since it is a forged fitting).

Recommendations:

In the Femdale to Allen section, I am of the opinion that the only issues that must be addressed prior to placing the section back in service from a Smart Pig point of view are the actions previously described relating to eliminating the risks at E3, E4, HND3, HND4, and HND6. I am of the opinion that most of this has been done and only final clarification is required. As soon as the new surveys are completed, all of these sites will be correlated in the field on the new logs for final confirmation.

In addition, all of the anomalies in the other 3 sections from 1996 should be correlated to the 2000 surveys to determine if corrections have been made where warranted and to see if there has been any change since the prior surveys.

It has been established that a High Resolution MFL survey will be run immediately after placing the Femdale to Allen pipeline segment back in limited service. This higher quality equipment (Hi-Res) will provide substantially better information than that which has been previously provided with the conventional MFL devices. This service is available through Tuboscope or PII (British Gas + Pipetronix), and they are both capable of providing the quality of data that this situation warrants.

I also recommend that a Deformation survey be performed at the same time and, in my opinion, the Tuboscope device is technically the most appropriate for this situation.

The Service Company chosen must be able to perform the surveys in a timely manner. They must be willing to perform a complete analysis of the data on the 37.4-mile section quickly, accurately, and on location so that decisions can be made very soon after the survey relative to allowing this section of the pipeline to remain in limited operation.

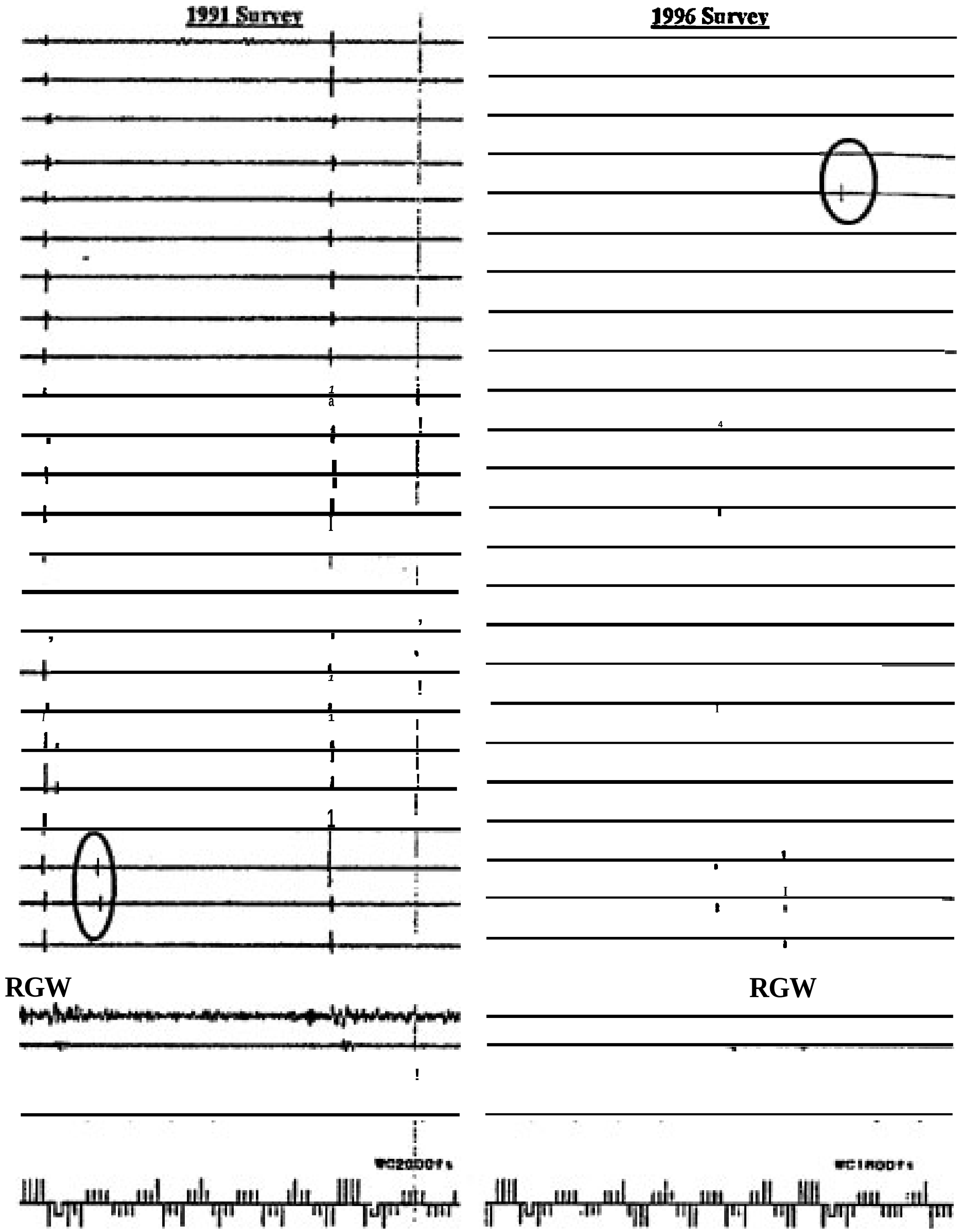
Attachments:

Appendix A ———————— —— 1991/1996 Linalog excerpts, Femdale to Renton.
Appendix B ——————————- Tabulation of results, Femdale to Renton.
Appendix C —————————— Tabulation of results, all sections, containing approximate location of County Lines.
Appendix D ————————— —— Details relating to Origin of Failure.

H. Noel Duckworth
January 24, 2000

APPENDIX A

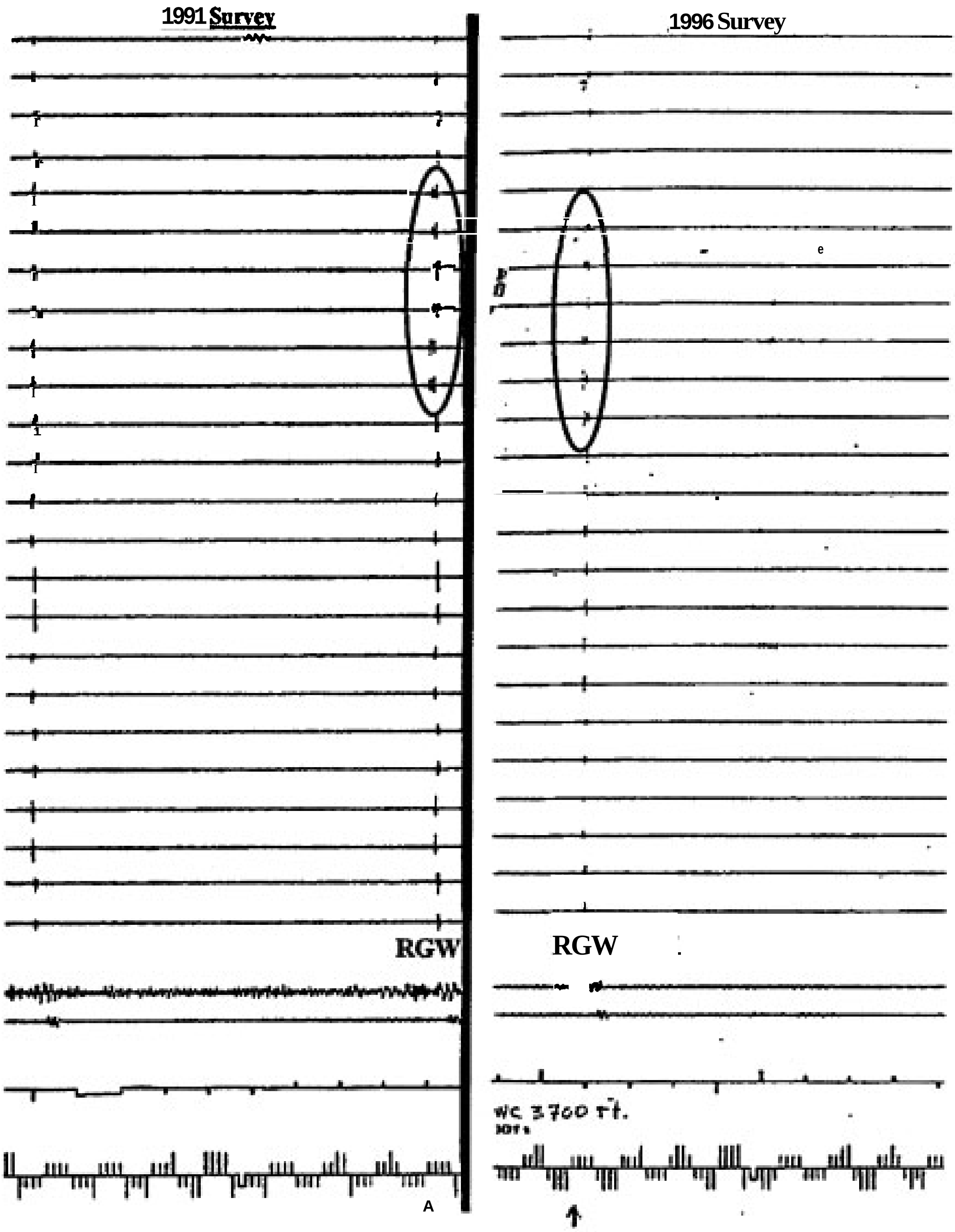
Linalog Survey - Olympic P/L - 16" FemdaIe to Allen



D1, RGW = **1792' 3.2", Defect** is 8' *7.4"* D/S **of** RGW at **5:00.** **Hi** Freq. **Mill origin type signal.**

APPENDIX A

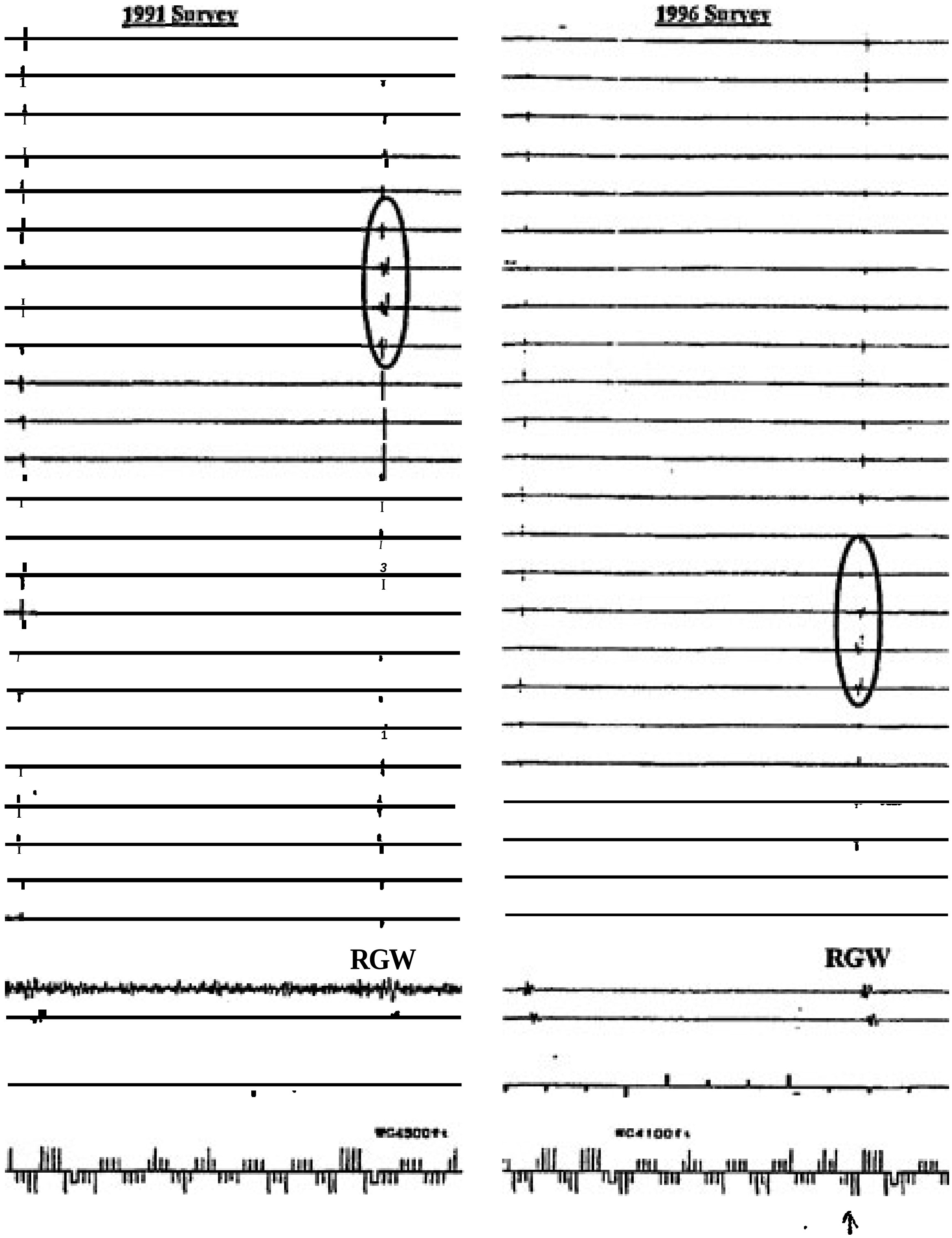
Linalog Survey - Olympic P/L - 16" Ferndale to Allen



D2, RGW = 3722' 2.3", Defect is 6.7" U/S of RGW at 3:00. Weld area corrosion pattern.

APPENDIX A

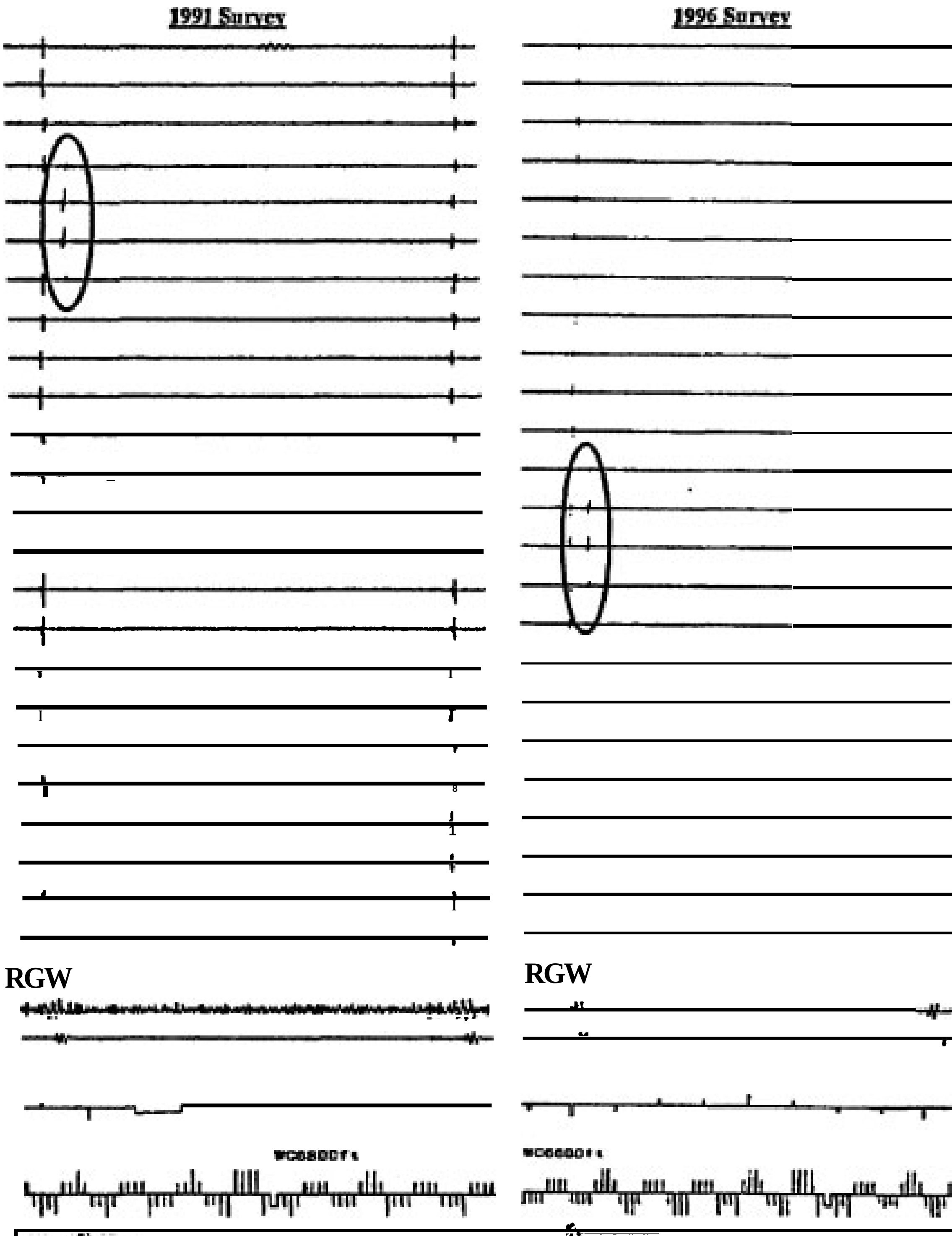
Linalog Survey - Olympic P/L - 16" Ferndale to Allen



D3, RGW = 4143' 8.2", Defect is 6" U/S & D/S of RGW at 4:00. Weld area corrosion.

APPENDIX A

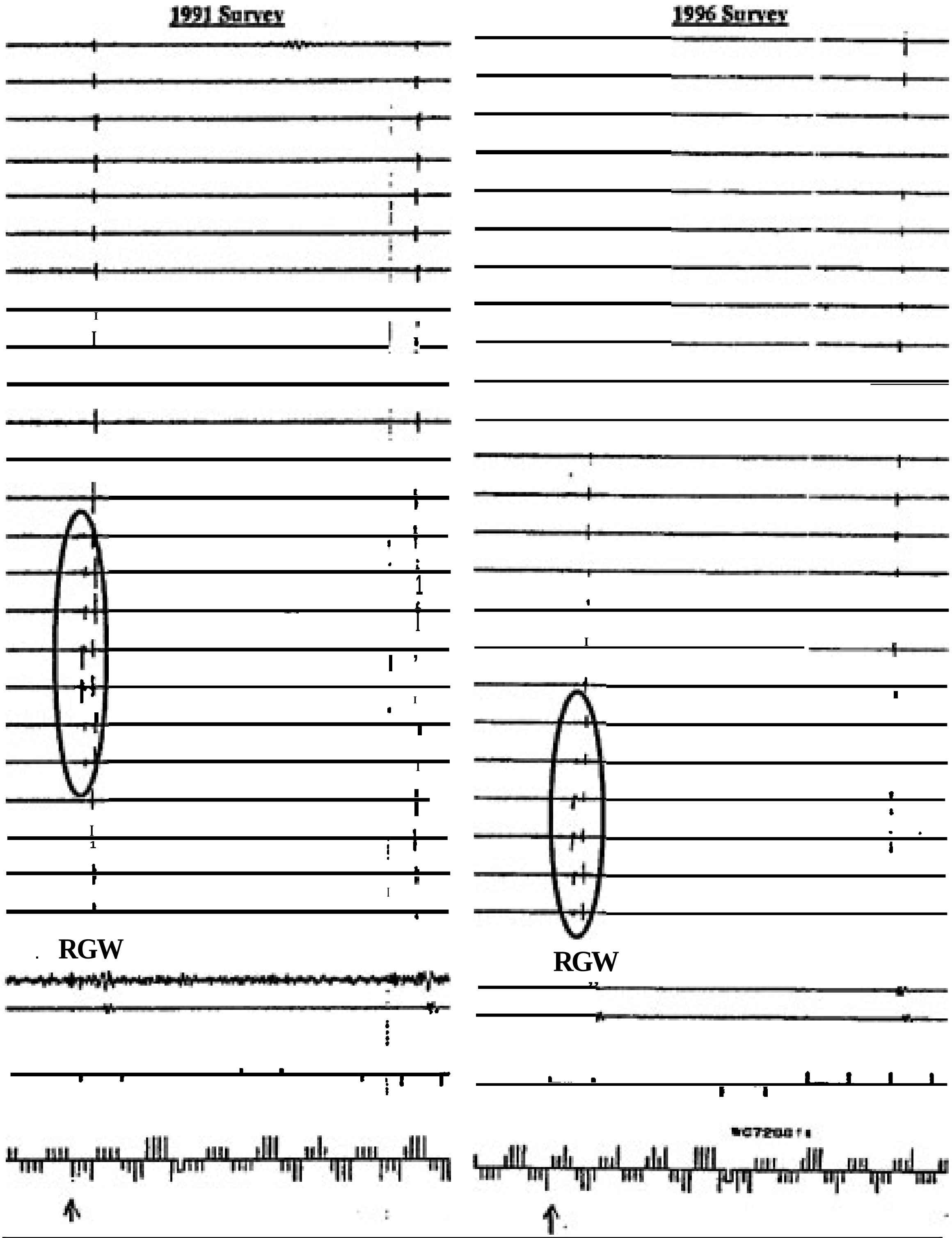
Linalog Survey - Olympic P/L - 16" Ferndale to Allen



FEATURE, RGW = 6610' 9.2", Defect is 3' D/S of RGW at 6:00. Isolated corrosion or mill origin defect.

APPENDIX A

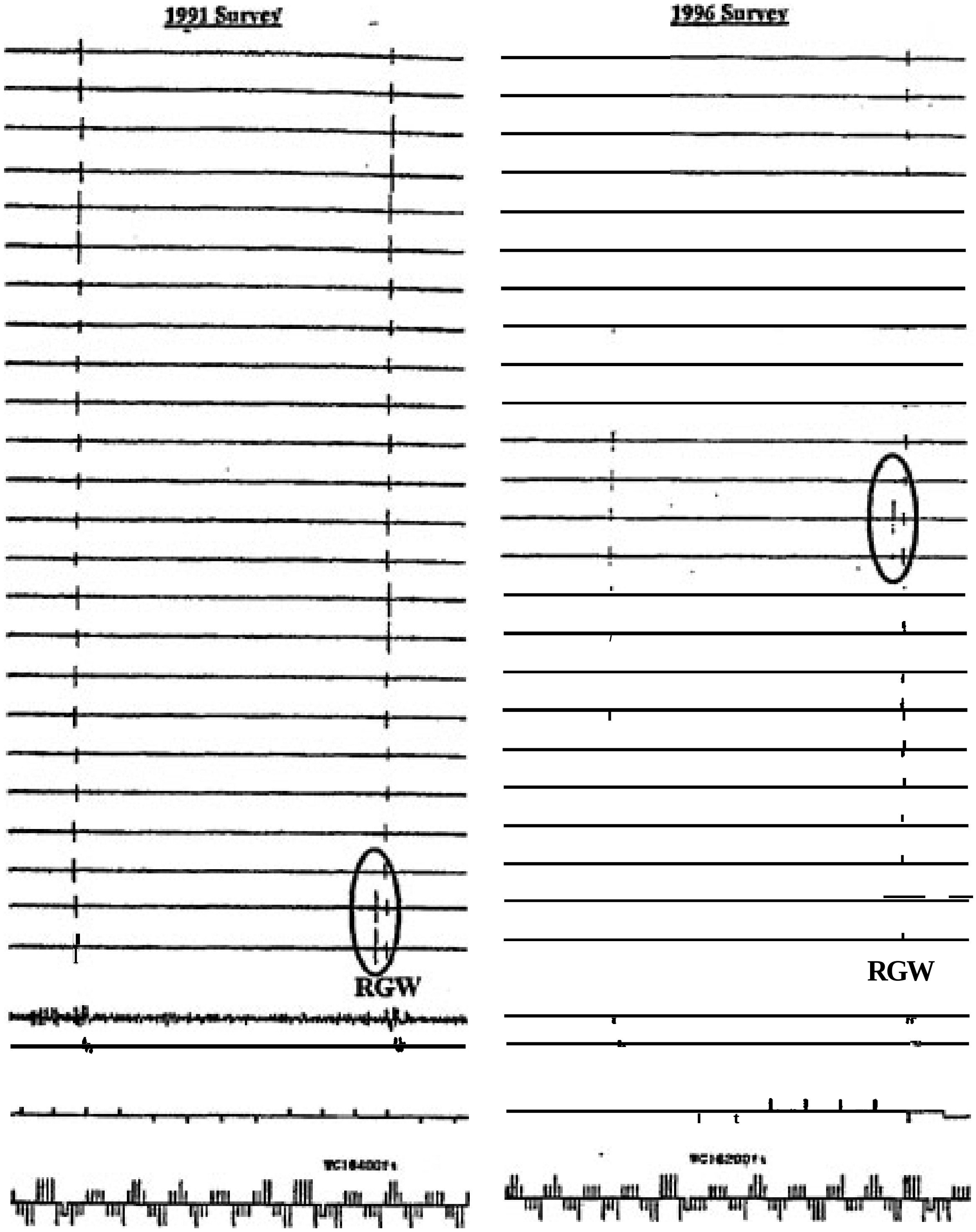
Linalog Survey - Olympic P/L - 16" Ferndale to Allen



FEATURE, RGW = 7175' 3.9", Defect is 1' 5" U/S of RGW at 8:00. Mill origin type signal.

APPENDIX A

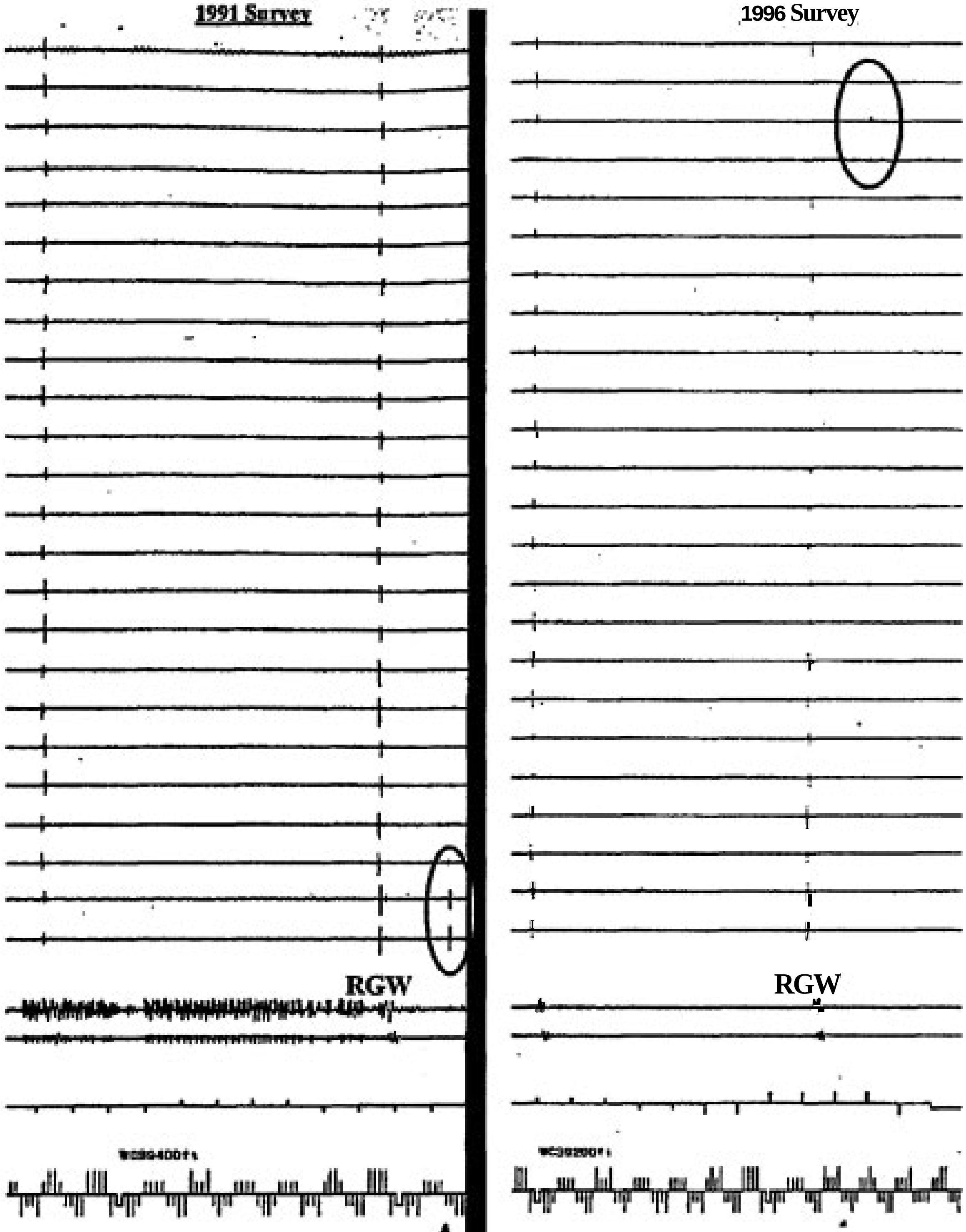
Linalog Survey - Olympic P/L - 16" Ferndale to Allen



D5, RGW =16244' 2.3", Defect is 2' 2.5" U/S of RGW at 4:00. Isolated Corrosion or Mill origin defect.

APPENDIX A

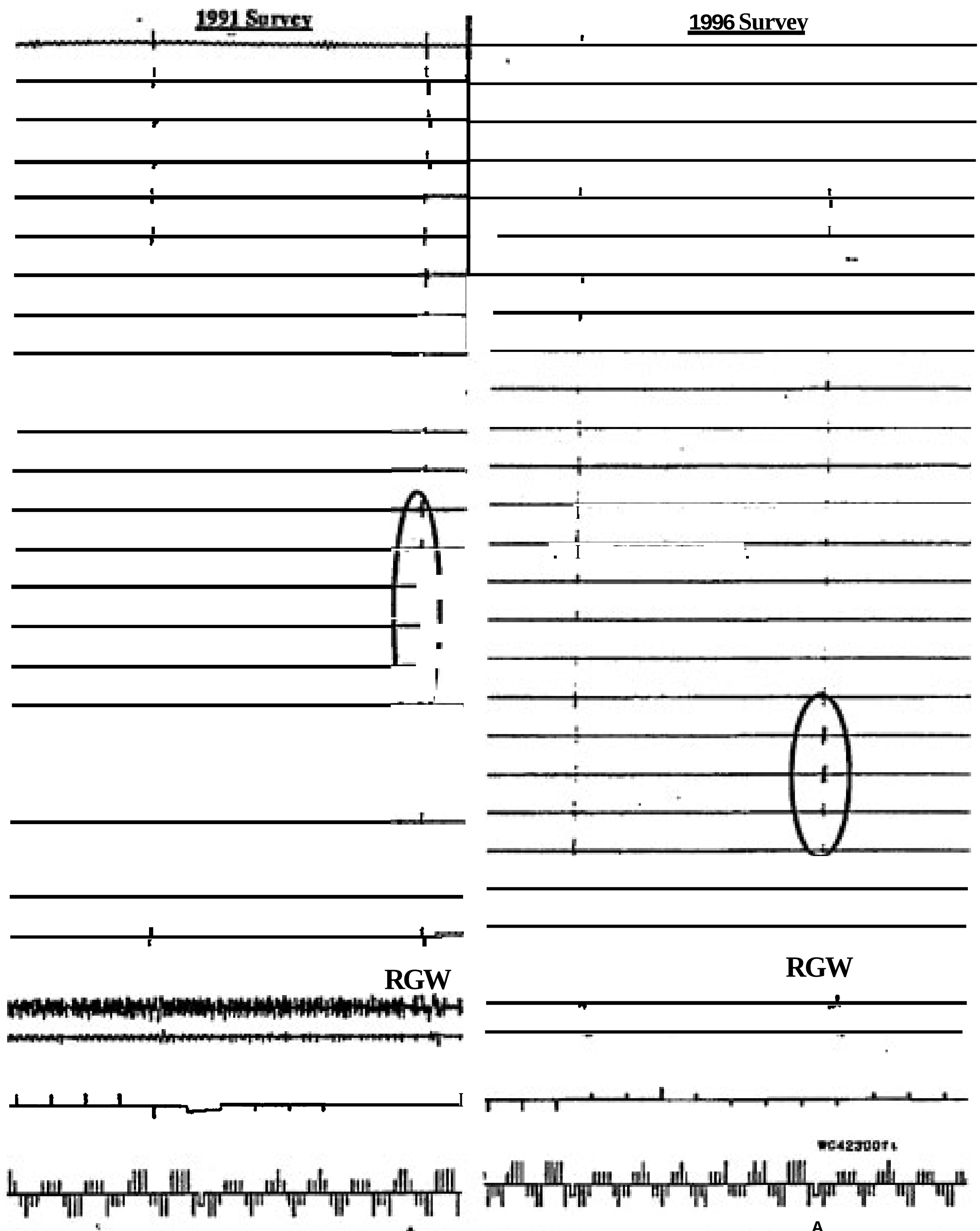
Linalog Survey - Olympic P/L - 16" Ferndale to Allen



D6, RGW =39259' 0.3", Defect is 12' 8.3" D/S of RGW at 6:00. Hi Freq, Mill origin Type defect.

APPENDIX A

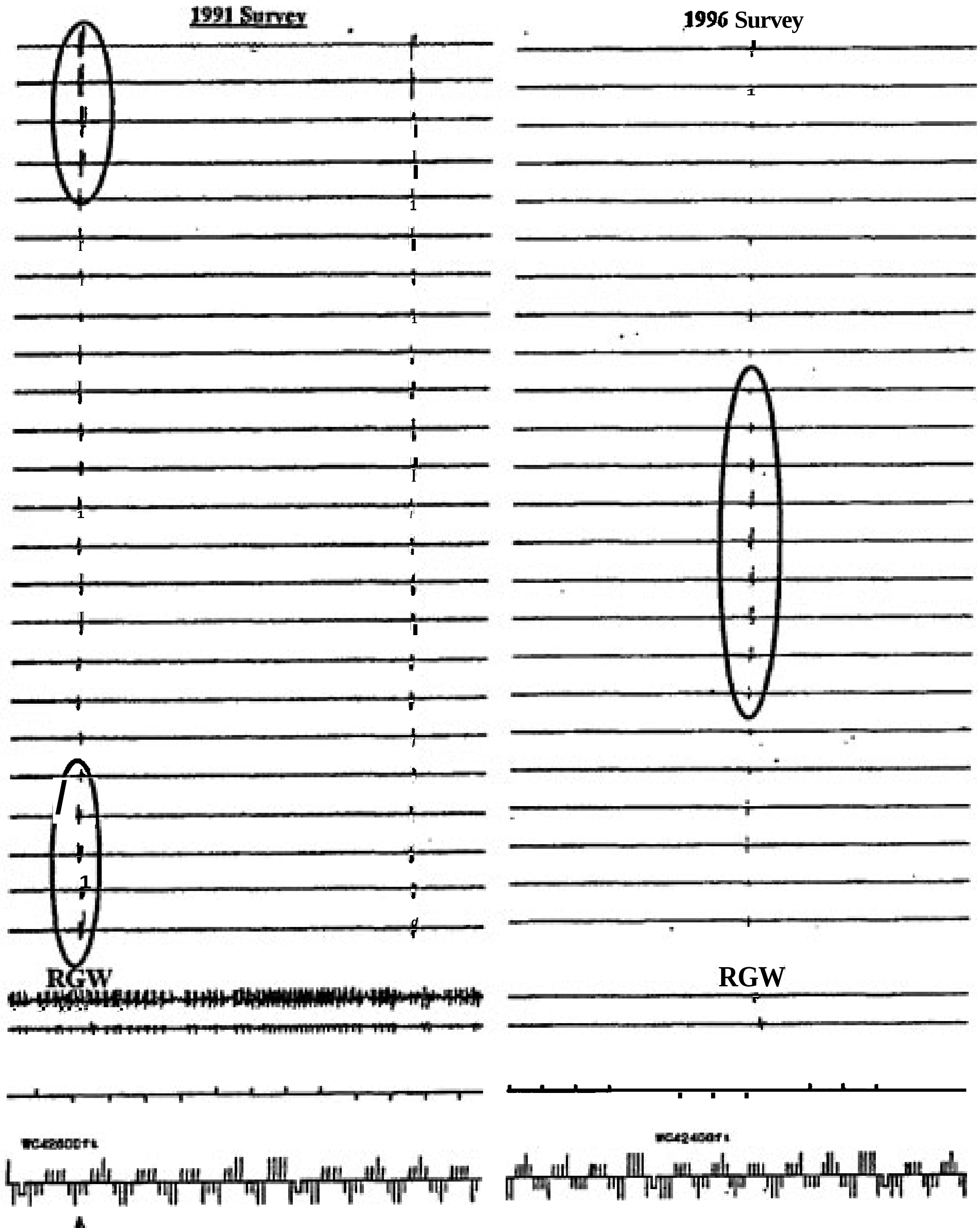
Linalog Survey - Olympic P/L - 16" Ferndale to Allen



D7, RGW =42309' 9.3", Defect is *6.0"* U/S & D/S of RGW at 4:00. Weld area corrosion.

APPENDIX A

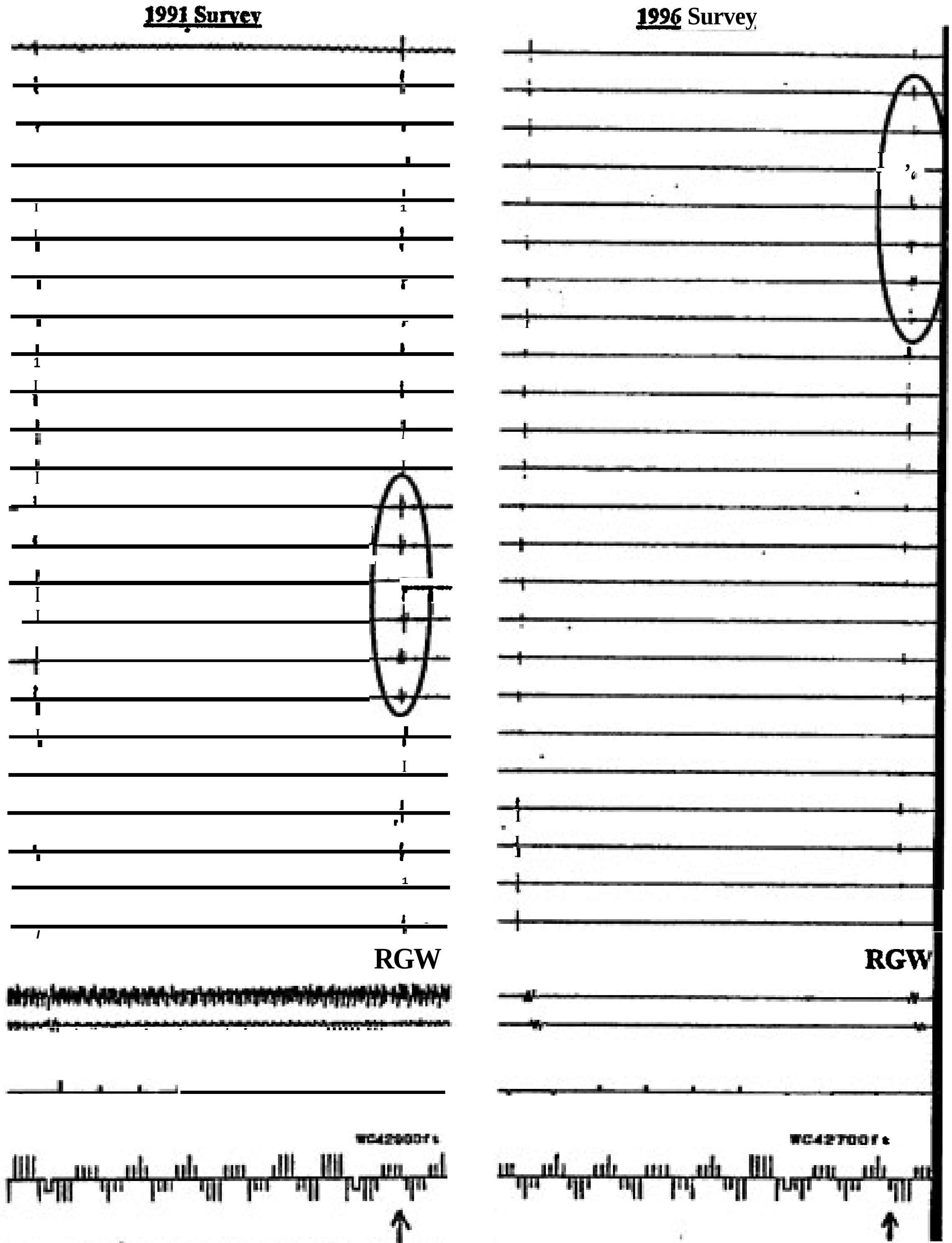
Linalog Survey - Olympic P/L - 16" Femdale to Allen



DS, RGW =42420' 7.7", Defect is *6.0"* U/S & D/S of RGW *at* 5:00. Weld area corrosion.

APPENDIX A

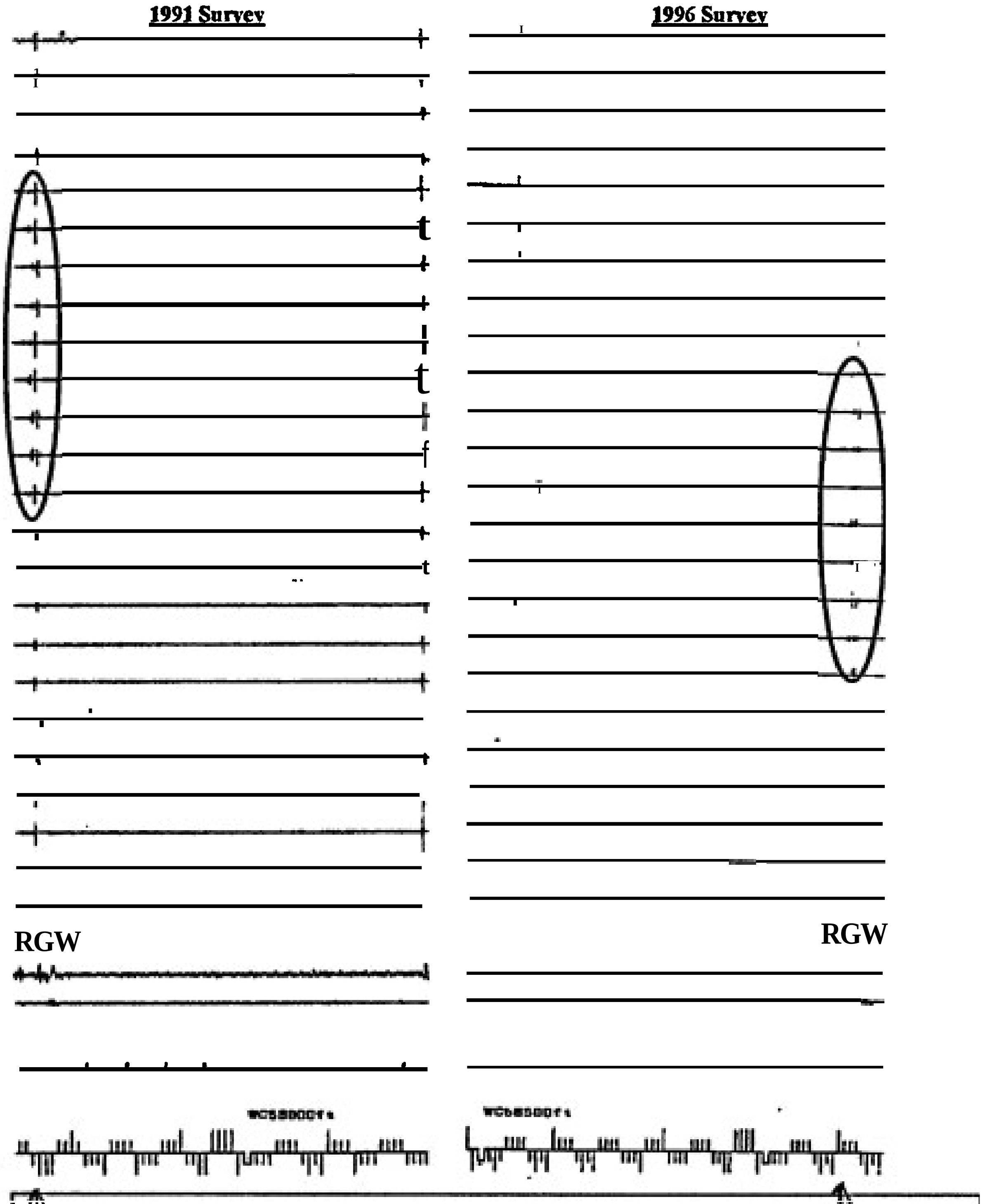
LinaIog Survey - OIympic P/L - 16" Ferndale to Allen



HND I, RGW 42718' 2.5", Defect is 6" U/S & D/S of RGW at 4:00. Weld area corrosion.

APPENDIX A

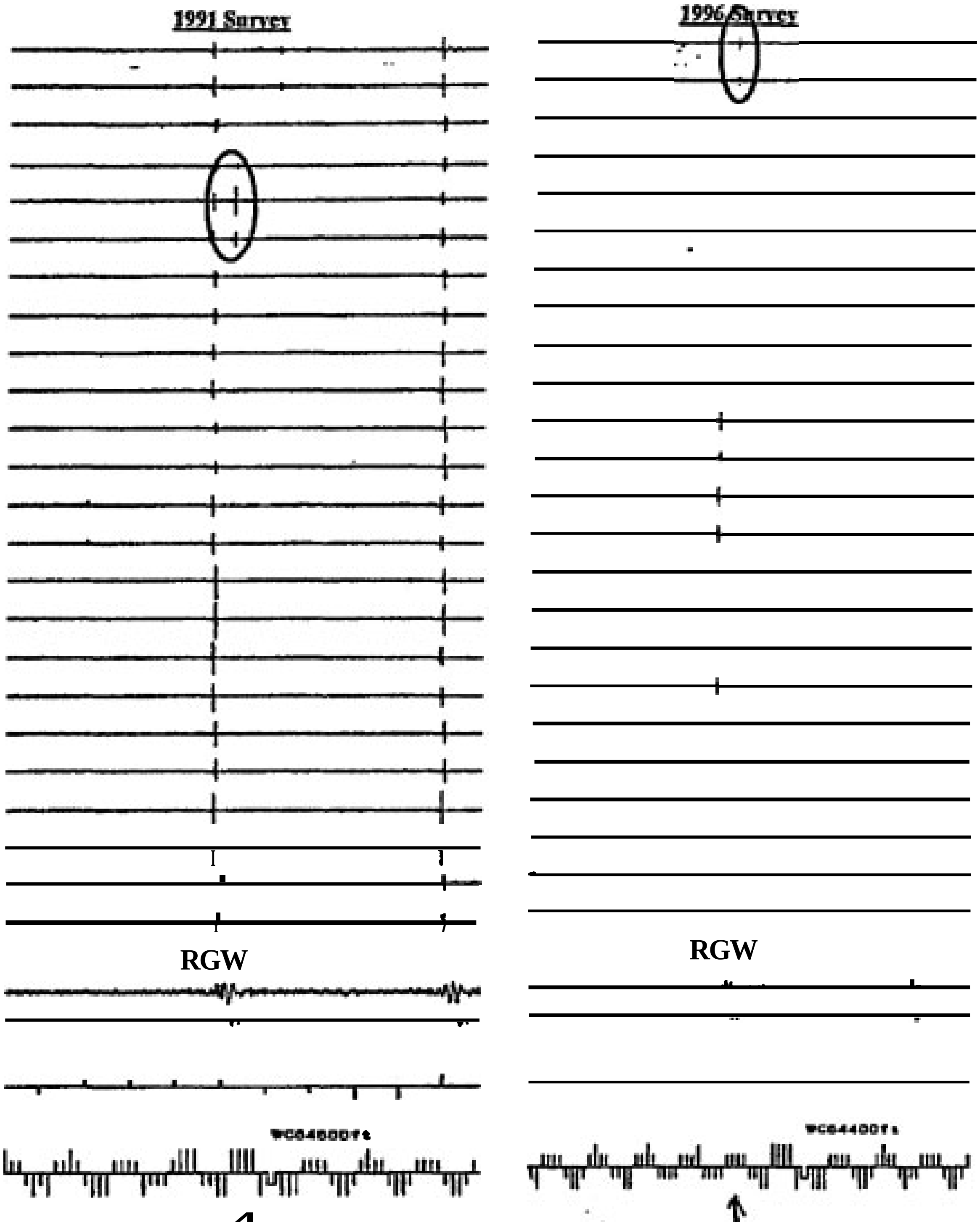
Linalog Survey - Olympic P/L - 16" Femdale to Allen



D9, RGW =58563' 10.7", Defect is 6.0" US&D/S of RGW at 6:30. Weld area corrosion.

APPENDIX A

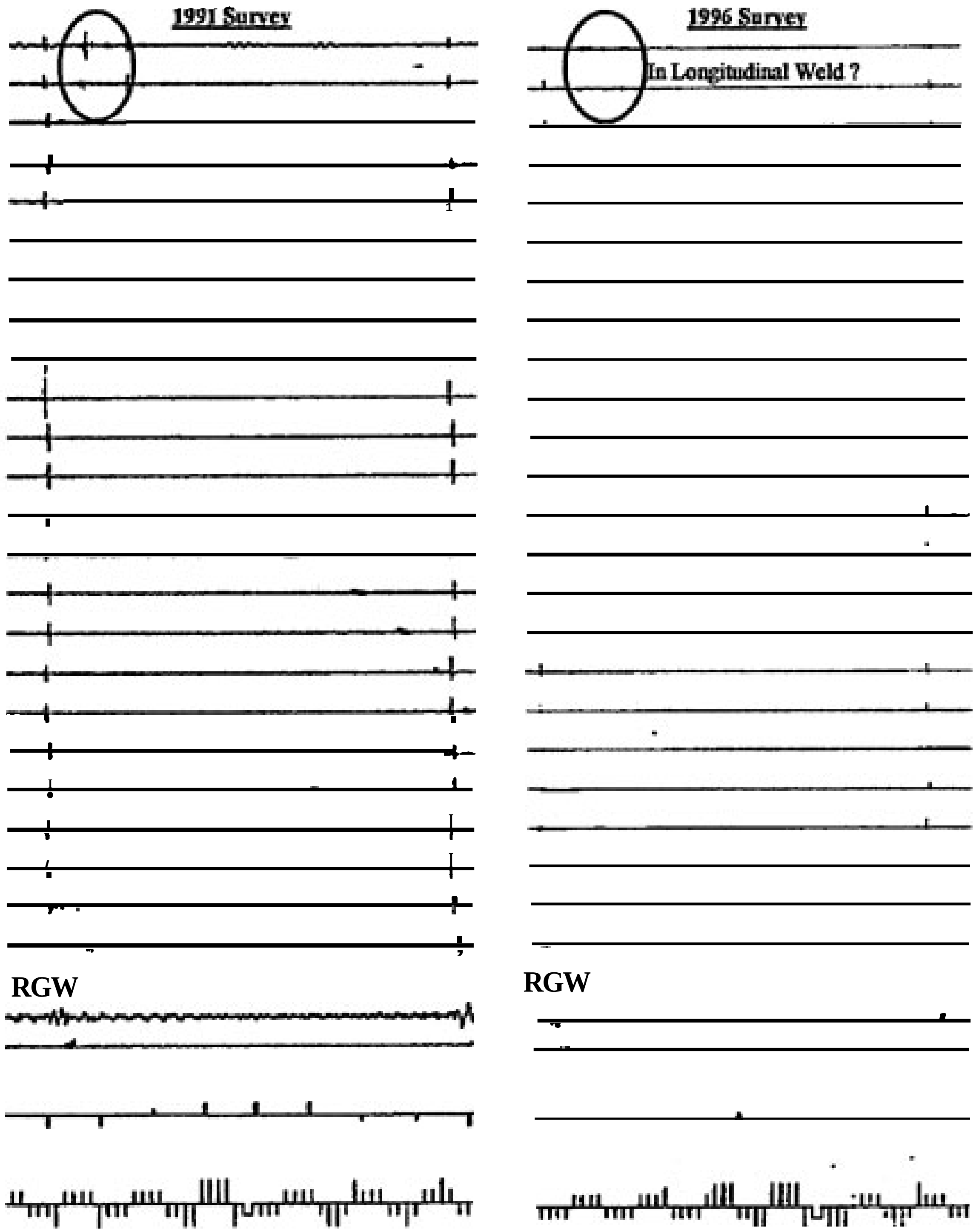
Linalog Survey - Olympic P/L - 16" Ferndale to Allen



D10, RGW =64385' 0.5", Defect is 3'0.5" D/S of RGW at 1:00. Hi Freq Mill origin.

APPENDIX A

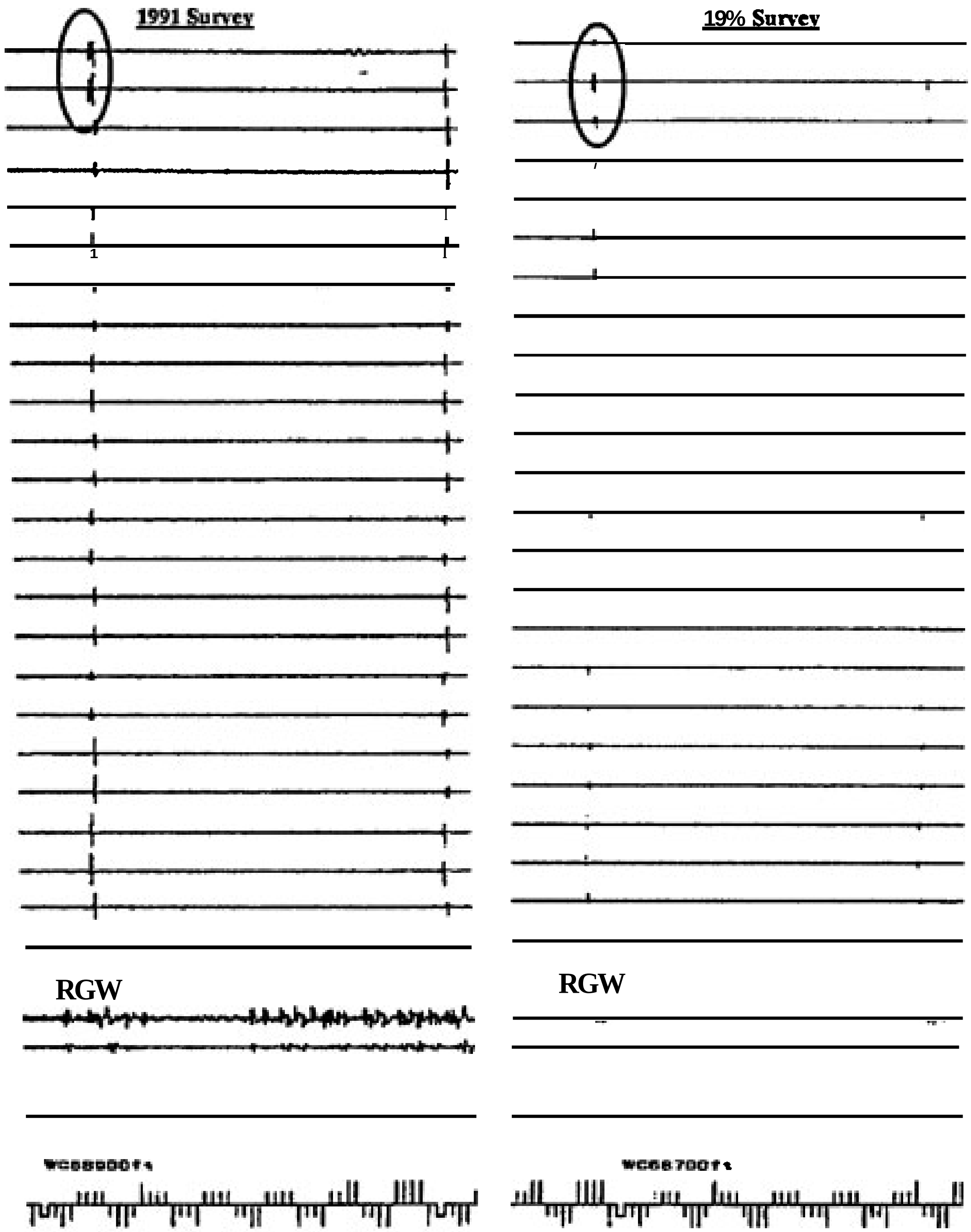
LinaIog Survey - Olympic P/L - 16” Ferndale to Allen



D11, RGW =68017’ 0.1”, Defect is 9’1.1” D/S of RGW at 1:00. Hi Freq Mill origin.

APPENDIX A

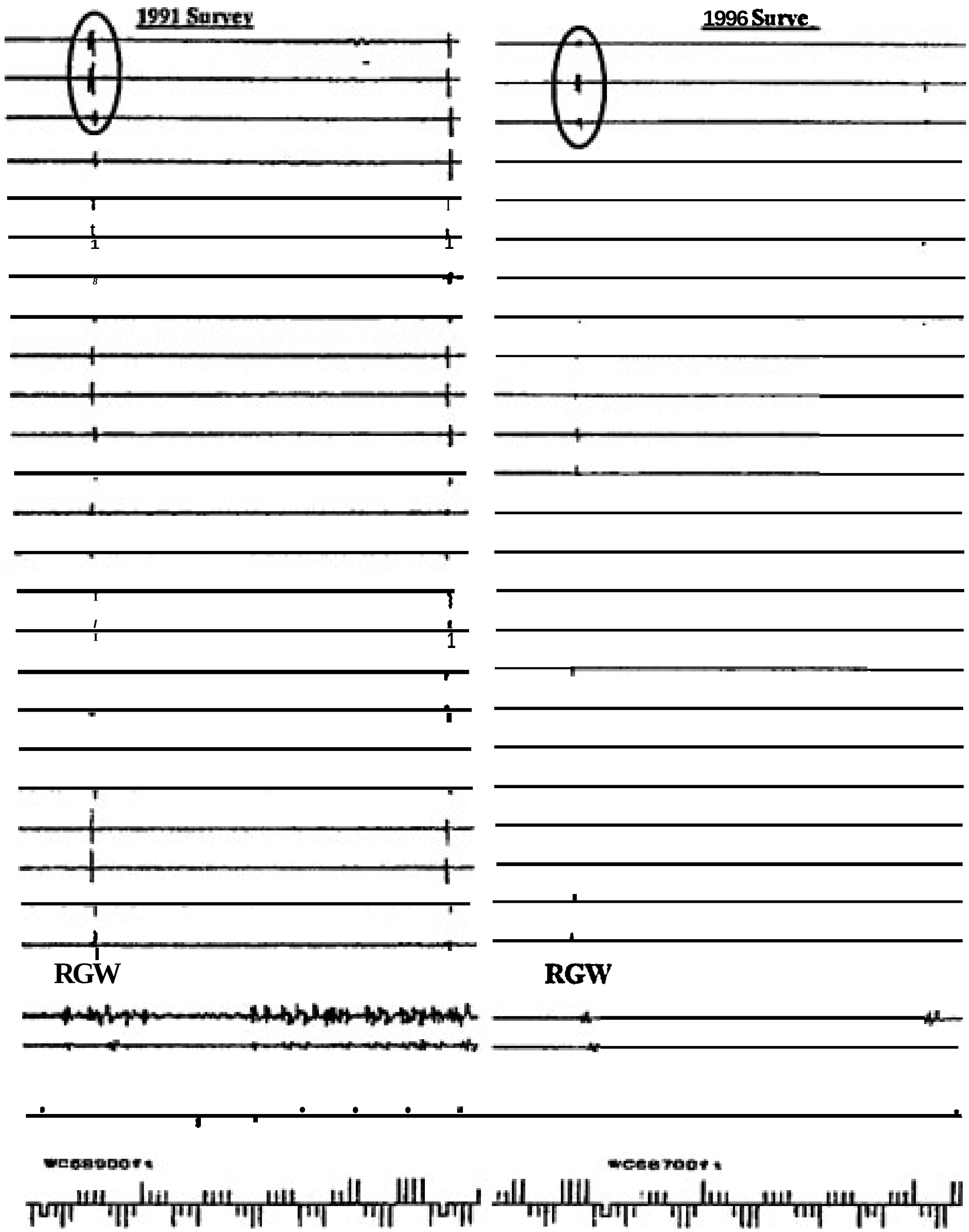
LinaIog Survey - Olympic P/L - 16” FerndaIe to Allen



D12, RGW =68695’ 10.9”, **Defect is** 5.5" **U/S of** RGW **at** 5:00. Weld *Area* Corrosion.

APPENDIX A

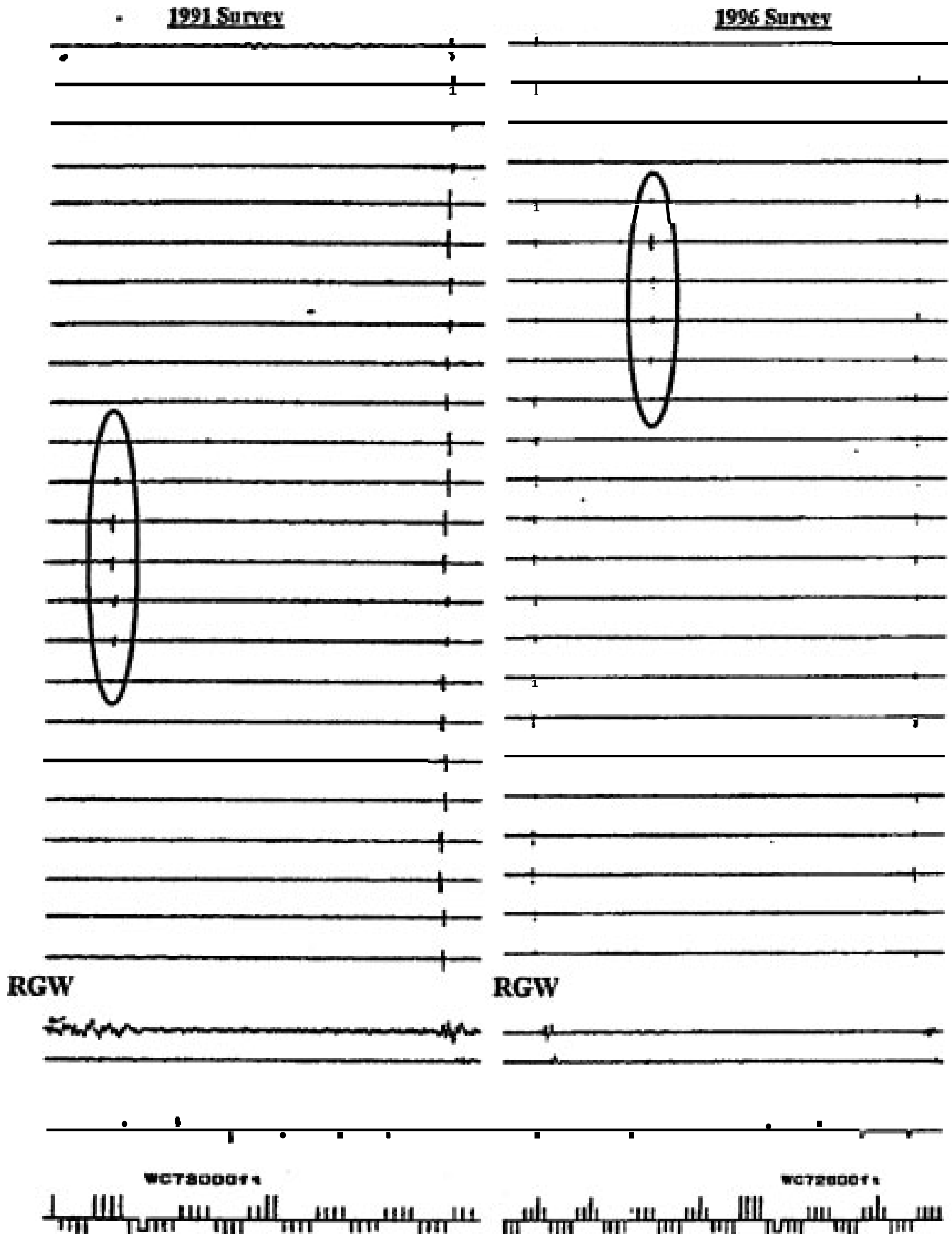
LinaIog Survey - OIympic P/L - 16" FerndaIe to Allen



D13, RGW =68695' 10.9", Defect is 2.7' U/S of RGW at 5:00. Weld Area Corrosion.

APPENDIX A

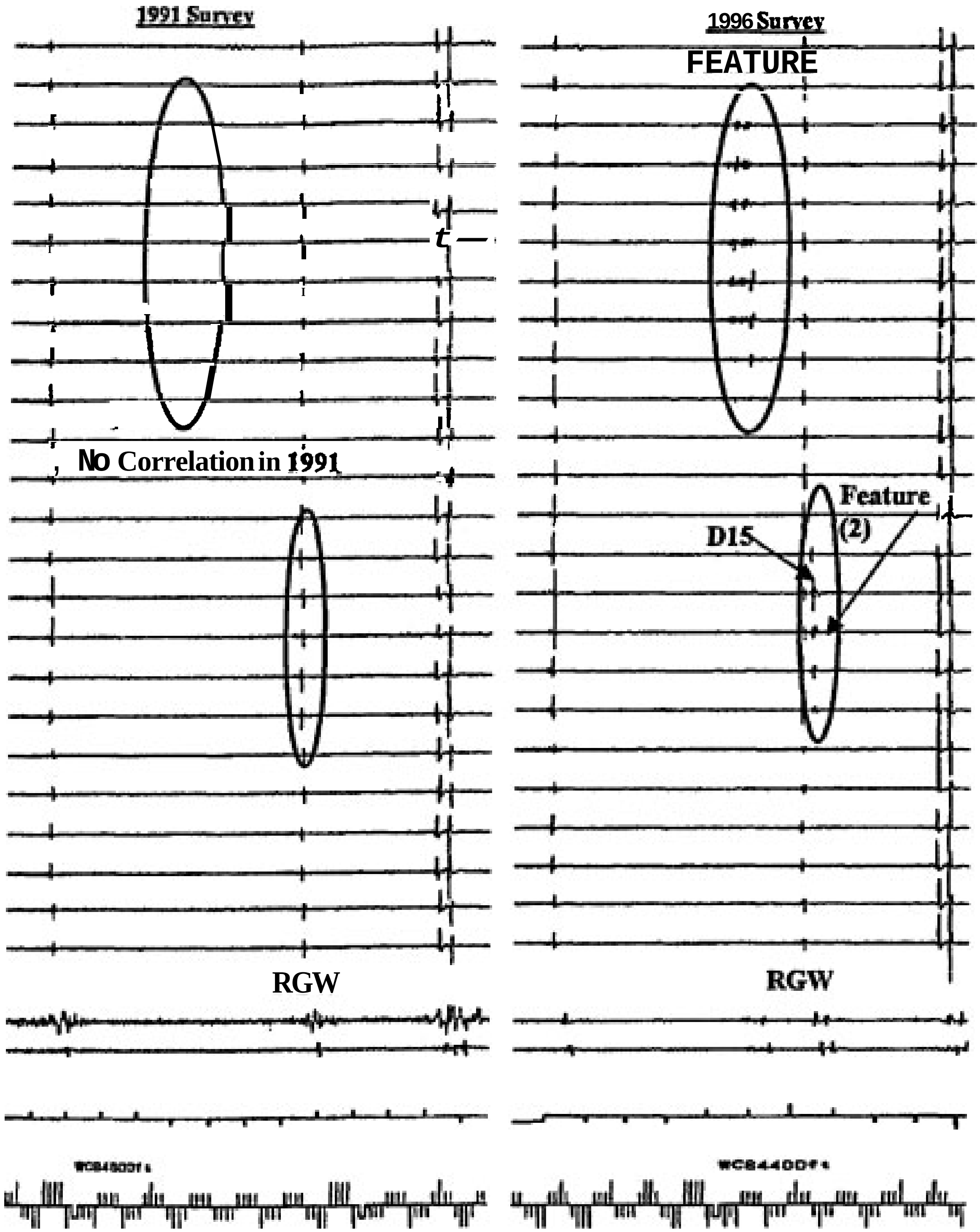
Linalog Survey - Olympic P/L - 16” Ferndale to Allen



D14, RGW =72764’ 6.4”, Defect is 17’ 3”” D/S of RGW *at* 7:00. Hi **Freq**, Mill origin.

APPENDIX A

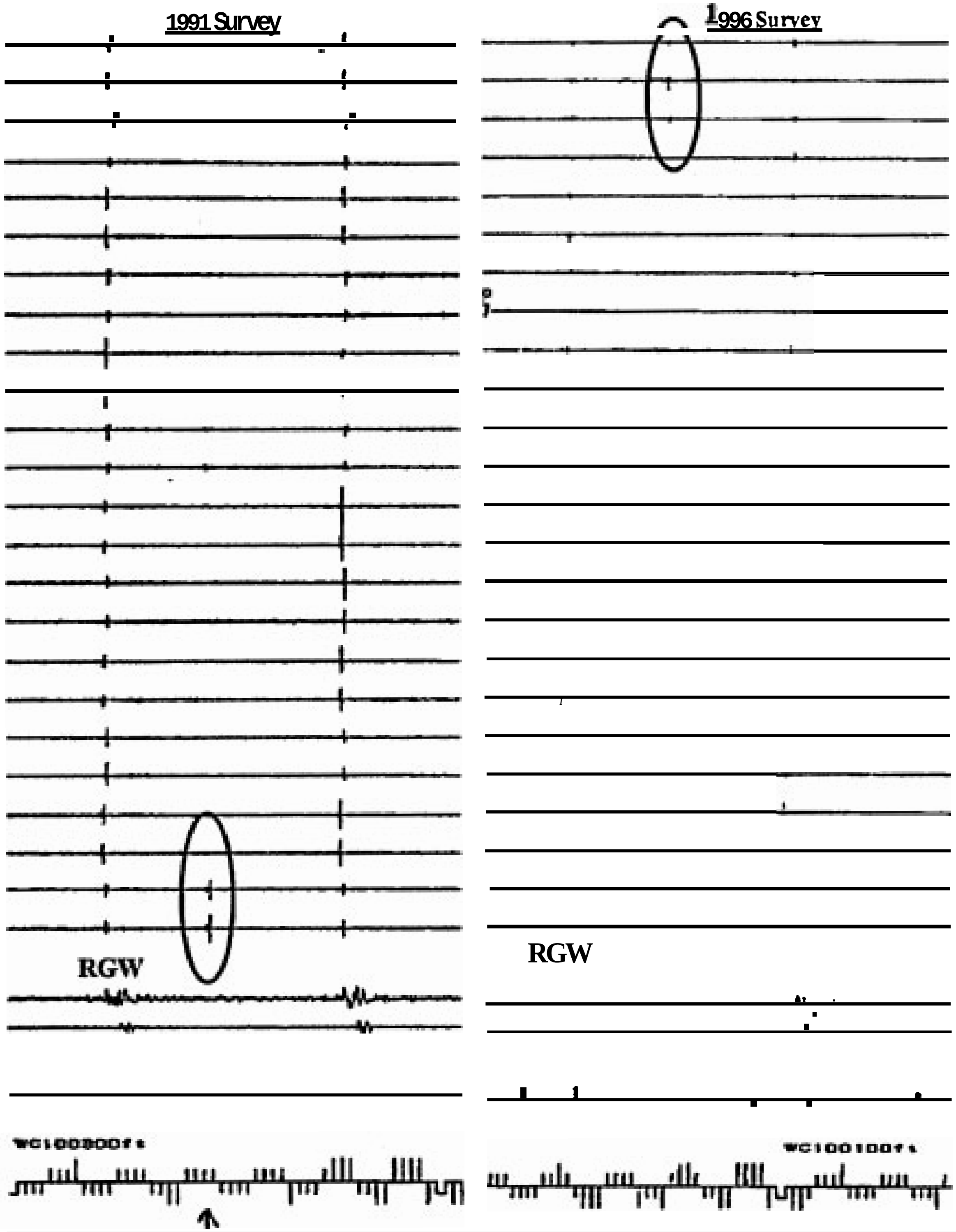
Linalog Survey - Olympic P/L - 16” Femdale to Allen



FEATURE, D15, Feature (2). **RGW=84402’, Defect** *Area* **contains Origin of Failure** and other *damage* **D/S of Origin.** See Body of Report for Details.

APPENDIX A

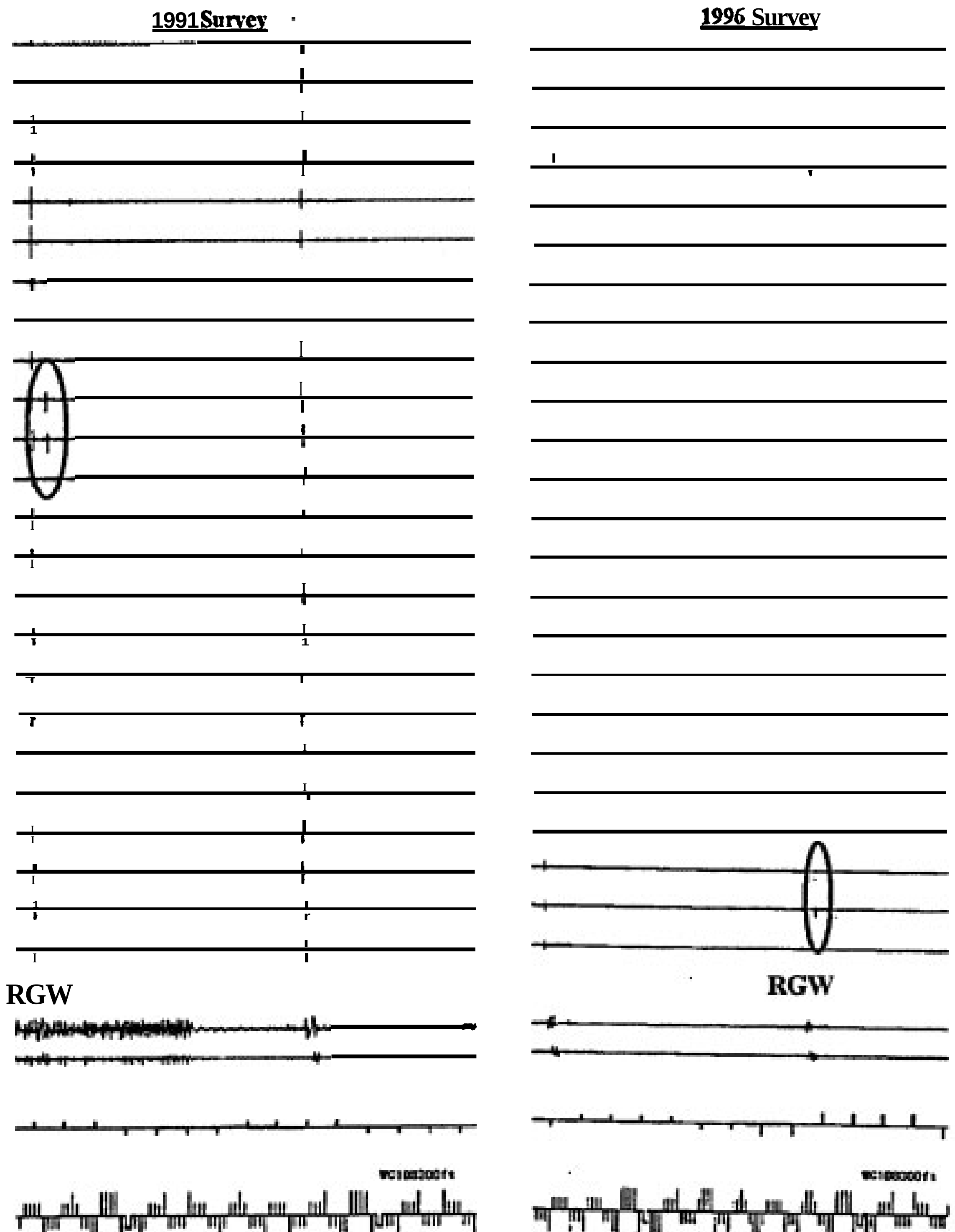
Linalog Survey - Olympic P/L - 16” Femdale to Allen



D16, RGW –100072’ 11”, Defect is 12’1.3” D/S of RGW at 10:00. Hi Freq, Mill origin.

APPENDIX A

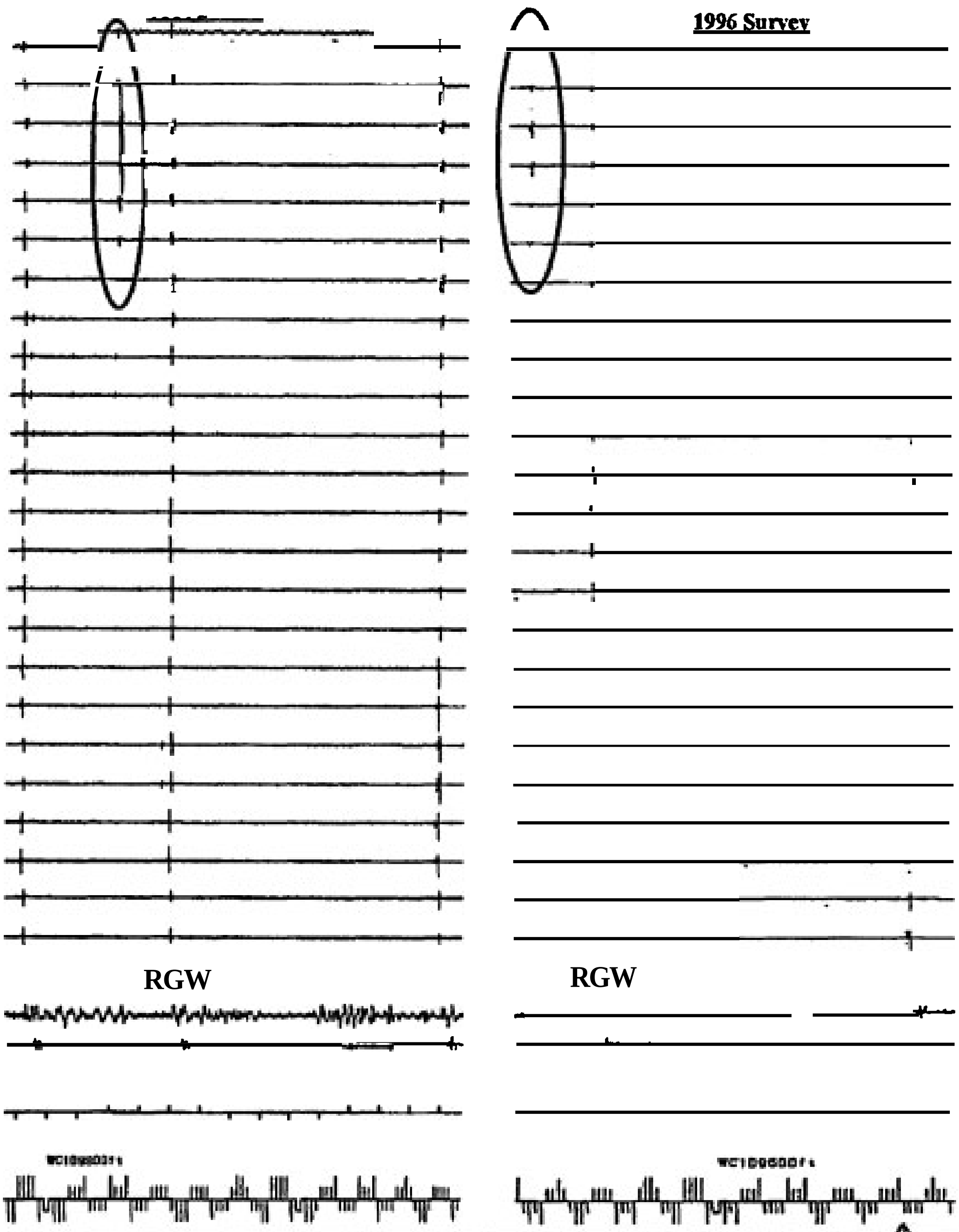
Linalog Survey - OIympic P/L - 16" FerndaIe to Allen



D17. RGW =107986' 3.1", Defect is 3'1.1" D/S of RGW at 8:00. Hi Freq, Mill origin.

APPENDIX A

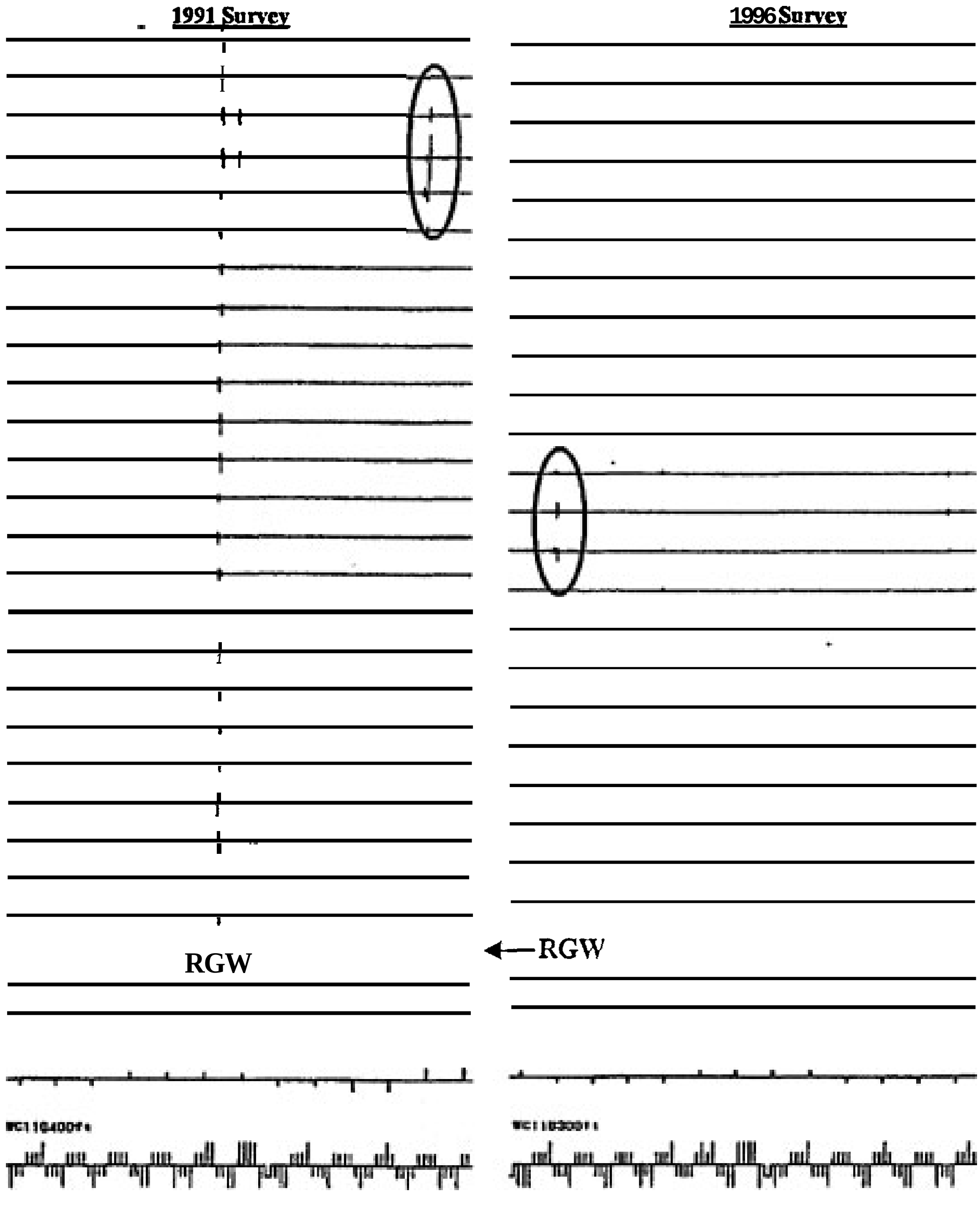
LinaIog Survey - Olympic P/L - 16” Ferndale to Allen



HNI 2, RGW =109634’ 0.8”, Defect is *8.0”* U/S of RGW at 6:00. Weld Area Corrosion.

APPENDIX A

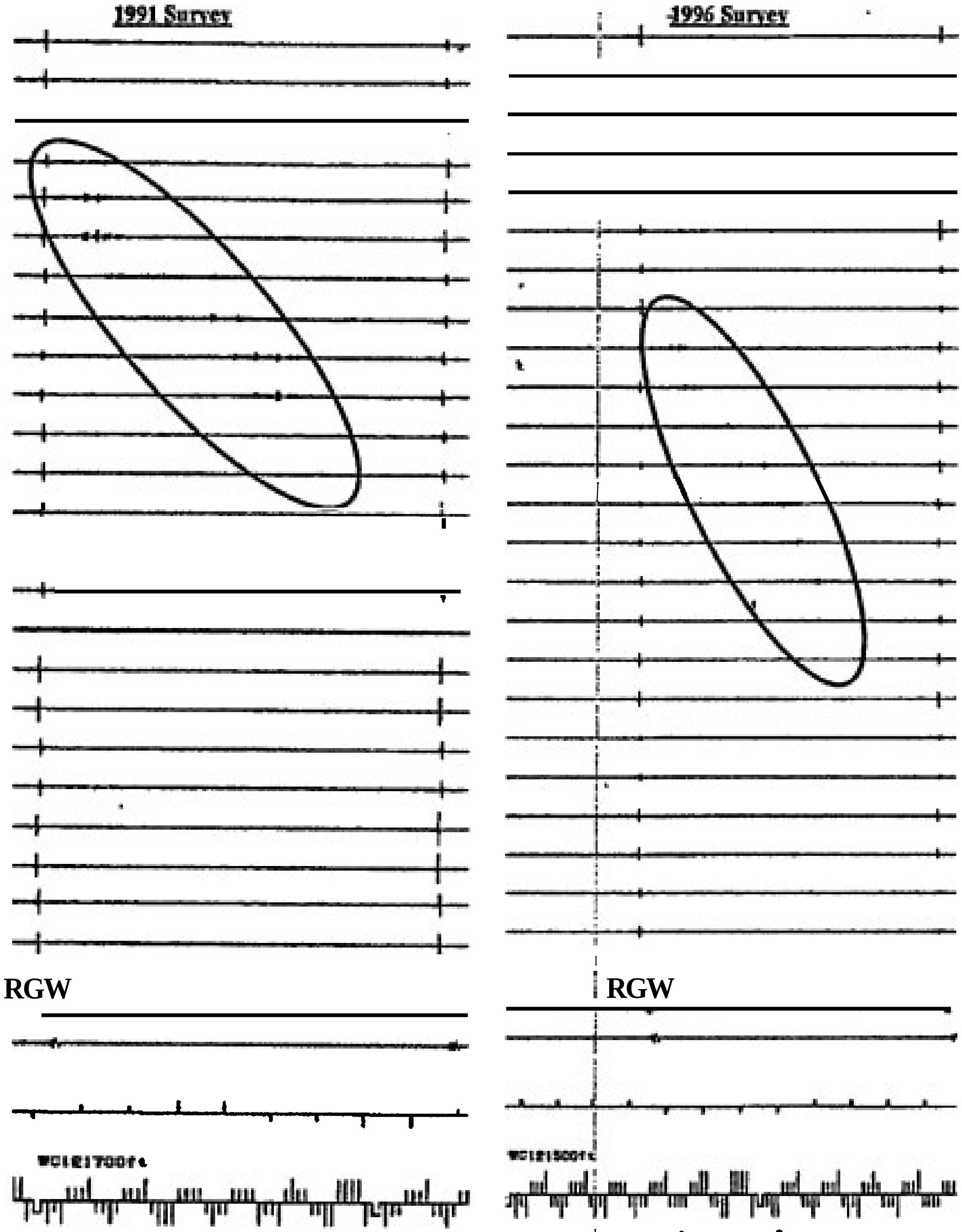
Linalog Survey - Olympic P/L - 16" Femdale to Allen



D18, RGW = 110330' 1.9", Defect is 20'10.2" U/S of RGW at 5:30. Isolated Corrosion or Mill origin Type.

APPENDIX A

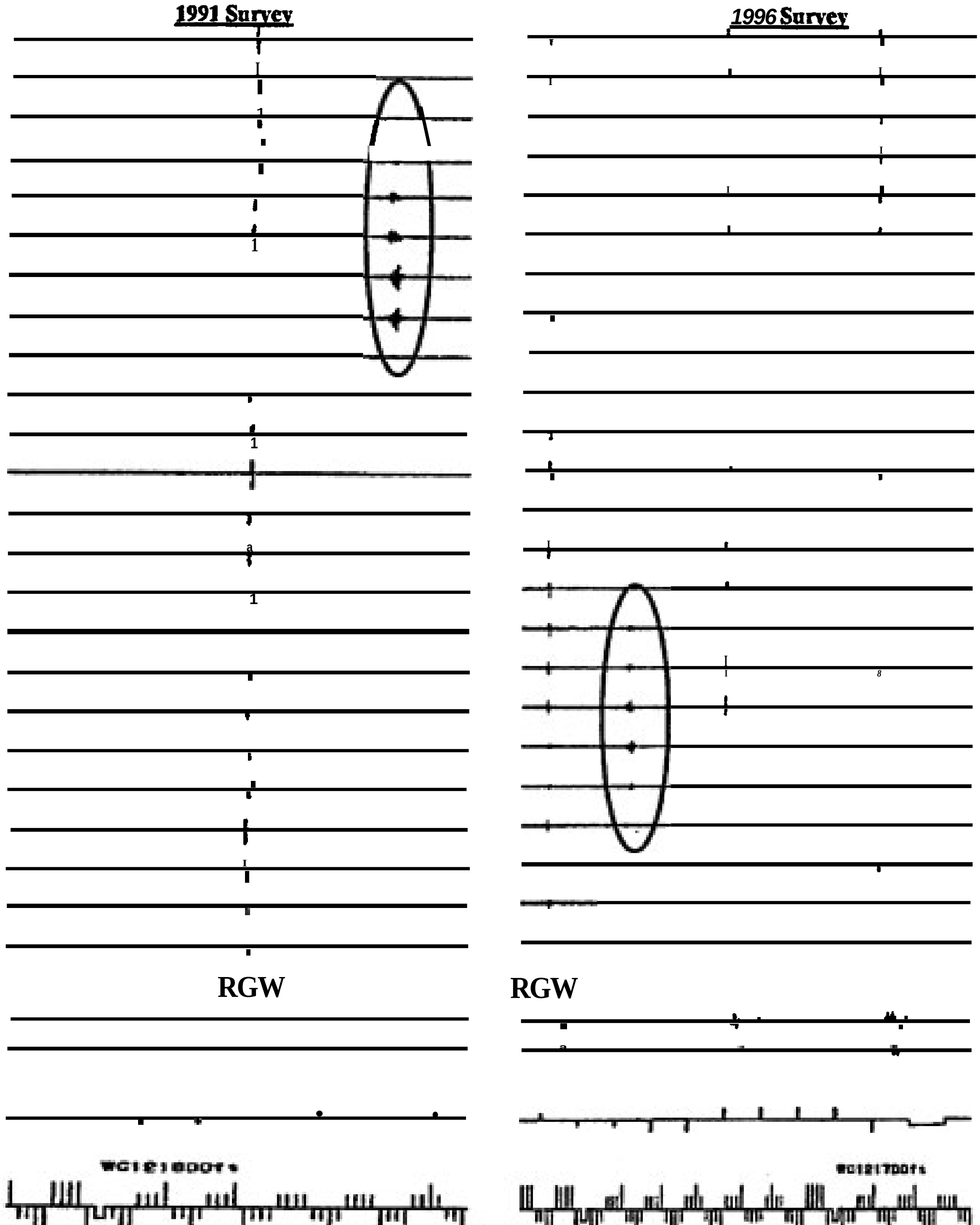
LinaIog Survey - Olympic P/L - 16" Ferndale to Allen



HND3,'RGW =121526' 9.5", Defect is 6' to 33' D/S of RGW at 11:00. Hi Freq, Very Light *Corrosion* or Mechanical Damage.

APPENDIX A

Linalog Survey - Olympic P/L - 16" Ferndale to Allen



HND4, RGW = 121643' 3.0", Defect is 16' D/S of RGW at 6:00. Hi Freq, Corrosion Area.

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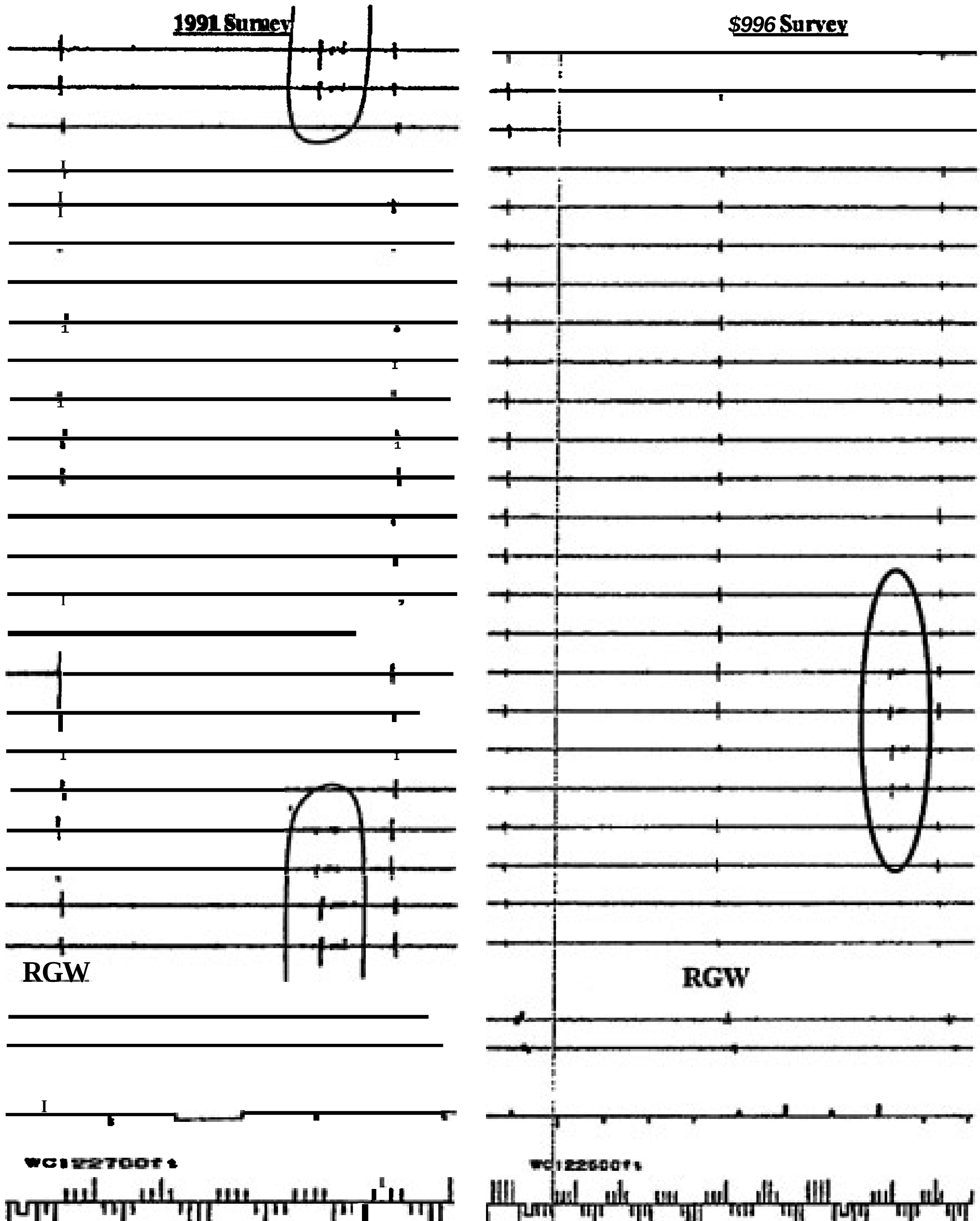
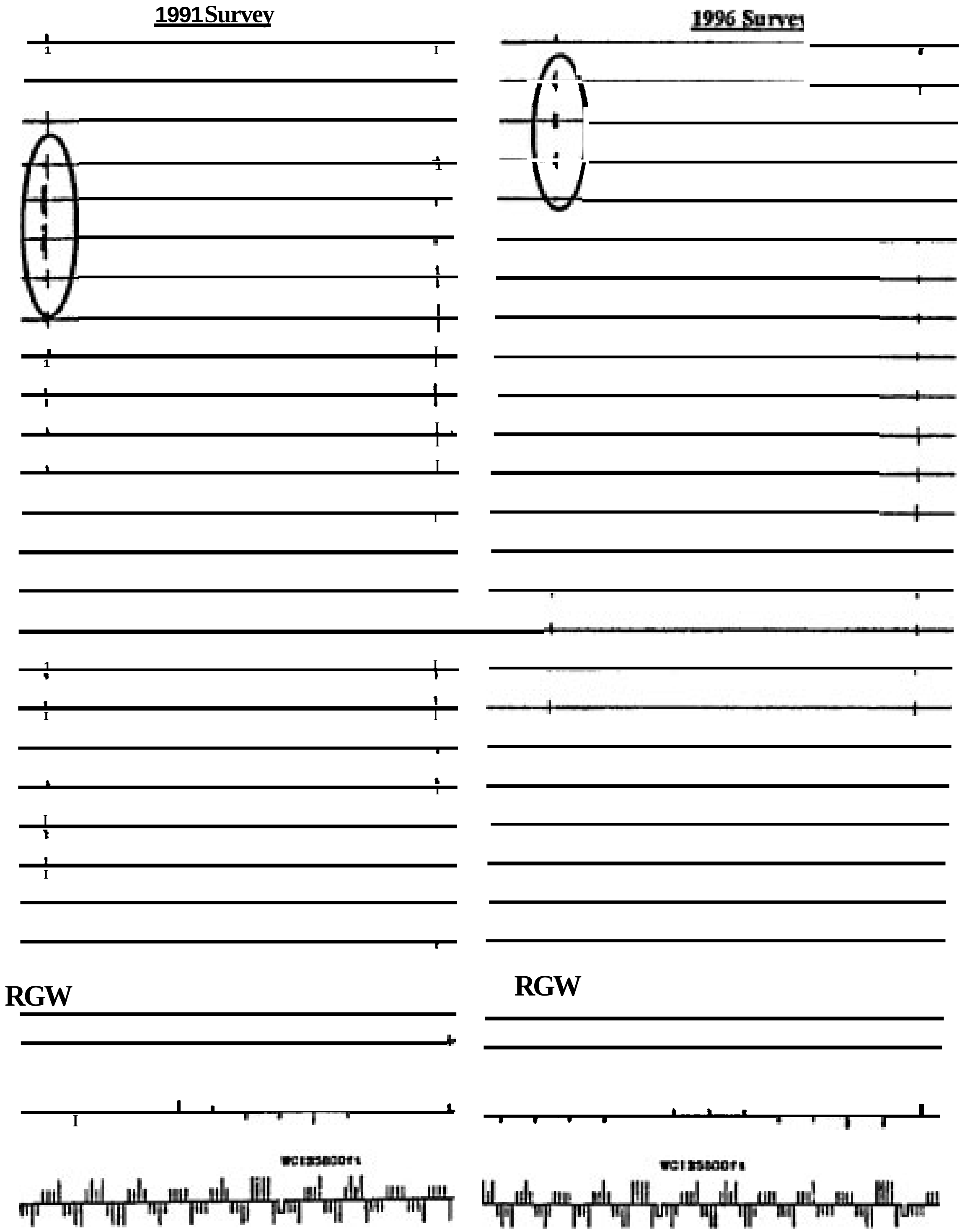
Linalog Survey - Olympic P/L - 16” Femdale to Allen



D19, RGW –122530’ 7.2”, Defect is 26’1.2” D/S of RGW at 5:00. Corrosion or Mill origin.

APPENDIX A

Linalog Survey - Olympic P/L - 16" Femdale to Allen



D20, RGW = 135577' 4.1", Defect is 6" U/S of RGW at 4:00. Weld Area Corrosion.

APPENDIX A

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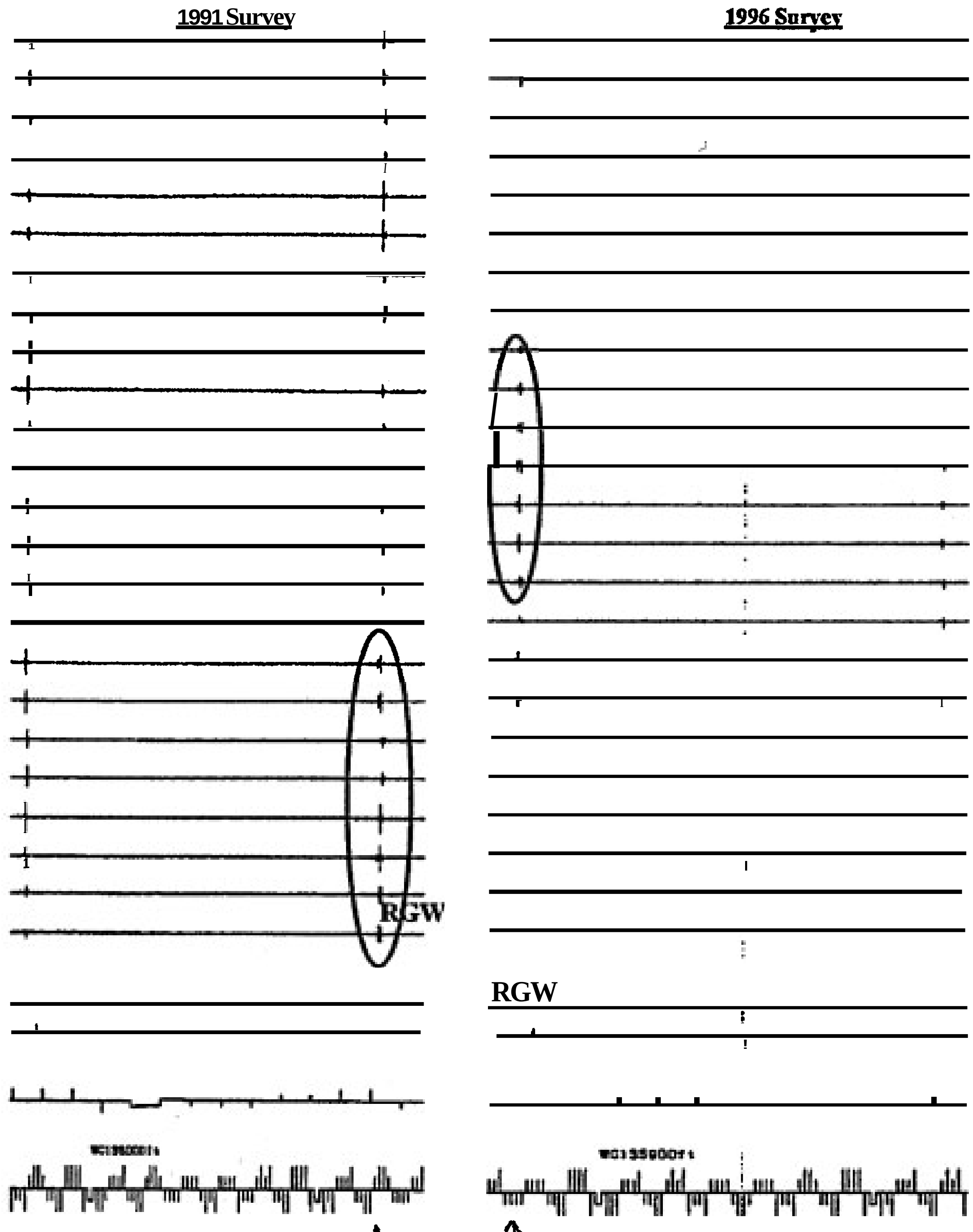
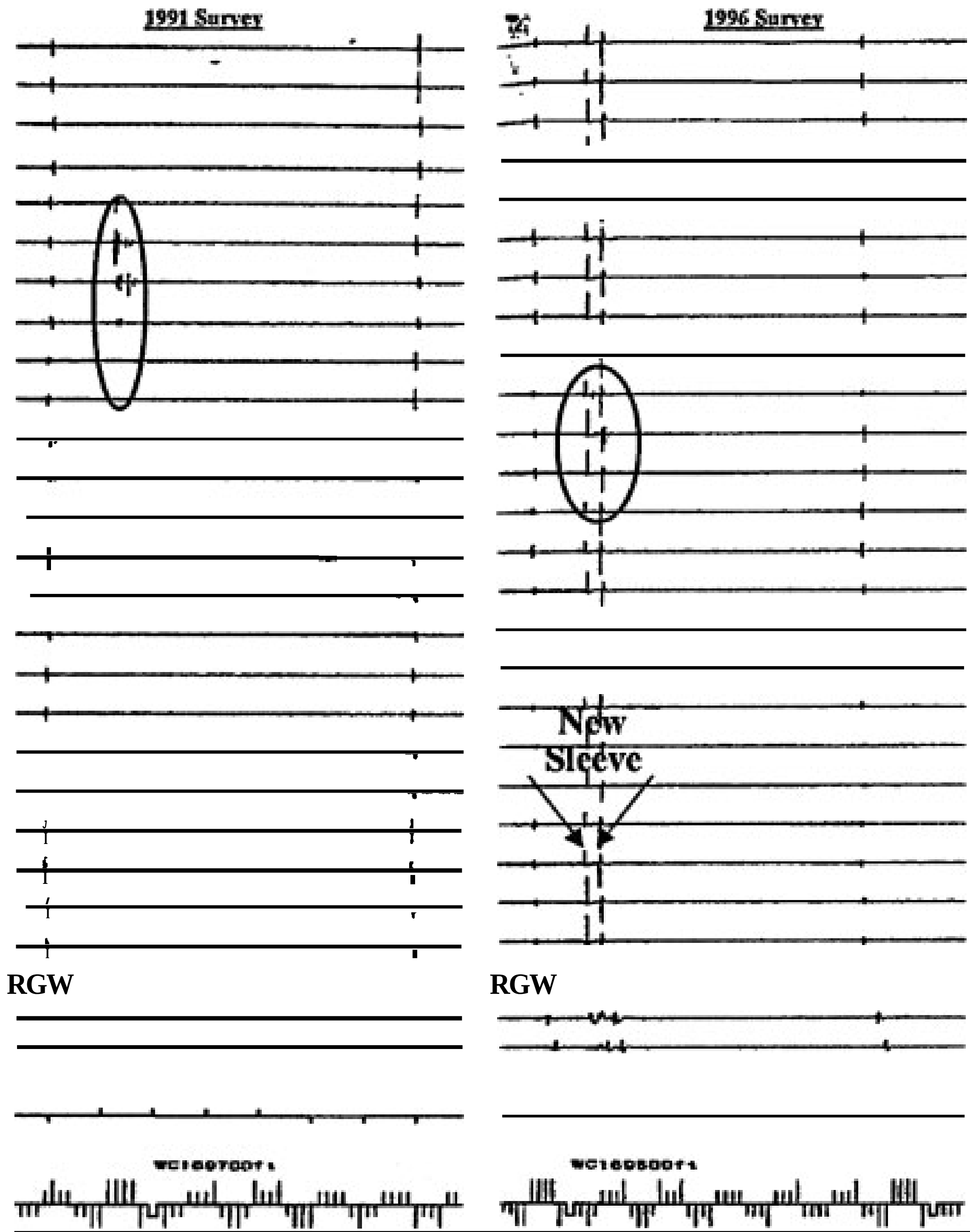


HND5, RGW =135885' 2.2", Defect is *6"* U&D/S of RGW at 4:00. Weld *Area* Corrosion.

APPENDIX A

Linalog Survey - Olympic P/L - 16” Ferndale to Allen



HND6, RGW =169502’ 9.1”, Defect is 2′1.1″ D/S of RGW. Sleeve does not cover defect.

Appendix B

OLYMPIC P/L CO. 16" REFINED PRODUCTS PIPELINE Defect Analysis, Ferndale to Allen, Wa.										
Identifier	Ref. Weld Linalog 1996 WC	Distance	Direction	O'Clock	Number of Chans.	1991 Tubo Log	1996 Tubo Log	1997 Enduro Log	Tubo / Enduro Comments	HND Comments
EI	Sta. 0+14					N	N	Y	"0.82" TOTAL-0.56" *SHARP* (In TEE)	Probably a Bar Aligned Poorly
M	1792' 3.2"	8' 7.4"	D/S	5:00	2	Y	Y	N		Hi Freq - Mill Origin Type Signal
D2	3722' 2.3"	6.7"	U/S	3:w	6	Y	Y	N		Weld Area
D3	4143' 8.2"	6.0"	U&D/S	4m	3	Y	Y	N		Weld Area
FEATURE	6610' 9.2"	3' 0"	D/S	6:00	4	Y	Y	N	Isolated Corr. or Mill Origin	Isolated Corr. or Mill Origin
FEATURE	7175' 3.9"	1' 5.0"	U/S	8:W	6	Y	Y	N	Poss. Mill or Mech.	Hi Freq - Mill Origin Type Signal
D5	16244' 2 3	22.6"	U/S	4:00	3	Y	Y	N		Isolated Corr. or Mill Origin
D6	38259' 0.3"	128.3"	D/S	6:00	3	Y	Y	N		Hi Freq - Mill Origin Type Signal
D7	42309' 9.3"	6"	U&D/S	4:w	4	Y	Y	N		Weld Area
D8	42420' 7.7"	6"	U&D/S	5:00	10	Y	Y	N		Weld Area
HNDI	42718' 2.5"	6"	U&D/S	4:00	4	Y	Y	N		Weld Area
D9	58563' 10.7"	6"	U&D/S	6-7:00	4	Y	Y	N		Weld Area
D10	64385' 0.5"	3' 0.5"	D/S	1:00	2	Y	Y	N		Hi Freq - Mill Origin Type Signal
mi	68017' 0.1"	9' 1.1"	D/S	1:00	2	Y	Y	N		Hi Freq - Mill Origin Type Signal
D12	68695' 10.9"	5.5"	U/S	5:00	3	Y	Y	N		Weld Area
D13	68695' 10.9"	2.7"	U/S	SW	3	Y	Y	N		Weld Area
D14	72764' 6.4"	17' 3.0"	D/S	7:w	6	Y	Y	N		Hi Freq - Mill Origin Type Signal
FEATURE	**84402' 6.6"**					N	Y	Y	**"POSSIBLE WRINKLE BEND"**	**Area Containing Origin of Failure**
D15	84415' 3.8"	1' 5.8"	D/S	1:30	5	N	Y	Y		Hi Freq at start of Lo Freq (D/S of Origin)
FEATURE	84415' 3.6"	1' 6"	D/S			N	Y	Y	"POSSIBLE MASH'	Lo Freq element of D15
E2	Sta. 843+69					N	Y	Y	"0.45", TOTAL SHARP"	Same as D15 and Mash Immediately Above
E3	Sta. 847+54					Y	Y	Y	"0.26", TOTAL SHARP' (in a bend)	Probably a Poor Line-up
D16	100072' 11.0'	12'1.3"	D/S	10:00	3	Y	Y	N		Hi Freq - Mill Origin Type Signal
D17	107988' 3.1"	3' 1.1"	D/S	8:00	2	Y	Y	N		Hi Freq - Mill Origin Type Signal
HND2	109634' 0.8"	8.0"	U/S	6:00	6	Y	Y	N		Weld Area
D18	110330' 1.9"	2010.2"	U/S	5:30	3	Y	Y	N		Isolated Corr. or Mill Origin - Hi Ampl.
HND3	121526' 9.5"	6' to 33'	D/S	11:00	3	Y	Y	N		Very Light Corrosion.
HND4	121643' 3.0"	16'	D/S	6:00	5	Y	Y	N		Corrosion Area
D19	122530' 7.2"	26' 1.2'	D/S	5:w	8	Y	Y	N		Isolated Corr. or Mill Origin
D20	135577' 4.1"	6"	U/S	4:00	3	Y	Y	N		Weld Area
HND5	135885' 2.2"	6"	U&D/S	4:00	11	Y	Y	N		Weld Area
HND6	**169502' 9.1"**	**2' 11'**	**D/S**			Y	Y	N		**SLEEVE DOES NOT COVER DEFECT.**
E4	Sta. 1973+54					N	N	Y	"0.52" TOTAL SHARP - IN BEND"	In Bend, Probably Line-up Problem

Note: D1 through D20 are identifiers as reported in the 1996 Linalog Survey Report. HND1 through HND6 are additional areas identified by HND which will require investigation. All references, distances, or circumferential positions are taken from the 1996 Linalog Report except those pipeline station numbers reported by Enduro at E1 through E4.

HND, MOD. 9/16/1999

Appendix C

Tabulation of Defects and Defect "Features"

Olympic Pipeline Company - Linaiog Surveys

(Includes County Boundaries)

16" Cherry Point to Ferndale:

Designation	wheel count (Feet)	Approximate Pipeline Mile Post	Depth (% of Wall)	Detect Length (inches)	Orientation (O'Clock)	Comments
Launch	226.0	0.0				Whatcom County
D1	8913.6	1.7	22.4	0.4	4	
D2	16753.6	3.2	29.2	0.5	6	
D3	22181.1	4.2	22.4	0.4	7	
Trap	27023.6	5.1				

16" Femdale to **Allen:**

Designation	Wheel Count (Feet)	Approximate Pipeline Mile Post	Depth (% of Wall)	Defect Length (inches)	Orientation (O'Clock)	Comments
Launch	127.0	0.0				
D1	1800.9	0.3	24.4	0.4	5	Possible Mill/Mechanical Related
F l	2946.0	0.6				Possible Attachment
D2	3722.2	0.7	28.8	0.5	4	Possible Mill/Mechanical Related
D3	4143.7	0.8	33.6	1.1	4	
D4	5510.6	1.0	24.4	0.3	6	Possible MilVMechanical Related
F2	6610.8	1.3				Possible Mill/Mechanical Anomaly
F3	7173.7	1.4				Possible Mill/Mechanical Anomaly
D5	16242.0	3.1	44.0	0.3	4	Possible MilVMechanical Related
D6	39271.7	7.4	26.0	3.1	6	Possible Mill/Mechanical Related
D7	42301.2	8.0	20.4	0.9	4	
D8	42421.1	8.0	21.6	2.0	5	
HNDI	42718.2	8.1				**HNDI - Weld Area** Corrosion
F4	58508.4	11.1				Possible Attachment

Appendix C
16" Femdale to Allen (Cont'd.):

Designation	Wheel Count (Feet)	Approximate Pipeline Mile Post	Depth (% of Wall)	Defect Length (Inches)	Orientation (O'Clock)	Comments
D9	58563.9	11.1	27.2	0.5	7	
D10	64388.1	12.2	26.4	0.8	1	Possible Mill/Mechanical Related
D11	68026.1	12.9	23.6	0.5	1	Possible Mill/Mechanical Related
D12	68695.5	13.0	26.4	0.8	5	
D13	68695.7	13.0	21.2	0.4	5	
D14	72781.8	13.8	24.0	0.6	7	
F5	83925.1	15.9				Possible Attachment
F6	83967.8	15.9				Possible Attachment
F7	83970.4	15.9				Possible Attachment
F8	83975.1	15.9				Possible Attachment
F9	84402.6	16.0				Possible Wrinkle Bend
D15	Q4416.8	16.0	23.6	0.4	1	Possible MilUMechanical Related
F10	84416.8	16.0				Possible Mash
D16	100085.0	19.0	30.0	0.5	10	Possible Mill/Mechanical Related
D17	107989.4	20.5	22.4	2.2	8	Possible Mill/Mechanical Related
HND2	109634.1	20.8				HND2- Weld Area Corrosion
D18	110309.3	20.9	48.0	2.0	6	
HND3	121526.8	23.0				HND3 - Lt Corr/Mechanical Damage
HND4	121643.3	23.0				HND4 - Corrosion Area
D19	122557.5	23.2	20.4	2.5	5	
County Line		24.0				~ Whatcom / Skagit County Line
020	135576.8	25.7	25.6	0.4	4	Possible MilVMechanical Related
HND5	135885.2	25.7				HND5 - Weld Area Corrosion
HND6	169502.8	32.1				HND6-Sleeve doesn't cover defect
Trap	197479.0	37.4				

Appendix C
16" Allen to Renton:

Designation	Wheel Count (Feet)	Approximate Pipeline Mile Past	Depth (% of Wall)	Defect Length (inches)	Orientation (O'Clock)	Comments
Launch	32.0	37.4				
D1	828.9	37.6	24.4	1.0	7	
02	8157.3	38.9	21.6	0.6	4	
D3	14807.5	40.2	32.4	1.4	4	
F1	14862.0	40.2				Possible Wrinkle Bend
F2	14870.0	40.2				Possible Wrinkle Bend
D4	20930.6	41.4	46.8	0.6	4	
D5	28464.7	42.8	20.4	1.4	9	
F3	30821.0	43.2				Possible Wrinkle Bend
D6	47001.7	46.3	22.4	0.3	12	
County Line		49.5				Skagit/Snohomish County tine
D7	47341.1	46.4	22.4	0.5	8	Possible MilUMechanical Related
F4	78346.0	52.2				Possible Mash
F5	80330.7	52.6				Possible MilUMechanical Anomaly
D8	81838.5	52.9	24.0	1.2	4	
D9	82033.5	52.9	29.6	2.3	9	
D10	107342.2	57.7	30.0	0.5	6	
F6	107578.4	57.8				Possible Mash
F7	119269.3	60.0				Possible Mash
D11	125787.4	61.2	27.6	0.8	2	Possible Mill/Mechanical Related
D12	128340.8	61.7	38.8	0.5	4	Possible Mill/Mechanical Related
013	140284.0	64.0	36.8	0.2	8	Possible Mill/Mechanical Related
014	143493.1	64.6	29.6	0.3	8	
D15	143493.1	64.6	25.6	1.1	7	
F8	154171.5	66.6				Possible Mash
F9	172430.0	70.1				Possible Mash
F10	178324.6	71.2				Possible Mash
D16	188700.5	73.1	30.8	2.0	6	
FI1	204953.4	76.2				Possible Attachment
D17	207992.5	76.8	31.6	0.5	2	Possible MilVMechanical Related
D18	213284.0	77.8	28.4	1.1	8	

Appendix C
16" Allen to Renton (Cont'd.):

Designation	wheel count (Feet)	Approximate Pipeline Mile Post	Depth (% of Wall)	Defect Length (Inches)	Orientation (O'Clock)	Comments
D19	220696.7	78.2	32.8	0.5	3	
F12	225096.8	80.0				Possible Wrinkle Bend
D20	226485.6	80.3	28.4	0.3	3	
F13	226893.8	80.4				Possible Mash
F14	228346.5	80.6				Possible Mash
D21	228601.9	80.7	25.2	0.7	6	
D22	228602.2	80.7	24.0	0.5	5	
F15	231956.1	81.3				Possible Mash
F16	232008.9	81.3				Possible Mash
F17	234049.8	81.7				Possible Mash
F18	238363.0	82.5				Possible Mash
D23	249556.3	83.0	28.4	0.4	6	
F19	241691.4	832				Possible Mash
D24	242700.3	03.4	22.4	0.7	8	
F20	245249.3	83.9				Possible Mash
D25	253180.5	85.4	22.4	0.3	12	
F21	201594.0	86.0				Possible Attachment
F22	261607.0	86.9				Possible Attachment
County Line	261360.0	88.Q				Snohomish/King County tine
D26	2691092	88.4	28.0	0.4	2	
D27	283235.5	91.0	21.6	0.6	11	
D28	285961.1	91.6	32.0	0.6	4	
F23	308431.1	95.8				Possible Mash
F24	311135.3	96.3				Possible Mash
D29	328475.7	99.6	39.6	0.5	7	
F25	342925.4	102.3				Possible Mash
030	356910.5	105.0	27.2	0.3	4	
F26	359507.7	105.5				Possible Mash
F27	382293.5	106.0				Possible Mash
D31	304613.3	106.5	25.2	0.3	12	
032	371614.1	107.8	27.2	0.7	5	

Appendix C
16" Allen to Renton (Cont'd.):

Designation	Wheel Count (Feet)	Approximate Pipeline Mile Post	Depth (% of Wall)	Defect Length (inches)	Orientation (O'Clock)	Comments
D33	373258.1	108.1	28.4	0.3	4	
D34	382498.0	109.8	22.4	0.6	12	Possible Mill/Mechanical Related
F28	386168.1	110.5				Possible Wrinkle Bend
D35	395192.8	112.2	22.4	0.2	8	Possible Mill/Mechanical Related
D36	396683.2	112.5	58.0	0.5	6	
D37	397084.0	112.6	23.6	0.3	3	
Trap	399289.0	113.0				

20" Allen to Renton:

Designation	Wheel Count (Feet)	Approximate Pipeline Mile Post	Depth (% of Wall)	Defect Length (inches)	Orientation (O'Clock)	Comments
Launch	31.0	37.4				
D1	1771.1	37.7	27.6	0.4	9	
F1	7558.2	38.8				Possible Attachment
F2	9280.9	39.2				Possible Mill/Mechanical Anomaly
D2	9292.7	39.2	32.8	2.7	6	
D3	10790.5	39.4	27.6	0.6	10	
D4	11984.2	39.7	23.6	0.6	1	
D5	13742.3	40.0	24.4	1.2	8	
D6	13746.8	40.0	28.4	1.2	8	
D7	21645.6	41.5	33.6	1.1	10	
D8	21645.9	41.5	38.8	0.6	10	
D9	26162.0	42.4	38.8	0.5	6	
D10	26883.7	42.5	28.0	0.7	11	
D11	27664.1	42.6	26.4	0.4	7	
F3	34964.5	44.0				Expander Marks
F4	38390.9	44.7				Expander Marks
D12	39466.8	44.9	38.8	1.1	2	

Appendix C
20" Ilen to Renton (Cont'd.):

Designation	Wheel Count (Feet)	Approximate Pipeline Mile Post	Depth (% of Wall)	Defect Length (inches)	Orientation (O'Clock)	Comments
F5	40480.5	45.1				Possible MilVMechanical Anomaly
D13	41110.0	45.2	30.0	1.2	7	
D14	41568.9	45.3	36.8	1.9	9	
D15	41569.3	45.3	22.4	0.6	9	
D16	41569.5	45.3	26.0	1.0	9	
D17	41569.7	45.3	29.6	1.5	9	
D18	41570.2	45.3	25.2	1.4	9	
D19	41571.5	45.3	39.6	1.9	9	
D20	42232.7	45.4	34.4	3.2	7	
D21	42697.9	45.5	21.6	0.3	2	
D22	44241.1	45.8	29.6	0.3	9	Possible MilVMechanical Related
F6	47388.9	46.4				Possible Attachment
F7	53589.0	47.6				Expander Marks
F8	58486.8	48.5				Possible Mash
D23	60667.4	48.9	38.4	0.4	3	Possible Mill/Mechanical Related
F9	60673.3	48.9				Expander Marks
D24	63184.8	49.4	46.0	0.5	7	
County Line		49.5				Skagit/Snohomish County Line
D25	04396.9	49.6	29.6	0.5	11	
D26	64613.1	49.6	22.0	0.3	7	
D27	65867.9	49.9	36.4	0.8	9	
D28	65881.1	49.9	20.8	0.3	10	
D29	65882.5	49.9	58.0	1.1	10	
030	65882.6	49.9	65.2	0.9	10	
D31	65889.3	49.9	51.6	1.9	9	
032	66840.4	50.1	35.2	0.5	8	
F10	70725.6	50.8				Possible Mash
F11	71151.5	50.9				Possible Mill/Mechanical Anomaly
F12	81809.5	52.9				Expander Marks
F13	83051.3	53.1				Expander Marks
033	84993.3	53.5	21.6	0.3	9	

Appendix C
20" Allen to Renton (C)

Designation	Wheel Count (Feet)	Approximate Pipeline Mile Post	Depth (% of Wall)	Defect Length (inches)	Orientation (O'Clock)	Comments
D34	88071.1	54.1	56.8	0.3	2	
D35	88267.3	54.1	27.6	1.4	7	
F14	90628.1	54.6				Expander Marks
F15	98550.1	56.1				Possible Mash
F16	103614.4	57.0				Expander Marks
D36	104606.2	57.2	35.2	0.9	3	
D37	105347.8	57.4	34.0	0.7	9	
F17	107151.6	57.7				Possible Mash
D38	107967.8	57.8	29.6	0.9	5	
D39	111448.8	58.5	29.6	0.5	11	
D40	114102.8	59.0	26.0	0.3	3	
D41	120573.2	60.2	21.6	1.5	12	
D42	122288.1	60.6	28.0	0.5	5	
D43	129409.8	61.9	27.2	0.4	5	
D44	130169.5	62.1	20.8	1.4	10	
D45	131619.6	62.3	22.4	0.5	8	
D46	133942.0	62.8	60.0	0.7	5	
D47	133942.7	62.8	44.0	0.4	5	
D48	133944.7	62.8	25.2	0.4	6	
D49	133949.9	62.8	58.0	1.9	6	
D50	133951.5	62.8	48.0	0.7	6	
D51	136170.1	63.2	21.2	0.3	10	
D52	143004.2	64.5	23.6	0.3	11	
D53	147277.7	65.3	22.0	0.3	8	
D54	150255.9	65.9	20.8	0.7	12	
D55	152306.4	66.2	30.0	1.3	6	
D56	156350.7	67.0	33.6	0.3	6	
D57	156362.0	67.0	34.8	0.3	7	
D58	156363.5	67.0	30.8	0.7	7	
D59	156367.9	67.0	36.8	2.3	8	
D60	164351.3	68.5	36.8	2.0	11	

Appendix C
20" Allen to Renton(Cont'd.):

Designation	Wheel Count (Feet)	Approximate Pipeline Mile Post	Depth (% of Wall)	Defect Length (inches)	Orientation (O'Clock)	Comments
D61	166492.0	68.9	36.0	0.3	9	
D62	169418.7	69.5	28.8	2.6	2	
D63	170813.7	69.8	23.6	2.5	6	
D64	171706.8	69.9	28.4	0.3	9	
D65	172654.2	70.1	48.4	1.3	11	
D66	172654.7	70.1	21.6	0.5	11	
D67	176131.0	70.8	24.0	0.4	12	
D68	177339.5	71.0	20.8	4.9	5	
D69	178717.8	71.2	22.4	0.3	3	
D70	179422.2	71.4	20.8	0.5	12	
D71	180181.4	71.5	25.2	0.3	11	
D72	185038.6	72.4	26.4	0.9	12	
D73	185039.3	72.4	29.6	0.8	12	
D74	185041.7	72.4	38.4	3.7	12	
D75	186802.6	72.8	25.6	0.9	5	
D76	196386.2	74.6	29.6	0.3	11	
D77	198980.3	74.7	26.8	0.3	5	
078	197514.0	74.8	31.6	0.7	3	
D79	199187.4	75.1	27.6	0.3	6	
D80	199190.4	75.1	37.6	0.6	6	
D81	109809.3	75.2	29.6	0.9	1	
D82	200870.6	75.4	21.2	0.6	11	
D83	200870.8	75.4	33.6	0.5	11	
D84	200871.6	75.4	26.8	13.5	11	
D85	200874.9	75.4	28.8	1.1	11	
D86	200997.5	75.5	29.6	0.4	10	
D87	200997.6	75.5	21.2	0.3	10	
D88	201546.7	75.6	30.8	0.8	3	Possible Mill/Mechanical Related
F18	202275.6	75.7				Possible MilVMechanical Anomaly
D89	202616.5	75.8	35.6	0.7	1	Possible Mill/Mechanical Related
D90	204364.6	76.1	22.0	0.8	6	

Appendix C
20" Allen to Renton (Cont'd.):

Designation	wheel Count (Feet)	Approximate Pipeline Mile Post	Depth (% of Wall)	Defect Length (inches)	Orientatton (O'Clock)	Comments
D91	204377.8	76.1	30.4	1.5	7	
D92	204882.6	76.2	38.0	0.7	4	
D93	205913.0	76.4	22.4	1.4	8	Possible Mill/Mechanical Related
D94	207583.0	76.7	27.2	1.8	9	
D95	208016.8	76.8	25.6	1.1	3	
D96	208016.8	76.8	25.2	1.1	9	
D97	208226.9	76.8	36.8	0.4	6	
D98	208610.2	76.9	36.8	0.3	8	
D99	210359.1	77.2	21.6	3.2	10	
D100	210359.6	77.2	24.4	6.0	10	
D101	210360.6	77.2	25.6	5.8	10	
D102	210361.3	77.2	25.6	4.9	10	
D103	210362.0	77.2	27.6	6.0	10	
D104	210363.2	77.2	21.6	5.0	10	
D105	211978.6	77.5	21.2	0.3	9	
F19	213748.1	77.9				Expander Marks
D106	217804.8	78.7	24.4	0.3	4	
D107	218843.7	78.8	23.6	0.8	10	
D108	219578.6	79.0	23.6	0.4	10	
D109	219579.2	79.0	25.6	1.1	10	
D110	223607.6	79.8	23.6	0.3	6	
D I I I	223698.5	79.8	29.6	0.8	5	
F20	225199.4	80.1				Possible Mash
F21	236903.3	82.3				Expander Marks
D112	237722.4	82.4	24.4	0.3	9	
D113	240390.2	82.9	30.8	1.3	1	
D114	240390.5	02.9	24.4	2.1	1	
F22	247761.1	84.3				Possible Mash
D115	254646.6	85.0	21.6	0.4	3	
County Line	281360.0	88.0				Snohomish/King County Line
D116	273484.3	89.2	22.8	1.8	0	

Appendix C
20" Allen to : (Cont'd.):

Designation	Wheel Count (Feet)	Approximate Pipeline Mile Post	Depth (% of Wall)	Defect Length (Inches)	Orientation (O'Clock)	Comments
D117	277005.8	89.9	27.2	0.3	9	
D118	279528.2	90.3	27.6	5.3	4	
D119	279947.4	90.4	23.2	2.2	a	
D120	283451.5	91.1	26.0	0.4	8	
D121	284410.7	91.3	24.4	1.1	7	
D122	288161.8	92.0	20.8	0.5	2	
D123	291445.6	92.6	25.6	0.3	6	
D124	293591.2	93.0	48.8	1.0	10	
D125	293591.5	93.0	28.4	0.3	10	
D126	296472.6	03.6	26.4	0.4	9	Possible Mill/Mechanical Related
F23	303505.5	94.9				Possible Mash
F24	307460.5	95.6				Possible Attachment
0127	309340.7	96.0	39.6	0.8	7	
D128	309348.9	96.0	29.6	0.7	8	
0129	310216.2	96.2	21.2	2.3	11	
F25	314151.0	96.9				Possible Mash
D130	322414.2	98.5	22.8	0.6	11	
F26	325035.0	99.0				Possible Attachment
D131	329610.9	99.8	28.4	0.3	3	Possible Mill/Mechanical Related
D132	332467.6	100.4	33.6	0.6	10	
D133	332580.4	100.4	22.4	0.4	1	
D134	332581.8	100.4	25.2	0.7	1	
0135	332586.4	100.4	48.8	0.5	1	
0130	332586.6	100.4	21.6	0.4	1	
D137	332592.5	100.4	20.8	0.3	1	
D138	332594.8	100.4	38.8	1.1	4	
D139	332598.0	100.4	37.6	1.6	1	
D140	333408.9	100.5	37.2	3.4	6	
D141	333409.4	100.5	28.4	0.7	8	
D142	333409.6	100.5	24.4	0.9	5	
D143	333409.7	100.5	32.8	0.8	6	

Appendix C
20" Allen to Renton (Cont'd.):

Designation	wheel count (Feet)	Approximate Pipeline Mile Post	Depth (% of Wall)	Defect Length (Inches)	Orientation (O'Clock)	Comments
D144	333807.8	100.6	26.4	0.5	3	
D145	334317.0	100.7	31.6	3.8	5	
D146	334317.1	100.7	24.8	0.8	5	
D147	336472.5	101.1	23.2	3.2	6	
F27	338013.1	101.4				Expander Marks
F28	340601.1	101.9				Begin Attachment
F29	340603.5	101.9				End Attachment
F30	340802.5	101.9				Possible Mash
D148	349002.9	103.5	25.2	0.7	8	
D149	351335.9	103.9	23.6	0.4	7	
D150	351357.1	103.9	29.6	0.4	3	
D151	353441.4	104.3	22.0	0.3	5	
D152	353946.3	104.4	20.8	0.5	2	
F31	354246.3	104.5				Possible Mash
D153	356377.6	104.9	21.6	0.4	4	
F32	356774.7	105.0				Possible Mash
D154	360526.3	105.7	39.6	1.0	5	
D155	360526.5	105.7	24.4	1.6	5	
D156	360528.6	105.7	22.4	0.8	5	
D157	361720.0	105.9	33.6	1.0	5	
F33	362054.8	106.0				Expander Marks
D158	365889.2	106.7	24.4	0.4	5	
D159	371123.6	107.7	22.8	0.4	1	Possible Mill/Mechanical Related
D160	371204.6	107.7	38.4	1.0	8	
0161	371554.4	107.8	22.4	0.2	1	Possible Mill/Mechanical Related
D162	373586.2	108.2	24.0	1.4	1	
D163	374644.6	108.4	55.2	1.0	5	
D164	374644.9	108.4	50.0	0.9	5	
D165	375122.0	108.4	27.2	0.3	8	
F34	387677.8	110.8				Possible Attachment
D166	396710.9	112.5	30.0	0.6	3	

Appendix C
20" Allen to Renton (Cont'd.):

Designation	Wheel Count (Feet)	Approximate Pipeline Mile Post	Depth (% of Wall)	Defect Length (inches)	Orientation (O'Clock)	Comments
D167	399340.6	113.0	24.4	0.3	2	Possible Mill/Mechanical Related
Trap	401432.0	113.4				

Appendix D:

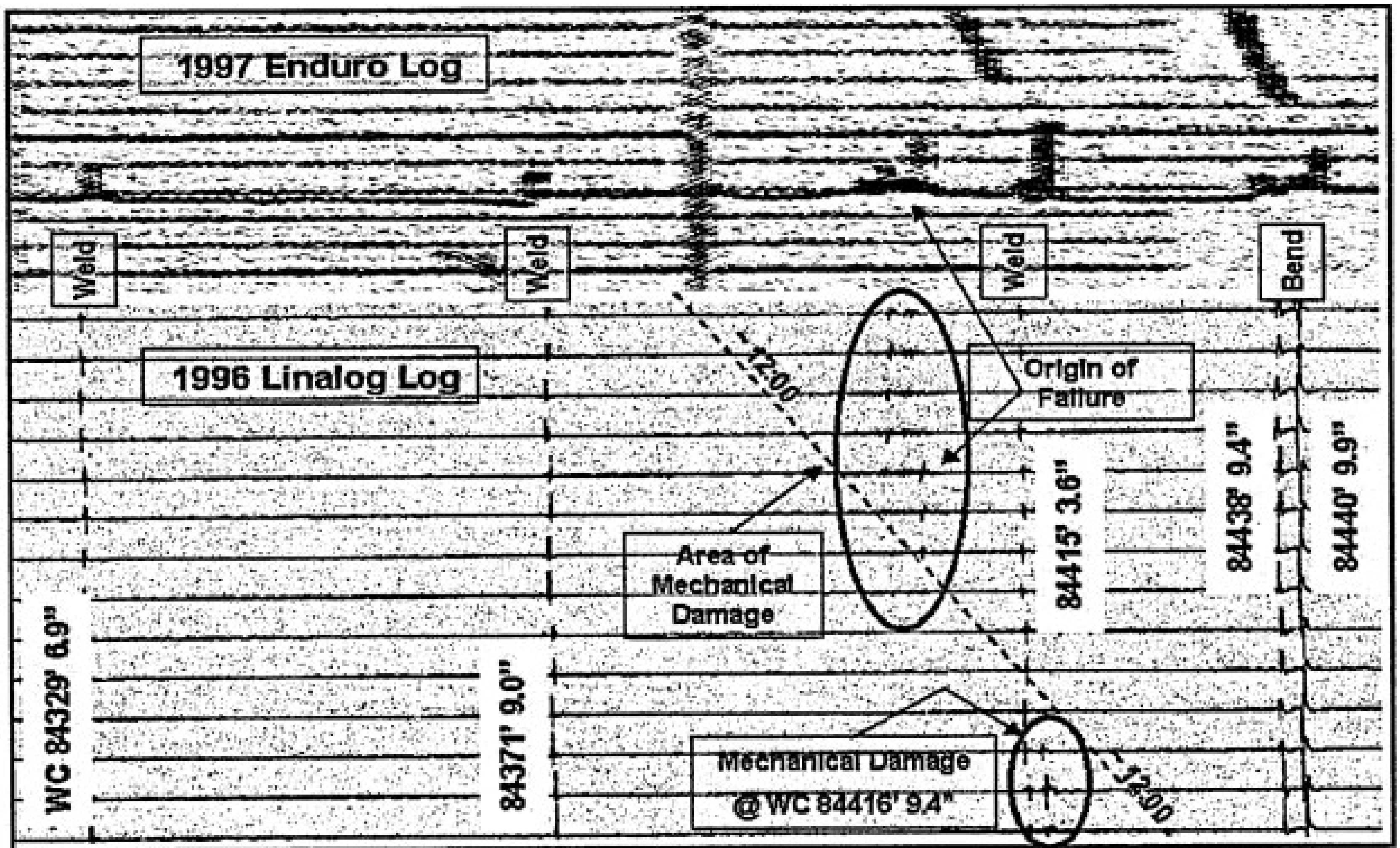
Correlation of Data

Page 2 of this Appendix contains an excerpt form the 1997 Enduro survey and an excerpt from the 1996 Linalog MFL survey. The Enduro survey excerpt was rotated 180 degrees along a vertical axis through the center. This was required because the two survey presentations are from opposite directions due to the method of recording. The two surveys were then adjusted in horizontal scale so that the girth welds were in reasonable alignment. The Enduro system has a mechanical drive device that advances the record paper as a function of the movement of the pig and thus all velocity variations are eliminated in the recording. The Linalog recording device is controlled as a function of time by a motor control circuit and thus pig velocity variations are reflected in the data. Thus, it is impossible to attain 100% correlation due to the small instantaneous velocity variations that are ever present. In this case, the velocity variations only cause a very minor alignment deviation at the welds. This graphic clearly proves that both systems did detect the damaged area around the origin of failure and in the joint downstream. It is my opinion that neither clearly detected the specific origin of failure (due to it's longitudinal orientation) *such* that one could point to a single set of signals within the many signals present and state with a high degree of certainty exactly which one is the origin of failure. They both, however, have recorded data indicative of mechanical damage beginning at least two feet upstream of the origin and ending 16 to 18 inches downstream. The Linalog survey shows signals from the shoes bouncing and minor flux leakage throughout the area along the top of the pipe that is low in amplitude but typical in signal form. The Enduro survey shows very little but a single event since the scale is 1"-250'.

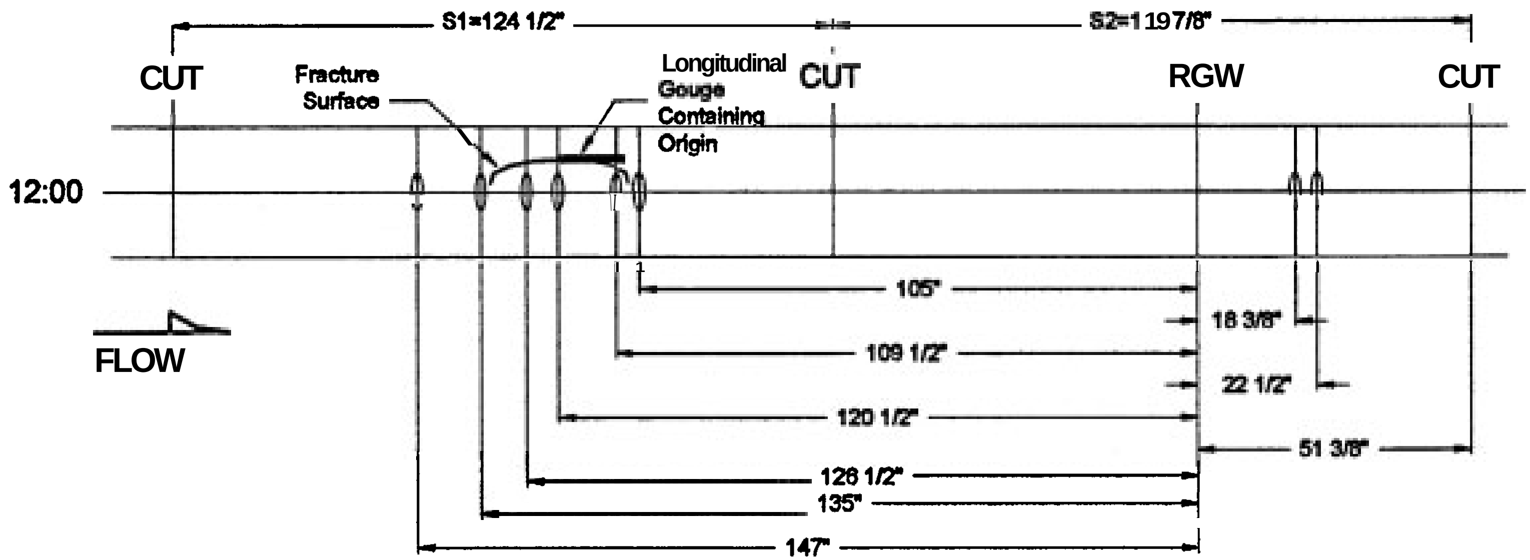
The Mechanical layout on page 3 shows there to be six paints of deformation in the area around the origin of failure and two points of deformation in the downstream joint. t was able to correlate all of these but the one 109 ½" upstream of the reference girth weld. It appears that this one is lost due to shoe bounce or some other similar element. There are signals where the defect should be but there is not a *clear* set that *can* be isolated and attributed to this particular point of damage.

OLYMPIC PIPELINE COMPANY 16", BELLINGHAM, WA.

LINALOG/ENDURO COMPARISON AT FAILURE LOCATION



16" OLYMPIC PIPELINE FAILURE - BELLINGHAM, WA.
MECHANICAL DEFORMATION LAYOUT



Note: Includes only those mechanical deformation locations that might be seen by a Magnetic Flux Leakage Pig.

Data Acquired By: H. Noel Duckworth
Data Acquisition Date: 12/15/1999
Data Acquisition Location: NTSB Headquarters
Washington, DC
Data Plot By: H. Noel Duckworth
Plot Date: 01/12/2000