Acknowledgments

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References

Chawner, J., J. Steinbrenner, N. Wyman. 2000. "Hybrid Grid Generation for Complex Geometries Using Gridgen." In *Proceedings of the 7th International Conference on Numerical Grid Generation in Computational Field Simulations*, September 2000, 417-26.

Cleveland, W.S. 1979. "Robust locally weighted regression and smoothing scatterplots." *Journal of the American Statistical Association* 74:829-836.

Cleveland, W.S. 1984. "Graphs in scientific publications." *The American Statistician* 38:270-280.

Computational Dynamics, Limited. 1999. User Guide, STAR-CD version 3.10.

Harper, D.G. and R.W. Blake. 1990. "Fast-start performance of rainbow trout *salmo gairdneri* and northern pike *esox lucius*." *J. Exp. Biol.* 150:321-342.

Hart, C., D. McChesney, and J. Stohr. 2001. *2001 Drought response; report to the Legislature.* Department of Ecology, Olympia, Washington.

McMichael, G.A., and R. L. Johnson. 2001. *Chandler Canal Smolt Loss Investigation*. Letter Report prepared for the U.S. Bureau of Reclamation, Yakima Project Office by Battelle, Pacific Northwest Division, Richland, Washington.

Neitzel, D.A., M.C. Richmond, D.D. Dauble, R.P. Mueller, R.A. Moursund, C.S. Abernethy, G.R. Guensch, and G.F. Cada. 2000. *Laboratory Studies of the Effects of Shear on Fish*. Prepared for the Advanced Hydropower Turbine System Team, U.S. Department of Energy, Idaho Falls, Idaho, by Pacific Northwest National Laboratory, Richland, Washington.

Rakowski, C.L. J.A. Serkowski, M.C. Richmond, and K.P. Recknagle. 2001. *Development and application of a 3D CFD model for the Bonneville Project Powerhouse 1 and Powerhouse 2.* Report to U.S. Army Corps of Engineers, CENWP, Portland District, Portland, Oregon.

U.S. Department of the Interior, Bureau of Reclamation. 1986. *Chandler Canal Fish Facilities, Yakima Project, Washington*. Design Summary.

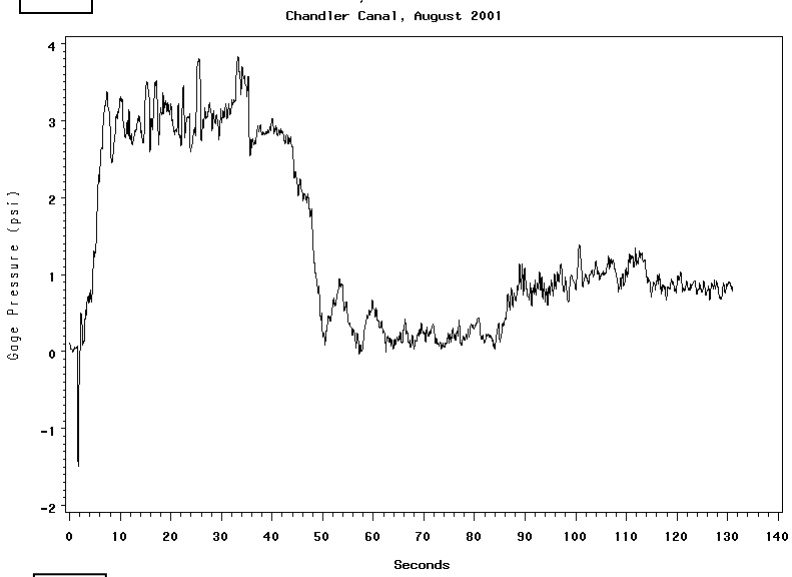
Watanabe, S., A. Takabayashi, M. Tanaka, and D. Yanagihara. 1991. "Neurovestibular Physiology in fish." In *Volume 1, Advances in Space Biology and Medicine*, JAI Press Inc., pp 99-128.

Appendix A

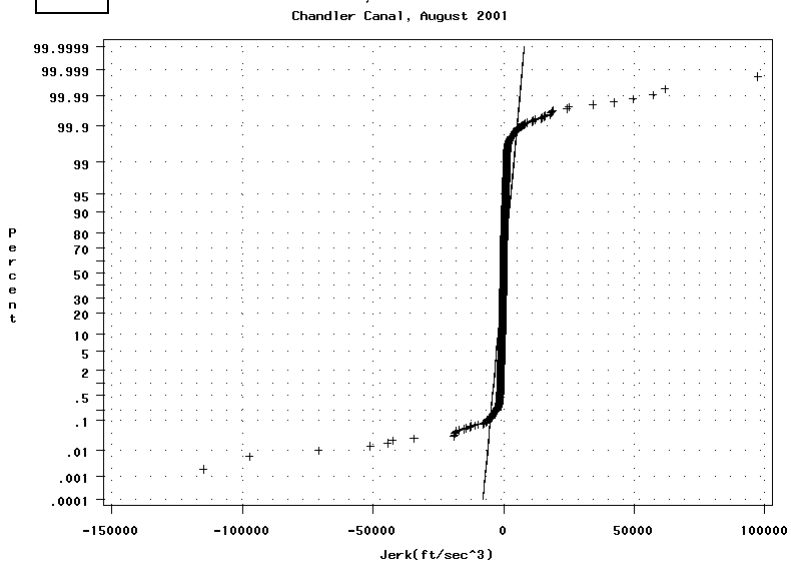
Gage Pressure and Acceleration Vector Magnitude Time Histories and Jerk and Velocity Vector Differential Cumulative Log Plots for Low Flow Sensor Fish Releases

Note: Each page in the appendix contains 4 plots labeled A, B, C, and D. Plot A is the time history of gage pressure in psi. Plot B is the cumulative distribution of jerk in ft/sec^3. Plot C is the time history of the magnitude of the sensor fish acceleration vector in ft/sec^2. Plot D is the cumulative distribution of the sensor fish velocity vector magnitude differential in ft/sec over time periods of 0.005 sec.

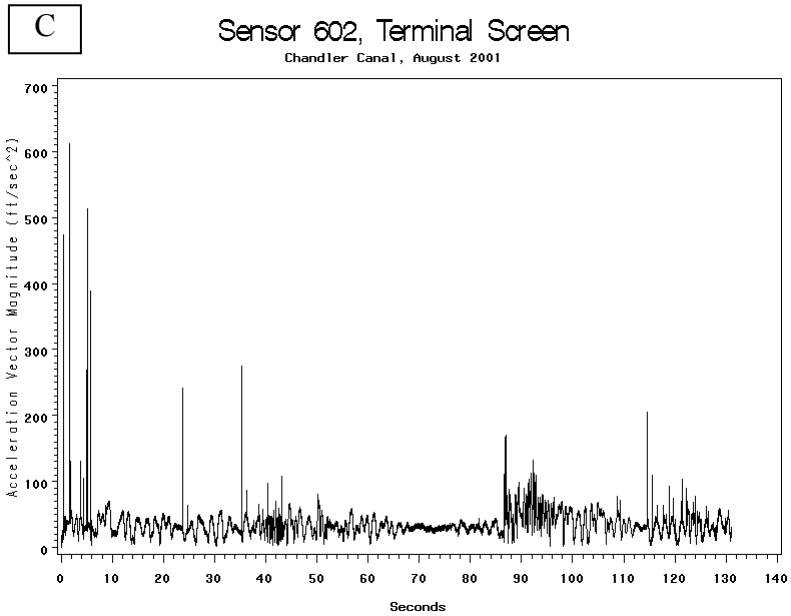
A


Sensor 602, Terminal Screen
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

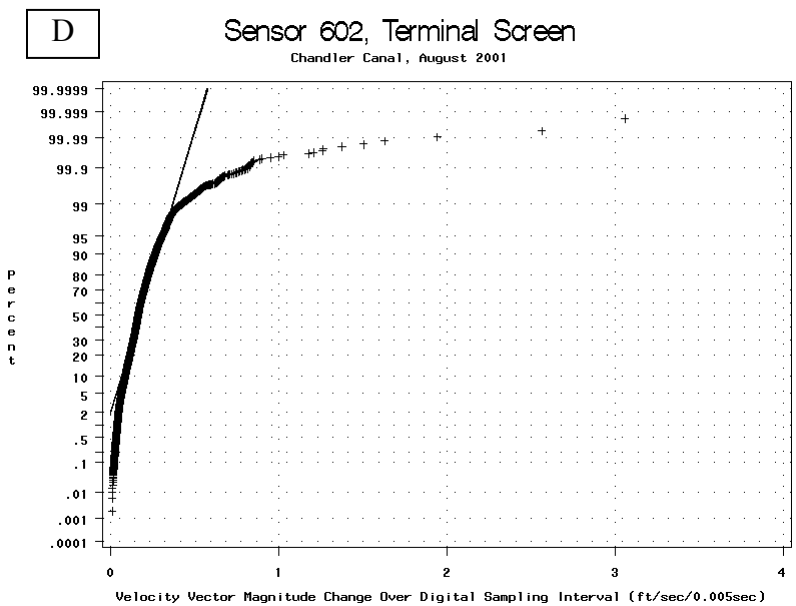
B


Sensor 602, Terminal Screen
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

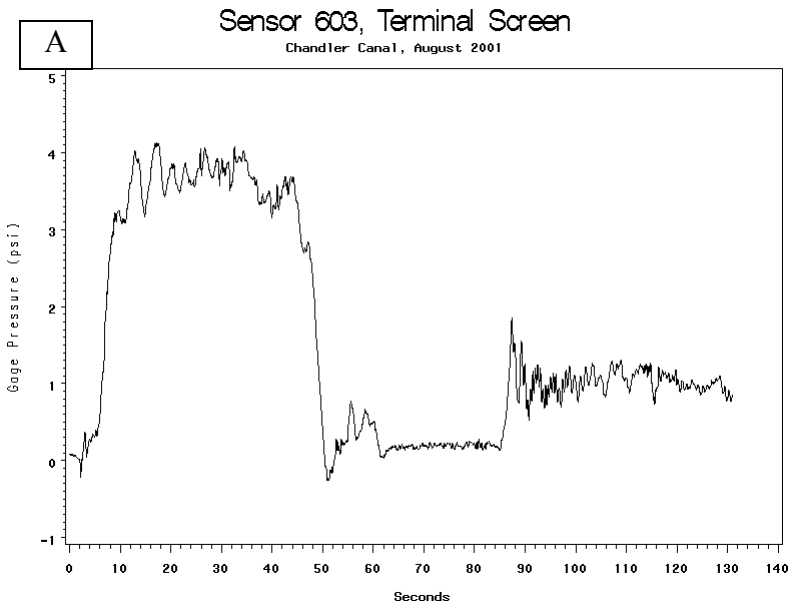
C


Sensor 602, Terminal Screen
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

D


Sensor 602, Terminal Screen
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

A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Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

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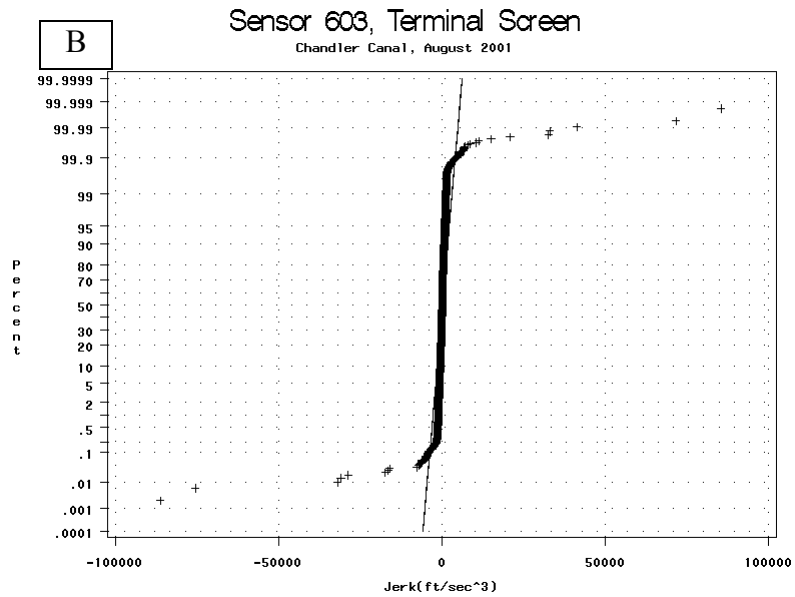
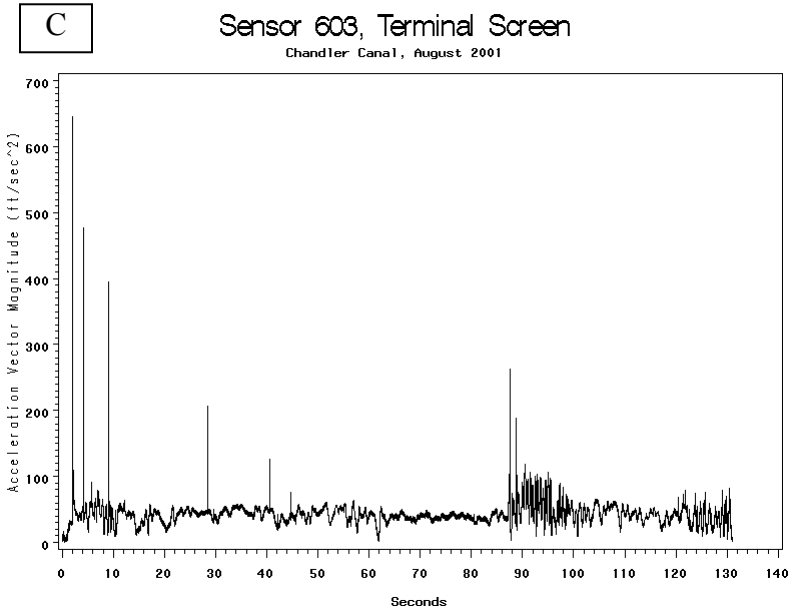

Sensor 603, Terminal Screen
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

C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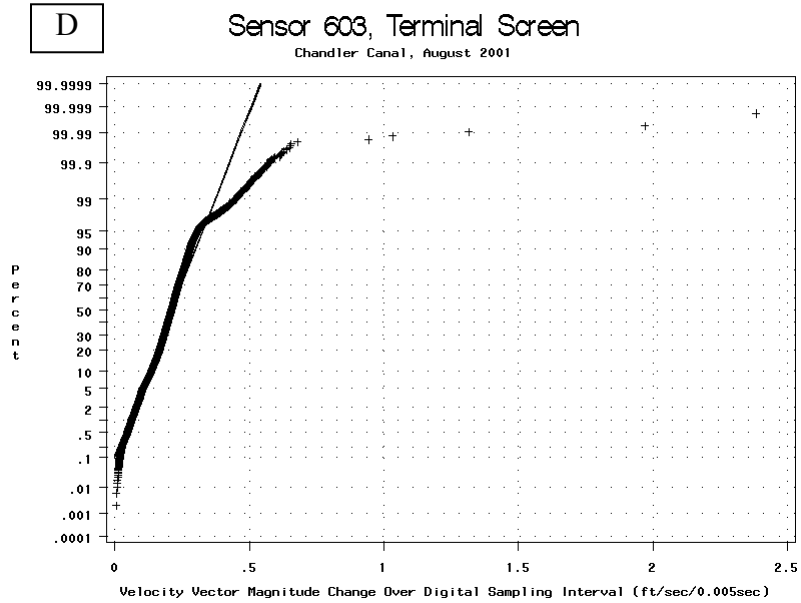
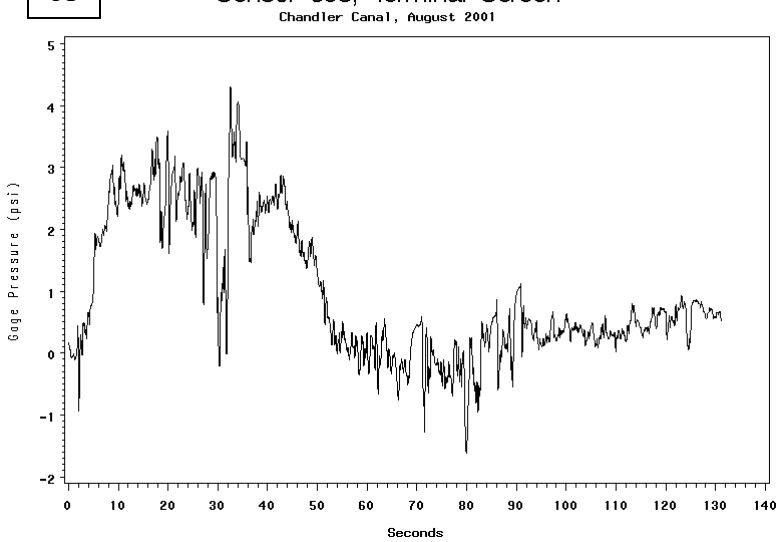
Acceleration Vector Magnitude (ft/sec^2)
Seconds

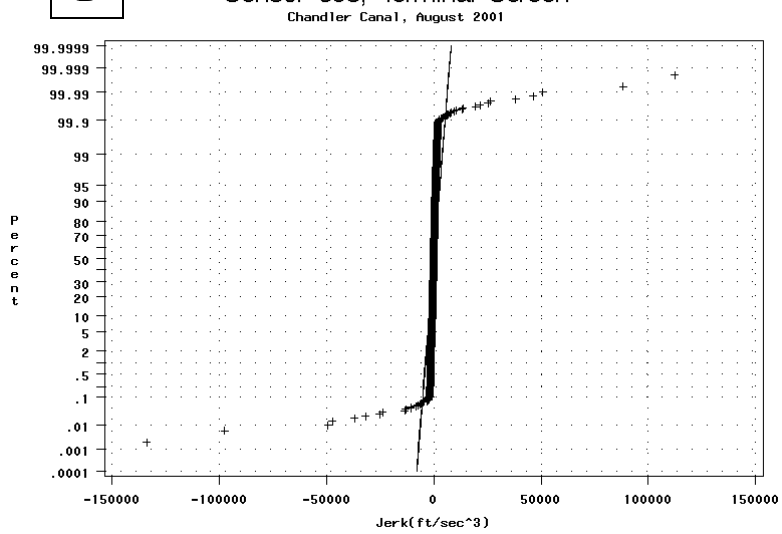
D


Sensor 603, Terminal Screen
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

A


Sensor 605, Terminal Screen
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

B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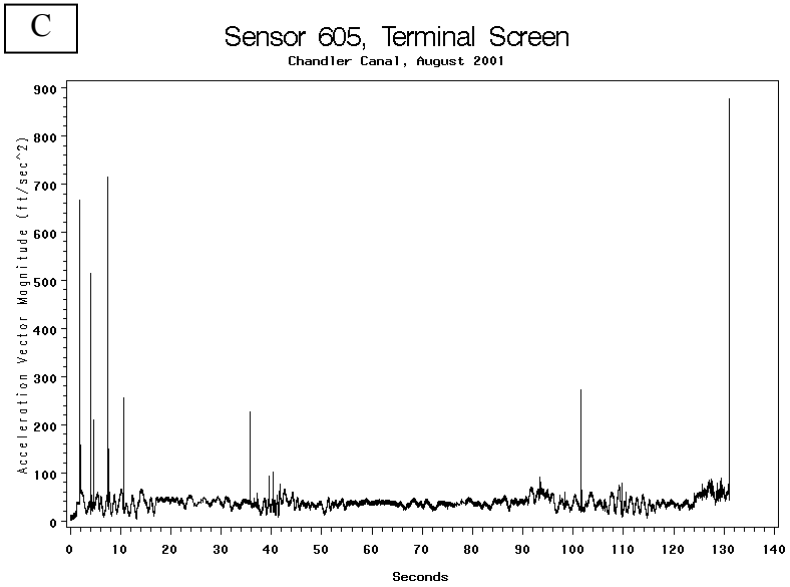
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

C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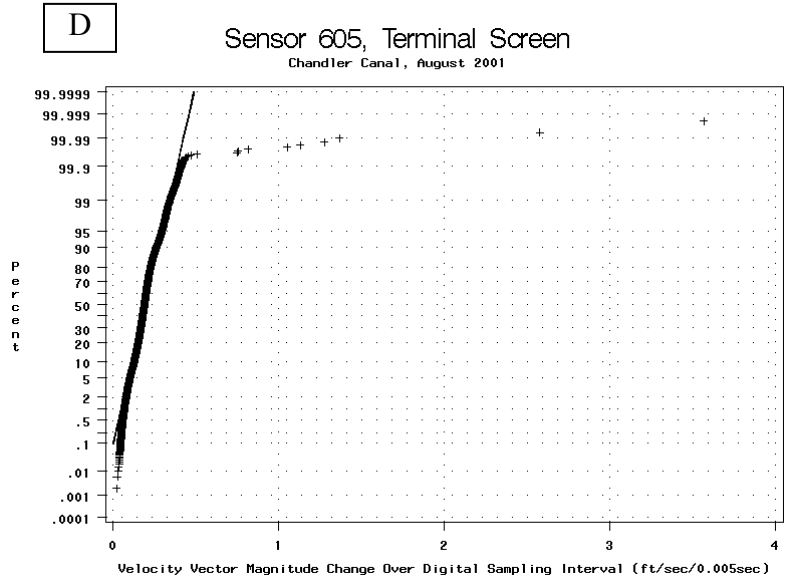
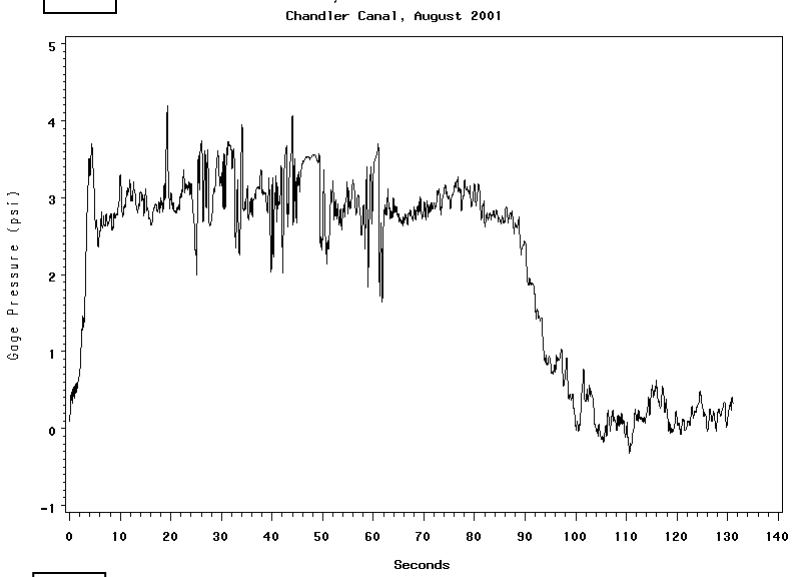
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

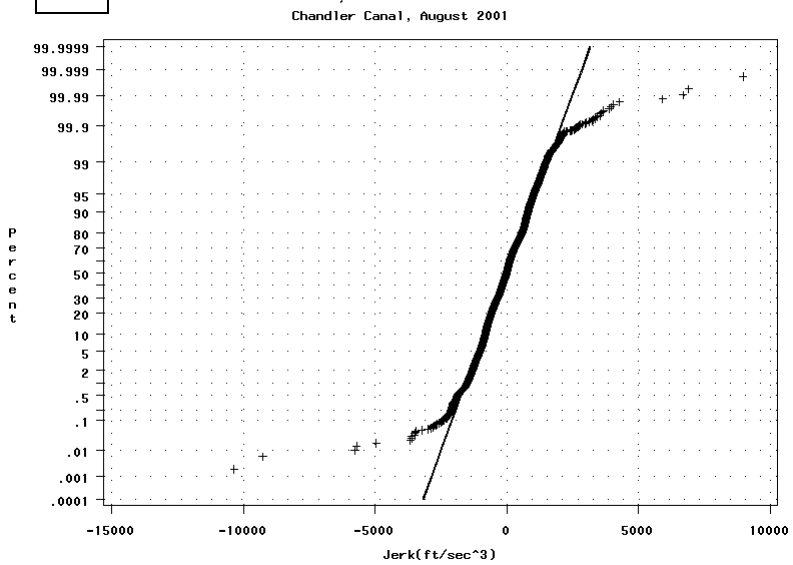
D


Sensor 605, Terminal Screen
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

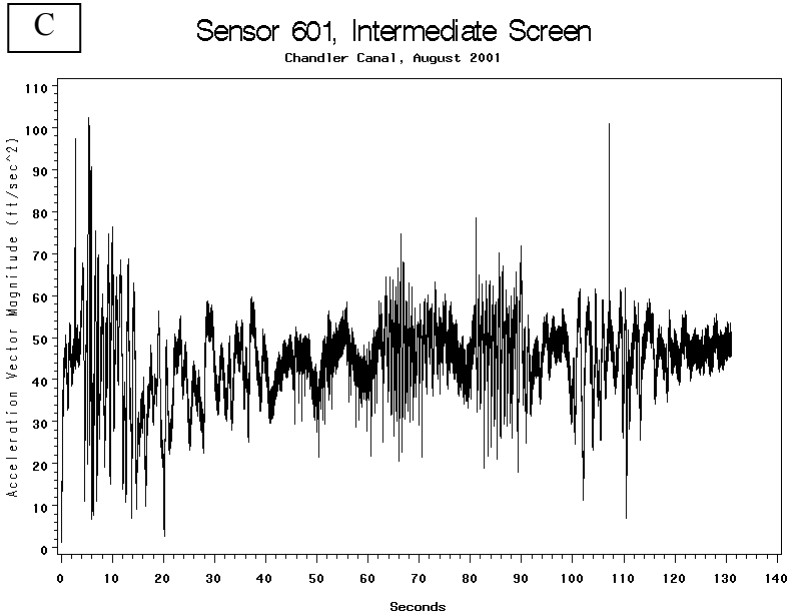
A


Sensor 601, Intermediate Screen
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

B


Sensor 601, Intermediate Screen
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

C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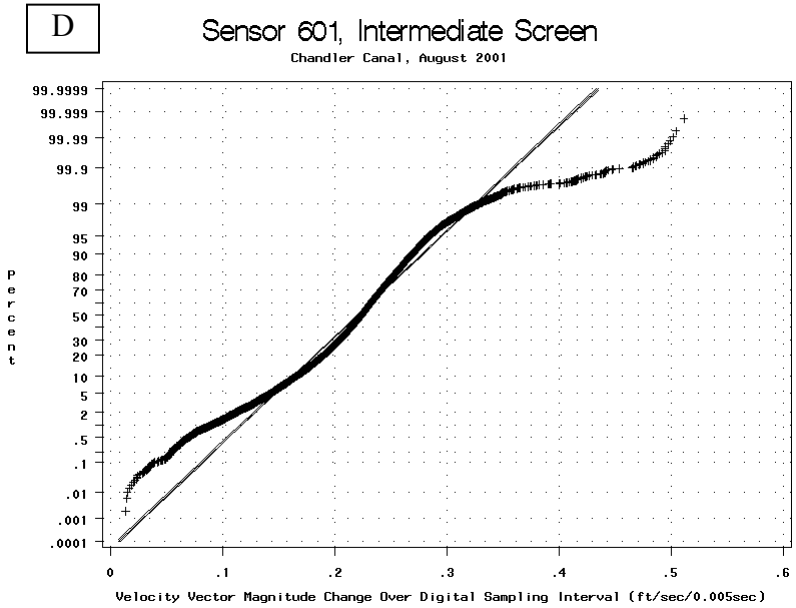
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

D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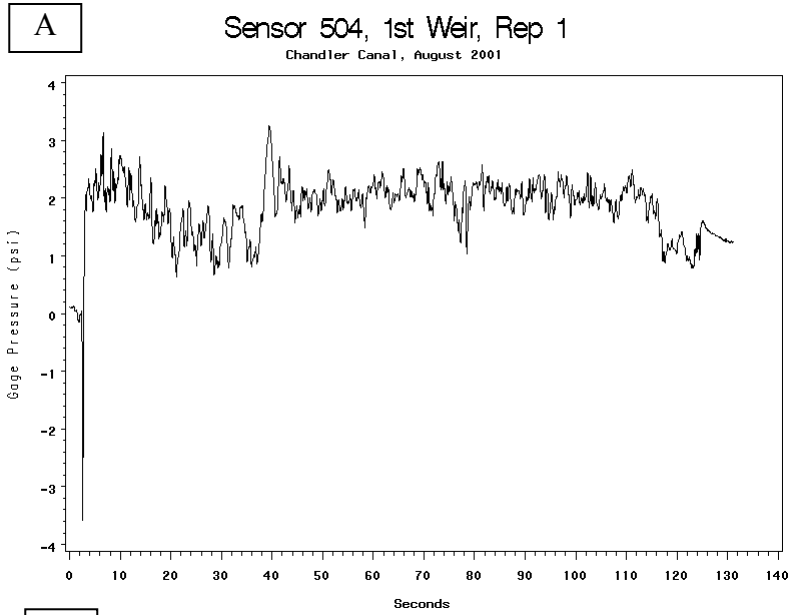
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

A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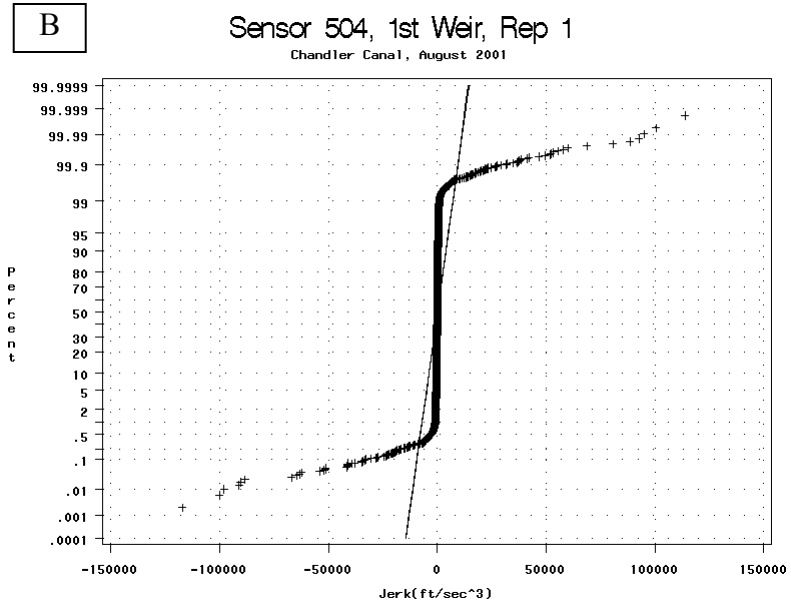
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

B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Percent
Jerk(ft/sec^3)

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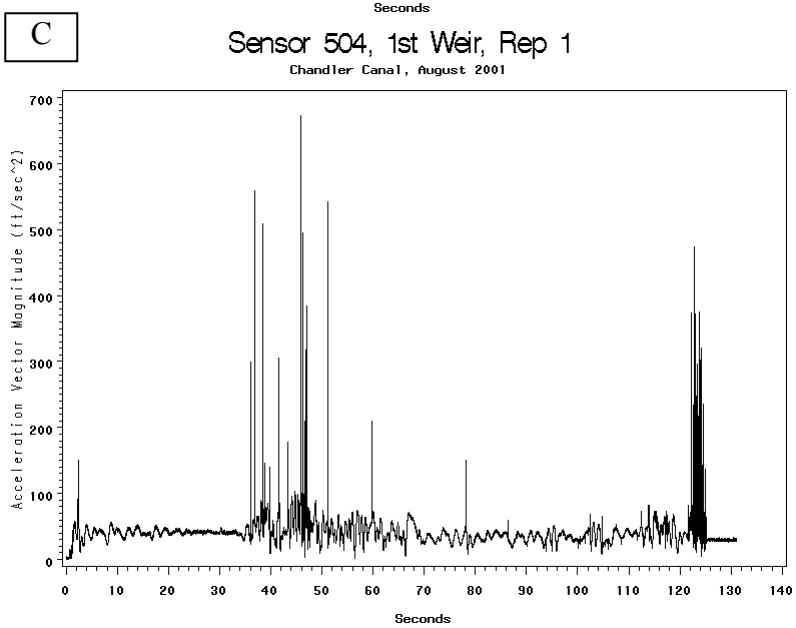
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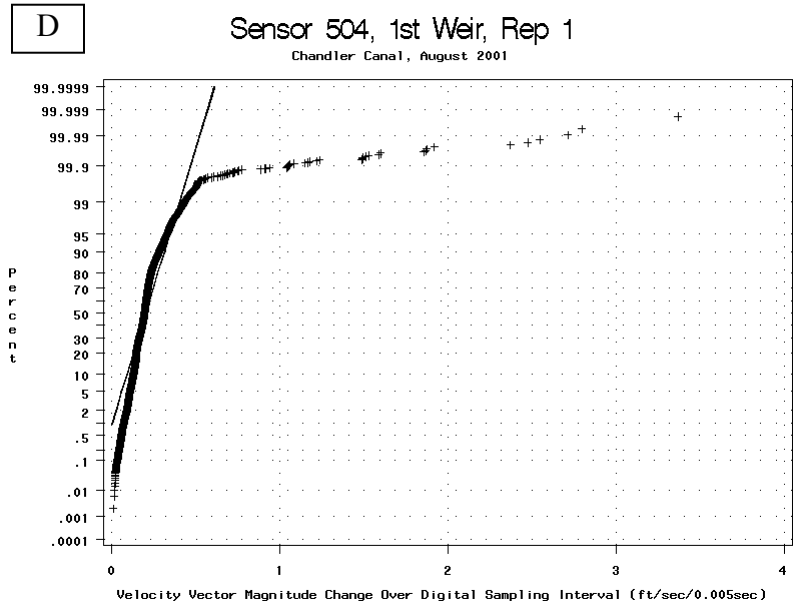
Acceleration Vector Magnitude (ft/sec^2)
Seconds

D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Percent
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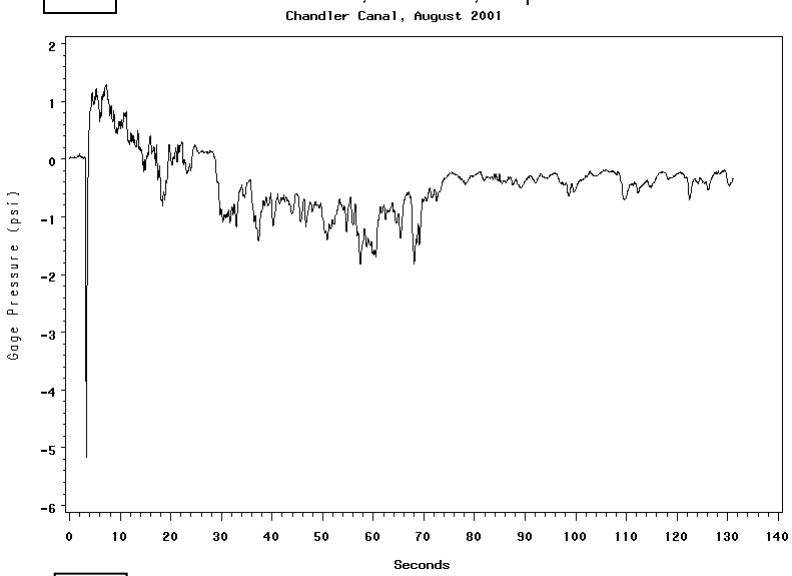
A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Gage Pressure (psi)
Seconds

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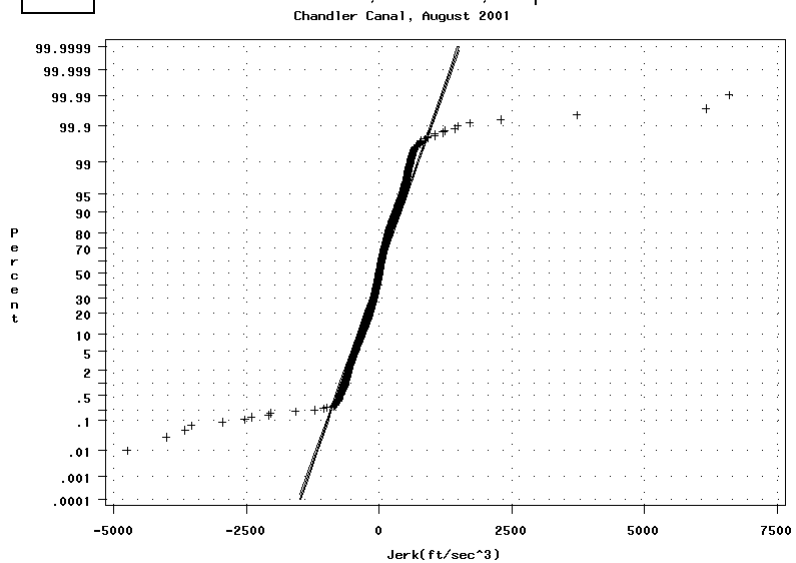
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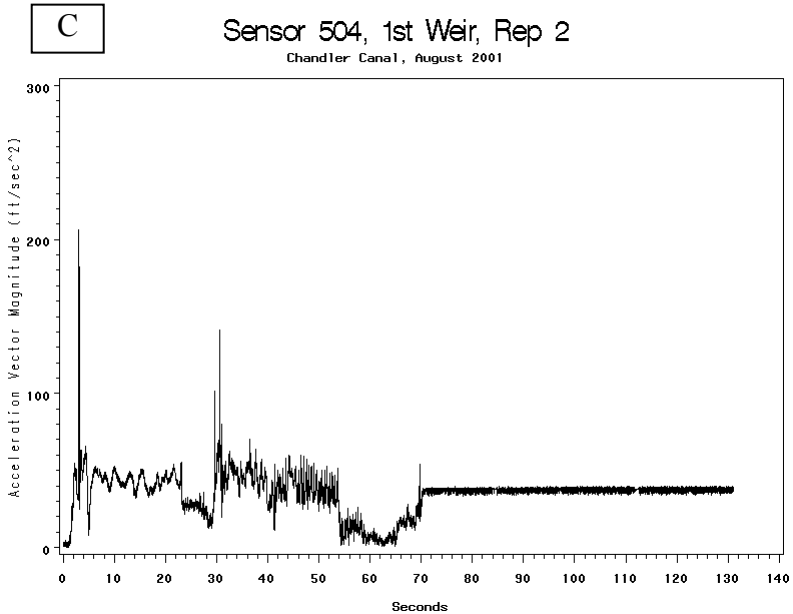
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

C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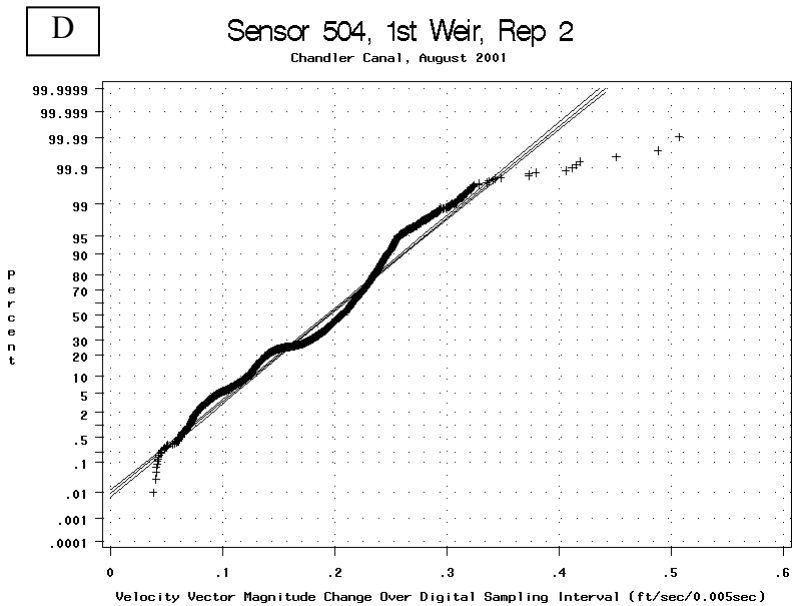
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

D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Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

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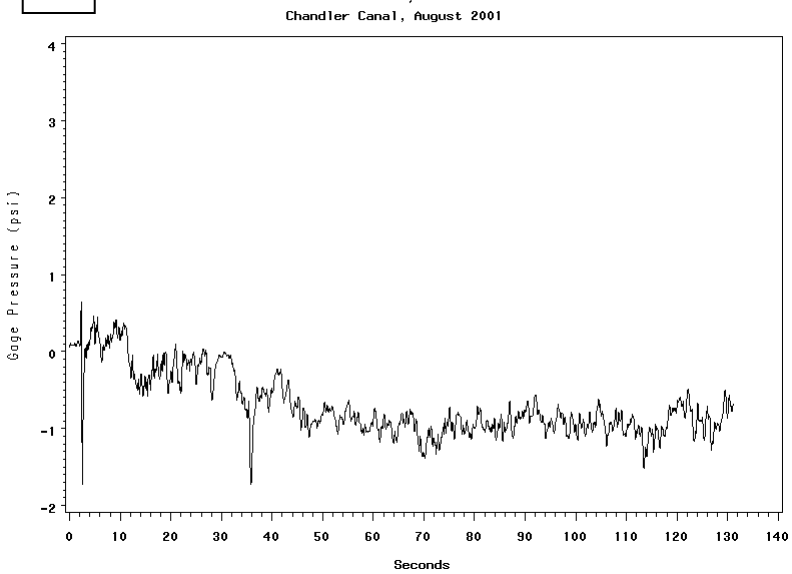
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Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

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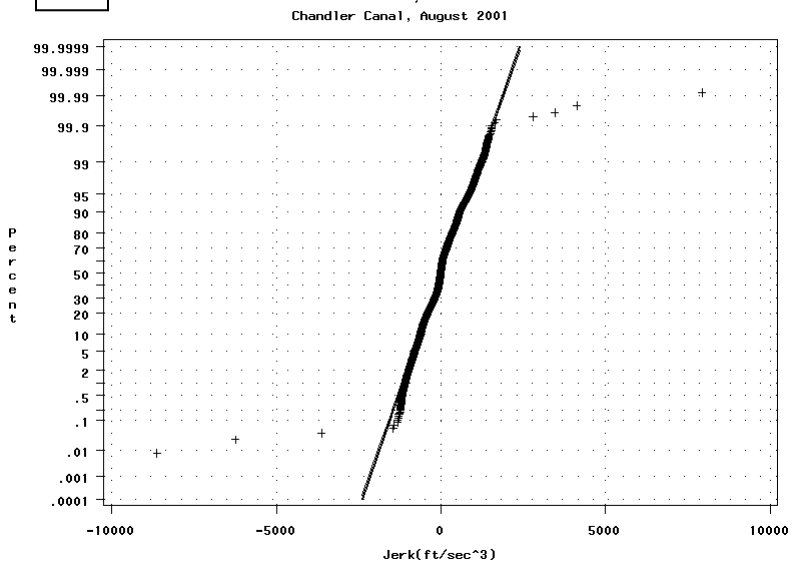
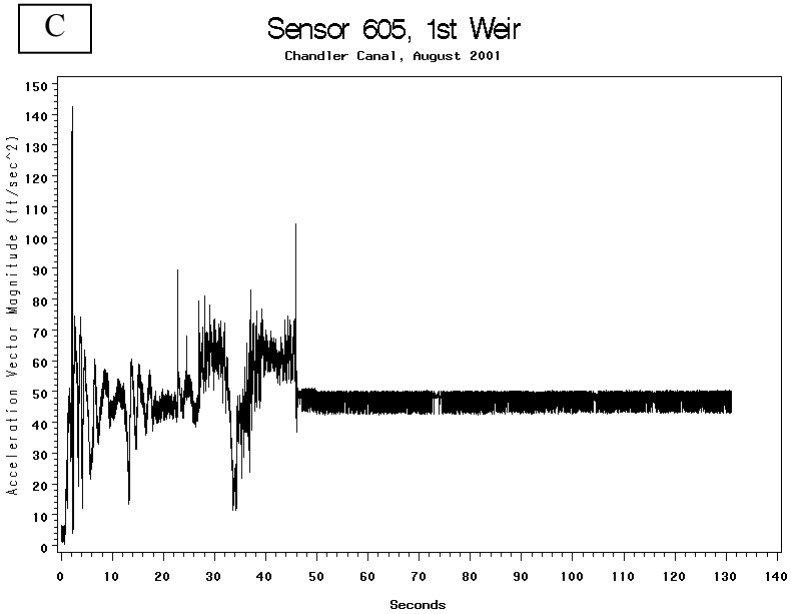
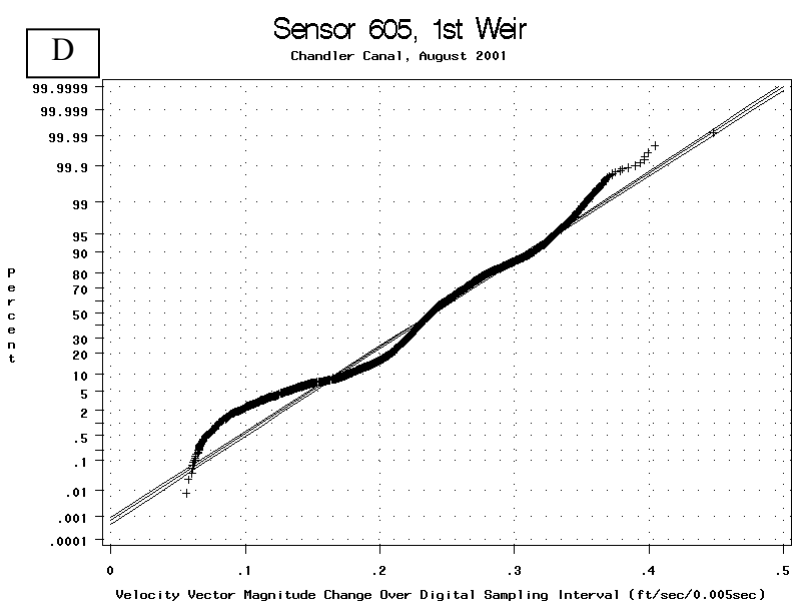

Sensor 605, 1st Weir
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

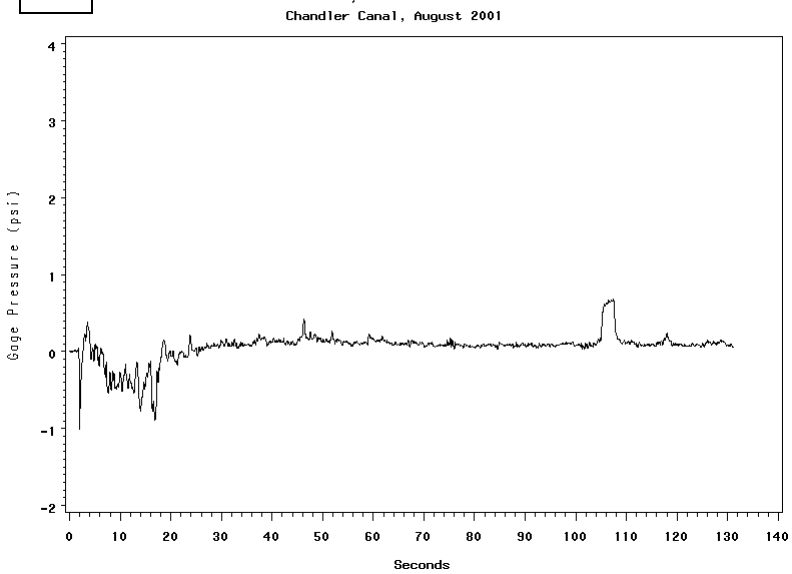
C


Sensor 605, 1st Weir
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

D


Sensor 605, 1st Weir
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

A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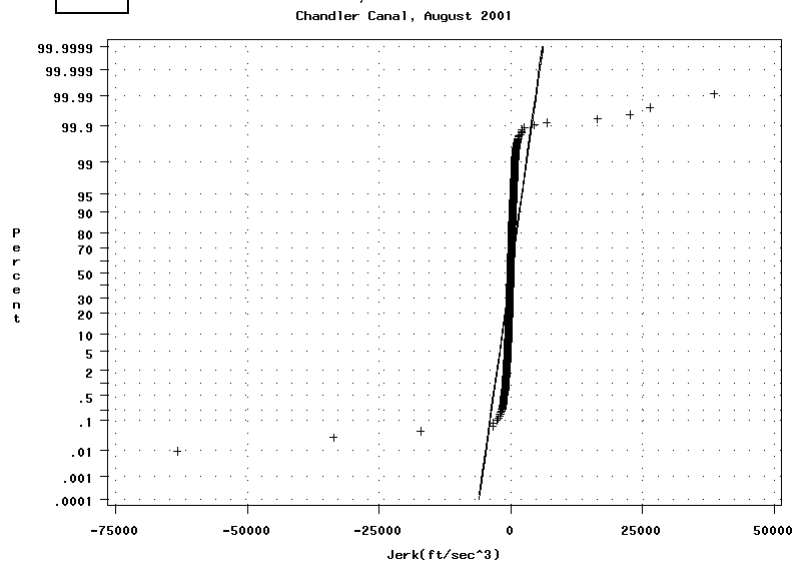
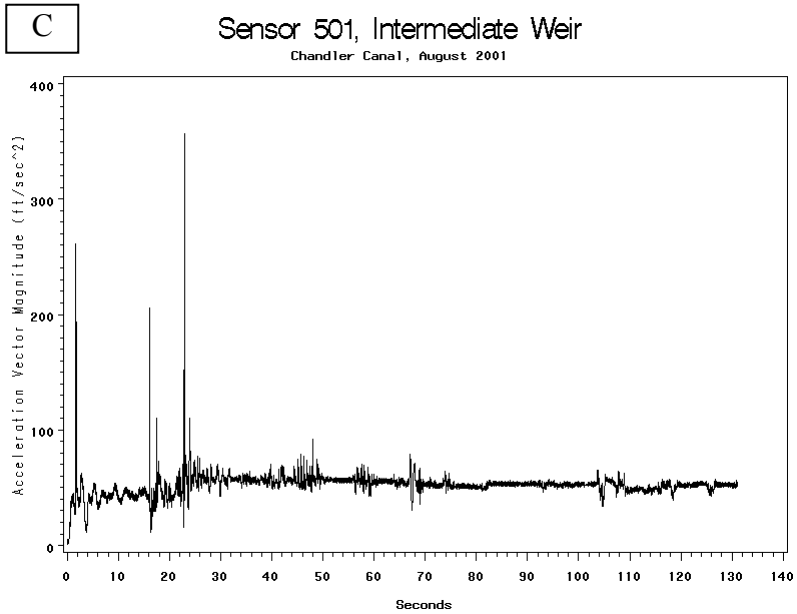
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

B


Sensor 501, Intermediate Weir
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

C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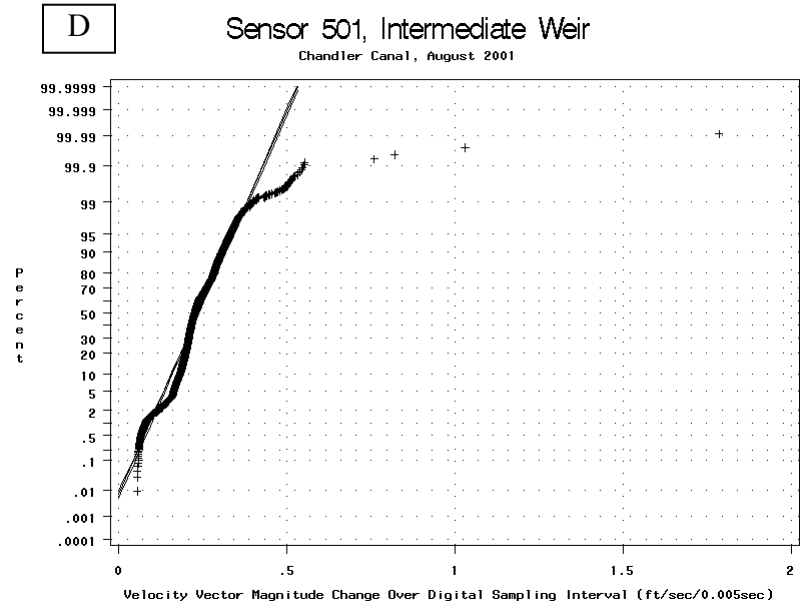
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

D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Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

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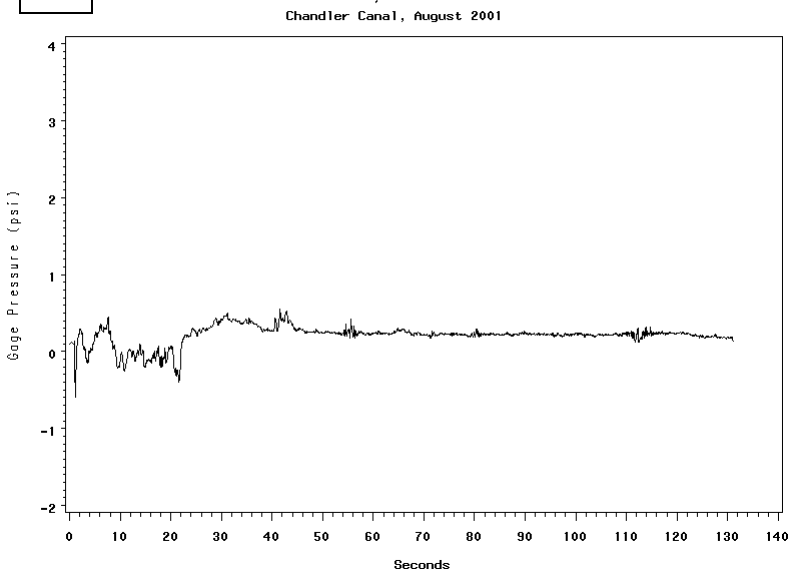
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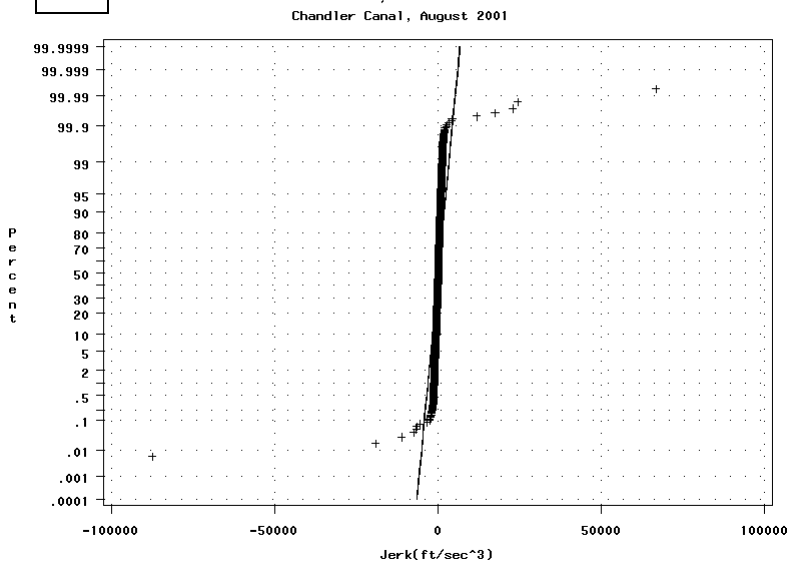
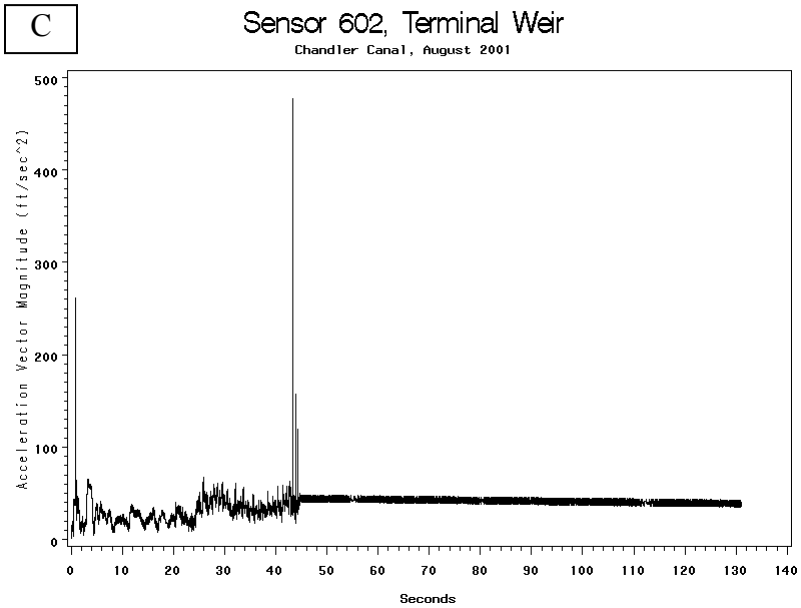
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

B


Sensor 602, Terminal Weir
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

C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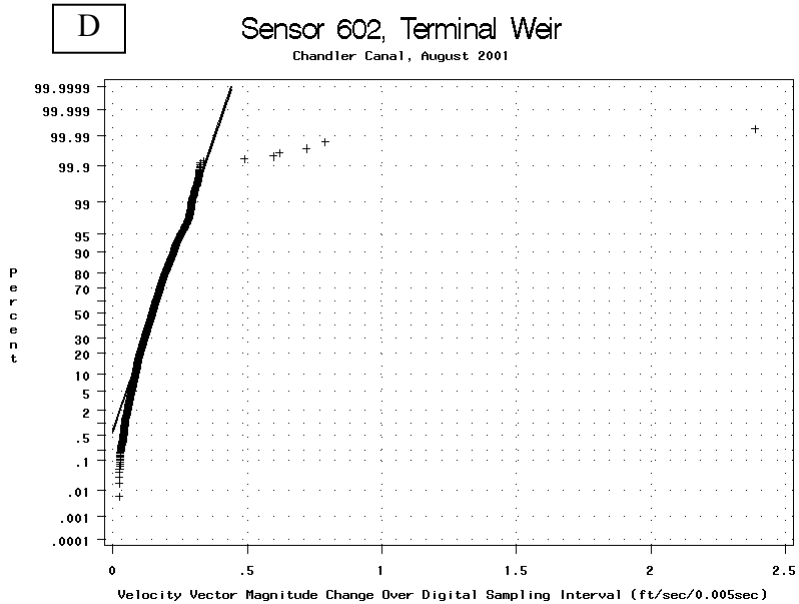
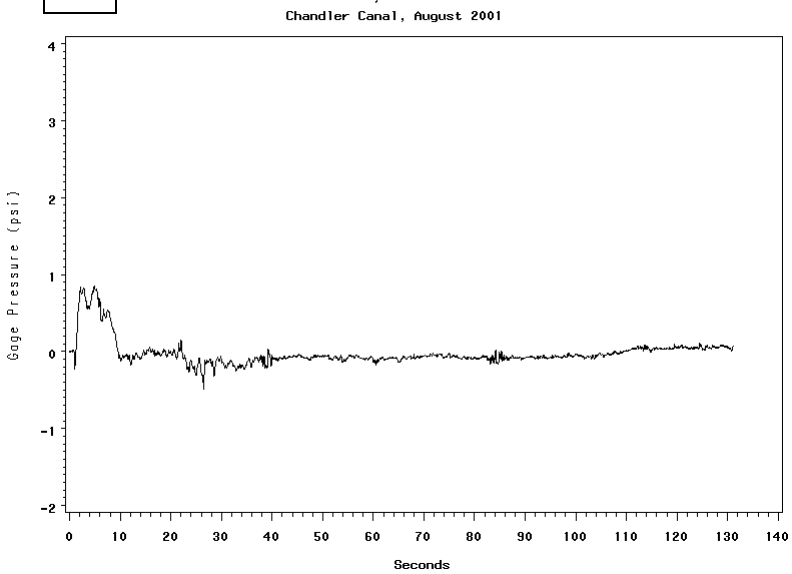
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

D


Sensor 602, Terminal Weir
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

A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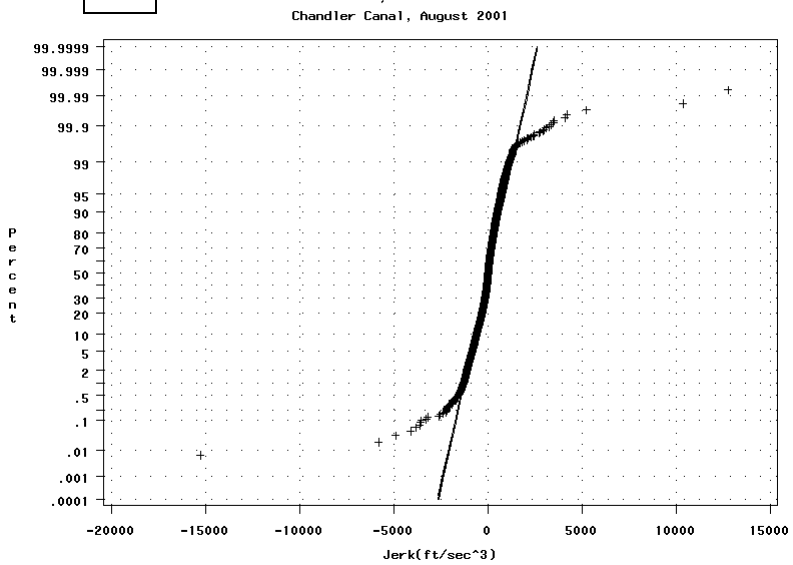
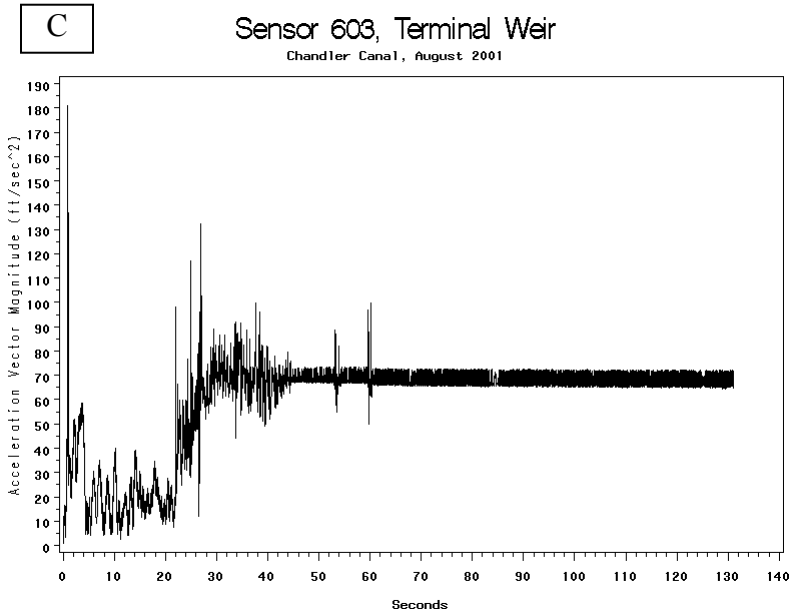
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

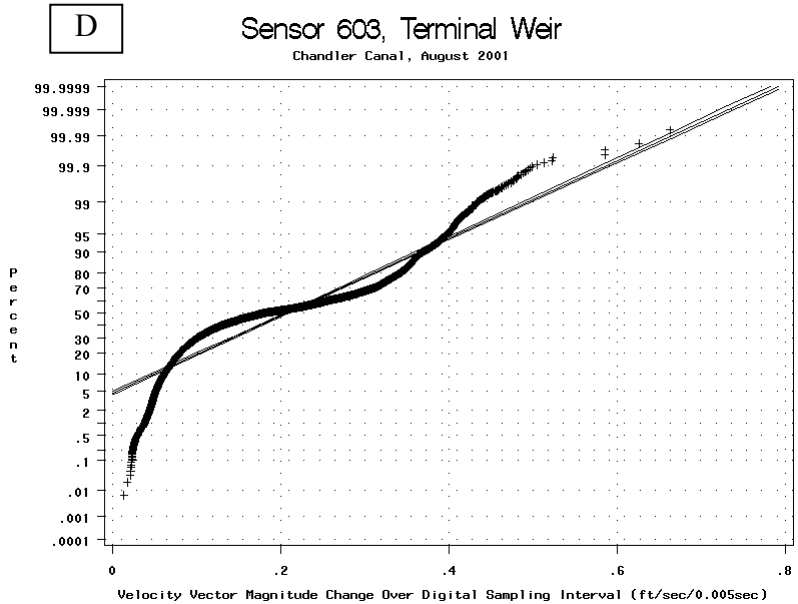
B


Sensor 603, Terminal Weir
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

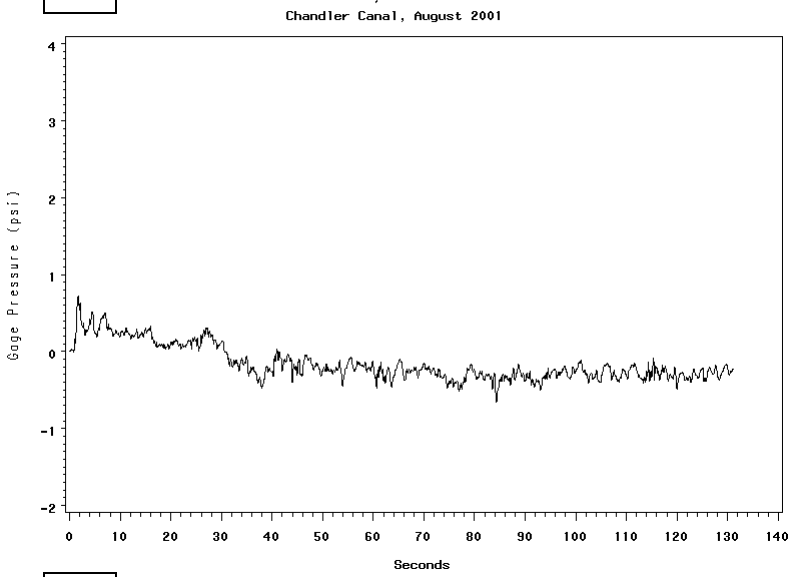
C


Sensor 603, Terminal Weir
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

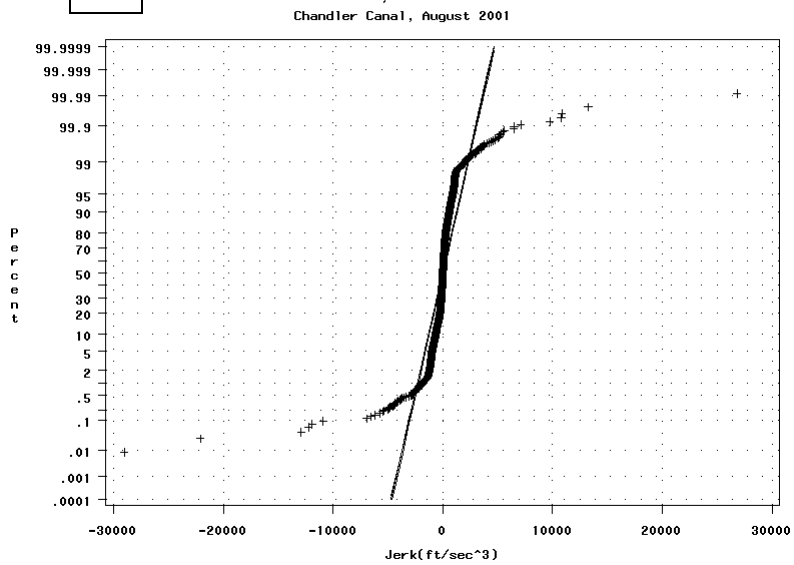
D


Sensor 603, Terminal Weir
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

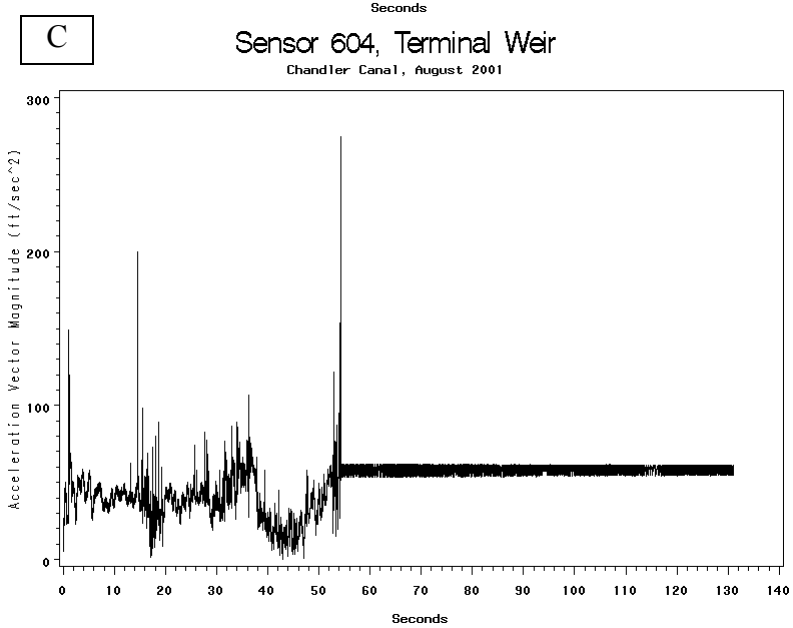
A


Sensor 604, Terminal Weir
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

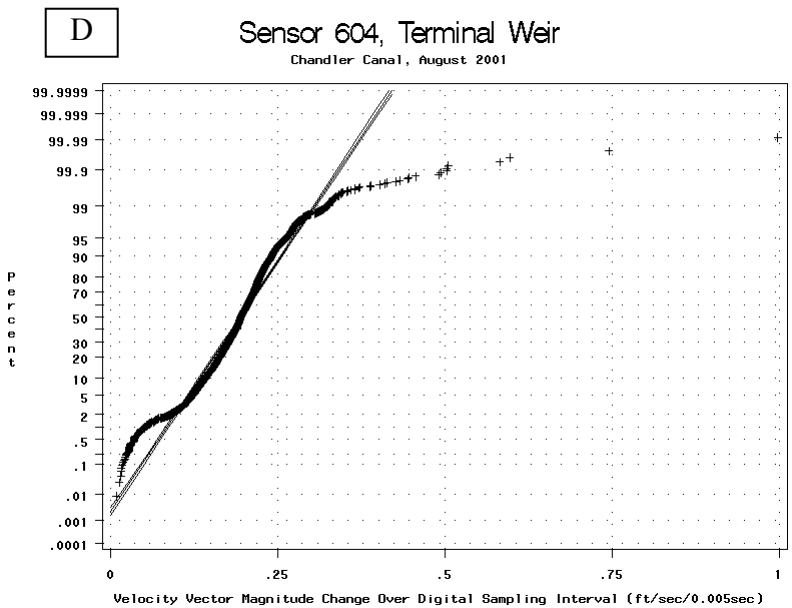
B


Sensor 604, Terminal Weir
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

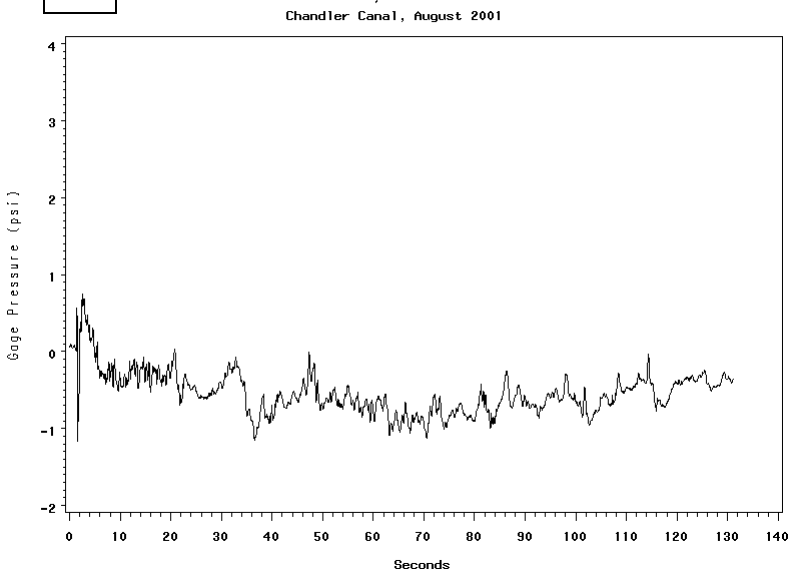
C


Sensor 604, Terminal Weir
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

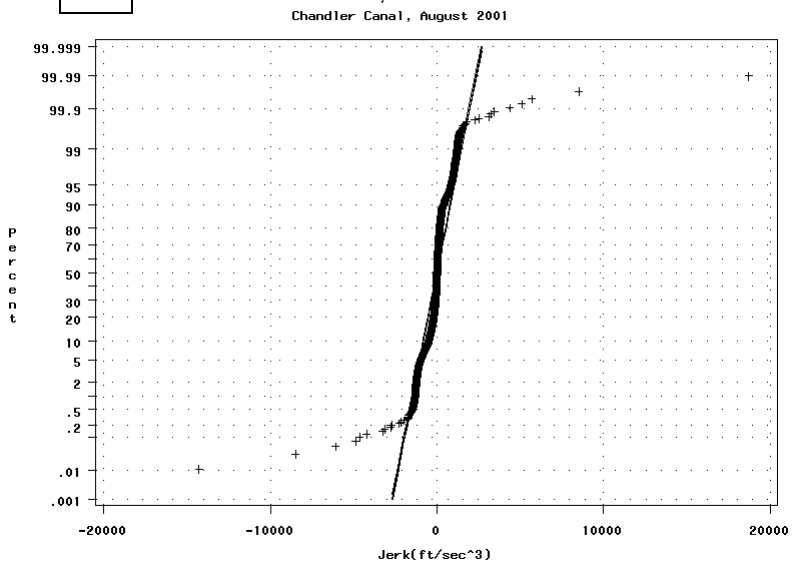
D


Sensor 604, Terminal Weir
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

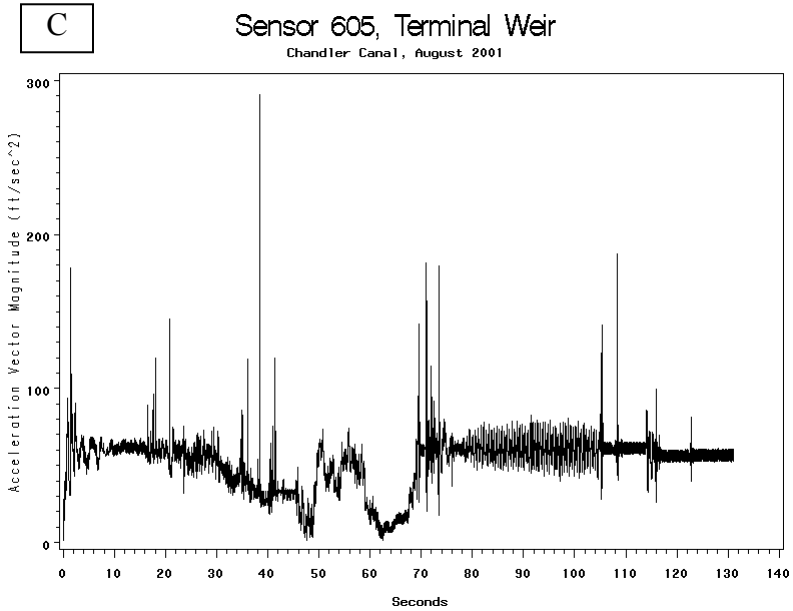
A


Sensor 605, Terminal Weir
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

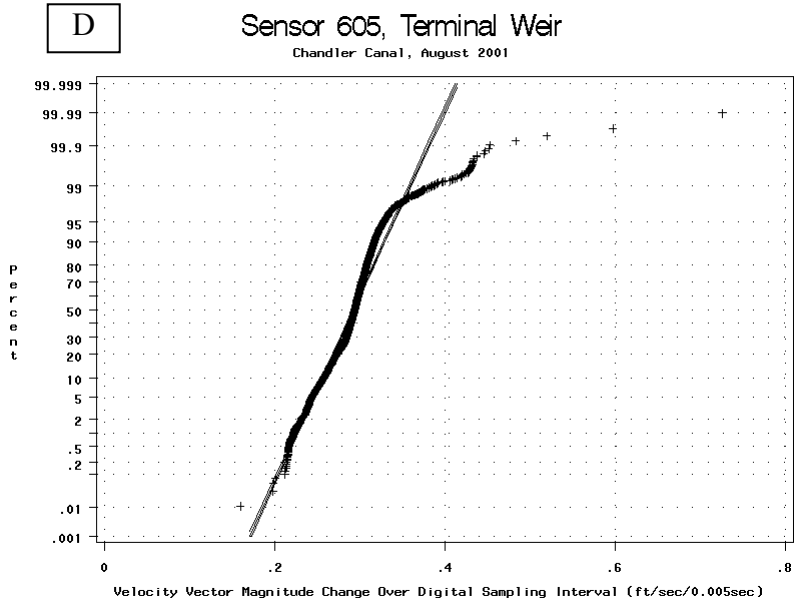
B


Sensor 605, Terminal Weir
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

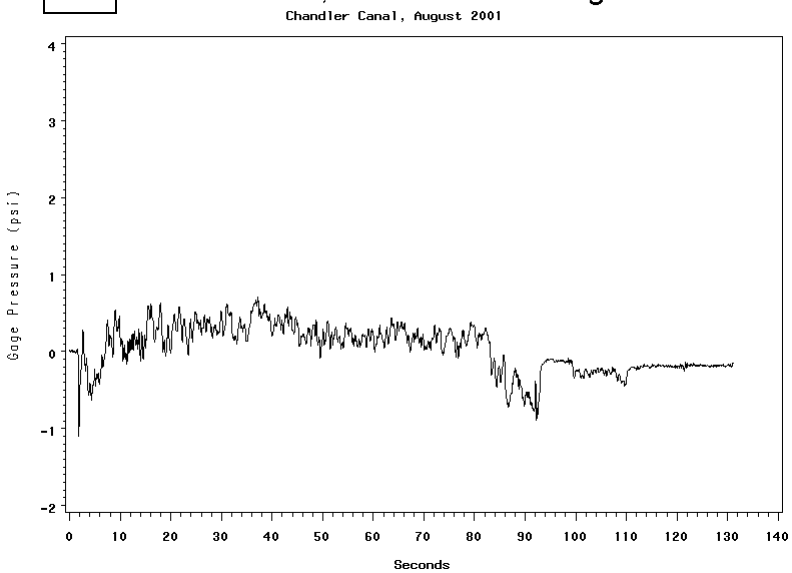
C


Sensor 605, Terminal Weir
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

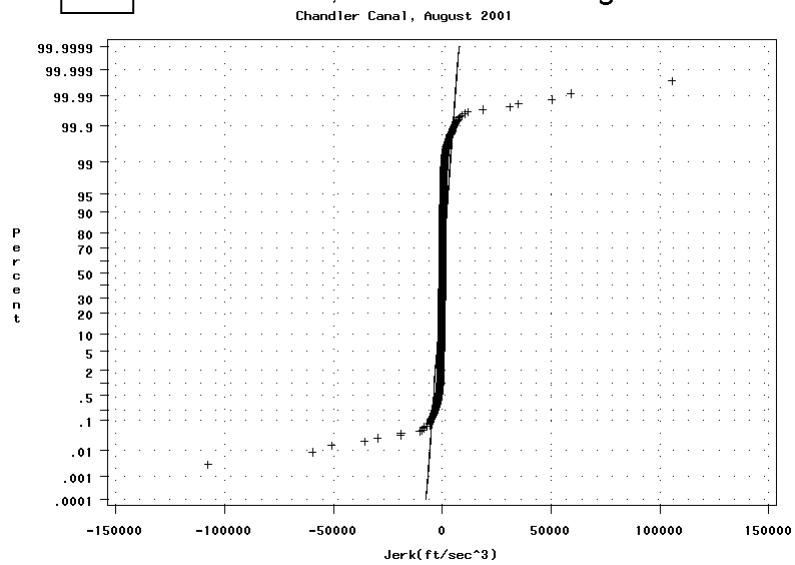
D


Sensor 605, Terminal Weir
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

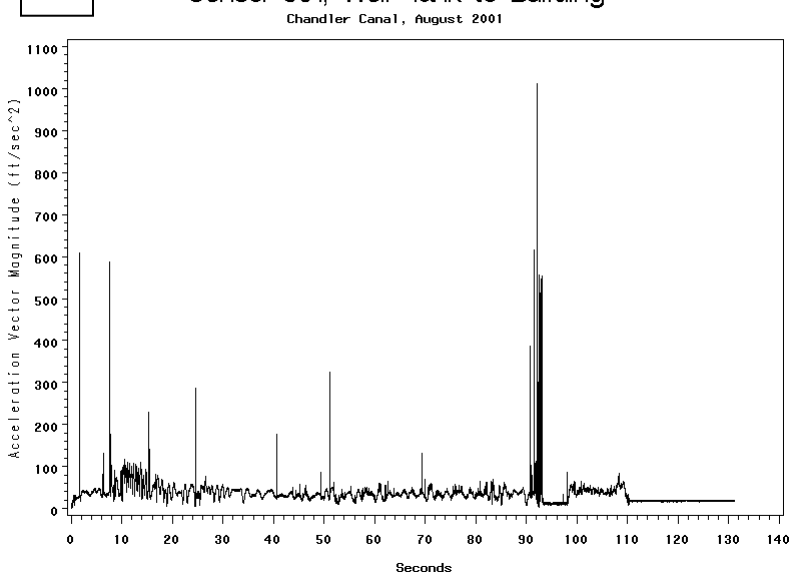
A


Sensor 501, Weir Tank to Building
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

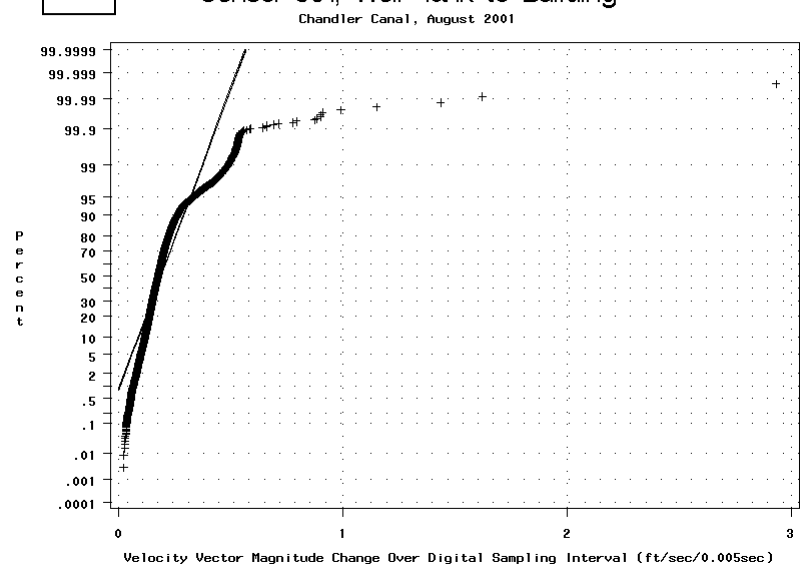
B


Sensor 501, Weir Tank to Building
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

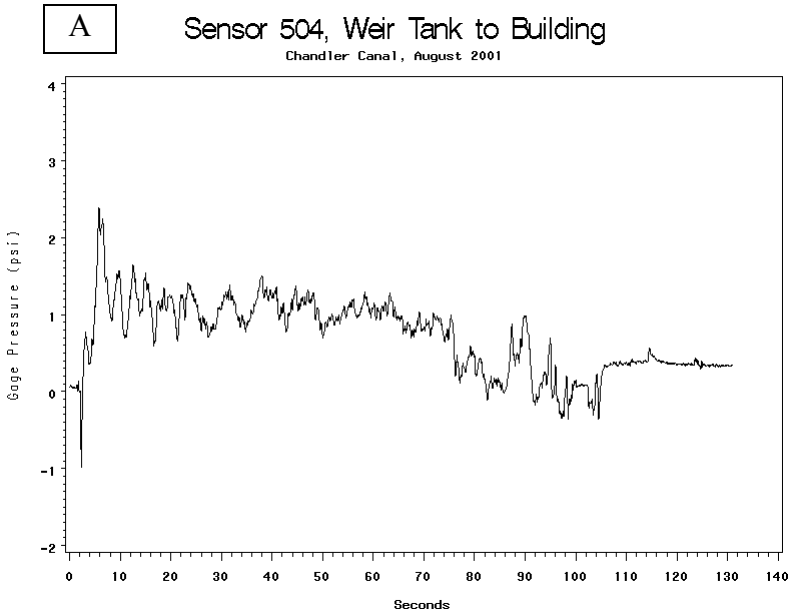
C


Sensor 501, Weir Tank to Building
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

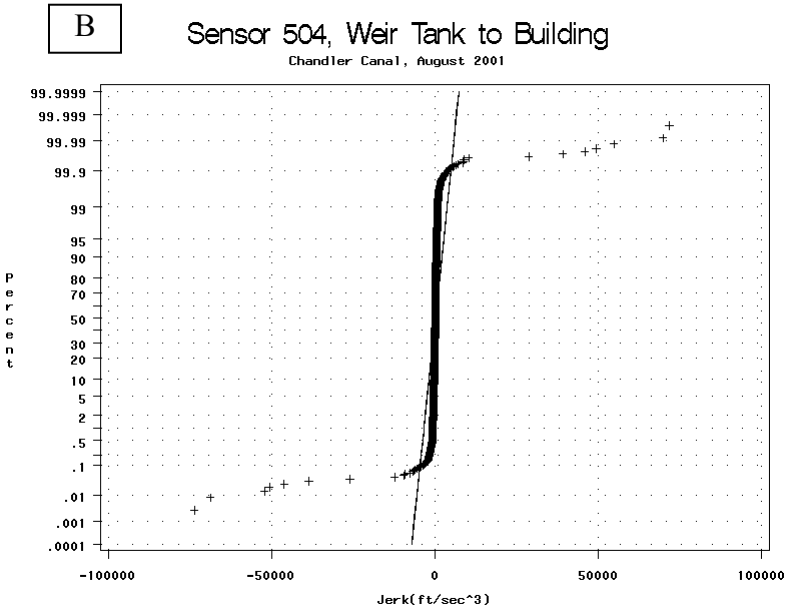
D


Sensor 501, Weir Tank to Building
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

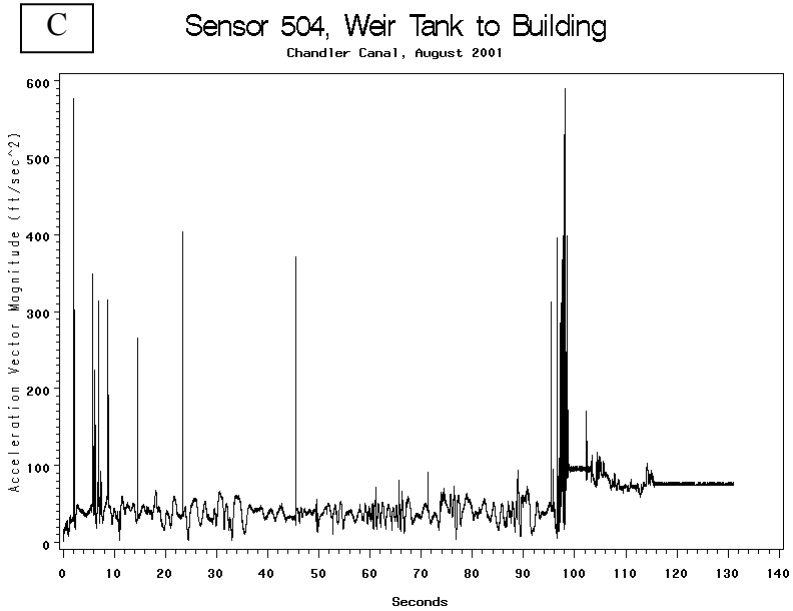
A


Sensor 504, Weir Tank to Building
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

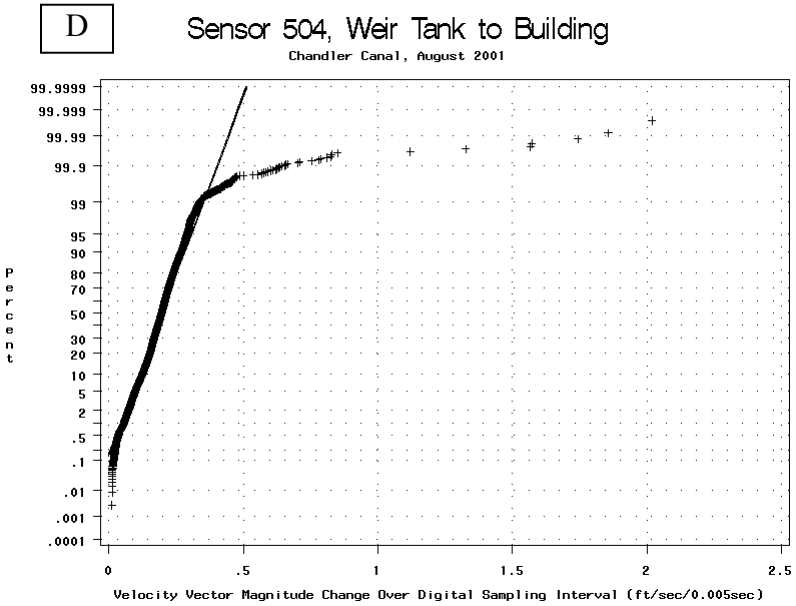
B


Sensor 504, Weir Tank to Building
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

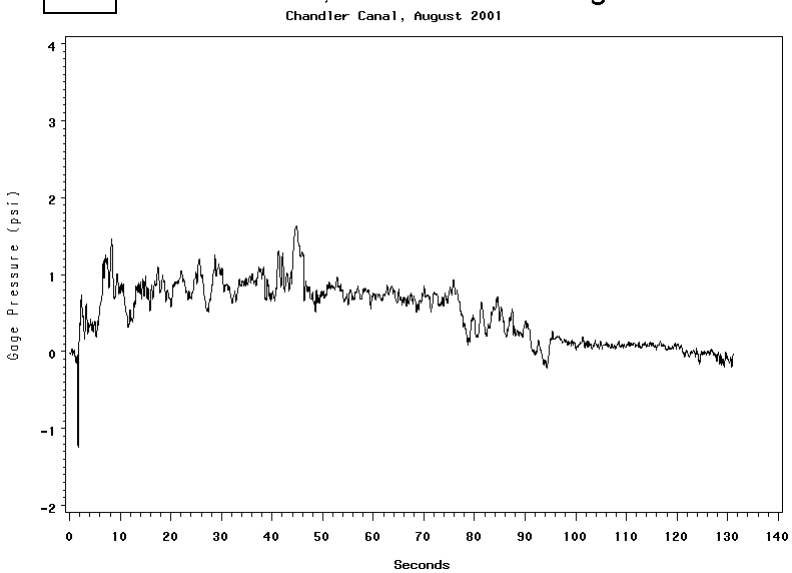
C


Sensor 504, Weir Tank to Building
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

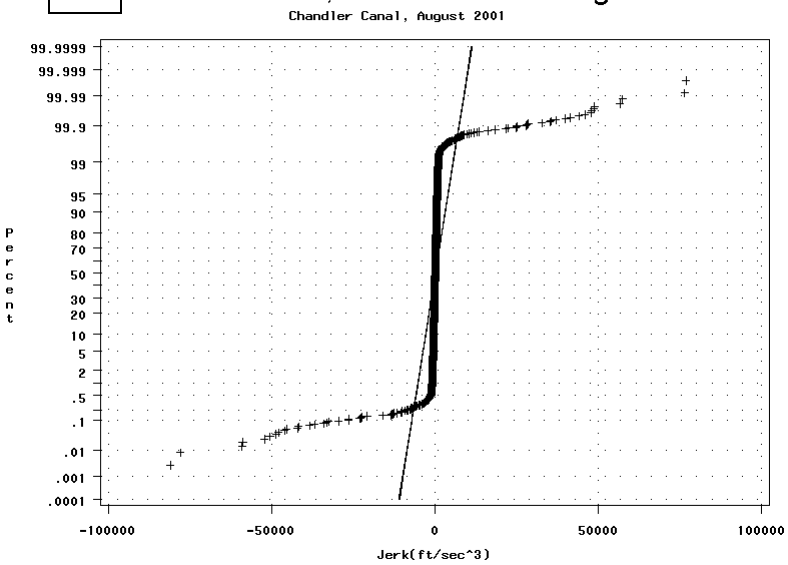
D


Sensor 504, Weir Tank to Building
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

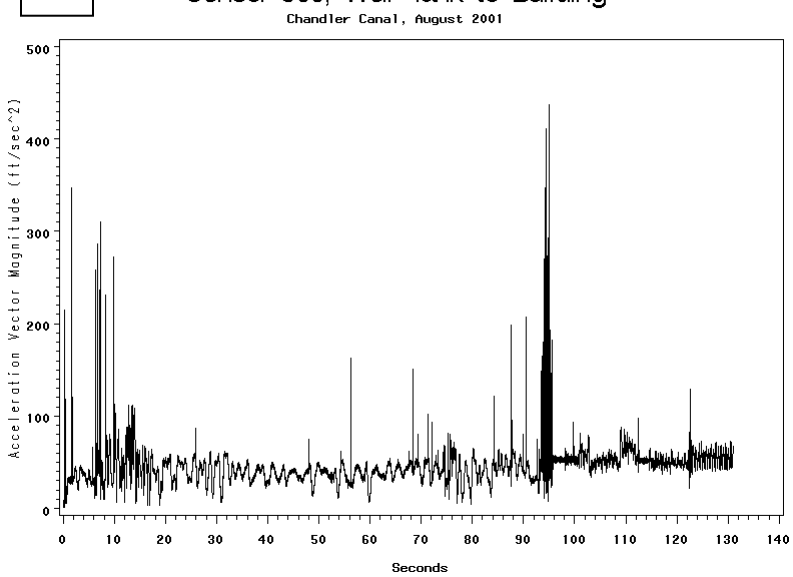
A


Sensor 506, Weir Tank to Building
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

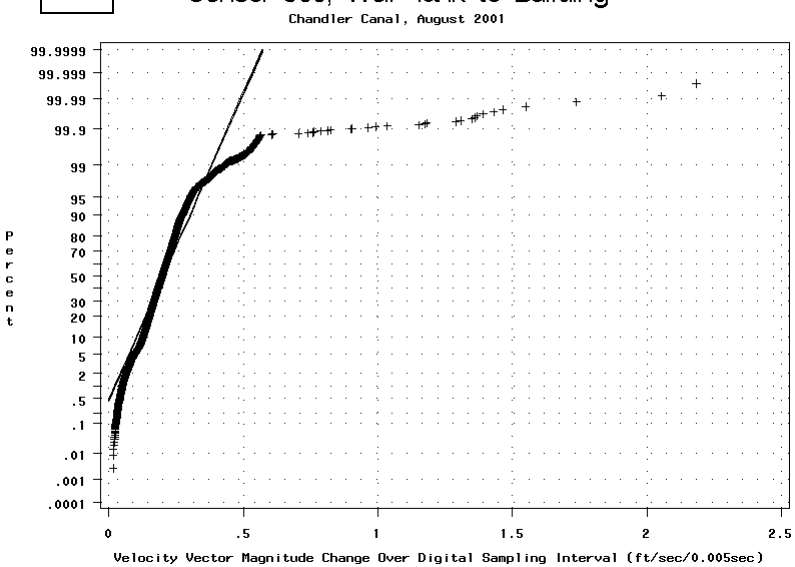
B


Sensor 506, Weir Tank to Building
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

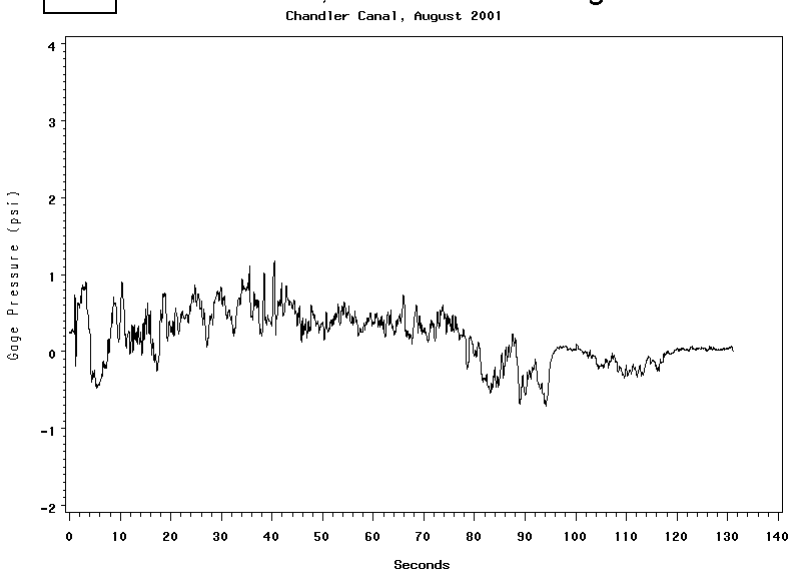
C


Sensor 506, Weir Tank to Building
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

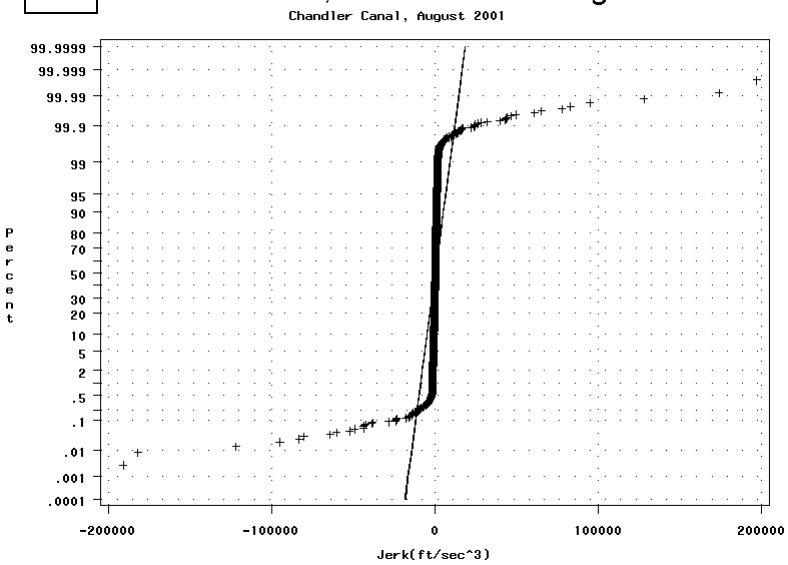
D


Sensor 506, Weir Tank to Building
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

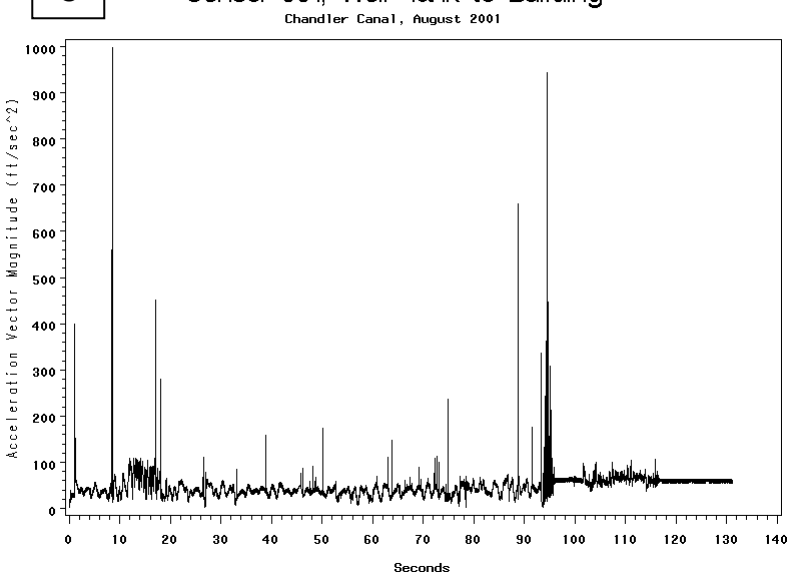
A


Sensor 601, Weir Tank to Building
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

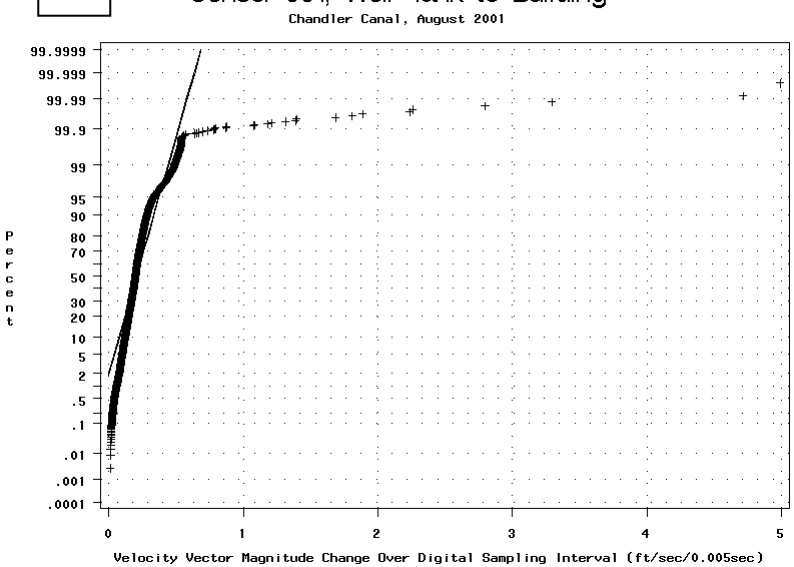
B


Sensor 601, Weir Tank to Building
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

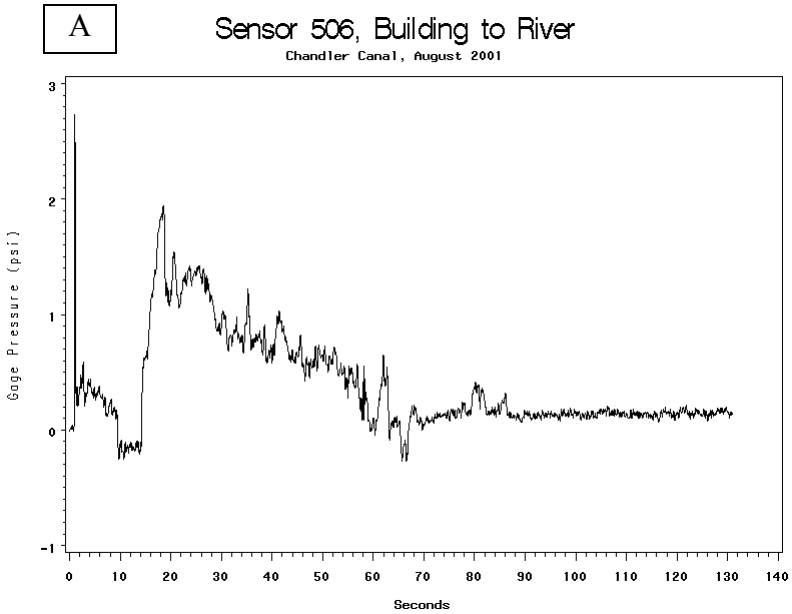
C


Sensor 601, Weir Tank to Building
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

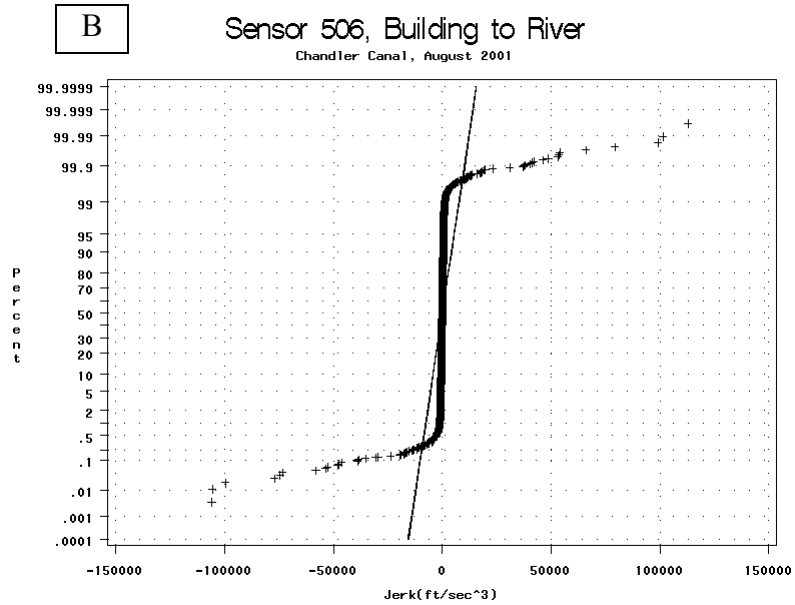
D


Sensor 601, Weir Tank to Building
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

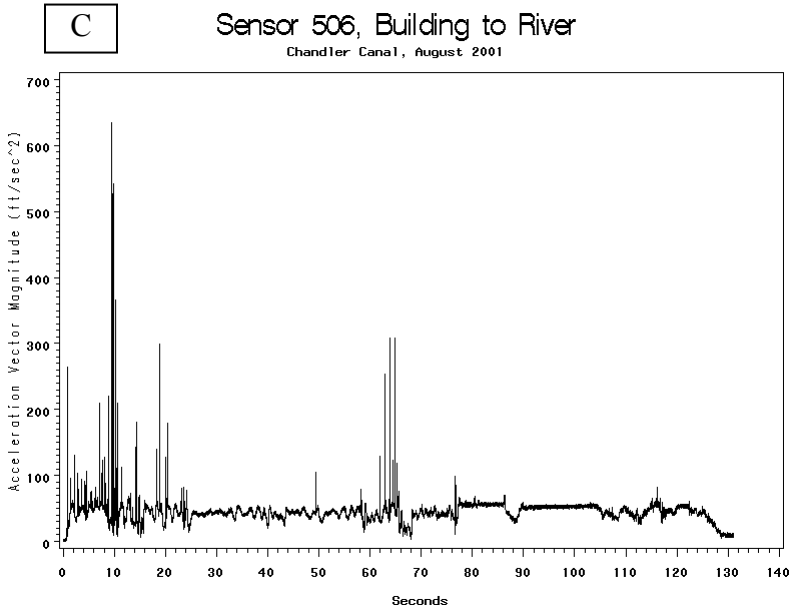
A


Sensor 506, Building to River
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

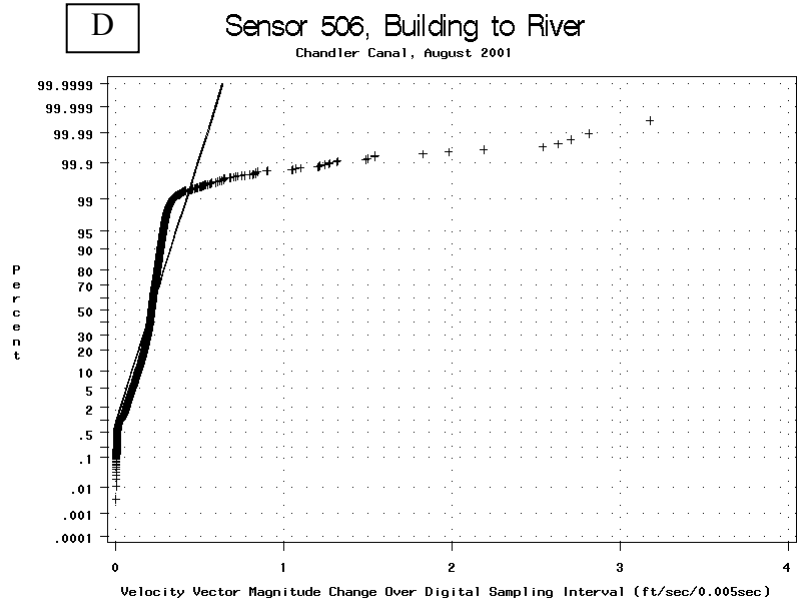
B


Sensor 506, Building to River
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

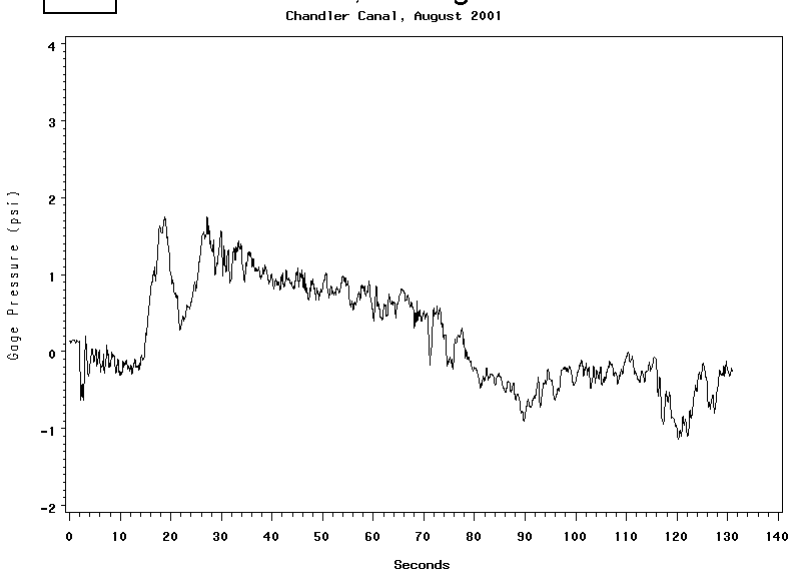
C


Sensor 506, Building to River
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

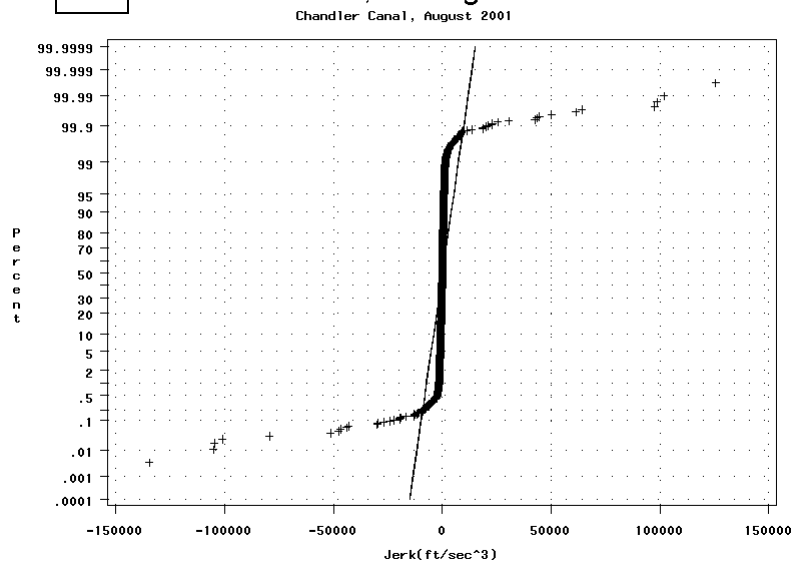
D


Sensor 506, Building to River
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

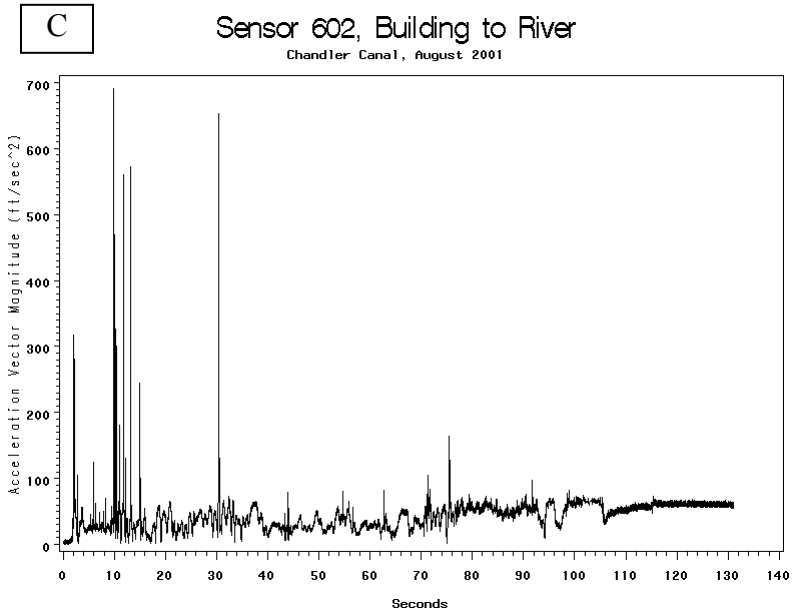
A


Sensor 602, Building to River
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

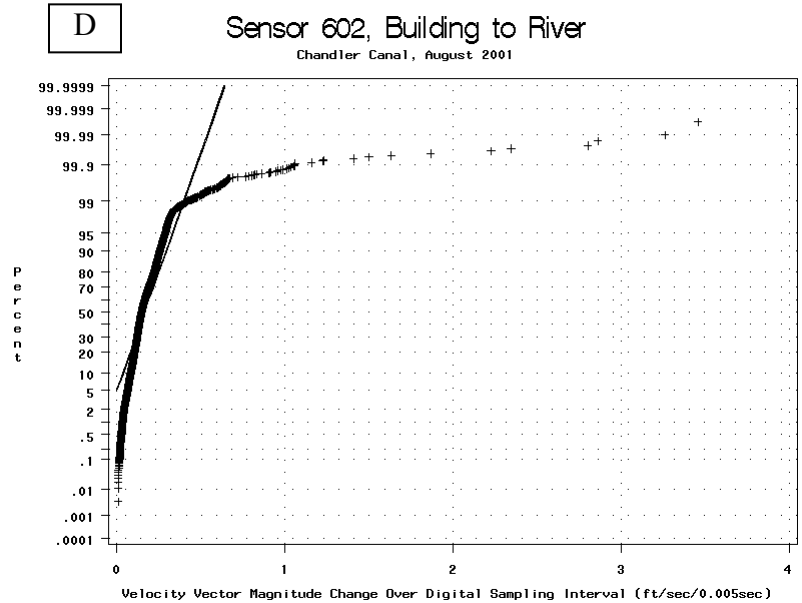
B


Sensor 602, Building to River
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

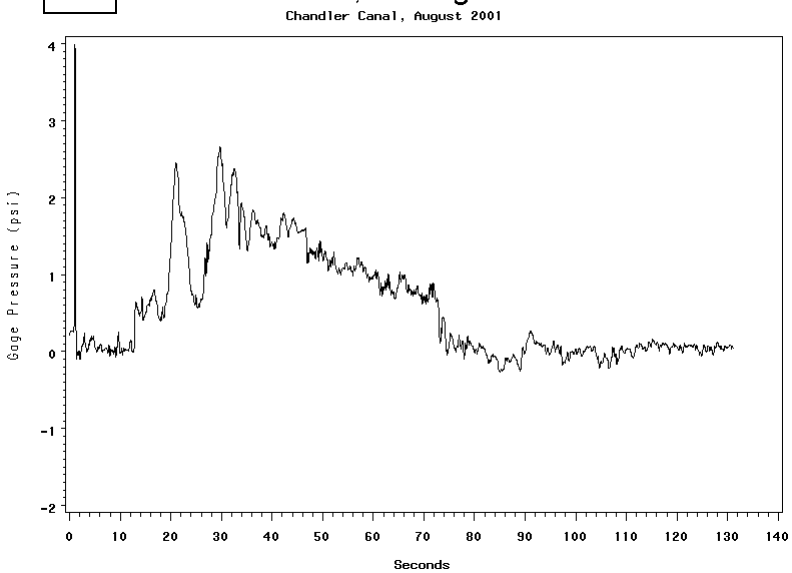
C


Sensor 602, Building to River
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

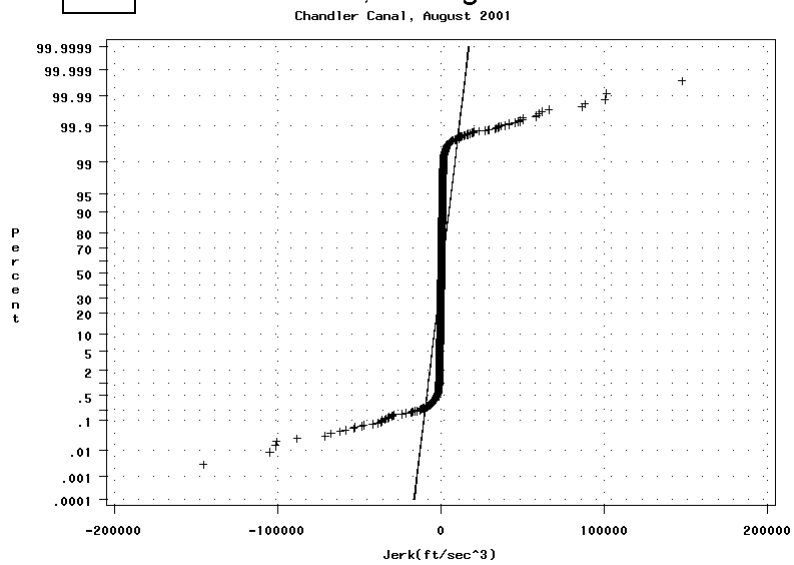
D


Sensor 602, Building to River
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

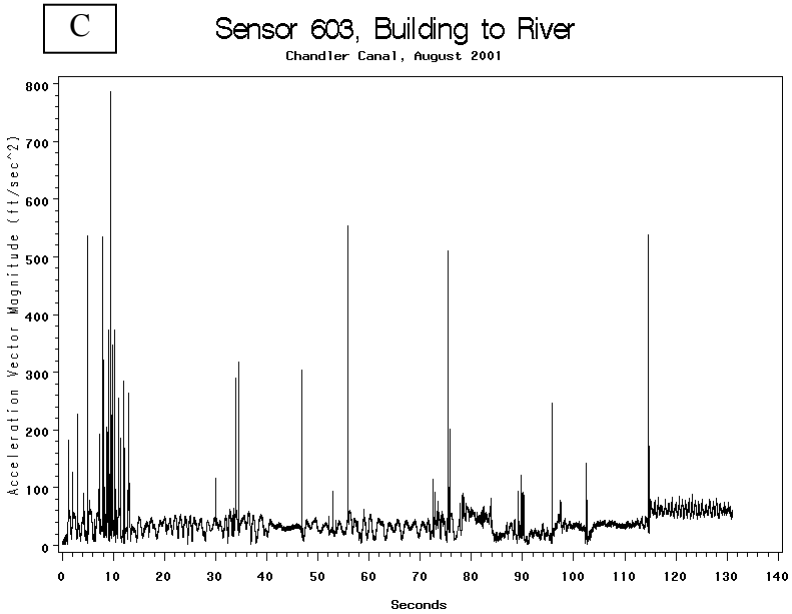
A


Sensor 603, Building to River
Chandler Canal, August 2001
Gage Pressure (psi)
Seconds

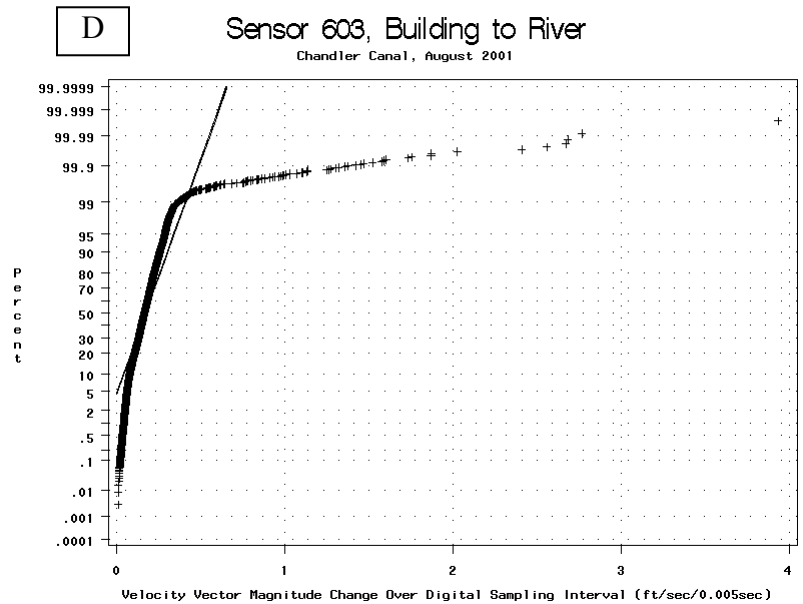
B


Sensor 603, Building to River
Chandler Canal, August 2001
Percent
Jerk(ft/sec^3)

C


Sensor 603, Building to River
Chandler Canal, August 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

D


Sensor 603, Building to River
Chandler Canal, August 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

Appendix B

Maximum and Minimum Jerk and Velocity Vector Magnitude Differential Values for Low Flow Sensor Fish Releases

Maximum and Minimum Jerk and Velocity Vector Magnitude Differential Values for Low Flow Sensor Fish Releases

	Jerk				Velocity Vector Delta			
File	Min	Time	Max	Time	Min	Time	Max	Time
501iw	-3297.73629	25.54	38598.6483	23.01	0.057186	3.76	1.784518	23.01
(Intermediate	-3414.78892	22.745	26438.7526	16.06	0.056229	3.75	1.029976	16.06
Weir)	-17125.6928	22.75	22721.9602	22.755	0.055749	3.755	0.819552	23.015
	-33691.8316	16.055	16500.0984	23.015	0.055452	3.73	0.75951	22.755
	-63295.5568	23.005	6871.68482	16.065	0.054649	3.745	0.552361	17.465
501ws	-29814.3791	40.705	105580.297	7.54	0.027019	18.92	2.932528	7.54
(Weir Tank	-35644.5617	15.38	59030.0884	51.135	0.0268	18.91	1.621383	51.135
To Bldg)	-50893.8713	24.61	50376.9373	24.615	0.026771	24.505	1.436846	24.615
	-59450.6016	51.13	34942.1073	15.385	0.022	24.495	1.150143	15.385
	-107670.659	7.535	31048.7632	40.71	0.021618	24.5	0.990956	7.645
504ew	-90354.5499	38.495	113998.758	45.79	0.019006	56.42	3.366084	45.79
(1st Weir)	-91136.7862	46.25	100497.936	36.875	0.01829	56.445	2.795436	36.875
	-97986.9803	51.11	94872.5711	38.5	0.015611	46.71	2.710429	51.115
	-99949.7905	36.87	92706.4996	51.115	0.013208	56.43	2.545382	38.5
	-117020.078	45.785	88504.8783	122.865	0.008664	56.425	2.472663	46.255
504ew2	-2946.53067	29.54	6592.76054	29.595	0.041323	4.995	0.507087	29.65
(1st Weir)	-3541.17389	29.645	6163.32495	29.55	0.040828	4.975	0.488037	29.655
	-3657.77787	29.62	3728.91825	29.625	0.040335	4.97	0.451008	29.66
	-4008.53016	29.585	2298.48418	29.72	0.040265	5.01	0.418558	29.645
	-4746.13402	29.59	1709.39192	29.665	0.037696	5.005	0.41538	29.665
504ws	-46297.4942	14.605	71731.2395	23.385	0.012617	11.05	2.018614	23.385
(Weir Tank	-50749.7484	8.77	69769.3375	45.49	0.012388	11.03	1.85687	45.49
To Bldg)	-52273.9461	5.815	54740.4284	5.82	0.011953	33.01	1.74416	5.82
	-68907.3026	45.485	49327.6029	8.775	0.011827	24.545	1.57364	8.775
	-73818.2229	23.38	45819.5859	14.61	0.011389	11.025	1.567017	6.92
506sr	-74569.0908	9.555	112874.19	9.56	0.002516	0.435	3.177025	9.56
(Bldg to	-77133.6255	9.695	101388.956	9.83	0.002364	0.14	2.813774	9.52
River)	-99590.1421	9.65	98974.8083	9.655	0.002364	0.19	2.7081	9.83
	-105511.95	9.825	79446.4189	9.7	0.002163	0.005	2.631527	9.655
	-105908.15	9.515	65975.9034	9.395	0.000668	0.54	2.537719	9.525
506ws	-52290.5429	94.885	76909.7014	94.51	0.021452	79.725	2.18452	94.955
(Weir Tank	-58938.2066	94.245	76376.3288	94.955	0.018906	16.485	2.054999	94.51
To Bldg)	-59169.3967	7.345	57333.9754	94.25	0.017145	18.87	1.73795	94.25
	-78177.4418	94.505	56613.5955	7.35	0.016459	16.935	1.550533	7.35
	-81221.0203	94.95	48760.1871	94.67	0.016294	18.895	1.464542	94.89

	Jerk				Velocity Vector Delta			
File	Min	Time	Max	Time	Min	Time	Max	Time
601mw	-4955.35173	66.78	8976.26081	107.225	0.018176	20.165	0.51152	5.445
(Intermediate	-5691.29613	82.72	6915.32755	2.715	0.016649	20.145	0.504231	107.225
Screen)	-5758.30502	81.06	6701.64528	81.065	0.014866	20.16	0.50186	5.495
	-9260.88273	107.22	5928.6934	66.785	0.014334	20.15	0.498743	5.425
	-10355.5639	2.705	4287.2915	82.715	0.013301	20.155	0.497399	5.44
601ws	-83484.1962	94.61	196926.04	8.515	0.015498	26.87	4.989959	8.515
(Weir Tank	-95146.1425	8.435	173763.479	94.565	0.015302	26.885	4.715423	94.565
To Bldg)	-122086.269	88.75	127818.923	88.755	0.014261	93.69	3.294063	88.755
	-182234.806	94.56	94954.4447	8.44	0.013918	78.39	2.797739	8.44
	-190942.768	8.51	82815.1962	94.615	0.013007	26.875	2.261427	17.1
602sr	-79409.9145	9.95	125581.858	9.9	0.010098	2.915	3.457711	9.9
(Bldg to	-101121.165	11.745	101850.955	13.205	0.009613	18.035	3.261256	30.465
River)	-104550.465	30.46	98772.1167	11.75	0.007321	12.76	2.860009	13.205
	-105251.408	13.2	97555.5612	30.465	0.00729	12.79	2.80214	11.75
	-134657.889	9.895	64075.8492	10.07	0.006735	11.305	2.345902	9.955
602tb	-44288.0294	5.75	97284.1669	5.06	0.012044	30.295	3.059111	1.575
(Terminal	-51062.5391	35.32	61713.7496	5.745	0.009912	30.335	2.565263	5.06
Screen)	-70720.6161	5.74	57145.5687	1.575	0.00888	98.235	1.941002	5.745
	-97389.9239	5.055	49631.9647	35.325	0.007849	98.24	1.630472	1.58
	-114877.611	1.57	42224.0582	23.68	0.00718	95.55	1.505359	5.755
602tw	-6751.77533	43.87	66732.8536	43.26	0.025707	2.395	2.388116	43.26
(Terminal	-7480.1432	43.285	24354.1605	43.875	0.025376	4.435	0.788885	43.875
Weir)	-11176.2159	44.285	22772.8918	43.265	0.024574	2.46	0.719795	43.265
	-19284.2477	43.865	17439.6852	44.29	0.024535	4.44	0.620091	43.87
	-87618.9897	43.255	11866.4815	43.295	0.023116	4.405	0.598137	44.29
603sr	-88303.2382	75.39	147462.306	9.42	0.01283	24.575	3.931202	9.42
(Bldg to	-100981.447	7.82	101266.507	4.95	0.012015	24.57	2.765161	55.87
River)	-101609.226	55.865	100288.224	55.87	0.010728	36.945	2.682642	4.95
	-104958.815	4.945	87812.305	75.395	0.008223	36.935	2.669859	7.825
	-145801.377	9.415	85948.7285	7.83	0.00819	36.94	2.555623	75.395
603tb	-28809.5069	87.525	85496.7421	4.13	0.010432	61.9	2.38464	4.13
(Terminal	-31031.5314	88.7	71696.9187	8.985	0.01002	130.985	1.971098	8.985
Screen)	-32130.923	28.52	41196.7458	87.53	0.008224	61.915	1.31441	87.53
	-75686.33	8.98	32901.4276	28.525	0.006567	61.885	1.033015	28.525
	-86410.6487	4.125	32510.2993	88.705	0.005732	61.855	0.943105	88.705

	Jerk				Velocity Vector Delta			
File	Min	Time	Max	Time	Min	Time	Max	Time
603tw	-3828.63704	24.98	12778.0732	22.05	0.021495	5.44	0.662413	26.81
(Terminal	-4098.5906	26.8	10390.8918	24.99	0.021351	12.685	0.625749	26.805
Weir)	-4883.09988	26.79	5251.9469	1.05	0.020834	12.755	0.585739	24.99
	-5823.65246	26.795	4214.65474	22.44	0.017576	11.155	0.585439	26.815
	-15299.5507	22.045	4082.36034	25.03	0.013062	11.185	0.523285	26.8
604tw	-11923.1924	17.475	26867.6014	14.51	0.015662	17.155	0.998211	14.51
(Terminal	-12246.1813	18.705	13268.6818	18.045	0.015411	17.195	0.745429	1.015
Weir)	-12923.8468	15.5	10859.9521	15.505	0.015137	17.18	0.597252	1.145
	-22089.5942	1.01	10800.8327	17.48	0.01243	17.215	0.582604	1.02
	-29054.4213	14.505	9765.43067	18.715	0.008212	17.165	0.504974	1.135
605ew	-1441.67457	6.24	7941.20134	22.755	0.06068	4.145	0.44776	22.755
(1st Weir)	-1446.91455	4.155	4133.44753	26.985	0.060479	34.235	0.404559	28.135
	-3629.40074	24.54	3469.23806	24.545	0.060366	34.21	0.399462	28.15
	-6236.095	26.98	2809.68626	26.99	0.05742	34.19	0.396788	26.985
	-8630.38098	22.75	1687.86121	31.285	0.056324	33.58	0.396664	28.13
605tb	-36766.2049	35.7	112573.378	7.525	0.035817	41.42	3.567564	7.525
(Terminal	-47385.2558	10.715	88324.6542	4.175	0.034841	6.675	2.576282	4.175
Screen)	-49379.3212	101.465	50905.1972	101.47	0.03008	114.75	1.364797	101.47
	-97629.3834	4.17	46297.7847	10.72	0.027285	13.11	1.274808	10.72
	-133736.941	7.52	38195.3293	35.705	0.020408	13.165	1.130398	35.705
605tw	-4613.05775	17.505	18734.9614	20.845	0.001059	21.115	0.726146	20.845
(Terminal	-4863.93031	20.835	8547.05703	18.11	0.001006	23.57	0.597492	18.11
Weir)	-6059.89937	16.49	5715.24949	16.495	0.000991	23.575	0.51957	18.105
	-8468.13633	18.1	5092.28358	17.51	0.00099	23.585	0.483353	17.765
	-14282.3906	20.84	4375.71914	17.765	0.000798	23.58	0.452839	2.39

File	Jerk >2000	VVMag >3.7	Total
501iw (Intermediate Weir)	10	0	5601
501ws (Weir Tank to Bldg)	75	0	17661
504ew (1st Weir)	163	0	25714
504ew2 (1st Weir)	4	0	5301
504ws (Weir Tank to Bldg)	36	0	18501
506sr (Bldg to River)	85	0	14001
506ws (Weir Tank to Bldg)	80	0	18601
601mw (Intermediate Screen)	72	0	26114
601ws (Weir Tank to Bldg)	105	2	18762
602sr (Bldg to River)	105	0	14601
602tb (Terminal Screen)	78	0	26014
602tw (Terminal Weir)	12	0	8781
603sr (Bldg to River)	109	1	17751
603tb (Terminal Screen)	53	0	25794
603tw (Terminal Weir)	21	0	7891
604tw (Terminal Weir)	61	0	5941
605ew (1st Weir)	4	0	6571
605tb (Terminal Screen)	31	0	25581
605tw (Terminal Weir)	10	0	4651
Total	1114	3	293832

August Low Flow

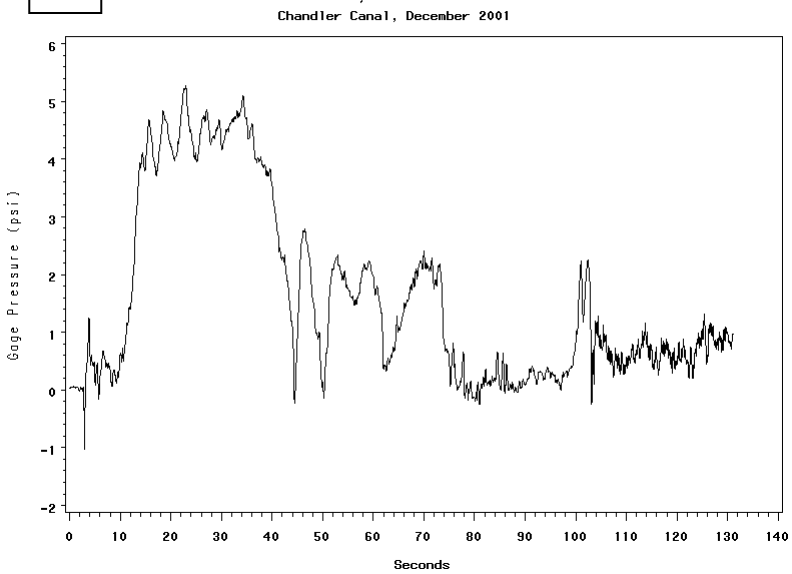
jerk >2000	0.003791282	**0.38%**
VVMag >3.7	1.02099E-05	**0.00102%**

Appendix C

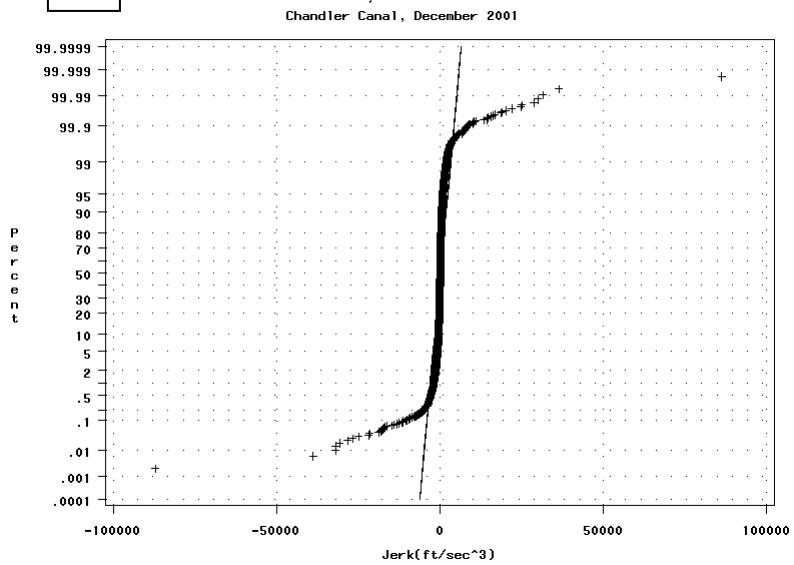
Gage Pressure and Acceleration Vector Magnitude Time Histories and Jerk and Velocity Vector Differential Cumulative Log Plots for High Flow Sensor Fish Releases

Note: Each page in the appendix contains 4 plots labeled A, B, C, and D. Plot A is the time history of gage pressure in psi. Plot B is the cumulative distribution of jerk in ftfec^3. Plot C is the time history of the magnitude of the sensor fish acceleration vector in ft/sec^2. Plot D is the cumulative distribution of the sensor fish velocity vector magnitude differential in ft/sec over time periods of 0.005 sec.

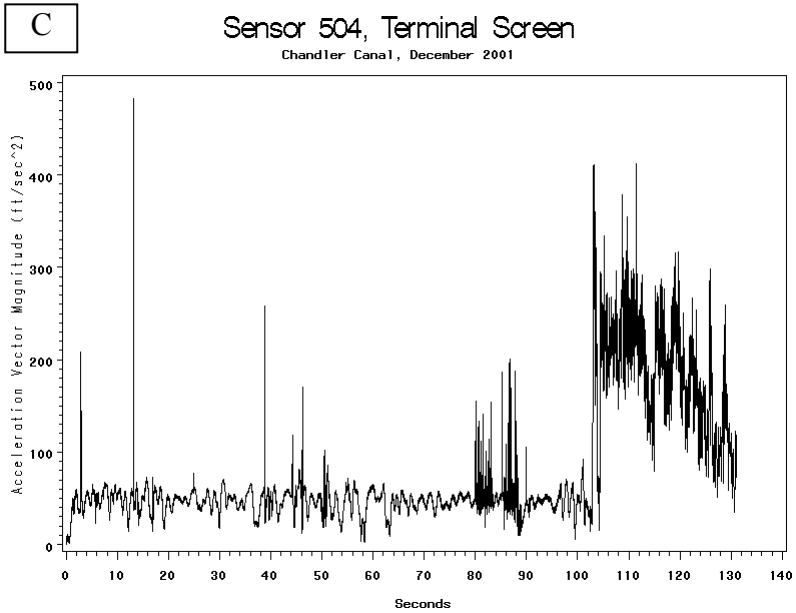
A


Sensor 504, Terminal Screen
Chandler Canal, December 2001
Gage Pressure (psi)
Seconds

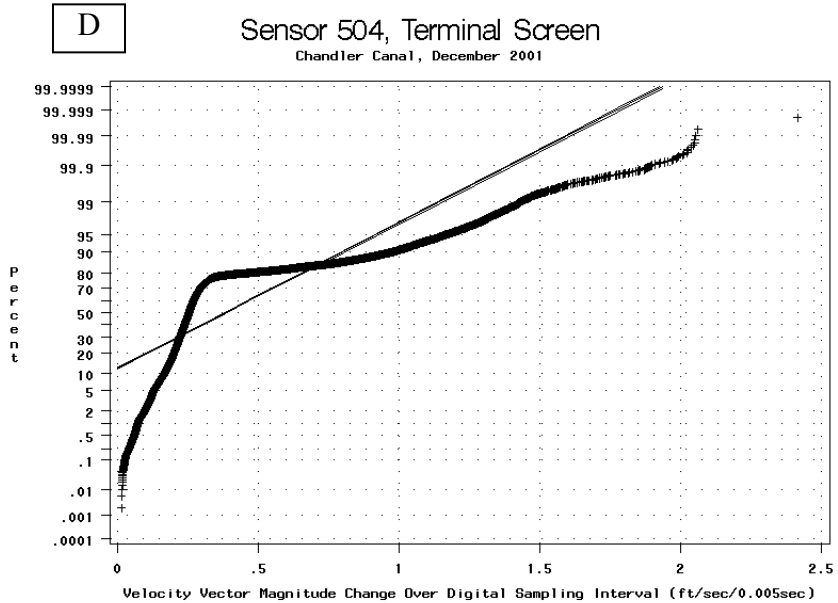
B


Sensor 504, Terminal Screen
Chandler Canal, December 2001
Percent
Jerk(ft/sec^3)

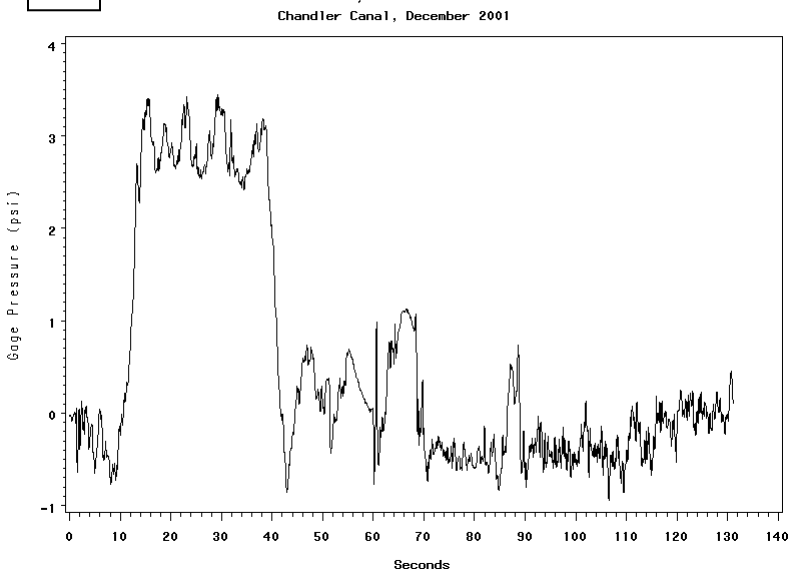
C


Sensor 504, Terminal Screen
Chandler Canal, December 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

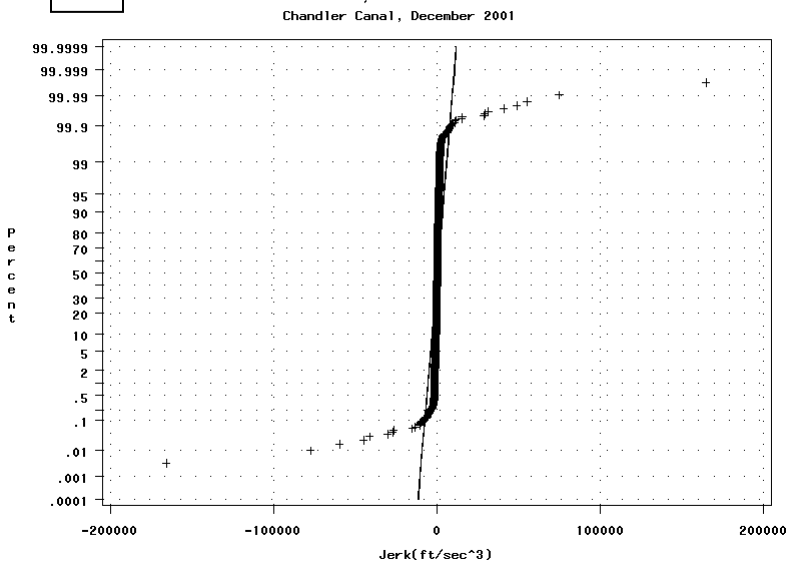
D


Sensor 504, Terminal Screen
Chandler Canal, December 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

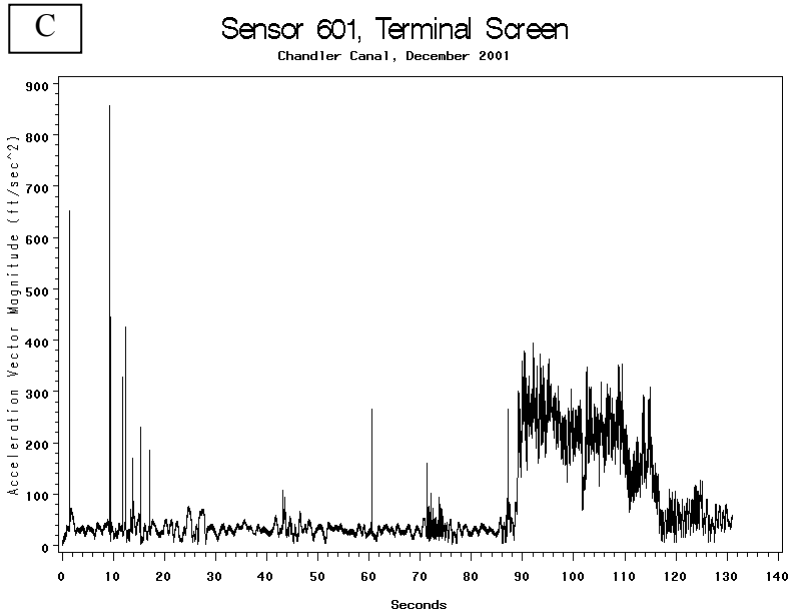
A


Sensor 601, Terminal Screen
Chandler Canal, December 2001
Gage Pressure (psi)
Seconds

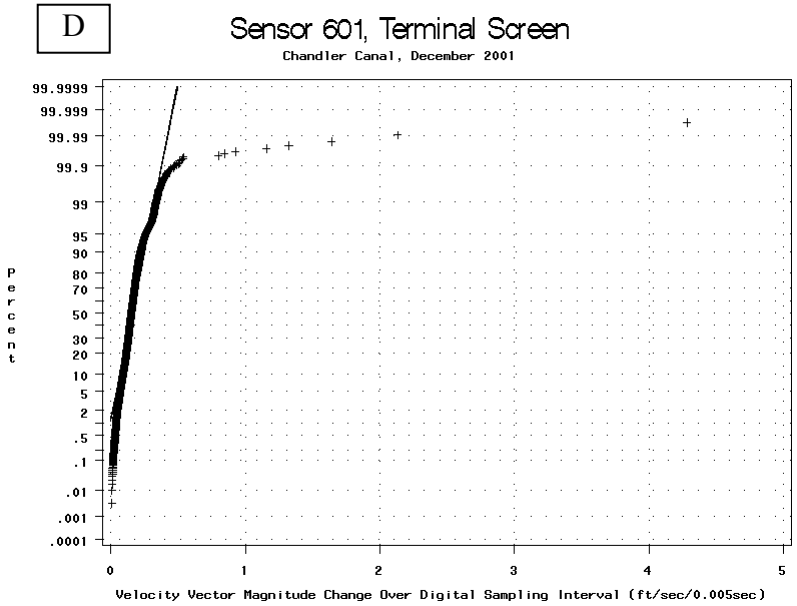
B


Sensor 601, Terminal Screen
Chandler Canal, December 2001
Percent
Jerk(ft/sec^3)

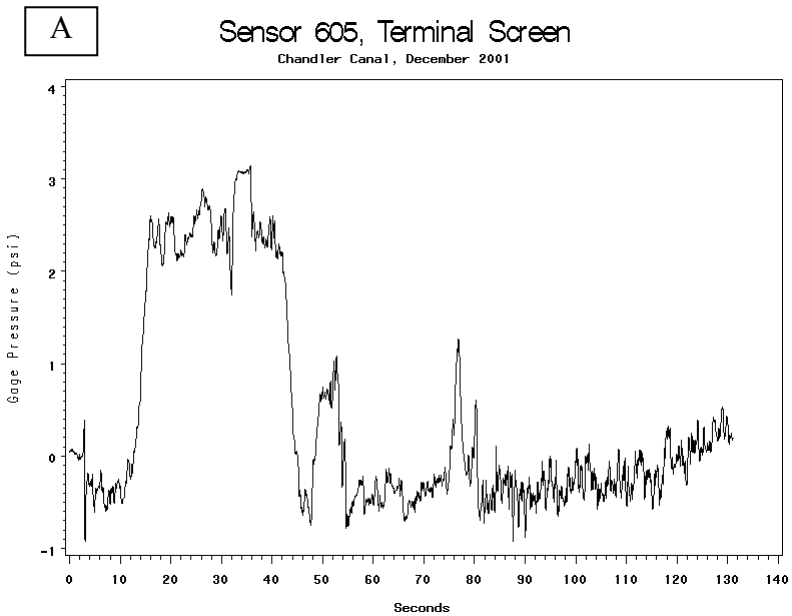
C


Sensor 601, Terminal Screen
Chandler Canal, December 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

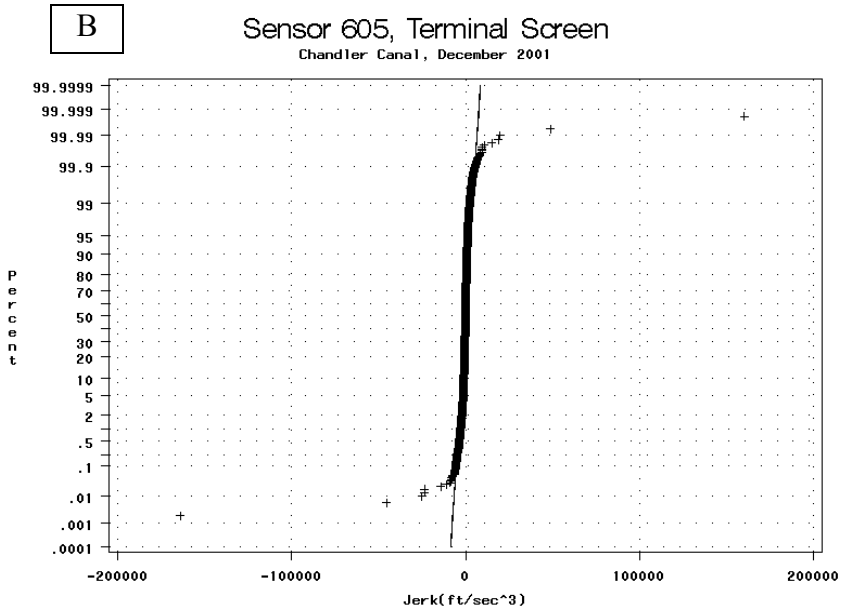
D


Sensor 601, Terminal Screen
Chandler Canal, December 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

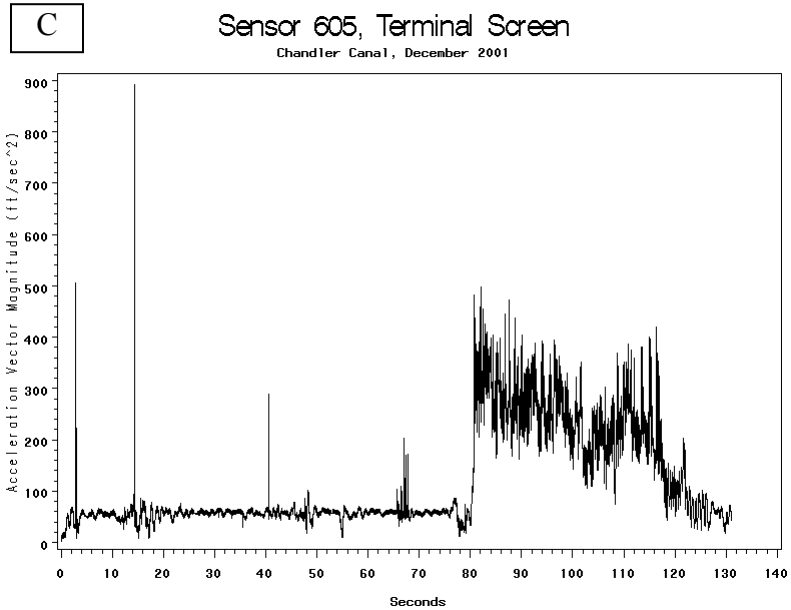
A


Sensor 605, Terminal Screen
Chandler Canal, December 2001
Gage Pressure (psi)
Seconds

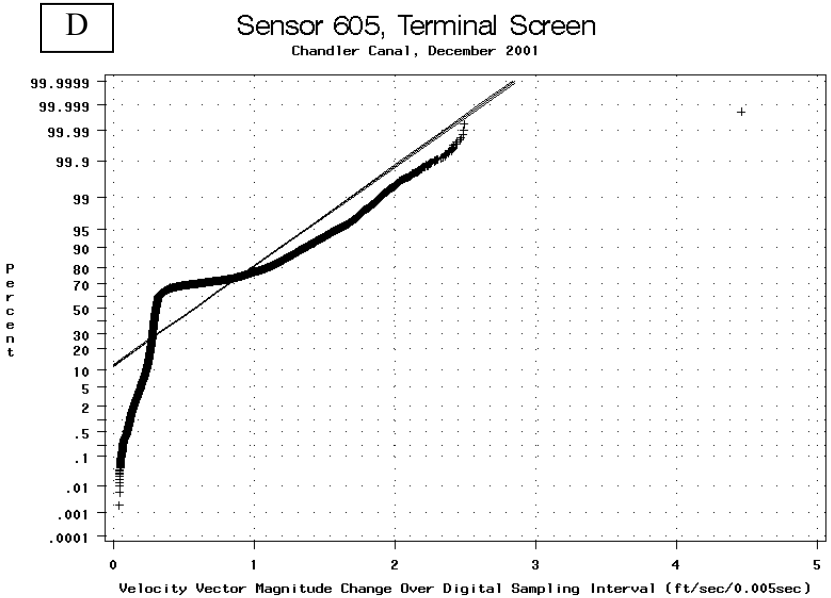
B


Sensor 605, Terminal Screen
Chandler Canal, December 2001
Percent
Jerk(ft/sec^3)

C


Sensor 605, Terminal Screen
Chandler Canal, December 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

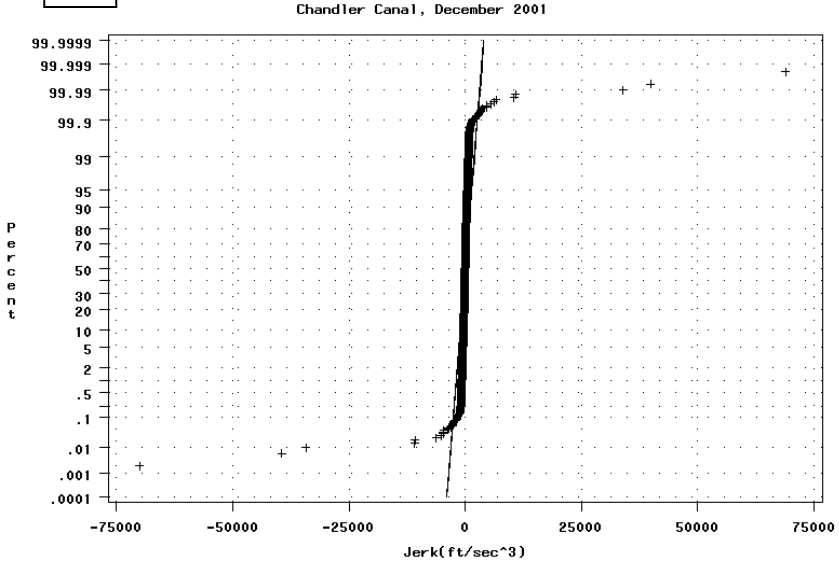
D


Sensor 605, Terminal Screen
Chandler Canal, December 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

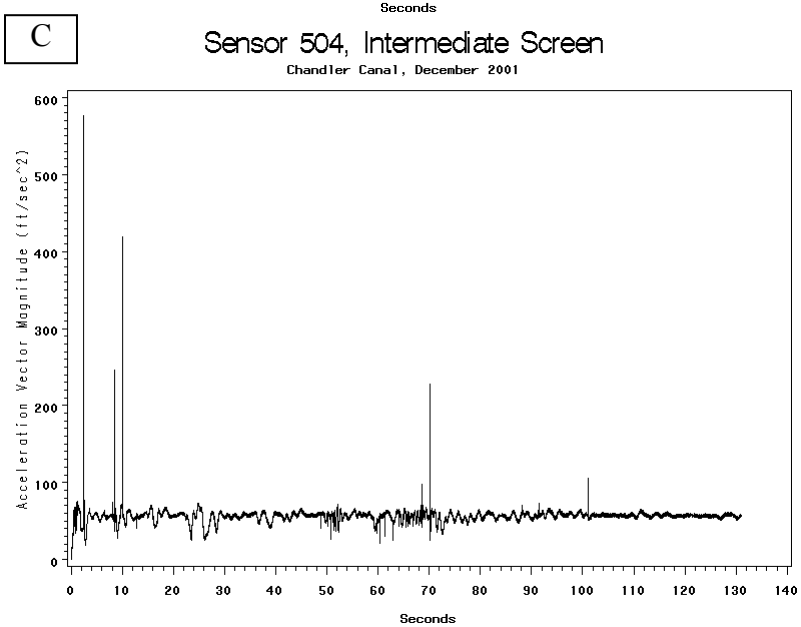
A

Sensor 504, Intermediate Screen
Chandler Canal, December 2001
Gage Pressure (psi)
Seconds

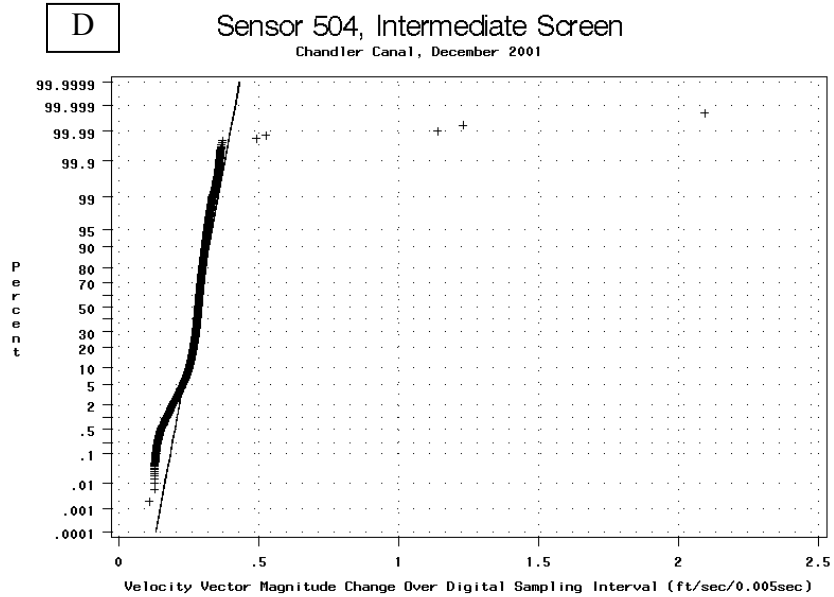
B


Sensor 504, Intermediate Screen
Chandler Canal, December 2001
Percent
Jerk(ft/sec^3)

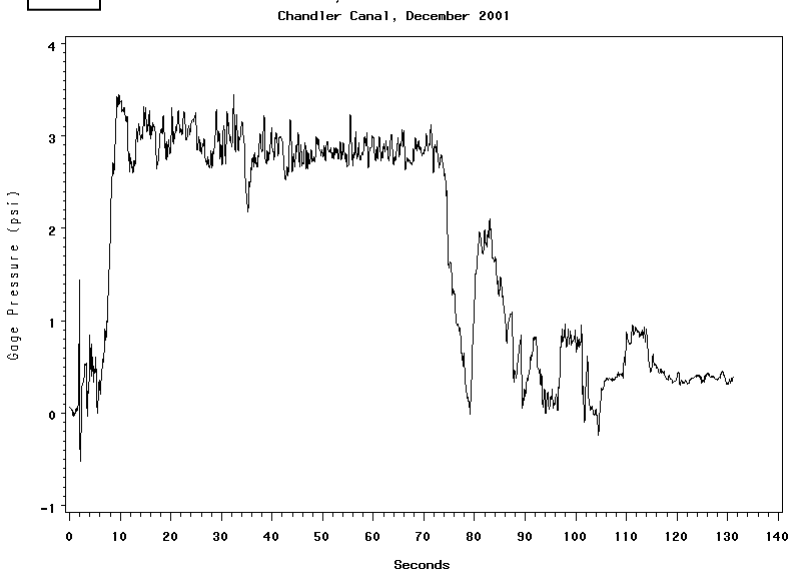
C


Sensor 504, Intermediate Screen
Chandler Canal, December 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

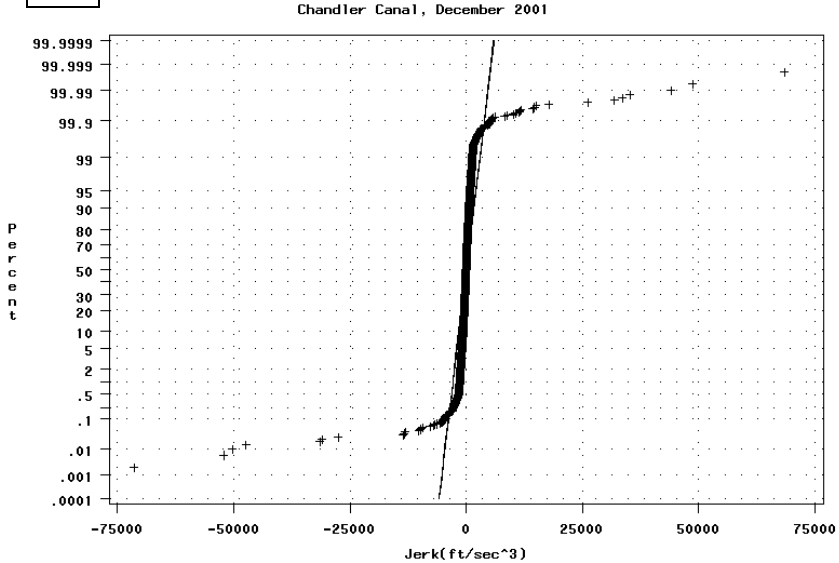
D


Sensor 504, Intermediate Screen
Chandler Canal, December 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

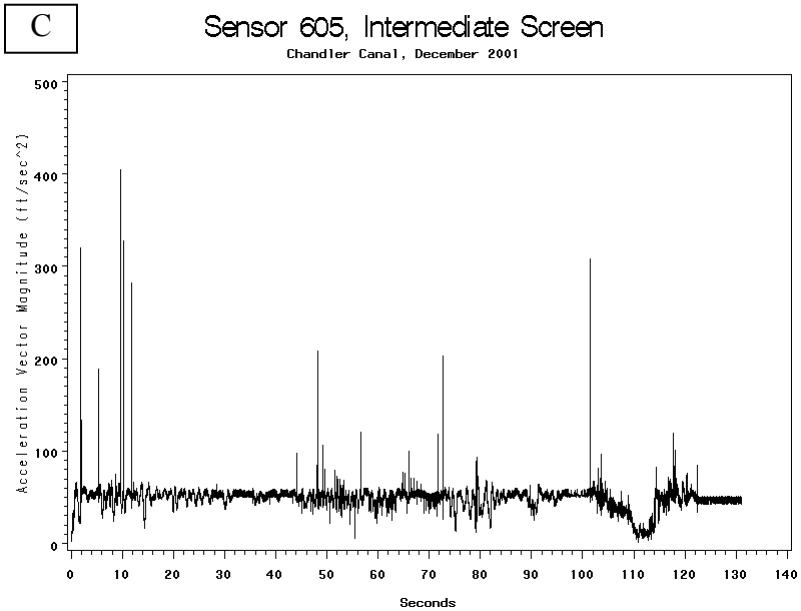
A


Sensor 605, Intermediate Screen
Chandler Canal, December 2001
Gage Pressure (psi)
Seconds

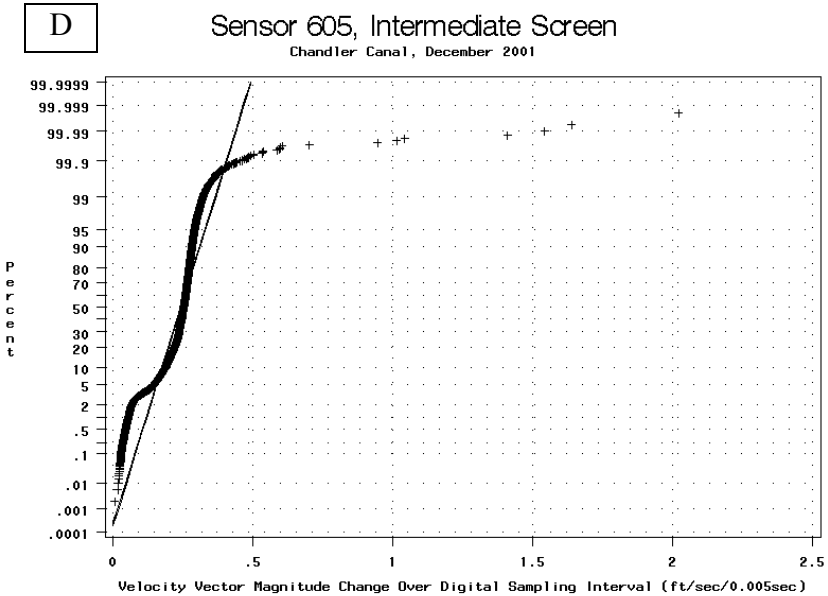
B


Sensor 605, Intermediate Screen
Chandler Canal, December 2001
Percent
Jerk(ft/sec^3)

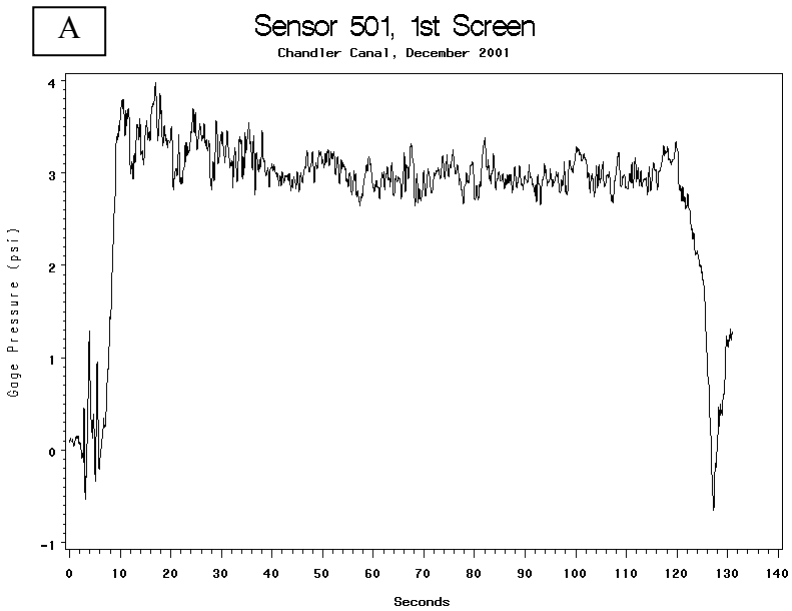
C


Sensor 605, Intermediate Screen
Chandler Canal, December 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

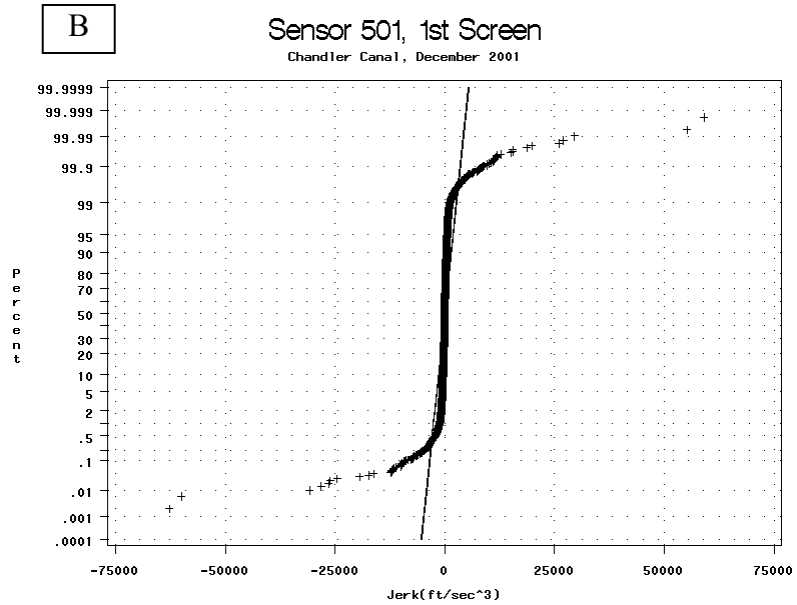
D


Sensor 605, Intermediate Screen
Chandler Canal, December 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

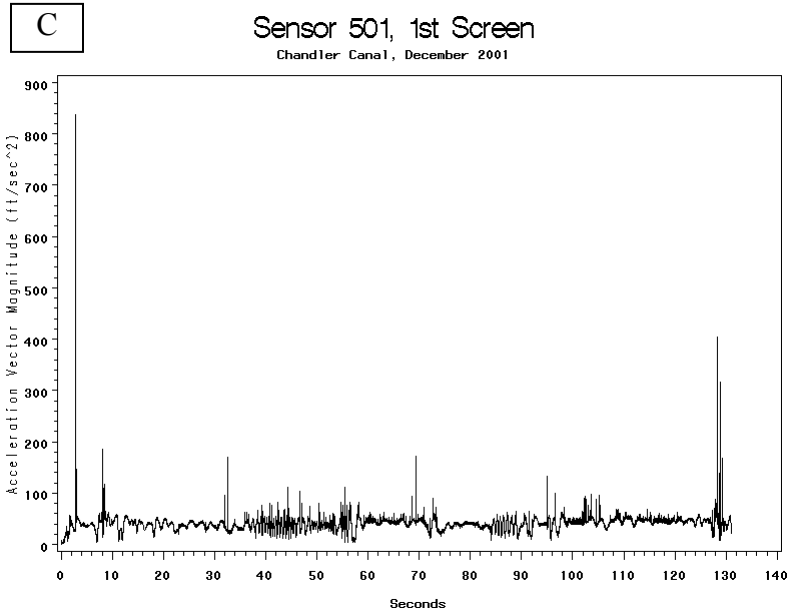
A


Sensor 501, 1st Screen
Chandler Canal, December 2001
Gage Pressure (psi)
Seconds

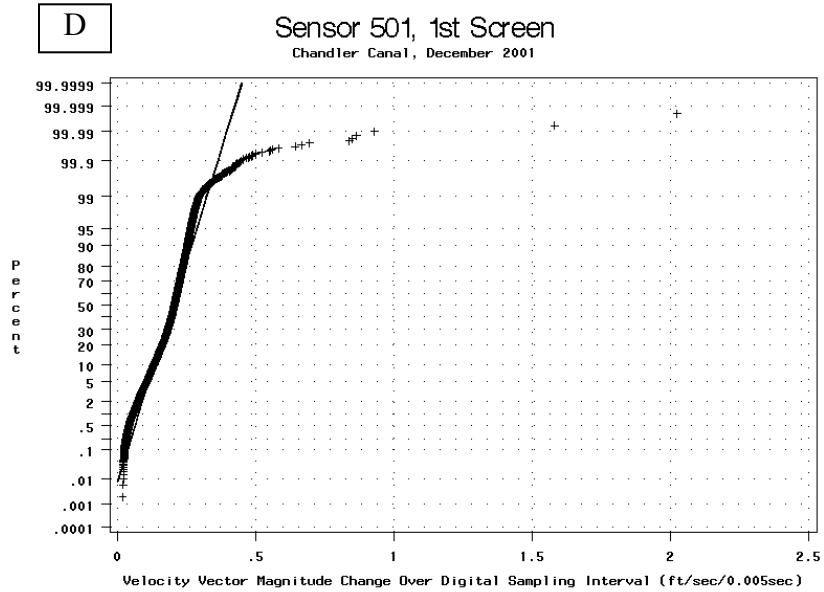
B


Sensor 501, 1st Screen
Chandler Canal, December 2001
Percent
Jerk(ft/sec^3)

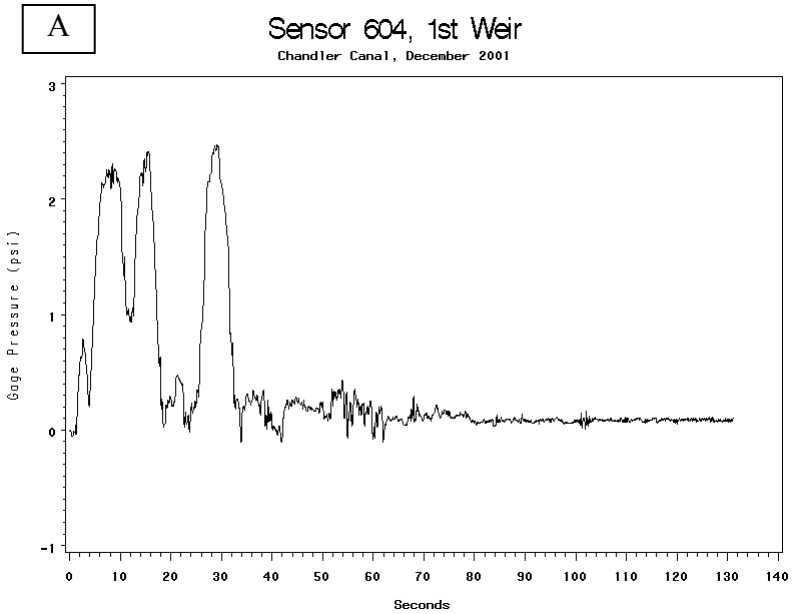
C


Sensor 501, 1st Screen
Chandler Canal, December 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

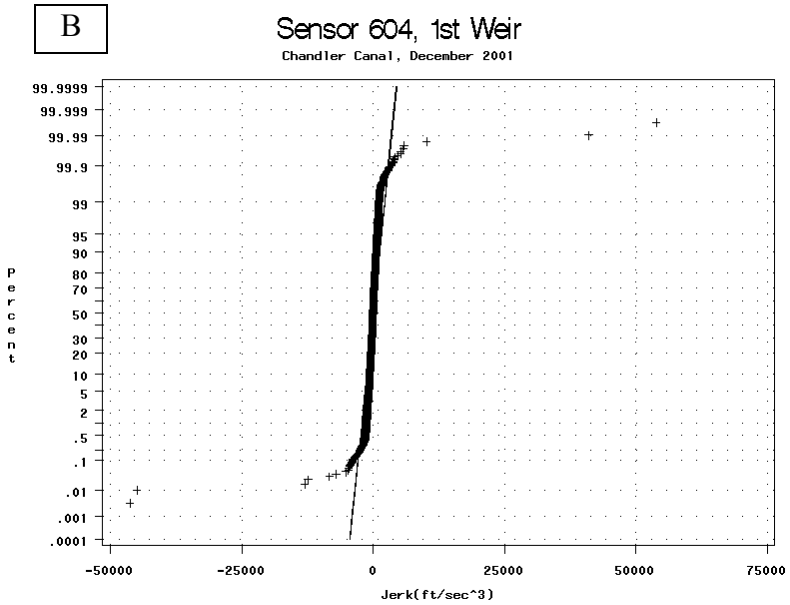
D


Sensor 501, 1st Screen
Chandler Canal, December 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

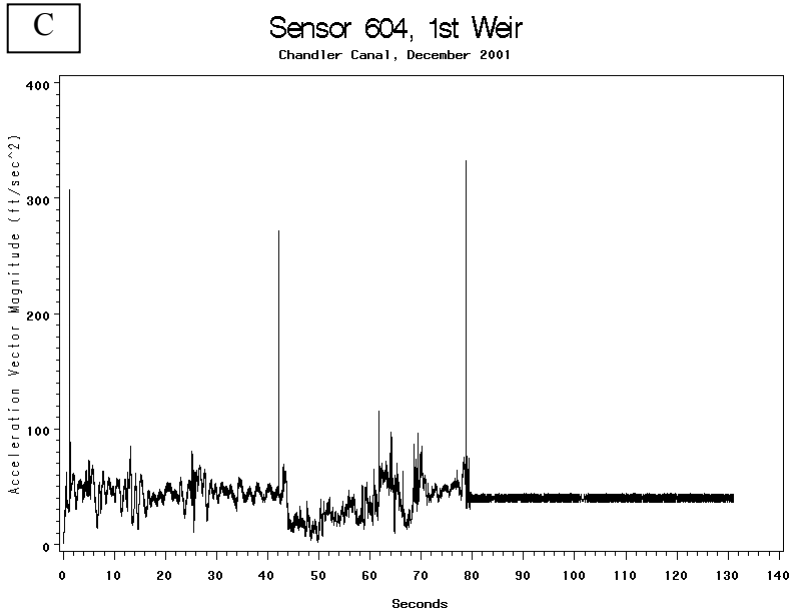
A


Sensor 604, 1st Weir
Chandler Canal, December 2001
Gage Pressure (psi)
Seconds

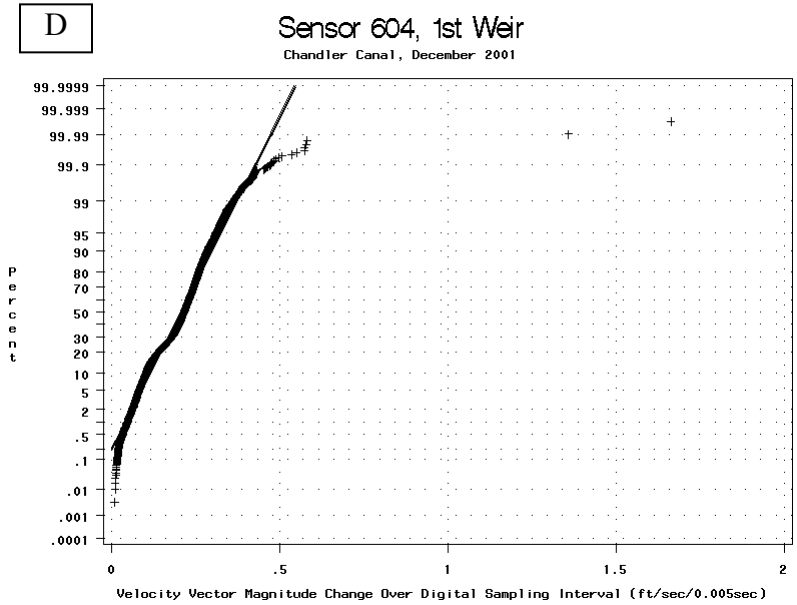
B


Sensor 604, 1st Weir
Chandler Canal, December 2001
Percent
Jerk(ft/sec^3)

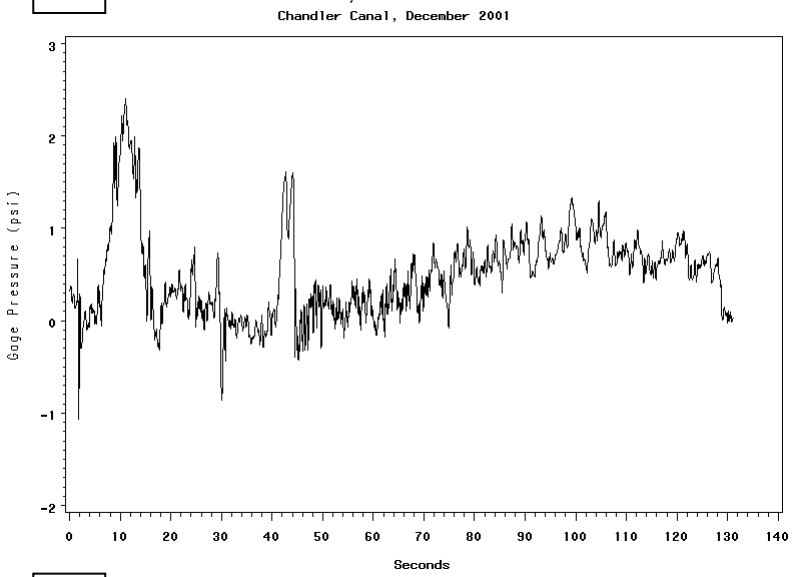
C


Sensor 604, 1st Weir
Chandler Canal, December 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

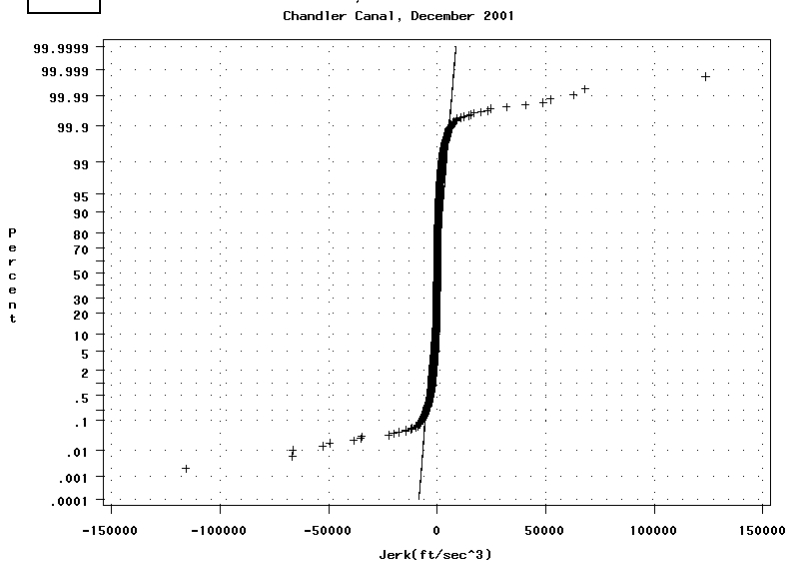
D


Sensor 604, 1st Weir
Chandler Canal, December 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

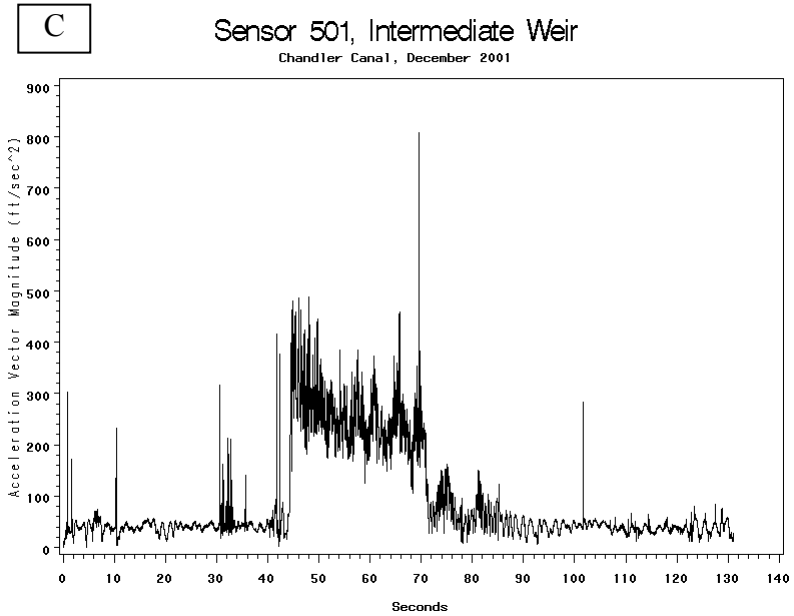
A


Sensor 501, Intermediate Weir
Chandler Canal, December 2001
Gage Pressure (psi)
Seconds

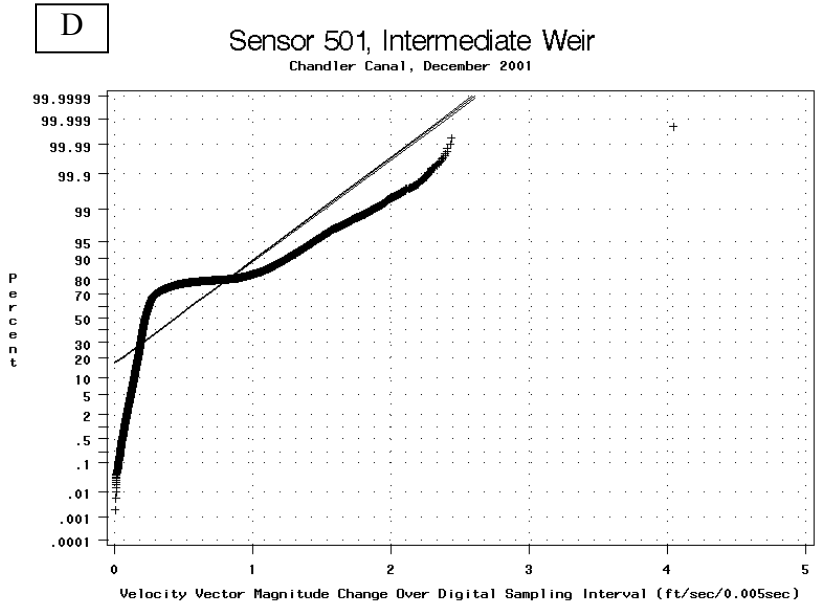
B


Sensor 501, Intermediate Weir
Chandler Canal, December 2001
Percent
Jerk(ft/sec^3)

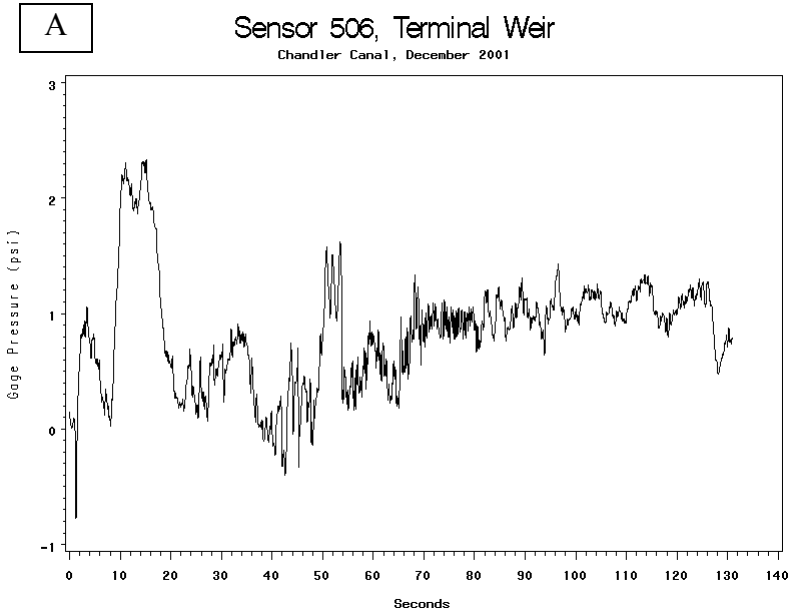
C


Sensor 501, Intermediate Weir
Chandler Canal, December 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

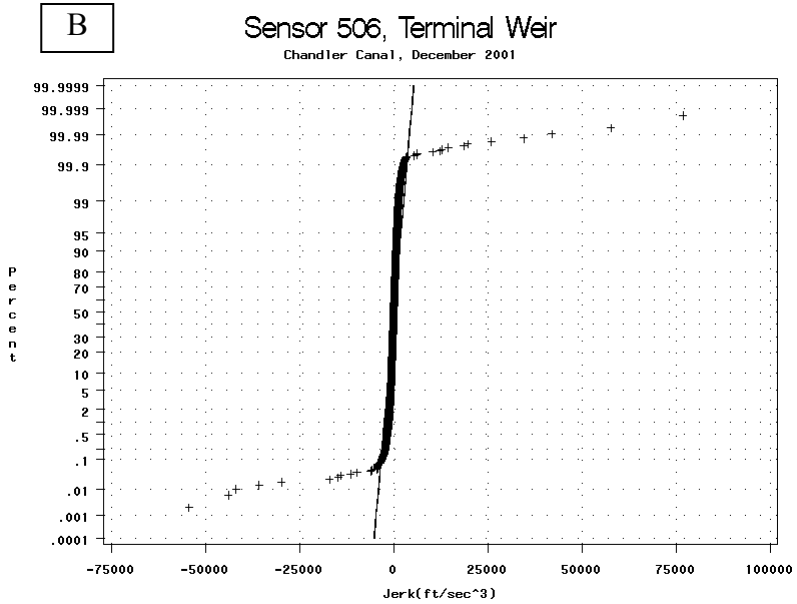
D


Sensor 501, Intermediate Weir
Chandler Canal, December 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

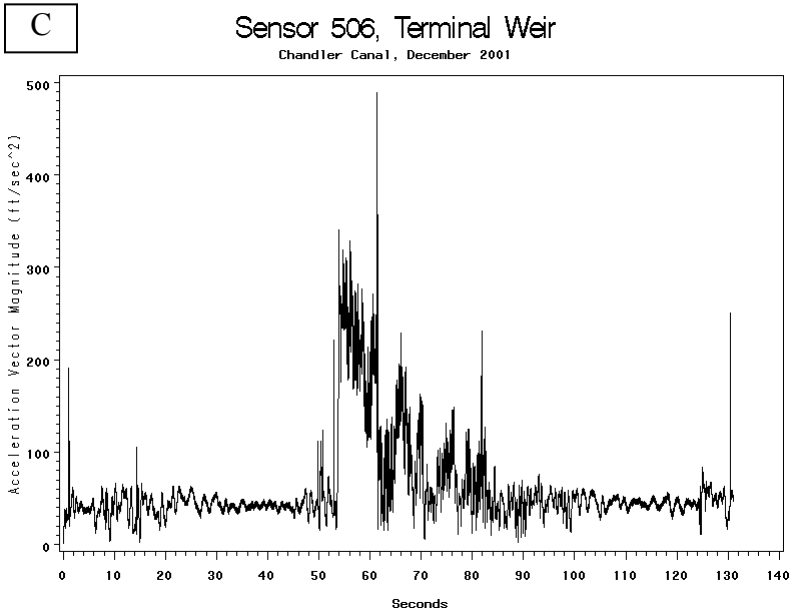
A


Sensor 506, Terminal Weir
Chandler Canal, December 2001
Gage Pressure (psi)
Seconds

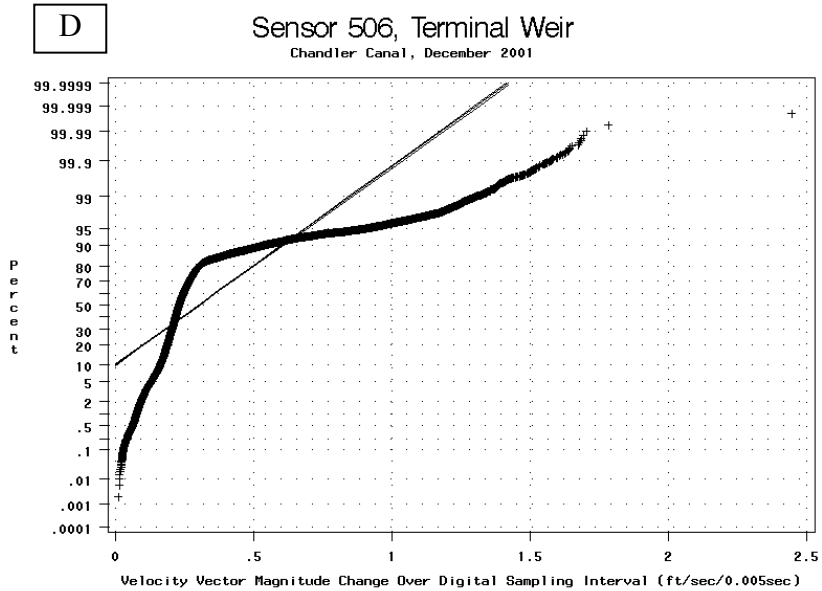
B


Sensor 506, Terminal Weir
Chandler Canal, December 2001
Percent
Jerk(ft/sec^3)

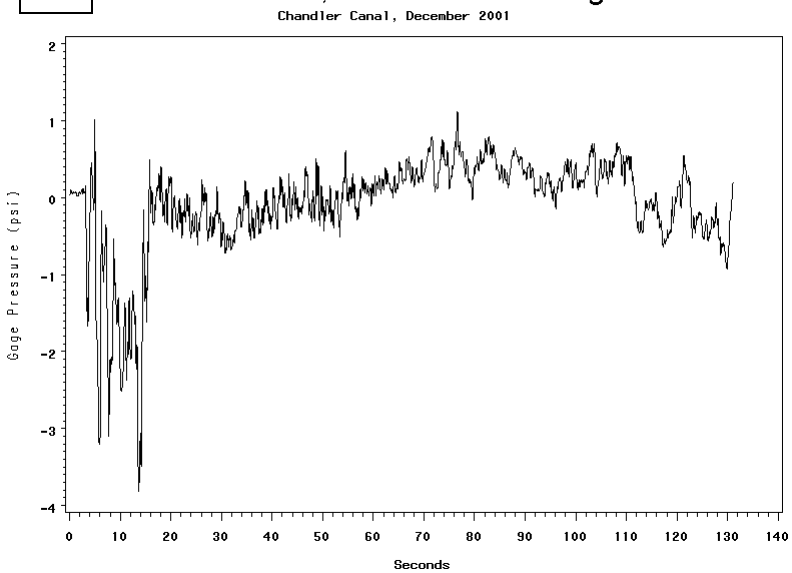
C


Sensor 506, Terminal Weir
Chandler Canal, December 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

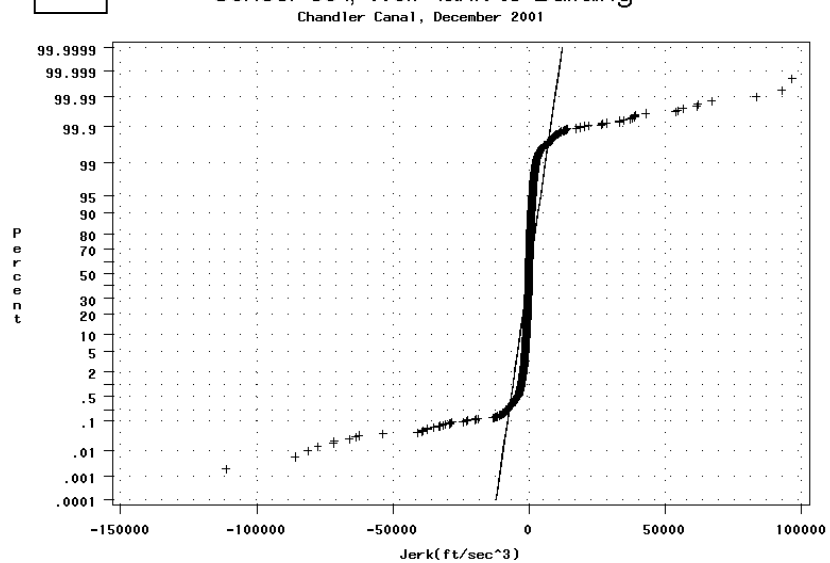
D


Sensor 506, Terminal Weir
Chandler Canal, December 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

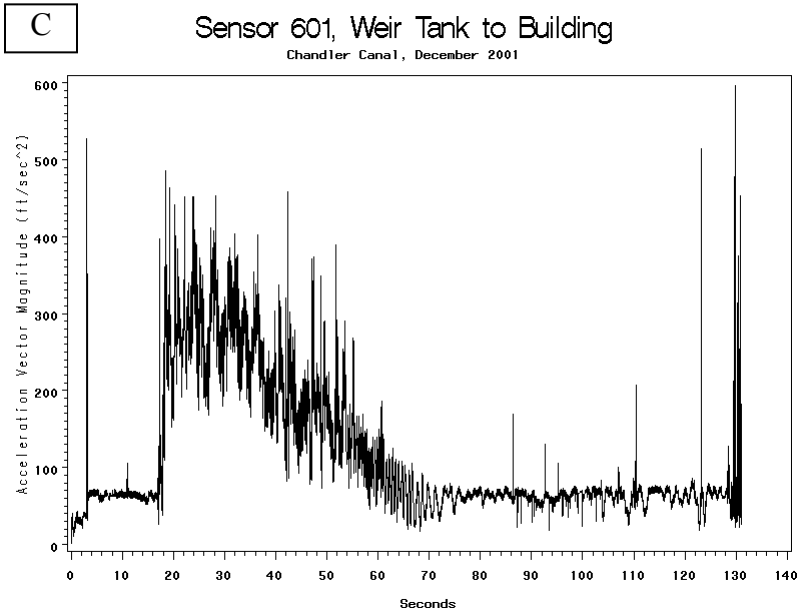
A


Sensor 601, Weir Tank to Building
Chandler Canal, December 2001
Gage Pressure (psi)
Seconds

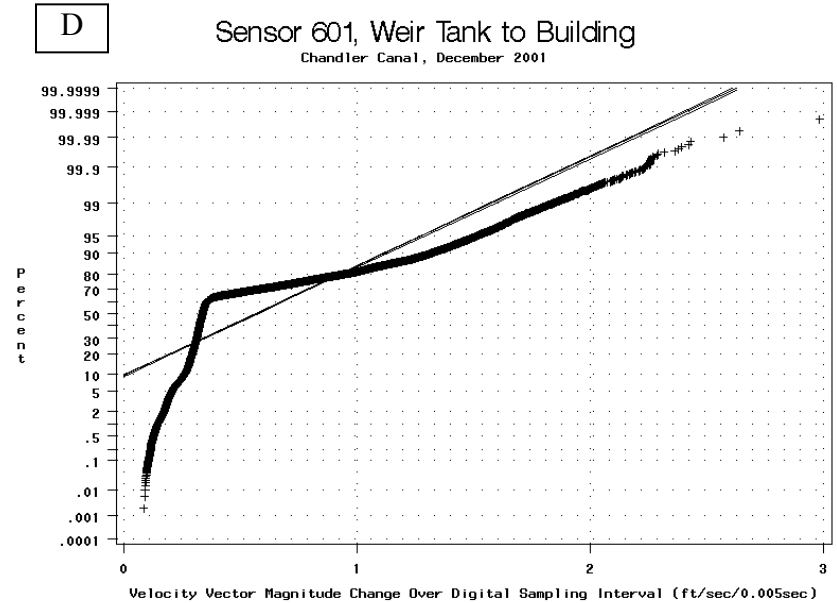
B


Sensor 601, Weir Tank to Building
Chandler Canal, December 2001
Percent
Jerk(ft/sec^3)

C


Sensor 601, Weir Tank to Building
Chandler Canal, December 2001
Acceleration Vector Magnitude (ft/sec^2)
Seconds

D


Sensor 601, Weir Tank to Building
Chandler Canal, December 2001
Percent
Velocity Vector Magnitude Change Over Digital Sampling Interval (ft/sec/0.005sec)

Appendix D

Maximum and Minimum Jerk and Velocity Vector Magnitude Differential Values for High Flow Sensor Fish Releases

Maximum and minimum jerk and velocity vector magnitude differential values for High Flow sensor fish releases

	Jerk				Velocity Vector Delta			
File	Min	Time	Max	Time	Min	Time	Max	Time
506TW	-54506.5	61.31	25946	81.98	0.008575	88.98	1.684338	53.93
(Terminal	-43966.6	61.505	34648.51	53	0.012017	15.015	1.692015	53.94
Weir)	-41983	130.37	41992.15	130.375	0.012854	88.99	1.703004	53.935
	-35858	52.995	57836.4	61.51	0.013915	88.985	1.782627	61.51
	-29955.6	81.975	76979.29	61.315	0.015044	15.01	2.443814	61.315
5011s	-62788	128.295	26041.4	129.195	0.018175	57.42	0.84802	32.605
(1st Screen)	-60001.9	128.88	27050.58	69.33	0.018916	56.01	0.863615	69.33
	-30790.9	8.065	29539.62	32.605	0.019172	57.44	0.927773	8.07
	-28217.7	32.6	55175.91	128.3	0.01922	55.45	1.579192	128.885
	-26477.6	69.325	59105.25	128.885	0.019903	7.005	2.022466	128.3
501iw	-115788	69.475	48755.39	101.655	0.003291	4.55	2.406309	44.92
(Intermediate	-66749.5	41.77	52157.24	30.695	0.007596	42.2	2.407138	46.07
Weir)	-66445.7	42.31	62933.69	42.315	0.008315	42.22	2.428062	46.075
	-52703.5	30.69	68135.3	41.775	0.008436	42.225	2.43681	48.115
	-49609.1	101.65	123687.1	69.48	0.008545	4.545	4.041013	69.48
504is	-69952.9	9.955	10505.09	101.16	0.106943	60.375	0.489477	68.58
(Intermediate	-39473.1	8.455	10893.36	68.58	0.125375	62.85	0.525622	101.16
Screen)	-34166.4	70.23	33964.37	70.235	0.125378	23.465	1.137152	70.235
	-10878.6	68.575	39879.64	8.46	0.125401	26.14	1.230428	8.46
	-10784.9	101.155	68982.02	9.96	0.125505	26.12	2.093717	9.96
504ts	-87326.9	13.21	28609.13	86.545	0.011581	58.355	2.049181	103.095
(Terminal	-38935.6	38.735	29987.26	46.18	0.011831	58.34	2.049423	103.32
Screen)	-32036.8	86.54	31426.88	86.785	0.014709	58.33	2.053259	103.325
	-31976.7	86.78	36330.12	38.74	0.01564	58.325	2.060815	111.45
	-30796.6	46.175	86215.05	13.215	0.015731	58.305	2.415638	13.215
601b	-111300	129.835	61932.88	129.9	0.083343	68.235	2.419698	18.415
(Weir Tank	-85765.5	123.26	67214.47	130.5	0.087998	68.26	2.430429	18.41
To Bldg)	-81245.9	129.63	83553.87	130.795	0.089588	68.245	2.570226	123.265
	-77491.1	130.79	92854.92	123.265	0.090936	93.375	2.638069	3.095
	-71795	129.755	96578.09	129.84	0.091095	122.895	2.982124	129.84

	Jerk				Velocity Vector Delta			
File	Min	Time	Max	Time	Min	Time	Max	Time
601ts	-165879	9.36	40909.36	15.26	0.007374	76.285	1.156912	15.26
(Terminal	-77644	12.395	48628.55	60.485	0.007641	28.085	1.323707	60.485
Screen)	-59875.9	11.8	55150.46	11.805	0.009479	28.09	1.642506	11.805
	-45264.3	60.48	74774.25	12.4	0.012367	26.57	2.130863	12.4
	-41556.4	15.255	164521.6	9.365	0.013203	28.075	4.285991	9.365
6041w	-46292.6	78.7	5729.117	79.235	0.008637	49.765	0.573065	61.805
(1st Weir)	-44898.8	42.12	5901.447	78.79	0.010437	49.74	0.577728	61.795
	-12956.2	78.745	10202.2	78.755	0.010576	49.795	0.580982	78.755
	-12357	69.395	41099.31	42.125	0.011253	49.735	1.35772	42.125
	-8318.45	78.695	53896.73	78.705	0.012014	49.815	1.663804	78.705
605is	-71468.9	9.72	33633.66	101.405	0.006544	110.89	1.041579	48.145
(Intermediate	-52200	10.25	35218.4	72.755	0.016633	110.81	1.40864	11.87
Screen)	-50274	101.4	44086.38	10.255	0.018122	112.85	1.541845	101.405
	-47379	11.865	48741.14	11.87	0.019203	112.885	1.638359	10.255
	-31398.2	48.14	68494.21	9.725	0.019382	110.87	2.02115	9.725
605ts	-163751	14.355	15147	67.765	0.04013	3.025	2.466226	82.055
(Terminal	-45589.6	40.62	19004.75	66.98	0.042276	17.15	2.47951	82.075
Screen)	-25013.9	66.975	19788.74	67.495	0.04234	15.165	2.486372	82.065
	-23615.8	67.76	48708.89	40.625	0.044271	15.175	2.491146	82.07
	-23420.2	67.49	160323.1	14.36	0.044395	54.94	4.45994	14.36

File	Jerk >2000	VVMag >3.7	Total
605TS (Terminal Screen)	461	1	25614
605is (Intermediate Screen)	93	0	25814
6041w (1st Weir)	41	0	25814
601ts (Terminal Screen)	272	1	25814
601b (Weir Tank to Building)	486	0	25814
506tw (Terminal Weir)	61	0	25814
504ts (Terminal Screen)	222	0	25814
504is Intermediate Screen)	23	0	25614
501iw (Intermediate Weir)	314	1	25814
5011s (1st Screen)	148	0	25614
Total	2121	3	257540

December High Flow		
jerk >2000	0.008235614	**0.800%**
VVMag >3.7	1.16487E-05	**0.001%**

Appendix E

Submergence Marking Assistance Task

Submergence marking assistance task:

(Note: A template for a submergence scale that could be applied next to the staff gage at the Chandler Canal Fish Screen Facility was provided to BoR on February 14, 2002)

The Chandler Fish Screens have been in operation since 1987. Operating criteria written in March 1987 describing the proper weir gate settings based on water surface elevation in the screens forebay. The staff gage (surface elevation in feet) was mounted in the forebay as an aid to set weir gates in the fish separation chamber. The gage also is an indicator of total canal flow.

Because screen submergence is one of the main criteria used to determine if a screen is being operated in a fish-friendly manner, submergence indicator marks are very useful when evaluating fish screen operation and performance. Drum screens are designed to operate between 65% and 85% submergence. Smaller screening facilities usually have screen submergence marks, either on the drum screen frame or forebay wall, to assist screen operators in setting up a site to specifications. However, larger fish screens frequently do not have submergence marks because their operating criteria are based on weir gate settings and forebay elevations. Forebay elevations and screen submergence are directly correlated, and although screening facilities were designed to operate at 75% submergence (with a 65-85% range), only surface elevations are used in the operations manual, and screen submergence is not mentioned.

As part of an ongoing project, Battelle was asked to look at the Chandler Fish Screens and develop a screen submergence reference guide to supplement the existing staff gage. Battelle reviewed construction diagrams and took measurements of several key features at the site to develop the relationship between canal forebay elevation and screen submergence.

On January 31, 2002, Battelle went to the Chandler Screens. Surface forebay elevation was 631.1 feet. All screens (2-24) were in operation. We reviewed site drawings and confirmed that the deck of the screening facility was 635.6 ft. We also determined forebay floor elevation (620.85 ft), wing wall height (10.625 ft), thickness of concrete between screen bays (4 ft), and drum screen diameter (13.5 ft). We then took measurements of:

- Forebay elevation staff gage as it related to the deck surface
- Top of drum screen in relation to deck surface
- Water surface to deck surface
- Top of wing wall in relation to deck surface.

Our measurements confirmed that the staff gage was accurately mounted on the forebay wall (top of the staff gage of 635.0 was 0.6 ft below the deck surface). At the measured forebay surface elevation (631.1), the top of the wing wall (several inches above the water line), the bottom of the deck slab (slightly more above the water line than the wing wall), and the water surface to deck surface measurements all matched very closely to the levels expected for surface elevations described in the construction drawings.

For a 13.5-ft-diameter drum screen, 5% submergence marks would be spaced 0.675 ft (8.1 in.) apart. Based on our measurements at Chandler, the 65% submergence mark would be at

630.0 ft surface elevation, 75% at 631.35 ft, and 85% at 632.7 ft. Submergence marks from 50 to 100% are shown in Table 1 and Figure 1. The top of the wing wall is 631.475 ft, or 0.125 ft (1.5 in.) above the 75% submergence level. The bottom of the deck slab is at 631.6 ft, roughly the equivalent of ~77% submergence. At 85% submergence, approximately 1.1 ft of the deck slab would be submerged (water surface 2.9 ft from deck surface). The top of the wing wall is the best indicator for "average" operations (631.475 ft).

Table E.1. Comparison of Surface Elevation to Screen Submergence, Chandler Screens.

	Elevation (ft)
Concrete Deck	635.6
Top of Screen	634.725
95%	634.05
90%	633.375
85%	632.7
80%	632.025
75%	631.35
70%	630.675
65%	630
60%	629.325
55%	628.65
50%	627.975

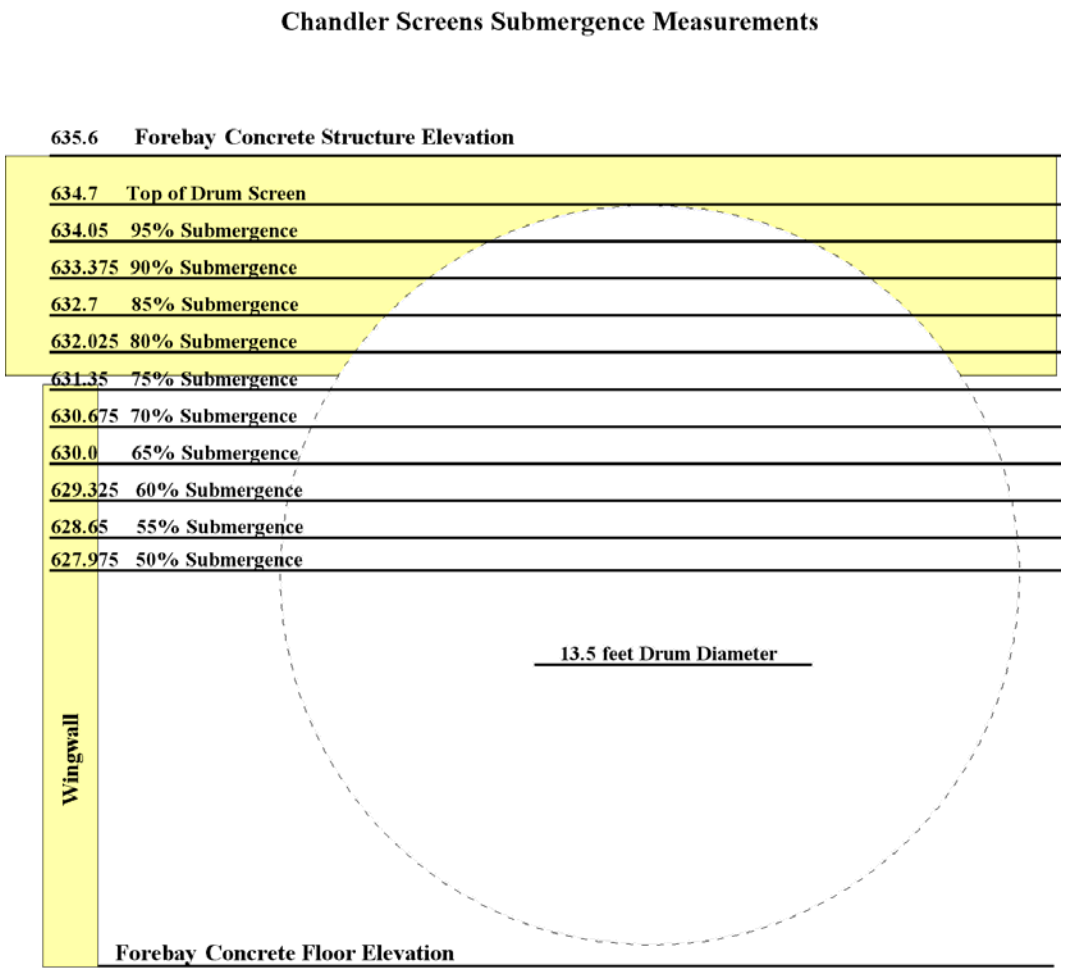


Figure E.1. Cross-section of Chandler Screens showing submergence relative to wing wall, deck, and drum screen.

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