

UNIVERSITY HONORS PROGRAM

SENIOR PROJECT - APPROVAL

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PROJECT TITLE: Determining Relationships between Pathogen Indicator Concentrations, Hydrologic Variables, and Land Use Classification in Stock Creek

I have reviewed this completed senior honors thesis with this student and certify that it is a project commensurate with honors level undergraduate research in this field.

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**Determining Relationships Between Pathogen Indicator
Concentrations, Hydrologic Variables and Land Use Classification
in Stock Creek**

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Monday, May 3, 2004

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Abstract

E.coli is a rod shaped bacterium that is a common intestinal organism. E.coli is a well-known water pollutant, transmitted through the feces of animals and humans. The toxins produced by this bacterium can cause kidney damage, diarrhea, meningitis, urinary system infections and, in some rare cases, death. The presence of E.coli is indicative of more dangerous viruses and water borne diseases.

The purpose of this study is to determine if there exists a discernable relationship between pathogen indicator concentrations, basic hydrologic variables and land use classification in Stock Creek, which is a 303(d) stream. The information gained from this can be used to evaluate if there is a relationship between the occurrence of E.coli and the land use practices in the area of a 303(d) designated stream. This research offers insight on DNA- based recognition of human versus animal pathogens and aids in determining if controls and regulations imposed on streams are adequate at controlling pollutants to desirable levels. This in turn will help evaluate if the implementation of TMDL programs are effective.

Introduction

Meeting a certain standard for E.coli in a stream does not necessarily mean that the public's health and safety is being maintained. There have been cases where there were streams that were meeting water quality standards and were still showing cases that 8 in 1000 persons were becoming ill.

Not all strains of E.coli are pathogenic, which means that just because it is present in water, doesn't mean that there is a direct relationship between its presence and the occurrence of water borne diseases. E.coli is variable and is a function of the health of an individual or animal. So, even though a stream may be meeting the required water quality standard for E.coli and the same amount of waste is deposited into a stream on a daily basis, the E.coli present could be more dangerous to human health than another on any day because E.coli is variable.

Within the last five years, more research has been performed in distinguishing between human and animal sources of E.coli. Currently it is known how to distinguish between bovine and human strains of E.coli, but the other types are unknown.

The Stock Creek watershed area was used as a control area to evaluate how certain practices impact a stream's water quality. The purpose of this study herein was to investigate the variability of basic

hydrologic variables and E.coli, by developing an empirical distribution by using the Plotting position method. The information gained from this study was used in determining which formula to base the determination of the probability of occurrence of E.coli and its variability along Stock Creek.

Background

Stock Creek is located in the Ft.Loudoun Lake Watershed. It is 30 miles in length and drains into the Little River. The area around within the Stock Creek watershed area consists of some dairy farming and agriculture and rural residential areas. The creek is classified as partially supporting, which means that it is somewhat impacted by pollution and water quality criteria are exceeded on some frequency. This is due to upland channelization and pasture grazing, which causes pathogens, siltation, and habitat alterations.

Since 49% of the land in Tennessee is used for agricultural, it is no surprise that this has a significant impact on the water quality of streams in the vicinity (Final 1998 303(d) List, 85). In stream watering of livestock is a significant source of fecal bacterium in many streams. Channelization is due to wetlands being converted to croplands and drainage and flood control bodies. This process transfers flood problems, increases erosion rates and destroys valuable and irreplaceable habitats that severely affects wildlife (Final 1998 303(d) List, 63). Siltation, a major pollutant of water quality in Tennessee, affects the physical, chemical and biological properties of water. Siltation can alter temperature patterns, which can have a negative affect on the aquatic life in streams. It also increases nutrient levels, which can cause a body of water to turn into a wetland, resulting in the smothering of aquatic life due to a lack of light and oxygen (Final 1998 303(d) List, 72).

According to the Total Maximum Daily Load information sheet, Stock Creek is a 303(d) stream, which means it is water quality limited. A water quality limited stream is one that violates one or more water quality standards. This means that the stream is significantly impacted by pollution, keeping its use limited from its full potential. The stream becomes a priority for water quality improvements, which is achieved by enforcing stringent regulations in order to reduce and control the amount of pollutants affecting a stream.

Once a stream is put on the 303(d) list, a TMDL (Total Maximum Daily Load) study is performed. This study quantifies the amount of a pollutant in a stream, identifies its sources, and makes

recommendations on actions that need to be performed in order for the stream to be in compliance with standards. TMDL is not appropriate for streams that already have a plan in place to regulate the amount of pollutants infiltrating a stream.

A TMDL is done on a five year schedule. During the first year, a monitoring plan is developed. Water quality data is collected for the next two years, followed by the assessing of data to form a TMDL in the fourth year. In the fifth year, a plan is developed that states the methods to be taken to work towards water quality standards being met in the future. The cycle is then repeated to insure remediation is taking place.

Several stations, labeled SC-2 through SC-7, were positioned along the stream to gather data used in this study. The location of the stations can be seen in figure 1. Conductivity, pH, temperature, flow and dissolved oxygen were measured in the field, while E.coli concentration and other parameters were determined by laboratory analysis. The data obtained from the stations can be found in the Appendix labeled Table 1 through 6.

Methodology

The plotting position method was used to develop an empirical distribution to determine the variability of the given hydrologic variables. The variables evaluated in this study were E.coli, pH, flow, conductivity, temperature, and dissolved oxygen. The data was collected over several months at different stations along the creek labeled SC2 through SC7. The data was arranged in order of magnitude from smallest to largest and an empirical cumulative probability of a value being less than a certain value was determined. Once all the data equal to a number "n" was ordered, an order number, m, was assigned to the position value.

The plotting position formulas used were Weibull, California, Foster and Exceedence. All have special characteristics that dictate its use over another formula. The Weibull formula does not tend to over or underestimate the true probability at extremes points and is usually used with 25 or more data points. The Exceedence formula is best for estimating the largest values encountered and is used with large amounts of data points. The California formula is best for estimating the lowest values and is generally used with a large amount of data points. The Foster formula is best for a small number of data points and

for high return periods. (Wanielista et al. 38) Each of the plotting position formulas are as follows:

Plotting Position Formulas

<u>Weibull</u>	<u>California</u>	<u>Foster</u>	<u>Exceedence</u>
$\frac{m}{n+1}$	$\frac{m}{n}$	$\frac{2m-1}{2n}$	$\frac{m-1}{n}$

The Weibull formula was used to determine the variability of the data because it is used most frequently in stormwater management and its ability to not over or under estimate probabilities.

Results and Discussion

The data was arranged several different ways in order to determine if there existed variability within the data. The probability of each parameter was determined based on the date the data was obtained, which can be found in the Appendix labeled Table 7-13. The probability of each parameter was determined based on the station that data was collected, which can be found in the Appendix labeled Table 14-19. Finally, the probability of the data was determined based on arranging all the data obtained for each parameter, which can be found in the Appendix labeled Table 20-25.

It was determined that looking at the probability of each parameter based on the station was the best way at evaluating the possible trends in the data in relation to land use practices. By looking at Table 14 through 19 at the dissolved oxygen, pH, conductivity, temperature and flow it can be seen that the data exhibits variability in data from station to station.

The flow for SC-2 ranged from 7.76 to 40.3 with a probability of the flow seen in the field being less than or equal to the given to be 0.14 to 0.86, respectively. This means that there is a 14 % chance that the flow encountered at SC-2 in Stock Creek will be 7.76 or lower and a 86% probability that the flow encountered will be 40.3 or lower. The flow at SC-3 ranged from 3.79 to 26.01, with a probability of 0.14 to 0.86. The flow at SC-4 was in the range of 4.25 to 27.48 with a probability of 0.14 to 0.86. The flow at SC-5 was in the range of 3.09 to 33.25 with a probability of 0.14 to 0.86. The flow at SC-6 was in the range of 2.59 to 10.44 with a probability of 0.14 to 0.86. The flow at SC-7 was in the range of 1.78 to 12, with a probability of 0.14 to 0.86. From the data it can be seen that the flow has a 14% probability of being

equal to or less than 7.76, 3.79, 4.25, 3.09, 2.59 and 1.78. The probability of seeing a given flow in the field is highly variable.

The pH for SC-2 ranged from 7.69 to 7.97 with a probability of the pH seen in the field being less than or equal to the given to be 0.14 to 0.86, respectively. This means that there is a 14 % chance that the pH encountered at SC-2 in Stock Creek will be 7.69 or lower and an 86% probability that the pH encountered will be 7.97 or lower. The pH at SC-3 ranged from 7.76 to 8.18, with a probability of 0.14 to 0.86. The pH at SC-4 was in the range of 7.76 to 8.26 with a probability of 0.14 to 0.86. The pH at SC-5 was in the range of 7.79 to 8.26 with a probability of 0.14 to 0.86. The pH at SC-6 was in the range of 7.71 to 8.16 with a probability of 0.14 to 0.86. The pH at SC-7 was in the range of 7.58 to 7.96, with a probability of 0.14 to 0.86. From the data it can be seen that the pH has a 14% probability of being equal to or less than 7.69, 7.76, 7.76, 7.79, 7.71 and 7.58. The pH data exhibits variability.

The temperature for SC-2 ranged from 16.74 to 20.63 with a probability of the temperature seen in the field being less than or equal to the given to be 0.14 to 0.86, respectively. This means that there is a 14 % chance that the temperature encountered at SC-2 in Stock Creek will be 16.74 or lower and a 86% probability that the temperature encountered will be 20.63 or lower. The temperature at SC-3 ranged from 16.63 to 20.87, with a probability of 0.14 to 0.86. The temperature at SC-4 was in the range of 16.68 to 21.28 with a probability of 0.14 to 0.86. The temperature at SC-5 was in the range of 16.68 to 20.23 with a probability of 0.14 to 0.86. The temperature at SC-6 was in the range of 15.84 to 18.84 with a probability of 0.14 to 0.86. The temperature at SC-7 was in the range of 15.55 to 18.96, with a probability of 0.14 to 0.86. From the data it can be seen that the temperature has a 86% probability of being equal to or less than 20.63, 20.87, 21.21, 20.23, 18.84, and 18.96. The temperature obtained from the field seems to be variable.

The dissolved oxygen (D.O.) for SC-2 ranged from 7.79 to 13.96 with a probability of the D.O. seen in the field being less than or equal to the given to be 0.14 to 0.86, respectively. This means that there is a 14 % chance that the D.O. encountered at SC-2 in Stock Creek will be 7.79 or lower and an 86% probability that the D.O. encountered will be 13.96 or lower. The D.O. at SC-3 ranged from 7.94 to 13.4, with a probability of 0.14 to 0.86. The D.O. at SC-4 was in the range of 7.39 to 14.18 with a probability of 0.14 to 0.86. The D.O. at SC-5 was in the range of 8.26 to 14.86 with a probability of 0.14 to 0.86. The D.O. at SC-6 was in the range of 8.48 to 14.8 with a probability of 0.14 to 0.86. The D.O. at SC-7 was in

the range of 8.37 to 15.64, with a probability of 0.14 to 0.86. From the data it can be seen that the D.O. has a 14% probability of being equal to or less than 7.79, 7.94, 7.39, 8.26, 8.48 and 8.37. The data exhibits variability.

The conductivity for SC-2 ranged from 203.1 to 378.1 with a probability of the conductivity seen in the field being less than or equal to the given to be 0.14 to 0.71, respectively. This means that there is a 14 % chance that the conductivity encountered at SC-2 in Stock Creek will be 203.1 or lower and an 71% probability that the conductivity encountered will be 378.1 or lower. The conductivity at SC-3 ranged from 206.9 to 388.7, with a probability of 0.14 to 0.71. The conductivity at SC-4 was in the range of 202.5 to 377.6 with a probability of 0.14 to 0.71. The conductivity at SC-5 was in the range of 191.5 to 361.7 with a probability of 0.14 to 0.71. The conductivity at SC-6 was in the range of 181.7 to 354.7 with a probability of 0.14 to 0.71. The conductivity at SC-7 was in the range of 178.4 to 341.7, with a probability of 0.14 to 0.71. From the data it can be seen that the conductivity has a 14% probability of being equal to or less than 203.1, 206.9, 202.5, 181.7, 178.4, and 191.5. The data seems to exhibit variability.

The E.coli for SC-2 ranged from 231 to 1986 with a probability of the E.coli seen in the field being less than or equal to the given to be 0.14 to 0.71, respectively. This means that there is a 14 % chance that the E.coli encountered at SC-2 in Stock Creek will be 231 or lower and an 71% probability that the E.coli encountered will be 1986 or lower. The E.coli at SC-3 ranged from 178 to 649, with a probability of 0.14 to 0.71. The E.coli at SC-4 was in the range of 184 to 649 with a probability of 0.14 to 0.71. The E.coli at SC-5 was in the range of 313 to 1041 with a probability of 0.14 to 0.71. The E.coli at SC-6 was in the range of 129 to 770 with a probability of 0.14 to 0.71. The E.coli at SC-7 was in the range of 44 to 326, with a probability of 0.14 to 0.71. From the data it can be seen that the E.coli has a 14% probability of being equal to or less than 231, 178, 184, 313, 129, and 44. It was decided that the E.coli did not exhibit very much variability based on the range of land use characteristics.

Conclusions and Recommendations

When analyzing the data for E.coli, you do not observe the variability seen in the other data obtained from the water. The E.coli data obtained from SC-7 was observably different from that observed at the other five stations, but it was decided that in general the E.coli data was variable. The concentration

of E.coli for each station consisted of similar ranges, which would not be very helpful in determining if relationship existed between hydrologic variables and the concentration of E.coli. Therefore, the E.coli concentration was converted to a waste load amount by multiplying the flow by the concentration. The waste load gives us the ability to look at the E.coli as a random variable and relate it to hydrologic parameters.

Therefore, based on the empirical probability determined in this study, Dr. Gentry decided to fit a theoretical Weibull distribution to the E.coli data. Weibull was used because of its common use in hydrology. His results can be seen in Figure 2, which shows the exceedence probability of E.coli waste load along the stream and its relation to the regulatory waste load limit. It can be seen from the figure that there is a 0.7 probability that the waste load along Stock Creek will be greater than the regulatory limit. This load is unacceptable because the likelihood of Stock Creek's ability to meet water quality standards is very low.

Now that this was determined, the next step into assessing the water quality of a stream and its causes is to determine the source of the pollutants. Is the contamination due to the surrounding land use or could it be due to infiltration from other areas due to karst topography that is common in Tennessee. The data obtained from this study can be used to assist in determining if best management practices used for agriculture are effective or need to be reevaluated. More data is needed to find out if there is a strong relationship between land use practices (agricultural) and waste load due to animals. Further studies will be performed which will hopefully result in the publication of an informative product.

APPENDIX

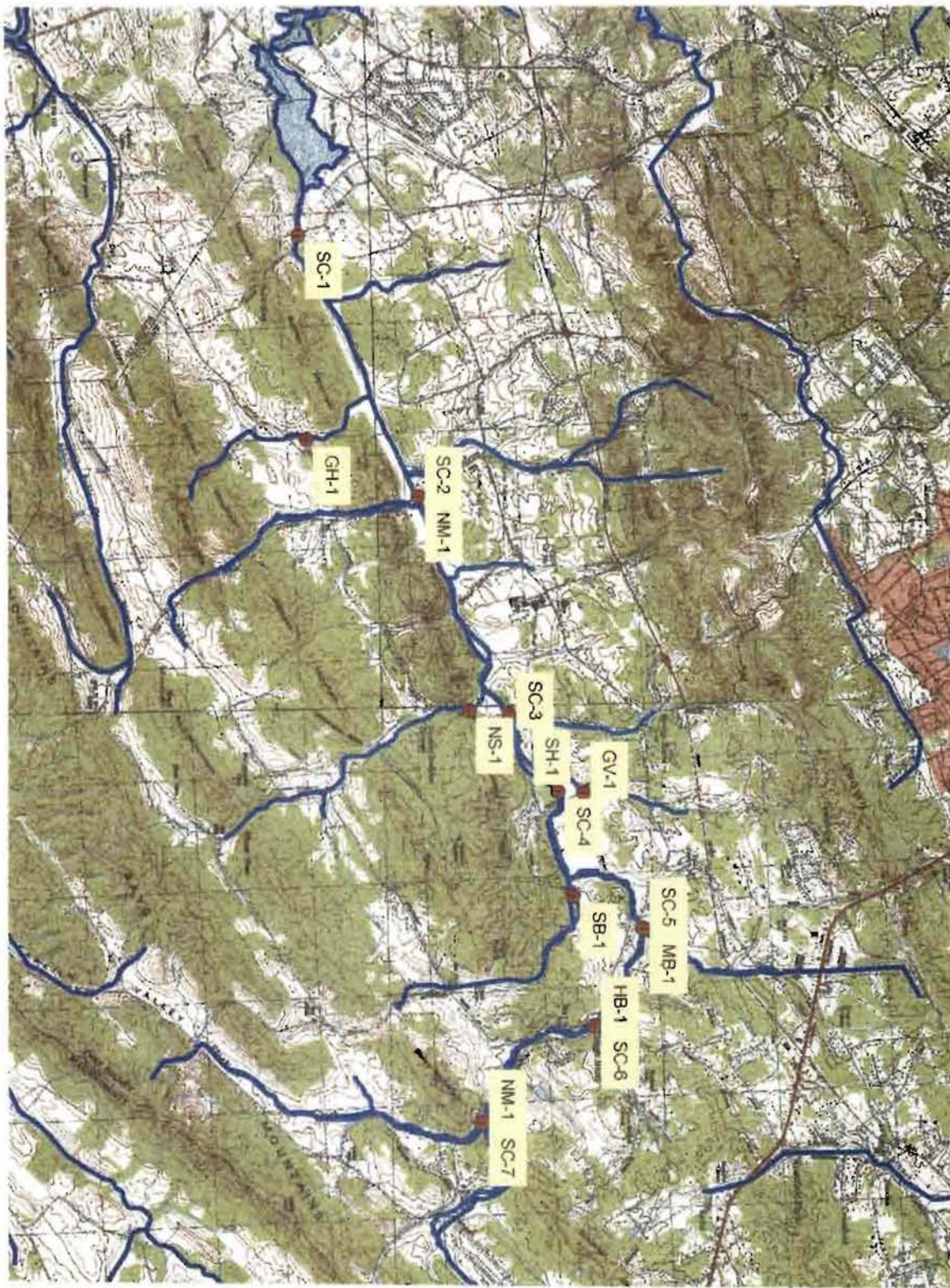


Figure 1: Layout of Stock Creek Data Collection Stations

Figure 2
Spatial Frequency Analysis
Colilert

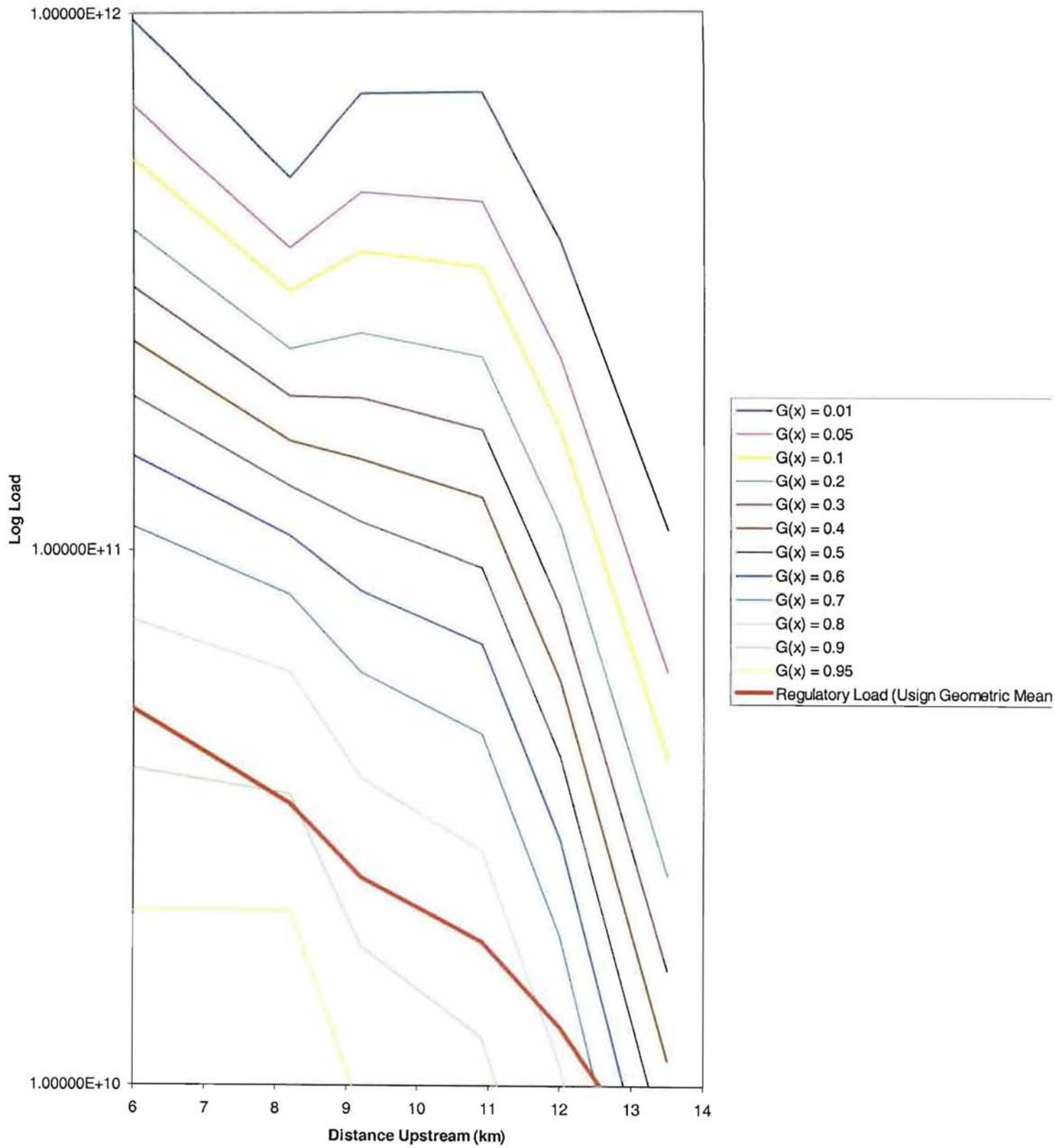


Table 1						
Flow						
	30-Apr	04-Jun	09-Jul	13-Aug	26-Aug	16-Sep
Sc2	24.58	21.12	30.52	40.30	7.76	15.58
Sc3	13.43	11.68	26.01	22.02	3.79	7.97
Sc4	14.39	7.17	27.48	8.67	4.25	9.79
Sc5	12.42	6.07	33.25	8.76	3.09	6.99
Sc6	6.36	3.89	10.44	5.44	2.59	2.62
Sc7	4.26	2.16	12.00	2.06	1.78	2.50

Table 2						
Dissolved Oxygen						
	30-Apr	04-Jun	09-Jul	13-Aug	26-Aug	16-Sep
Sc2	9.2	9.4	7.79	13.96	8.76	9.06
Sc3	9.3	9.8	7.94	13.4	8.94	9.11
Sc4	9.5	10	7.39	14.18	8.59	9.58
Sc5	9.7	10.1	8.26	14.86	9.5	9.8
Sc6	9.9	10.3	8.48	14.8	10.09	10.78
Sc7	9.9	10.5	8.37	15.64	10.93	10.81

Table 3						
pH						
	30-Apr	04-Jun	09-Jul	13-Aug	26-Aug	16-Sep
Sc2	7.97	7.84	7.76	7.83	7.69	7.83
Sc3	8.07	8.18	7.89	7.94	7.76	7.98
Sc4	8.13	8.26	7.89	7.99	7.76	8.01
Sc5	8.13	8.26	7.9	7.83	7.79	8.02
Sc6	8.01	8.16	7.76	7.86	7.71	7.93
Sc7	7.94	7.96	7.64	7.68	7.58	7.7

Table 4						
Conductivity						
	30-Apr	04-Jun	09-Jul	13-Aug	26-Aug	16-Sep
Sc2	299	298.3	222.5	203.1		378.1
Sc3	305	306.9	221.6	206.9		388.7
Sc4	305	317.1	222.3	202.5		377.6
Sc5	287	317.2	206.3	191.5		361.7
Sc6	273	273.1	192.5	181.7		354.7
Sc7	270	261.4	182.8	178.4		341.7

Table 5						
Temp						
	30-Apr	04-Jun	09-Jul	13-Aug	26-Aug	16-Sep
Sc2	17.6	16.74	20.63	19.21	20.17	16.93
Sc3	17.4	16.86	20.87	19.43	20.38	16.63
Sc4	17.5	16.86	21.28	19.55	20.71	16.68
Sc5	17.3	16.86	20.23	18.91	19.92	16.68
Sc6	16.6	15.91	18.82	18.84	18.64	15.84
Sc7	17.9	15.55	18.64	18.73	18.96	16.38

Table 6						
E-Coli(Colilert)						
	30-Apr	04-Jun	09-Jul	13-Aug	26-Aug	16-Sep
Sc2	388	488	365	231	1986	
Sc3	178	613	219	276	649	
Sc4	205	649	308	272	184	
Sc5	313	1041	488	548	345	
Sc6	166	248	770	129	291	
Sc7	91	44	144	84	326	

Table 7: Summary (13 Aug 03)									
Sorted Flow Rates	Sorted pH	Sorted Temp	Sorted Cond.	Sorted D.O.	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
2.06	7.68	18.73	178.4	13.4	1	0.1429	0.1667	0.0833	0.0000
5.44	7.83	18.84	181.7	13.96	2	0.2857	0.3333	0.2500	0.1667
5.76	7.83	18.91	191.5	14.18	3	0.4286	0.5000	0.4167	0.3333
8.67	7.86	19.21	202.5	14.8	4	0.5714	0.6667	0.5833	0.5000
22.02	7.94	19.43	203.1	14.86	5	0.7143	0.8333	0.7500	0.6667
40.30	7.99	19.55	206.9	15.64	6	0.8571	1.0000	0.9167	0.8333

Table 8: Summary (11 July 03)									
Sorted Flow Rates	Sorted pH	Sorted Temp	Sorted Cond.	Sorted D.O.	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
10.44	7.64	18.64	182.8	7.39	1	0.1429	0.1667	0.0833	0.0000
12.00	7.76	18.82	192.5	7.79	2	0.2857	0.3333	0.2500	0.1667
26.01	7.76	20.23	206.3	7.94	3	0.4286	0.5000	0.4167	0.3333
27.48	7.89	20.63	221.6	8.26	4	0.5714	0.6667	0.5833	0.5000
30.52	7.89	20.87	222.3	8.37	5	0.7143	0.8333	0.7500	0.6667
33.25	7.9	21.28	222.5	8.48	6	0.8571	1.0000	0.9167	0.8333

Table 9: Summary (4 June 03)										
Sorted Flow Rates	Sorted pH	Sorted Temp	Sorted Cond.	Sorted D.O.	m Plotting Position	Weibull	California	Foster	Exceedence	
						m/(n+1)	m/n	(2m-1)/2n	(m-1)/n	
10.44	7.64	18.64	182.8	7.39	1	0.1429	0.1667	0.0833	0.0000	
12.00	7.76	18.82	192.5	7.79	2	0.2857	0.3333	0.2500	0.1667	
26.01	7.76	20.23	206.3	7.94	3	0.4286	0.5000	0.4167	0.3333	
27.48	7.89	20.63	221.6	8.26	4	0.5714	0.6667	0.5833	0.5000	
30.52	7.89	20.87	222.3	8.37	5	0.7143	0.8333	0.7500	0.6667	
33.25	7.9	21.28	222.5	8.48	6	0.8571	1.0000	0.9167	0.8333	

Table 10: Summary (20 April 03)										
Sorted Flow Rates	Sorted pH	Sorted Temp	Sorted Cond.	Sorted D.O.	m Plotting Position	Weibull	California	Foster	Exceedence	
						m/(n+1)	m/n	(2m-1)/2n	(m-1)/n	
4.26	7.94	16.6	270	9.2	1	0.1429	0.1667	0.0833	0.0000	
6.36	7.97	17.3	273	9.3	2	0.2857	0.3333	0.2500	0.1667	
12.42	8.01	17.4	287	9.5	3	0.4286	0.5000	0.4167	0.3333	
13.43	8.07	17.5	299	9.7	4	0.5714	0.6667	0.5833	0.5000	
14.39	8.13	17.6	305	9.9	5	0.7143	0.8333	0.7500	0.6667	
24.58	8.13	17.9	305	9.9	6	0.8571	1.0000	0.9167	0.8333	

Table 11: Summary (16 Sept 03)										
Sorted Flow Rates	Sorted pH	Sorted Temp	Sorted Cond.	Sorted D.O.	m Plotting Position	Weibull	California	Foster	Exceedence	
						m/(n+1)	m/n	(2m-1)/2n	(m-1)/n	
2.50	7.7	15.84	341.7	9.06	1	0.1429	0.1667	0.0833	0.0000	
2.62	7.83	16.38	354.7	9.11	2	0.2857	0.3333	0.2500	0.1667	
6.99	7.93	16.63	361.7	9.58	3	0.4286	0.5000	0.4167	0.3333	
7.97	7.98	16.68	377.6	9.8	4	0.5714	0.6667	0.5833	0.5000	
9.79	8.01	16.68	378.1	10.78	5	0.7143	0.8333	0.7500	0.6667	
15.58	8.02	16.93	388.7	10.81	6	0.8571	1.0000	0.9167	0.8333	

Table 12: Summary (26 Aug. 03)										
Sorted Flow Rates	Sorted pH	Sorted Temp	Sorted Cond.	Sorted D.O.	m Plotting Position	Weibull	California	Foster	Exceedence	
						m/(n+1)	m/n	(2m-1)/2n	(m-1)/n	
1.78	7.58	18.64	--	8.59	1	0.1429	0.1667	0.0833	0.0000	
2.59	7.69	18.96	--	8.76	2	0.2857	0.3333	0.2500	0.1667	
3.09	7.71	19.92	--	8.94	3	0.4286	0.5000	0.4167	0.3333	
3.79	7.76	20.17	--	9.5	4	0.5714	0.6667	0.5833	0.5000	
4.25	7.76	20.38	--	10.09	5	0.7143	0.8333	0.7500	0.6667	
7.76	7.79	20.71	--	10.93	6	0.8571	1.0000	0.9167	0.8333	

Table 13: Summary (30 April 03)									
Sorted Flow Rates	Sorted pH	Sorted Temp	Sorted Cond.	Sorted D.O.	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
4.26	7.94	16.6	270	9.2	1	0.1429	0.1667	0.0833	0.0000
6.36	7.97	17.3	273	9.3	2	0.2857	0.3333	0.2500	0.1667
12.42	8.01	17.4	287	9.5	3	0.4286	0.5000	0.4167	0.3333
13.43	8.07	17.5	299	9.7	4	0.5714	0.6667	0.5833	0.5000
14.39	8.13	17.6	305	9.9	5	0.7143	0.8333	0.7500	0.6667
24.58	8.13	17.9	305	9.9	6	0.8571	1.0000	0.9167	0.8333

Table 14a: Sc2								
Sorted Flow Rates	Sorted pH	Sorted Temp	Sorted D.O.	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
7.76	7.69	16.74	7.79	1	0.1429	0.1667	0.0833	0.0000
15.58	7.76	16.93	8.76	2	0.2857	0.3333	0.2500	0.1667
21.12	7.83	17.6	9.06	3	0.4286	0.5000	0.4167	0.3333
24.58	7.83	19.21	9.2	4	0.5714	0.6667	0.5833	0.5000
30.52	7.84	20.17	9.4	5	0.7143	0.8333	0.7500	0.6667
40.30	7.97	20.63	13.96	6	0.8571	1.0000	0.9167	0.8333

Table 14b: Sc2						
Sorted Cond	Sorted E.coli	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
203.10	231	1	0.1429	0.1667	0.0833	0.0000
22.50	365	2	0.2857	0.3333	0.2500	0.1667
298.30	388	3	0.4286	0.5000	0.4167	0.3333
299.00	488	4	0.5714	0.6667	0.5833	0.5000
378.10	1986	5	0.7143	0.8333	0.7500	0.6667

Table 15a: Sc3								
Sorted Flow Rates	Sorted pH	Sorted Temp	Sorted D.O.	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
3.79	7.76	16.63	7.94	1	0.1429	0.1667	0.0833	0.0000
7.97	7.89	16.86	8.94	2	0.2857	0.3333	0.2500	0.1667
11.68	7.94	17.4	9.11	3	0.4286	0.5000	0.4167	0.3333
13.43	7.98	19.43	9.3	4	0.5714	0.6667	0.5833	0.5000
22.02	8.07	20.38	9.8	5	0.7143	0.8333	0.7500	0.6667
26.01	8.18	20.87	13.4	6	0.8571	1.0000	0.9167	0.8333

Table 15b: Sc3						
Sorted Cond	Sorted E.coli	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
206.90	178	1	0.1429	0.1667	0.0833	0.0000
221.60	219	2	0.2857	0.3333	0.2500	0.1667
305.00	276	3	0.4286	0.5000	0.4167	0.3333
306.90	613	4	0.5714	0.6667	0.5833	0.5000
388.70	649	5	0.7143	0.8333	0.7500	0.6667

Table 16a: Sc4								
Sorted Flow Rates	Sorted pH	Sorted Temp	Sorted D.O.	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
4.25	7.76	16.68	7.39	1	0.1429	0.1667	0.0833	0.0000
7.17	7.89	16.86	8.59	2	0.2857	0.3333	0.2500	0.1667
8.67	7.99	17.5	9.5	3	0.4286	0.5000	0.4167	0.3333
9.79	8.01	19.55	9.58	4	0.5714	0.6667	0.5833	0.5000
14.39	8.13	20.71	10	5	0.7143	0.8333	0.7500	0.6667
27.48	8.26	21.28	14.18	6	0.8571	1.0000	0.9167	0.8333

Table 16b: Sc4						
Sorted Cond	Sorted E.coli	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
202.50	184	1	0.1429	0.1667	0.0833	0.0000
222.30	205	2	0.2857	0.3333	0.2500	0.1667
305.00	272	3	0.4286	0.5000	0.4167	0.3333
317.10	308	4	0.5714	0.6667	0.5833	0.5000
377.60	649	5	0.7143	0.8333	0.7500	0.6667

Table 17a: Sc5								
Sorted Flow Rates	Sorted pH	Sorted Temp	Sorted D.O.	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
3.09	7.79	16.68	8.26	1	0.1429	0.1667	0.0833	0.0000
6.07	7.83	16.86	9.5	2	0.2857	0.3333	0.2500	0.1667
6.99	7.9	17.3	9.7	3	0.4286	0.5000	0.4167	0.3333
8.76	8.02	18.91	9.8	4	0.5714	0.6667	0.5833	0.5000
12.42	8.13	19.92	10.1	5	0.7143	0.8333	0.7500	0.6667
33.25	8.26	20.23	14.86	6	0.8571	1.0000	0.9167	0.8333

Table 17b: Sc5						
Sorted Cond	Sorted E.coli	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
202.50	184	1	0.1429	0.1667	0.0833	0.0000
222.30	205	2	0.2857	0.3333	0.2500	0.1667
305.00	272	3	0.4286	0.5000	0.4167	0.3333
317.10	308	4	0.5714	0.6667	0.5833	0.5000
377.60	649	5	0.7143	0.8333	0.7500	0.6667

Table 18a: Sc6								
Sorted Flow Rates	Sorted pH	Sorted Temp	Sorted D.O.	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
2.59	7.71	15.84	8.48	1	0.1429	0.1667	0.0833	0.0000
2.62	7.76	15.91	9.9	2	0.2857	0.3333	0.2500	0.1667
3.89	7.86	16.6	10.09	3	0.4286	0.5000	0.4167	0.3333
5.44	7.93	18.64	10.3	4	0.5714	0.6667	0.5833	0.5000
6.36	8.01	18.82	10.78	5	0.7143	0.8333	0.7500	0.6667
10.44	8.16	18.84	14.8	6	0.8571	1.0000	0.9167	0.8333

Table 18b: Sc6						
Sorted Cond	Sorted E.coli	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
181.70	129	1	0.1429	0.1667	0.0833	0.0000
192.50	166	2	0.2857	0.3333	0.2500	0.1667
273.00	248	3	0.4286	0.5000	0.4167	0.3333
273.10	291	4	0.5714	0.6667	0.5833	0.5000
354.70	770	5	0.7143	0.8333	0.7500	0.6667

Table 19a: Sc7								
Sorted Flow Rates	Sorted pH	Sorted Temp	Sorted D.O.	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
1.78	7.71	15.84	8.37	1	0.1429	0.1667	0.0833	0.0000
2.06	7.76	15.91	9.9	2	0.2857	0.3333	0.2500	0.1667
2.16	7.86	16.6	10.5	3	0.4286	0.5000	0.4167	0.3333
2.50	7.93	18.64	10.81	4	0.5714	0.6667	0.5833	0.5000
4.26	8.01	18.82	10.93	5	0.7143	0.8333	0.7500	0.6667
12.00	8.16	18.84	15.64	6	0.8571	1.0000	0.9167	0.8333

Table 19b: Sc7						
Sorted Cond	Sorted E.coli	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
178.40	44	1	0.1429	0.1667	0.0833	0.0000
182.80	84	2	0.2857	0.3333	0.2500	0.1667
261.40	91	3	0.4286	0.5000	0.4167	0.3333
270.00	144	4	0.5714	0.6667	0.5833	0.5000
341.70	326	5	0.7143	0.8333	0.7500	0.6667

Table 20					
Sorted Flow Rates	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
1.78	1	0.027	0.028	0.014	0.000
2.06	2	0.054	0.056	0.042	0.028
2.16	3	0.081	0.083	0.069	0.056
2.50	4	0.108	0.111	0.097	0.083
2.59	5	0.135	0.139	0.125	0.111
2.62	6	0.162	0.167	0.153	0.139
3.09	7	0.189	0.194	0.181	0.167
3.79	8	0.216	0.222	0.208	0.194
3.89	9	0.243	0.250	0.236	0.222
4.25	10	0.270	0.278	0.264	0.250
4.26	11	0.297	0.306	0.292	0.278
5.44	12	0.324	0.333	0.319	0.306
6.07	13	0.351	0.361	0.347	0.333
6.36	14	0.378	0.389	0.375	0.361
6.99	15	0.405	0.417	0.403	0.389
7.17	16	0.432	0.444	0.431	0.417
7.76	17	0.459	0.472	0.458	0.444
7.97	18	0.486	0.500	0.486	0.472
8.67	19	0.514	0.528	0.514	0.500
8.76	20	0.541	0.556	0.542	0.528
9.79	21	0.568	0.583	0.569	0.556
10.44	22	0.595	0.611	0.597	0.583
11.68	23	0.622	0.639	0.625	0.611
12.00	24	0.649	0.667	0.653	0.639
12.42	25	0.676	0.694	0.681	0.667
13.43	26	0.703	0.722	0.708	0.694
14.39	27	0.730	0.750	0.736	0.722
15.58	28	0.757	0.778	0.764	0.750
21.12	29	0.784	0.806	0.792	0.778
22.02	30	0.811	0.833	0.819	0.806
24.58	31	0.838	0.861	0.847	0.833
26.01	32	0.865	0.889	0.875	0.861
27.48	33	0.892	0.917	0.903	0.889
30.52	34	0.919	0.944	0.931	0.917
33.25	35	0.946	0.972	0.958	0.944
40.30	36	0.973	1.000	0.986	0.972

Table 21					
Sorted D.O.	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
7.39	1	0.027	0.028	0.014	0.000
7.79	2	0.054	0.056	0.042	0.028
7.94	3	0.081	0.083	0.069	0.056
8.26	4	0.108	0.111	0.097	0.083
8.37	5	0.135	0.139	0.125	0.111
8.48	6	0.162	0.167	0.153	0.139
8.59	7	0.189	0.194	0.181	0.167
8.76	8	0.216	0.222	0.208	0.194
8.94	9	0.243	0.250	0.236	0.222
9.06	10	0.270	0.278	0.264	0.250
9.11	11	0.297	0.306	0.292	0.278
9.20	12	0.324	0.333	0.319	0.306
9.30	13	0.351	0.361	0.347	0.333
9.40	14	0.378	0.389	0.375	0.361
9.50	15	0.405	0.417	0.403	0.389
9.50	16	0.432	0.444	0.431	0.417
9.58	17	0.459	0.472	0.458	0.444
9.70	18	0.486	0.500	0.486	0.472
9.80	19	0.514	0.528	0.514	0.500
9.80	20	0.541	0.556	0.542	0.528
9.90	21	0.568	0.583	0.569	0.556
9.90	22	0.595	0.611	0.597	0.583
10.00	23	0.622	0.639	0.625	0.611
10.09	24	0.649	0.667	0.653	0.639
10.10	25	0.676	0.694	0.681	0.667
10.30	26	0.703	0.722	0.708	0.694
10.50	27	0.730	0.750	0.736	0.722
10.78	28	0.757	0.778	0.764	0.750
10.81	29	0.784	0.806	0.792	0.778
10.93	30	0.811	0.833	0.819	0.806
13.40	31	0.838	0.861	0.847	0.833
13.96	32	0.865	0.889	0.875	0.861
14.18	33	0.892	0.917	0.903	0.889
14.80	34	0.919	0.944	0.931	0.917
14.86	35	0.946	0.972	0.958	0.944
15.64	36	0.973	1.000	0.986	0.972

Table 22					
Sorted p.H.	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
7.58	1	0.027	0.028	0.014	0.000
7.64	2	0.054	0.056	0.042	0.028
7.68	3	0.081	0.083	0.069	0.056
7.69	4	0.108	0.111	0.097	0.083
7.70	5	0.135	0.139	0.125	0.111
7.71	6	0.162	0.167	0.153	0.139
7.76	7	0.189	0.194	0.181	0.167
7.76	8	0.216	0.222	0.208	0.194
7.76	9	0.243	0.250	0.236	0.222
7.76	10	0.270	0.278	0.264	0.250
7.79	11	0.297	0.306	0.292	0.278
7.83	12	0.324	0.333	0.319	0.306
7.83	13	0.351	0.361	0.347	0.333
7.83	14	0.378	0.389	0.375	0.361
7.84	15	0.405	0.417	0.403	0.389
7.86	16	0.432	0.444	0.431	0.417
7.89	17	0.459	0.472	0.458	0.444
7.89	18	0.486	0.500	0.486	0.472
7.90	19	0.514	0.528	0.514	0.500
7.93	20	0.541	0.556	0.542	0.528
7.94	21	0.568	0.583	0.569	0.556
7.94	22	0.595	0.611	0.597	0.583
7.96	23	0.622	0.639	0.625	0.611
7.97	24	0.649	0.667	0.653	0.639
7.98	25	0.676	0.694	0.681	0.667
7.99	26	0.703	0.722	0.708	0.694
8.01	27	0.730	0.750	0.736	0.722
8.01	28	0.757	0.778	0.764	0.750
8.02	29	0.784	0.806	0.792	0.778
8.07	30	0.811	0.833	0.819	0.806
8.13	31	0.838	0.861	0.847	0.833
8.13	32	0.865	0.889	0.875	0.861
8.16	33	0.892	0.917	0.903	0.889
8.18	34	0.919	0.944	0.931	0.917
8.26	35	0.946	0.972	0.958	0.944
8.26	36	0.973	1.000	0.986	0.972

Table 23					
Sorted Cond	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
178.40	1	0.032	0.033	0.017	0.000
181.70	2	0.065	0.067	0.050	0.033
182.80	3	0.097	0.100	0.083	0.067
191.50	4	0.129	0.133	0.117	0.100
192.50	5	0.161	0.167	0.150	0.133
202.50	6	0.194	0.200	0.183	0.167
203.10	7	0.226	0.233	0.217	0.200
206.30	8	0.258	0.267	0.250	0.233
206.90	9	0.290	0.300	0.283	0.267
221.60	10	0.323	0.333	0.317	0.300
222.30	11	0.355	0.367	0.350	0.333
222.50	12	0.387	0.400	0.383	0.367
261.40	13	0.419	0.433	0.417	0.400
270.00	14	0.452	0.467	0.450	0.433
273.00	15	0.484	0.500	0.483	0.467
273.10	16	0.516	0.533	0.517	0.500
287.00	17	0.548	0.567	0.550	0.533
298.30	18	0.581	0.600	0.583	0.567
299.00	19	0.613	0.633	0.617	0.600
305.00	20	0.645	0.667	0.650	0.633
305.00	21	0.677	0.700	0.683	0.667
306.90	22	0.710	0.733	0.717	0.700
317.10	23	0.742	0.767	0.750	0.733
317.20	24	0.774	0.800	0.783	0.767
341.70	25	0.806	0.833	0.817	0.800
354.70	26	0.839	0.867	0.850	0.833
361.70	27	0.871	0.900	0.883	0.867
377.60	28	0.903	0.933	0.917	0.900
378.10	29	0.935	0.967	0.950	0.933
388.70	30	0.968	1.000	0.983	0.967

Table 24					
Sorted Temp	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
15.55	1	0.027	0.028	0.014	0.000
15.84	2	0.054	0.056	0.042	0.028
15.91	3	0.081	0.083	0.069	0.056
16.38	4	0.108	0.111	0.097	0.083
16.63	5	0.135	0.139	0.125	0.111
16.60	6	0.162	0.167	0.153	0.139
16.68	7	0.189	0.194	0.181	0.167
16.68	8	0.216	0.222	0.208	0.194
16.74	9	0.243	0.250	0.236	0.222
16.86	10	0.270	0.278	0.264	0.250
16.86	11	0.297	0.306	0.292	0.278
16.86	12	0.324	0.333	0.319	0.306
16.93	13	0.351	0.361	0.347	0.333
17.30	14	0.378	0.389	0.375	0.361
17.40	15	0.405	0.417	0.403	0.389
17.50	16	0.432	0.444	0.431	0.417
17.60	17	0.459	0.472	0.458	0.444
17.90	18	0.486	0.500	0.486	0.472
18.64	19	0.514	0.528	0.514	0.500
18.64	20	0.541	0.556	0.542	0.528
18.73	21	0.568	0.583	0.569	0.556
18.82	22	0.595	0.611	0.597	0.583
18.84	23	0.622	0.639	0.625	0.611
18.91	24	0.649	0.667	0.653	0.639
18.96	25	0.676	0.694	0.681	0.667
19.21	26	0.703	0.722	0.708	0.694
19.43	27	0.730	0.750	0.736	0.722
19.55	28	0.757	0.778	0.764	0.750
19.92	29	0.784	0.806	0.792	0.778
20.17	30	0.811	0.833	0.819	0.806
20.23	31	0.838	0.861	0.847	0.833
20.38	32	0.865	0.889	0.875	0.861
20.63	33	0.892	0.917	0.903	0.889
20.71	34	0.919	0.944	0.931	0.917
20.87	35	0.946	0.972	0.958	0.944
21.28	36	0.973	1.000	0.986	0.972

Table 25					
Sorted E.Coli	m Plotting Position	Weibull $m/(n+1)$	California m/n	Foster $(2m-1)/2n$	Exceedence $(m-1)/n$
44.00	1	0.032	0.033	0.017	0.000
84.00	2	0.065	0.067	0.050	0.033
91.00	3	0.097	0.100	0.083	0.067
129.00	4	0.129	0.133	0.117	0.100
144.00	5	0.161	0.167	0.150	0.133
166.00	6	0.194	0.200	0.183	0.167
178.00	7	0.226	0.233	0.217	0.200
184.00	8	0.258	0.267	0.250	0.233
205.00	9	0.290	0.300	0.283	0.267
219.00	10	0.323	0.333	0.317	0.300
231.00	11	0.355	0.367	0.350	0.333
248.00	12	0.387	0.400	0.383	0.367
272.00	13	0.419	0.433	0.417	0.400
276.00	14	0.452	0.467	0.450	0.433
291.00	15	0.484	0.500	0.483	0.467
308.00	16	0.516	0.533	0.517	0.500
313.00	17	0.548	0.567	0.550	0.533
326.00	18	0.581	0.600	0.583	0.567
345.00	19	0.613	0.633	0.617	0.600
365.00	20	0.645	0.667	0.650	0.633
388.00	21	0.677	0.700	0.683	0.667
488.00	22	0.710	0.733	0.717	0.700
488.00	23	0.742	0.767	0.750	0.733
548.00	24	0.774	0.800	0.783	0.767
613.00	25	0.806	0.833	0.817	0.800
649.00	26	0.839	0.867	0.850	0.833
649.00	27	0.871	0.900	0.883	0.867
770.00	28	0.903	0.933	0.917	0.900
1041.00	29	0.935	0.967	0.950	0.933
1986.00	30	0.968	1.000	0.983	0.967

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