

# STATISTICAL COMPARISON TO BACKGROUND FOR BORON USING THE GEHAN TEST FORM 1

## Kielian 2-2 Wellhead

*Prepared for*

**Entrada Consulting Group**  
Denver, Colorado

*Prepared by*

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Geosyntec Project DE0638

February 2026

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Project Number: DE0638

February 2026

## TABLE OF CONTENTS

1. INTRODUCTION .....	1
2. DATA SUMMARY .....	1
3. STATISTICAL COMPARISON TO BACKGROUND .....	5
4. SUMMARY AND CONCLUSIONS .....	5
5. REFERENCES .....	6

## LIST OF TABLES

Table 1:	Boron concentrations measured at Kielian 2-2 Wellhead
Table 2:	Summary statistics for boron at background (bkg) vs. Site sample locations

## LIST OF FIGURES

Figure 1:	Boxplots of boron concentrations in background (Bkg) soil and Site soil
Figure 2:	Test for normality – background soils
Figure 3:	Test for normality – Site soils

## LIST OF APPENDICES

Appendix:	Appendix A - ProUCL Outputs
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## 1. INTRODUCTION

Geosyntec Consultants, Inc., (Geosyntec) has prepared this report for the Entrada Consulting Group (Entrada) comparing concentrations of boron in site samples to background samples at the Kielian 2-2 Wellhead located in the southeast ¼ of the southeast ¼ of Section 2, Township 4 North, Range 67 West in Weld, Colorado (Site).

Data analysis was conducted using ProUCL 5.2 (USEPA, 2022a) and Microsoft Excel. Statistical methods used were conducted in a manner consistent with the USEPA *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (USEPA, 2002) and the *ProUCL Version 5.2.0 Technical Guide* (USEPA 2022b). Specifically, Test Form 1 of the Gehan Test with a significance level of 0.05 was used for the analysis.

## 2. DATA SUMMARY

Eleven samples from the Site and fourteen samples from background locations were analyzed for boron. One (9.09%) of the Site samples was undetected for boron, and all background samples were detected for boron. Boron concentrations are shown below in Table 1, with non-detects (NDs) denoted by a less-than (<) symbol followed by the reporting limit.

**Table 1: Boron concentrations measured at Kielian 2-2 Wellhead**

Boron Concentrations - Site Samples		Boron Concentrations - Background Samples	
Sample Name	Concentration (mg/kg)	Sample Name	Concentration (mg/kg)
SS3@4-8	<2.00	BG02-3	0.359
SS4-2	1.32	BG03-3	1.78
EX01-2	1.16	BKG08@2	2.51
EX01-2	2.97	BKG09@2	1.18
EX02-2	1.81	BKG10@2	1.8
EX02-2	0.623	BKG11@2	0.742
EX04-2	1.5	BKG12@2	1.17
EX04-2	2.71	BKG13@2	0.539
EX05-3	0.331	BKG14@2	1.3
EX06-3	0.61	BKG15@2	2.16
SB01-5	0.443	BKG16@2	0.932
		BKG17@2	1.11
		BKG18@2	0.458
		BKG19@2	2.88

mg/kg = milligrams per kilogram

Summary statistics for the Site and background samples are shown in Table 2 below, and ProUCL outputs are included in Appendix A. Box plots of the two datasets are shown in Figure 1.

**Table 2: Summary statistics for boron at background (bkg) vs. Site sample locations.**

Variable	Number of Samples	Number (Percent) of Non-detects	Minimum Detection	Maximum Detection	KM Mean	Median	KM SD	IQR
Boron (bkg)	14	0 (0%)	0.359	2.88	1.35	1.18	0.776	1.01
Boron (Site)	11	1 (9.09%)	0.331	2.97	1.31	1.32	0.856	1.29

Concentrations are in milligrams per kilogram (mg/kg). Unless otherwise specified, statistics are calculated using statistical methods that can accommodate data sets with both detects and non-detects.

KM = Kaplan-Meier method

SD = standard deviation

IQR = interquartile range

The minimum and maximum detected concentrations in Site data (minimum 0.331 mg/kg; maximum 2.97 mg/kg) and background data (minimum 0.359 mg/kg; maximum 2.88 mg/kg) are similar. The Kaplan-Meier (KM) mean boron concentration in the Site samples (1.31 mg/kg) is lower than that in the background samples (1.35 mg/kg). The median of the Site dataset (1.32 mg/kg) was higher than the median of the background dataset (1.18 mg/kg).

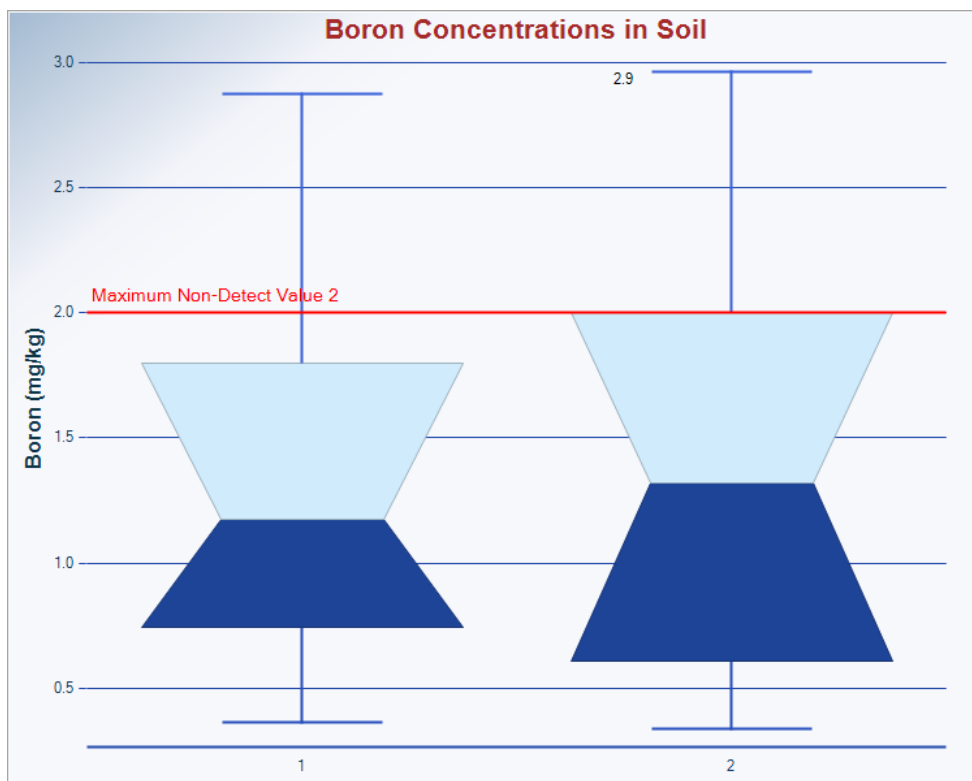


Figure 1. Boxplots of boron concentrations in background (1) soil and Site (2) soil. Whiskers represent 1.5 times the interquartile range (75<sup>th</sup> percentile – 25<sup>th</sup> percentile), while the top and bottom of each box represent the 75<sup>th</sup> and 25<sup>th</sup> percentiles, respectively. The narrowest point of the box is the median. Potential outliers are shown as dots above or below the whiskers. ProUCL generates box plots using reporting limits and draws a horizontal line at the highest reporting limit.

Normality was tested using the Shapiro-Wilk Test at the 0.05 significance level, and normality was further confirmed by visual inspection of quantile-quantile (Q-Q) plots against the normal

distribution. The results of these tests are shown in Figure 2 for background soils and Figure 3 for Site soils.

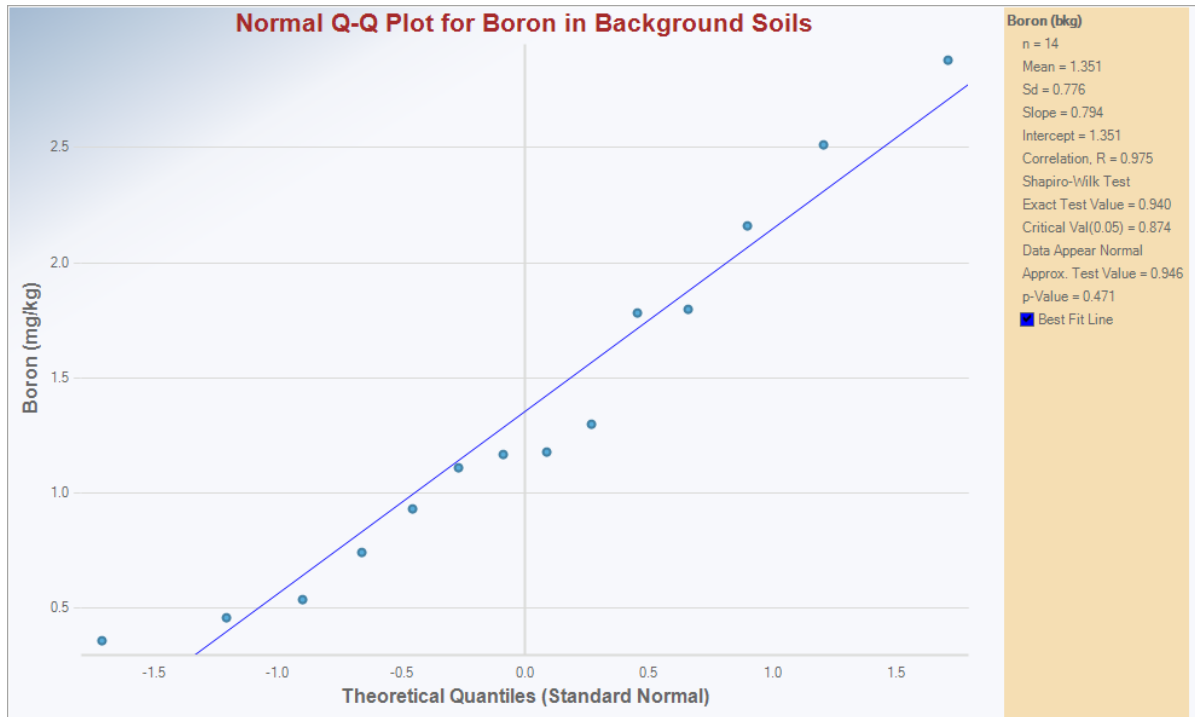


Figure 2. Test for normality – background soils.

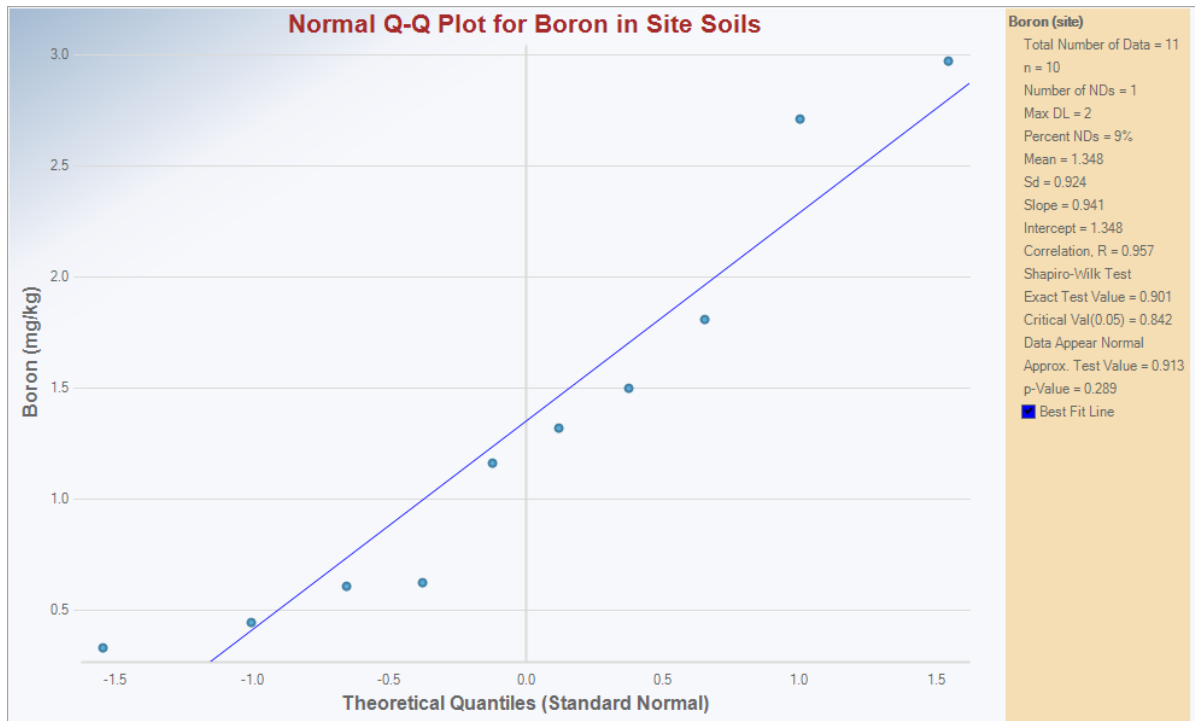


Figure 3. Test for normality – background soils.

The Wilcoxon-Mann-Whitney test may be used with datasets that contain ND values; however, other methods, such as the Gehan Test, are recommended when NDs exceed the detection limit in the dataset (USEPA, 2022b). Therefore, the Gehan test was used to assess the relationship between the Site and background boron concentrations.

### 3. STATISTICAL COMPARISON TO BACKGROUND

Site samples were compared with background samples using the Gehan Test (Test Form 1) in ProUCL 5.2. Test Form 1 of the Gehan test assesses whether it is possible to reject the following alternative hypothesis,  $H_A$ , in favor of the null hypothesis,  $H_0$ :

- $H_0$ , the *null hypothesis*, is that the mean/median of boron concentration in Site samples is statistically below or equal to the mean/median of boron concentration in background samples.
- $H_A$ , the *alternative hypothesis*, is that the mean/median of boron concentration in Site samples is greater than the mean/median of boron concentration in background samples.

The mean and median of boron concentration in Site samples (KM mean 1.32 mg/kg, median 1.32 mg/kg), with a non-detect of 2.00 mg/kg, were found to be similar to the mean and median of background (mean 1.35 mg/kg, median 1.18 mg/kg). The Gehan test using Test Form 1 at the 0.05 significance level does not reject the null hypothesis. Therefore, the mean/median of boron concentration in Site samples is statistically below or equal to the mean/median of boron concentration in background samples. The ProUCL outputs of the Gehan test for boron using Test Form 1 are included in Appendix A.

### 4. SUMMARY AND CONCLUSIONS

Concentrations of boron in Site and background soils at Kielian 2-2 Wellhead were compared using statistical methods recommended by EPA guidance and EPA's ProUCL software. Based on the results of the Gehan Test using Test Form 1, the Site mean/median boron concentration is statistically below or equal to the Site-specific background mean/median concentration. Therefore, Site boron concentrations are not elevated above background boron concentrations.

## 5. REFERENCES

USEPA. 2002. *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*. Final. United States Environmental Protection Agency, Office of Solid Waste and Emergency Response. EPA-540-R-01-003. September.

USEPA. 2022a. *ProUCL: Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations*. Version 5.2. <https://www.epa.gov/land-research/proucl-software>.

USEPA. 2022b. *ProUCL Version 5.2.0 Technical Guide*. United States Environmental Protection Agency, Office of Research and Development. June. [https://cfpub.epa.gov/si/si\\_public\\_file\\_download.cfm?p\\_download\\_id=544825&Lab=CESE](https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=544825&Lab=CESE) R.

# APPENDIX

## ProUCL Outputs

**General Statistics on Uncensored Data**  
 Date/Time of Computation ProUCL 5.2 2/6/2026 5:42:36 PM  
**User Selected Options**  
 From File Kielian 2-2 input.xls  
 Full Precision OFF

From File: Kielian 2-2 input.xls

**General Statistics for Censored Data Set (with NDs) using Kaplan Meier Method**

Variable	NumObs	# Missing	Num Ds	NumNDs	% NDs	Min ND	Max ND	KM Mean	KM Var	KM SD	KM CV
Boron (bkg)	14	0	14	0	0.00%	N/A	N/A	1.351	0.602	0.776	0.574
Boron (site)	11	0	10	1	9.09%	2	2	1.314	0.734	0.856	0.652

**General Statistics for Raw Data Sets using Detected Data Only**

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Median	Var	SD	MAD/0.675	Skewness	CV
Boron (bkg)	14	0	0.359	2.88	1.351	1.175	0.602	0.776	0.912	0.628	0.574
Boron (site)	10	0	0.331	2.97	1.348	1.24	0.854	0.924	0.924	0.761	0.686

**Percentiles using all Detects (Ds) and Non-Detects (NDs)**

Variable	NumObs	# Missing	10%ile	20%ile	25%ile(Q1)	50%ile(Q2)	75%ile(Q3)	80%ile	90%ile	95%ile	99%ile
Boron (bkg)	14	0	0.482	0.661	0.79	1.175	1.795	1.944	2.405	2.64	2.832
Boron (site)	11	0	0.443	0.61	0.617	1.32	1.905	2	2.71	2.84	2.944

**Goodness-of-Fit Test Statistics for Data Sets with Non-Detects**

**User Selected Options**

Date/Time of Computation ProUCL 5.2 2/6/2026 6:01:45 PM  
From File Kielian 2-2 input.xls  
Full Precision OFF  
Confidence Coefficient 0.95

**Boron (bkg)**

**Raw Statistics**

Number of Valid Observations 14  
Number of Distinct Observations 14  
Minimum 0.359  
Maximum 2.88  
Mean of Raw Data 1.351  
Standard Deviation of Raw Data 0.776  
Khat 3.065  
Theta hat 0.441  
Kstar 2.456  
Theta star 0.55  
Mean of Log Transformed Data 0.129  
Standard Deviation of Log Transformed Data 0.637

**Normal GOF Test Results**

Correlation Coefficient R 0.975  
Shapiro Wilk Test Statistic 0.94  
Shapiro Wilk Critical (0.05) Value 0.874  
Approximate Shapiro Wilk P Value 0.471  
Lilliefors Test Statistic 0.169  
Lilliefors Critical (0.05) Value 0.226

Data appear Normal at (0.05) Significance Level

**Gamma GOF Test Results**

Correlation Coefficient R 0.988  
A-D Test Statistic 0.195  
A-D Critical (0.05) Value 0.742  
K-S Test Statistic 0.113  
K-S Critical(0.05) Value 0.23

Data appear Gamma Distributed at (0.05) Significance Level

**Lognormal GOF Test Results**

Correlation Coefficient R 0.986  
Shapiro Wilk Test Statistic 0.961  
Shapiro Wilk Critical (0.05) Value 0.874  
Approximate Shapiro Wilk P Value 0.795  
Lilliefors Test Statistic 0.127  
Lilliefors Critical (0.05) Value 0.226

Data appear Lognormal at (0.05) Significance Level

**Boron (site)**

Raw Statistics	Num Obs	Num Miss	Num Valid	Detects	NDs	% NDs
	11	0	11	10	1	9.09%
	Number	Minimum	Maximum	Mean	Median	SD
Statistics (Non-Detects Only)	1	2	2	2	2	N/A
Statistics (Detects Only)	10	0.331	2.97	1.348	1.24	0.924
Statistics (All: NDs treated as DL value)	11	0.331	2.97	1.407	1.32	0.898
Statistics (All: NDs treated as DL/2 value)	11	0.331	2.97	1.316	1.16	0.883
Statistics (Normal ROS Imputed Data)	11	0.331	2.97	1.323	1.16	0.88
Statistics (Gamma ROS Imputed Data)	11	0.331	2.97	1.311	1.16	0.885
Statistics (Lognormal ROS Imputed Data)	11	0.331	2.97	1.302	1.16	0.889
	K hat	K Star	Theta hat	Log Mean	Log Stdv	Log CV
Statistics (Detects Only)	2.27	1.656	0.594	0.0623	0.753	12.09
Statistics (NDs = DL)	2.408	1.812	0.584	0.12	0.74	6.182
Statistics (NDs = DL/2)	2.447	1.84	0.538	0.0566	0.715	12.62
Statistics (Gamma ROS Estimates)	2.432	1.829	0.539	0.0511	0.716	14
Statistics (Lognormal ROS Estimates)	--	--	--	0.0417	0.718	17.23

**Normal GOF Test Results**

Correlation Coefficient R	No NDs	NDs = DL	NDs = DL/2	Normal ROS
	0.957	0.972	0.955	0.956
Test value	Crit. (0.05)	Conclusion with Alpha(0.05)		
Shapiro-Wilk (Detects Only)	0.901	0.842	Data Appear Normal	
Shapiro-Wilk (NDs = DL)	0.928	0.85	Data Appear Normal	
Shapiro-Wilk (NDs = DL/2)	0.9	0.85	Data Appear Normal	
Shapiro-Wilk (Normal ROS Estimates)	0.901	0.85	Data Appear Normal	
Lilliefors (Detects Only)	0.184	0.262	Data Appear Normal	
Lilliefors (NDs = DL)	0.172	0.251	Data Appear Normal	
Lilliefors (NDs = DL/2)	0.147	0.251	Data Appear Normal	
Lilliefors (Normal ROS Estimates)	0.15	0.251	Data Appear Normal	

**Gamma GOF Test Results**

Correlation Coefficient R	No NDs	NDs = DL	NDs = DL/2	Gamma ROS
	0.978	0.978	0.983	0.984
Test value	Crit. (0.05)	Conclusion with Alpha(0.05)		
Anderson-Darling (Detects Only)	0.269	0.735		
Kolmogorov-Smirnov (Detects Only)	0.187	0.269	Detected Data Appear Gamma Distributed	
Anderson-Darling (NDs = DL)	0.269	0.737		
Kolmogorov-Smirnov (NDs = DL)	0.176	0.258	Data Appear Gamma Distributed	
Anderson-Darling (NDs = DL/2)	0.213	0.737		
Kolmogorov-Smirnov (NDs = DL/2)	0.156	0.258	Data Appear Gamma Distributed	
Anderson-Darling (Gamma ROS Estimates)	0.21	0.737		
Kolmogorov-Smirnov (Gamma ROS Est.)	0.154	0.258	Data Appear Gamma Distributed	

**Lognormal GOF Test Results**

Correlation Coefficient R	No NDs	NDs = DL	NDs = DL/2	Log ROS
	0.982	0.978	0.989	0.99
Test value	Crit. (0.05)	Conclusion with Alpha(0.05)		
Shapiro-Wilk (Detects Only)	0.948	0.842	Data Appear Lognormal	
Shapiro-Wilk (NDs = DL)	0.94	0.85	Data Appear Lognormal	
Shapiro-Wilk (NDs = DL/2)	0.964	0.85	Data Appear Lognormal	
Shapiro-Wilk (Lognormal ROS Estimates)	0.966	0.85	Data Appear Lognormal	
Lilliefors (Detects Only)	0.161	0.262	Data Appear Lognormal	
Lilliefors (NDs = DL)	0.152	0.251	Data Appear Lognormal	
Lilliefors (NDs = DL/2)	0.134	0.251	Data Appear Lognormal	
Lilliefors (Lognormal ROS Estimates)	0.127	0.251	Data Appear Lognormal	

**Note: Substitution methods such as DL or DL/2 are not recommended.**

## Gehan Sample 1 vs Sample 2 Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options  
Date/Time of Computation ProUCL 5.2 2/6/2026 5:59:15 PM  
From File Kielian 2-2 input.xls  
Full Precision OFF  
Confidence Coefficient 95%  
Selected Null Hypothesis Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)  
Alternative Hypothesis Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Boron(site)

Sample 2 Data: Boron(bkg)

### Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	11	14
Number of Non-Detects	1	0
Number of Detect Data	10	14
Minimum Non-Detect	2	N/A
Maximum Non-Detect	2	N/A
Percent Non-detects	9.09%	0.00%
Minimum Detect	0.331	0.359
Maximum Detect	2.97	2.88
Mean of Detects	1.348	1.351
Median of Detects	1.24	1.175
SD of Detects	0.924	0.776
KM Mean	1.314	1.351
KM SD	0.856	0.776

### Sample 1 vs Sample 2 Gehan Test

H0: Mean/Median of Sample 1 <= Mean/Median of background

Gehan z Test Value -0.142  
Critical z (0.05) 1.645  
P-Value 0.557

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)