Numbers! Speak to me! Interpretation of Environmental Statistics

Instructors

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Schedule

1:00	Introduction
1:15	Where does data come from?
1:45	Making the numbers talk
2:45	*Break*
3:00	What data distributions look like
3:30	Seeing data (class exercise)
4:00	Describing a Data Set (class exercise)
4:30	*Conclude*

3

Data Quality

- Meaningful only when "data quality" relates to intended use of data.
- Some data are good ("high quality") for some purposes but are bad ("low quality") for others

4

Visual Basic Statistics

- Histogram
- Scatterplot
- Boxplot
- Stem-and-leaf
- Data distributions
- Estimation
- Precision and Bias

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Course Objectives

At the end of this course, you should be able to:

- Explain why statistics are important and how they can be applied to your projects.
- Interpret basic statistics and simple graphs.

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Where Does Data Come From?

Data is data, is data, is data

It is very common to think there are two types of data:

- Data collected for or by you
- Somebody else's data

Are they the same?

From a data analyst's point of view…Yes

But from a project manager's point of view…Maybe

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How was data collected?

Not statistical sample selection scheme but more to do with the regime under which the data were collected

- **Data collected by or for you:**
  - ***Use of systematic planning***
  - ***Data Quality Objectives***
  - ***Sampling and Analysis Plans***
  - ***QA Project Plans***

- **Someone else's data:**
  - ***Use of systematic planning***
  - ***Performance Criteria (for new data)***
  - ***Acceptance Criteria (for existing data)***

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Commonality: Systematic Planning

The use of systematic planning is both good common sense and proper scientific practice

- **EPA Order 5360.1 A2 (2000) Section 6.a.(6) "Use of a systematic planning approach to develop acceptance or performance criteria for all work covered by this Order."**

- **The Data Quality Objectives Process is the Agency's recommended approach when data are being used in decision-making or deriving an estimate**

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Unknown quality of data can affect results

Consider the potential effects of data being analyzed when it is thought that all went well during its collection:

- **Suppose there has been a significant departure from the Sampling and Analysis Plan:**
  - ***samples not taken where they were supposed to be***
  - ***improper mixing of samples in the field***

- **Suppose there has been a serious departure from the QA Project Plan:**
  - ***failure to calibrate equipment correctly***
  - ***samples held longer than the holding time***

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Types of Data Gathering

- ***Survey Data***
  - **National Agricultural Statistics Survey**
  - **Bureau of Labor Statistics**
- ***Administrative Data***
  - **EPA Discharge Permits**
  - **Toxic Release Inventory**
- ***Surveillance Data***
  - **Passports**
  - **Credit Cards**
- ***Scientific Data***
  - **Systematically planned investigations**
  - **Scientific research experiments**

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Even the easy datasets are not

- Duplication of entries:
  - Denise Wise
  - Denice Wise
  - D'Nise Wise
- Manipulation of data:
  - All less than detection entries suppressed
  - Data thought to be outliers discarded
  - Several data sets combined to make one large one

…these can make interpretation difficult

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The Literary Digest survey 1936

In 1936, Franklin Delano Roosevelt had been President for one term. The magazine, *The Literary Digest*, predicted that Alf Landon would beat him in that year's election by 57% to 43%.

The Digest mailed over 10 million questionnaires to names drawn from lists of automobile and telephone owners, and over 2.3 million people responded - a huge sample.

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The Literary Digest survey 1936

At the same time, a survey researcher named George Gallup sampled only 50,000 people and predicted that Roosevelt would win. Gallup's prediction was ridiculed as naive. After all, *The Literary Digest* had predicted the winner in every election since 1916, and had based its predictions on the largest response to any poll in history.

Roosevelt won with 62% of the vote. What went wrong?

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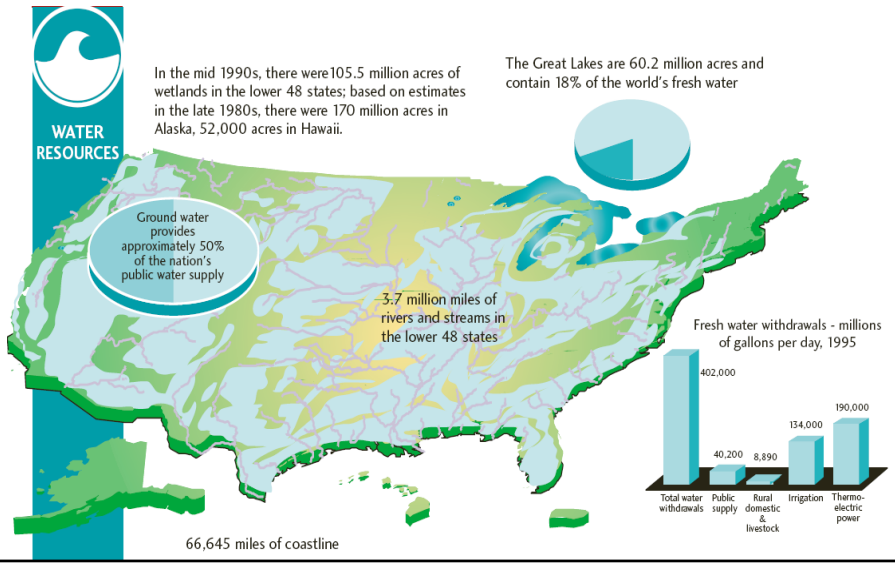
EPA Draft Report on the Environment 2003



But if you google: “U.S. Coastline”

Teachervision: 88,633 miles

EPA 2003 Report: 66,645 miles

CIA Factbook: 12,383 miles

Infoplease: 12,383 miles General Coastline
88,633 miles Tidal Shoreline

Fractal Geometry: Infinite miles because the smaller the measuring device, the more intricate details can be measured.

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Data must have integrity

“The Government are very keen on amassing statistics. They collect them, add them, raise them to the nth power, take the cube root and prepare wonderful diagrams.

But you must never forget that every one of these figures comes in the first instance from the village watchman, who just puts down what he damn pleases.”

Sir Josiah Stamp
Inland Revenue
1896 - 1919

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Looking at the Data: Making the Numbers Talk

Calibration Problem

- Four Technicians doing same analysis
- X = Controlled variable
- Y = Measured variable

A		B		C		D	
X	Y	X	Y	X	Y	X	Y
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.74	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.10	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.10	4	5.39	19	12.50
12	10.84	12	9.13	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

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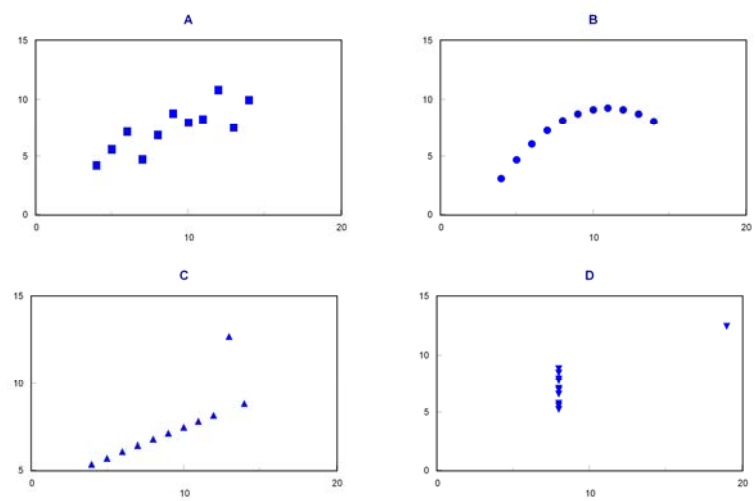
Computer Printout of Summary Statistics

For each technician:

- n = 11
- mean of X_s = 9.0
- mean of Y_s = 7.5
- equation of regression line: Y = 3+0.5X
- s.e. estimate of slope = 0.118
- *t* statistic = 4.24 (significant)
- sum of squares = 110.00
- regression sum of squares = 27.50
- residual sum of squares of Y = 13.75
- correlation coefficient = 0.82

Within rounding error, each technician had identical summary statistics . . . or did they?

Actual Results in Graphical Form



Moral: Numerical statistics alone don't tell everything!

What is "Statistics"?

- A *statistic* is a numerical summary
- *Statistics* is the science of data collection, analysis and interpretation
- *Statistical methods* present information to a manager in a useful form

Applying Statistics

- Objective is to learn from the data:
  - Analyze the data to examine features
  - Interpret these features
- Interpretation depends on:
  - Method used to summarize
  - Assumptions about how data came about
  - Context in which inference will be made

Importance of Context

- Interpretation requires context
- The context should include:
  - Description of the big picture (conceptual model)
  - Description of the methods used
  - Definitions, units of measurements, etc.
- Without context, interpretation loses its scientific and realistic basis

Displaying Data

- Histogram
- Scatterplot
- Boxplot
- Stem-and-Leaf

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Histogram: Initial Data

Cadmium concentration in 100 random samples from the Midway Municipal Site (ppm)

10.46	10.06	11.49	9.47	11.02
11.39	10.91	11.18	8.50	9.31
11.37	9.52	8.62	11.01	9.99
11.39	11.79	9.89	8.66	11.04
9.72	8.81	12.27	9.56	11.40
10.20	10.16	9.49	10.04	8.87
10.77	10.38	10.16	10.29	11.03
9.67	9.71	8.58	8.65	11.25
10.42	10.38	10.86	9.45	9.69
12.46	10.59	9.65	10.24	9.15
9.49	7.47	9.51	9.53	9.44
11.68	8.96	10.60	10.76	10.23
9.74	9.85	11.83	9.10	8.84
7.99	9.64	8.86	10.54	7.94
10.21	11.18	9.66	10.36	9.77
10.08	10.27	9.11	9.69	7.90
11.28	8.36	10.49	9.48	12.99
9.46	9.86	9.11	10.19	9.80
9.56	8.06	7.13	9.76	10.53
8.31	10.66	8.35	9.37	10.40

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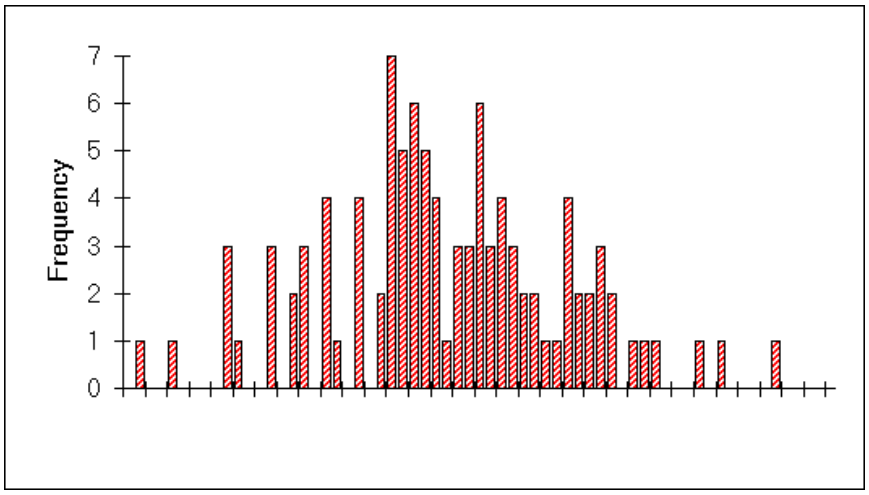
Difficult to comprehend unless we "trim away" some decimals.

Rounded to Nearest Tenth

10.5	10.1	11.5	9.5	11.0
11.4	10.9	11.2	8.5	9.3
11.4	9.5	8.6	11.0	10.0
11.4	11.8	9.9	8.7	11.0
9.8	8.8	12.3	9.6	11.4
10.2	10.2	9.5	10.0	8.9
10.8	10.4	10.2	10.3	11.0
9.7	9.7	8.6	8.7	11.3
10.4	10.4	10.9	9.5	9.7
12.5	10.6	9.6	10.2	9.3
9.5	7.5	9.5	9.5	9.4
11.7	9.0	10.6	10.8	10.2
9.7	9.9	11.8	9.1	8.8
8.0	9.6	8.9	10.5	7.9
10.2	11.2	9.7	10.4	9.8
10.2	10.3	9.1	9.7	7.9
11.3	8.4	10.5	9.5	13.0
9.5	9.9	9.1	10.2	9.8
9.6	8.1	7.1	9.8	10.5
8.3	10.7	8.4	9.4	10.4

Getting any clearer?

Histogram of Data Rounded to Nearest Tenth

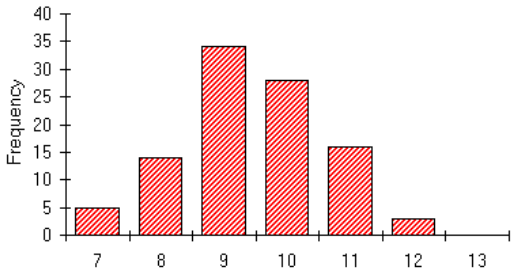


Rounded to Nearest Whole Number

10	10	11	9	11
11	11	11	9	9
11	10	9	11	10
11	12	10	9	11
10	9	12	10	11
10	10	9	10	9
11	10	10	10	11
10	10	9	9	11
10	10	11	9	10
12	11	10	10	9
9	7	10	10	9
12	9	11	11	10
10	10	12	9	9
8	10	9	11	8
10	11	10	10	10
10	10	9	10	8
11	8	10	9	13
9	10	9	10	10
10	8	7	10	11
8	11	8	9	10

Better?

Histogram of Data Rounded to the Nearest Whole Number

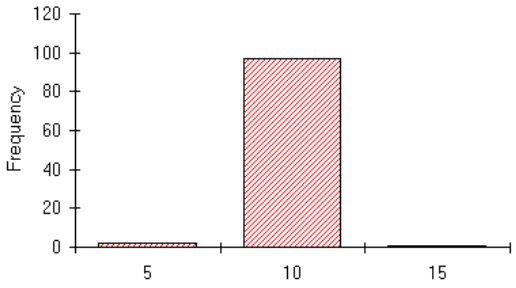


Rounded to Nearest 5

10	10	10	10	10
10	10	10	10	10
10	10	10	10	10
10	10	10	10	10
10	10	10	10	10
10	10	10	10	10
10	10	10	10	10
10	10	10	10	10
10	10	10	10	10
10	10	10	10	10
10	5	10	10	10
10	10	10	10	10
10	10	10	10	10
10	10	10	10	10
10	10	10	10	10
10	10	10	10	10
10	10	10	10	15
10	10	10	10	10
10	10	5	10	10
10	10	10	10	10

Even better?

Histogram of Data Rounded to Nearest 5



Conclusions for Histograms

- Different groupings (box or bin sizes) can lead to different conclusions.
  - Try several bin-sizes and "feel out" the data
- Different scales can change conclusions.
  - Make the bins equal in width and contiguous to each other.
- Histograms are used to assess fit for different theoretical distributions, for example, Normal or Lognormal
- Histograms have good visual impact and are useful in expressing probabilities and error distributions

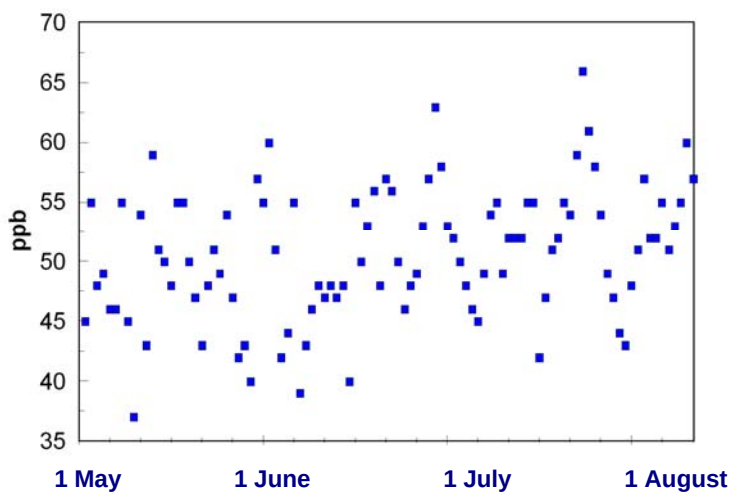
Scatterplots:
Comstock Air Monitoring Station

Ozone ppb

May 1	45	48	48	52	59	
	55	51	47	Jul 1	50	66
	48	49	48	48	61	
	49	54	40	46	58	
	46	47	55	45	54	
	46	42	50	49	49	
	55	43	53	54	47	
	45	40	56	55	44	
	37	57	48	49	43	
	54	55	57	52	48	
	43	60	56	52	51	
	59	Jun 1	51	50	52	57
	51	42	46	55	Aug 1	52
	50	44	48	55	52	
	48	55	49	42	55	
	55	39	53	47	51	
	55	43	57	51	53	
	50	46	63	52	55	
	47	48	58	55	60	
	43	47	53	54	57	

***100 consecutive days in Summer 2005**

Comstock Ozone Readings



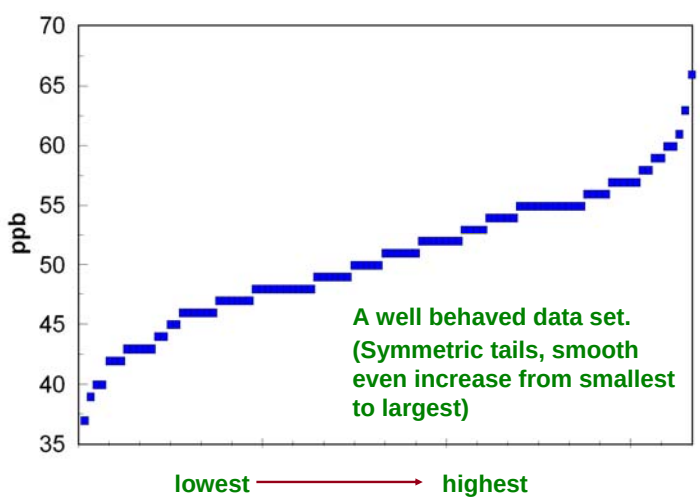
Rank Ordered Data: Smallest to Largest

Comstock Air Monitoring Station Ozone ppb

37, 39, 40, 40, 42, 42, 42, 43, 43, 43, 43, 43, 44, 44, 45, 45, 46, 46, 46, 46, 46, 46, 47, 47, 47, 47, 47, 47, 48, 48, 48, 48, 48, 48, 48, 48, 48, 48, 49, 49, 49, 49, 49, 49, 50, 50, 50, 50, 50, 51, 51, 51, 51, 51, 51, 52, 52, 52, 52, 52, 52, 52, 53, 53, 53, 53, 54, 54, 54, 54, 54, 55, 55, 55, 55, 55, 55, 55, 55, 55, 55, 55, 55, 56, 56, 56, 56, 57, 57, 57, 57, 57, 58, 58, 59, 59, 60, 60, 61, 63, 66

- 100 Observations
- Minimum = 37
- Maximum = 66
- Range = 29

Comstock Ozone



Lode Air Monitoring Station

May 1	37		48	65		45	47
	48		58	44	July 1	45	46
	48		64	45		43	52
	47		54	47		48	46
	46		48	47		48	44
	47		48	44		45	48
	48		45	43		46	47
	49		43	47		46	47
	48		47	42		47	45
	48		48	43		47	45
	54		44	43		47	48
	45	June 1	61	43		49	46
	45		56	45		56	August 1 45
	45		64	44		63	50
	47		45	45		50	45
	47		45	44		47	45
	46		52	47		45	50
	44		63	47		48	46
	45		66	45		44	44
	48		59	44		45	45

*100 Consecutive Days in Summer 2005

Rank Ordered Data: Smallest to Largest

Lode Air Monitoring Station Ozone ppb

37, 42, 43, 43, 43, 43, 43, 43, 44, 44, 44, 44, 44, 44, 44, 44, 44, 44, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 46, 46, 46, 46, 46, 46, 46, 46, 47, 47, 47, 47, 47, 47, 47, 47, 47, 47, 47, 47, 47, 47, 47, 47, 48, 48, 48, 48, 48, 48, 48, 48, 48, 48, 48, 48, 48, 48, 48, 49, 49, 50, 50, 50, 52, 52, 54, 54, 56, 56, 58, 59, 61, 63, 63, 64, 64, 65, 66

- 100 Observations
- Minimum = 37
- Maximum = 66
- Range = 29

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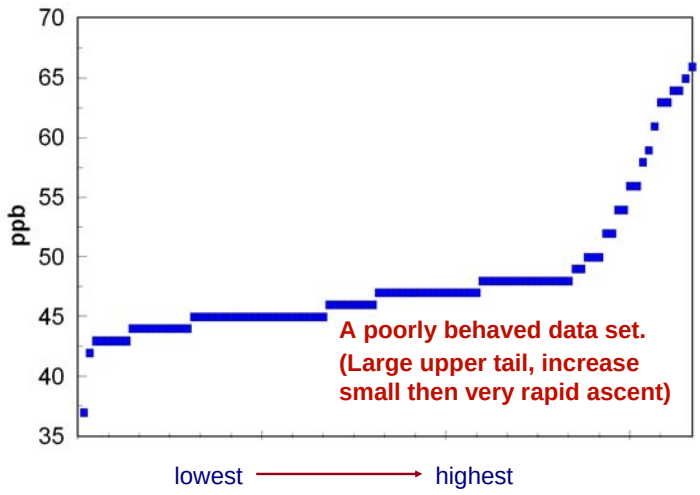
Lode Ozone



Conclusions for Scatterplots

- Simple graph over time can show potential trends and relationships clearly
- Potential anomalies are easy to identify
- Plotting the ordered data should give a smooth sinuous display to indicate approximate Normal distribution:
  - Clearly defined roughly equal tails
  - Steady rise from smallest to largest
  - Fairly large plateau in the center
- Unknown distribution indicated by:
  - Unequal tails
  - Abrupt changes in the rise of values
  - Poorly defined or unequal tails

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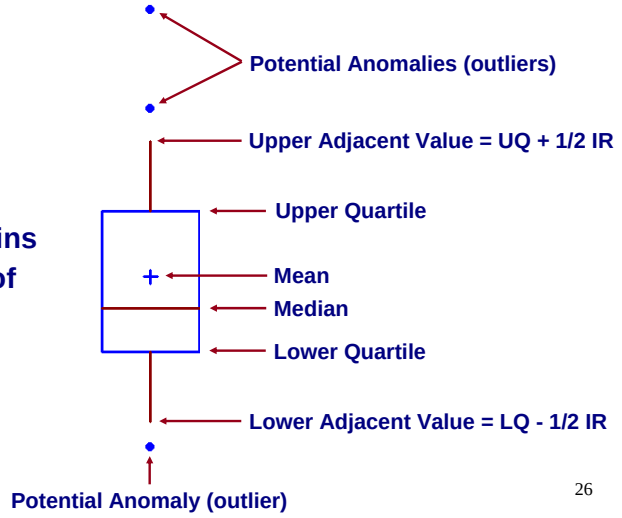
Boxplots

- Puts into visual form data percentiles using:
- Median: the value such that half of all values are larger, half are smaller = 50th percentile
- Upper quartile (UQ): the value such that 25% of all values are larger =75th percentile
- Lower quartile(LQ): the value such that only 25% of all values are smaller = 25th percentile
- Interquartile Range (IR): IR = UQ - LQ

A Boxplot Actually Uses a Box

The "Box" contains the central 50% of the data.



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Comstock Ozone
(Well Behaved Data)

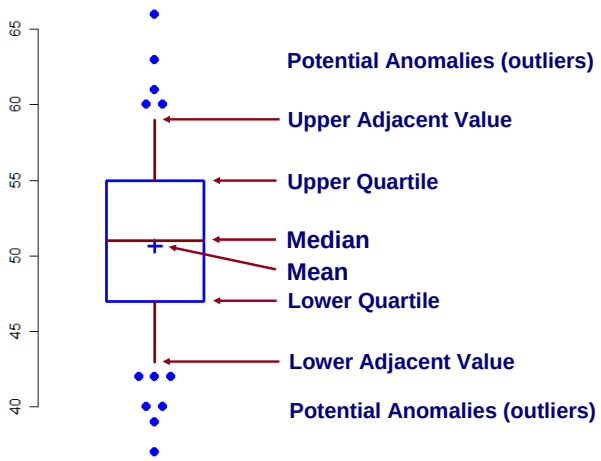
Comstock Air Monitoring Station Ozone ppb

37, 39, 40, 40, 42, 42, 42, 43, 43, 43, 43, 43, 44, 44, 45, 45, 46, 46, 46, 46, 46, 46, 47, 47, 47, 47, 47, 47, 48, 48, 48, 48, 48, 48, 48, 48, 48, 48, 49, 49, 49, 49, 49, 49, 50, 50, 50, 50, 50, 51, 51, 51, 51, 51, 51, 52, 52, 52, 52, 52, 52, 52, 53, 53, 53, 53, 54, 54, 54, 54, 54, 55, 55, 55, 55, 55, 55, 55, 55, 55, 55, 55, 55, 56, 56, 56, 56, 57, 57, 57, 57, 57, 58, 58, 59, 59, 60, 60, 61, 63, 66

LQ is between 25th & 26th data points = 47
Median is between 50th & 51st data points = 51
UQ is between 75th & 76th data points = 55

IR = UQ - LQ = 55 - 47 = 8

Comstock Ozone - Well Behaved Data



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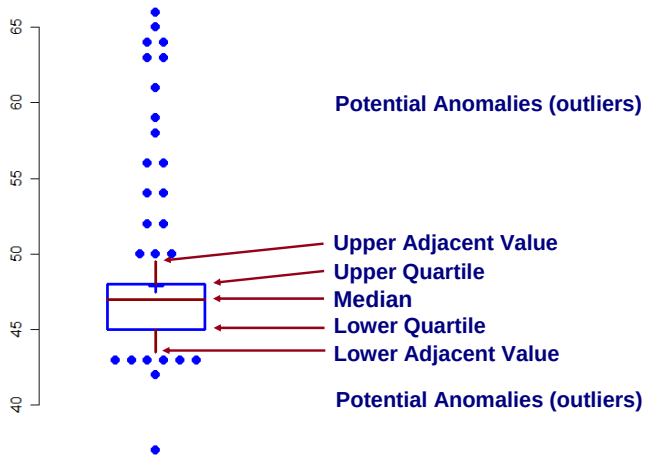
Lode Ozone - Poorly Behaved Data

37, 42, 43, 43, 43, 43, 43, 43, 44, 44, 44, 44, 44, 44, 44, 44, 44, 44, 45, 45,
45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45,
46, 46, 46, 46, 46, 46, 46, 46, 47, 47, 47, 47, 47, 47, 47, 47, 47, 47, 47, 47,
47, 47, 47, 47, 47, 48, 48, 48, 48, 48, 48, 48, 48, 48, 48, 48, 48, 48, 48, 48,
49, 49, 50, 50, 50, 52, 52, 54, 54, 56, 56, 58, 59, 61, 63, 63, 64, 64, 65, 66

LQ is between 25th & 26th data points = 45
Median is between 50th & 51st data points = 47
UQ is between 75th & 76th data points = 48

IR = UQ - LQ = 48 - 45 = 3

Lode Ozone (Poorly Behaved Data)



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Conclusions for Boxplots

- Few potential anomalies should be observed
- Many potential anomalies makes identification of distribution difficult
- "Eliminating" the central mass of data by replacing it with a "box" facilitates an understanding of the data distribution

Stem and Leaf Displays

Major value = stem
Minor value = leaf

Comstock Ozone June Data

Stem	Leaf
60	3
55	5 5 5 6 7 7 8
50	0 0 1 2 3 3 3
45	5 6 7 7 8 8 8 8 8 9
40	0 2 3 4
35	9

Stem and Leaf Comparison

Lode Ozone June		Comstock Ozone June
6 5 4 3 1	60	3
9 6	55	5 5 5 6 7 7 8
2	50	0 0 1 2 3 3 3
7 7 7 7 7 5 5 5 5 5 5	45	5 6 7 7 8 8 8 8 8 9
4 4 4 4 4 4 3 3 3 3 2	40	0 2 3 4
	35	9

The imbalance between the data sets shows they are probably from different distributions

Other Graphical Methods

- Frequency graphs
- Parallel coordinate plots
- Empirical Quantile-Quantile plots
- Normal plots

Bizarre: Unaccountable Gaps

pH of effluent discharge reported fom Hoffner Plant

1 pm	2 pm	3 pm	5 pm	6 pm	7 pm	9 pm	10 pm
4.6	4.5	4.1	4.5	4.4	4.0	4.8	4.7

–Why are 4 pm and 8 pm missing?
–If deliberate, could they be extreme values?
–If accidental, can we impute a value?

Bizarre: Preponderance of Values

Opacity reading from the Churchman smoke stack
(0 = clear, 1.0 = opaque)

0.5,	0.1,	0.5,	0.2,	0.5,	0.8,	1.0,	1.0,
0.5,	0.5,	0.1,	0.5,	1.0,	0.8,	0.5,	0.5,
0.5,	0.5,	0.1,	0.5,	1.0,	0.5,	0.8,	0.5,
1.0,	0.5,	0.5,	0.5,	0.1,	0.5,	0.5,	0.8.

–Where are values like 0.6 or 0.4?
–Why so many 0.5 values?
–Can 0.1 really be distinguished from 0.2?

Bizarre: Too Many Decimals

Arsenic in soil (ppm)

March - April:	**12.0, 13.0, 12.0, 12.0,**
May - June:	**12.5632, 13.1129, 13.0076, 12.9665**

- **How much accuracy? Four decimal places or one?**
- **Different methods or different analysts?**
- **Data rounded off prior to recording?**
- **Spurious decimals to give illusion of precision?**

Conclusions

"A picture is worth a _ _ _ _ _ _ _ words"

What Data Distributions Look Like

Raw data must be grouped in order to see patterns

- Data in numerical form are difficult to visualize directly
- Identification of patterns in data help us use the information from the sample in an efficient manner
- The most obvious pattern in everyday data is the way in which the data values group together
  - Clustering of values round an average
  - Predominance of very small values
  - Occurrence of a few high values with mostly low values

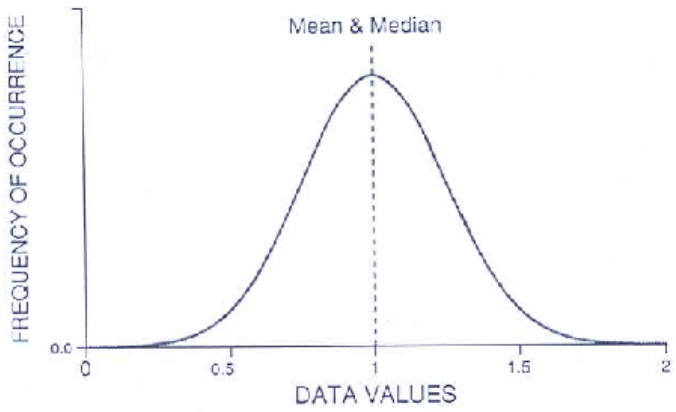
Environmental data comes as two types

- Environmental data comes in one of two forms; continuous (measurement type data) and discrete (counting type data)
- Continuous data requires the calculus of integration, discrete requires the use of summation techniques
- Continuous data can be mistaken for discrete data due to the fact we must round off some of the decimal places
  - e.g. A measurement of 8.2341152787345873459096 3… is recorded as 8.23 or even as just 8 depending on what is the final disposition of the values

The most commonly encountered types

- Continuous:
  - Normal
    - *bell-shaped curve*
  - Lognormal
    - *Logarithm of the values are Normal*
- Discrete:
  - Binomial
    - *Everything is one thing or another*
  - Poisson
    - *Extreme case of a Binomial*

The Normal Distribution



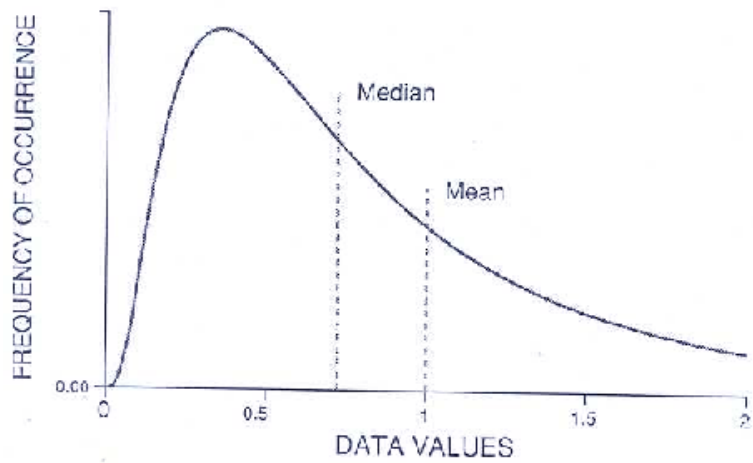
Normal data

- **Normal data are continuous data**
- **Often "taken for granted" with data sets (see the Central Limit Theorem later)**
- **Measurements of arsenic at Royal Smelting (in ppm)**

1.251, 1.423, 1.323, 0.789, 0.429,
3.033, 2.131, 2.055, 1.001, 1.488

- **Note roughly symmetric around a mean of roughly 1.5**
- **No really extreme values**

The Lognormal Distribution



Lognormal data

- **Lognormal data are continuous data**
- **Not always obvious when dealing with small data sets**
- **Measurements of selenium in Melrose Lake (in ppb):**

3.16, 4.15, 3.75, 2.20, 1.53,
20.76, 8.42, 7.81, 2.72, 4.43

- **Note the suspicious high value**
- **Is this an outlier or genuine value?**
- **If data are transformed by taking logarithms, does approximate normality result?**

The Binomial Distribution

Binomial data

- **Binomial data are discrete data**
- **Need a fixed (albeit unknown) probability of an occurrence**
- **Need a fixed number of possibilities**
- **Infected cells (out of 6 possibilities) in a biometer used 8 times**

  4/6, 0/6, 3/6, 3/6

  6/6, 3/6, 4/6, 2/6
- **Total number of infections = 25 out of 48 cells**

  assuming independence, chance is 25/48 i.e. roughly 0.5
- **Each time the biometer was used, any out of a fixed number of 6 cells could be infected**

The Poisson Distribution

Poisson data

- **Poisson data are discrete data**
- **Usually arises in the investigation of rare events**
- **Number of non-compliance-weeks per year at Butte River:**

  0, 0, 1, 1, 0, 3, 0, 0

- **Assumes a non-compliance-week is a rare event**
- **Total number of non-compliance-weeks = 5 out of 416 weeks assuming independence, chance is 5/416 i.e roughly 0.12**
- **Can be used to approximate a Binomial**

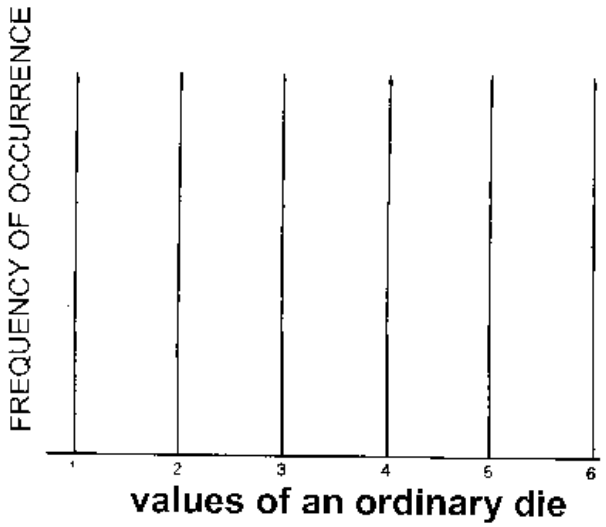
Identification of "outlier" depends on the assumed distribution

- Recall the Melrose Lake lognormal data:
  3.16, 4.15, 3.75, 2.20, 1.53,
  20.76, 8.42, 7.81, 2.72, 4.43
- 20.76 was <u>not</u> an outlier as this was lognormal data. However, suppose it was assumed that it was normal data, what then?
- Statistical outlier tests are easy to apply but all of them assume that the distribution of all the data other than the suspected outlier is known. Is this true in practice?
- Could the Melrose Lake data be roughly normal when the 20.76 value is omitted? Very difficult for small data sets.

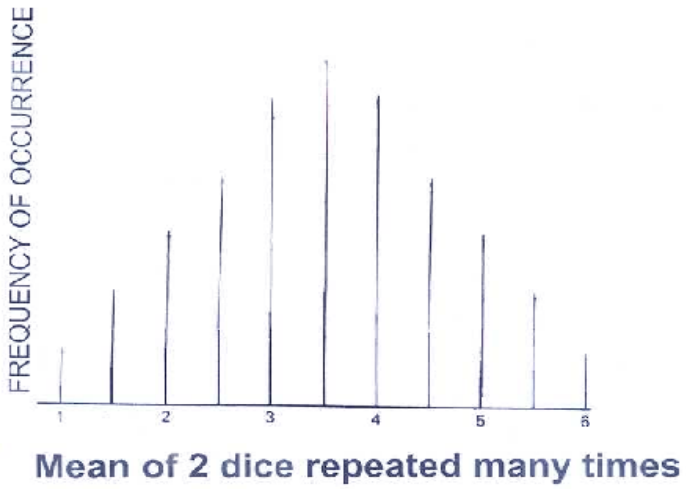
Why is everybody so concerned with the mean of a sample?

- The power of the Central Limit Theorem (CLT)
- In everyday words, the CLT says: As the sample size becomes large, the mean of that random sample will behave as if it came from a normal even though the original data does not.
- In practical terms:
  Take as large a sample as you possibly can
  find the average and hope the number in the
  sample is large enough for the CLT to hold
- Why? Normal data are nice and easy to deal with!

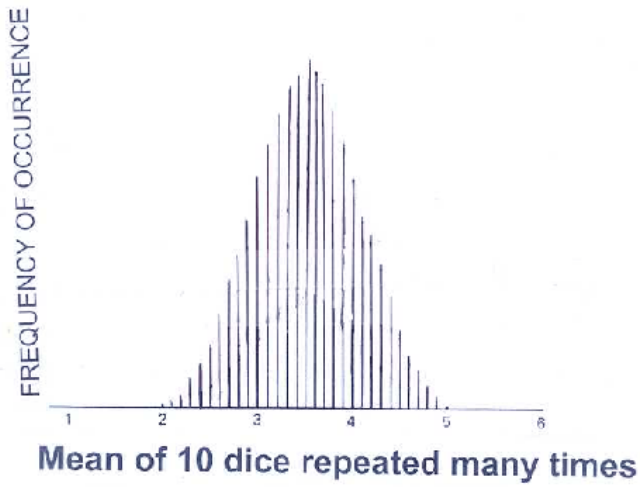
CLT demonstrated when the original data was from a rectangular distribution



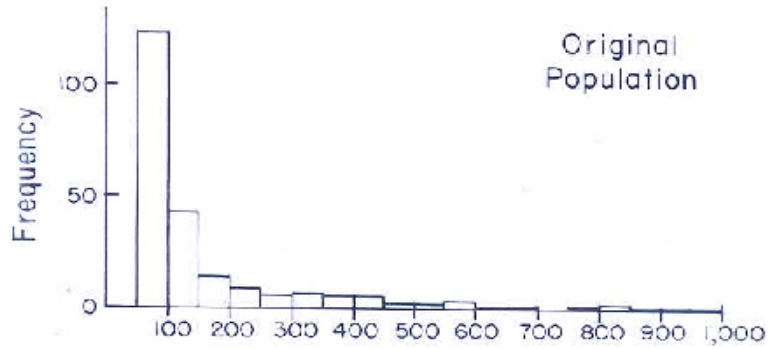
CLT demonstrated when the original data was from a rectangular distribution



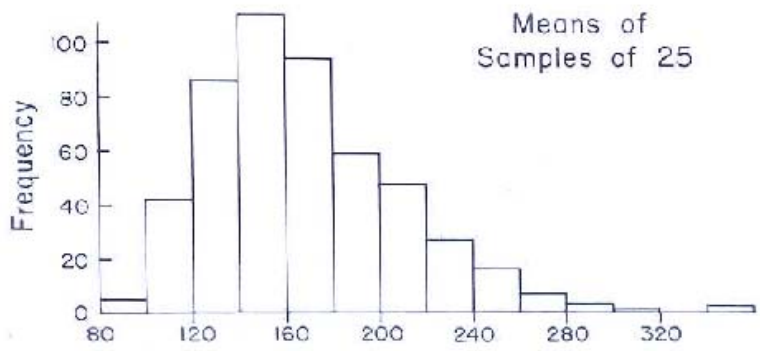
CLT demonstrated when the original data was from a rectangular distribution



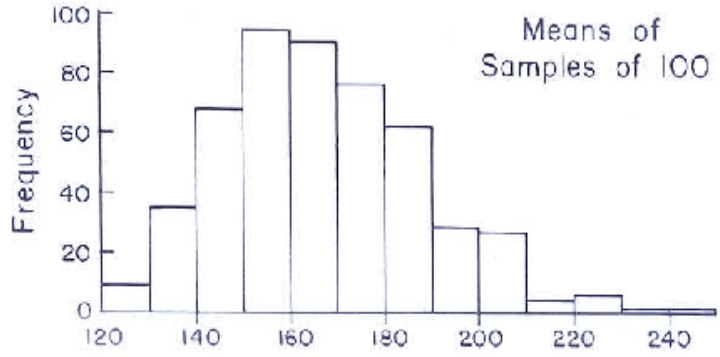
CLT demonstrated when the original distribution is unknown



CLT demonstrated when the original distribution is unknown



CLT demonstrated when the original distribution is unknown



Distributions and statistical tests

Does it really matter if the distribution is unknown?

YES:
- **+ The appropriate statistical test will be more powerful**
- **+ Enables quantifiable estimates of decision errors**
- **+ Better understanding of the problem**

NO:
- **- Need nonparametric statistical tests (not as powerful)**
- **- Need large sample sizes (CLT)**
- **- Not so great understanding of the problem**

Good news

- **Most of the standard statistical tests designed with the assumption of normality are actually quite robust (strong) to departures from normality**
- **Approximate normality or even the assurance of approximate symmetry about the average is sufficient for the test to work quite well and the assumed "level of significance" and associated "statistical power" are denigrated only slightly**
- **If large sample sizes are available the CLT can apply and also nonparametric tests can out perform standard statistical tests**

Seeing Data (Class Exercise)

There are three different scenarios

- Identify the probable distribution of data for each scenario
- Use only common sense, a pencil, and paper
- Complicated calculations are not necessary
- Potential choices for each scenario:

  - Approximate normal distribution
  - Approximate lognormal distribution
  - Possible Binomial distribution
  - Possible Poisson distribution
  - Approximate normal with outlier
  - Approximate lognormal with outlier
  - Possible Poisson with outlier
  - Some unknown distribution

Three Scenarios

For each scenario identify the approximate distribution of the data without recourse to software or extensive calculations. Choose from the following possibilities:

A. Approximate normal distribution
B. Approximate lognormal distribution
C. Possible Binomial distribution
D. Possible Poisson distribution
E. Approximate normal with outlier
F. Approximate lognormal with outlier
G. Possible Poisson with outlier
H. Some unknown distribution

Scenario 1

The Montgomery Burns Memorial Park is to be sited on a former brownfields reclaimed area and the construction crew is within days of starting work. Final soil samples are obtained by randomly sampling the site and measurements of Opprobrium Sulfite (the contaminant of concern) determined:

Opprobrium Sulfite (ppm)

15.0263	**8.55096**	**13.2041**	**9.6007**	**10.6014**
14.1769	**13.0767**	**22.2536**	**10.0311**	**14.3051**
10.1701	**11.1276**	**10.8037**	**15.1695**	**17.5163**
10.1543	**8.6574**	**16.3806**	**15.5138**	**18.3394**
14.4675	**11.7306**	**13.8547**	**17.7268**	**13.4046**
9.6111	**14.7561**	**15.8932**	**13.0063**	**11.4072**
13.1847	**9.5524**	**15.1745**	**12.5424**	**15.5924**
17.2666	**9.8220**	**17.4321**	**12.0704**	**9.5230**
12.9409	**11.5795**	**17.9144**	**18.5729**	**16.1568**
11.7136	**13.6099**	**11.8472**	**13.7129**	**11.2402**

Scenario 2

The Maggie Simpson Pacifier Company has been issued a Special Discharge Monitoring Permit by the State Department of Exigency. Under this permit exceedances are to be expected but not significantly more than 2 per week. The data for a whole year shows the following weekly exceedances:

1, 2, 3, 1, 4, 2, 2, 1, 2, 6, 1, 2, 3,
0, 1, 1, 4, 2, 3, 1, 2, 1, 2, 3, 1, 3,
2, 0, 0, 5, 0, 4, 0, 2, 1, 1, 2, 5, 2,
2, 3, 0, 3, 0, 2, 3, 4, 2, 1, 2, 1, 3

Scenario 3

The Ned Flanders Diddliecious Corporation has a waste water effluent discharge permit from the Springfield Department of Miscellaneous Waste. This permit states the 95th percentile of Shooger (the principal substance in the effluent) should not exceed 40ppb. Is it likely the Corporation has violated its permit? 50 readings:

33.8404	**26.9521**	**25.0957**	**31.7289**	**35.3794**
34.0947	**29.2158**	**31.4727**	**32.5356**	**29.9609**
36.5615	**34.4991**	**30.7497**	**31.0712**	**32.9491**
24.4866	**34.3041**	**30.2466**	**60.5943**	**31.9614**
27.3924	**33.4967**	**29.6122**	**29.8709**	**33.9009**
40.8593	**23.2216**	**29.4604**	**27.2575**	**20.8051**
32.8069	**30.4305**	**29.9197**	**27.5573**	**37.9682**
31.6374	**33.7318**	**32.4547**	**24.2115**	**28.1558**
35.0355	**36.0667**	**26.4973**	**35.2084**	**30.0254**
40.0994	**30.2491**	**28.0129**	**31.9072**	**28.3091**

Describing a Data Set

Thorium-228 Data

- 62 readings taken from a site in New Mexico
- Readings in pico-curies per gram
- Samples collected according to an approved QAPP
- Samples analyzed at an accredited laboratory
- No statisticians available to analyze the results
- You do not have a calculator
- Your management wants meaningful conclusions

Thorium-228 Data

The remainder of this module is an instructor led class discussion

Thorium-228 Data

Location ID	Sample ID	Value	Unit	Depth (in.)	Sample Type
z37p-1861	99-037-7513	0.781	pCi/g	0–3	
z37p-1861	99-037-7515	1.141	pCi/g	6–12	
z37p-1861	99-037-7515	1.630	pCi/g	6–12	lab replicate
z37p-1863	99-037-7514	1.031	pCi/g	0–3	
z37p-1863	99-037-7514	1.544	pCi/g	3–6	
z37p-1863	99-037-7514	1.714	pCi/g	6–12	
z37p-1864	99-037-7517	2.310	pCi/g	0–3	
z37p-1864	99-037-7517	1.684	pCi/g	3–6	
z37p-1864	99-037-7517	1.663	pCi/g	6–12	
z37p-1865	99-037-7519	4.453	pCi/g	0–3	
z37p-1865	99-037-7519	2.023	pCi/g	3–6	
z37p-1865	99-037-7519	0.899	pCi/g	6–12	
z37p-1867	99-037-7516	1.443	pCi/g	0–3	
z37p-1867	99-037-7518	1.234	pCi/g	6–12	
z37p-1867	99-037-7518a	1.179	pCi/g	6–12	field split
z37p-1868	99-037-7520	0.953	pCi/g	0–3	
z37p-1868	99-037-7520	2.405	pCi/g	3–6	
z37p-1868	99-037-7520	0.614	pCi/g	6–12	
z37p-1869	99-037-7521	0.775	pCi/g	0–3	
z37p-1869	99-037-7521	1.421	pCi/g	3–6	
z37p-1869	99-037-7521	2.112	pCi/g	6–12	
z37p-1871	99-037-7510	1.646	pCi/g	0–3	
z37p-1871	99-037-7510	1.359	pCi/g	0–3	lab replicate
z37p-1871	99-037-7511	0.581	pCi/g	3–6	
z37p-1871	99-037-7511a	1.384	pCi/g	3–6	field split
z37p-1871	99-037-7512	1.785	pCi/g	6–12	
z37p-1872	99-037-7522	1.173	pCi/g	0–3	
z37p-1872	99-037-7522	1.172	pCi/g	3–6	
z37p-1872	99-037-7522	1.404	pCi/g	6–12	
z37p-1873	99-037-7523	1.990	pCi/g	0–3	
z37p-1873	99-037-7523	1.761	pCi/g	3–6	
z37p-1873	99-037-7523	1.265	pCi/g	6–12	
z37p-1874	99-037-7524	0.892	pCi/g	0–3	

Location ID	Sample ID	Value	Unit	Depth (in.)	Sample Type
z37p-1874	99-037-7524	0.811	pCi/g	3–6	
z37p-1874	99-037-7524	1.527	pCi/g	6–12	
z37p-1876	99-037-7525	1.176	pCi/g	0–3	
z37p-1876	99-037-7525	5.944	pCi/g	3–6	
z37p-1876	99-037-7525	1.586	pCi/g	6–12	
z37p-1879	99-037-7527	1.108	pCi/g	0–3	
z37p-1879	99-037-7527	1.056	pCi/g	3–6	
z37p-1879	99-037-7527	1.521	pCi/g	6–12	
z37p-1882	99-037-7529	1.157	pCi/g	0–3	
z37p-1882	99-037-7529	5.268	pCi/g	3–6	
z37p-1882	99-037-7529	1.537	pCi/g	6–12	
z37p-2568	99-037-7275	0.987	pCi/g	0–3	
z37p-2568	99-037-7275a	1.034	pCi/g	0–3	field split
z37p-2568	99-037-7276	1.207	pCi/g	3–6	
z37p-2569	99-037-7279	1.127	pCi/g	3–6	
z37p-2569	99-037-7279	1.078	pCi/g	3–6	lab replicate
z37p-2569	99-037-7280	1.946	pCi/g	6–12	
z37p-2570	99-037-7277	1.186	pCi/g	0–3	
z37p-2570	99-037-7277	1.307	pCi/g	3–6	
z37p-2570	99-037-7277	1.953	pCi/g	6–12	
z37p-2571	99-037-7278	2.116	pCi/g	0–3	
z37p-2571	99-037-7278	1.623	pCi/g	3–6	
z37p-2571	99-037-7278	2.065	pCi/g	6–12	
z37p-2574	99-037-7281	0.991	pCi/g	0–3	
z37p-2574	99-037-7281	1.289	pCi/g	3–6	
z37p-2574	99-037-7281	1.510	pCi/g	6–12	
z37p-2577	99-037-7282	0.831	pCi/g	0–3	
z37p-2577	99-037-7282	2.419	pCi/g	3–6	
z37p-2577	99-037-7282	0.516	pCi/g	6–12	

Thorium-228 0-3” Level

Location ID	Sample ID	Value	Unit	Depth (in.)	Sample Type
z37p-1861	99-037-7513	0.781	pCi/g	0–3	
z37p-1863	99-037-7514	1.031	pCi/g	0–3	
z37p-1864	99-037-7517	2.310	pCi/g	0–3	
z37p-1865	99-037-7519	4.453	pCi/g	0–3	
z37p-1867	99-037-7516	1.443	pCi/g	0–3	
z37p-1868	99-037-7520	0.953	pCi/g	0–3	
z37p-1869	99-037-7521	0.775	pCi/g	0–3	
z37p-1871	99-037-7510	1.646	pCi/g	0–3	
z37p-1871	99-037-7510	1.359	pCi/g	0–3	lab replicate
z37p-1872	99-037-7522	1.173	pCi/g	0–3	
z37p-1873	99-037-7523	1.990	pCi/g	0–3	
z37p-1874	99-037-7524	0.892	pCi/g	0–3	
z37p-1876	99-037-7525	1.176	pCi/g	0–3	
z37p-1879	99-037-7527	1.108	pCi/g	0–3	
z37p-1882	99-037-7529	1.157	pCi/g	0–3	
z37p-2568	99-037-7275	0.987	pCi/g	0–3	
z37p-2568	99-037-7275a	1.034	pCi/g	0–3	field split
z37p-2570	99-037-7277	1.186	pCi/g	0–3	
z37p-2571	99-037-7278	2.116	pCi/g	0–3	
z37p-2574	99-037-7281	0.991	pCi/g	0–3	
z37p-2577	99-037-7282	0.831	pCi/g	0–3	

Thorium-228 3-6” Level

Location ID	Sample ID	Value	Unit	Depth (in.)	Sample Type
z37p-1863	99-037-7514	1.544	pCi/g	3–6	
z37p-1864	99-037-7517	1.684	pCi/g	3–6	
z37p-1865	99-037-7519	2.023	pCi/g	3–6	
z37p-1868	99-037-7520	2.405	pCi/g	3–6	
z37p-1869	99-037-7521	1.421	pCi/g	3–6	
z37p-1871	99-037-7511	0.581	pCi/g	3–6	
z37p-1871	99-037-7511a	1.384	pCi/g	3–6	field split
z37p-1872	99-037-7522	1.172	pCi/g	3–6	
z37p-1873	99-037-7523	1.761	pCi/g	3–6	
z37p-1874	99-037-7524	0.811	pCi/g	3–6	
z37p-1876	99-037-7525	5.944	pCi/g	3–6	
z37p-1879	99-037-7527	1.056	pCi/g	3–6	
z37p-1882	99-037-7529	5.268	pCi/g	3–6	
z37p-2568	99-037-7276	1.207	pCi/g	3–6	
z37p-2569	99-037-7279	1.127	pCi/g	3–6	
z37p-2569	99-037-7279	1.078	pCi/g	3–6	lab replicate
z37p-2570	99-037-7277	1.307	pCi/g	3–6	
z37p-2571	99-037-7278	1.623	pCi/g	3–6	
z37p-2574	99-037-7281	1.289	pCi/g	3–6	
z37p-2577	99-037-7282	2.419	pCi/g	3–6	

Thorium-228 6-12” Level

Location ID	Sample ID	Value	Unit	Depth (in.)	Sample Type
z37p-1861	99-037-7515	1.141	pCi/g	6–12	
z37p-1861	99-037-7515	1.630	pCi/g	6–12	lab replicate
z37p-1863	99-037-7514	1.714	pCi/g	6–12	
z37p-1864	99-037-7517	1.663	pCi/g	6–12	
z37p-1865	99-037-7519	0.899	pCi/g	6–12	
z37p-1867	99-037-7518	1.234	pCi/g	6–12	
z37p-1867	99-037-7518a	1.179	pCi/g	6–12	field split
z37p-1868	99-037-7520	0.614	pCi/g	6–12	
z37p-1869	99-037-7521	2.112	pCi/g	6–12	
z37p-1871	99-037-7512	1.785	pCi/g	6–12	
z37p-1872	99-037-7522	1.404	pCi/g	6–12	
z37p-1873	99-037-7523	1.265	pCi/g	6–12	
z37p-1874	99-037-7524	1.527	pCi/g	6–12	
z37p-1876	99-037-7525	1.586	pCi/g	6–12	
z37p-1879	99-037-7527	1.521	pCi/g	6–12	
z37p-1882	99-037-7529	1.537	pCi/g	6–12	
z37p-2569	99-037-7280	1.946	pCi/g	6–12	
z37p-2570	99-037-7277	1.953	pCi/g	6–12	
z37p-2571	99-037-7278	2.065	pCi/g	6–12	
z37p-2574	99-037-7281	1.510	pCi/g	6–12	
z37p-2577	99-037-7282	0.516	pCi/g	6–12	

Conclusions

Basic References

- **Data Quality Assessment: Reviewer's Guide (QA/G-9R)**
  www.epa.gov/quality/qa_docs.html
- **Data Quality Assessment: Statistical Tools for Practitioners (QA/G-9S)**
  www.epa.gov/quality/qa_docs.html
- ***Statistical Methods for Environmental Pollution Monitoring*** **by Richard O. Gilbert, John Wiley & Sons**
- ***Statistical Tools for Environmental Quality Measurement*** **by Michael E. Ginevan & Douglas E. Splitstone, CRC Press**

Advanced References

- *Environmental Statistics with S-Plus* by Steven P. Millard & Nagaraj K. Neerchal, CRC Press
- *Statistics for Environmental Science and Management* by Bryan F. J. Manly, CRC Press
- *Statistical Methods for Detection and Quantification of Environmental Contamination* by Robert D. Gibbons & David E. Coleman, John Wiley & Sons
- *Nondetects and Data Analysis* by Dennis R. Helsel, John Wiley & Sons