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Attainment Training

November 27, 2012

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LSRPA Future Events

- Dec. 5 - Business Practice Seminar
  LSRP Liability, Insurance & Contract Language
  Holiday Inn, East Windsor, Exit 8 of NJTPK
- Jan. 3 - LSRPA Exam Review Course
- Jan. 10 - LSRPA Annual Meeting
- Jan. 17 - 4th LSRP Exam
- Planning Technical Courses for LSRP credit in 2013

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Technical Guidance for the Attainment of Remediation Standards and Site-Specific Criteria

November 27, 2012

The Committee

- Nick DeRose – Langan
- Barry Frasco - NJDEP
- David Haymes - NJDEP
- Kathy Katz - NJDEP
- Jim Kearns - GES
- Joe Nowak - NJDEP
- Steve Posten - AMEC
- Swati Toppin - NJDEP
- Ted Toskos - AMEC

Presentation Outline

- Overview
- General Concepts
- Environmental Media
  - Soil
    - Applicable standards
    - Available compliance options
  - Ground Water
    - Applicable standards
    - Available compliance options

Presentation Outline

- Environmental Media
  - Surface Water
    - Applicable standards
    - Available compliance option
- Compliance Options
  - Single point
    - Description
  - Arithmetic mean
    - Description
    - Example

Presentation Outline

- Compliance Options
  - 95% Upper Confidence Level
    - Description
    - Example
  - Spatially Weighted Average
    - Description
    - Example
  - 75% / 10X procedure
    - Description
    - Example

Overview

- Purpose of guidance document
  - To assist investigator in identifying and applying applicable remediation standards*
    - At each area of concern
    - For all environmental media
    - For each phase of remediation

* Includes promulgated remediation standards, site-specific or interim-specific standards, criteria, and generic screening levels

Overview

- Purpose of guidance document
  - To ensure protection of public health and safety and the environment by determining compliance with applicable remediation standards, using available compliance options

This Guidance Does Not Address

- Technical aspects of sampling
  - Sampling methods/devices
  - Sample locations
  - Number of samples*

* Except for minimum number of samples required for compliance averaging using Arithmetic Mean, 95% UCL and 75%/10X

This Guidance Does Not Address

- Petroleum Hydrocarbons
  - "Protocol for Addressing Extractable Petroleum Hydrocarbons"
- Ecological Impacts
  - "Ecological Evaluation Technical Guidance"
- Vapor Intrusion
  - "Vapor Intrusion Technical Guidance Document" *

* Compliance guidance document does discuss averaging ground water screening levels

General Concepts
Applicable Remediation Standard

- For the purposes of this guidance document, the phrase "applicable remediation standard" is to be applied to
  - A promulgated remediation standard
  - An interim remediation standard
  - An alternative remediation standard
  - A site-specific criterion
  - A screening level

General Concepts
Applicable Remediation Standard

- The applicable remediation standard for a given contaminant depends upon
  - The intended future use of the site
    - Residential
    - Non-residential
    - Other

General Concepts
Applicable Remediation Standard

- The applicable remediation standard for a given contaminant depends upon
  - Exposure pathways that are being remediated
    - Soil - direct contact
    - Soil - impact to ground water
    - Ground water
    - Surface water

General Concepts
Compliance Options

- In most cases, several options to achieve compliance
  - Single point
  - Simple statistical tests/approaches
    - Arithmetic mean
    - 75%/10X
  - Robust numerical and spatial statistical methods
    - 95% UCL (upper confidence level of the mean)
    - Spatially weighted average

General Concepts
Compliance Options

- Options to achieve compliance dependent on phase of remediation
  - Site Investigation: single-point compliance only
  - Remedial Investigation: multiple compliance options
  - Remedial Action: multiple compliance options

Questions?

Soil: Applicable Standards Direct Contact Pathway

- Ingestion/Dermal & Inhalation
  - Promulgated Soil Remediation Standards
    - N.J.A.C. 7:26D Appendix 1: Tables 1A/1B
      - Residential
      - Non-Residential
  - Alternative Remediation Standards (ARS)
    - N.J.A.C. 7:26D-7 & Appendix 4 (Ingestion/Dermal)
    - N.J.A.C. 7:26D-7 & Appendix 5 (Inhalation)

Soil: Applicable Standards Direct Contact Pathway

- Alternative Remediation Standards Conditions
  - Allowable conditions for use of an ARS
    - New chemical toxicity data
    - New risk assessment methodology or models
    - Alternative land use planned for the site
    - Site-specific conditions that support the modification of input parameters for models

Soil: Applicable Standards Direct Contact Pathway

- Alternative Remediation Standards Conditions
  - Requires Department approval prior to use (some exceptions; see N.J.A.C. 7:26D-7.5 and below)
  - Modifying certain site-specific input parameters for the inhalation pathway does not require prior DEP approval:
    - Depth range of contamination
    - Organic carbon concentration
    - Vegetative cover
    - The average number of vehicle trips

Soil: Applicable Standards Direct Contact Pathway

- N.J.A.C. 7:26D-5: Interim Soil Remediation Standards
  - Constituent not listed in N.J.A.C. 7:26D Appendix 1, Tables 1A or 1B
  - Developed using N.J.A.C. 7:26D Appendix 2 (ingestion/dermal) or 3 (inhalation)

Soil: Applicable Standards Impact to Ground Water Pathway

- Remediation standards developed on a site specific basis (N.J.A.C. 7:26D-1.1(b))
  - Dependent on ground water classification (I, II, III)
  - Initial starting point
    - Screening level developed using the soil-water partition equation with default input parameters
    - Table 1: "Development of Site-Specific IGW Soil Remediation Standards Using the Soil-Water Partition Equation"

Soil: Applicable Standards Impact to Ground Water Pathway

- Various guidance documents are available
  - Synthetic precipitation leachate procedure (SPLP)
  - Soil-water partition equation
  - Dilution attenuation factor (DAF)
  - SESOIL (vadose zone modeling)
  - SESOIL and AT123D (vadose/saturated zone modeling)

Soil: Applicable Standards Impact to Ground Water Pathway

- Department approval required for more complex applications:
  - SESOIL
  - SESOIL/AT123D
- If multiple methods applied to derive IGW standard, highest calculated value used as standard

Soil: Compliance

- Overall purpose: to determine if remediation is needed or not needed
- Options to achieve compliance dependent on phase of remediation:
  - Site Investigation
  - Remedial Investigation
  - Remedial Action

Soil: Compliance

- Comparison of contaminant concentrations to most restrictive (lowest) applicable soil remediation standard
  - Usually the residential direct contact or IGW
  - 5 contaminants for which the non-residential inhalation pathway standard is the most restrictive (acenaphthylene, benzo(ghi)perylene, cobalt, manganese and phenanthrene)

Soil: Compliance

- Site Investigation Phase
  - Single-point compliance **only**
  - If the applicable soil remediation standard is exceeded, proceed to RI or RA
  - If the applicable soil remediation standard is not exceeded, no remediation required

Soil: Compliance

- Remedial Investigation
  - Before any compliance options can be used:
    - Need to complete horizontal and vertical delineation first to the applicable soil remediation standard
  - Must use single-point compliance for determining whether delineation is complete
  - If off-site migration determined, delineation to most restrictive direct contact standard and IGW standard

Soil: Compliance

- For Direct Contact Pathway, delineation end points based on different land uses:
  - Unrestricted Use – delineate to the most restrictive direct contact standard
  - Limited Restricted Use – delineate to the non-residential standard. Delineate offsite to the most restrictive direct contact standard.
  - Restricted Use
    - Residential sites - delineate to the most restrictive direct contact standard at the boundary of the restricted area
    - Non-res sites – delineate to the non-residential std at the boundary of the restricted area and the most restrictive direct contact standard at the property boundary

Soil: Compliance

- Remedial Investigation
  - Determine need for remedial action (all pathways) by using these compliance options:
    - Arithmetic mean
    - 95% UCL (upper confidence limit of mean)
    - Spatially weighted average

Soil: Compliance

- Remedial Investigation
  - If applicable remediation standard is exceeded, conduct remedial action
  - If applicable remediation standard is not exceeded, remediation complete

Soil: Compliance

- Remedial Action verification
  - For all pathways determine whether:
    - Compliance with applicable soil remediation standard has been achieved

      or

    - Whether additional remedial action required

Soil: Compliance

- Remedial Action verification
  - Compliance achieved using 1 of the 5 options:
    - Single point compliance

      OR

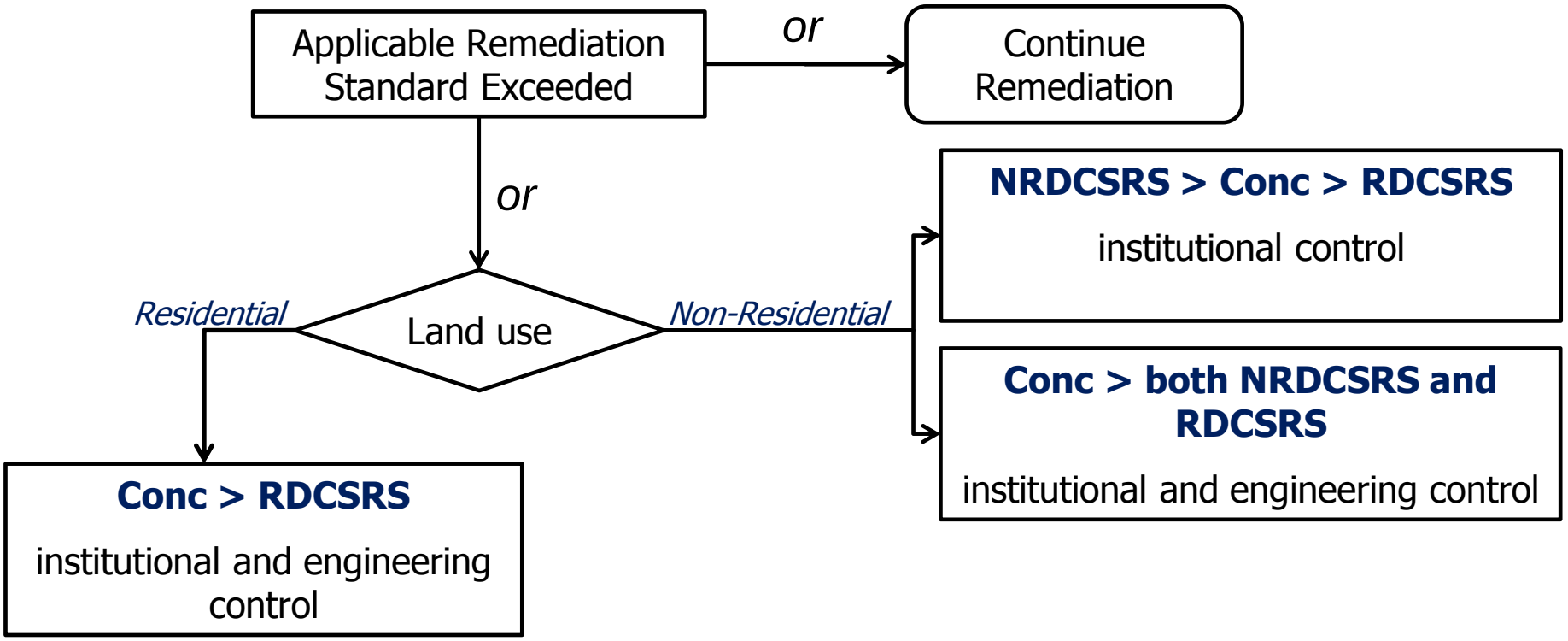
    - Compliance options:
      - Arithmetic mean
      - 95% UCL (upper confidence limit of mean)
      - Spatially weighted average
      - 75%/10X

Soil: Compliance

- Remedial Action verification
  - If applicable remediation standard is exceeded:
    - For the direct contact pathway - either continue with remedial action or implement an engineering and/or institutional control
    - For the IGW pathway - continue with remedial action
  - If applicable remediation standard is not exceeded, remediation complete

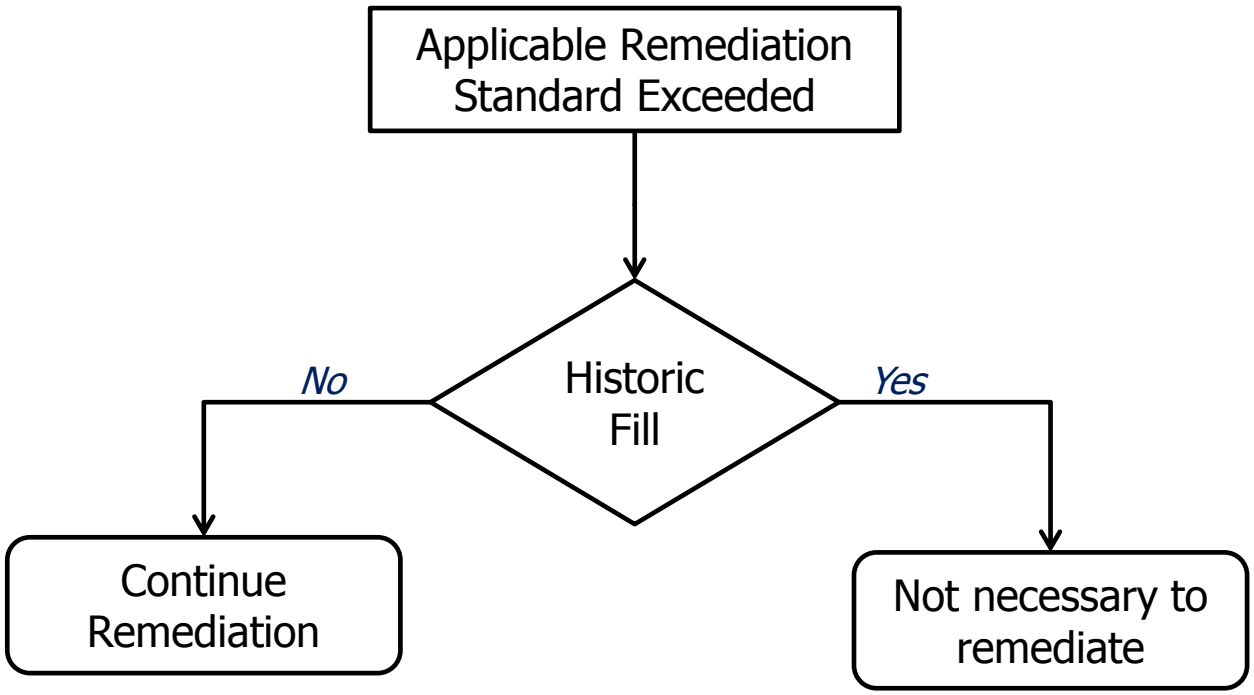
Soil: Compliance

Remedial Action verification - direct contact pathway



Soil: Compliance

Remedial Action verification - IGW pathway



Engineering controls (cap) generally may not be used in lieu of remediation

Soil: Compliance

- Additional compliance options to demonstrate no further remediation required for IGW pathway:
  - "Guidance for the Evaluation of Immobile Chemicals for the Impact to Ground Water Pathway"
  - "Site Soil and Ground Water Analytical Data Evaluation - Metals and SVOCs"
  - "Site Soil and Ground Water Analytical Data Evaluation - VOC including MTBE and TBA derived from discharges of Petroleum Mixtures"

Questions?

Ground Water: Applicable Standards

- Minimum Ground Water Remediation Standards
  - N.J.A.C. 7:26D-2 = 7:9C-1.7 GWQS
    - Class I (exceptional ecological areas; Pinelands)
    - Class II (potable)
    - Class III (aquitards; salt water intrusion)
  - Interim GWQS (N.J.A.C. 7:9C-1.7(c)2)
  - Alternative Remediation Standards not allowed (N.J.A.C. 7:26D-2.2(b))

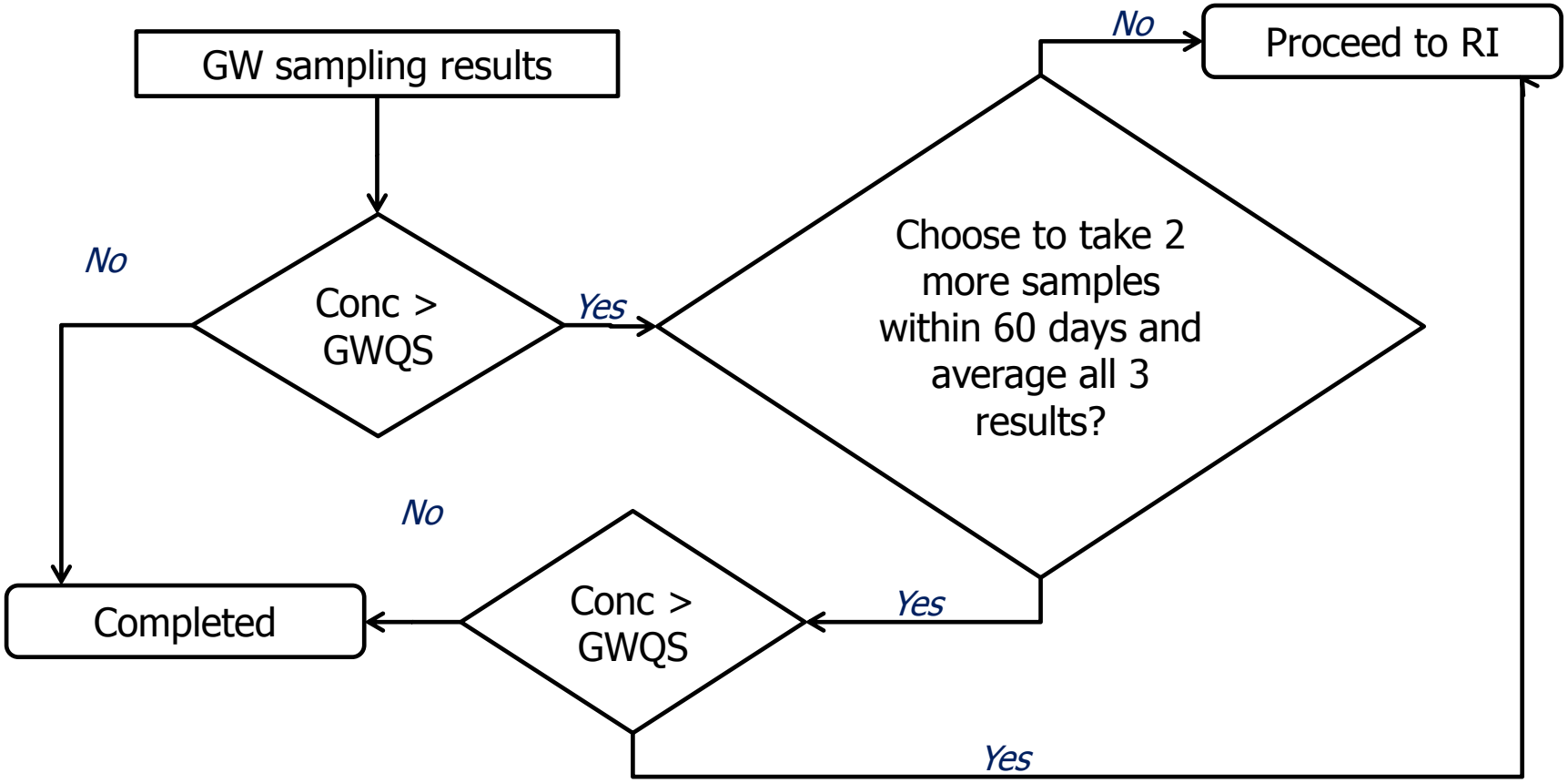
Ground Water: Compliance

- Single point compliance for all stages of remedial investigation (SI/RI/RA)

- Allow for temporal averaging

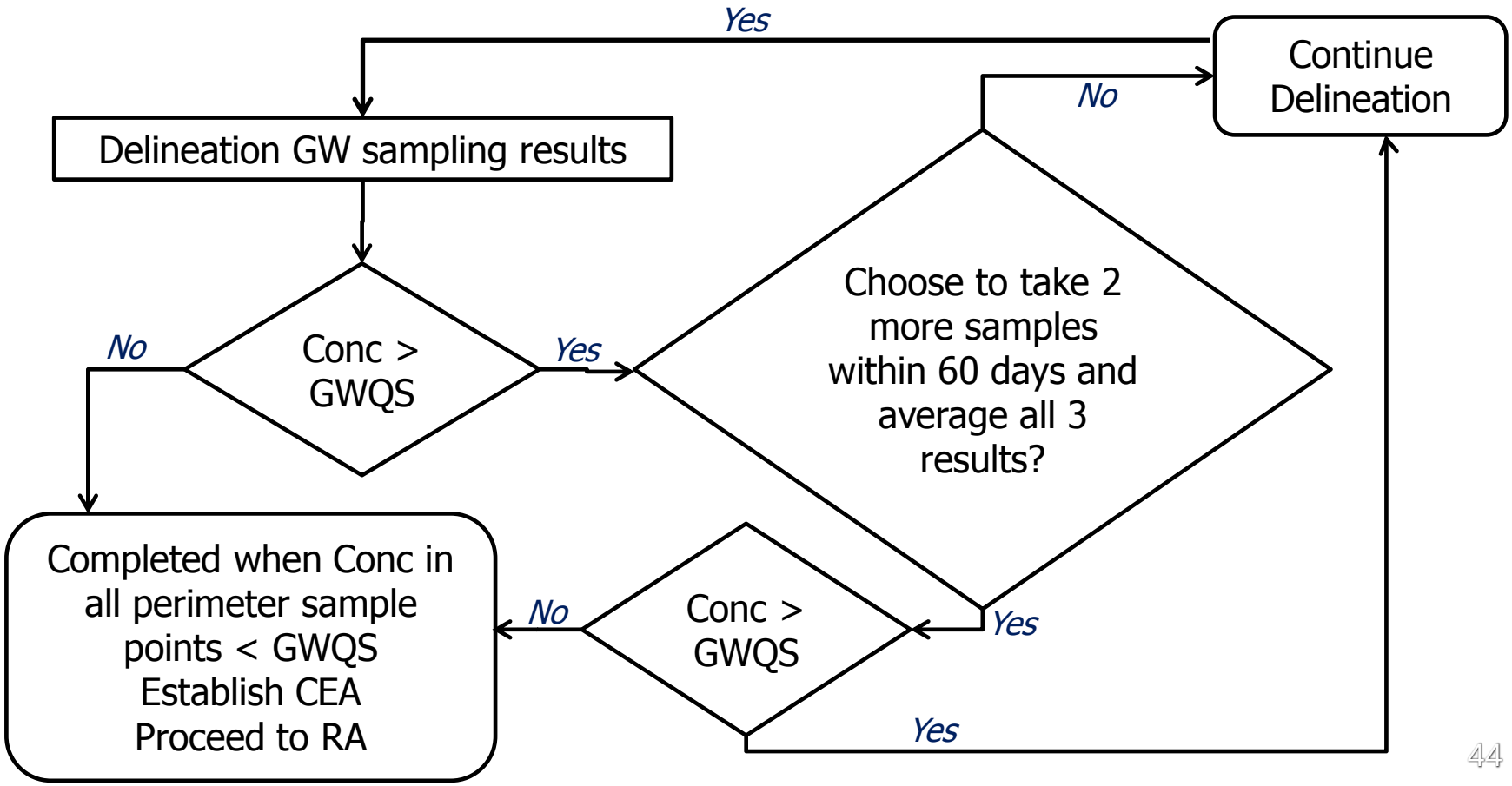
Ground Water: Compliance

- **Site Investigation**



Ground Water: Compliance

- **Remedial Investigation**
  - Horizontal and vertical delineation of all aquifers impacted by contamination originating from site/AOC



Ground Water: Compliance

- Remedial Action/Remedial Action Permit:
  - Active remediation
    - System operating as designed for minimum of one year
      - NJDEP issues GW Remedial Action Permit
      - LSRP issues RAO

Ground Water: Compliance

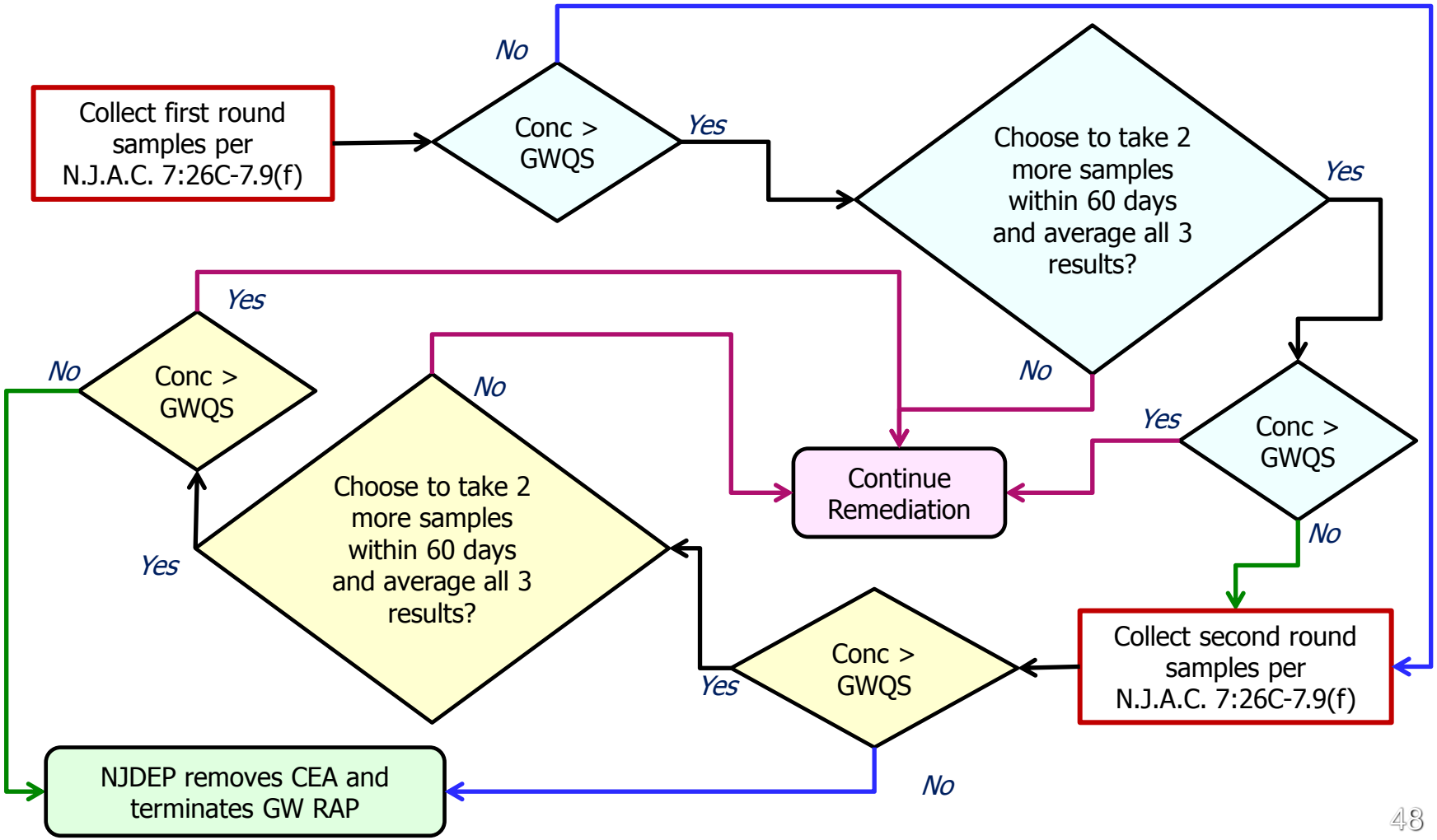
- Remedial Action/Remedial Action Permit
  - Passive remediation (MNA)
    - Either meets requirements in
      - MNA technical guidance (Section 7); or
      - "Issuance of Response Action Outcomes" guidance (Attachment 2)
    - NJDEP issues GW Remedial Action Permit
    - LSRP issues RAO

Ground Water: Compliance

- Remedial Action/Remedial Action Permit
  - Permit termination/CEA removal
    - Two (2) consecutive confirmatory sampling events from all monitoring wells < GWQS pursuant to N.J.A.C. 7:26C-7.9(f)
      - If concentration exceeds GWQS in any sample collected pursuant to N.J.A.C. 7:26C-7.9(f), ground water may be re-sampled to confirm presence of contamination
        - Minimum (2) confirmation samples collected within 60 days of initial sample and results averaged with original result
    - NJDEP removes CEA and terminates GW RAP

Ground Water: Compliance

- Remedial Action/Remedial Action Permit



Ground Water: Compliance for Vapor Intrusion

- Also necessary to determine whether there is exceedance of Vapor Intrusion Screening Levels

- For both SI and RI
  - Compliance average ground water results to see whether below VI Ground Water Screening Level

Questions?

Surface Water: Applicable Standards

- Human-health based minimum remediation standards
  - N.J.A.C. 7:26D-3 = N.J.A.C. 7:9B-1.14 SWQS
    - Surface water sample; or
    - Ground water sampler collected immediately adjacent to surface water (where ground water has been shown to discharge into surface water)
  - Alternative remediation standards not allowed (N.J.A.C. 7:26D-3.2(b))
- Ecological surface water screening levels
  - "Ecological Evaluation Technical Guidance"

Surface Water: Compliance

- Site Investigation
  - Single point
  - If concentration exceeds SWQS, proceed to Remedial Investigation
  - Also necessary to determine whether there is exceedance of ecological surface water screening levels

Surface Water: Compliance

- Remedial Investigation
  - Single point; or
  - Alternative site-specific method using applicable technical guidance as specified in SRRA
  - If concentration exceeds SWQS based on single point or alternative method, proceed to Remedial Action
  - Also necessary to determine whether there is exceedance of ecological surface water screening levels

Surface Water: Compliance

- Remedial Action
  - Site closure
    - Single point compliance, or
    - Alternative site-specific method using applicable technical guidance as specified in SRRA
  - If concentration < SWQS based on single point or alternative method, remediation complete
  - Also necessary to determine whether there is exceedance of ecological surface water screening levels

Questions?

Compliance Averaging

- Delineation must be completed
- Need to ensure compliance with other pathways
- Direct contact = Offsite is its own thing

Compliance Averaging

- The key (and most difficult) step is determining which data are to be included in the compliance averaging calculation(s)
- Grouping the data
  - By contaminant
  - Functional Areas
    - Residential
      - Ingestion/Dermal - 0.25 acres
      - Inhalation - 0.5
    - Non-residential (2.0 acres)
  - Vertical Zones
    - Surface (0 to 2 feet)
    - Subsurface (greater than 2 feet)

Compliance Averaging – arithmetic mean

- Only used when have nine (9) or fewer samples or two (2) or fewer distinct values

- The arithmetic mean or average is the sum of all the sample values divided by the number of sample values

Compliance averaging at the 95 percent UCL of the mean

- Remedial investigation or remedial action stage
- Applicable to all soil pathways
- Entails definition of "functional area"
  - Functional area = area within which compliance averaging performed
  - Size of functional area varies by pathway and end use (0.25 acre to 2 acres)
  - Vertical zones must also be evaluated; vary by pathway

Compliance Averaging

- From the modeling perspective, a square functional area is ideal
- To facilitate the process, rectangular functional areas, generally up to a 4:1 length/width ratio, are allowable
- To facilitate the process, the last functional area can be increased up to 50% of its standard area

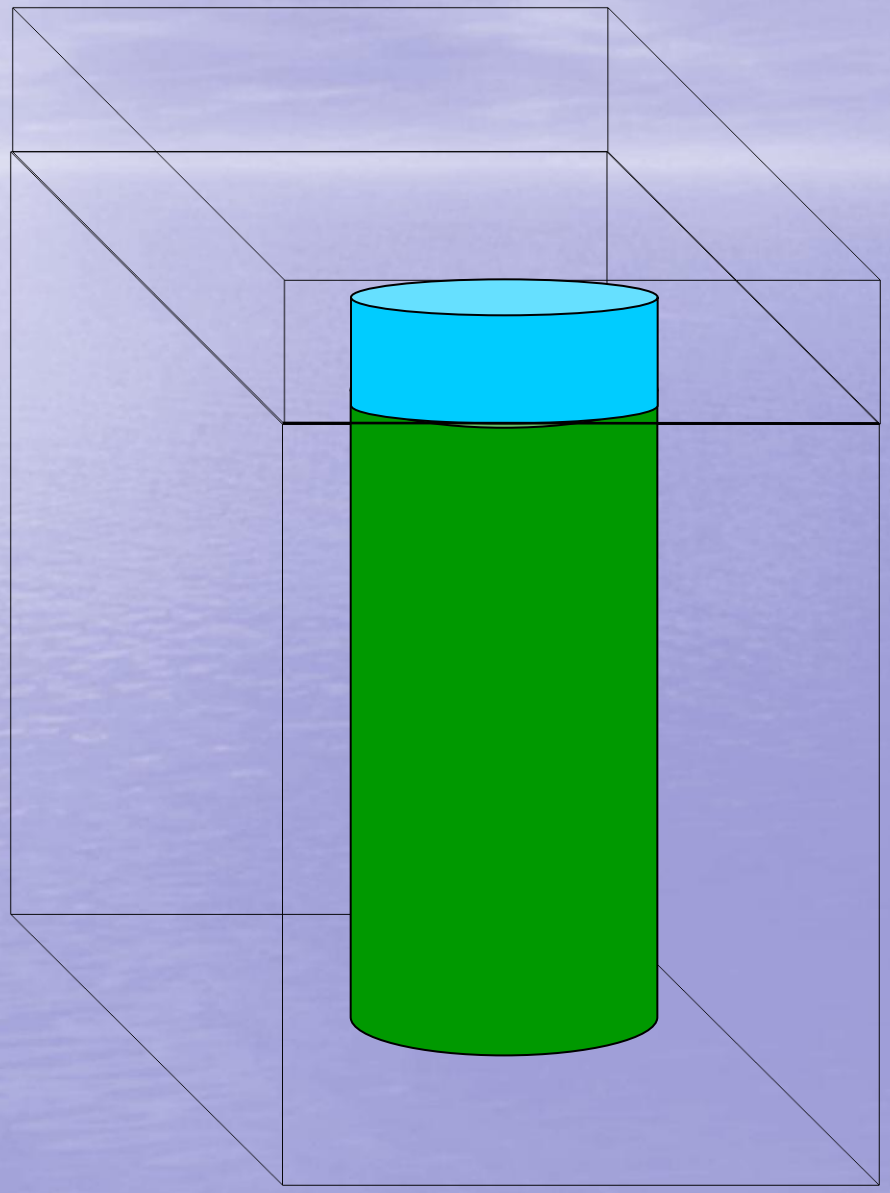
Compliance averaging at the 95 percent UCL of the mean

- EPA ProUCL statistical package recommended
- Minimum 10 samples required
- No "excessive sampling" of uncontaminated areas
- No remediation required (RI stage) or remediation complete (RA stage) if 95% UCL < applicable remediation standard

Compliance averaging at the 95 percent UCL of the mean

- Distinguish vertical zones based on pathway
- Distinguish functional area based on pathway and end use
- Worst-case first

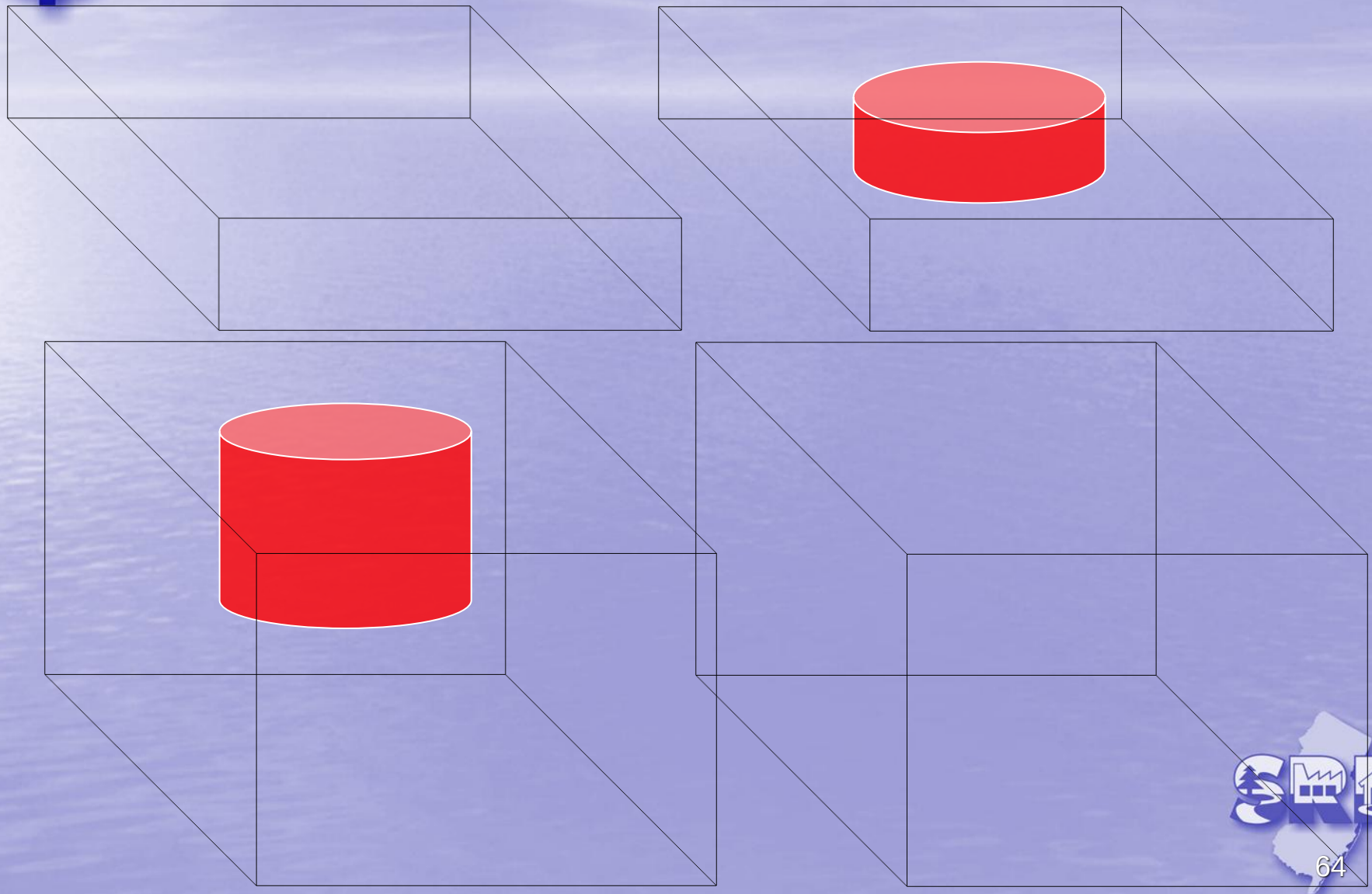
Vertical Zones Illustration



Surface = 0 to 2 feet bgs

Subsurface = >2 feet bgs

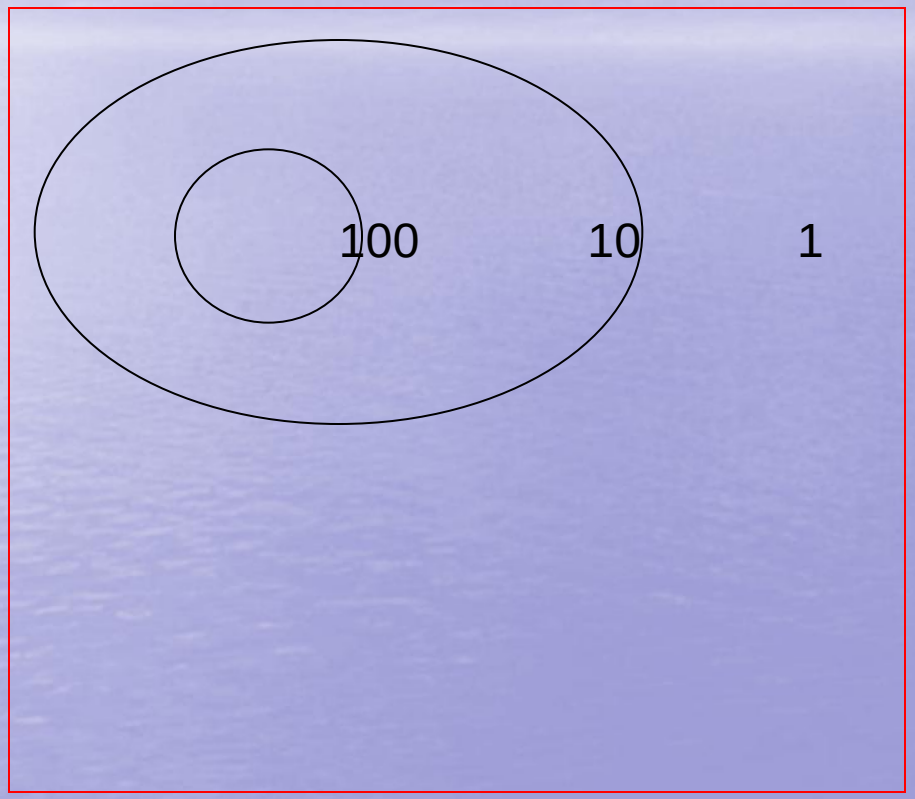
Multiple Functional Areas Required



Compliance Averaging

- Worst case first, continue until standard is achieved
- Areas that do not exceed relevant standard do not have to be evaluated
- Off-site areas handled separately
- When the area of concern is smaller than default functional area, still apply relevant standard

Example – Functional Areas

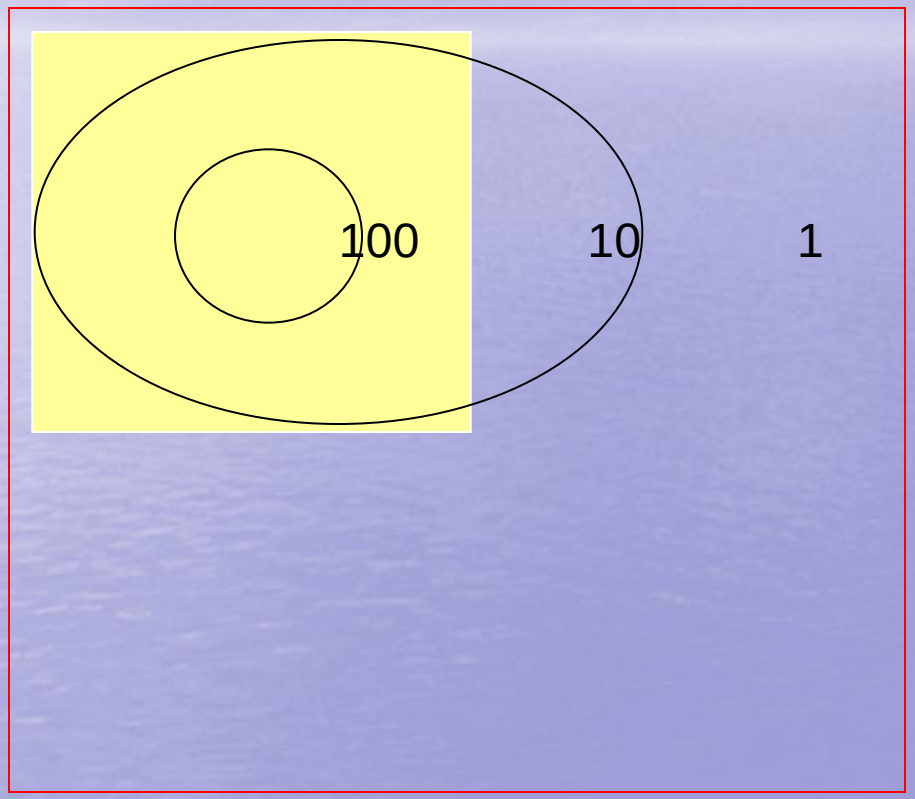


Property boundary

Standard = 10 mg/kg

Surface contamination only

Example – Worst Case First



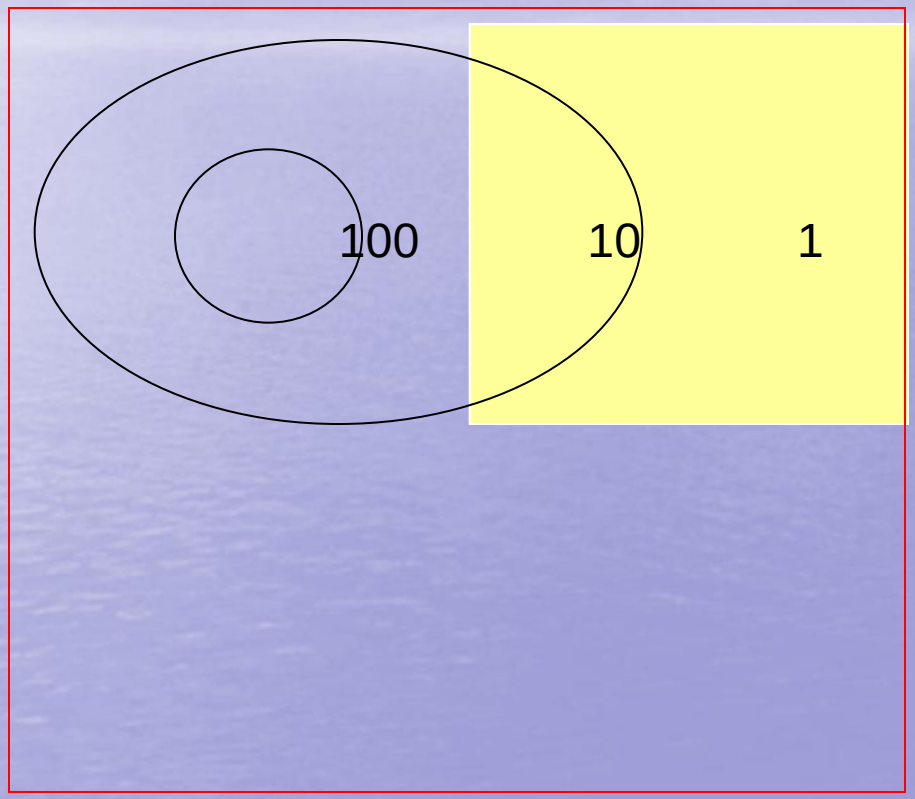
Property boundary

Standard = 10 mg/kg

Surface contamination only

= functional area

Example – Worst Case Fails, Evaluate Remainder



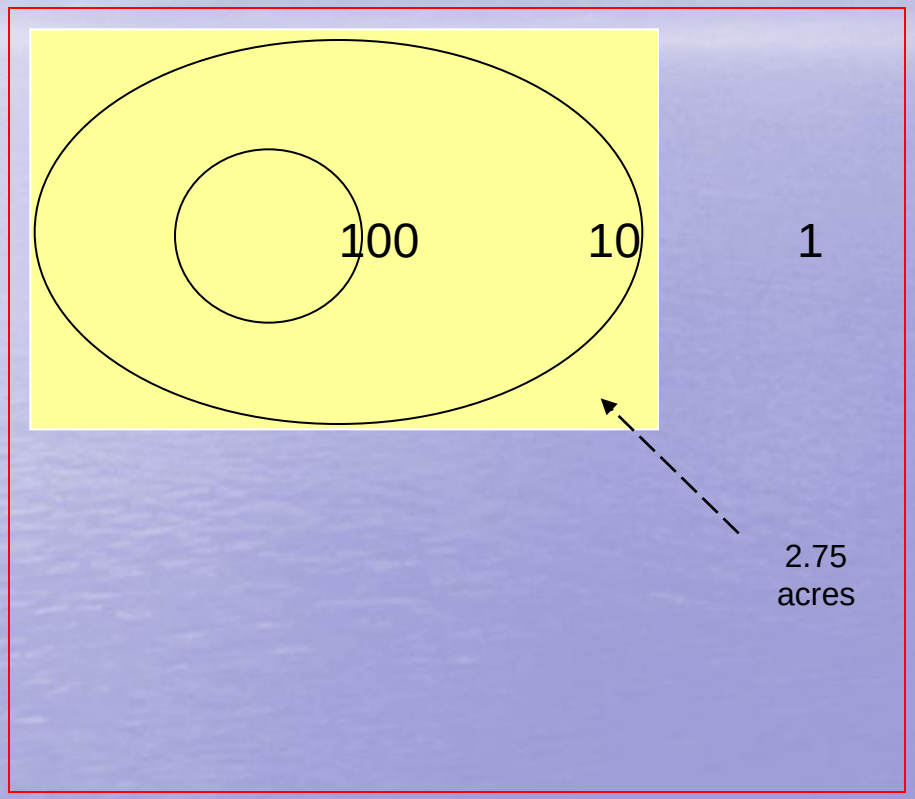
Property boundary

Standard = 10 mg/kg

Surface contamination only

= functional area

Example - Use Of Larger Functional Area



Property boundary

Standard = 10 mg/kg

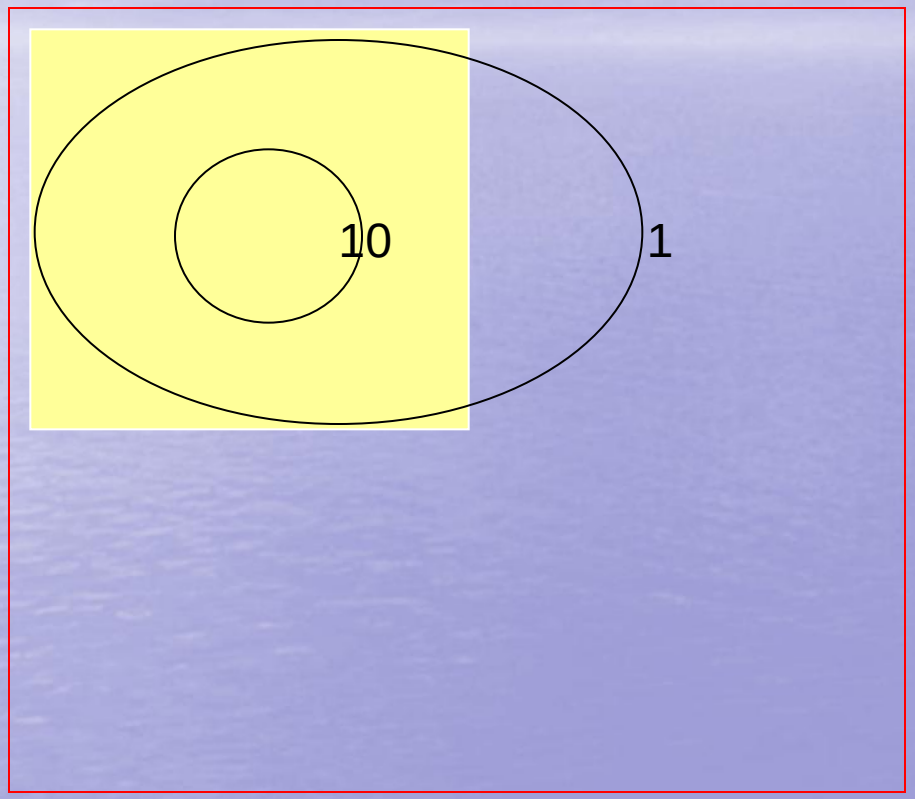
Surface contamination only

= functional area

Site size = 8 acres

Non-residential site

Example - Area of Concern Less Than Default Functional Area



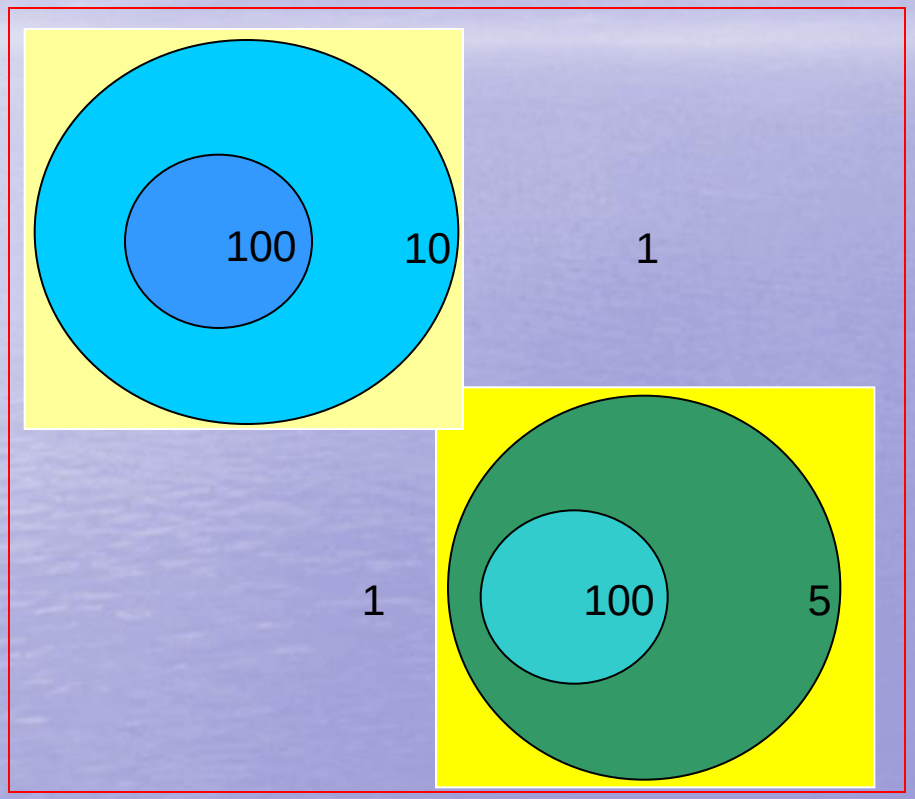
Property boundary

Standard = 10 mg/kg

Surface contamination only

= functional area

Example - Multiple Functional Areas



Property boundary

Non-residential site
Site size = 8 acres

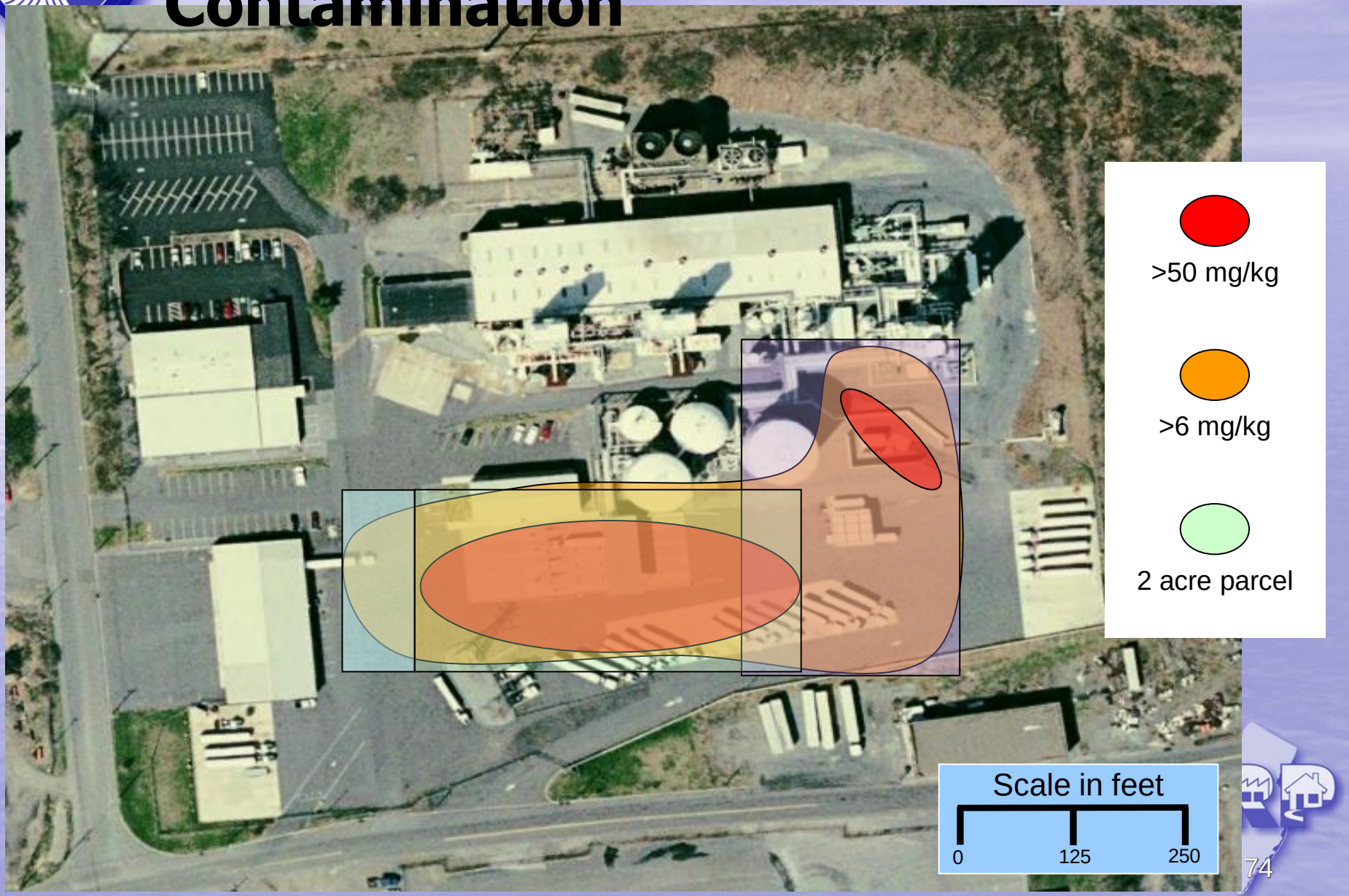
Contaminant #1
Standard = 10 mg/kg

Contaminant #2
Standard = 5 mg/kg

Example - 15 Acre Site

Example – Benzene Contamination

Example – Naphthalene Contamination



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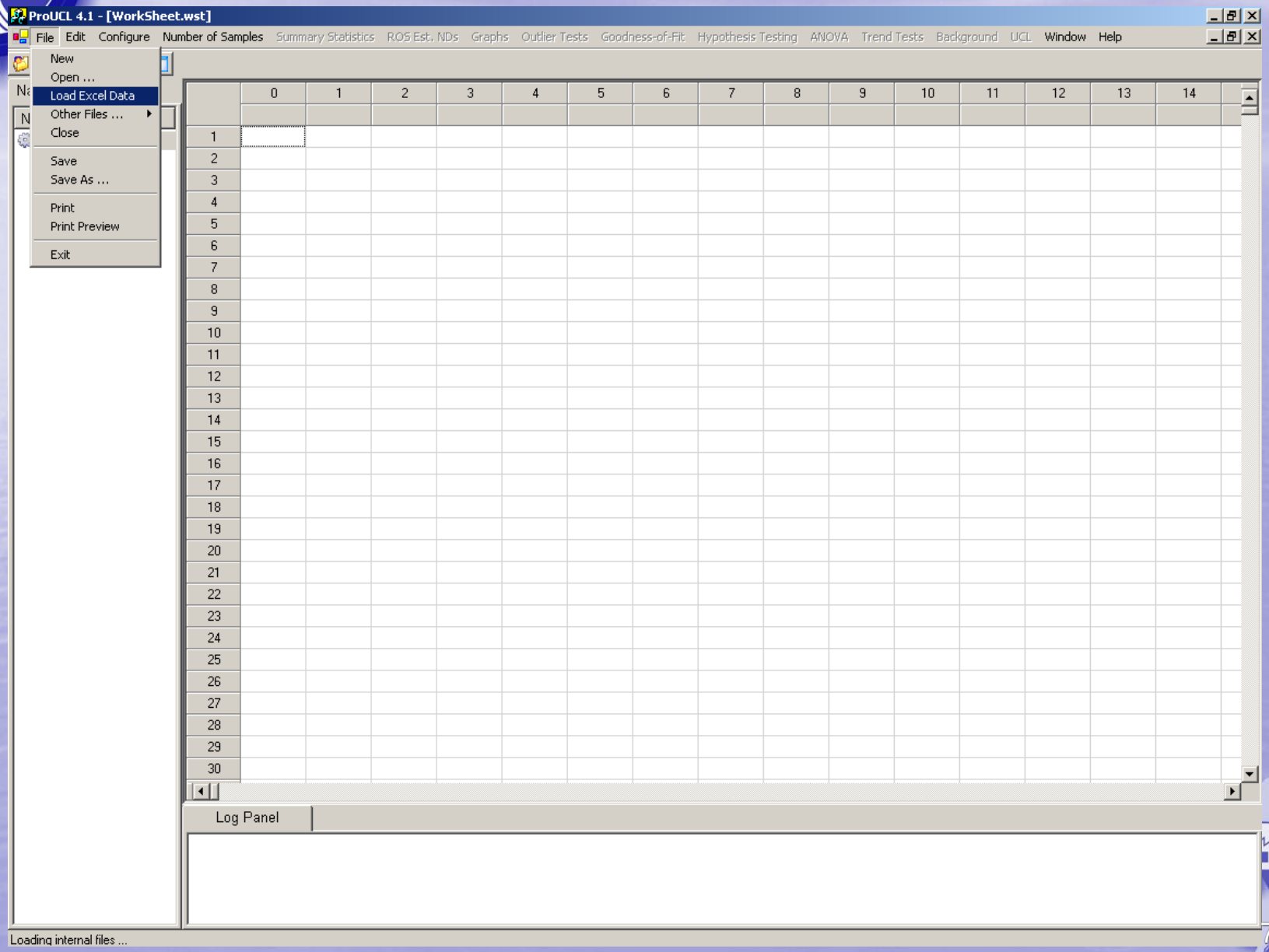
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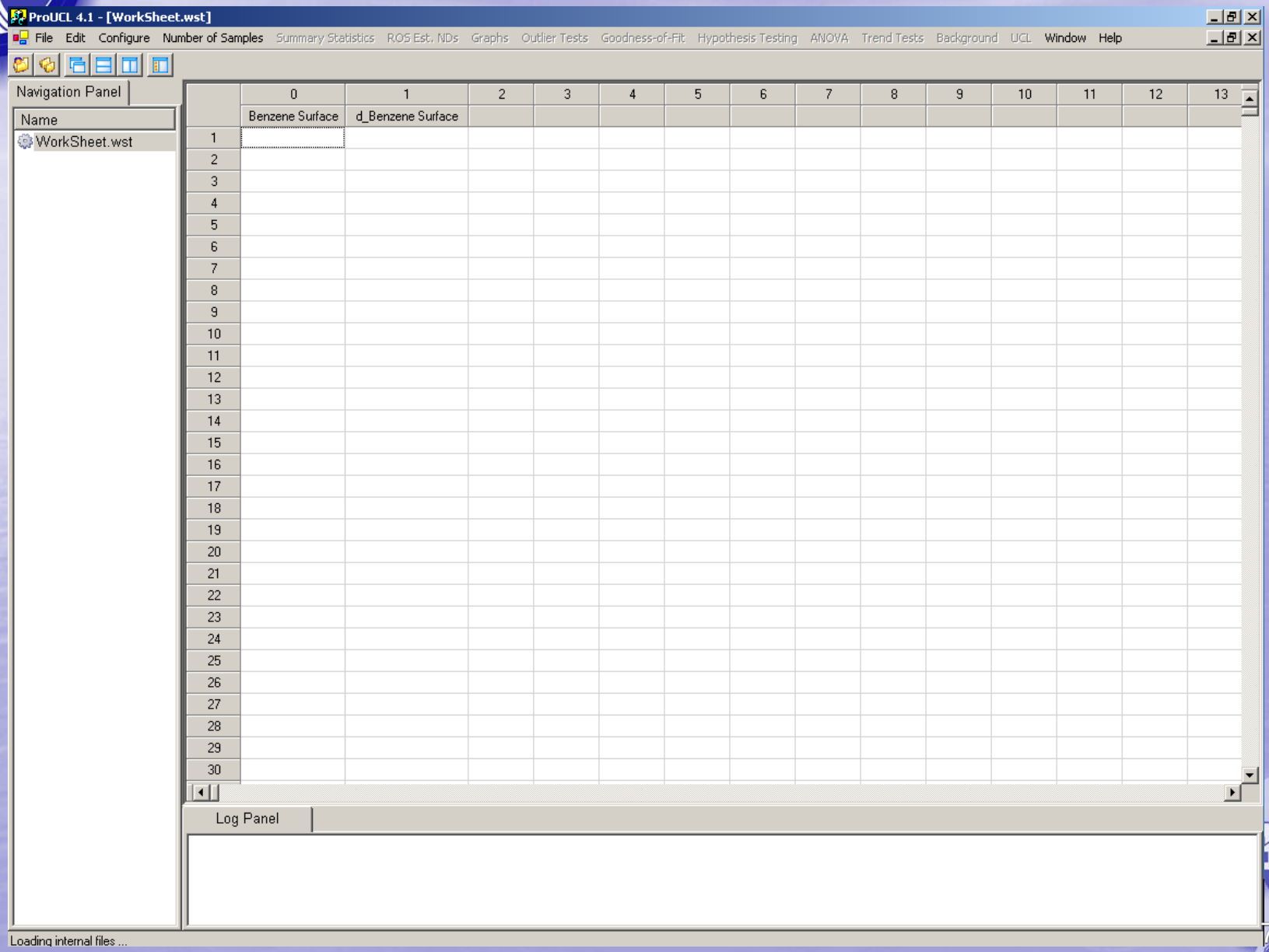
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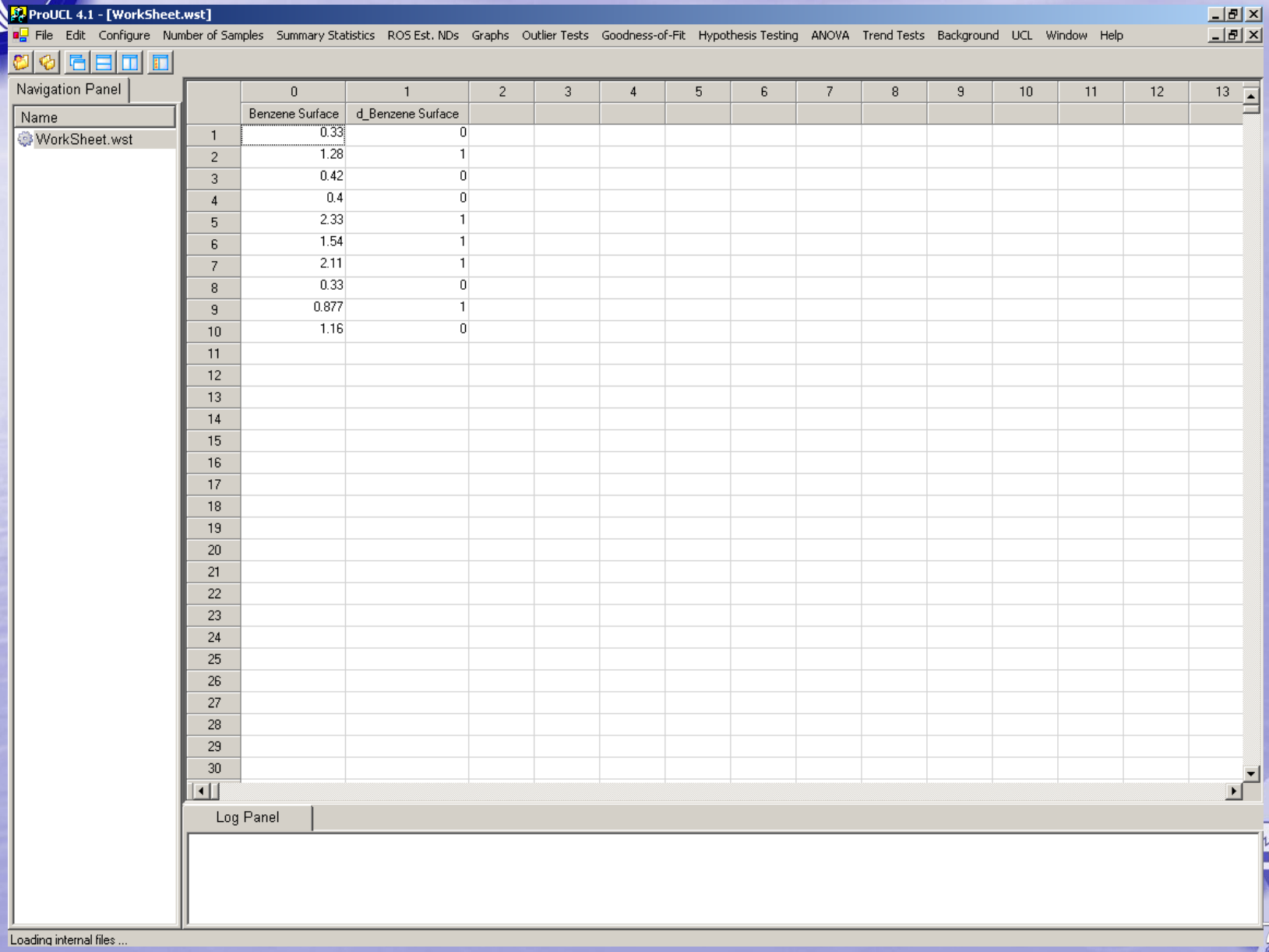

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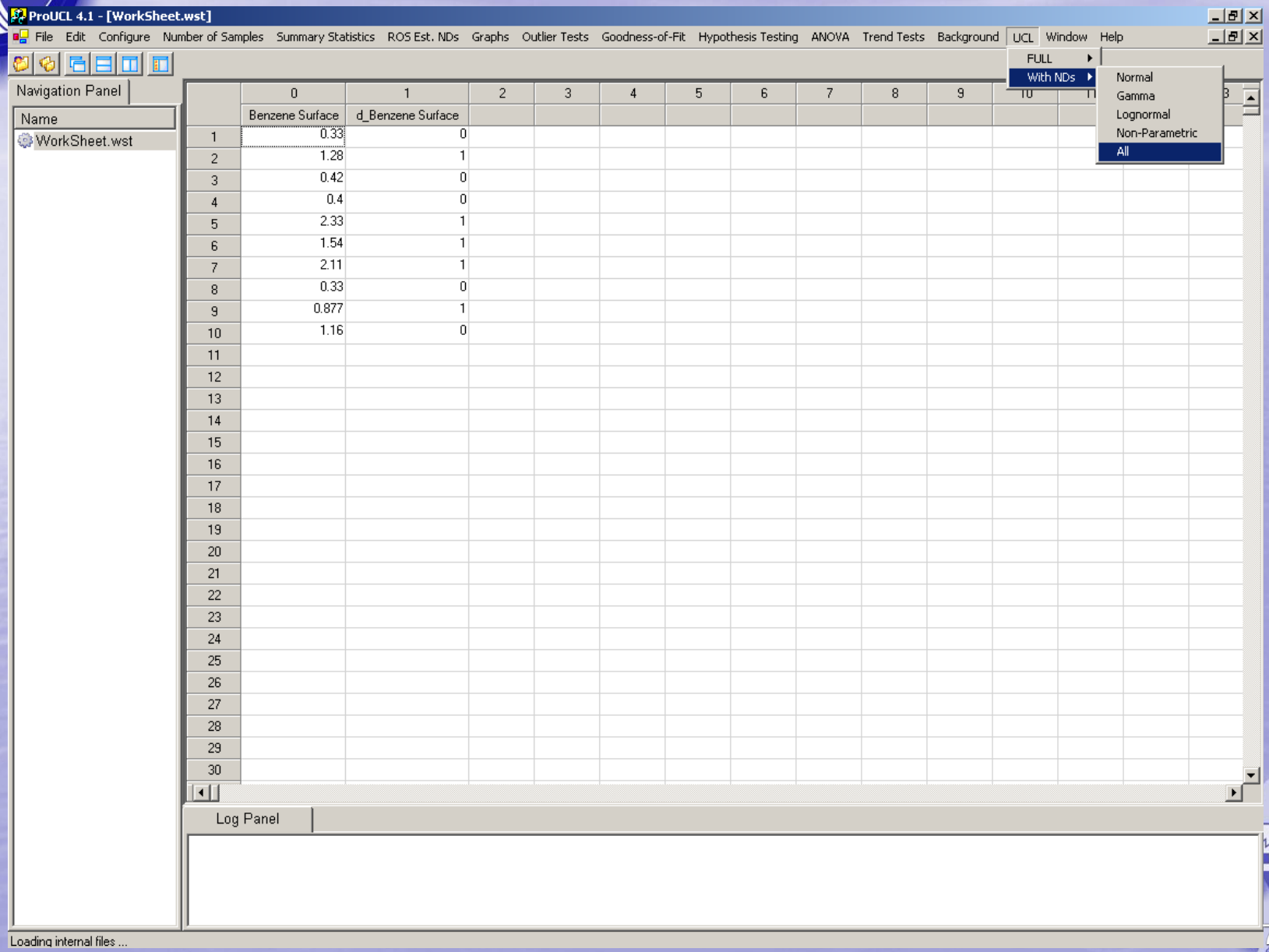
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0.42 0
0.4 0
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1.54 1
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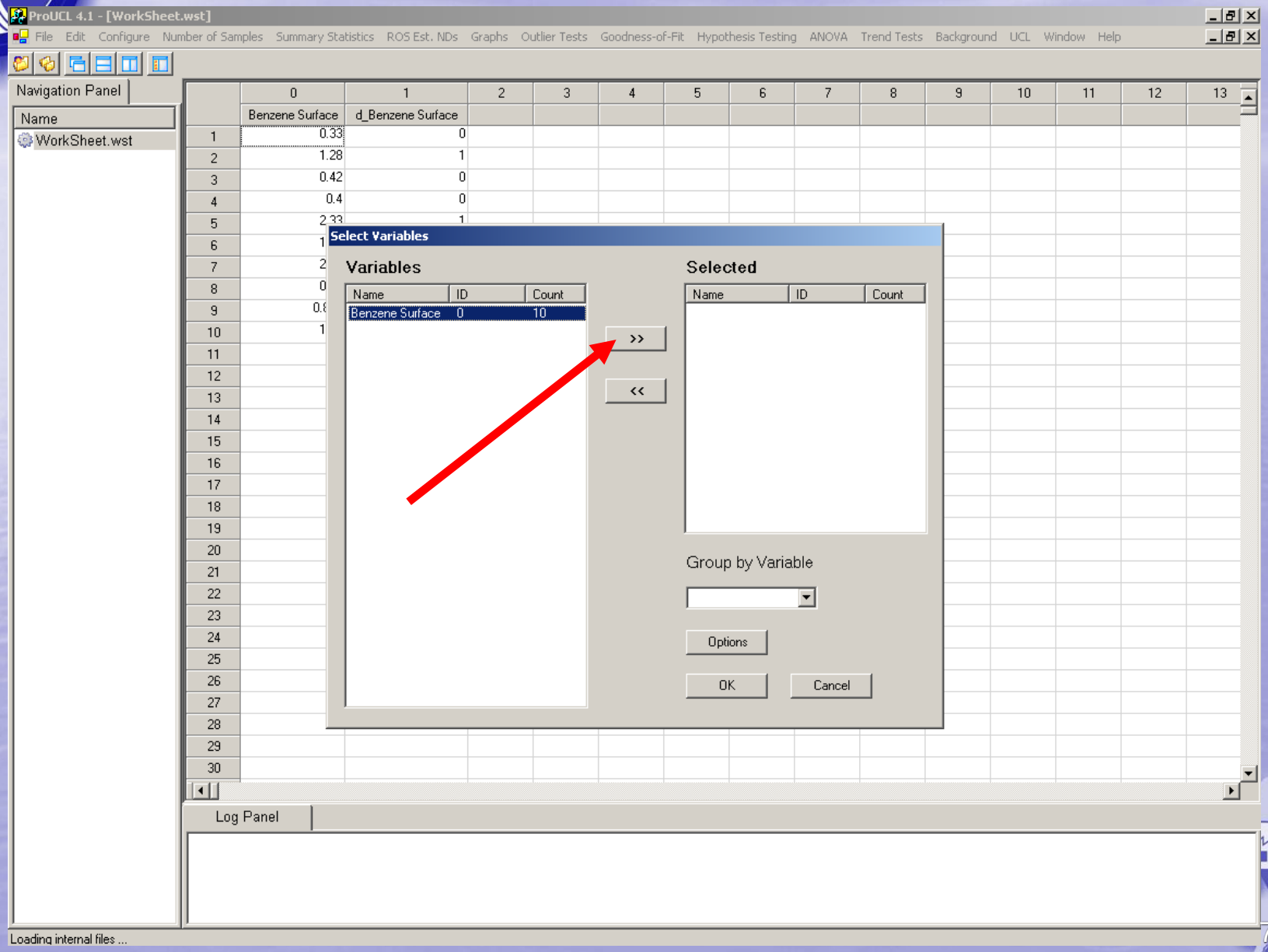
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File Edit Configure Number of Samples Summary Statistics ROS Est. NDs Graphs Outlier Tests Goodness-of-Fit Hypothesis Testing ANOVA Trend Tests Background UCL Window Help
Navigation Panel
Name
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Benzene Surface
d_Benzene Surface
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Benzene Surface 0 10
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Name ID Count
Group by Variable
Options
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Log Panel
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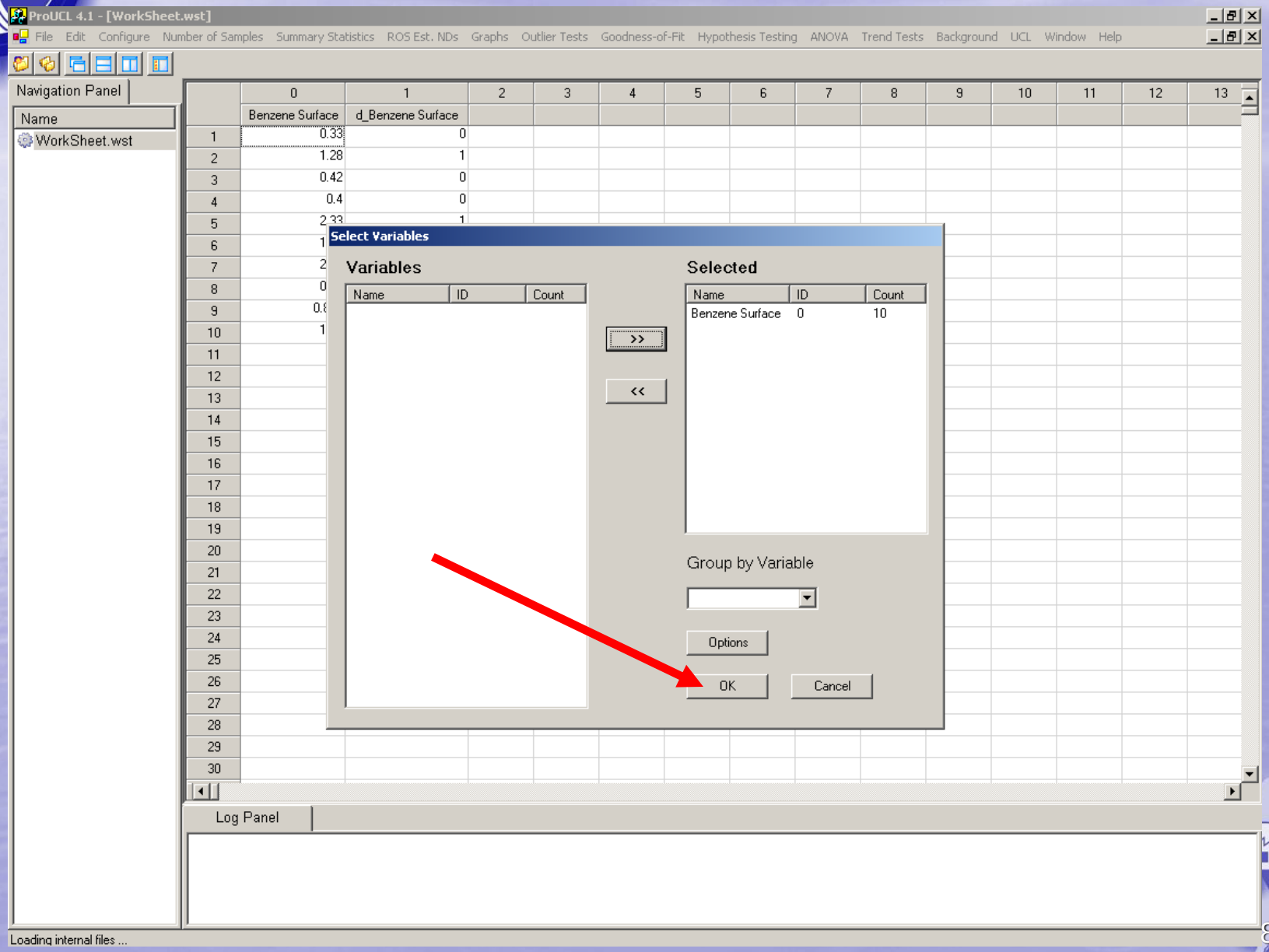
ProUCL 4.1.00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File Edit Configure Number of Samples Summary Statistics ROS Est. NDs Graphs Outlier Tests Goodness-of-Fit Hypothesis Testing ANOVA Trend Tests Background UCL Window Help
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WorkSheet.wst
Benzene Surface
d_Benzene Surface
Select Variables
Variables
Name ID Count
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Name ID Count
Benzene Surface 0 10
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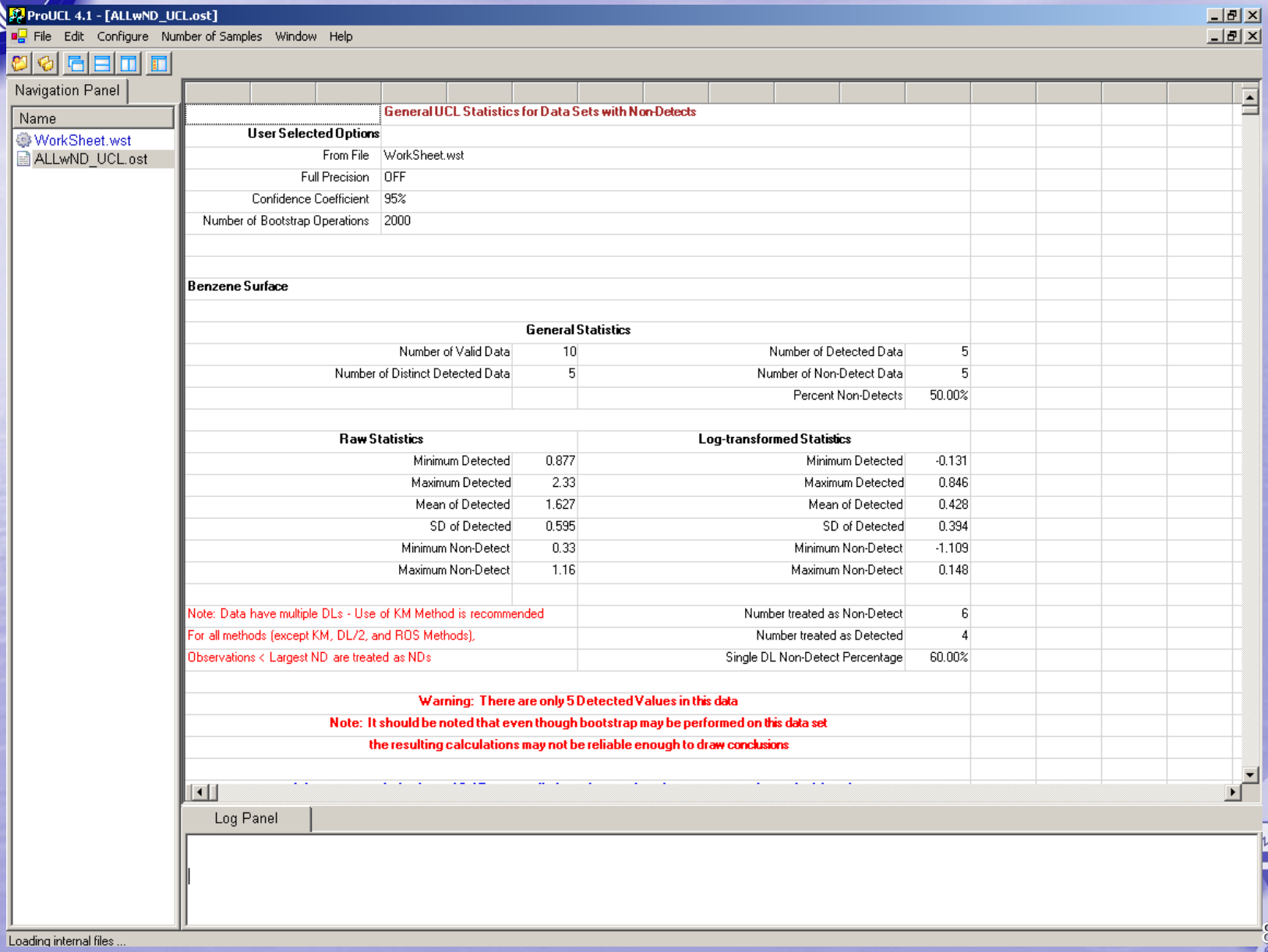
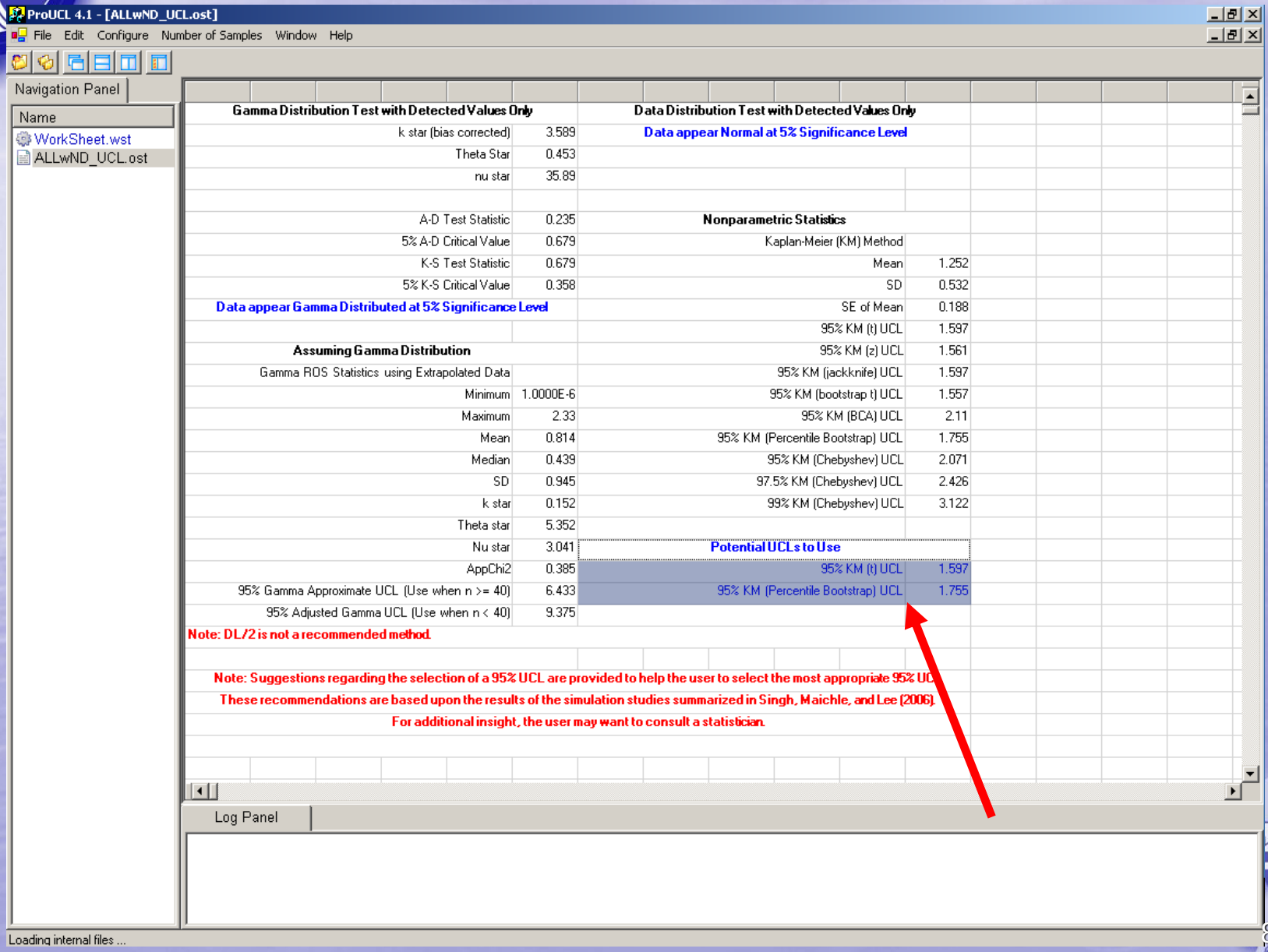
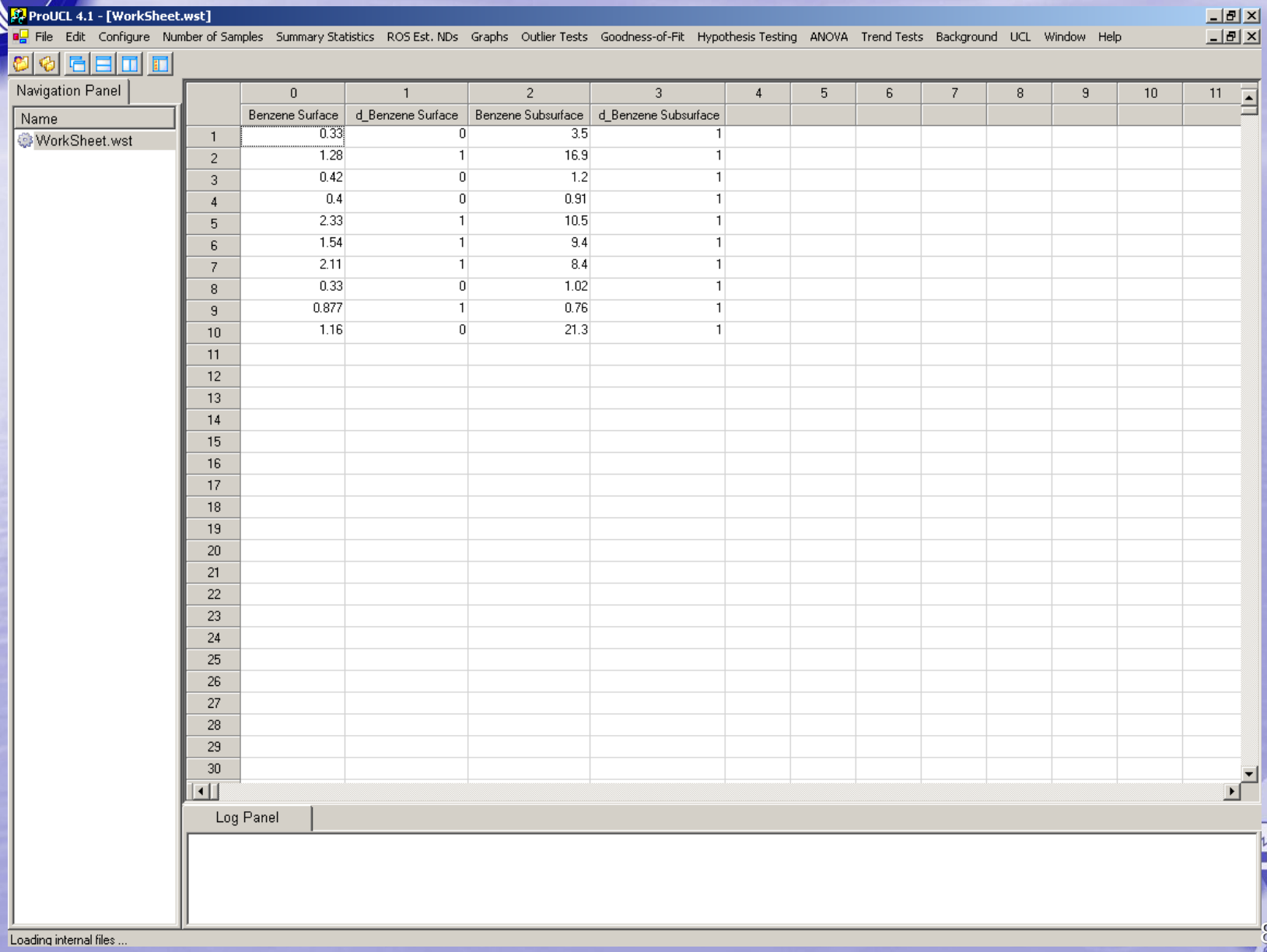
ProUCL 4.1.00


ProUCL 4.1 - [ALLwND_UCL.ost]
File Edit Configure Number of Samples Window Help
Navigation Panel
Name
WorkSheet.wst
ALLwND_UCL.ost
General UCL Statistics for Data Sets with Non-Detects
User Selected Options
From File WorkSheet.wst
Full Precision OFF
Confidence Coefficient 95%
Number of Bootstrap Operations 2000
Benzene Surface
General Statistics
Number of Valid Data 10
Number of Detected Data 5
Number of Distinct Detected Data 5
Number of Non-Detect Data 5
Percent Non-Detects 50.00%
Raw Statistics
Minimum Detected 0.877
Maximum Detected 2.33
Mean of Detected 1.627
SD of Detected 0.595
Minimum Non-Detect 0.33
Maximum Non-Detect 1.16
Log-transformed Statistics
Minimum Detected -0.131
Maximum Detected 0.846
Mean of Detected 0.428
SD of Detected 0.394
Minimum Non-Detect -1.109
Maximum Non-Detect 0.148
Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs
Number treated as Non-Detect 6
Number treated as Detected 4
Single DL Non-Detect Percentage 60.00%
Warning: There are only 5 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions
Log Panel
Loading internal files ...

ProUCL 4.1.00


ProUCL 4.1 - [ALLwND_UCL.ost]
File Edit Configure Number of Samples Window Help
Navigation Panel
Name
WorkSheet.wst
ALLwND_UCL.ost
Gamma Distribution Test with Detected Values Only
k star (bias corrected) 3.589
Theta Star 0.453
nu star 35.89
A-D Test Statistic 0.235
5% A-D Critical Value 0.679
K-S Test Statistic 0.679
5% K-S Critical Value 0.358
Data appear Gamma Distributed at 5% Significance Level
Assuming Gamma Distribution
Gamma ROS Statistics using Extrapolated Data
Minimum 1.0000E-6
Maximum 2.33
Mean 0.814
Median 0.439
SD 0.945
k star 0.152
Theta star 5.352
Nu star 3.041
AppChi2 0.385
95% Gamma Approximate UCL (Use when n >= 40) 6.433
95% Adjusted Gamma UCL (Use when n < 40) 9.375
Note: DL/2 is not a recommended method.
Data Distribution Test with Detected Values Only
Data appear Normal at 5% Significance Level
Nonparametric Statistics
Kaplan-Meier (KM) Method
Mean 1.252
SD 0.532
SE of Mean 0.188
95% KM (t) UCL 1.597
95% KM (z) UCL 1.561
95% KM (jackknife) UCL 1.597
95% KM (bootstrap t) UCL 1.557
95% KM (BCA) UCL 2.11
95% KM (Percentile Bootstrap) UCL 1.755
95% KM (Chebyshev) UCL 2.071
97.5% KM (Chebyshev) UCL 2.426
99% KM (Chebyshev) UCL 3.122
Potential UCLs to Use
95% KM (t) UCL 1.597
95% KM (Percentile Bootstrap) UCL 1.755
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UC
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.
Log Panel
Loading internal files ...

ProUCL 4.1.00



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1	0.33	0	3.5	1								
2	1.28	1	16.9	1								
3	0.42	0	1.2	1								
4	0.4	0	0.91	1								
5	2.33	1	10.5	1								
6	1.54	1	9.4	1								
7	2.11	1	8.4	1								
8	0.33	0	1.02	1								
9	0.877	1	0.76	1								
10	1.16	0	21.3	1								
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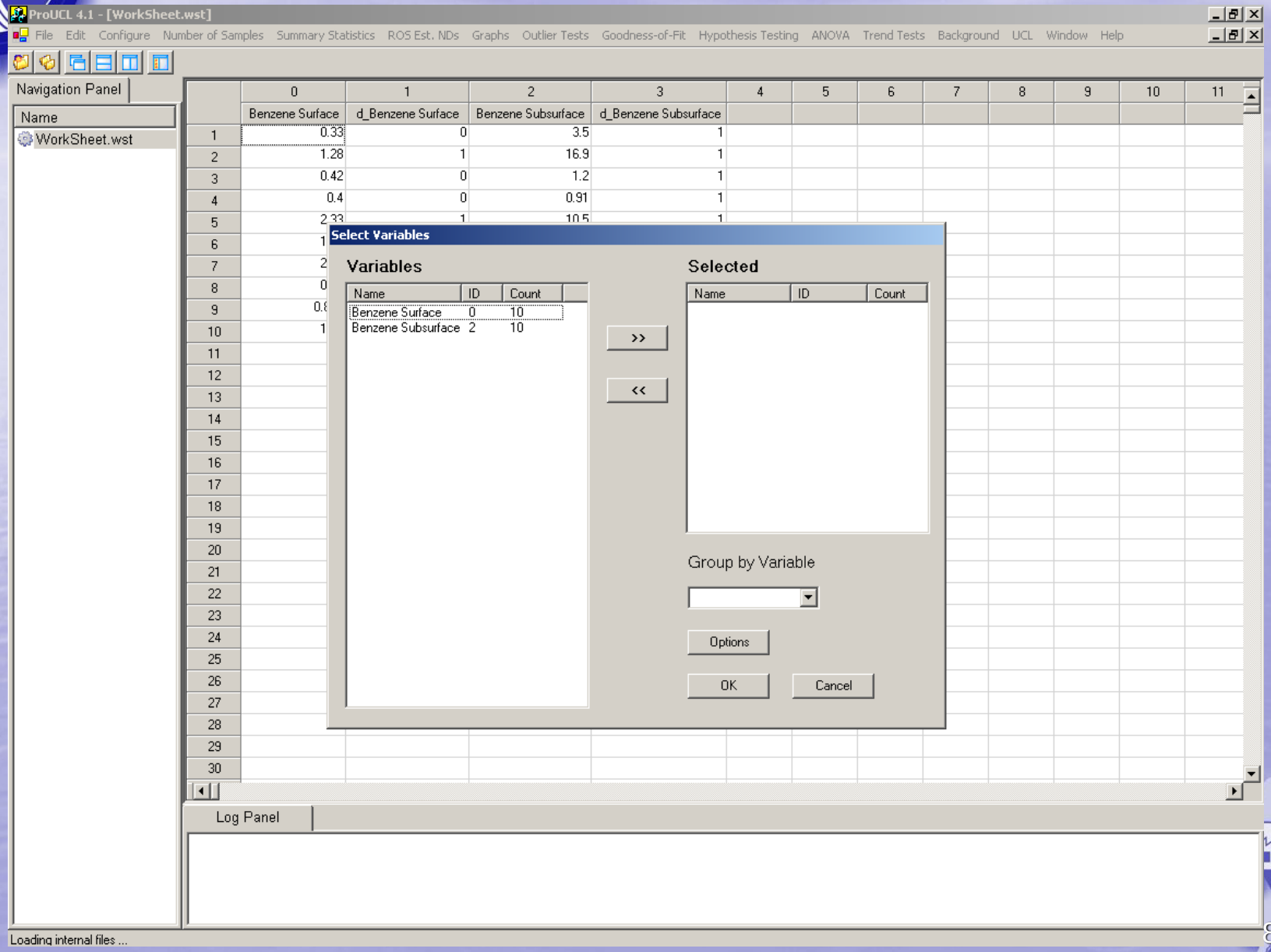
ProUCL 4.1.00


ProUCL 4.1 - [WorkSheet.wst]
File Edit Configure Number of Samples Summary Statistics ROS Est. NDs Graphs Outlier Tests Goodness-of-Fit Hypothesis Testing ANOVA Trend Tests Background UCL Window Help
Navigation Panel
Name
WorkSheet.wst
Benzene Surface
d_Benzene Surface
Benzene Subsurface
d_Benzene Subsurface
Select Variables
Variables
Name ID Count
Benzene Surface 0 10
Benzene Subsurface 2 10
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Log Panel
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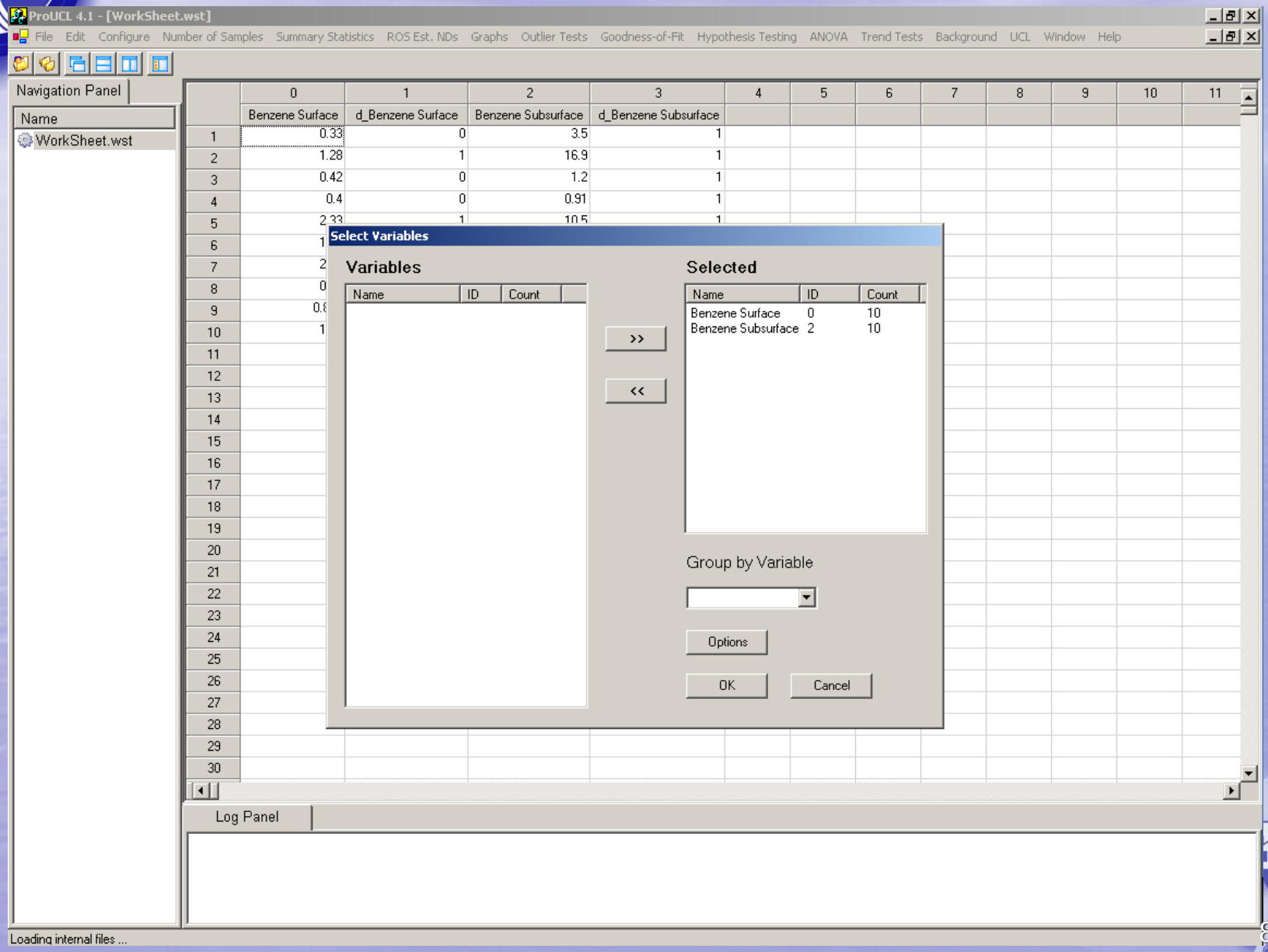
ProUCL 4.1.00


ProUCL 4.1 - [WorkSheet.wst]
File Edit Configure Number of Samples Summary Statistics ROS Est. NDs Graphs Outlier Tests Goodness-of-Fit Hypothesis Testing ANOVA Trend Tests Background UCL Window Help
Navigation Panel
Name
WorkSheet.wst
Benzene Surface
d_Benzene Surface
Benzene Subsurface
d_Benzene Subsurface
Select Variables
Variables
Name ID Count
Selected
Name ID Count
Benzene Surface 0 10
Benzene Subsurface 2 10
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Options
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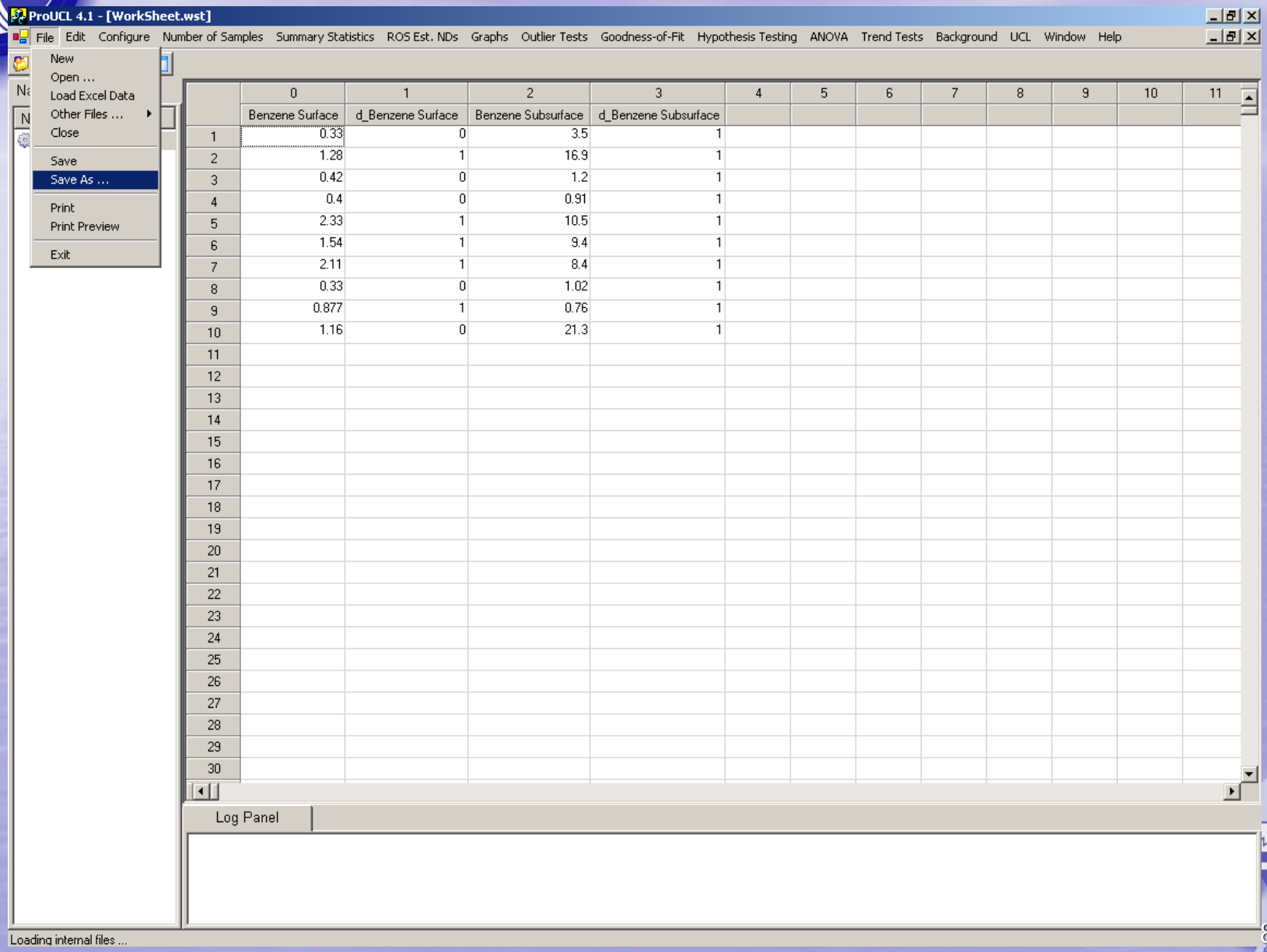
ProUCL 4.1.00



	0	1	2	3	4	5	6	7	8	9	10	11
	Benzene Surface	d_Benzene Surface	Benzene Subsurface	d_Benzene Subsurface								
1	0.33	0	3.5	1								
2	1.28	1	16.9	1								
3	0.42	0	1.2	1								
4	0.4	0	0.91	1								
5	2.33	1	10.5	1								
6	1.54	1	9.4	1								
7	2.11	1	8.4	1								
8	0.33	0	1.02	1								
9	0.877	1	0.76	1								
10	1.16	0	21.3	1								
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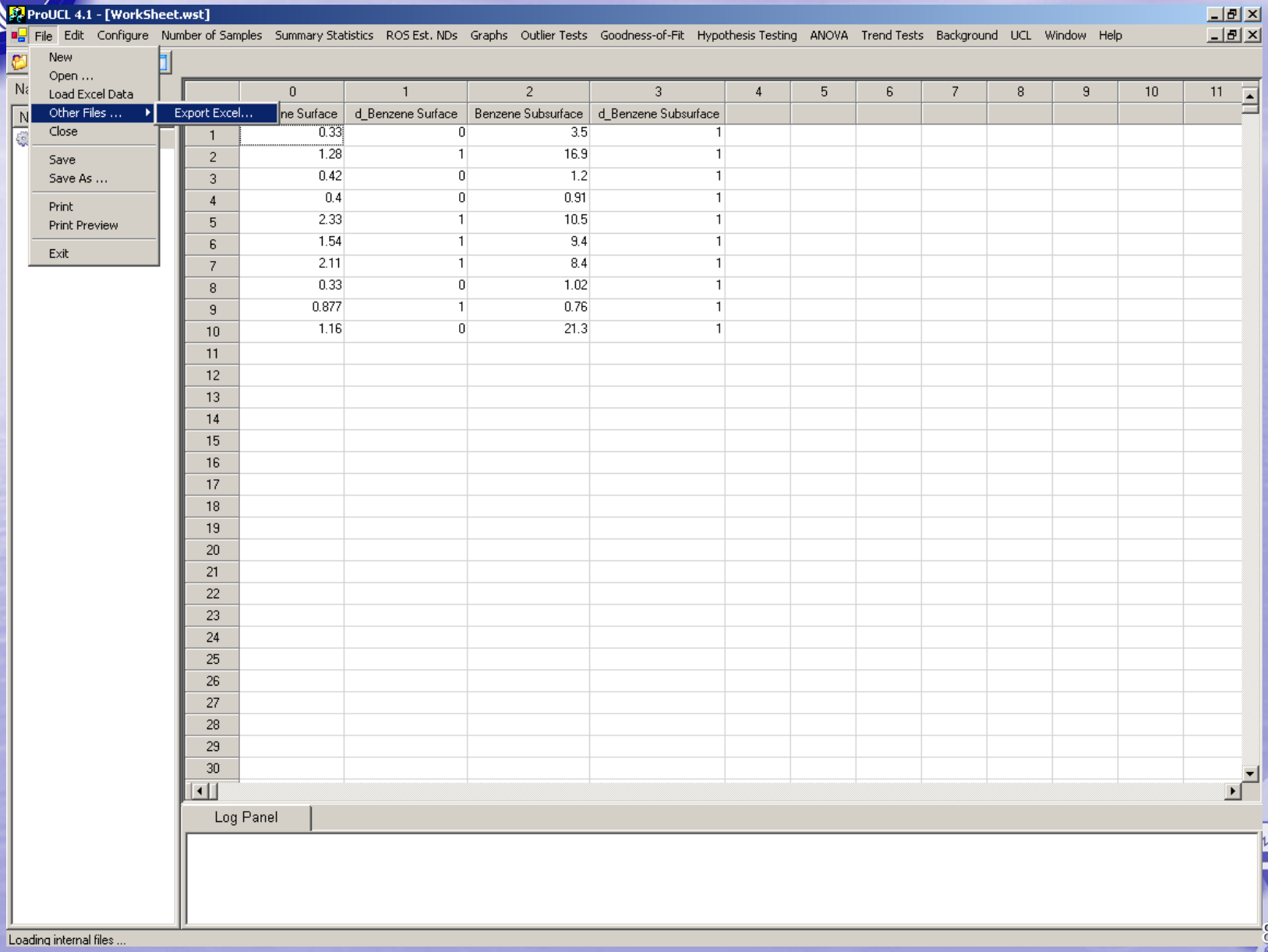
ProUCL 4.1.00


ProUCL 4.1 - [WorkSheet.wst]
File Edit Configure Number of Samples Summary Statistics ROS Est. NDs Graphs Outlier Tests Goodness-of-Fit Hypothesis Testing ANOVA Trend Tests Background UCL Window Help
New
Open ...
Load Excel Data
Other Files ...
Export Excel...
Close
Save
Save As ...
Print
Print Preview
Exit
0 1 2 3 4 5 6 7 8 9 10 11
ne Surface
d_Benzene Surface
Benzene Subsurface
d_Benzene Subsurface
1 0.33 0 3.5 1
2 1.28 1 16.9 1
3 0.42 0 1.2 1
4 0.4 0 0.91 1
5 2.33 1 10.5 1
6 1.54 1 9.4 1
7 2.11 1 8.4 1
8 0.33 0 1.02 1
9 0.877 1 0.76 1
10 1.16 0 21.3 1
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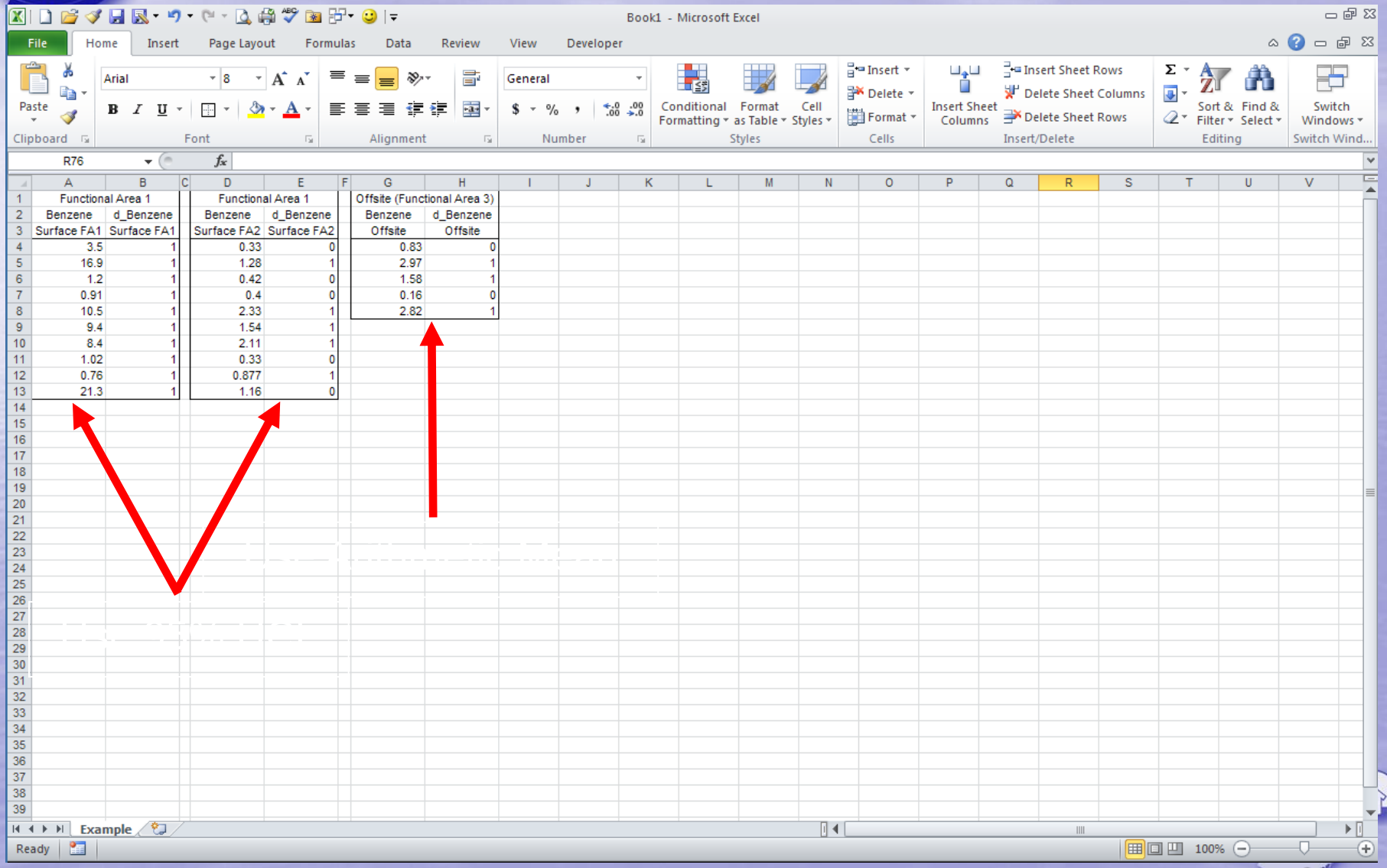
ProUCL vs. Arithmetic Mean



	A	B	D	E	G	H
1	Functional Area 1		Functional Area 1		Offsite (Functional Area 3)	
2	Benzene	d_Benzene	Benzene	d_Benzene	Benzene	d_Benzene
3	Surface FA1	Surface FA1	Surface FA2	Surface FA2	Offsite	Offsite
4	3.5	1	0.33	0	0.83	0
5	16.9	1	1.28	1	2.97	1
6	1.2	1	0.42	0	1.58	1
7	0.91	1	0.4	0	0.16	0
8	10.5	1	2.33	1	2.82	1
9	9.4	1	1.54	1		
10	8.4	1	2.11	1		
11	1.02	1	0.33	0		
12	0.76	1	0.877	1		
13	21.3	1	1.16	0		

Questions?

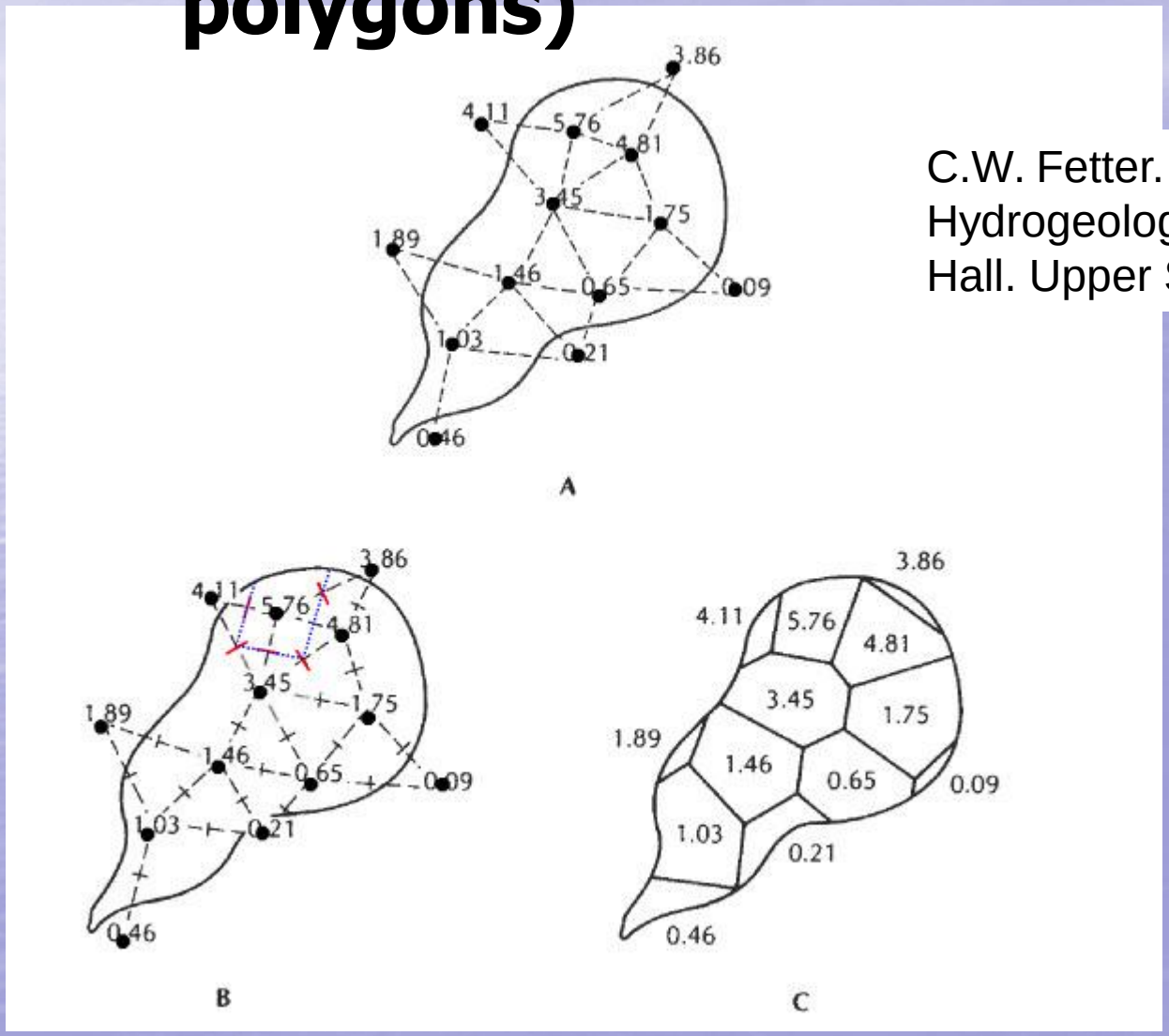
Compliance Averaging - Spatially Weighted Average (e.g., Thiessen polygons)

- Typically requires CAD/GIS software
  - ESRI ArcGIS
- Typically applied as an iterative remedial process
- No remediation required (RI stage) or remediation complete (RA stage) if spatially weighted average < applicable remediation standard

Compliance Averaging - Spatially Weighted Average (e.g., Thiessen polygons)

- Remedial investigation or remedial action stage
  - Applicable to all pathways
  - Entails definition of "functional area" (same as 95% UCL)
    - Functional area = area within which compliance averaging performed
    - Size of functional area varies by pathway and end use (1/4 acre up to 2 acre)
    - Vertical zones must also be evaluated; vary by pathway

Compliance Averaging - Spatially Weighted Average (e.g., Thiessen polygons)



C.W. Fetter. 2001. Applied Hydrogeology, 4th Ed. Prentice Hall. Upper Saddle River, NJ.

Example – Spatially weighted average (e.g., Thiessen polygons)

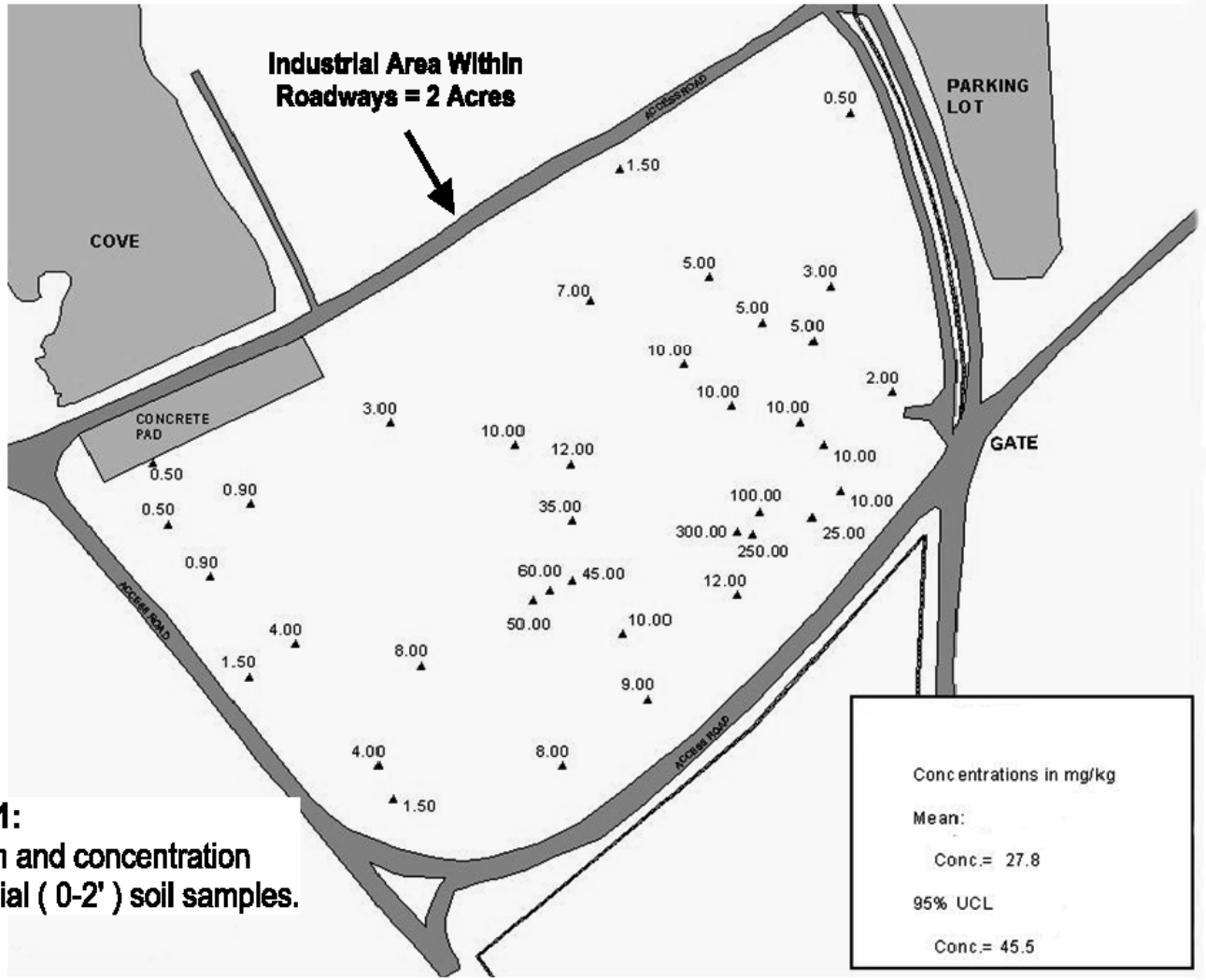


Figure 1:
Location and concentration of surficial (0-2') soil samples.

Example – Spatially weighted average (e.g., Thiessen polygons)

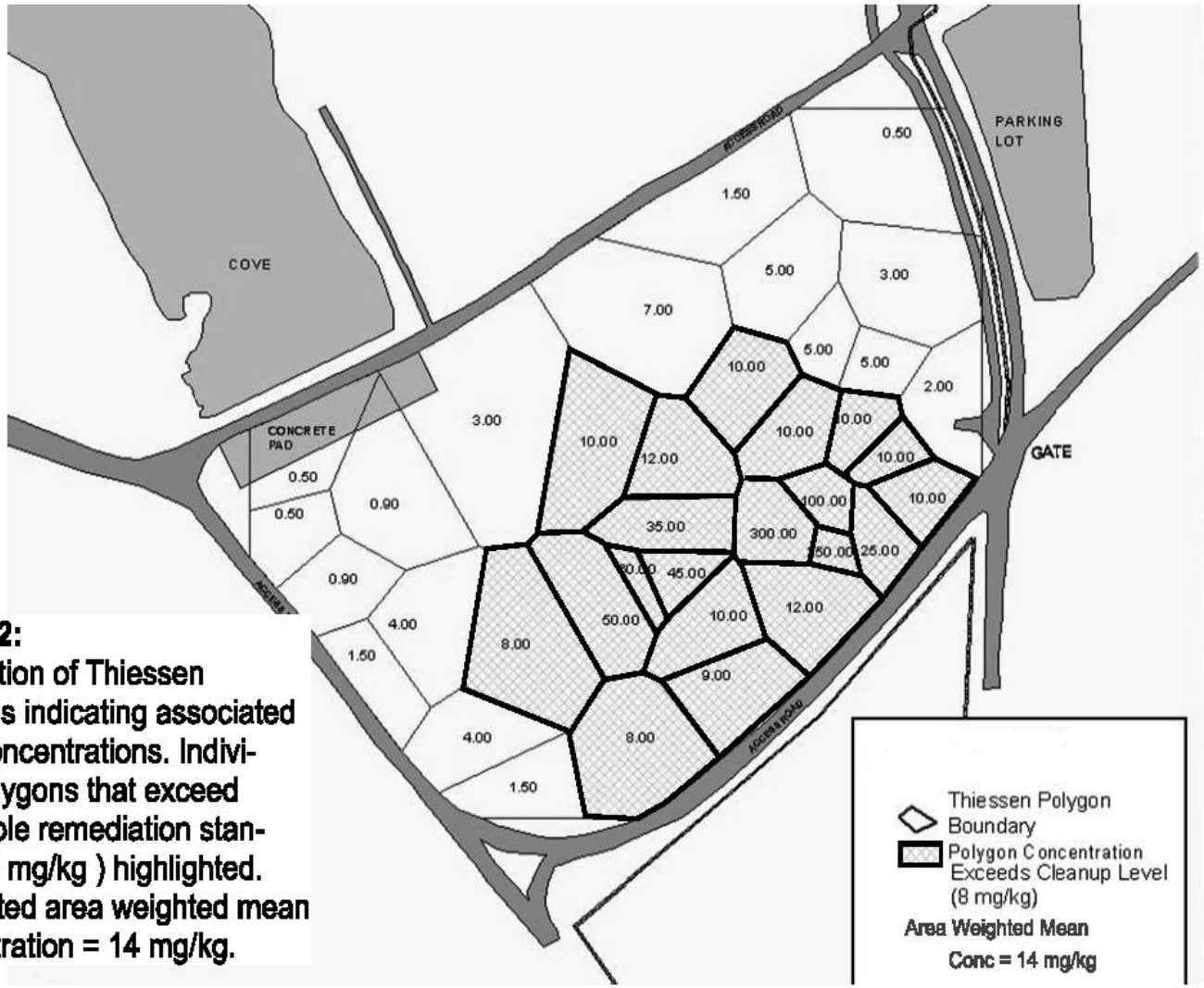


Figure 2:
Delineation of Thiessen polygons indicating associated areal concentrations. Individual polygons that exceed applicable remediation standard (8 mg/kg) highlighted. Calculated area weighted mean concentration = 14 mg/kg.

Example – Spatially weighted average (e.g., Thiessen polygons)

OBJECTID	loc_name1	X_coord	Y_coord	Concentration	units	Shape_Area
16	UR3-HF-01A-DUP	502703.69	601351.05	7.00	PPM	38,497.05
13	UR5-HF-01A	502687.61	601202.58	10.00	PPM	27,542.72
19	MR5-HF-01A	503007.75	601638.15	30.00	PPM	21,108.90
4	MR3-HF-01A	503150.71	601702.97	0.33	PPM	21,033.71
36	LR3-HF-01A	503293.07	601947.02	0.31	PPM	6,963.33
16	UR3-HF-10A	502837.01	601302.01	**300.00**	PPM	6,041.68
22	UR2-HF-10A	502852.87	601349.13	70.00	PPM	5,659.82
8	UR7-HF-10A	502804.52	601039.34	0.77	PPM	4,930.68
38	2012-HFA-4	503476.85	601663.19	2.45	PPM	4,624.13
30	MR6-HF-09A	503019.11	601505.12	37.00	PPM	4,431.57
44	2012-HF-1	503430.37	601772.47	3.60	PPM	4,354.49
37	2012-HFA-3	503438.66	601693.57	1.10	PPM	4,326.55
39	LR1-HF-03A	503268.53	602034.94	250.00	PPM	4,209.63
33	MR2-HF-09A	503297.31	601664.90	0.41	PPM	4,132.73
18	MR5-HF-02A	503022.87	601618.35	0.04	PPM	4,109.06
6	2012-HFE-2	503532.84	601802.95	0.04	PPM	4,055.55
36	2012-HFA-2	503398.29	601722.65	0.98	PPM	4,006.52
45	2012-HF-2	503460.23	601810.83	79.00	PPM	3,841.17
39	2012-HFF-1	503555.41	601661.45	0.04	PPM	3,839.11
12	UR6-HF-09B	502795.22	601104.22	0.59	PPM	2,938.72
17	UR3-HF-09A	502816.66	601312.16	0.38	PPM	2,913.71
23	UR1-HF-10A	502888.10	601387.41	100.00	PPM	2,889.09
49	LR3-HF-10A	503430.74	601887.85	0.49	PPM	2,817.01
50	LR3-HF-09A	503411.51	601902.85	0.44	PPM	2,816.19
7	UR7-HF-03B	502703.43	601064.33	4.40	PPM	952.50
8	UR7-HF-02A	502684.83	601081.29	2.30	PPM	860.78
32	MR5-HF-08A	503057.66	601553.81	0.65	PPM	641.64

Area Weighted Avg = 13.98

Example – Spatially weighted average (e.g., Thiessen polygons)

Figure 3 - Iteration 1:
Replacement of highest concentration polygon with "background" concentration of 0.3 mg/kg.
Recalculated area weighted mean concentration = 10 mg/kg.

Example – Spatially weighted average (e.g., Thiessen polygons)

OBJECTID	loc_name1	X_coord	Y_coord	Concentration	units	Shape_Area
16	UR3-HF-01A-DUP	502703.69	601351.05	7.00	PPM	38,497.05
13	UR5-HF-01A	502687.61	601202.58	10.00	PPM	27,542.72
19	MR5-HF-01A	503007.75	601638.15	30.00	PPM	21,108.90
4	MR3-HF-01A	503150.71	601702.97	0.33	PPM	21,033.71
36	LR3-HF-01A	503293.07	601947.02	0.31	PPM	6,963.33
16	UR3-HF-10A	502837.01	601302.01	**0.30**	PPM	6,041.68
22	UR2-HF-10A	502852.87	601349.13	70.00	PPM	5,659.82
8	UR7-HF-10A	502804.52	601039.34	0.77	PPM	4,930.68
38	2012-HFA-4	503476.85	601663.19	2.45	PPM	4,624.13
30	MR6-HF-09A	503019.11	601505.12	37.00	PPM	4,431.57
44	2012-HF-1	503430.37	601772.47	3.60	PPM	4,354.49
37	2012-HFA-3	503438.66	601693.57	1.10	PPM	4,326.55
39	LR1-HF-03A	503268.53	602034.94	250.00	PPM	4,209.63
33	MR2-HF-09A	503297.31	601664.90	0.41	PPM	4,132.73
18	MR5-HF-02A	503022.87	601618.35	0.04	PPM	4,109.06
6	2012-HFE-2	503532.84	601802.95	0.04	PPM	4,055.55
36	2012-HFA-2	503398.29	601722.65	0.98	PPM	4,006.52
45	2012-HF-2	503460.23	601810.83	79.00	PPM	3,841.17
39	2012-HFF-1	503555.41	601661.45	0.04	PPM	3,839.11
12	UR6-HF-09B	502795.22	601104.22	0.59	PPM	2,938.72
17	UR3-HF-09A	502816.66	601312.16	0.38	PPM	2,913.71
23	UR1-HF-10A	502888.10	601387.41	100.00	PPM	2,889.09
49	LR3-HF-10A	503430.74	601887.85	0.49	PPM	2,817.01
50	LR3-HF-09A	503411.51	601902.85	0.44	PPM	2,816.19
7	UR7-HF-03B	502703.43	601064.33	4.40	PPM	952.50
8	UR7-HF-02A	502684.83	601081.29	2.30	PPM	860.78
32	MR5-HF-08A	503057.66	601553.81	0.65	PPM	641.64

Area Weighted Avg = 10.00

Example – Spatially weighted average (e.g., Thiessen polygons)

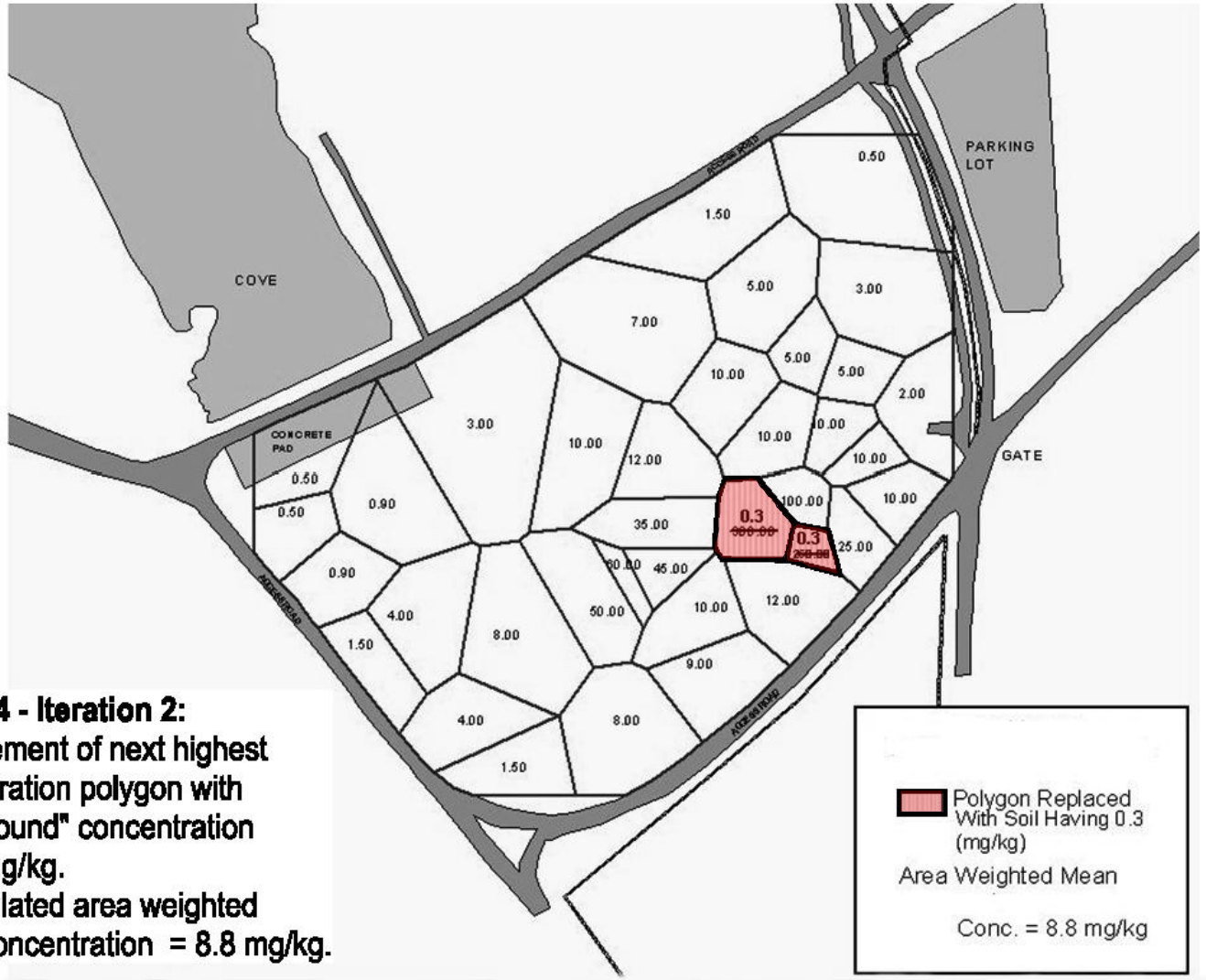


Figure 4 - Iteration 2:
Replacement of next highest concentration polygon with "background" concentration of 0.3 mg/kg.
Recalculated area weighted mean concentration = 8.8 mg/kg.

Example – Spatially weighted average (e.g., Thiessen polygons)

OBJECTID	loc_name1	X_coord	Y_coord	Concentration	units	Shape_Area
16	UR3-HF-01A-DUP	502703.69	601351.05	7.00	PPM	38,497.05
13	UR5-HF-01A	502687.61	601202.58	10.00	PPM	27,542.72
19	MR5-HF-01A	503007.75	601638.15	30.00	PPM	21,108.90
4	MR3-HF-01A	503150.71	601702.97	0.33	PPM	21,033.71
36	LR3-HF-01A	503293.07	601947.02	0.31	PPM	6,963.33
16	UR3-HF-10A	502837.01	601302.01	**0.30**	PPM	6,041.68
22	UR2-HF-10A	502852.87	601349.13	70.00	PPM	5,659.82
8	UR7-HF-10A	502804.52	601039.34	0.77	PPM	4,930.68
38	2012-HFA-4	503476.85	601663.19	2.45	PPM	4,624.13
30	MR6-HF-09A	503019.11	601505.12	37.00	PPM	4,431.57
44	2012-HF-1	503430.37	601772.47	3.60	PPM	4,354.49
37	2012-HFA-3	503438.66	601693.57	1.10	PPM	4,326.55
39	LR1-HF-03A	503268.53	602034.94	**0.30**	PPM	4,209.63
33	MR2-HF-09A	503297.31	601664.90	0.41	PPM	4,132.73
18	MR5-HF-02A	503022.87	601618.35	0.04	PPM	4,109.06
6	2012-HFE-2	503532.84	601802.95	0.04	PPM	4,055.55
36	2012-HFA-2	503398.29	601722.65	0.98	PPM	4,006.52
45	2012-HF-2	503460.23	601810.83	79.00	PPM	3,841.17
39	2012-HFF-1	503555.41	601661.45	0.04	PPM	3,839.11
12	UR6-HF-09B	502795.22	601104.22	0.59	PPM	2,938.72
17	UR3-HF-09A	502816.66	601312.16	0.38	PPM	2,913.71
23	UR1-HF-10A	502888.10	601387.41	100.00	PPM	2,889.09
49	LR3-HF-10A	503430.74	601887.85	0.49	PPM	2,817.01
50	LR3-HF-09A	503411.51	601902.85	0.44	PPM	2,816.19
7	UR7-HF-03B	502703.43	601064.33	4.40	PPM	952.50
8	UR7-HF-02A	502684.83	601081.29	2.30	PPM	860.78
32	MR5-HF-08A	503057.66	601553.81	0.65	PPM	641.64
				Area Weighted Avg =		
				8.83		

Example – Spatially weighted average (e.g., Thiessen polygons)

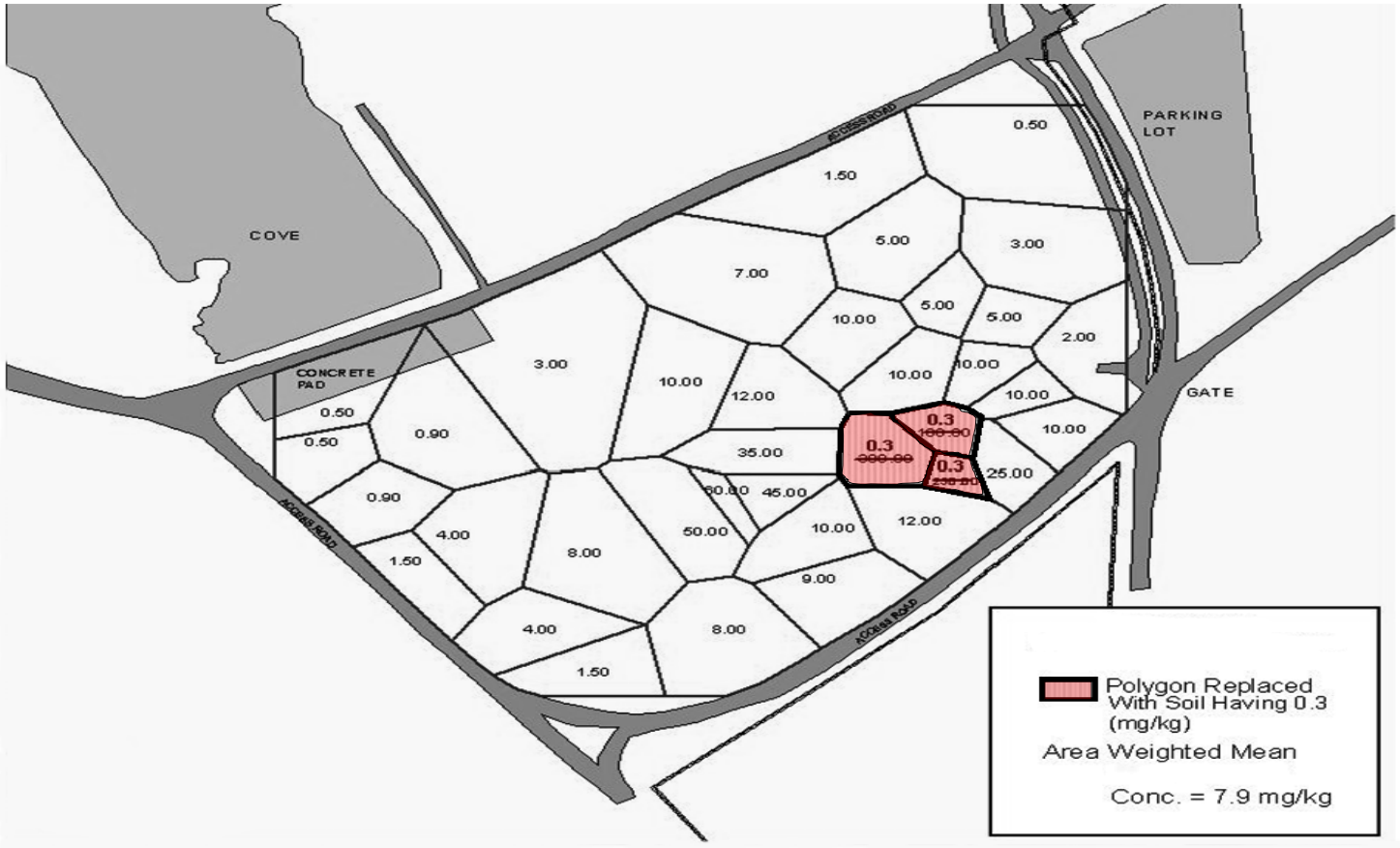


Figure 5 - Iteration 3:
Replacement of next highest concentration polygon with "background" concentration of 0.3 mg/kg. Recalculated area weighted mean concentration = 7.9 mg/kg.
Area weighted mean concentration below applicable remediation standard. Remediation complete.

Example – Spatially weighted average (e.g., Thiessen polygons)

OBJECTID	loc_name1	X_coord	Y_coord	Concentration	units	Shape_Area
16	UR3-HF-01A-DUP	502703.69	601351.05	7.00	PPM	38,497.05
13	UR5-HF-01A	502687.61	601202.58	10.00	PPM	27,542.72
19	MR5-HF-01A	503007.75	601638.15	30.00	PPM	21,108.90
4	MR3-HF-01A	503150.71	601702.97	0.33	PPM	21,033.71
36	LR3-HF-01A	503293.07	601947.02	0.31	PPM	6,963.33
16	UR3-HF-10A	502837.01	601302.01	**0.30**	PPM	6,041.68
22	UR2-HF-10A	502852.87	601349.13	70.00	PPM	5,659.82
8	UR7-HF-10A	502804.52	601039.34	0.77	PPM	4,930.68
38	2012-HFA-4	503476.85	601663.19	2.45	PPM	4,624.13
30	MR6-HF-09A	503019.11	601505.12	37.00	PPM	4,431.57
44	2012-HF-1	503430.37	601772.47	3.60	PPM	4,354.49
37	2012-HFA-3	503438.66	601693.57	1.10	PPM	4,326.55
39	LR1-HF-03A	503268.53	602034.94	**0.30**	PPM	4,209.63
33	MR2-HF-09A	503297.31	601664.90	0.41	PPM	4,132.73
18	MR5-HF-02A	503022.87	601618.35	0.04	PPM	4,109.06
6	2012-HFE-2	503532.84	601802.95	0.04	PPM	4,055.55
36	2012-HFA-2	503398.29	601722.65	0.98	PPM	4,006.52
45	2012-HF-2	503460.23	601810.83	79.00	PPM	3,841.17
39	2012-HFF-1	503555.41	601661.45	0.04	PPM	3,839.11
12	UR6-HF-09B	502795.22	601104.22	0.59	PPM	2,938.72
17	UR3-HF-09A	502816.66	601312.16	0.38	PPM	2,913.71
23	UR1-HF-10A	502888.10	601387.41	**0.30**	PPM	2,889.09
49	LR3-HF-10A	503430.74	601887.85	0.49	PPM	2,817.01
50	LR3-HF-09A	503411.51	601902.85	0.44	PPM	2,816.19
7	UR7-HF-03B	502703.43	601064.33	4.40	PPM	952.50
8	UR7-HF-02A	502684.83	601081.29	2.30	PPM	860.78
32	MR5-HF-08A	503057.66	601553.81	0.65	PPM	641.64

Area Weighted Avg = 7.87

Questions?

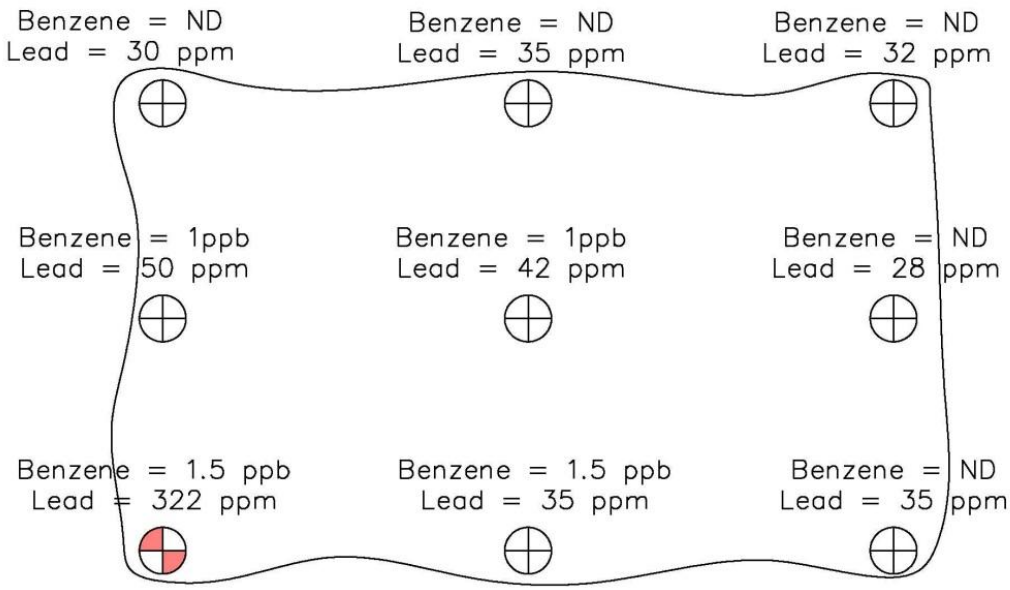
Compliance Averaging – 75%/10x procedure

- Based on PADEP Technical Guidance Manual (June 2002)
- Remedial action stage only
- Applicable to all soil pathways
  - Ingestion/Dermal
  - Inhalation
  - Impact to Ground Water
- Applicability
  - Post-Excavation Soil Sampling
  - Post-Treatment Soil Sampling
  - UST removals with over-excavation

Compliance Averaging – 75%/10x procedure

- Remediation complete if:
  - 75% of all samples are less than applicable remediation standard
  - No sample exceeds applicable remediation standard by 10X
- Minimum 8 post-remedial samples required
  - 8 samples for up to 125 cubic yards excavated soil
  - 12 samples for up to 3,000 cubic yards
  - 12 additional samples for each 3,000 cubic yards thereafter
- All samples used to demonstrate compliance should be collected from appropriate locations

Compliance Averaging – 75%/10x procedure



1) ALL SAMPLES COLLECTED AT 8–8.5 FEET
2) BENZENE UNRESTRICTED USE SOIL REMEDIATION STANDARD = 2 PPB
3) LEAD UNRESTRICTED USE SOIL REMEDIATION STANDARD = 59 PPM
4) BENZENE DETECTION LIMIT = 0.5 PPB

⊕ = SAMPLE LOCATION

◪ = LEAD > STANDARD

Plan View

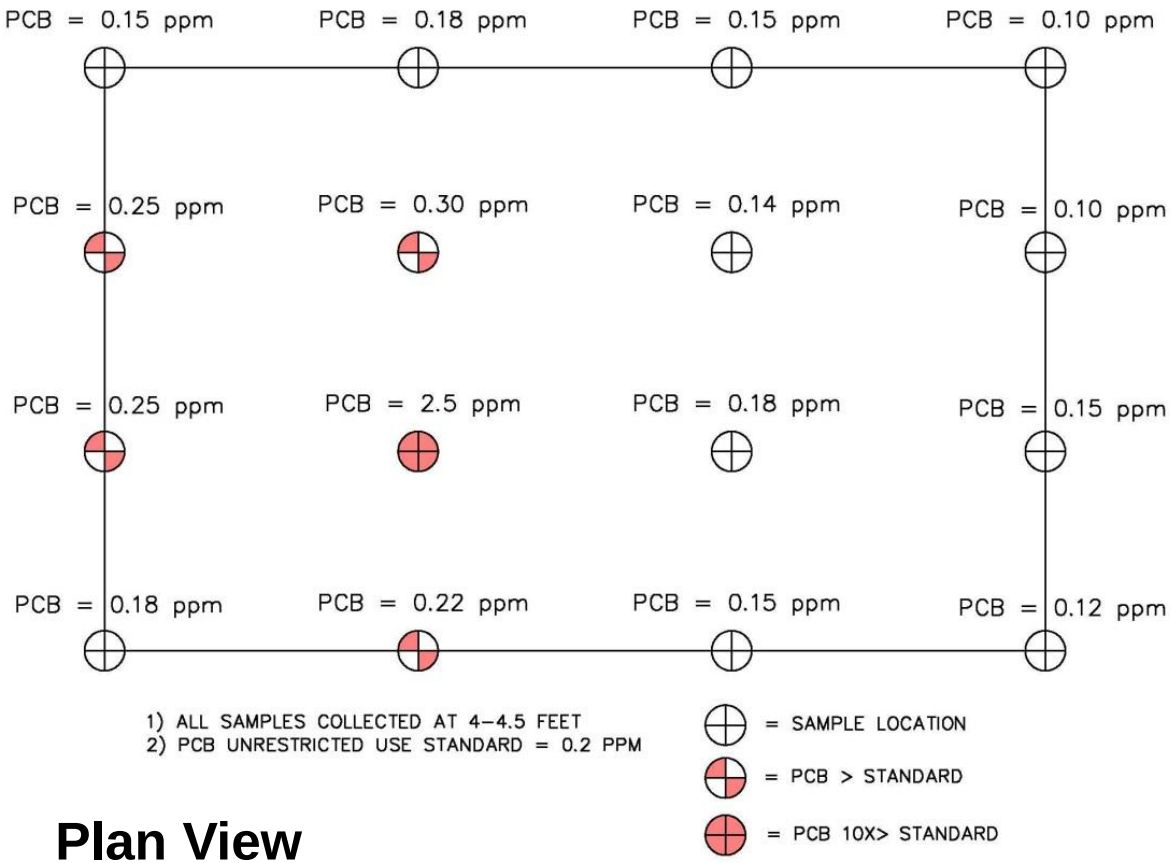
Summary

Benzene: 0/9 > SRS
0/9 10X > SRS

Lead: 1/9 > SRS
0/9 10X > SRS

Therefore, no remediation required

Compliance Averaging – 75%/10x procedure



Plan View

Summary

5/20 > SRS

1/20 10X > SRS

Therefore, based on one PCB concentration >10X SRS, additional remediation is required

Questions?

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  - www.nj.gov/dep/srp/guidance/rs/partition_equation.pdf
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  - www.nj.gov/dep/srp/guidance/rs/petroleum_mixtures.htm
- "Monitored Natural Attenuation Technical Guidance"
  - http://www.nj.gov/dep/srp/guidance/srra/mna_guidance_v_1_0.pdf

Questions?