Applied Technologies For Soil and Groundwater Remediation

Pro. Vision Environmental Engineering Corporation

Web Site : www.pveec.com.tw

Presenter : Joseph Fan GM

Our Vision

Cultivate the Earth's doctors that love and protect the Earth.

Restore the Earth that would be filled with health and happiness.

Accomplish the blessed mission that manage and restore the Earth.

Core Value

- Integrity
- Authenticity
- Certainty
- Solidity

Our Service

- Soil and Groundwater Contamination Investigation and Restoration
- Combined Management of Surface water and Groundwater
  - (1) Aquifer Storage Recovery, ASR Wells
  - (2) Gravity Filtration Through Pounds
- Geophysical Prospecting (None-Destruct Survey)
  - (1) Subsurface Contamination and Waste Investigation
  - (2) Sliding hillside, Colluvium or Alluvium
  - (3) Riverbed and Reservoir Sedimentation

Career Information – Joseph Fan

- BS, Civil Engineering, Tamkang University, Taiwan, 1987
- MS, Environmental Engineering, Colorado State University, 1992
- Life Member of Taiwan Association of Soil and Groundwater Environmental Protection
- Over 26 years experience of Soil and groundwater investigation and remediation
- Directed environmental site assessment projects (Phase I & II, and EHS) for multinational companies.
- Managed several remedial projects for soils contaminated with petroleum hydrocarbons and received closure letters from USA government.
- Managed heat-enhanced bioremediation projects for soils containing crude oils, gasoline, diesel and kerosene.
- Developed the electro-kinetic treatment method for soil and groundwater contamination in porous media having low permeability.
- Managed and performed pilot tests to remove heavy metals from contaminated soil and extract selenium, boron and salts from groundwater.
- Directed and performed numerous in-situ soil and groundwater remediation involving LNAPL and DNAPL clean up, using a combination of biodegradation, heat-enhanced soil venting, air sparging, and electro-kinetic techniques.

Content

Case 1:

Electro-kinetic enhanced bioventing of gasoline in clayey soil

Site Introduction

- A 10,000 gallon of underground storage tank of gasoline was spill, in San Diego, California.
- The soil plume covers an area of about 2,400 ft^2 (220 m^2) and to a depth of about 30 ft (9 m).
- The depth of in surface from 0 to 15 ft (4.5 m) was clay, and the other was conglomerate sandstone.
- The soil was contaminated, but groundwater was not.
- Total gasoline in soil plume is estimate at about 1,000 lbs (455 kg) of gasoline in about 3,200 tones of soil.
- The gasoline concentration in the soil plum range from 100 to 2,200 (ppm) and the target cleanup level was below 100 (ppm).

Problem

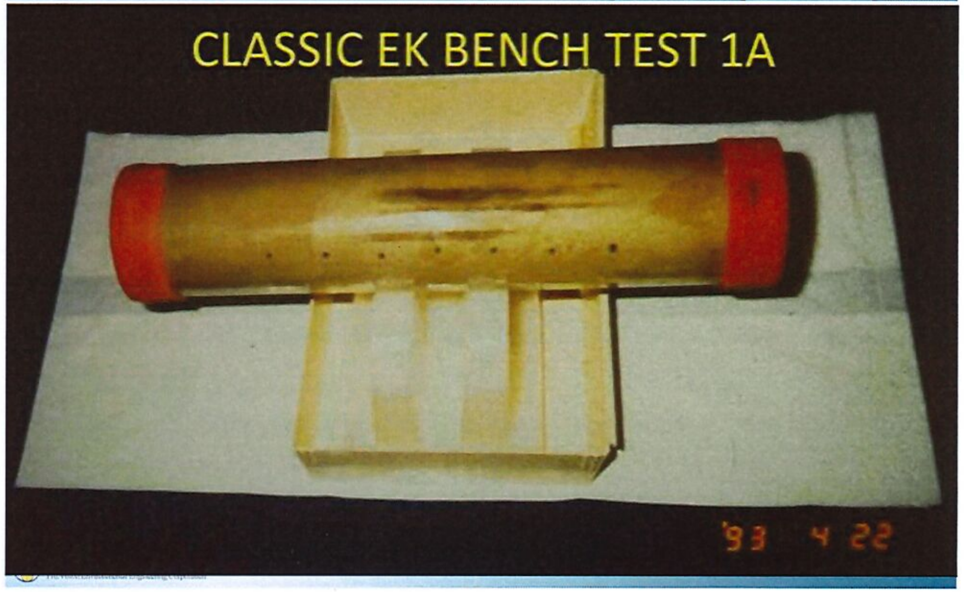
Find problem

- Using open excavation pit was not an economic option.
- The conventional vapor extraction system would not work with the low permeability clay.

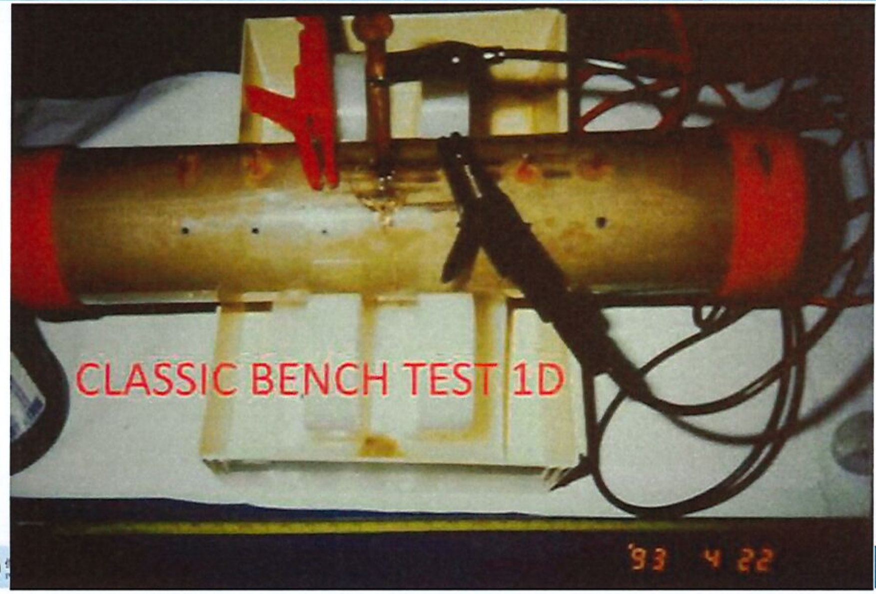
Solve problem

- The electro-kinetic enhanced bioventing method can be applied to treat this clayey soil.
- The electro-kinetic system was operated at electricity flow to dry out the gasoline in clayey soil.
- The technology provides a cost effective and minimum disruption to business operation.

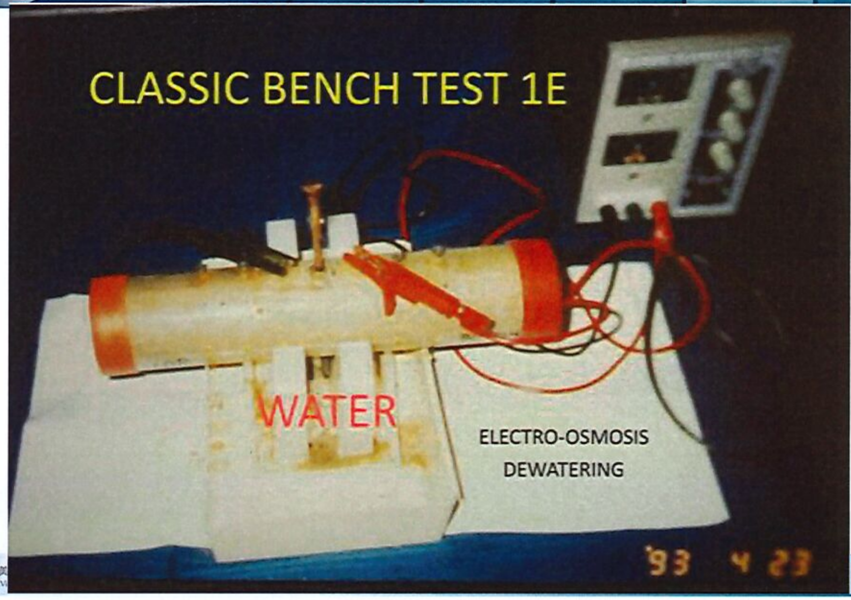
EK Bench Scale Test



EK Bench Scale Test – Cont.



EK Bench Scale Test – Cont.



EK Bench Scale Test – Cont.

EK Bench Scale Test Result

TABLE 1

**BENCH SCALE ELECTROCHEMICAL OXIDATION TEST RESULTS
GASOLINE CONTAMINATED CLAYEY SOIL
PEPBOYS SITE
SAN DIEGO, CALIFORNIA**

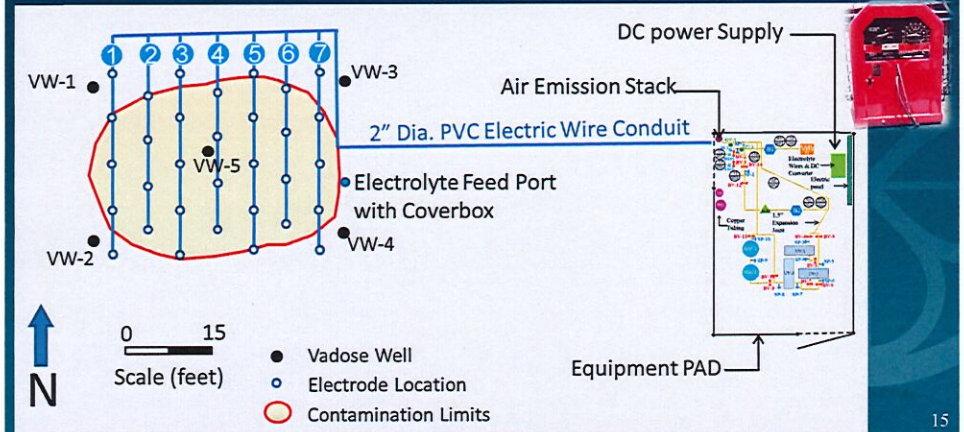
(Units in mg/Kg)

	Initial	After 8 Hours of Treatment EK-1	EK-2	Destruction Efficiency %
TPH AS GASOLINE	230.00	ND(<5)	ND(<5)	97.82+
BENZENE (B)	1.9	ND(<0.005)	ND(<0.005)	99.73+
TOLUENE (T)	6.3	ND(<0.005)	ND(<0.005)	99.92+
ETHYLBENZENE (E)	2.8	ND(<0.005)	ND(<0.005)	99.82+
XYLENES (X)	13.0	ND(<0.005)	ND(<0.005)	99.96+

Remedial System Description

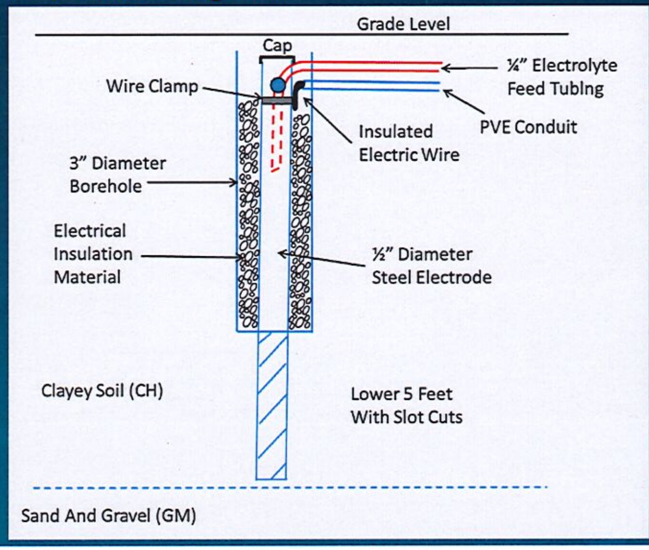
Electro-kinetic Treatment System

- The 39 electrodes was connected to DC power supply.
- Electricity flow was operated at about 5 to 15 ampere.



Remedial System Description

Electro Installation Diagram

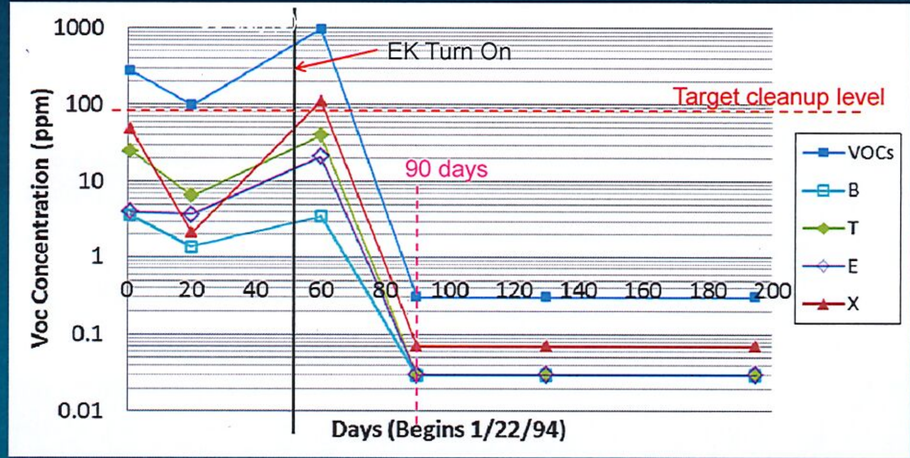


Remedial System Description

Pipe and Equipment Layout

Field Analysis Data

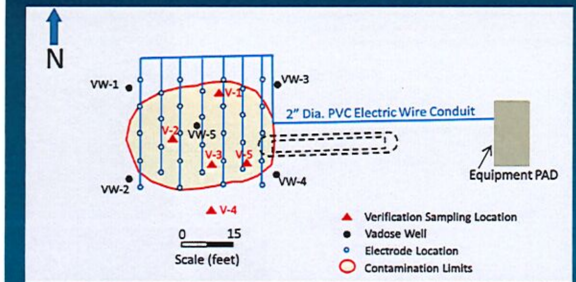
VOCs Concentration



Confirmation Result

Confirmation Drilling

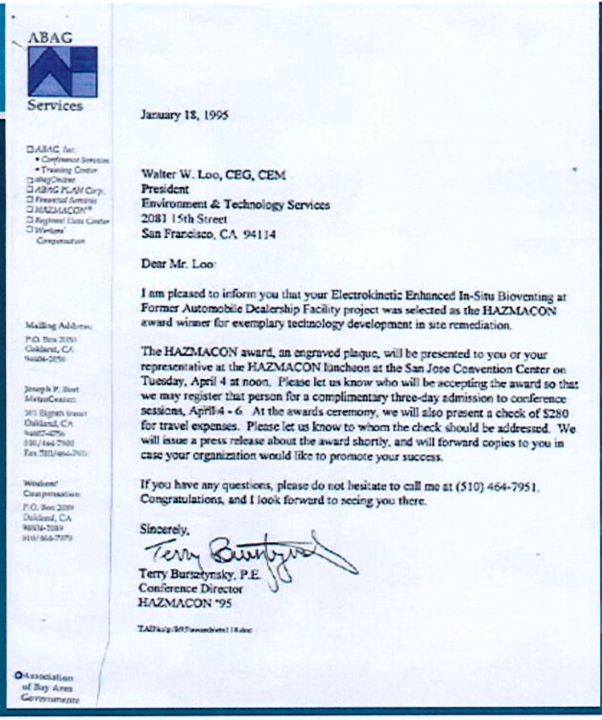
Sampling depth intervals：10, 15, 20, 25, and 30 (ft)



Sample ID	TPH as Gasoline (ppm)	B (ppm)	T (ppm)	E (ppm)	X (ppm)
V1-10'	ND	ND	ND	ND	ND
V1-15'	1.2	0.0079	0.039	0.0098	0.073
V1-20'	ND	ND	ND	ND	ND
V1-25'	ND	ND	ND	ND	ND
V1-26'	ND	ND	ND	ND	ND
V2-1-10'	0.1	0.017	0.013	ND	ND
V2-2-15'	1.7	0.048	0.062	0.015	0.069
V2-3A-20'	ND	ND	ND	ND	ND
V2-3B-20'	ND	ND	ND	ND	ND
V2-4-26'	ND	ND	ND	ND	ND
V2-5-30'	ND	ND	ND	ND	ND
V3-1-10'	ND	ND	ND	ND	ND
V3-2-15'	170	1	9	3.5	19
V3-3-20'	220	ND	1	2.5	18
V3-4-31'	290	0.22	1.8	2.7	15
V4-1-10'	ND	ND	ND	ND	ND
V4-2-15'	1.3	0.033	0.15	0.03	0.22
V4-3-20'	4.4	0.047	0.3	0.099	0.72
V4-4A-25.5'	12	ND	ND	ND	ND
V4-4B-25.5'	11	ND	0.0087	0.05	0.42
V5-1A-10'	ND	ND	ND	ND	ND
V5-1B-10'	0.28	ND	ND	ND	ND
V5-2A-15'	126	3.6	11	1.2	6.6
V5-2B-15'	3.4	ND	0.09	0.046	0.27
V5-3-20'	14	ND	0.14	0.1	0.69
V5-4-26	98	0.0085	1.4	1.6	12
Average	36.707	0.156	0.964	0.458	2.815

Conclusion

- Two 120 cfm explosion proof blowers were operated with 35~70 cfm
- The remediation effort was completed about 90 days.
- The average concentration was below the proposed cleanup level 100 ppm.
- The cost of treatment is about $50 per ton.
- The technology provides a cost effective and minimum disruption to business to operation.



ABAG Services

January 18, 1995

Walter W. Loo, CEG, CEM
President
Environment & Technology Services
2081 15th Street
San Francisco, CA 94114

Dear Mr. Loo:

I am pleased to inform you that your Electrokinetic Enhanced In-Situ Bioventing at Former Automobile Dealership Facility project was selected as the HAZMACON award winner for exemplary technology development in site remediation.

The HAZMACON award, an engraved plaque, will be presented to you or your representative at the HAZMACON luncheon at the San Jose Convention Center on Tuesday, April 4 at noon. Please let us know who will be accepting the award so that we may register that person for a complimentary three-day admission to conference sessions, April 4 - 6. At the awards ceremony, we will also present a check of $280 for travel expenses. Please let us know to whom the check should be addressed. We will issue a press release about the award shortly, and will forward copies to you in case your organization would like to promote your success.

If you have any questions, please do not hesitate to call me at (510) 464-7951. Congratulations, and I look forward to seeing you there.

Sincerely,

Terry Burszytynsky, P.E.
Conference Director
HAZMACON '95

Association of Bay Area Governments

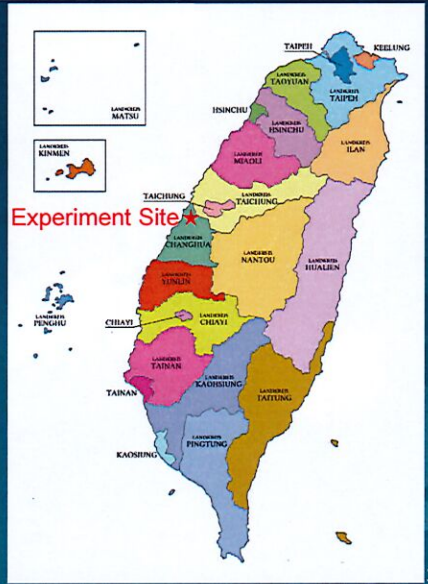
Case 2 :

Electro-kinetic Enhanced Soil Washing For Heavy Metals Contaminated Soil

Soil Washing and EK for Heavy Metals – Vandenberg Air Force Base, CA

Site Introduction

- The experiment site was in Changhua county, Taiwan.
- The site was heavy metal contaminated farmland.
- The contaminants were Cd, Cr and Pb.

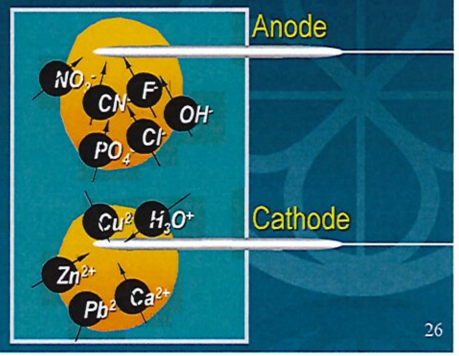


Electro-kinetic Methodology

- Desorption of Heavy Metals :

$$[\text{soil}]\text{-}Cd^{2+},\ Pb^{2+} + \text{Acid} \longrightarrow [\text{soil}]\text{-}H^{+},\ H^{+} + Cd^{2+} + Pb^{2+} + Cl^{-}$$

- Electro-kinetic :
  - Electrophoresis
  - Electro-osmosis
  - Electrolysis
  - Ion Exchange

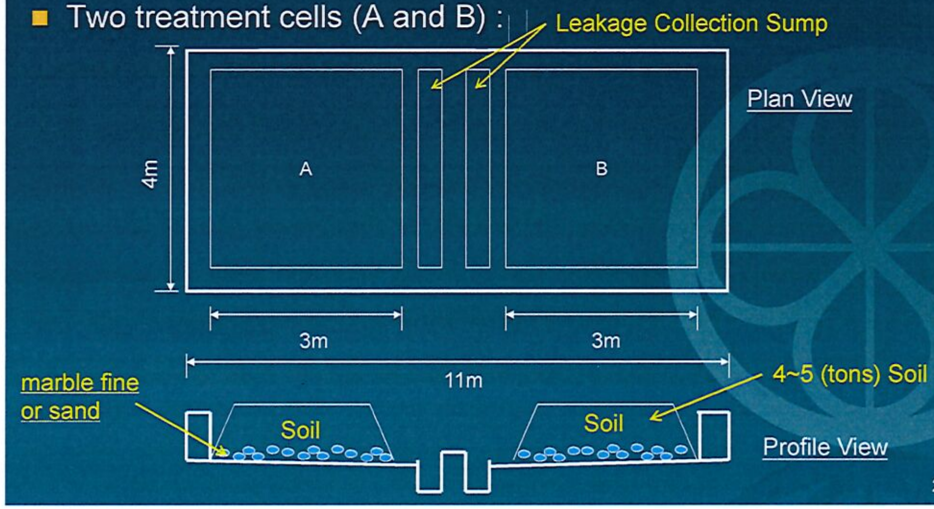


Electro-kinetic Methodology

- Electrophoresis is the motion of dispersed particles relative to a fluid under the influence of a spatially uniform electric field.
- Electro-osmosis is the motion of liquid induced by an applied potential across a porous material, capillary tube, membrane, microchannel, or any other fluid conduit.
- Electrolysis is a technique that uses a DC current to drive an otherwise non-spontaneous chemical reaction.
- Ion Exchange is an exchange of ions between two electrolytes or between an electrolyte solution and a complex.

Experimental Layout

- Study of electro-kinetic Enhanced Soil Washing for heavy metals contaminated soil
- Two treatment cells (A and B) :



Field Construction

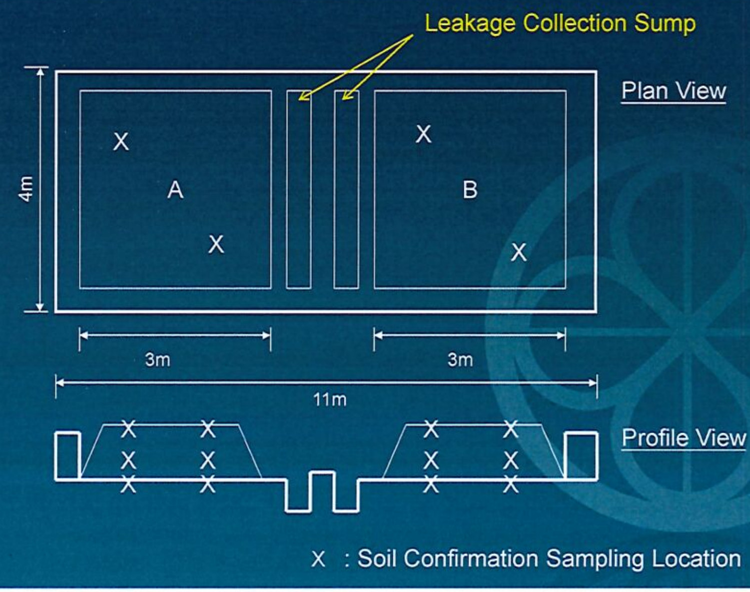
Treatment Cell Construction

29

Covered with Plastic Sheet

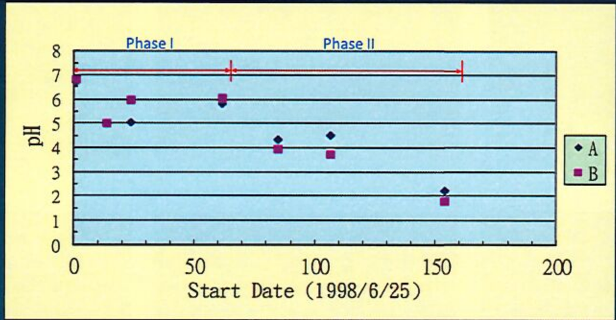
Leakage Collection Sump

Confirmation Sampling



Result of Experiment

pH



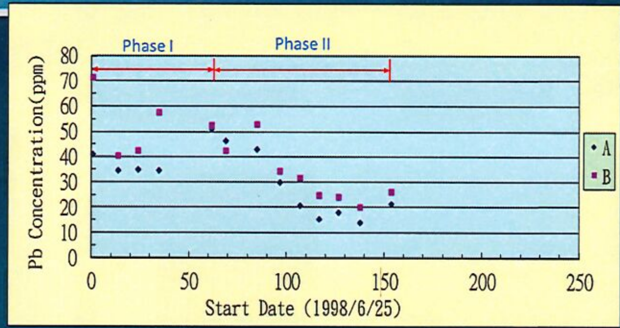
Pb	Phase I			Phase II			
Date	6/26	7/8	7/18	8/25	9/17	10/9	11/25
AC-1	6.80	3.82	3.80	5.89	3.57	4.51	1.48
AC-2	6.70	4.96	2.00	5.75	4.83	4.78	2.56
AC-3	6.60	6.16	6.20	5.72	4.55	4.22	2.56
Ave.	6.70	4.98	4.00	5.79	4.32	4.50	2.20
BC-1	6.70	3.18	6.10	5.67	2.74	3.02	1.19
BC-2	6.70	5.77	5.80	6.27	3.91	3.72	1.77
BC-3	6.90	6.01	5.90	6.16	5.14	4.29	2.33
Ave.	6.77	4.99	5.93	6.03	3.93	3.68	1.76

Result of Experiment

0.1 N HCL
→Pb

Aqua Regia =
4~5 x 0.1 N
HCL

90 → 30 ppm



Pb
Cleanup
Level
For Farm
Land
500 PPM
Aqua
Regia

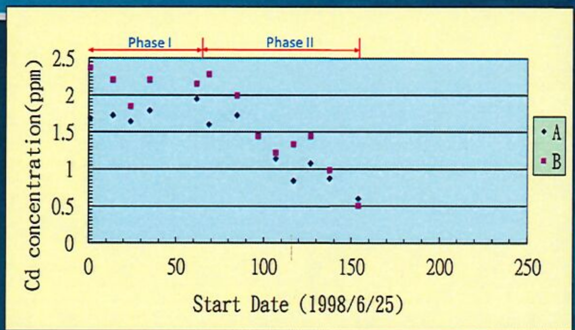
Pb	Phase I					Phase II									Removal (%)	Total Removal(%)
Date	6/26	7/8	7/18	7/29	Removal(%	8/25	9/1	9/17	9/29	10/9	10/19	10/29	11/9	11/25		
AC-1	22.36	13.76	10.70	13.78	38.36	17.62	5.93	13.17	12.95	9.14	9.09	11.92	8.25	6.18	64.93	72.36
AC-2	19.48	15.13	9.62	14.07	27.80	18.94	6.89	16.93	26.34	11.96	11.66	16.38	11.0	7.99	57.81	58.98
AC-3	20.22	14.61	9.71	17.21	14.90	17.54	6.34	18.20	17.33	13.13	11.49	15.46	13.0	8.54	51.32	57.76
Ave.	20.69	14.50	10.01	15.02	27.40	18.03	6.39	16.10	18.87	11.41	10.75	14.59	10.7	7.57	58.02	63.41
BC-1	25.45	8.95	9.08	10.75	57.78	12.98	13.4	12.34	16.79	10.23	9.19	11.83	5.33	4.09	68.49	83.93
BC-2	23.30	14.40	10.40	11.69	49.85	17.88	3.46	13.12	17.75	12.66	12.09	14.89	11.4	6.26	64.98	73.13
BC-3	27.66	15.96	13.80	13.02	52.95	15.66	5.02	14.19	18.25	18.52	12.40	15.46	10.7	7.21	53.97	73.93
Ave.	25.47	13.10	11.09	11.82	53.61	15.51	3.96	13.22	17.60	13.8	11.14	14.06	9.20	5.85	62.25	77.02

Result of Experiment

0.1 N HCL
→Cd

Aqua Regia =
4~5 x 0.1 N
HCL

10 → 3 ppm



Cd Cleanup
Level
For Farm
Land
5 PPM
Aqua Regia

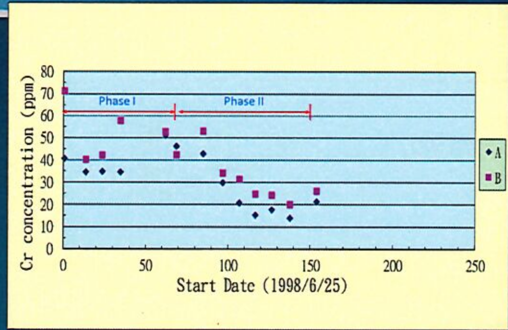
Cd	Phase I					Phase II									Removal (%)	Total Removal(%)
Date	6/26	7/8	7/18	7/29	Removal(%	8/25	9/1	9/17	9/29	10/9	10/19	10/29	11/9	11/25		
AC-1	1.84	1.56	1.44	1.11	39.84	1.85	1.33	1.40	0.83	0.77	0.64	0.27	0.4	0.26	85.91	85.87
AC-2	1.56	1.90	1.61	2.09	0.00	2.14	1.48	1.94	1.67	1.36	1.02	1.38	1.2	0.72	66.37	53.85
AC-3	1.65	1.69	1.87	2.18	0.00	1.86	1.95	1.82	1.85	1.29	0.87	1.56	0.9	0.79	57.55	52.12
Ave.	1.68	1.72	1.64	1.79	0.00	1.95	1.59	1.72	1.45	1.14	0.84	1.07	0.8	0.59	69.73	64.95
BC-1	2.28	1.73	1.24	1.11	51.18	1.91	1.61	1.49	0.67	0.45	0.41	0.64	0.2	0.12	93.72	94.74
BC-2	2.06	2.41	1.75	2.41	0.00	2.37	2.46	1.89	1.66	1.46	1.65	2.02	1.0	0.50	78.91	75.73
BC-3	2.74	2.47	2.54	3.08	0.00	2.17	2.75	2.58	1.97	1.73	1.93	1.65	1.5	0.89	58.99	67.52
Ave.	2.36	2.20	1.84	2.20	6.84	2.15	2.28	1.99	1.43	1.21	1.33	1.44	0.9	0.50	76.6	78.67

Result of Experiment

0.1 N HCL
→Cr

Aqua Regia =
4~5 x 0.1 N
HCL

260 → 105 ppm



Cr Cleanup
Level For
Farm Land
250 PPM
Aqua Regia

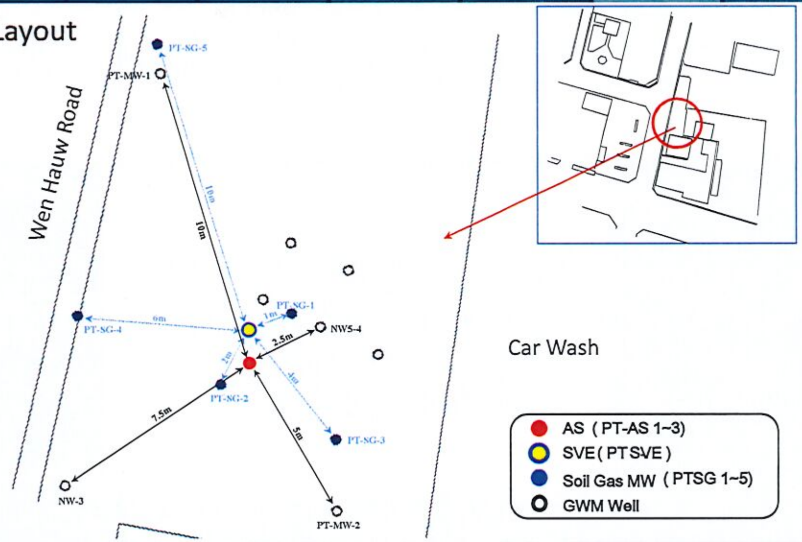
Cr	Phase I					Phase II									Removal (%)	Total Removal(%)
Date	6/26	7/8	7/18	7/29	Removal(%	8/25	9/1	9/17	9/29	10/9	10/19	10/29	11/9	11/25		
AC-1	51.46	44.02	47.10	52.76	0.00	48.80	3.52	30.33	22.67	16.97	11.08	11.29	11.5	27.23	44.20	47.09
AC-2	32.74	30.70	29.90	26.09	20.31	55.29	5.19	49.73	32.65	17.58	16.75	15.14	13.4	16.02	71.02	51.07
AC-3	37.62	28.40	27.20	24.57	34.69	48.98	9.34	48.32	33.99	27.44	17.55	26.75	16.4	19.99	59.16	46.86
Ave.	40.61	34.37	34.73	34.47	15.1	51.01	6.02	42.79	29.77	20.66	15.13	17.73	13.8	21.08	58.68	48.09
BC-1	69.60	46.38	43.80	64.63	7.14	37.04	1.81	52.03	30.69	23.75	18.62	28.77	20.4	20.72	44.05	70.23
BC-2	57.49	34.38	31.50	41.48	27.85	65.75	1.22	53.80	30.75	28.40	27.49	21.56	18.7	28.35	56.88	50.69
BC-3	86.20	39.19	50.70	66.27	23.12	54.26	3.23	52.15	40.60	41.64	27.75	21.61	19.9	28.82	46.89	66.57
Ave.	71.1	39.98	42.00	57.46	19.18	52.35	2.09	52.66	34.01	31.27	24.62	23.98	19.6	25.96	50.40	63.48

Conclusion

- The lower pH 2~3 in soil could be more effective desorption of heavy metals.
- Adding the desorbent could increase desorption heavy metal contaminants in soil and improved soil fertility.
- Exchanging the cathode and anode could increase desorption Cr elements in soil.
- The remediation experiment was completed about 90 days.

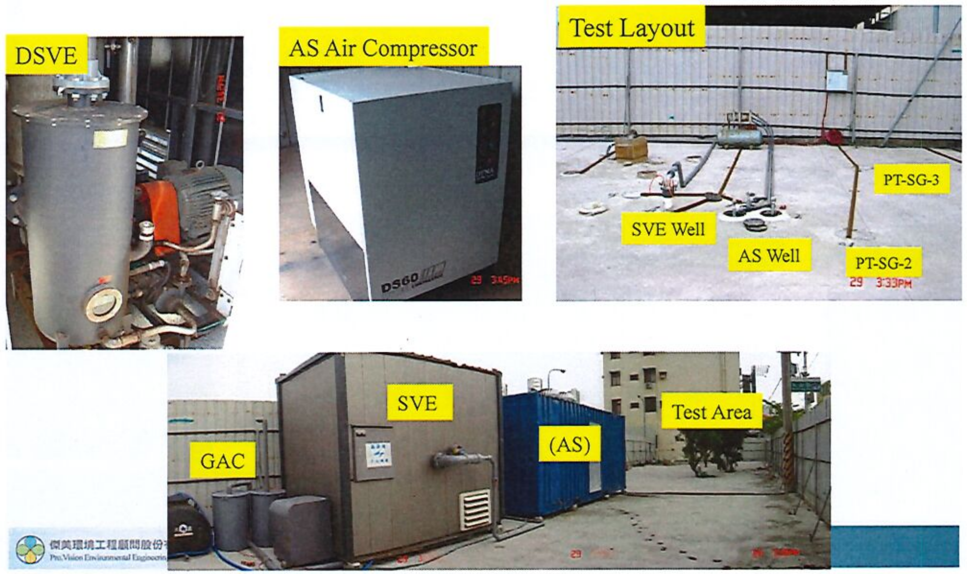
EK Remediation Case 3 -
In-Situ Bioremediation with EK for TPH Contam. GW

Pilot Test Layout

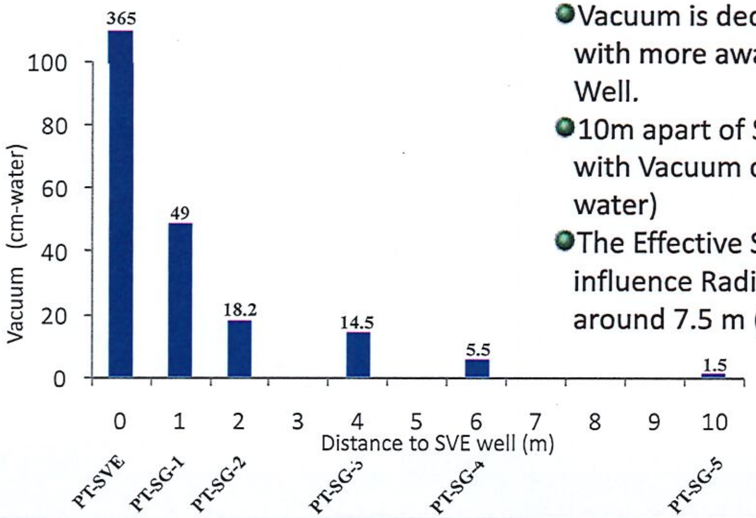


Site Preparation

Remediation Equipment

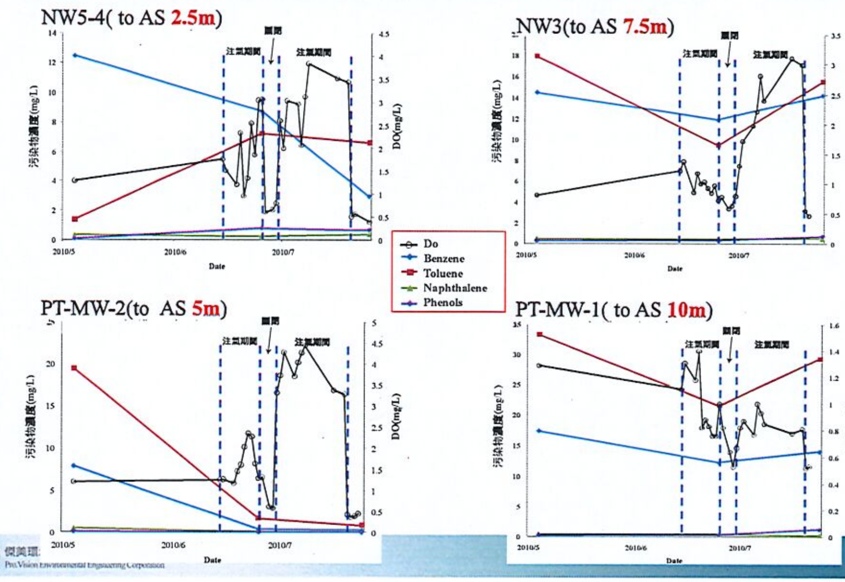


Single Well Test - SVE

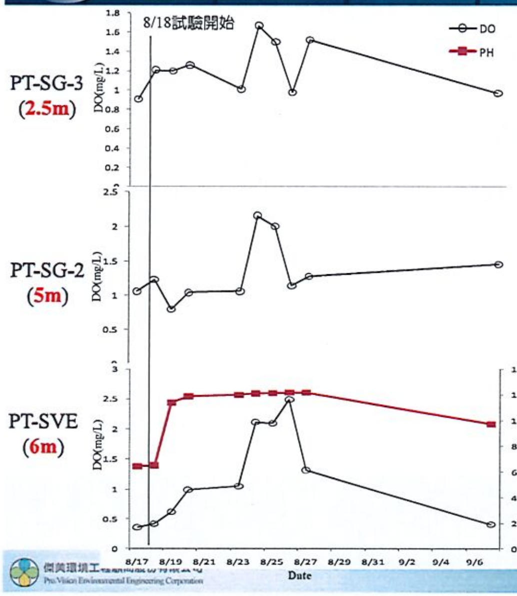


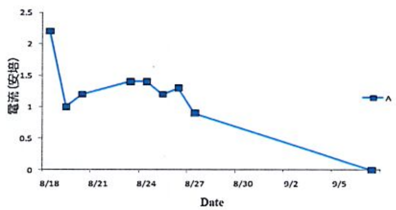
- Vacuum is decreased with more away of SVE Well.
- 10m apart of SVE Well with Vacuum of 1.5 (cm-water)
- The Effective SVE influence Radius is around 7.5 m (cm-water)

Single Well Test - AS



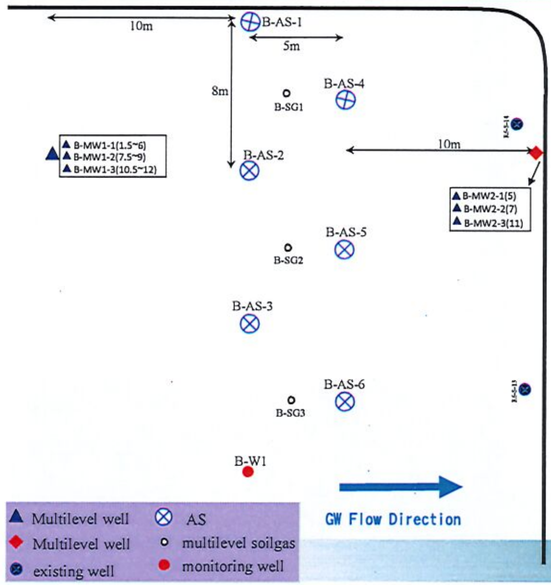
Single Well Test - EK





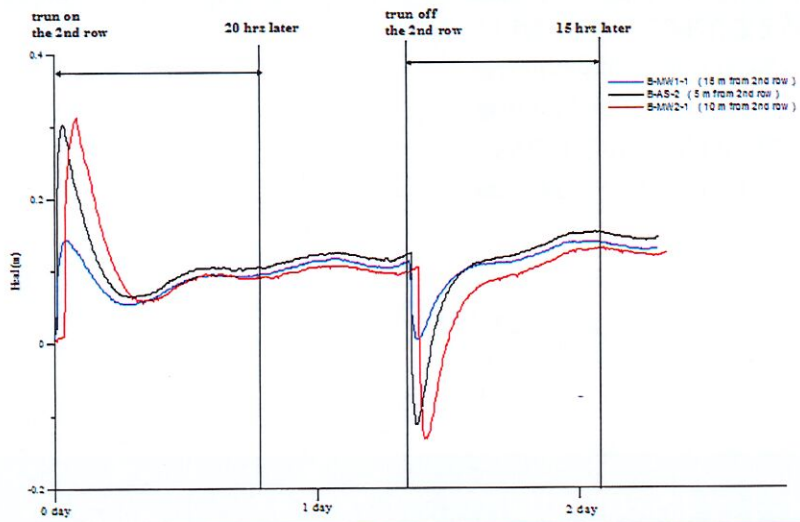
- PT-MW-2 is Anode(+), PT-SVE is Cathode, 6m apart.
- Anode injected ORC
- GW velocity was 0.45~1.85 m/yr , 6m needed 3.2 years
- Cathode DO was increased after EK turned on.

LNAPL Remediation Case 4 – Air Sparging Curtain For Refinery

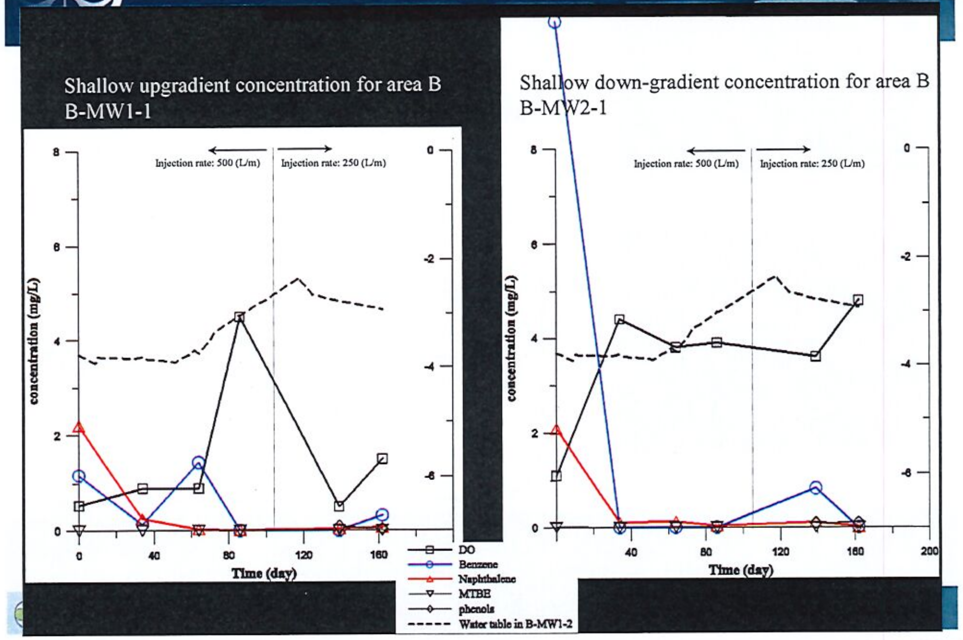


Operating Plant

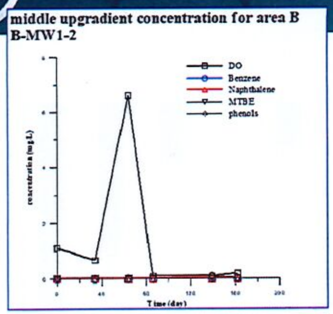
Groundwater Table Measuring

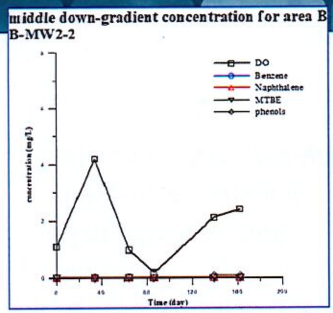


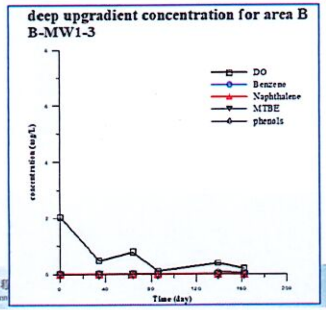
GW Analysis Results – Upper Level

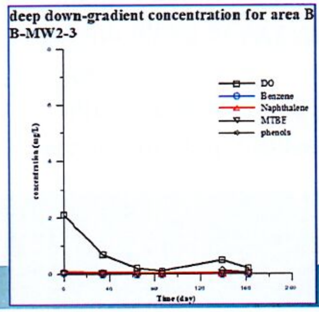


GW Analysis Results – Middle & Lower Levels









Thank You !

APOLLO TECH
Apollo Technology Co., Ltd.

Soil Washing Treatment for Mercury Contaminated Site

Speaker:
Jen-Chou Lu

APOLLO TECH

Outline

1. Background
2. Treatment Technologies for Mercury
3. Soil Washing Treatment for An-Shun Site
4. Summary

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1 Background

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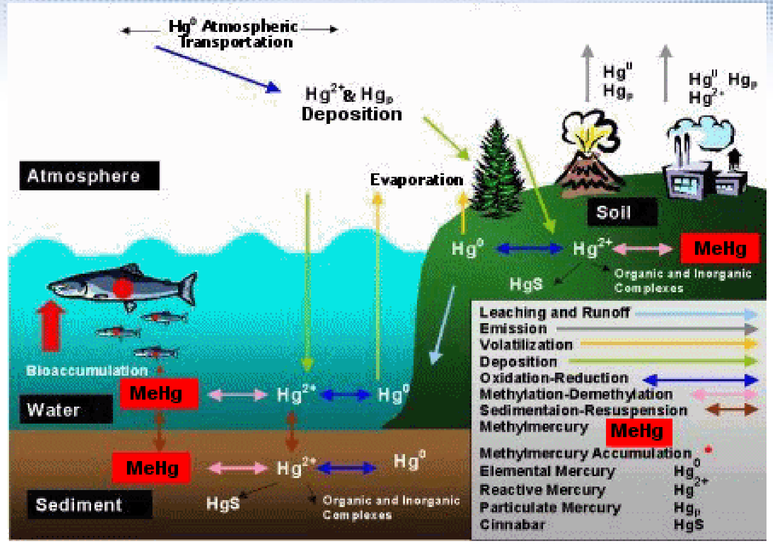
Properties of Mercury

- Industrial facilities use mercury in their processes / products such as chlor-alkali plants/ battery, thermometers, barometers, fluorescent light.
- Mercury has high toxicity, volatility and is tendency to bio-accumulate in human body. It is the most hazardous metal for human health and environment
- It is now in such disfavour that an international treaty exists to curb its use.

Conceptual Mercury Cycle



Ref: Environment Canada http://www.ec.gc.ca/mercure-mercury/default.asp?lang=En&n=67E16201-1

4

An-Shun Site

Taiwan, Tainan

An-Shun

Ref: CPDC, Remediation of CPDC An-shun Site: An Introduction

6

Site History

- **1940-1944 (World War II)**
- Owner: Japan Kaneka Soda Co., Ltd.
  日本鐘淵曹達株式會社
- Object: Supply Military material
  (Use Soda to dissolve Aluminum)
  (Use Bromine as anti-knock agent)
- Factory: Salt land 600 Ha
  Bromine Plant 500kg/D
  NaOH Plant 100T/D (Mercury electrode)
- Construction: 1940-1944
- Operation: 1944
- Shut down: 1944/10 (ruined by US Air force Bomb)

Ref: CPDC, Remediation of CPDC An-shun Site: An Introduction

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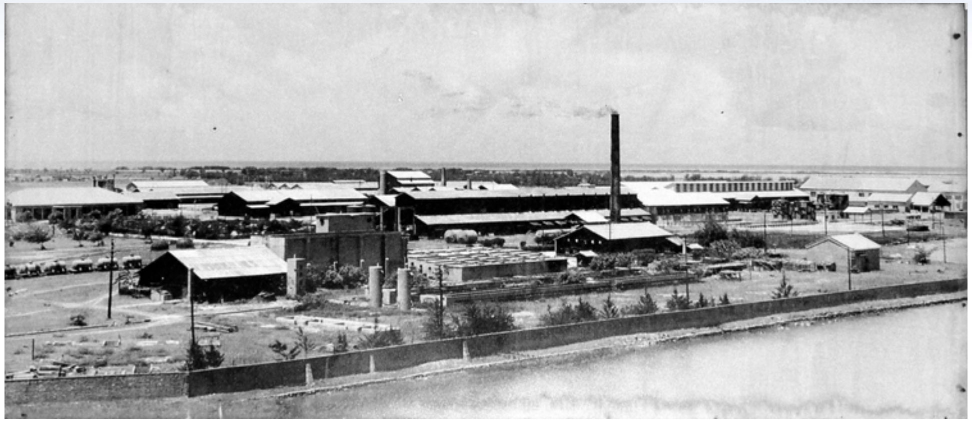
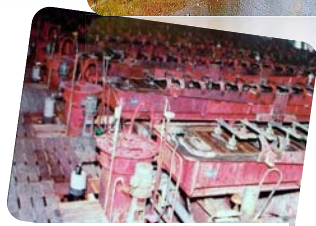
Site History

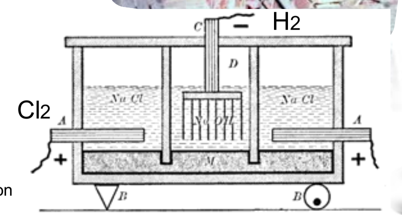


Ref: CPDC, Remediation of CPDC An-shun Site: An Introduction

Site History

- **1945-1964 (Mercury Pollution)**
- Owner: Taiwan Soda Company
- Factory: NaOH Plant 50T/D (Mercury electrode)
- Product: 45% Soda solu. / Flake soda Liq.CL_2 / H^2 / $NaClO_3$ Solu. / HCl Solu.
- Reconstruction: 1946
- Operation: 1946 - 3T/D
  1964 - 100T/D





Ref: CPDC, Remediation of CPDC An-shun Site: An Introduction
Wikipedia,: Castner–Kellner process

Site History

- **1964-1982 (Mercury / PCP Pollution)**
- Owner: Taiwan Soda Company
- Factory: NaOH Plant 50T/D (Mercury electrode)
  Pentachlophenol plant 5T/D
- Product: 45% Soda solu. / Flake soda Liq.CL_2 / H^2 / $NaClO_3$ Solu. / HCl Solu.
  Na-PCP
- Shut down: 1982.07
  (Mercury Pollution Problem)

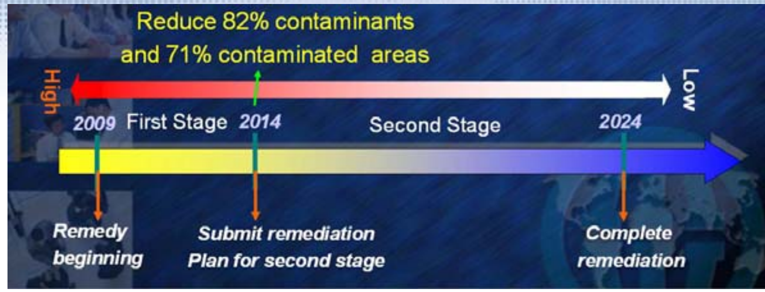
Ref: CPDC, Remediation of CPDC An-shun Site: An Introduction

Site History

- **1983-2009 (Mercury / PCP)**
- Owner: China Petrochemical Develop. Company (CPDC)
  Before 1993 CPDC State-run
  After 1993 CPDC Private
- Remediation:
  - 1989 PCP-polluted groundwater remediation
  - 2003 An investigation of Dioxin
  - 2003 promulgated as Remediation Site
  - 2008 Court judged CPDC's responsibility
  - 2009 Remediation plan was approved by Tainan government, and started since May, 2009

Ref: CPDC, Remediation of CPDC An-shun Site: An Introduction

Remediation Plan 2009-2024



Ref: CPDC, Remediation of CPDC An-shun Site: An Introduction

- **Remediation Criteria** promulgated in 2003
- **Soil**
  - Dioxin < 1000 ng-I-TEQ/KG Hg < 20 mg/kg
- **Sediment**
  - Dioxin < 150 ng-I-TEQ/KG Hg < 1 mg/kg

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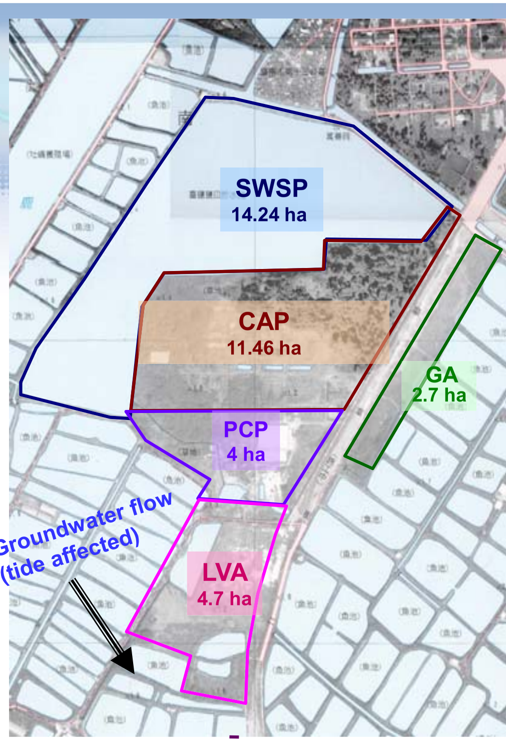
An-Shun Site



SWSP, Sea water storage pond
CAP, Chlor-alkali plant area
PCP, Pentachlorophenol-plant area
LVA, Lime vegetation area
GA, Grass area

Soil & sediment polluted:
37.1 ha
Contaminated soil/sediment:
288,000M³

Target contaminants:
Mercury, Dioxin
(and also Pentachlorophenol)

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Site History

Ref: CPDC, Remediation of CPDC An-shun Site: An Introduction

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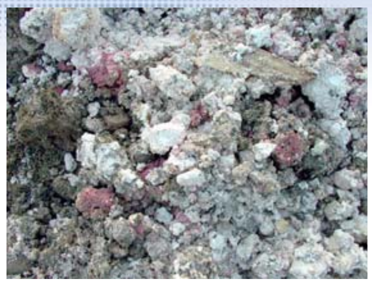
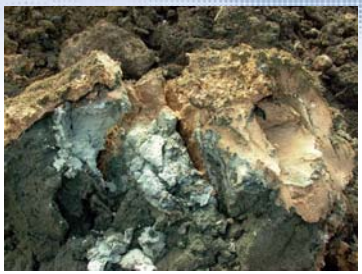
Site History

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Site History

Ref: CPDC, Remediation of CPDC An-shun Site: An Introduction

How to clean up?

How to treat?

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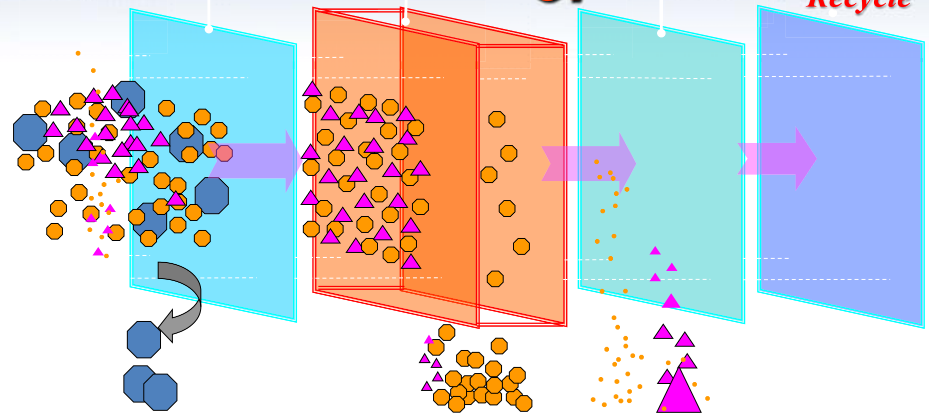
2 Treatment Technologies For Mercury

Treatment Technologies For Mercury

Technology	Description
Solidification / Stabilization	Physically binds or encloses contaminants within a stabilized mass and chemically reduces the hazard potential of a waste by converting the contaminants into less soluble, mobile, or toxic forms.
Soil Washing / Acid Extraction	Uses the principle that some contaminants preferentially adsorb onto the fines fraction of soil. The soil is suspended in a wash solution and the fines are separated from the suspension, thereby reducing the contaminant concentrations in the remaining soil. Acid extraction uses an extracting chemical, such as hydrochloric acid or sulfuric acid.
Thermal Desorption / Retorting	Application of heat and reduced pressure to volatilize mercury from the contaminated medium, followed by conversion of the mercury vapors into liquid elemental mercury by condensation. Off-gases may require further treatment through additional air pollution control devices such as carbon units.

Ref: U.S. EPA, Treatment Technologies For Mercury in Soil, Waste, and Water, 2007

Soil Washing



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3 Soil Washing Treatment for An-Shun Site

Soil Washing Treatment Proposal for An-Shun Site

Hg	Dioxin
< 200 mg/kg	< 1,000
Soil / Sediment	

→ Washing → Thermal → Treated soil

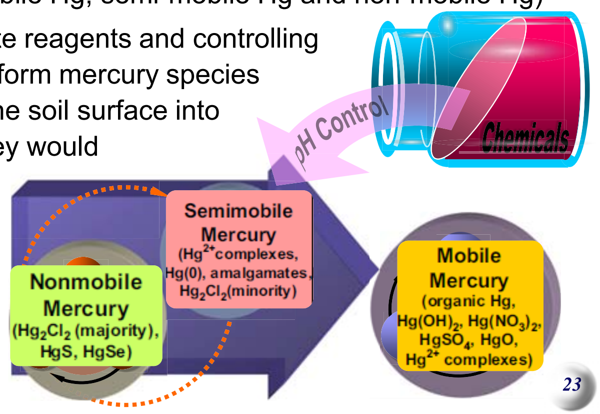
Washing → Treated soil

Contaminated soil

- With the limited available storage space at An-shun site, China Petrochemical Development Corporation (CPDC) was considering economical and efficient methods for soil treatment.
- Soil with low mercury concentration and with dioxin below regulation standard is targeted for priority treatment.
- The goal is to reduce the amount of soil required for thermal treatment or more complicated treatment in the future, in hope to reduce the overall remediation cost for soil treatment.

Experimental Study

- Interpreting the mercury speciation in soil
- Implementing a sequential extraction process of different operationally defined fractions (mobile Hg, semi-mobile Hg and non-mobile Hg)
- Applying the adequate reagents and controlling the pH value to transform mercury species that are adhered to the soil surface into mercury complex, they would dissolve in the water



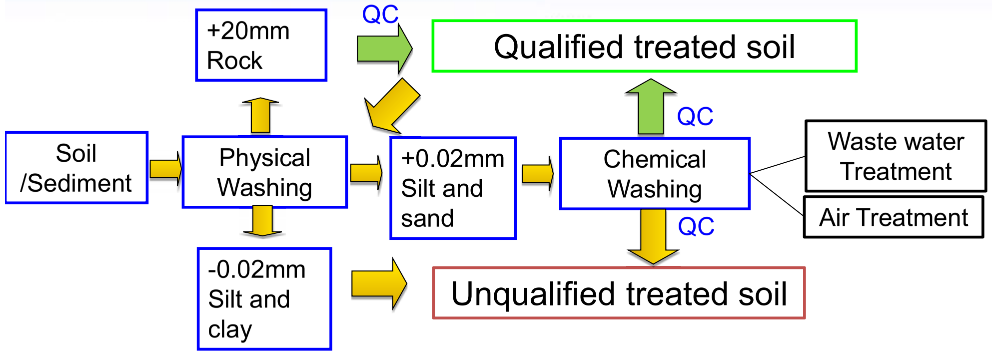
Lab test results

Samples	Mobile Hg (mg/kg)		Semimobile Hg (mg/kg)		Nonmobile Hg (mg/kg)	
	Conc.	%	Conc.	%	Conc.	%
Sea pond B	12.27	13%	30.82	34%	49.24	53%
Sea pond B	13.32	13%	30.66	31%	56.58	56%
Sea pond B	23.35	8%	138.9	51%	115.1	41%
Alkali-chloro area	11.66	22%	30.91	58%	11.07	20%
Grass area	5.37	15%	28.17	79%	2.06	6%
Grass area	3.42	10%	27.40	81%	3.00	9%

After washing

Samples	Mobile Hg (mg/kg)		Semimobile Hg (mg/kg)		Nonmobile Hg (mg/kg)	
	Conc.	%	Conc.	%	Conc.	%
Sea pond B	0.62	4%	14.31	85%	1.83	11%
Sea pond B	1.88	13%	10.62	72%	2.29	15%
Sea pond B	7.61	57%	4.37	33%	1.38	10%
Alkali-chloro area	2.93	56%	1.71	33%	0.61	12%
Grass area	4.77	43%	5.73	52%	0.53	5%
Grass area	4.09	46%	4.47	50%	0.34	4%

Soil washing treatment process



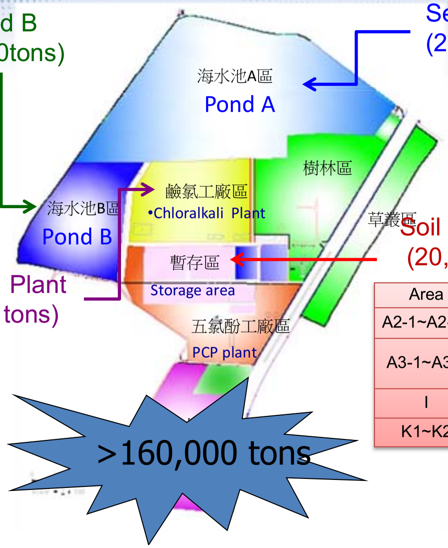
Quantities of Mercury Contaminated Soil / Sediment

Sediment from Pond B
(34,000 m³，54,000tons)

Depth (cm)	Volume(m³)
0-30	9,200
30-60	6,250
60-90	6,250
90-150	7,000
150-210	5,300

Soil from Chloralkali Plant
(30,000 m³，48,000 tons)

Depth (cm)	Volume (m³)
0-50	12,000
50-100	8,000
100-150	4,000
150-200	4,000
200-250	2,000



Sediment from Pond A
(21,000 m³，34,000tons)

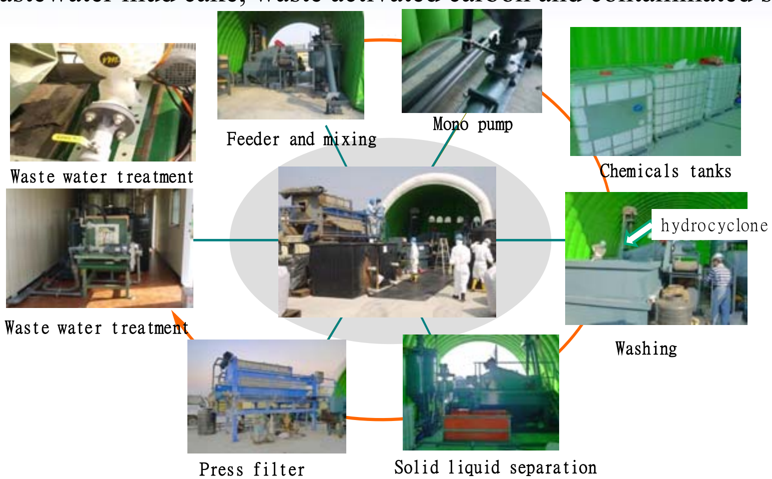
Depth (cm)	Volume (m³)
0-30	21,000
30-60	0
30-90	0

Soil from Storage space
(20,000 m³，32,000tons)

Area	Sources	Volume (m³)
A2-1~A2-12	Chloralkali Plant	10,000
A3-1~A3-7	Chloralkali Plant	5,500
I	Grass Area	500
K1~K2	Grass Area	4,000

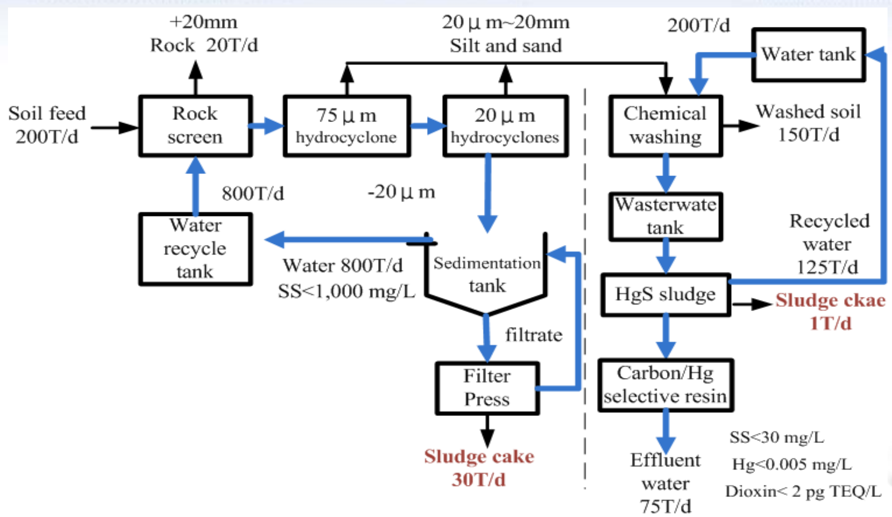
The Feasibility Study – A Pilot Test

15 tons of mercury contaminated soil was treated by soil washing. The percentage of qualified treated soil is 78%. The unqualified soil includes wastewater mud cake, waste activated carbon and contaminated soil.

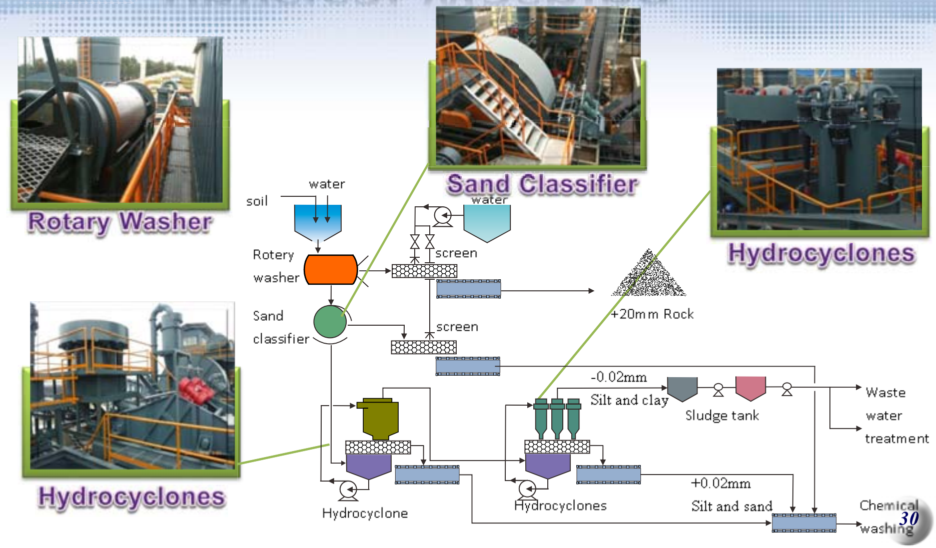


Building Soil Washing Plant

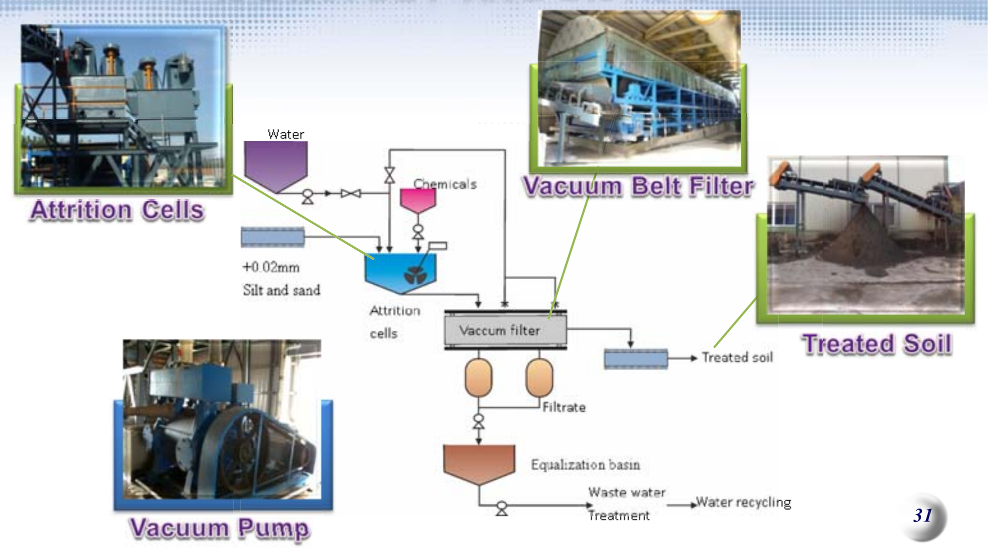
Soil Washing Treatment Process

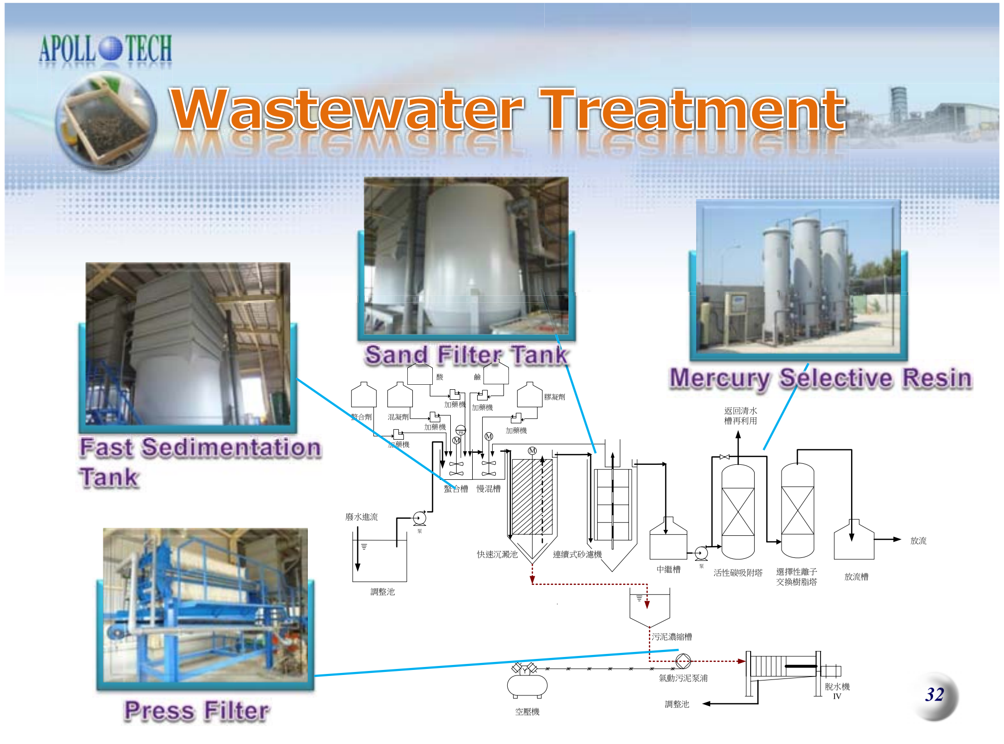


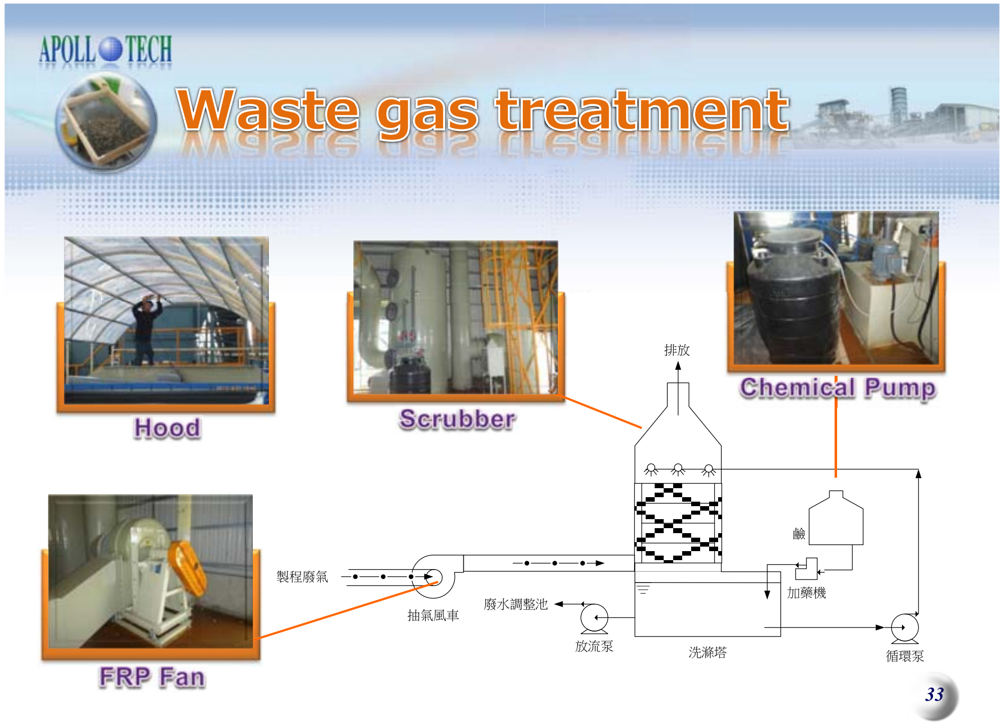
Soil Washing – Physical Washing



Soil Washing – Chemical Washing




APOLLOTECH
Wastewater Treatment
Sand Filter Tank
Mercury Selective Resin
Fast Sedimentation Tank
Press Filter
廢水進流
調整池
快速沉澱池
連續式砂濾機
中繼槽
活性碳吸附塔
選擇性離子交換樹脂塔
放流槽
放流
返回清水槽再利用
污泥濃縮槽
氣動污泥泵浦
空壓機
脫水機
32


APOLLOTECH
Waste gas treatment
Hood
Scrubber
Chemical Pump
FRP Fan
排放
製程廢氣
抽氣風車
廢水調整池
放流泵
洗滌塔
鹼
加藥機
循環泵
33


APOLLOTECH
Sediment Transport
Dredging Boat
GPS System
Cutter Suction
Pipeline on the pond
Pipeline on the ground
Feed location
34


APOLLOTECH
Quality Control
Field XRF
Portable XRF
MA-3000 mercury analyzer
EMP-2 mercury vapor analyzer

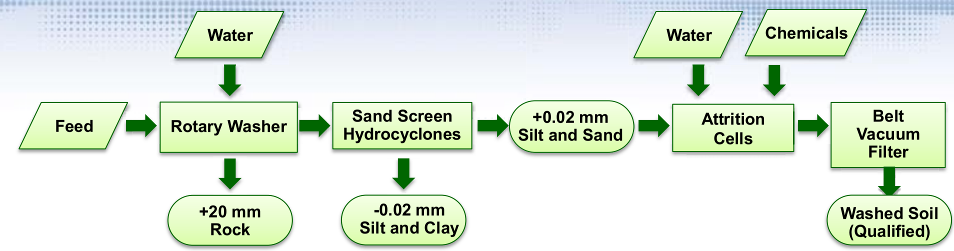
Project Flow Chart

1. Preparation
   - Experimental study（2010.3～2010.12）
   - Pilot test（2011.3）
   - Soil washing treatment proposal → EPB authorized
   - Building Plant （2012.5）
   - Commissioning （2012.8）← Proposal approval
   - Results verified

2. Full scale treatment (4,000 tons/month) ← Inspection
   - Soil Washing treatment
   - Pollution control and monitoring
   - Quality control and verification

3. Treated soil verification

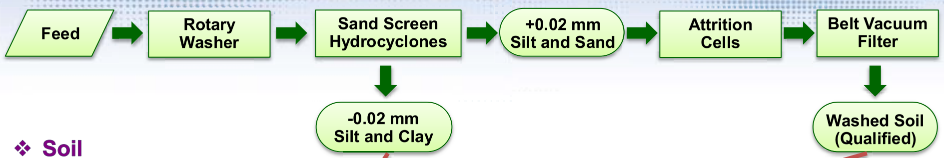
Plant Commissioning



Soil	Feed	Rock	Treated soil
Weight (tons)	1140	190	709
Sediment	**Feed**	**Rock**	**Treated soil**
Weight (tons)	1100.75	few	787.55

Qualified soil >70%

Mercury Mass Balance During Commissioning



❖ Soil

	Input Hg	Output Hg				
	Feed	Silt and Clay (unqualified soil)	Silt and Clay Filtrate	Washed Soil	Washed Filtrate	Total
Conc. (mg/kg)	27.8~283	115~835	0~0.5	0~49.7	1.09~62.6	
Hg Mass (kg)	108.82	89.05	0.36	12.36	16.86	118.62

Difference 9%

❖ Sediment

	Input Hg	Output Hg				
	Feed	Silt and Clay (unqualified soil)	Silt and Clay Filtrate	Washed Soil	Washed Filtrate	Total
Hg Mass (kg)	203.15	179.02	-	6.21	2.02	187.25

Difference 8%

Dioxin Enrichment During Commissioning

❖ Soil

Unit: ng-TEQ/kg Date	Input Dioxin	Output Dioxin	
	Feed	Silt and Clay (unqualified soil)	Washed Soil (qualified soil)
2012/9/26	438	1,230	82.9
2012/9/28	1,120	1,800	323
2012/10/5	1,128	6,948	585
2012/10/7	1,640	5,329	1,007

❖ Sediment

Unit: ng-TEQ/kg Date	Input Dioxin	Output Dioxin	
	Feed	Silt and Clay (unqualified soil)	Washed Soil (qualified soil)
101.11.21	11,800	6,900	504
101.11.26	1,020	6,000	274
101.11.28	7,180	16,200	702
101.11.30	28,500	16,200	222
101.12.04	328	5,400	217

Quantities of washed Soil Up to 2018.5.24

Feed	Feed Weight (tons)	Washed Soil Weight (tons)	
		Self verified	Washed rock
Soil	43,696.95	27,387.13	7,058.92
Sediment	44,408.00	38,734.19	--
subtotal	88,104.95	66,121.32	7,058.92
Total	88,104.95	73,180.24	

The percentage of qualified treated soil = $\frac{73,180.24}{88,104.95} \times 100\% = 83\%$

EPB verified soil: 66,121.32 tons

4 Summary

Apollo Technology Co., Ltd.

Summary

- Key to successful remediation not only depends on understanding the ppm concentration level of the contamination, but also on the soil properties. Due to the complexity of the soil, remediation techniques should be assessed and specialized case by case.
- While thermal treatment is a common practice, soil washing treatment could be another practice that can be used effectively in mercury remediation. Furthermore, if the two treatments can be combined in the remediation process, the results is not only effective, but economical.
- The soil washing plant in An-Shun site is currently in process. Other than mercury treatment, the plant is also proved valid for treating dioxins at lower concentration.

Thank you for your attention

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E-mail: Luclu@apollotech.com.tw
Website: www.apollotech.com.tw

Management of Groundwater Arsenic Contamination in Taiwan

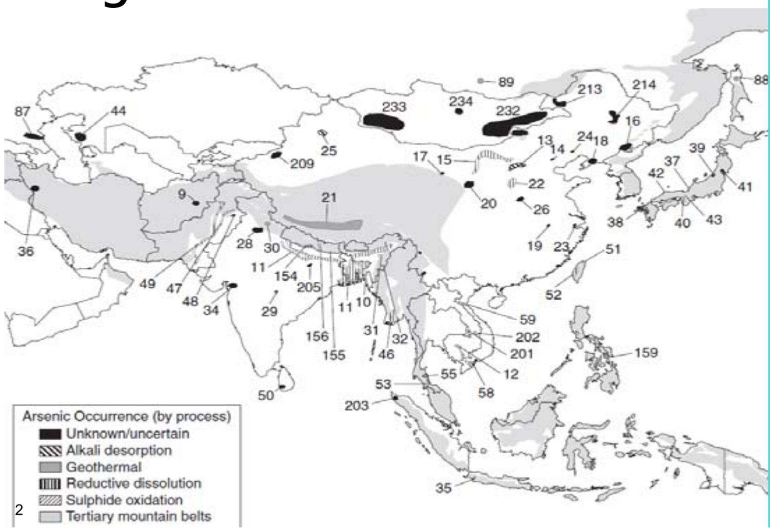
Dr. Sheng-Wei Wang

Arsenic contamination

We concerned

- Water quality
- Soil accumulation
- Crop/Food safety
- Health risk

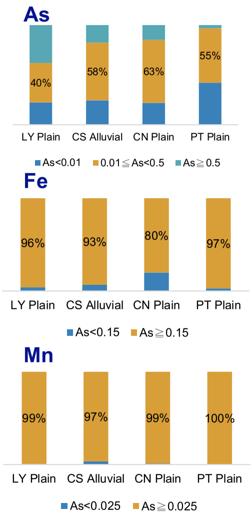
Origin of Arsenic contamination



Groundwater

Reductive dissolution of As-Fe hydroxides is the primary geochemical process in Taiwan

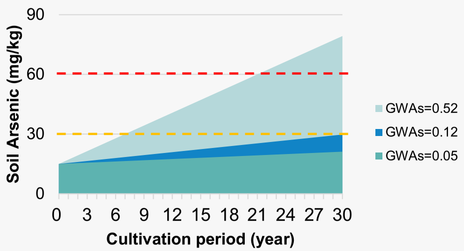
Groundwater As distribution



Approaches of preventing As in soil and crop

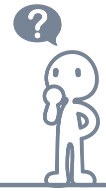
Quantity
- Reducing the use of As-groundwater
- Ensuring sufficient irrigation demand?

Quality
- Reducing groundwater As conc.

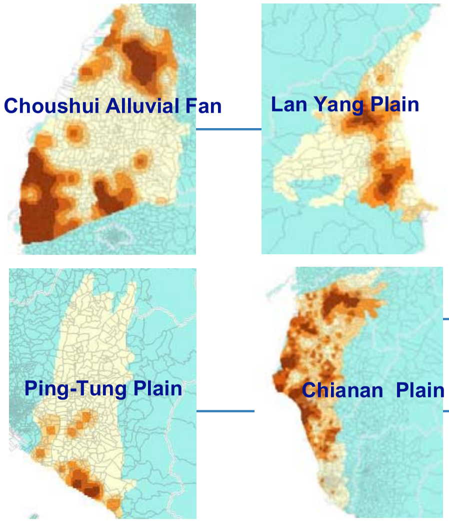


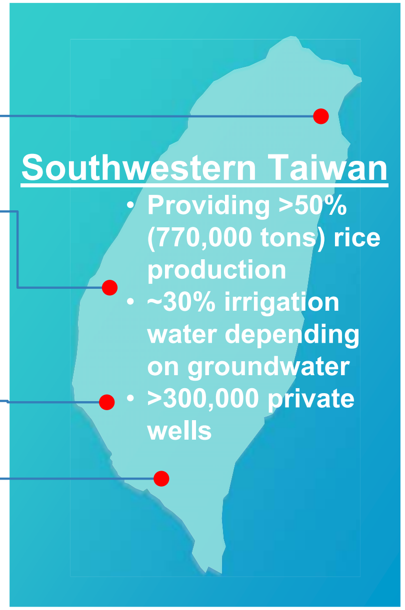
What
- Cost?
- Removal threshold?
- Effective?
- Enough space?
- Easy to implement?
- Re-contaminations?

Goal
- Extending the use of farm land
- Decreasing the cost of soil remediation



Potential areas of groundwater As

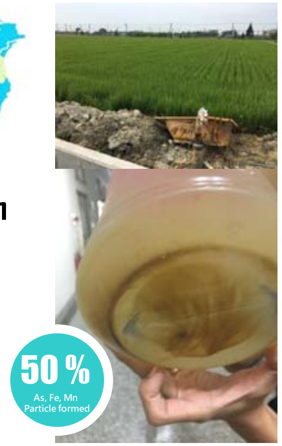




Batch tests of groundwater As removal

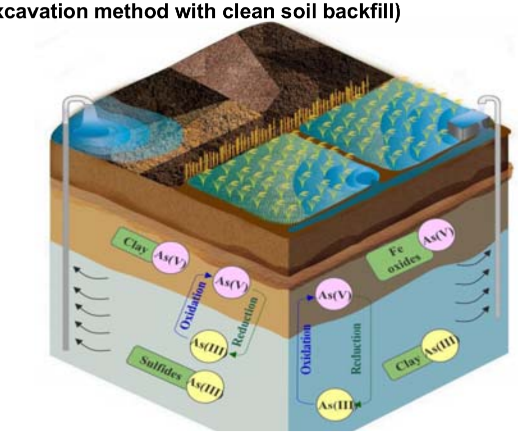
(I) Air exposure

- Oxidation and precipitation of As and Fe
  - $HAsO_4^{2-} \rightarrow HAsO_3^{-}$
  - $FeOH + AsO_4^{3-} + 3H^{+} \rightarrow FeH_2AsO_4 + H_2O$
- Key findings
  - Fe/As>25
  - Low cost (exposure electricity)
  - Take 4 hours for precipitation
  - No addition chemicals required



As distribution in paddy field

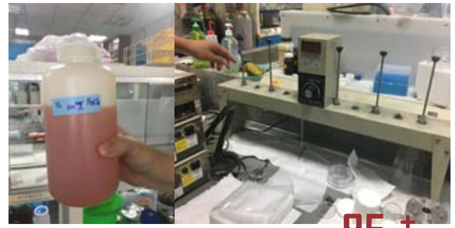
- According to a 29,460 ha investigation byTaiwan EPA, paddy field of soil As > 60 and 30 mg/kg are 93 and 532 ha, respectively
- Total cost is ~12 million USD for 93 ha remediation(Soil excavation method with clean soil backfill)

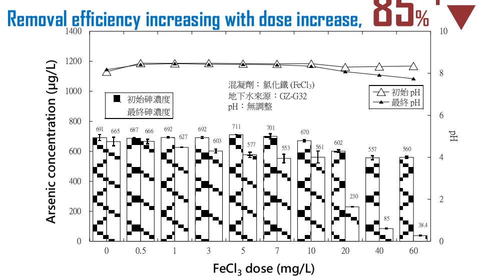


Batch tests of groundwater As removal

(II) Coagulation

- Co-precipitation and surface adsorption of As by formed $Fe(OH)_3$ and $FeOOH$
- Key findings
  - Effective removal efficiency, 85% reduction
  - Removal efficiency increased with higher $FeCl_3$ dose
  - Wastes treatment is required
  - Additional chemicals and energy is requested

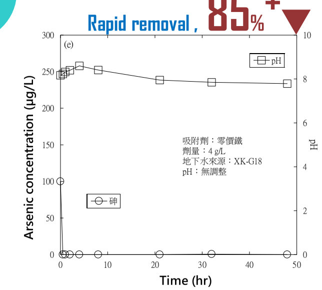




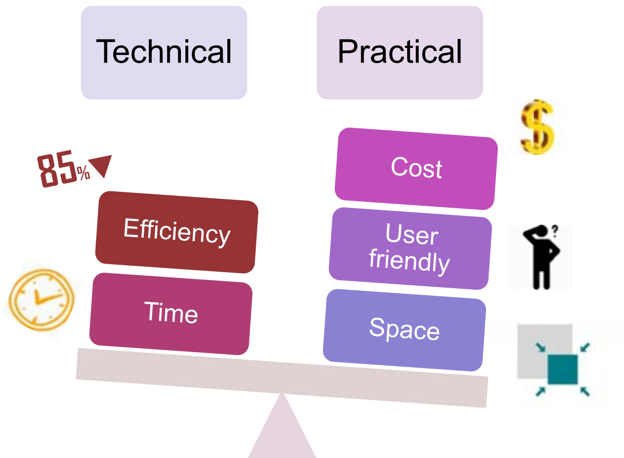
Batch tests of groundwater As removal

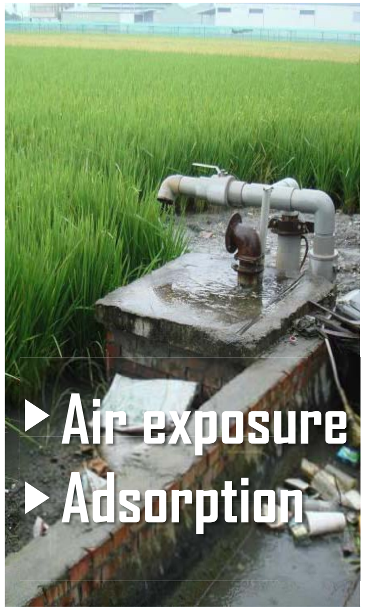
(III) Adsorption

- ZVI is oxidized to $Fe(OH)_3$
  - $Fe(OH)_3 + H_3AsO_4 \rightarrow FeAsO_4 \cdot 2H_2O + H_2O$
- Key findings
  - Short reaction time
  - Commercial resin cost is high
  - Recycled industrial wastes efficiency high and cheaper
  - Wastes should be further treated



Scale-up experiments in field

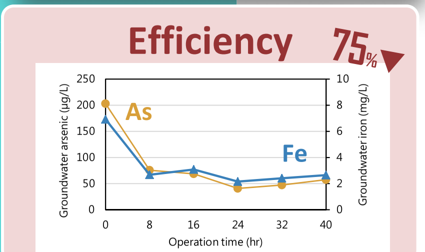




Groundwater Arsenic removal- Air exposure

Time
Flowrate is designed to meet paddy **irrigation demand**
~3 m³/h

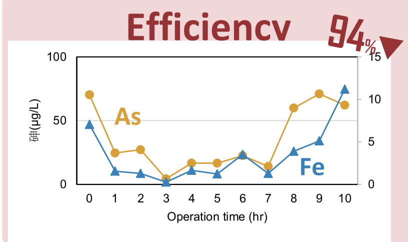
Cost
Sand and gravel are **easy to obtain and cheap**
Maintaining 150 USD/ha-yr



User friendly
Periodical clean and sand replacement

Space
Not big difference, replace the energy elimination equipment
2m*2m

Groundwater Arsenic removal- Adsorption



Time

Flowrate is designed to meet paddy **irrigation demand**

~3 m^3/h

Cost

ZVI dose is required, cost for replacement is **high**

Maintaining 160,000 USD/ha-yr

User friendly

Frequently replacement of ZVI is necessary, increase the difficulties of use

Space

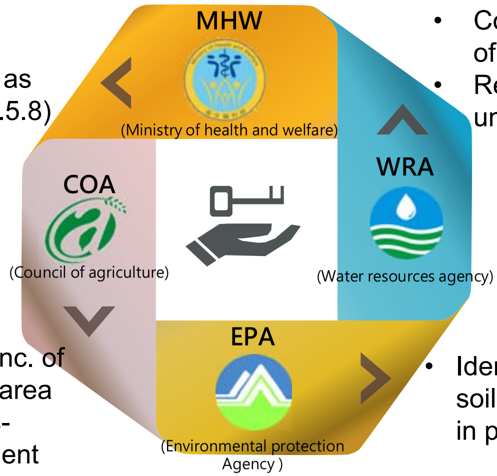
Not big difference, only replace the equipment for energy elimination

2m*2m

Air exposure is a practical solution

Coming challenges

- Announced the standard of rice as 0.2 mg/kg(2018.5.8)



- Confirm the Water Right of private wells
- Restrict the operation of unapproved wells

- Detection As conc. of rice in potential area
- Promotion of As-removal equipment

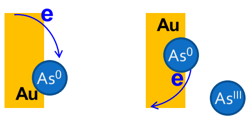
- Identifying the source of soil and groundwater As in paddy field

New method for in-situ As measurement

ASV(Anodic Stripping Voltammetry) detection for As(III) at Gold electrode

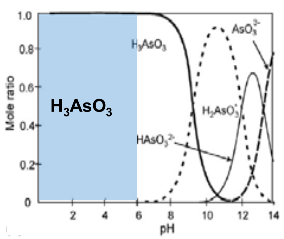
Principle (In acidic media)

Step 1 Deposition   Step 2 Stripping

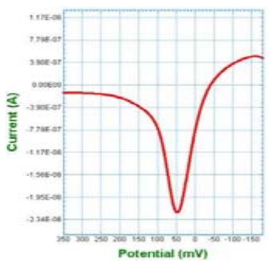


$As^{III}(OH)_3 + 3H^+ + 3e^- \rightarrow As^0 + 3H_2O$ (R1)

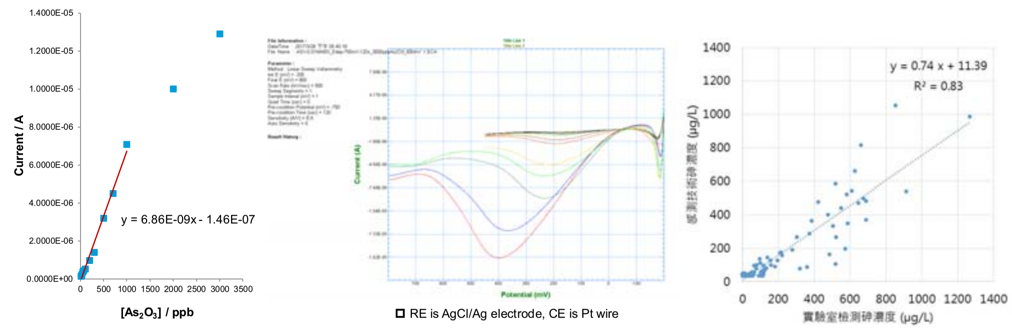
$As^0 + 3H_2O \rightarrow As^{III}(OH)_3 + 3H^+ + 3e^-$ (R2)



(pK_1 9.22, pK_2 12.13, pK_3 13.4)

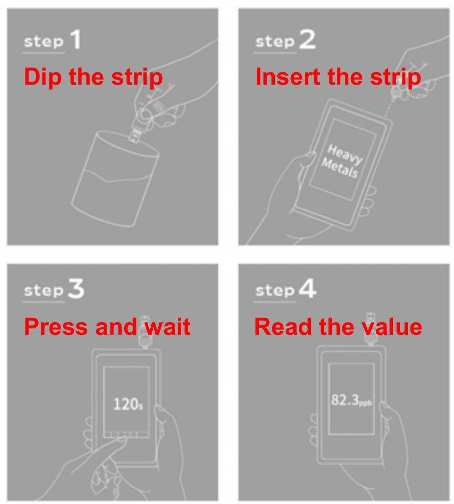


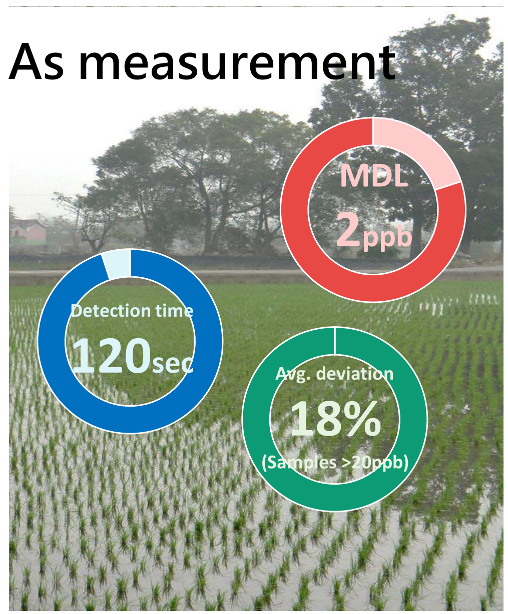
New method for in-situ As measurement
Calibration in lab and determination in field has been approved



□ RE is AgCl/Ag electrode, CE is Pt wire

New method for in-situ As measurement

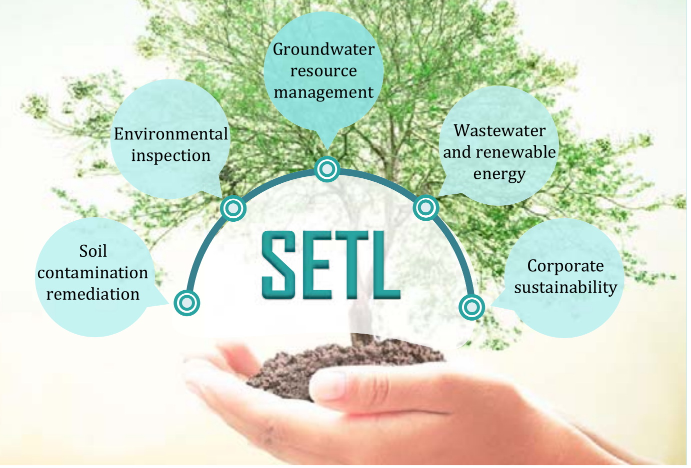




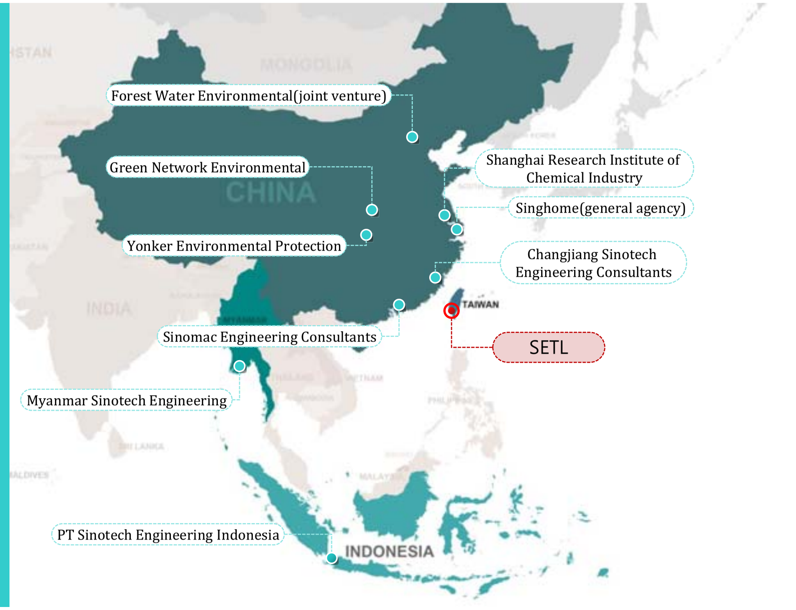
New method for in-situ As measurement

Advantages & Applications of Screen Printed Electrode (SPE)

Service



Cooperation



IN THE FUTURE
TOGETHER WITNESS

達萬物之理　還天地之美

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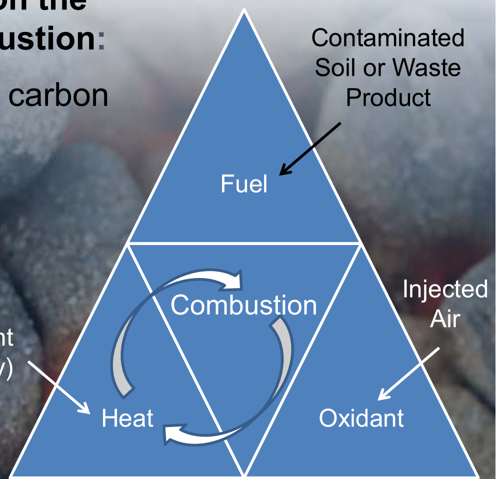
Overview

- **STAR – Self-sustaining Treatment for Active Remediation**
- **Smoldering Combustion (flameless combustion)**
- **Our Solutions (Modes of Application)**
- **STAR (in situ)**
  - Case Study: STAR Evaluation at a NPL Site in Taiwan

Smoldering Combustion

STAR and STARx are based on the process of smoldering combustion:

Exothermic reaction converting carbon compounds to $CO_2 + H_2O$



Smoldering possible due to large surface area of organic liquids (e.g., NAPL) within the presence of a porous matrix (e.g., aquifer)

Smoldering Combustion

Video accelerated 50 times

Smoldering Combustion

Treatability study soils (before and after) for the New Jersey Case Study

Modes of Application

Modes of Application

STAR

- **In situ (below ground)**
  - Applied via wells in portable in-well heaters
- **Above or below the water table**
- **Range of contaminants:**
  - Petroleum Hydrocarbons
  - Coal tar
  - Creosote

STARx

- **Ex situ (above ground)**
  - Fabricated vessels
  - Soil piles
- **Highly effective and controlled applications**
- **Ideal for:**
  - Excavated contaminated soils and sediments
  - Waste oils / tank bottom residuals
  - Lagoon sludge

Case Study – Vessel Systems

Results

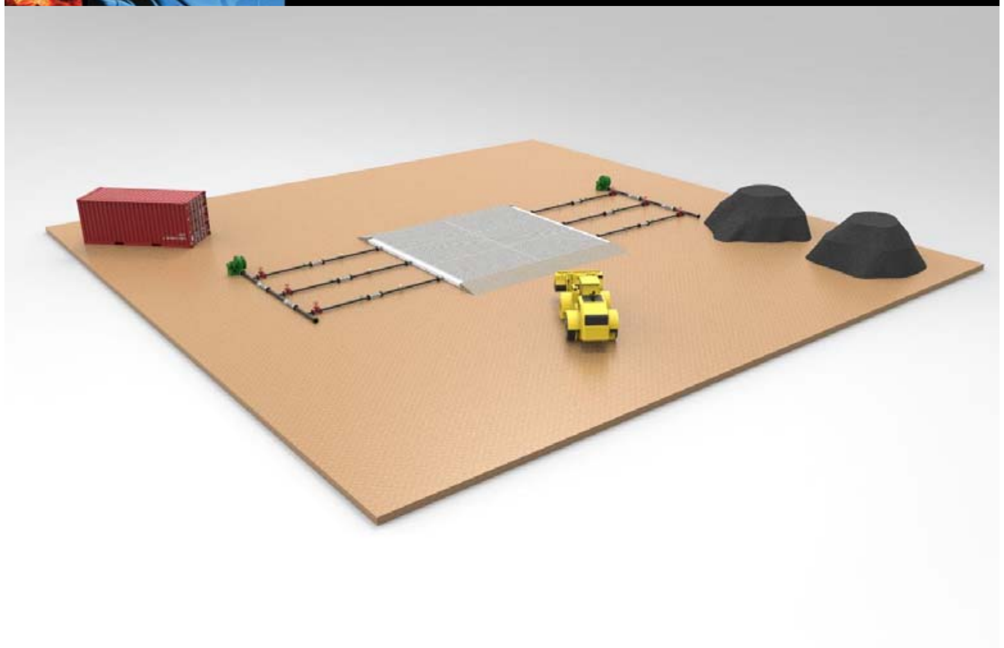
TPH_{avg} = 137,000 mg/kg

TPH = ND

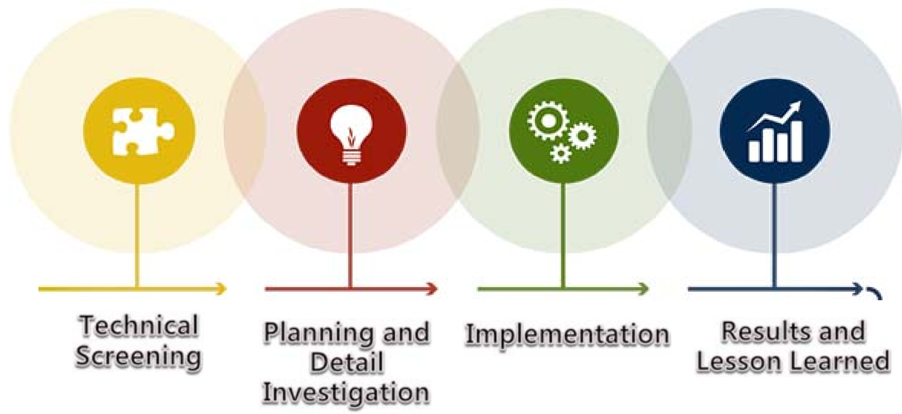
STAR – In Situ Systems

Case Study: STAR Evaluation at a NPL Site in Taiwan

STARx – Soil Pile Systems



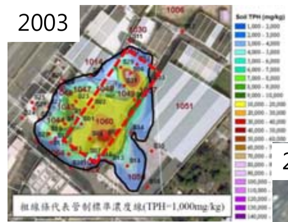
Introduction

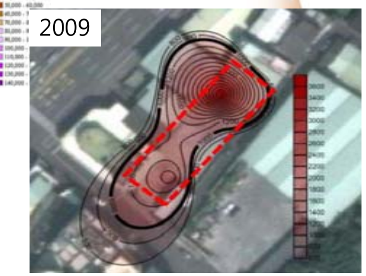


Conceptual Site Model

- ▶ Detail site investigation

Historical Site Investigation



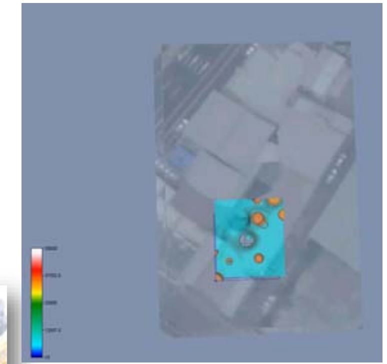


SI Plan

- ☑ Hydrogeology
  - Hydrogeological Profiling Tool (HPT)
  - Geological Boring
- ☑ Contamination
  - Membrane Interface Probe (MIP)
  - Soil Sampling
  - Groundwater Sampling
  - Analysis for Total Petroleum Hydrocarbon (TPH)

Conceptual Site Model

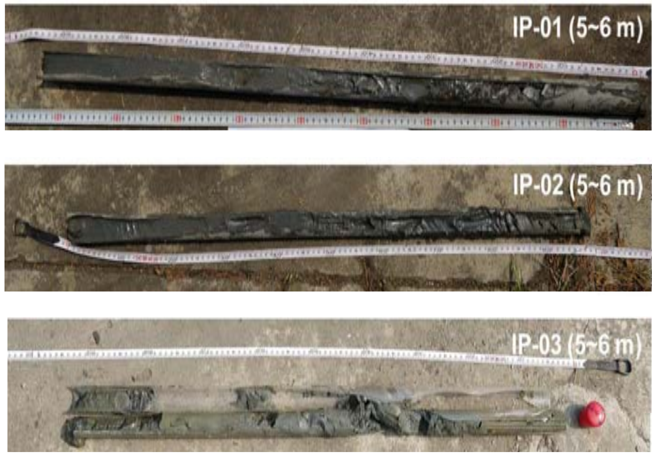
- ▶ Results and Conditions
  - ☑ Hydrogeology
    - Hydraulic Conductivity (K) $10^{-2} \sim 10^{-3}$ cm/s
    - Permeability is good for air transmmission
  - ☑ TPH at 4~5.5 m bgs exhibited high TPH concentration (> 10000 mg/kg)
  - ☑ Potential good continuity of contamination



Public Communication

Implementation

Where to put the Ignition Point (IP)



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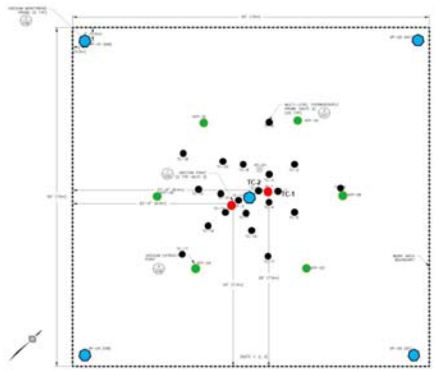
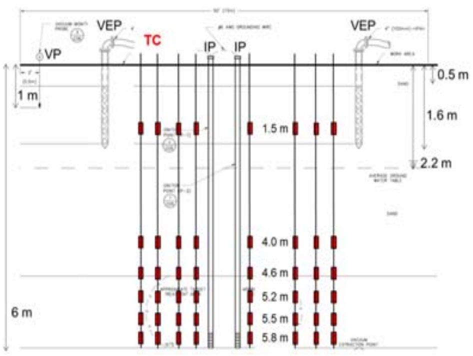
Implementation

- Ignition depth set at 6 m bgs to effectively covered the contamination zone
- Thermal sensors (20 sets) placed at 1.5, 4, 4.6, 5.2, 5.5 and 5.8 m bgs



TOP



Side View

18

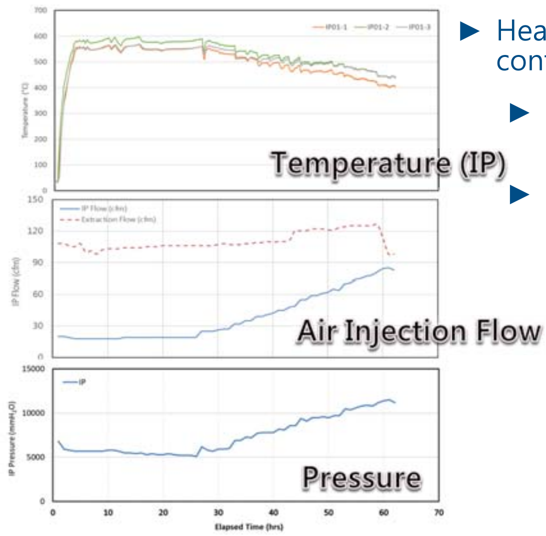
Implementation

19

Implementation

20

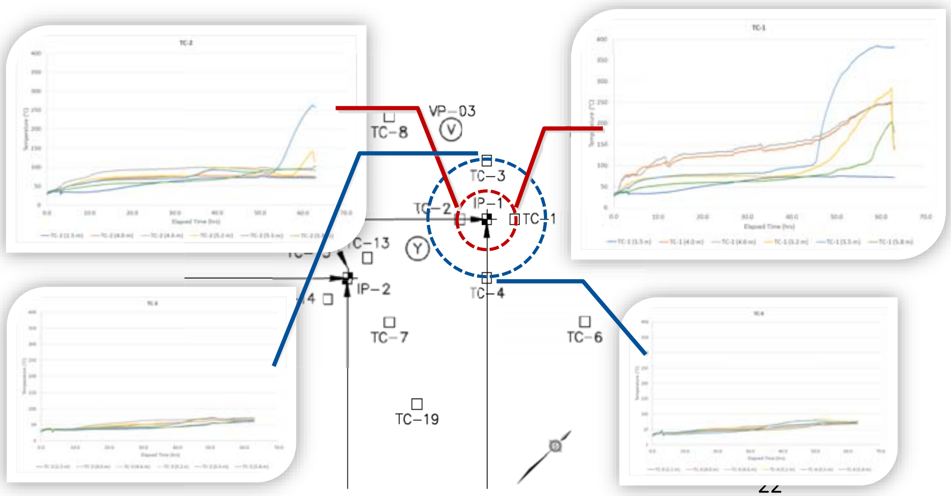
Results and Lesson Learned



- Heating and air injection control
  - Temperature maintained above 400°C
  - The air flow and pressure increased in response to the initiation of smoldering mechanism

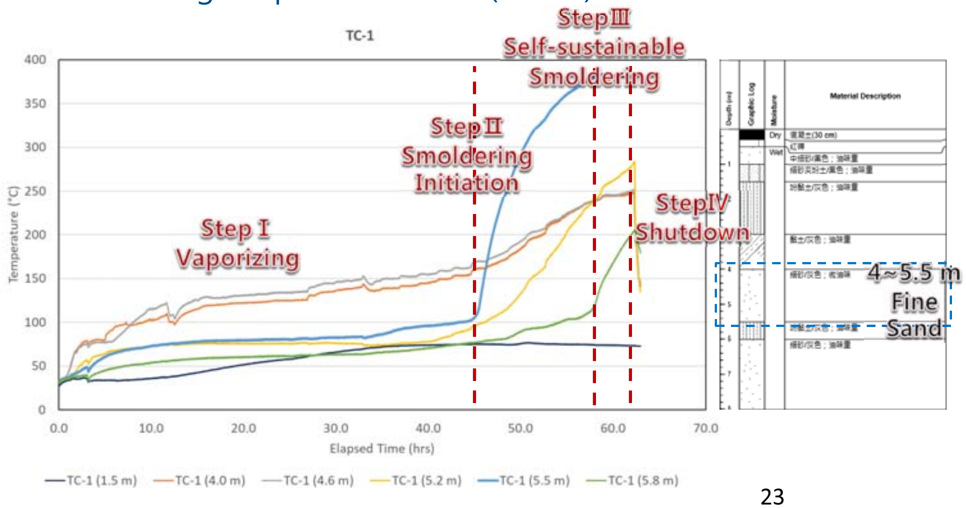
Results and Lesson Learned

- Smoldering Response (63 hrs)



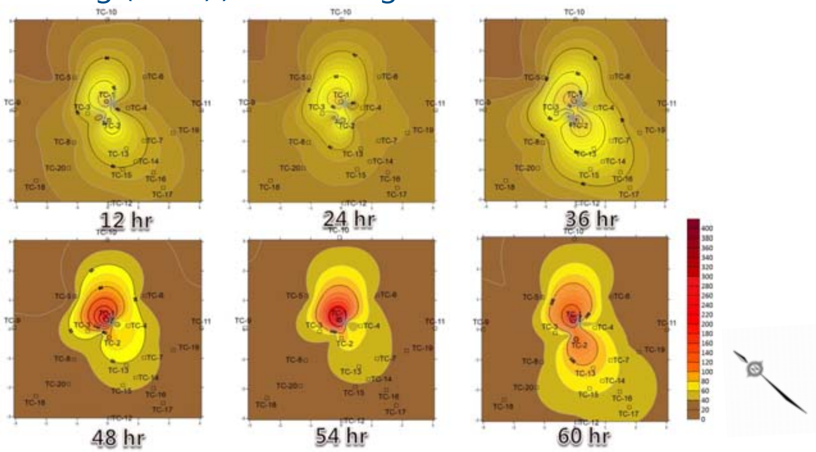
Results and Lesson Learned

- Smoldering Response at TC-1 (63 hrs)

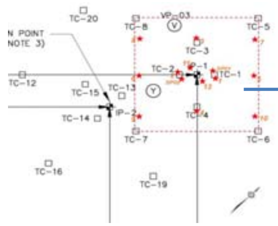


Results and Lesson Learned

- Smoldering (63 hr)) at 5.5 m bgs



Results and Lesson Learned



40點驗證數據

Results and Lesson Learned

▶ TPH concentration before and after (at vicinity to IP)

反應半徑	悶燃前 點位	深度 (m)	TPH C6-C40 (mg/kg)	悶燃後 點位	深度 (m)	TPH C6-C40 (mg/kg)	移除率 (%)
東側 ≈1ft	IP-1	-	-	S11	1.0-1.5	12,600	-
		4.8-5.0	ND		4.5-5.0	2,370	0%
		-	-		5.0-5.25	ND	-
		5.3-5.5	21,566		5.25-5.5	333	98.4%
		5.5-5.75	3,221		5.5-6.0	ND	100%
南側 ≈1ft	IP-1	-	-	SP01	4.0-4.5	700	-
		4.8-5.0	ND		-	-	-
		-	-		-	-	-
		5.3-5.5	21,566		5.0-5.5	198	99.1%
		5.5-5.75	3,221		-	-	-
西側 ≈1ft	IP-1	-	-	S12	1.0-1.5	9,970	-
		4.8-5.0	ND		4.5-5.0	ND	-
		-	-		5.0-5.25	ND	-
		5.3-5.5	21,566		5.25-5.5	553	97.4%
		5.5-5.75	3,221		5.5-6.0	ND	100%
北側 ≈1ft	IP-1	-	-	SP02	4.0-4.5	267	-
		4.8-5.0	ND		-	-	-
		-	-		-	-	-
		5.3-5.5	21,566		5.0-5.5	ND	100%
		5.5-5.75	3,221				

- ☑ With smoldering mechanism, TPH contamination can be reduced by >97%
- ☑ STAR exhibits the potential to reduce the TPH concentration from 20,000 mg/kg to below remediation goal or Control Standard

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Results and Lesson Learned

▶ GSR Assessment

- ☑ ISCO
- ☑ Excavation
- ☑ STAR

方案編號	方案名稱	方案評分	方案排序	方案基本資料	GSR評估
1	ISCO	11.35	2	查看	評估
2	排客土	6.37	3	查看	評估
3	悶燃	11.56	1	查看	評估

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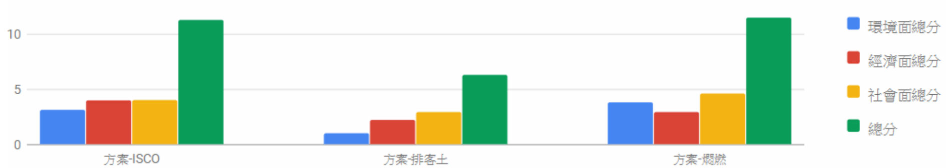
Results and Lesson Learned

▶ GSR Assessment

方案名稱	方案評分	方案排序
ISCO	11.35	2
排客土	6.37	3
悶燃	11.56	1

	☑ ISCO	☑ Excavation	☑ STAR
環境面總分	3.2	1.08	3.88
經濟面總分	4.06	2.29	3
社會面總分	4.09	3	4.68
總分	11.35	6.37	11.56

總得分比較



Results and Lesson Learned

- ▶ STAR is potential feasibility to remediate heavy TPH to Control Standard
- ▶ Geological conditions affect the transmission of air flow, hence the distribution of smoldering mechanism.
- ▶ The off-gas contains >90% of carbon dioxide indicated the combustion instead of desorption

Acknowledgement

This work is supported by

- Taiwan EPA under project number EPA-106-GA13-03-A078
- Savaron Solutions
- Geosyntec

創聚環境管理顧問股份有限公司 InnoFusion Environmental Management Co., LTD

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Thank You for Your Attention

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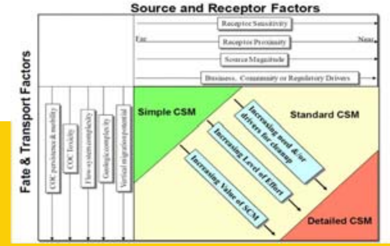
savron smoldering solutions

Site Investigations in Support of Risk-Based Decision-Making

Pollution Control Dept CLM Workshop, Bangkok
June 2018

Tai Tang Oh
Shell Projects & Technology Soil & Groundwater Team Lead
Asia Pacific

Sanjay Garg
Shell Projects & Technology Soil & Groundwater Team Lead
Americas



Biodata for Tai Tang Oh

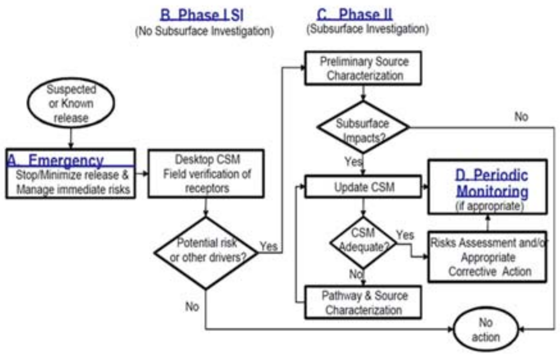
- More than 17 years of experience of applying sustainable risk-based principles to problems of contaminated land management
- Joined Shell in 2005 as a Program Manager
- Presently the **Asia Pacific Soil & GW Team Lead for Shell Projects & Technology** (formerly Shell Global Solutions); leads a team of environmental S&GW scientists/engineers based in Kuala Lumpur, Malaysia
- Worked as a environmental consultant (ENVIRON, URS, Dames & Moore) prior to joining Shell
- Geologist by training (member of Institute of Geology Malaysia)

Disclaimer

Outline

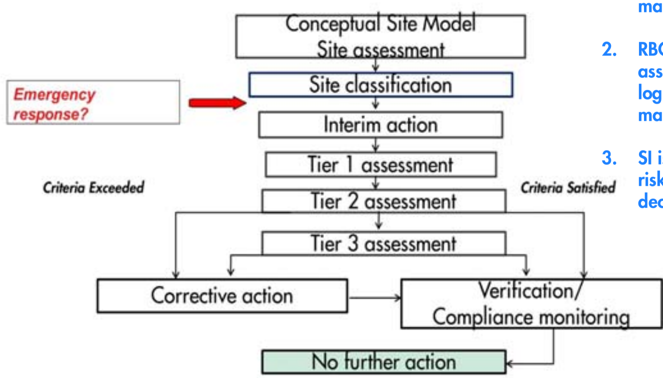
- Role of site investigation (SI) in risk-based corrective action
- Framework for undertaking SI to support risk-based decisions
- Discuss key considerations involved in undertaking SI

Generic Framework for Risk-based Site Investigations



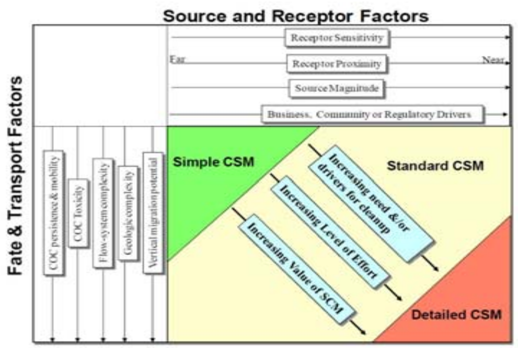
- Trigger for site investigation
- Useful to start with a Phase 1 assessment (desktop)
  - High-level understanding of site/problem
  - Relatively low cost
  - Is there a potential issue requiring further investigation?
- Data from Phase 1 used to plan/scope out Phase 2 (intrusive) assessment if needed.
  - Confirm presence of subsurface contamination
  - Refine CSM (characterization of contamination, pathways, receptors)
  - May need multiple investigations to fully characterize site
  - Data from Phase 2 used to support risk assessment and corrective action decisions

Risk-Based Corrective Action and Role of Site Investigation



1. RBCA is industry best practice for management of contaminated land
2. RBCA integrates site investigation, risk assessment & corrective action within a logical, flexible and tiered decision-making framework
3. SI is a critical activity that supports the risk assessment & management decisions within RBCA

Factors Influencing Level of Site Investigation Effort



- Not all site investigation scopes are equal
- Important to determine level of effort (fit for purpose)
- Influencing factors include:
  - Site complexity
    - Geology/hydrogeology, types of contaminants
    - Type & size of site (built-up vs. vacant land)
    - Current/historical site uses
  - Site risk profile
    - Receptor profile (type, proximity, sensitivity)

Site Investigation supports Conceptual Site Model Development

Source → (Hazard)	Pathway →	Receptor
Leaking tank Waste pit Contaminated soil	Unsaturated/Saturated zone Direct contact Vapour migration Groundwater transport	Child playing in soil Worker / resident Sensitive ecology/habitat Abstraction borehole

- A linkage between all 3 must be present for there to be actual risk to receptor(s)
- Whether a risk is *unacceptable* depends on magnitude and likelihood of an undesirable effect
- The conceptual site model (CSM) includes descriptions of plausible source-pathway-receptor linkages

SI obtains relevant data to support CSM development

Scoping a Phase 2 (Subsurface) Investigation – Data needs & quality

Data needs questions:

- Site investigation objectives? [New release, establish baseline, further delineation, validation]
- Types of data & level of detail? [Soil/aquifer properties, contaminant chemistry, receptor type]
- How will the data be used to make a decision? [confirm presence of contamination, risk assessment, remediation design]
- Is the data critical in understanding the site/problem?
- Number of sampling points and where to sample?
- What environmental media to sample? [Soil, GW, SW, soil gas]

Data quality considerations/objectives:

- Appropriate field sample collection methods - disturbed vs. undisturbed samples, correct containers, sample preservation & handling
- Appropriate field sampling QA/QC protocols – blanks & duplicates, equipment decon
- Use of properly trained and qualified personnel for field sampling
- Use of a suitably accredited laboratory
- Appropriate lab testing methods - capable of identifying and detecting the chemicals of concern
- Appropriate lab QA/QC protocols - blanks, matrix spikes, duplicates
- Timely shipment and analysis of samples - able to meet sample holding times

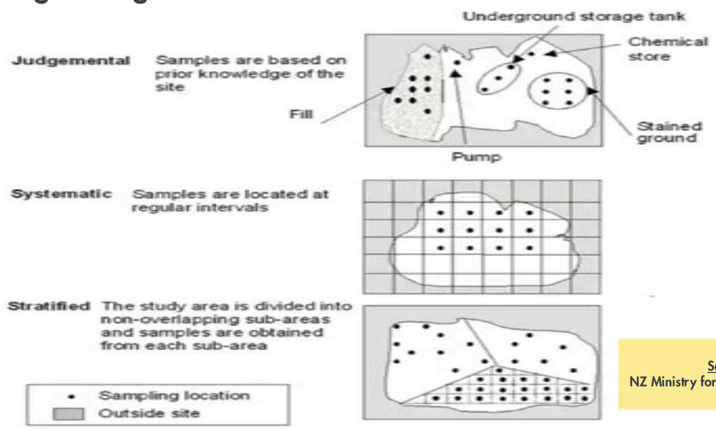
Scoping a Phase 2 (Subsurface) Investigation – Types of data

Source Characterization
- ❑ Information on composition, spatial extent and magnitude of contamination
- ❑ Multi-media (soil, GW, etc) sampling strategy
- ❑ Chemicals of potential concern (if uncertain, cast a wide net)

Pathway Characterization
- ❑ Info on pathways controlling contaminant fate & transport
- ❑ Soil/aquifer properties – lithology, depth to GW, permeability, flow rates/direction
- ❑ Contaminant plume delineation – spatial extent & concentrations
- ❑ GW geochemical indicators for natural attenuation – are conditions conducive?
- ❑ Vapour migration pathway – vadose zone soil vapour sampling
- ❑ Man-made preferential pathways – subsurface utilities/drains
- ❑ GW-SW interface – can plume reach a SW body? Sample SW/sediment, estimate mixing and dilution potential.

Receptor Characterization
- ❑ Identification of potential receptors
- ❑ Info on type/sensitivity of receptor, location/proximity from site
- ❑ Receptor-specific details like well pumping rate and building floor condition (vapour intrusion)

Sampling Strategies



Source:
NZ Ministry for Environment, 2011

Comparing Targeted and Grid-based Sampling

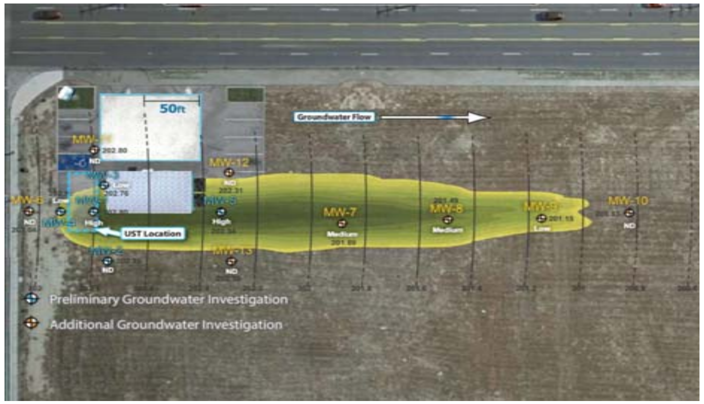
Targeted/Judgemental Sampling
- ❑ Ideal when there is already prior knowledge about site (current/past operations, known/suspected release, surrounding landuse/receptors)
- ❑ Highly effective for smaller, less complex sites (e.g., petrol stations)
- ❑ Cost effective as sampling plan can be optimized/customised to site
- ❑ Reliant on professional judgement
- ❑ Potential to introduce bias into sampling plan (e.g., may miss hotspots)

VS.

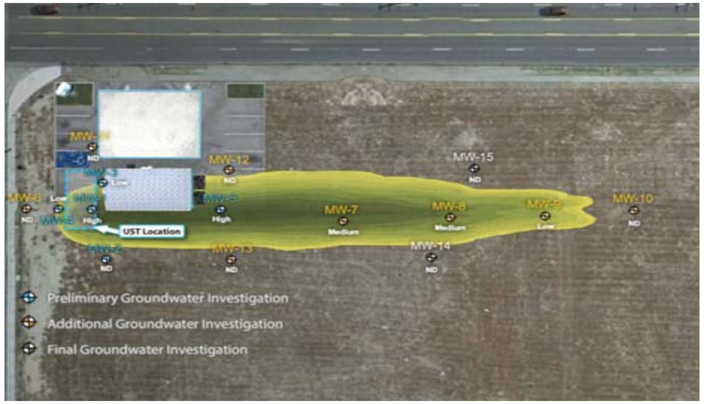
Grid/Systematic Sampling
- ❑ Useful when there is little or no prior knowledge about site
- ❑ Statistically defensible (grids can be based on statistics) and less biased
- ❑ Less reliant on professional judgement
- ❑ Can lead to oversampling (i.e., can be more costly)

Initial site investigation (targeted) – chemical release example

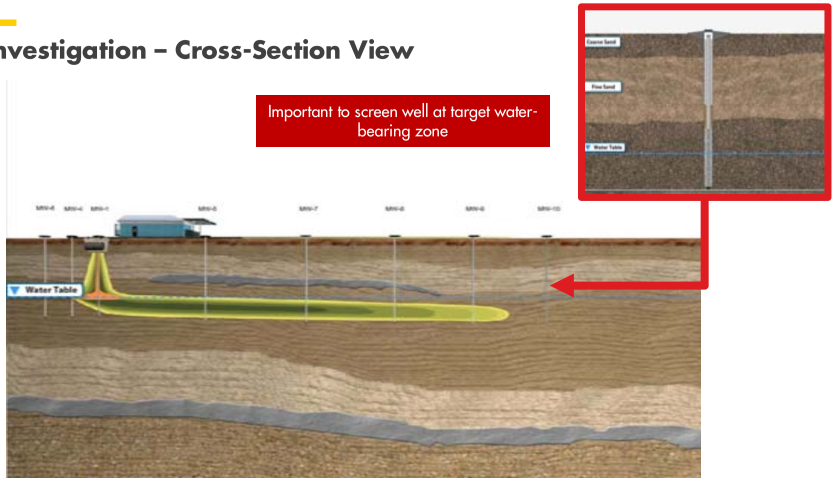
Followup investigation to further delineate plume



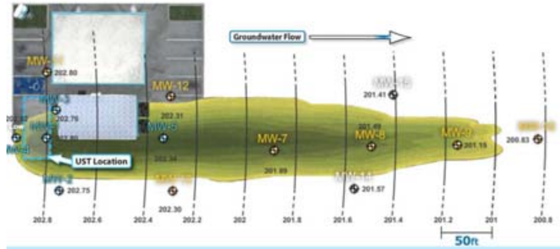
Final investigation



Final investigation – Cross-Section View

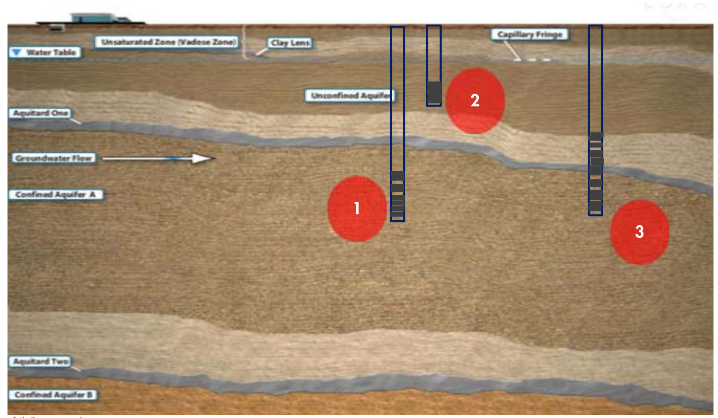


Chemical Release Example – Estimating GW flow velocity



$$\text{Groundwater Velocity} = \frac{\text{Hydraulic Conductivity} \times \text{Hydraulic Gradient}}{\text{Effective Porosity}}$$

Which one represents inappropriate well installation?

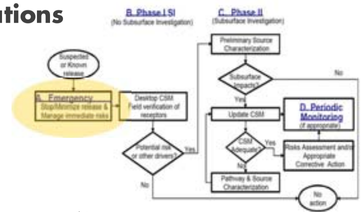


Safety Considerations for Subsurface Investigation

Health & Safety Safeguards

- ❑ Prepare a Health & Safety Plan identifying key risks, precautions & mitigation
- ❑ Borehole clearance procedure:
  - (1) Check site drawings;
  - (2) Conduct u/g utility survey before drilling;
  - (3) Manual drilling (hand-auger) to safe depth (e.g., 1m) before using mechanical rig.

Emergency Response – Some key considerations



In a chemical release scenario:

- Always assess and address potential emergency situations **FIRST**.

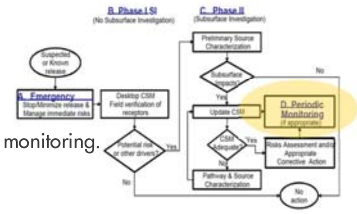
For example:

- Has the release been stopped/fixed?
- Any immediate or short-term risks (fire/explosion, acute human health exposures)?

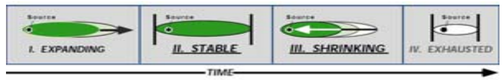
- Site investigations can take weeks, months or even years for some very complex sites.

> **Important Reminder:**
> Stopping the leak/spill early can help reduce the magnitude of the resulting environment impact, therefore reducing the need/scope for site investigation and corrective action

Role of Groundwater Monitoring



- Following site investigation, there may be a need for periodic GW monitoring.
  - Establish if contaminant plume is stable, expanding or reducing



  - Assess seasonal fluctuation (e.g., wet/dry) in GW elevations and concentrations
  - Validate effectiveness or performance of an engineered remedial action
  - Validate occurrence of natural attenuation for plumes amenable to biodegradation (e.g., petroleum releases)
- Monitoring frequency and well spacing will typically depend on GW flow velocity and proximity of potential receptors or points of compliance (collectively, GW travel time)

Site Investigation and Sampling Techniques

Technique	Advantages	Disadvantages
Grab sampling (trowel, shovel or scoop – plastic/stainless steel)	• Low cost and quick • Minimal equipment needed • Minimal space requirements • Good for soil stockpiles or exposed soil	• Surface or shallow soil sampling only • Relatively disturbed samples
Hand-auger	• Ability to sample subsurface soil • Relatively low cost and quick • Minimal space requirements • Relatively disturbed samples	• More labour intensive than grab sampling • Not practical for very coarse soils/materials
Traditional mechanical drilling (hollow-/solid-stem auger, air rotary drilling, cable tool/percussion)	• Depth-discrete, undisturbed soil samples • Ability to drill to substantial depths in most geologic settings	• More expensive than manual sampling/digging • Needs more space • Requires competent/skilled operators • Greater health and safety risks • Can cause cross-contamination if drilling not done or well not installed properly
Direct push drilling (e.g., GeoProbe, HydroPunch)	• Less labour intensive conventional mechanical drilling • Smaller rig/equipment setup = less space needed • Produces less drill cuttings than conventional drilling • Multi-probe functionality allowing data collection	• Not practical for very • Can be more costly • May not be available in certain markets

Main Take-Aways

- When planning to undertake SI, always ensure that you have a plan to manage related health & safety risks
- Prior to undertaking any SI, ensure assessment objectives are clear to optimize data collection (only collect data you need)
- Consider undertaking site investigation in a phased manner in order to minimize unnecessary time, effort and cost.
- Level of site investigation effort (or the scope) is dependent on a number of site-specific factors including site complexity and risk profile.

Further Information/Resources

- American Petroleum Institute (API), 1996. Guide to the Assessment and Remediation of Underground Petroleum Releases, Publication no. 1628. Third Edition
- American Society for Testing and Materials (ASTM), 2004. Standard Guide for Site Characterization for Environmental Purposes with Emphasis on Soil, Rock, the Vadose Zone and Groundwater. D5730 – 04.
- ASTM, 2004. Standard Practice for Design and Installation of Groundwater Monitoring Wells. D5092 – 04.
- ASTM, 2011. Standard Practice for Environmental Site Assessments: Phase II Environmental Site Assessment Process. E1903 – 11
- ASTM, 2013. Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process. E1527 – 13
- New Zealand Ministry for Environment (NZMFE), 2011. Contaminated Land Management Guidelines No. 5: Site investigation and analysis of soils. Publication no. ME1073.

Data Quality Objectives (DQOs) and Project Planning

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June 19, 2018

Presenter's Background

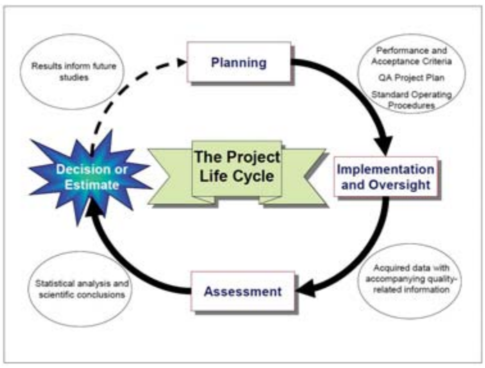
John J. Coffey II, Ph.D.
Principal Technologist
Jacobs Engineering (formerly CH2M)

- Environmental/Analytical Chemist with 28 years of experience as an environmental consultant including projects in 21 countries
- CH2M's Environmental Chemistry Practice Leader for 15 years
- Broadly experienced in the technical integration of chemistry, data management and risk assessment activities in support of environmental and industrial process projects including site characterization, site remediation, nuclear facility deconstruction/demolition and munitions destruction

Agenda

1. The Project Data Lifecycle
2. Data Quality Objectives (DQOs) – Overview
3. The USEPA Seven Step Model
4. Systematic Planning and Data Quality Objectives
5. Analytical Requirements and the Quality Assurance Plan (QAP)
6. Laboratory Method Selection Examples
7. DQOs – A Short Exercise (Lead-in to Data Validation)
8. DQO References

The Project Data Life Cycle



Always Have the *End Use Goal* in mind…

- Project development
- Implementation
- Ongoing data assessment as results are received
- Reporting

…throughout the Project Life Cycle

Data Quality Objectives – Underlying Principles

- All collected data have associated errors
- Absolute certainty in any given result is not achievable
- The DQO Process defines tolerable error rates
- In the absence of DQOs, decisions are uninformed
- Uninformed decisions tend to be conservative and expensive

DQO Details

DQOs are quantitative and qualitative criteria that:

- Clarify study objectives
- Define appropriate types of data to collect
- Specify the tolerable levels of potential decision errors

DQOs are designed to answer:

- What does the project need?
- Why does the project need it?
- How will the project use it?
- What is the project's tolerance for errors (rejected data)?

Data Quality Objective (DQO) Process

The DQO Process (USEPA Seven Step Approach) is a systematic planning approach for generating environmental data that will be sufficient quality and quantity for their intended end use:

1. Define the Problem
2. Identify the Goal of the Study
3. Identify Information Inputs
4. Define the Boundaries of the Study
5. Develop the Analytical Approach (Decision Rules)
6. Specify Performance or Acceptance Criteria
7. Develop the Plan for Obtaining Data (Optimize Design)

Other Applications of the DQO Process

- Waste management
- Environmental remediation and restoration
- Facility transition and management
- Facility decontamination and decommissioning
- Technology development

DQO Planning Teams

DQO Project Planning Teams enables Data Users and Technical Experts to work together to specify their needs:

- Field Sampling Teams
- ***Laboratory Project Managers***
- Subject Matter Experts, SMEs (e.g., chemists, toxicologists, geologists, hydrologists, etc.)
- Data End Users (Analysts) and Decision-makers (e.g., responsible parties, risk assessors, remediation leads, project managers, external stakeholders)

Systematic Planning and Data Needs

The data needs/end uses for each project are determine through:

- Data Quality Objective (DQO) Development
- Quality Assurance Project Plan (QAPP also QAP)
- Provincial and Federal Regulatory Reporting Requirements
- Special Needs: Client, Peer and SME Inputs
- Data Quality Assessment (DQA)

Systematic Planning and DQO Crosswalk

Elements of Systematic Planning Process	Corresponding Step in the DQO Process
Identifying and involving the project manager/decision maker, and project personnel	Step 1. Define the problem
Identifying the project schedule, resources, milestones, and requirements	Step 1. Define the problem
Describing the project goal(s) and objective(s)	Step 2. Identify the problem
Identifying the type of data needed	Step 3. Identify information needed for the decision
Identifying constraints to data collection	Step 4. Define the boundaries of the study
Determining the quality of the data needed	Step 5. Develop a decision rule Step 6. Specify limits on decision errors
Determining the quantity of the data needed	Step 7. Optimize the design for obtaining data
Describing how, when, and where the data will be obtained	Step 7. Optimize the design for obtaining data

DQOs: Focus on Analytical Requirements and Data Quality Assessment

DQOs: Establish the project's need for analytical data of known quality to be used for decision-making purposes:

- Determine the number and type of QA/QC samples to be collected
- Determine the methods to be followed during sample collection and laboratory analysis
- Identify the laboratory reporting requirements (Level 1- Level 4)
- Establish the level of data review/validation needed
- Finalize details as part of the data quality assessment process.

DQOs and Laboratory Data Reporting Levels

Level 1	Level 2	Level 3	Level 4
Certificate of Analysis	Certificate of Analysis	Certificate of Analysis	Certificate of Analysis
Field Sample Results	Field Sample Results	Field Sample Results	Field Sample Results
Field QC Results (often none or limited)	Field QC Results	Field QC Results	Field QC Results
	Case Narrative	Case Narrative	Case Narrative
		Calibration Information	Calibration Information
			Instrument Raw Data Output

Data Reporting Levels based on USEPA Contract Laboratory Program (CLP)

Data Needs by Project Type – Example Considerations

Project Type	Target List/Limits Drivers	Method Selection	Data Review/Validation
Initial Site Investigation	Previous investigations Site History/Use Regulations	Target List & Limits - Many parameters can be analyzed by multiple methods with limits, limitations and costs	Dependent on Site Investigation Purpose
Long Term Monitoring (LTM)	Contaminants of Concern Project Limits Set	Contaminants of Concern previously established, may be able to use less expensive (rapid) methods for monitoring	Initial Data Review/Verification with limited validation (Level 2) if questionable data quality is suspected
Permit or Regulated Site	Based on issued permit of regulatory agreement	Selected methods must be compliant with permit or regulations	Typically, Level 2 is sufficient
Site Closure w/ Risk Assessments	As needed by regulatory agency or to minimize future liability	Methods must be able to accurately measure contaminants of concern to required risk levels	Likely Data Validation (Level 2+ or Level 3) sufficient
Site Litigation	Withstand third party technical scrutiny	Methods must be able to accurately measure contaminants of concern to required risk levels	Likely Data Validation (Level 3) with SME involvement, potentially Level 4

Quality Assurance Project Plan Overview

QA Project Plan (**QAPP or QAP**) is written document that describes:

- Quality assurance procedures
- Quality control requirements
- Other technical activities that are required ensure that the end results of the project meet the project needs/requirements
- Project activities: primary data collection, secondary data usage, and data processing (such as modeling)
- Requirements by regulatory agencies

Quality Assurance Plan – LODs and LOQs

QAPPs should include project specific reporting levels (limits of detection “seen”, LODs and limits of quantitation “measured”, LOQs) for each analyte to ensure that the laboratory can report below these levels.

Required Reporting Levels may be based on:

- Risk-based concentrations or screening levels
- Technology limitations (e.g., analytical detection limits)
- Regulatory standards or criteria
- Conceptual Site Model (CSM) information (receptors, media, and contaminants of concern
- A combination of any or all of the above…
- *LOQs must support the lowest required screening or remediation level, (preferability 50% or less than that level)*

Always Have Data End Use(s) in mind!

QAPP – Analytical Method Selection

The QAPP identifies:

Test Methods to be used in the field:

- Screening methods (pH, temp, DO, Conductivity etc.)
- On-site lab? Definitive data?

Test Methods to be used by the laboratory:

- Screening methods
- Definitive methods

Test method selections may be based on:

- Data drivers (criteria, regulations, etc.)
- Modifications or special needs for project
- Historical data
- Budgetary Constraints

Knowledge Check

What is the fundamental difference between a Limit of Detection (LOD) and a Limit of Quantitation (LOQ)?

Laboratory Method Selection Example – Arsenic

Analytical Technique	Water RL (µg/L)	Soil RL (mg/kg)	Cost	Application
Conventional ICP (Inductively Coupled Plasma – Atomic Emission Spectroscopy)	10	1	\$20 (digestion) \$10 (per metal)	Multiple metals reported; Standard reporting limits are required; Tolerates “dirtier” samples and higher dissolved solids
ICP-MS (Inductively Coupled Plasma - Mass Spectrometry)	1	0.5	\$20 (digestion) \$10 (per metal)	Multiple metals reported; Low level limits are required; Lab cleanliness key to achieving low limits
GFAA (Graphite Furnace Atomic Absorption Spectroscopy)	5	0.5	\$20 (digestion) \$15 (per metal)	Smaller list of metals; Low level reporting limits are required
Field XRF (X-Ray Florescence)	NA	10	Instrument rental and total field time	Arsenic is known contaminant, immediate (field) results required

Laboratory Method Selection Example -- Pentachlorophenol

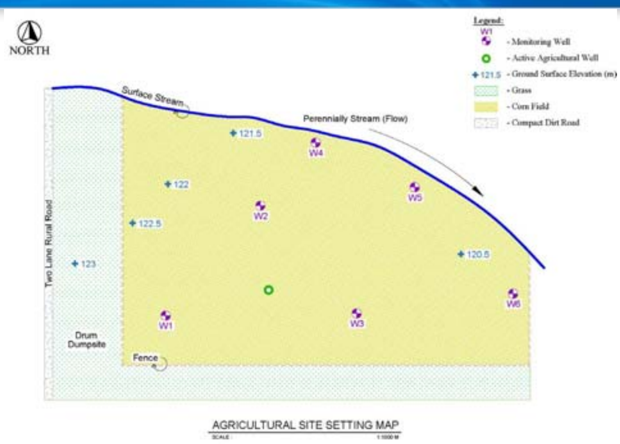
Analytical Technique	Water RL (µg/L)	Soil RL (mg/kg)	Approximate Cost	Application
GC/MS (Gas Chromatography/Mass Spectrometry)	10	0.33	\$125	High regulatory limit Delineating higher concentrations Already analyzing SVOCs
GC/MS SIM (Selective Ion Monitoring)	0.2	*0.0067*	\$200	Low regulatory limit Delineating lower concentrattection)ions PCP only CoC or one of few
GC/ECD (Electron Capture Detection)	0.25	*0.033*	\$100	Low regulatory limit Delineating lower concentrations Other herbicides also CoCs
GC/FID (Flame Ionization Detection)	5	0.15	\$50	High regulatory limit Delineating higher concentrations
Field Test Kits	~0.5-10*	~0.5-10*	TBD	PCP is known contaminant, need immediate results

The DQO Exercise

Example Project: Contaminated Agricultural Site

- Abandoned and uncontrolled drum dump site discovered adjacent to farm property (1-4 m below ground surface), drums in poor condition with no identifiable markings
- Active farming area with corn crops, owner considering sale of property for future residential development
- On-site well currently used for crop irrigation and livestock water supply
  - Depth to water 12-15 m
  - Transient solvent odor noted in well water
  - Initial test results showing PCE at 300 ug/L and low concentrations of TCE and VC (<20 ug/L)
- Initial Investigation to define nature and extent of contamination
- Extent of initial investigation limited to active farming area, access not available to surrounding properties

Agricultural Site Setting



DQO Steps 1 and 2

DQO Step	Action	Detail
Step 1. State the Problem	Identify the planning team members including decision makers.	*Client: Farm Owner and Legal Consul* *Regulatory Authority: Environment Canada and Alberta Environment* *Consultant Group (PM, SMEs, Field Staff, Lab PM*
	Describe the problem; develop a conceptual site model	*Drum dump site impacting GW (VOC contamination)*
	Determine resources - budget, personnel, and schedule	What are the drivers?
Step 2. Identify the Decision	Identify the principal study question.	*Does the concentration of contaminants in ground water exceed acceptable levels?*
	Define alternative actions.	*1. Take No Action* *2. Initiate additional characterization efforts*
	Develop a decision statement	*Does the outcome of the initial site investigation support one of the alternative actions?*

DQO Step 3

DQO Step	Action	Detail
Step 3. Identify the Inputs to the Decision	Identify the information needed	*Groundwater flow direction* *Groundwater quality (potable?)* *Contaminant concentrations in GW across the site*
	Determine sources for this information	*Existing site-specific information very limited (regional soil and groundwater data and one-time sampling agricultural well VOC analytical data* *New data required on GW and soil conditions for the site (planned investigation)*
	Determine the basis for determining the Action Level.	*Alberta Tier 1 (potable) GW values assuming future domestic use of GW based on stated residential development plans*
	Identify sampling and analysis methods that can meet the data requirements.	*Permanent vs temporary wells (direct push installation)?* *Low flow sampling (expected VOC contaminants)* *Typical GC/MS method (such as USEPA Method 8260C) will meet requirements*

DQO 4

DQO Step	Action	Detail
Step 4. Define the Boundaries of the Study Area	Define the target population of interest	*Current receptors include farm animals and corn crops, future residential human exposure possible*
	Specify the spatial boundaries that clarify what the data must represent	*Initial SI is farm boundary as no other access has been granted. Investigation funded by farm owner*
	Determine the time frame for collecting data and making the decision	*Weather and planting cycle impacting site access* *Future plans for sale of property for residential development*
	Determine the practical constraints on collecting data	*Initial SI is farm boundary as no other access has been granted*
	Determine the smallest subpopulation, area, volume, or time for which separate decisions must be made.	*Only considering the farmed area in total (size of property) based on no access to surrounding areas*

DQO 5 and 6

DQO Step	Action	Detail
5. Develop a Decision Rule	Specify an appropriate population parameter (mean, median, percentile).	*Initial investigation will perform point-by-point comparisons to action levels*
	Confirm the Action Level exceeds measurement detection limits.	*Limits of Quantification (LOQs) for VC, TCE and PCE all at 1 ug/L and below Action Levels*
	Develop a decision rule (If...then...statement).	*If GW contaminant concentrations exceed Tier 1 values, continue sampling the defined grid*
6. Specify Tolerable Limits on the Decision Errors	Determine the range of the parameter of interest.	*Action levels to at least 400 ug/L for PCE*
	Choose a null hypothesis	
	Examine consequences of making an incorrect decision	*Discussion of False Positives and False Negatives*
	Assign probability values to points above and below the Action Level that reflect tolerable probability for potential decision errors.	*The Decision Performance Curve and statistical considerations for sampling – advanced planning needs.*

DQO 7 – The End Game

DQO Step	Action	Detail
7. Optimize the Design for Obtaining Data	Review the DQO outputs.	*Initial delineation to Tier 1 levels, limited sampling requirements*
	Develop data collection design alternatives.	*Limited initial investigation does not require more rigorous analysis of alternatives.*
	Formulate mathematical expressions for each design.	
	Select the sample size that satisfies the DQOs.	*Judgmental Sampling– six wells*
	Decide on the most resource effective design, or agreed alternative.	*Well types?*
	Document details in the QA Project Plan.	*Six wells* *Targets: VC, TCE and PCE by Method 8260C (GC/MS)* *QC Samples:* *1 - Field Duplicate* *1 - Trip Blank* *1 - MS/MSD Pair*

Project Planning and DQO References

Guidance for the Data Quality Objectives Process, EPA QA/G-4

https://www.orau.org/ptp/PTP%20Library/library/EPA/QA/g4.pdf

Hawaii UST Technical Guidance Manual, Data Quality Objectives, Appendix 7-A

http://health.hawaii.gov/shwb/files/2013/06/app7a.pdf

Guidance Manual For Environmental Site Characterization In Support Of Environmental And Human Health Risk Assessment
https://www.ccme.ca/en/files/Resources/csm/Volume%201-Guidance%20Manual-Environmental%20Site%20Characterization_e%20PN%201551.pdf

Project Planning and DQO References

An Application Of USEPA's Data Quality Objective Process

https://clu-in.org/download/char/dataquality/kstorne.pdf

Visual Sampling Plan – Statistical Design and Analysis to Support Confident (Sampling) Decisions

https://vsp.pnnl.gov/

Environmental Analytical Methods 5th Edition (Dated)

http://www.genium.com/pdf/eam_TOC_sample_pgs_v5.pdf

Chapter Two of the US EPA SW-846 Compendium: Choosing the Correct Procedure

https://www.epa.gov/sites/production/files/2015-10/documents/chap2_1.pdf

Clean Water Act Analytical Methods

https://www.epa.gov/cwa-methods

Environmental Site Assessment

20 June 2018

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Important

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ESA Presentation Outline

- Overview of ESA
- Phase II ESA
- Field Event Planning and Preparation
- Field Documentation
- Soil Logging and Soil Sampling
- Monitoring Well Installation
- Groundwater Sampling
- ESA Report

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Overview of ESA

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Environmental Site Assessment (ESA)

“The process that determines whether contamination is present at the site and identifying the nature and extent of contaminants if any.”

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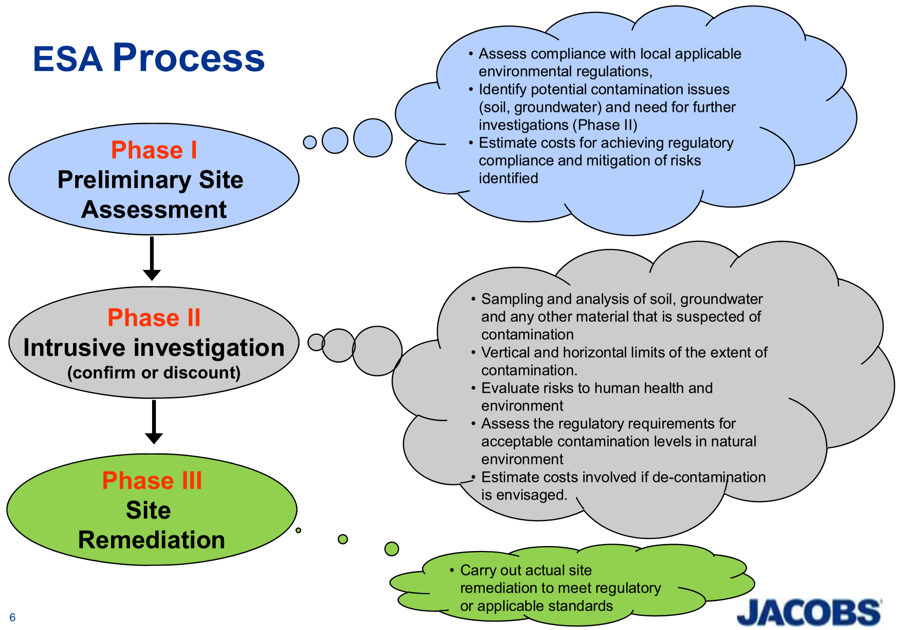
ESA Process



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Phase I ESA

- Phase I Environmental Site Assessment – *initial review*
  - Four Components
    - ➢ *Records Review*: To help identify likely contaminants and locations
      - – Facility Information (site layout, previous assessment, permits)
      - – Environmental and Health Record Databases and Public Records
    - ➢ *Site Reconnaissance*: To observe use and condition of the property and to identify areas that may warrant further investigation.
      - – Features to Look for: property and adjacent property; odors; wells; pits, ponds, and lagoons; drums or storage containers; stained soil or pavement; distressed vegetation; chemical storage areas; waste storage areas; tanks and piping.
    - ➢ *Interviews (*site owner and/or site manager, site occupants, government officials and neighbors)*:* To obtain additional information on prior and/or current uses and conditions of the property.
    - ➢ *Evaluation and Report Preparation:*
      - – Areas of Potential Concern
      - – Presence and potential impact of contaminants
      - – Necessity for site investigation or no further action recommendation
  - ASTM E 1527 “*Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process*”

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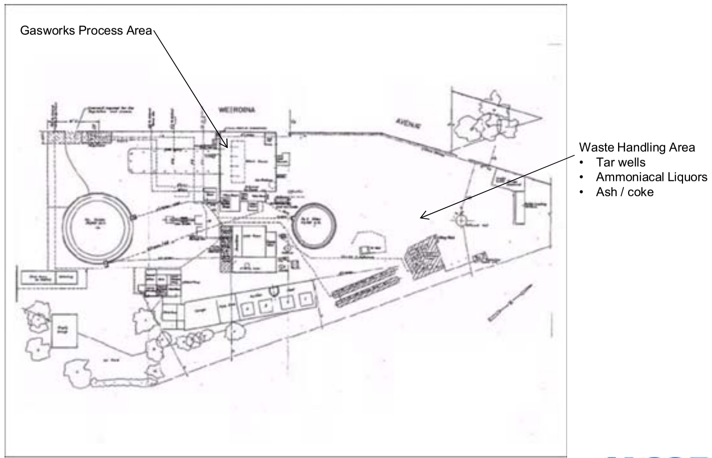
Phase I ESA - Site History ..Know where your sources might be!



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What is Considered Recognized Environmental Concern (REC)?

Petroleum Products

Chemical Solvents

Pesticides

 Source: Missouri Department of Natural Resources

What is Considered REC?

Polychlorinated biphenyls (PCBs)

Polycyclic aromatic hydrocarbons (PAHs)

Heavy Metals: e.g. *Mercury*

 Source: Missouri Department of Natural Resources

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Phase I ESA Outcome

- An indication that all appropriate inquiries have been conducted and no recognized environmental conditions were encountered.
- An indication of environmental concerns that, in the opinion of the environmental professional preparing the report, do not pose a threat to the property’s environmental integrity.
- A list or recognized environmental concerns that may require further investigations (Phase 2).

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Phase II ESA

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Phase II ESA include:

- Field activities
- Data evaluation and regulatory interpretation
- Discussion of potential risks associated with property
- Conclusions and recommendations (i.e. no further ESA, additional Phase II ESA warranted, coordination with regulating agencies)

Phase II ESA

- Purpose: to determine the presence or absence of hazardous substances identified in the Phase I ESA have impacted the soil and/or groundwater conditions beneath a property through sampling and laboratory analysis.
- Two considerations
  - ➢Investigate environmental conditions
  - ➢Baseline facility (future liability)
- Intrusive investigation
  - ➢Soil
  - ➢Groundwater
  - ➢Surface water/sediment
  - ➢Other media (PCBs, asbestos)
- Follow ASTM E1903-97 – "Standard Practice for Environmental Site Assessments: Phase II Site Assessment Process"

Field Event Planning and Preparation

Phase II ESA Strategy

- Strategy achieves
  - **Purpose driven, Adequate scope, Representative data**
- Plan the approach
  - **Site 'end-point strategy' drives characterisation**
  - **identify/consult stakeholders**
- Develop prelim. CSM
- DQOs and Sampling Plan

Field Event Planning and Preparation – Phase II ESA

- Project role and responsibility
  - Project team – assign tasks to appropriate individuals: project manager, field team leader, field team
  - Role and responsibility
    - Project manager (PM): Managing project as agreed with client and deliver a quality project.
    - Field team leader (FTL): planning, managing and overseeing the successful completion of project field tasks to meet project objectives as well as establish and reinforce the HSE culture. FTL have demonstrated knowledge and skills to conduct the work.
    - Field crew: conduct assigned tasks.

- Review project document and ESA objectives
  - Previous reports (Phase I ESA, EIA)
  - Review project objectives for investigation (DQO)
  - Scope of Phase II ESA to achieve objectives (potential impacts from areas of potential concern, borehole and well location, field activities, laboratory analysis and reporting)

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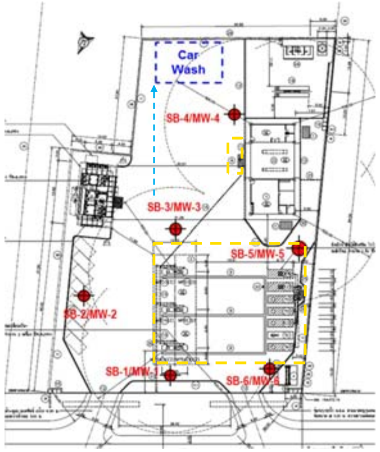
Field Event Planning and Preparation – Phase II ESA (cont'd)



- Discussion on borehole and monitoring well location ??

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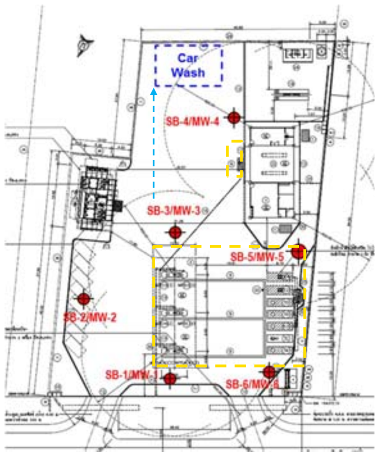
Field Event Planning and Preparation – Phase II ESA (cont'd)



Borehole/ Monitoring Well ID	Justification
SB1/MW1	Adjacent and upgradient of pump island area and coverage on northern boundary of the Site.
SB2/MW2	Along the eastern boundary of the Site.
SB3/MW3	Adjacent to and down gradient of the pump islands.
SB4/MW4	Assumed downgradient of likely contamination sources (including waste oil UST) and on downgradient site boundary.
SB5/MW5	Adjacent and downgradient of USTs area
SB6/MW6	Adjacent and upgradient of USTs area and on northern (upgradient) boundary.

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Field Event Planning and Preparation – Phase II ESA (cont'd)

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Field Event Planning and Preparation- Phase II (cont'd)

- Procuring contractors and supplies
  - Drilling contractor: Pre-Qualification
  - Laboratory selection criteria
    - Pre-Qualification: Laboratories are evaluated by experiences in laboratory accreditation, technical capability, quality system and operations.
    - Site visit for audit: to verify qualification and quality system as well as health and safety described in pre-qualification

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Field Event Planning and Preparation- Phase II (cont'd)

- Equipment preparation and calibration

PID

Gas Detector

Peristaltic Pump

Interface Probe

Water Quality Meter

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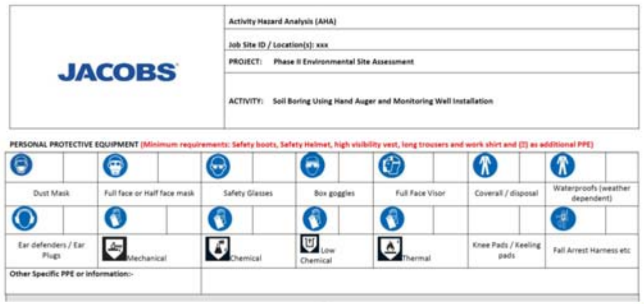
Field Event Planning and Preparation- Phase II (cont'd)

- Prepare a site specific health and safety plan: job safety analysis (JSA), personal protective equipment (PPE) and emergency response and evacuation
- Providing storage/disposal for investigation derived waste (IDW)



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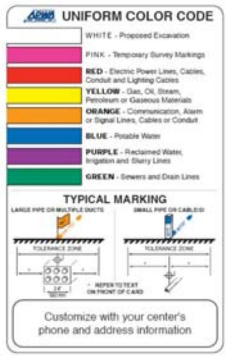
Field Event Planning and Preparation- Phase II (cont'd)

- Obtain utility clearance prior to breaking ground
  - Electromagnetic Detector
  - Ground Penetrating Radar



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Field Documentation

Field Event Planning and Preparation- Phase II (cont'd)

Activity Hazard Analysis – Borehole drilling (Hand Auger) and Well Installation

No	Job Steps	Potential Hazard	Critical Actions	RAM Sore	Responsible Party
Borehole drilling using Hand Auger and Well Installation					
1	Identification of site activities and site hazards	Interference with existing site activities	• Report to site operator. • Identify any site hazards and ensure site operator understands the tasks to be undertaken.		• CH2M • L3 Contractor
2	Setting up working area at borehole location	Manual Handling	• Ensure that proper lifting, carrying and pulling/pushing techniques are followed as indicated in the Manual Handling guidance from Shell (separate attachment). • Avoid awkward posture		• CH2M • L3 Contractor
		Slips, strain and falls	• Steady foot step on uneven floor. • Use safety boot (slip resistant sole) • Eye on path and make sure the path is clear.		• CH2M • L3 Contractor
		Exposure to Public Vehicular Traffic	• All personnel must wear reflective high-visibility safety vests or high visibility reflective shirts throughout the job. • Work site must be properly barricaded using traffic cones, hard/solid barricades and caution tape or safety nets. • Assign TRAFFIC PERSON/S or SPOTTER/S.		• CH2M • L3 Contractor

JHA Reference No.: AAK – 380 – 02 JHA Review No.:

Predetermined JHA shall be verified and reviewed on site every day before performing the work

Description of work and number of days anticipated :

Step No	Job Step	Job Step Hazard	Job Step Control

Field Documentation – Phase II ESA

- Project guidance
  - Work plan
  - Standard Operating Procedures (SOP): a document providing instruction to execute a task.
    For example, SOP of soil logging is to provides guidance to obtain accurate and consistent descriptions of soil characteristics during soil sampling.
  - Sampling and Analysis Plan (SAP): a document outlines the tasks and responsibilities of project team with respect to sampling and analysis to be performed at the site. It intends to be *a site specific guide* for use by the field team while performing the sampling and analysis.

Field Event Planning and Preparation- Phase II (cont'd)

Emergency Contact Number

PPE

Question??

- What do you need to prepare if you are assigned for a field event?

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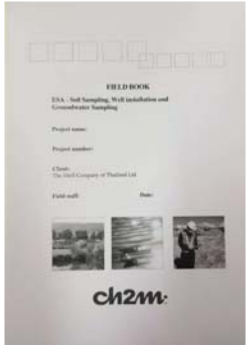
Field Documentation – Phase II ESA (cont'd)

- HASP (PPE, competent person operating machine)
- Field book, field forms, Chain of Custody (CoC) and photograph



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Soil Logging and Soil Sampling

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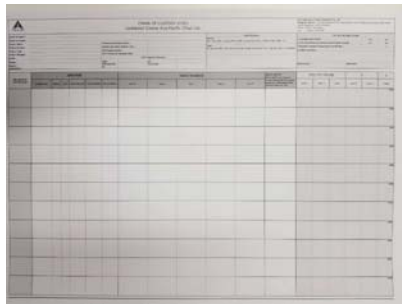
Field Documentation – Phase II ESA (cont'd)



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Soil Borehole Logging and Classification

Soil Logging is Critical

- Less $$/ labor spent revising logs in the office
- Better decisions made regarding well screen placement, remedial design, etc.
- Ability to construct accurate cross-sections and hydrologic conceptual site models.
- Less risk of penetrating confining layers and causing cross contamination

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Soil Borehole Logging and Classification (cont'd)

Soil Classification Systems

- USCS: Unified Soil Classification System
- Other Systems:
  - Burmister
  - Wentworth
  - US Department of Agriculture (USDA)

This presentation will focus on the USCS as the most common soil classification system for engineering.

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Soil Borehole Logging and Classification (cont'd)

References for Primary Logging Standards:

- ASTM D 5434-93 "Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock"
- ASTM D 2487-93 "Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System- USCS) (Geotechnical – lab based)
- ASTM D 2488-93 "Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)"

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Soil Borehole Logging and Classification (cont'd)

D2488 Description and Identification of Soils:

- Field classification of soils
- More descriptive information is contained in this method than often appears in boring logs
- D2488 is frequently cited in project SOPs
- Non-laboratory testing methods
- D2487 are for laboratory methods

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Soil Borehole Logging and Classification (cont'd)

Logging of Soils:

- Primary Soil Type (>50%) Written in all caps
- Secondary Soil Type (<50%)
- Color (use the Munsell chart or else keep i simple)
- Moisture ("dry, moist or wet")
- Consistency/ Density
- Grain Size (for coarse grained materials)
- Odor/ staining
- Other Characteristics (fossils, shell, structure, grain shape (angular, rounded, sub-angular)

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

TABLE 5 Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about ¼ in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

TABLE 3
Relative Density of Coarse-Grained Soil

Blows/Ft	Relative Density
0-4	Very loose
5-10	Loose
11-30	Medium
31-50	Dense
50	Very Dense

Source: Sowers, 1979

EXAMPLE:

SAND with silt, light brown, moist, dense, fine-grained, slight odor, no staining

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Soil Borehole Logging and Classification (cont'd)

USCS Highlights

- Fine-grained (Silts & Clays)
  - Pass through #200 sieve (75-um)
  - Clays less than 50-um
- Coarse-grained (Gravels & Sands)
  - Sand > 75-um and < 4.75 mm (0.19 in)
  - Gravel is > 4.75 mm and < 75 mm (2.95 in)
- Soil Symbols:
  - **G – Gravel**
  - **S – Sand**
  - **M – Silt**
  - **C – Clay**
  - **O – Organic**
- Plasticity Symbols:
  - **L – Low Plasticity** **H – High Plasticity**
- Grain Size Gradation Modifiers:
  - **P – Poorly Graded** **W – Well Graded**

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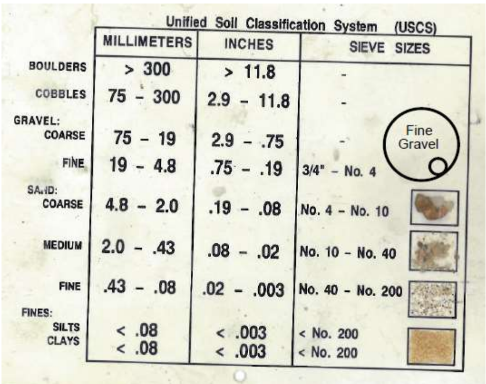
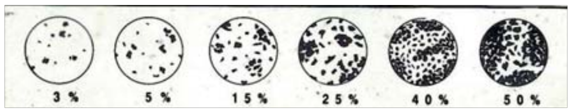
Soil Borehole Logging and Classification (cont'd)



Unified Soil Classification System (USCS)

	MILLIMETERS	INCHES	SIEVE SIZES
BOULDERS	> 300	> 11.8	-
COBBLES	75 – 300	2.9 – 11.8	-
GRAVEL: COARSE	75 – 19	2.9 – .75	-
FINE	19 – 4.8	.75 – .19	3/4" – No. 4
SAND: COARSE	4.8 – 2.0	.19 – .08	No. 4 – No. 10
MEDIUM	2.0 – .43	.08 – .02	No. 10 – No. 40
FINE	.43 – .08	.02 – .003	No. 40 – No. 200
FINES: SILTS	< .08	< .003	< No. 200
CLAYS	< .08	< .003	< No. 200



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Soil Borehole Logging and Classification (cont'd)

COARSE-GRAINED SOILS
(more than 50% of material is larger than No. 200 sieve size.)

Clean Gravels (Less than 5% fines)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
Gravels with fines (More than 12% fines)		
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
Clean Sands (Less than 5% fines)		
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
Sands with fines (More than 12% fines)		
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures

FINE-GRAINED SOILS
(50% or more of material is smaller than No. 200 sieve size.)

SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

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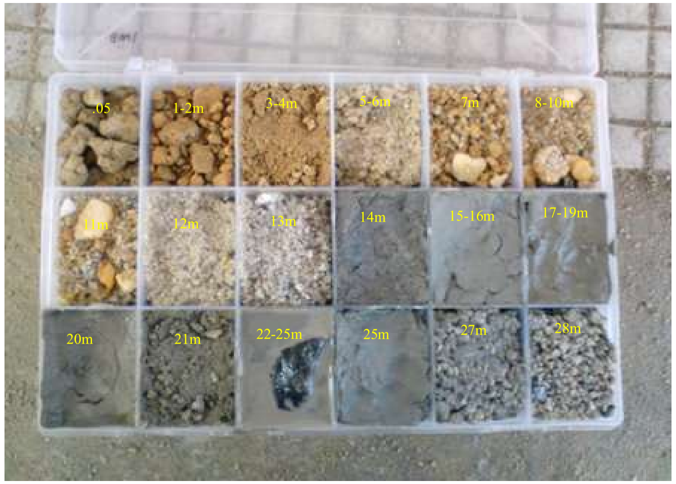
Example of Chip Box



Soil Borehole Logging and Classification (cont'd)

Borehole Logs- Critical Information

- **Date(s) and Times- When started, when finished, when samples collected (to cross check against chain of custody)**
- **Site Location (Site Name, City, Province)**
- **Project Name and Number**
- **Field personnel/subcontractor company and personnel**
- **Borehole ID and approximate location (sketch a map)**
- **Drilling method/equipment, sampling method/equipment**
- **Depth to water (initial and static) and borehole total depth**
- **Sample depth intervals and sample IDs**
- **Detailed well construction information**
- **Field Screening information (PID, odor, staining)**
- **Drilling notes (hard to drill, poor recovery, etc)**
- **Blow counts (if applicable)**
- **Soil Description according to USCS**
- **Fate of boreholes**

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Question

- Soil logging and classification is critical because…
- What is the name of common Soil Classification System used?

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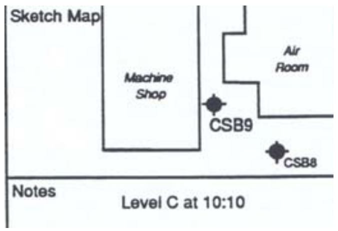
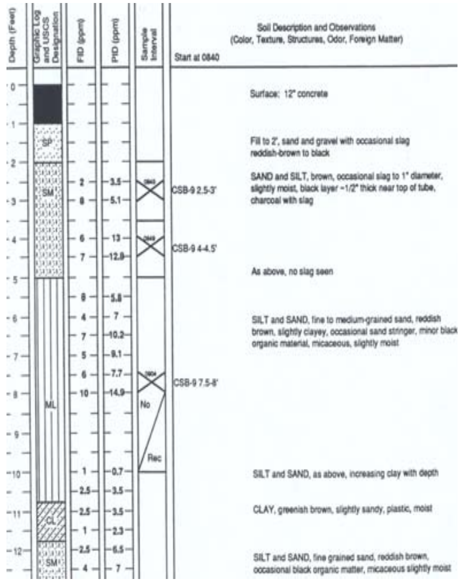
Example Bore Log





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Soil Sampling

Drilling methods

- ○ Hand auger

- ○ Solid stem auger

- ○ Direct push (Geoprobe)

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Soil Sampling

- Surface soil – trowel, shovel
  - Pros – easy to use, not invasive, does not require a dig permit (generally!)
  - Cons - Need to be careful if the instrument is appropriate for the task
- Subsurface soil
  - Hand auger
    - Pros – easy to operate, may not require a dig permit (may be required if utilities present), need small space
    - Cons – high labour effort, lots of IDW, somewhat disturbed soil sample
  - Solid stem auger – split spoon sampler
    - Pros – can get through most material, commonly available, able to drill/sample at depth and below water table, undisturbed soil sample
    - Cons – poor recovery from split spoons, relatively slow, lots of IDW, need more space

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Soil Sampling – getting the soil

- Subsurface Soil (cont'd)
  - Direct push probe
    - Pros – relatively fast, exact interval known, can use boring for GW sample, need less space, very good where sand heave a problem, low IDW, undisturbed soil sample
    - Cons – no geotechnical data for boring, borehole too small for MW installation, may have depth limitations
  - Test pit
    - Pros – can 'see' soil horizons vertically and horizontally, good for delineating extent
    - Cons – lots of IDW, utilities, disturb soil samples, air emissions if soil heavily impacted

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Soil Sampling – Selecting Intervals

- Two primary methods
  - Proscribed Interval – identified as a specific interval in the Work Plan or Project Instructions
  - Field Observations – highest observed odor, PID reading, or staining

Note – the method used to select soil samples needs to be specified in the Work Plan, Project Instructions, or at least discussed in the Kickoff Meeting. If it is not, ask!

- Soil samples are generally collected above the water table (otherwise you're sampling groundwater!)

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Soil Sampling – Taking the Sample

- For metals, SVOCs, etc – generally all you do is stuff the soil in the lab-supplied jar
- VOC sampling – method depends on project. A few examples:
  - Soil jar – generally not used anymore
  - Encore/ Terracore/ Lock n' Load



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Soil Sampling

- Before sampling, decontamination must be performed on all non-disposable equipment (such as hand auger, flight auger, extension rods and soil sampler).
- Soil samples will be collected at *intervals* or *areas that are impacted* and placed into a zip lock bag and the laboratory-supplied soil sampling jar. After equilibrate to ambient temperatures for at least 10-15 minutes, soil samples in the zip lock bag will be visually inspected, screened for total volatile organic compounds (TVOCs) using a PID.
- Soil samples for laboratory analysis will be selected from
  - area above the groundwater level
  - at the first encountered groundwater
  - at depth with highest PID readings
  - at the bottom of the borehole

  This may change based on project specific objectives or the conditions encountered in the borehole.
- Sample for laboratory will be capped, labeled and temporarily stored on site in a cooler box.

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Soil Sampling - Tips

- Place plastic sheeting on ground to keep all decontaminated equipment clean
- Collect soil samples with decontaminated stainless steel or disposable equipment
- Avoid including roots and other vegetation in the sample
- Fill VOC jars with no head space
- Fill any remaining space in boreholes with bentonite, or as required at your site.

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Monitoring Well Installation

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Well Screen and Riser

10-slot (0.010-inch) screen

- **Composition:** new, chemically inert material (Typically Schedule 40 uPVC), machine-slotted screen
- **Diameter:** depend on application
  - 2-inch ID suitable for most monitoring purposes
- **Assembly:** flush-joint threaded with end cap or coupling
- **Slot Size:** Selected to retain >70% of formation grains and >90% of primary filter pack

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Monitoring Well Installation

- Objective of a monitoring well is to provide an access point for measuring ground-water levels and to permit the procurement of groundwater samples that represent in-situ groundwater conditions at the specific point of sampling.
- To achieve the objective, it is necessary to fulfill the following criteria:
  - construct the well with minimum disturbance to the formation.
  - construct the well of materials that are compatible with the anticipated geochemical and chemical environment
  - properly complete the well in the desired zone.
  - adequately seal the well with materials that will not interfere with the collection of representative samples; and
  - sufficiently develop the well to remove any additives associated with drilling and provide unobstructed flow through the well.

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Filter Pack

- **Composition:** Inert granular material (commonly silica sand)
- **Grain Size:** Intended to minimize passage of formation material into the well:
  - screen slot size < effective size of primary filter pack
- **Grading:** Uniform (well-sorted/poorly-graded)

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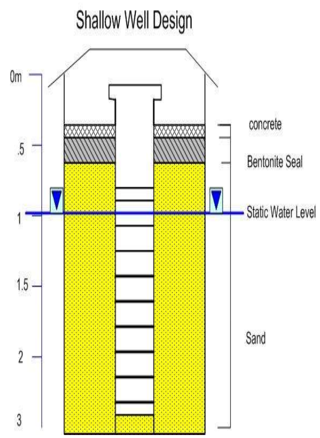
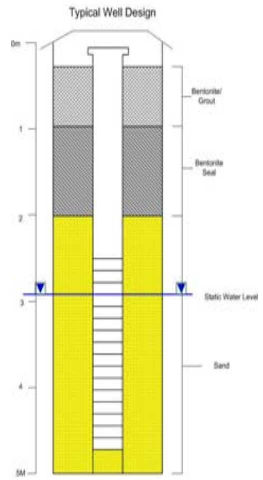
Monitoring Well Design





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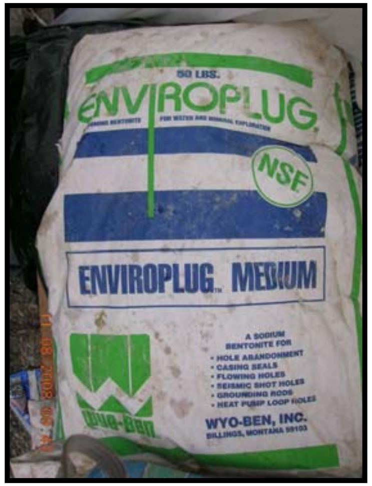
Bentonite Seal



- Composition: sodium montmorillonite (bentonite)
  - Inert
  - Expansive – expands when in contact with water, forming a seal
- Several types
  - Powdered (<200 mesh)
  - Granular – fine chips
  - Chip (<3/8") – irregular but graded size
  - Pellet (>1/4") – formed into machined sizes, and coated to delay expansion
- Can be used directly (granular, chip, pellet) or formed into a slurry (powder) to seal the well

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Grout Seal

- **Composition:** Typically Type I Portland cement mixed with water and bentonite
- **Mixing Requirements:** 5-6 gallons of water per 94-lb sack of cement.
  - 3-5 lbs (3-8% by weight) of bentonite powder may be added to mixture to reduce shrinkage, increase fluidity, and hold cement particles in suspension
- Has enough been used? Estimate the volume of the void to be filled and compare to the volume used.
  - Record the volumes of cement, bentonite, and water used
- ALWAYS be tremie and/or pressure injected at the base of the interval for better seal

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Grout Seal - Problems

- Grout contamination
  - If your well groundwater has an alkaline pH (>10) or has clear evidence of bentonite (gray, turbid) then grout has migrated into the screened interval
  - Particularly common when the grout is too thin, there is too coarse a sand pack (easily migrates downward), or bypasses your well seal and travels through coarse native material into the screen

  ➢ Remember – grout is heavier than water, and tends to migrate downward under the hydraulic head you are creating.

- Preventing grout contamination
  - Install several feet of bentonite chips or pellets and give it time to hydrate
  - Ensure your grout is thick and installed with a tremie tube

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Surface Seal and Well Head Protection

- The well seal typically constructed of bentonite chips/pellets, bentonite slurry, concrete, bentonite-cement grout, or cement
- Common well head types include flush-mount and stick-up protective casings

TIP: Fill protective stick-up casings to within ~about 8 inches of the top of the PVC well casing so you don't lose your keys or create a home for bees!

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Groundwater Sampling

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Common Surface Completions

Flush Mount

Stickup

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Groundwater Sampling

- Overall goal of groundwater sampling is to collect water samples with no alteration in water chemistry and representative of site conditions.
- Some of the most common methods of groundwater sampling are:
  - GW grab – done in borings typically in a temporary well or through a disposable well point via direct push technology. Lower quality groundwater sample generally used for screening purposes
  - *Well purge method* – remove a set number of well volumes . Generally out of favor due to impacts on VOC concentrations and turbidity that impacts metals concentrations.
  - *Low flow groundwater sampling* – the well is purged to stable water quality parameters while maintaining drawn down of water level. More representative than *Well Purge Method* or *GW grab*
  - *No-purge Methods* – sampling is conducted with little or no purge or equilibrating in screened interval. Suitable for assessing the progress (trends) of remediation actions and natural attenuation. It requires sufficient historical data. Limited sample volume can be sampled.

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Well Construction Logs

Critical Information for Well Construction Logs:

- Borehole diameter
- Casing material type, diameter, lengths, and type/screen
- Depth intervals for blank, screen, silt trap, and annual fill material
- Type and amount of annular fill material used:
  - Number of bags sand/chips/pellets
  - Type of sand used
  - Bentonite-pellets, chips, powder
  - Grout- cement bentonite mixture (proportions)
- Surface seal and completion type (flush mount or aboveground)

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Groundwater Sampling

Methods	Sampling Equipment	Advantage	Disadvantage
Well Purge	• Bailer • Peristatic Pump	• Minimal skill level required. • Simple equipment can be used	• Can result in large volume of purge water • Can take extended period of time with large diameter of wells or long water columns. **Bailer**: • High effort • Higher turbidity impact metals results • Possibly aerating upper water column, degrading VOC concentrations
Low Flow	• Peristatic Pump • Submersible Pump • Bladder Pump	• Lower volume of purge water • May be faster, especially for longer water column • More representative sample than samples collected from well purge • Can leave tubing in place for subsequent sampling	• Require greater skill for consistent results. • May have longer purge time and volumes if parameters do not stabilize quickly • Higher tubing costs than well purge
No-Purge	• Passive diffusion bag • Hydra sleeves	• Very little or no waste water • Less sampling time	• Limited analytical suites can be sampled • Low sample volumes • No groundwater parameters

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Field Parameter Measurement

- Water levels
- Location data
- pH
- Temperature
- Conductivity
- Dissolved oxygen (DO)
- Oxidation-reduction potential (ORP)
- Turbidity

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What the Field Parameter Data Can Tell You

- pH
- DO
- ORP
- Turbidity
- Temperature
- Conductivity

Development & purge stability, plus…

- **Contaminant fate and transport**
- **Remedial design parameters**

- **Groundwater recharge**
- **Flow zones**
- **Aquifer continuity**
- **Tidal influences**

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Well Purging

- Remove stagnant water from a well, immediately prior to sampling, causing its replacement by groundwater from the adjacent formation that is representative of actual aquifer conditions.

- Purge until parameters stabilize
  - pH +/- 0.1
  - Conductivity 5%
  - ORP (redox) 10mV
  - Turbidity 10%, or <10 NTU
  - Dissolved oxygen 0.3

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ESA Reporting

QA/QC Sampling Field Sheet

QA/QC Sampling

QA/QC Sample	Description	Frequency	Additional Comments
Duplicate	Measures the reproducibility of lab and field procedures	10% or 1 per every 10 *field* samples. Do NOT count blanks, MS/MSDs, or other duplicates in count	When collecting duplicates, collect parameters for original sample and duplicate together for greatest consistency (i.e., volatiles first for both original and duplicate, then SVOCs for both, etc.) Soil types should be similar.
Equipment Blank	Measures the effectiveness of decontamination procedures	1 per day for equipment that must be decontaminated and re-used for sampling	ASTM Type II water must be used for equipment blanks Lab should provide water with certification that water meets ASTM Type II requirements When performing metals analysis and collecting equipment blanks, must submit an equipment blank for filtered samples
Field Blank	Measures ambient conditions	1 per week unless there are dusty or windy conditions which require 1 per day. Large projects may require 1 per sampling area	Remember to fill sample containers for *ALL* parameters collected during that week
Trip Blank	Measures outside sources of VOC contamination occurring during transportation	1 per cooler containing VOCs	If there are multiple coolers, put all VOC samples, if possible, in one cooler to minimize number of trip blanks A trip blank must be included with each cooler containing VOC samples whether it is aqueous or soil
Matrix Spike and Matrix Spike Duplicate samples (MS/MSDs)	Measures sample-specific interfaces due to the matrix (e.g., soil, water, sediment, etc.) of the sample	1 MS/MSD for every group of 20 total samples (includes duplicates, trip blanks, field blanks, equipment blanks). **MUST** provide *TRIPLE* volume to cover the sample, the MS, and the MSD	Frequency may change if there is a gap in sampling (e.g., 5 samples collected on Monday and 6 samples collected on Friday will likely need 2 MS/MSD samples since lab will not be able to run all 11 samples in same batch) Use only one line on COC for field sample and MS/MSD. Write in the total number of sample containers submitted including the MS/MSD. Note in comments section "Run QC". **DO NOT** list MS/MSD on a separate line on the COC

ESA Result and Reporting

TABLE OF CONTENTS

Factual Report

Content

Interpretative Report

Groundwater Sampling Take-Aways

- Do necessary field preparation and attend field kick-off meetings
- Use clean, decontaminated or disposable equipment
- Always sample for VOCs first
- Immediately pack samples on ice
- Use appropriate PPE
- Collect necessary QA/QC samples EARLY when you have the volume
- Data will be used in the office
- Keep in mind what 'normal' groundwater parameters are. So, if you read a pH of 11 that means either your probe is malfunctioning or your well is grout contaminated. Be curious!
- Back-up data as necessary with field test kits

ESA Result and Reporting (cont'd)

- **ESA is adequate/ complete when:**
  - DQOs are met
  - Risks posed by the site are adequately defined
  - Need for remedial action (or lack thereof) is demonstrated
  - Rationale for selecting a remedial action alternative is supported

Thank you

June 20, 2018

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Laboratory Data Quality Overview

and

Interactive Validation Exercise

June 20, 2018

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Agenda

1. Data Verification, Validation and Quality Evaluations
2. Anatomy of an Environmental Laboratory Report
3. Data Verification Details
4. Data Validation Details
5. Flagging Conventions for Analytical Results
6. Data Validation Exercise
7. Summary of Data Verification and Validation – The Data Quality Evaluation Report
8. Data Review and Validation References
9. Additional References on Reporting Formats

1.0 Introduction
Analytical Data Review/Validation

➢**Laboratory Data Review:** analytical data is reviewed for accuracy and completion by the laboratory prior to submittal to the client.

➢**Data Verification:** is the process for evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual specifications. It essentially evaluates performance against pre-determined specifications.

➢**Data Validation:** is a complete evaluation of the analytical data to determine the quality and usability of the data. The level of data validation varies between projects and should be determined during project planning.

2.0 Anatomy of a Laboratory Data Package – Level 2 Example

All Fractions		
Sample Receipt Report		
Chain of Custody		
Laboratory Case Narrative		
GC/MS Organic Fractions	**Form or equiv.**	**Level 2**
Sample Results	1	•
Surrogate Recovery Summary (w/ applicable control limits)	2	•
MS/MSD Accuracy & Precision Summary **	3	•
LCS Accuracy Summary	3	•
Method Blank Summary	4	•
Sample preparation logs		•
Metals/Inorganic Fractions	**Form or equiv.**	**Level 2**
Sample Results	1	•
Initial and Continuing Calibration Blanks and Method Blanks Summary	3	•
Pre-digestion Matrix Spike Recoveries Summary	5A	•
Native Duplicate or MS/MSD Precision Summary	6	•
Laboratory Control Sample Recovery Summary	7	•
Preparation Log Summary	12	•
Analysis Run Log	13	•

Forms - referenced to USEPA CLP Reporting Forms

Knowledge Check

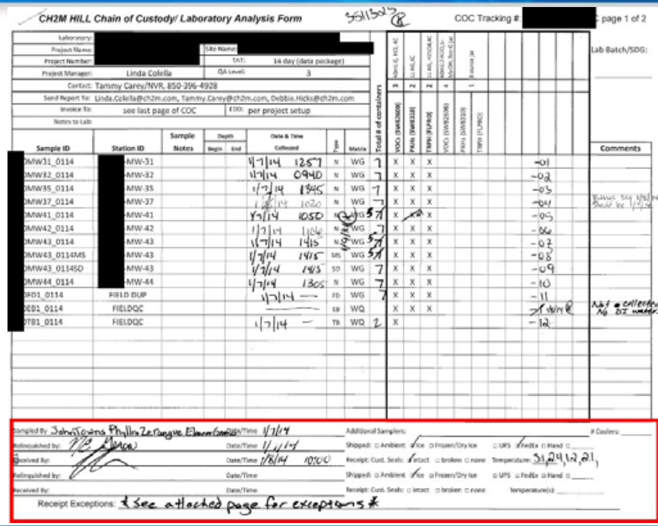
Does the Chain of Custody (CoC) Represent a Binding Agreement with the Laboratory?

Can it Supersede the Laboratory Statement of Work and Quality Assurance Plan?

2.1 Laboratory Sample Receipt (Acceptance) Report

Sample Receipt Checklist		
Cooler Received/Opened On:	**Rep sample Temp (Deg C):**	
Temp Blank:	**Carrier name:**	
Last 4 digits of Tracking No.:	**Cooling process:**	
Packing Material Used:		
Ice Ice Pack Dry Ice Other		
1. Shipping container/cooler in good condition?	☐ Yes	☐ No
2. Custody seals intact, signed, dated on shippping container/cooler?	☐ Yes	☐ No
3. Custody seals intact on sample bottles?	☐ Yes	☐ No
4. Chain of custody present?	☐ Yes	☐ No
5. Sampler's name present in COC?	☐ Yes	☐ No
6. Chain of custody signed when relinquished and received?	☐ Yes	☐ No
7. Chain of custody agrees with sample labels?	☐ Yes	☐ No
8. Samples in proper container/bottle?	☐ Yes	☐ No
9. Sample containers intact?	☐ Yes	☐ No
10. Sufficient sample volume for indicated test?	☐ Yes	☐ No
11. All samples received within holding time?	☐ Yes	☐ No
12. Temperature of rep sample or Temp Blank within acceptable limit?	☐ Yes	☐ No
13. Water - VOA vials have zero headspace?	☐ Yes	☐ No
14. Water - pH acceptable upon receipt? Example: pH > 12 for (CN,S); pH<2 for Metals	☐ Yes	☐ No
15. Did the bottle labels indicate correct preservatives used?	☐ Yes	☐ No
16. Were there Non-Conformance issues at login?	☐ Yes	☐ No
Was Client notified?	☐ Yes	☐ No
Comments:		
Date and Time Received: January 29, 2018 4:00 pm		
Via FedEx		

2.2 – Lab Deliverables Sample Chain of Custody (CoC)


CH2M HILL Chain of Custody/ Laboratory Analysis Form

COC Tracking #: [redacted] page 1 of 2

Laboratory: [redacted]
Project Name: [redacted] Site Name: [redacted]
Project Number: [redacted] TAT: 14 day (data package)
Project Manager: Linda Colella QA Level: 3
Contact: Tammy Carey/NVR, 850-396-4928
Send Report To: Linda.Colella@ch2m.com, Tammy.Carey@ch2m.com, Debbie.Hicks@ch2m.com
Invoice To: see last page of COC EDD: per project setup
Notes to Lab:

Lab Batch/SDG:

Sample ID	Station ID	Type	Matrix	VOCs	PAHs	TRPH
[redacted]MW31_0114	[redacted]MW-31	N	WG	X	X	X
[redacted]MW32_0114	[redacted]MW-32	N	WG	X	X	X
[redacted]MW35_0114	[redacted]MW-35	N	WG	X	X	X
[redacted]MW37_0114	[redacted]MW-37	N	WG	X	X	X
[redacted]MW41_0114	[redacted]MW-41	N	WG	X		X
[redacted]MW42_0114	[redacted]MW-42	N	WG	X	X	X
[redacted]MW43_0114	[redacted]MW-43	N	WG	X	X	X
[redacted]MW43_0114MS	[redacted]MW-43	MS	WG	X	X	X
[redacted]MW43_0114SD	[redacted]MW-43	SD	WG	X	X	X
[redacted]MW44_0114	[redacted]MW-44	N	WG	X	X	X
[redacted]FD1_0114	FIELD DUP	FD	WG	X	X	X
[redacted]EB1_0114	FIELDQC	EB	WQ	X	X	X
[redacted]TB1_0114	FIELDQC	TB	WQ	X		

Receipt Exceptions: * See attached page for exceptions *

2.3 – Lab Deliverables: Case Narrative Example

Laboratory ID
Client ID

1. Sample Receipt
2. Sample Holding Times
   - Preparation
   - Analysis
3. Methods Performed
4. Sample Preparation
5. Analysis
   - Calibration
   - Blanks
   - Surrogates
   - Spikes:
     - Laboratory Control Samples
     - Matrix Spikes/Matrix Spike Duplicates
   - Internal Standards
   - Sample Performance
6. Certification of Analysis
   - Authorized Signature
   - Date

2.4 – Lab Deliverables - Sample Results Example (USEPA Form 1/Certificate of Analysis)

Lab. Delivery Group	AND1250						
Anlaysis	VOCs BY GC-MS						
Test No:	EPA 8260C						
Prep-Test No:	EPA 5030C						
Customer	CH2M HILL PH00010						
	PHASE II ESA, 10010						
Project: Lab ID:	AND1250-002A						
Client Sample ID	W-01						
Collection Date:	12/15/17 10:00						
Matrix:	Groundwater						
QC Batch:	00629						
RunID:	GCMS02_160222A		PrepDate:	12/18/2017		Analyst:	RBA
Analyte		Result	PQL	Units	DF	Date/Time Analyzed	
Benzene		ND	1.0	µg/L	1	12/18/2017	10:45PM
Ethylbenzene		ND	1.0	µg/L	1	12/18/2017	10:45PM
m,p-Xylene		ND	2.0	µg/L	1	12/18/2017	10:45PM
o-Xylene		ND	1.0	µg/L	1	12/18/2017	10:45PM
Toluene		ND	1.0	µg/L	1	12/18/2017	10:45PM
Surr: 1,2-Dichloroethane-d4		126	60-140	%REC	1	12/18/2017	10:45PM
Surr: 4-Bromofluorobenzene		95.5	60-140	%REC	1	12/18/2017	10:45PM
Surr: Toluene-d8		87.2	60-140	%REC	1	12/18/2017	10:45PM

3.0 Sample Verification Details

- Examination of the Chain of Custody
  - Samples and required analyses clearly indicated
  - Dates/times and Signatures at hand-overs completed
  - Corrections properly executed
  - Other required information present
- Cross check of CoC against Lab Sample Receipt Report
  - Samples received (IDs) match CoC
  - Required sample volumes appropriate for requested analyses and containers intact
  - Samples arrived at or below required temperature

In most countries, the CoC is a Legal Document!

4.0 Data Validation Details: QA/QC Definitions

➢ **Holding Time -** maximum times that samples may be held prior to prep and/or analysis and still be considered valid or not compromised.

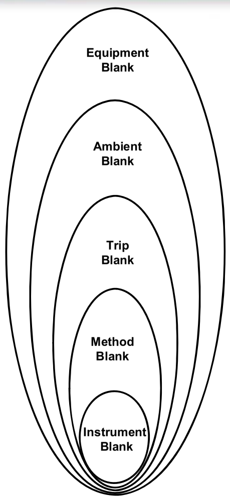
➢ **Control Limits (Acceptance Limits):** specified limits for characteristics of an item, process, or service defined in requirement documents

Quality Control is a set of measures listed within an analytical method to assure that the sample preparation and analysis are in control.

QC measures may be:

- Procedural (e.g., samples must be analyzed within 12 hours of instrument calibration)
- Numerical (e.g., the recovery of a spiked analyte must be 80%-120%)

4.1 – QA/QC Definitions: Blanks



Blank samples are used to trace sources of artificially introduced contamination. The diagram shows the comparison of different blank sample results and how they are used to identify and isolate the source of contamination introduced in the field and/or the laboratory.

➢ **Field Blanks:**
- **Equipment Blank** results include total field and lab sources of contamination
- **Ambient Blank** results include total ambient conditions during sampling and lab sources of contamination
- **Trip Blank** results include shipping and lab sources of contamination (volatiles only)

➢ **Laboratory Blanks:**
- **Method Blank** results show sources of contamination from sample preparation and/or analysis
- **Instrument Blank** results show only lab (instrument) sources of contamination

4.2 – QA/QC Definitions: Spiked Samples

Spiked samples contain a known amount of target analyte(s) added to a sample at the lab and used to determine recovery efficiency of the analytical process.

➢**Laboratory Control Sample (LCS) –** also called “blank spike”. Contaminant-free water or an inert solid spiked with know concentrations of the target analytes. LCS is carried through complete sample prep & analyses and used to determine whether the method is in control.

➢**Matrix Spike/Matrix Spike Duplicate (MS/MSD)** – a portion of a field sample is spiked (prior to sample prep & analysis) with known concentrations of the target analytes. MS/MSD are used to document potential matrix effects.

➢**Post Digestion Spike (PDS)** – analytes are added after sample preparation and prior to analysis to verify the accuracy of the analytical method (inorganic methods)

➢**Surrogates** -- compounds similar to the target analyte(s) but not normally found in environmental samples are added to each field and QC sample; surrogates are used to evaluate accuracy, method performance, and extraction efficiency (typically organic methods only).

4.3 – QA/QC Definitions: Duplicate and Split Samples

➢**Laboratory duplicates** – two portions of a field sample are taken through the preparation and analytical process to access the precision of the lab.

➢**Field duplicates** -- two portions of a field sample are collected at the same time and in the same location. The sample location of the second portion (duplicate sample) is not provided to the lab. Field duplicate samples are carried through the preparation and analytical process to access the precision of data collection activities (including sampling, analysis, and site heterogeneity)

➢**Split samples** -- two or more representative portions taken from the same sample in the field or laboratory that are analyzed by at least two different labs and/or methods. Split samples are used to assess precision, variability, and data comparability between labs and/or methods. Prior to splitting, the sample should be mixed thoroughly (except for VOCs, oil and grease, or otherwise directed) to minimize sample heterogeneity.

4.4 - Data Validation Options

➢ Validation and flagging guidelines are established in QAPP
- Review data package deliverables
- Complete data validation worksheet
- Assign final validation flags to sample results

➢Data validation can be completed in several ways:
- Using hardcopy (paper) lab reports – qualification flags are hand written on the forms 1s and manually entered into an excel spreadsheet or access database. Scan the validated forms and save with the project files.
- Using pdf lab reports – add qualification flags to the pdf forms, manually entering validation flags into excel or database, and then save validated results pdf with the project files.
- Electronically -- using one of several tools. EQuIS DQM is one commercially available data validation tool.

Knowledge Check

Is Data Validation Required for All Sampling and Analysis Activities?

5.0 – Validation Data Flagging: Application of Qualifiers

Basic/General Flagging

- **U** - The analyte was analyzed for, but not detected above the LOD.
- **J** - The analyte was positively detected, the quantitation is an estimation.
- **UJ** - The analyte was analyzed for, but not detected and the quantitation is an estimate.
- **R** - (rejected) unusable data.
- **X** - (excluded) multiple results were reported for parameter, result excluded as a better result was available.

Project-Specific or Expanded Project Flagging (customization examples)

- **JH** - analyte detected, result estimated due to potential high bias
- **UI** - analyte not detected, RL elevated due to interferences (which may explain why criteria not met)
- **B** - analyte detected in sample and in an associated blank (result may be due to contamination or inflated by contamination)
- **UJL** -the analyte was analyzed for, but not detected and the quantitation is an estimate due to potential low bias.

Section 5.1 - Data Validation Guidelines (example)

Data Validation Conventions – General

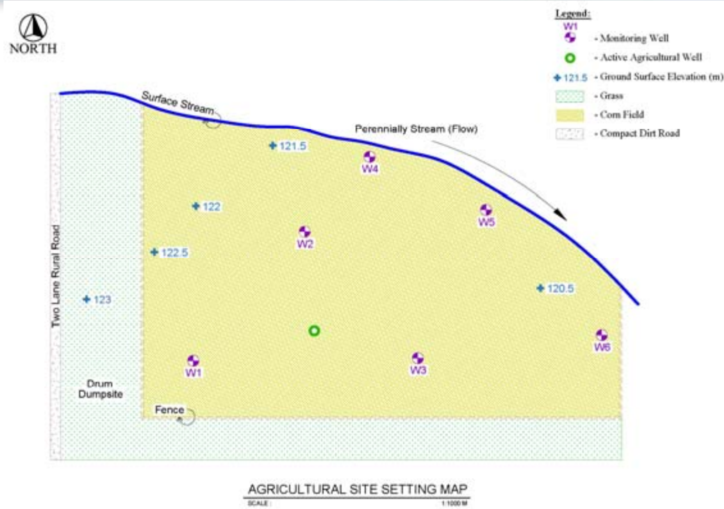
QC Requirement	Criteria	Flag	Flag Applied To
Holding Time	Time exceeded for extraction or analysis	J for the positive results R or UJ for non-detects*	All analytes in the sample
LCS	% R > UCL (upper control limit) %R < LCL (lower control limit)	J for the positive results J for the positive results, R for the non-detects	The specific analyte(s) in all samples in the associated AAB
Method Blank	Analyte(s) detected > ½ RL	B	The specific analyte(s) in all samples in the associated AAB with results above the MDL
Equipment Blank	Analyte(s) detected > ½ RL	B	The specific analyte(s) in all samples with the same sampling date as the equipment blank
Field duplicates	RPD > CL and field duplicates > RLs or one field duplicate > RL, one ND	J for the positive results UJ for the non-detects	The specific analyte(s) in all samples collected on the same sampling date. **Note:** No flagging is required for RPDs based on F-flagged results
MS/MSD	MS or MSD % R > UCL or MS or MSD % R < LCL or MS/MSD RPD > CL	M for all results	The specific analyte(s) in all samples collected from the same site as the parent sample
Sample Preservation/ Collection	Preservation/collection requirements not met	J for the positive results R or UJ for non-detects*	All analytes in the sample
Sample Storage	< 2°C or > 6°C or as required	J for the positive results R or UJ for non-detects*	All analytes in the sample

6.0 Data Validation Exercise

6.1 Example Project: Agricultural Site Details

- Abandoned and uncontrolled drum dump site discovered adjacent to farm property (1-4 m below ground surface), drums in poor condition with no identifiable markings
- Active farming area with corn crops
- On-site well used for crop irrigation and livestock water supply
  - Depth to water 15 m
  - Transient solvent odor noted in well water
  - Initial test results showing PCE at 300 ug/L and low concentrations of TCE and VC (<20 ug/L)
- Initial Investigation to define nature and extent of contamination
- Extent of initial investigation limited to active farming area

6.2 Agricultural Site Setting



6.3 Data Verification – Lab Sample Receipt Report

Item	Planned	Collected	Comment
GW Field Samples	6	6	
QC Samples			
Field Duplicate	1	1	W5
MS/MSD	1 pair	1 pair	W5
Trip Blank	1	1	
Analyzed as Requested - 8260C	Yes		
Containers Intact	Yes		
Within temperature	Yes		
At Lab Within Holding Time	Yes		

Is a resampling triggered by the sample conditions on receipt at the lab?

6.4 Field Sample Results

			GW Results (ug/L)			Surrogate Recoveries % (Limits 70-120%)		
Well	**Date Collected**	**Date Analyzed**	**VC**	**TCE**	**PCE**	***1,2-DCA-d4***	***4-BFB***	***Tol-d8***
W1	18-Dec-17	20-Dec-17	18	55	1250	88	87	103
W2	18-Dec-17	20-Dec-17	8	14	125	93	89	99
W3	18-Dec-17	27-Dec-17	4	6	200	96	91	97
W4	18-Dec-17	20-Dec-17	2	3	40	102	106	101
W5*	18-Dec-17	20-Dec-17	3	7	50	92	101	93
W5 FD	18-Dec-17	20-Dec-17	2	6	55	95	91	92
W6	18-Dec-17	20-Dec-17	ND	ND	8	94	89	92
Trip Blank	18-Dec-17	20-Dec-17	ND	ND	2.5	91	87	87

ND = Not detected

FD = Field Duplicate sample
* = MS/MSD Sample Volumes collected with W5

6.5 Laboratory Control Sample Results

Laboratory Control Sample

Analyte	LCS Results	PQL	Spike Value	Units	%REC	Low Limit	High Limit
Vinyl Chloride	42.3	1.0	50.0	ug/L	84.6%	70	120
Trichloroethylene (TCE)	43.0	1.0	50.0	ug/L	85.9%	70	120
Tetrachloroethylene (PCE)	88.5	2.0	100.0	ug/L	88.5%	70	120
Surr:1,2-Dichloroethane-d4	44.1		50.0	ug/L	88.2%	70	120
Surr:4-Bromofluorobenzene	49.1		50.0	ug/L	98.2%	70	120
Surr:Toluene-d8	39.1		50.0	ug/L	78.2%	70	120

Laboratory Control Sample Duplicate

Analyte	LCSD Result	PQL	Spike Value	%REC	Units	High Limit	Low Limit	LCS Result	RPD	Limit
Vinyl Chloride	43.6	1.0	50.0	87.3%	ug/L	70	120	42.3	3.1	20.0
Trichloroethylene (TCE)	43.9	1.0	50.0	87.8%	ug/L	70	120	43.0	2.1	20.0
Tetrachloroethylene (PCE)	90.4	2.0	100.0	90.4%	ug/L	70	120	88.5	2.1	20.0
Surr:1,2-Dichloroethane-d4	44.9		50.0	89.9%	ug/L	70	120			
Surr:4-Bromofluorobenzene	50.2		50.0	100.4%	ug/L	70	120			
Surr:Toluene-d8	48.5		50.0	96.9%	ug/L	70	120			

6.8 Field Sample Results with Qualification Flags

			GW Results (ug/L)			Surrogate Recoveries % (Limits 70-120%)		
Well	Date Collected	Date Analyzed	VC	TCE	PCE	*1,2-DCA-d4*	*4-BFB*	*Tol-d8*
W1	18-Dec-17	20-Dec-17	18	55	1250	88	87	103
W2	18-Dec-17	20-Dec-17	8	14	125	93	89	99
W3	18-Dec-17	27-Dec-17	4 J	6 J	200 J	96	91	97
W4	18-Dec-17	20-Dec-17	2	3	40	102	106	101
W5*	18-Dec-17	20-Dec-17	3	7	50	92	101	93
W5 FD	18-Dec-17	20-Dec-17	2	6	55	95	91	92
W6	18-Dec-17	20-Dec-17	ND	ND	8 U	94	89	92
Trip Blank	18-Dec-17	20-Dec-17	ND	ND	2.5	91	87	87

ND = Not detected

FD = Field Duplicate sample

* = MS/MSD Sample Volumes collected with W5

6.6 Matrix Spike Results

MS Results

Analyte	MS Results	PQL	SPK Value	Native Conc	%REC	Low Limit	High Limit
Vinyl Chloride	51.0	1.0	50.0	3.0	96.0%	70	120
Trichloroethylene (TCE)	60.0	1.0	50.0	7.0	106.0%	70	120
Tetrachloroethylene (PCE)	144.0	1.0	100.0	50.0	94.0%	70	120
Surr:1,2-Dichloroethane-d4	46.8		50.0		93.8%	70	120
Surr:4-Bromofluorobenzene	53.15		50.0		106.3%	70	120
Surr:Toluene-d8	52.5		50.0		105.0%	70	120

MSD Results

Analyte	MSD Result	PQL	SPK Value	Native Conc	%REC	High Limit	Low Limit	MS Result	RPD	Limit
Vinyl Chloride	45.4	1.0	50.0	3.0	84.9%	70	120	51.0	11.6	20
Trichloroethylene (TCE)	48.0	1.0	50.0	7.0	82.0%	70	120	60.0	22.2	20
Tetrachloroethylene (PCE)	131.0	2.0	100.0	50.0	81.0%	70	120	144.0	9.5	20
Surr:1,2-Dichloroethane-d4	44.8		50.0		89.6%	70	120			
Surr:4-Bromofluorobenzene	51.1		50.0		102.3%	70	120			
Surr:Toluene-d8	50.8		50.0		101.5%	70	120			

Section 7.0 - Validation Deliverables Use of PARCCS for Data Usability Assessment

QC Element	Laboratory Measures	Field Measures	Basis of Evaluation
Precision	Laboratory Control Sample (LCS) LCS Duplicates (LCSD) Matrix Duplicates Historical Data Trends	Field Duplicates Matrix Spike Duplicates Matrix Duplicates Appropriate Sampling Procedure	Evaluation of Project **Precision** Data Quality Indicators by Media Type. Evaluation of Compliance with Project's Data Quality Objectives.
Accuracy	LCSs Matrix Spikes Internal Standards Surrogate Recovery Initial Calibration Continuing Calibration Standard Reference Material	Matrix Spikes/Matrix Spike Duplicates Inclusion of "Blind" Samples Appropriate Sampling Procedures Appropriate Sample Containers Appropriate Sample Preservation Holding Times Equipment Blank/Field Blank	Evaluation of Project **Accuracy** Data Quality Indicators by Media Type. Evaluation of Compliance with Project's Data Quality Objectives
Representativeness	Laboratory Homogenization Appropriate Sub-sampling Appropriate Dilutions "As Received" Sample Preservation Meeting Hold Times	Appropriate Sampling Procedures Appropriate Sample Containers Appropriate Sample Preservation Incorporation of Field Screening Data	Evaluation of consistency of data with Conceptual Site Model Evaluation of consistency of analytical data with field data and hydrogeological site data Evaluation of spatial and temporal variabilities
Comparability	GC/MS Tuning Calibration Analytical Method Followed	Comparison to Previous Data Points Comparison to Similar Data Points	Evaluation of inter-comparability of all site data and information by media type
Completeness	% Sample Per Batch Analyzed and Reported All Critical Samples Reported and Unqualified	% Planned Samples Collected All Critical Samples Collected	Analyte list consistent with site history Number of data points adequate to describe the magnitude and areal extent of release
Sensitivity	Method Blanks Instrument Blanks Reporting Limit (Lowest Calibration Standard) Appropriate Analytical Method	Equipment Blank/Field Blanks Appropriate Sample Volume or Weight	Evaluate whether reporting limits for data adequate to demonstrate compliance with applicable standards

6.7 Qualification of Results

- Interactive Discussion and Application of Qualification Flags
  - General Inspection of Field Sample Results – trends, concerns, data gaps; what observations can be made?
  - Holding Time Exceedance for W6 sample
  - Positive detection of PCE in the Trip Blank sample
  - RPD Exceedance for TCE in MS/MSD samples

Section 7.1 - Validation Deliverables: Data Quality Evaluation (DQE) Reports

Like data validation, DQE format and level of detail can be modified to meet project needs:

- Basic DQE – bullet summary of data validated (methods, laboratory, QC collected) and any exceptions that resulted data flagging.
- Extended DQE – detailed data validation report which may include statistic, QC graphs, tables summarizing original data and final data, frequency of detects in blanks and samples, matrix spike recoveries, surrogate recoveries, summary of rejected data

Section 7.2 - Validation Deliverables Data Assessment -- PARCCS

- **Precision -** Measured using replicates (duplicates) (field and lab)
- **Accuracy (bias) -** Measured using blanks and matrix spikes (field and lab)
- **Representativeness** - Does the sample design and collection represent the site conditions? (e.g., preservation, holding time, sample location)
- **Comparability** - data are reported in correct units and comparable methods(e.g., Nutrients *as nitrogen* or *as nitrate,* data from different laboratories by different methods)
- **Completeness** - defines how much data is required to meet Quality Objectives
- **Sensitivity** - method detection limits/reporting limits are sufficient for Quality Objectives

7.3 Benefits of Data Validation (DV)

- DV is the process of evaluating the completeness, correctness, consistency, and compliance data against a standard or project-specific criteria.
- Validity of analytical data important -- serves as a basis for evaluating compliance with the rules and for regulatory actions
- Enable program to review analytical data for consistency, quality and relevance before using it as a basis for making decisions that will affect closure and corrective action sites.
- DV adds confidence to the data set by ensuring that data are of a known and acceptable quality.
  - Defensibility
  - Identify contamination (not indicative of environmental conditions
  - Eliminating stray or inappropriate data.
  - Work with field and lab real-time to solve & alleviate problems

8.0 Data Reporting and Validation References

- Guidance on Environmental Data Verification and Data Validation (PDF) (6 pp, 373 K)
- National Functional Guidelines for Organic Superfund Methods Data Review (SOM02.4) (PDF) (250 pp, 2 MB, January 2017, EPA-540-R-2017-002)
- National Functional Guidelines for Inorganic Superfund Methods Data Review (ISM02.4) (PDF) (138 pp, 1 MB, January 2017, EPA-540-R-2017-001)
- **USEPA SW-846 Analytical Methods Compendium:** https://www.epa.gov/hw-sw846/sw-846-compendium

9.0 Additional References on Data Reporting Formats

9.1 Lab Deliverables GC/MS Organic Fractions

GC/MS Organic Fractions	Form or equiv.	Level 1	Level 2	Level 3	Level 4
Sample results	1	•	•	•	• + raw
Surrogate Recovery Summary (w/ applicable control limits)	2		•	•	• + raw
MS/MSD Accuracy & Precision Summary **	3		•	•	• + raw
LCS Accuracy Summary	3		•	•	• + raw
Method Blank Summary	4		•	•	• + raw
Manual integration documentation				•	
Instrument Tuning Summary (including tuning summary for applicable initial calibrations)	5			•	• + raw
Initial Calibration Summary (including std concentration levels)	6			•	• + raw
Initial Calibration Verification Summary	7			•	• + raw
Continuing Calibration Verification Summary	7			•	• + raw
Internal Standard Summary (including all applicable initial calib.)	8			•	•
Instrument Analytical Sequence	8			•	•
Internal COC, standard certificate of analysis				•	•
Sample preparation logs			•	•	•

9.2 Lab Deliverables Metals

Metals/Inorganic Fractions	Form or equiv.	Stage 1	Stage 2	Stage 3	Stage 4
Sample Results	1	•	•	•	• + raw
Initial and Continuing Calibration Summary	2A			•	• + raw
CRQL Check Standard	2B			•	• + raw
Initial and Continuing Calibration Blanks and Method Blanks Summary	3		•	•	• + raw
ICP-AES Interference Check	4			•	• + raw
ICP-MS Interference Check	4B			•	• + raw
Pre-digestion Matrix Spike Recoveries Summary	5A		•	•	• + raw
Post Digestion Spike (PDS)Recoveries Summary	5B			•	• + raw
Native Duplicate or MS/MSD Precision Summary	6		•	•	• + raw
Laboratory Control Sample Recovery Summary	7		•	•	• + raw
Serial Dilution	8			•	• + raw
Detection Limits (RL/MDL)	9			•	• + raw
ICP-AES Interelement Correction Factors	10			•	• + raw
ICP-MS Interelement Correction Factors	10B			•	• + raw
Linear Range Summary	11			•	• + raw
Preparation Log Summary	12		•	•	•
Analysis Run Log	13		•	•	•
ICP-MS Tune	14			•	• + raw
ICP-MS Internal Standards Relative Intensity Summary	15			•	• + raw