



Biological Iron and Manganese Filtration Eliminates Chemical Addition

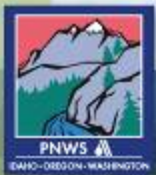
Pilot Studies:
Arugum Bay, Sri Lanka; Jefferson
County, WA; and Fairbanks, AK

Enoch Nicholson

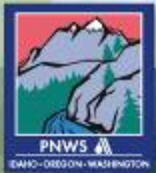
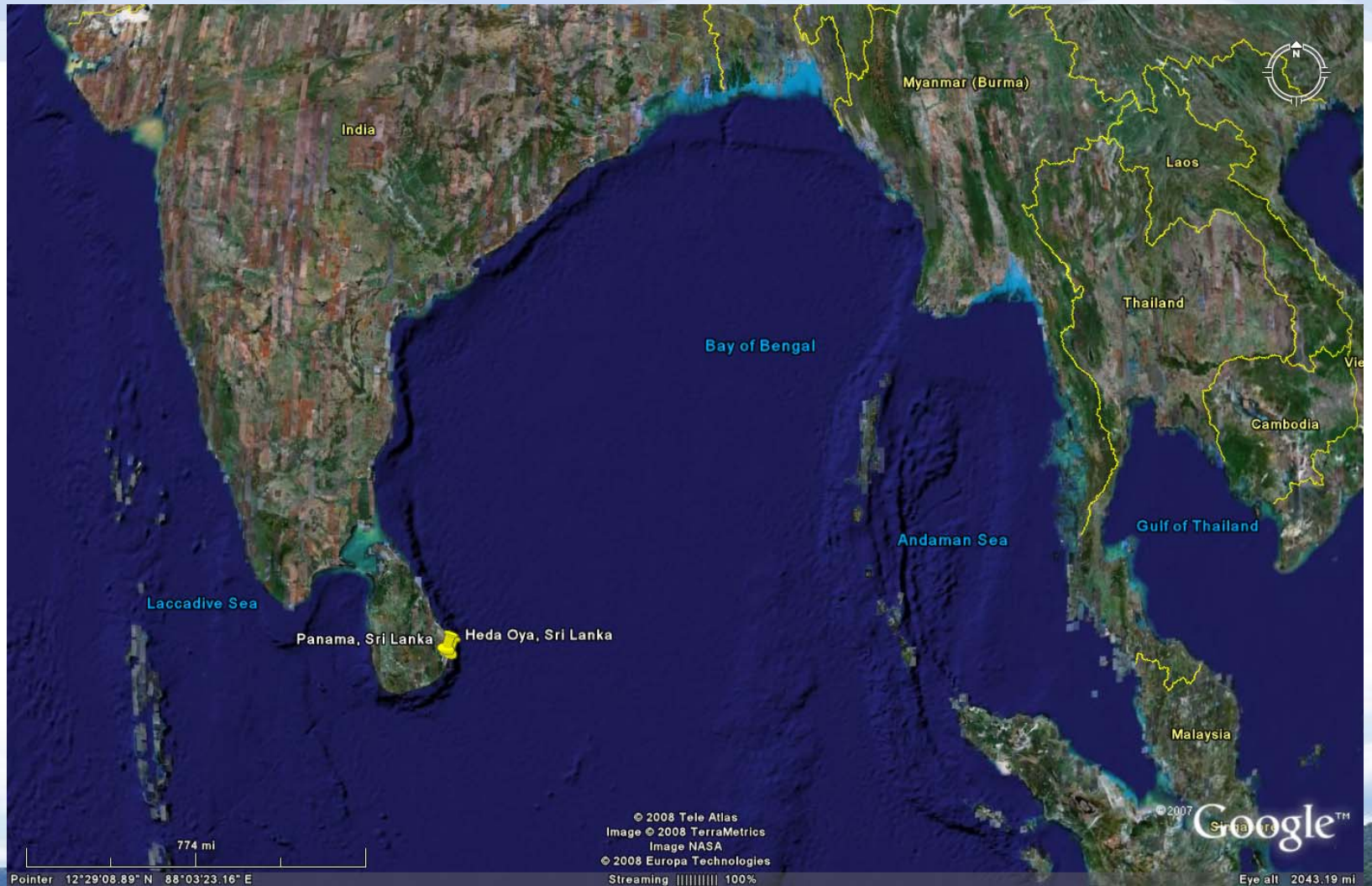


Projects

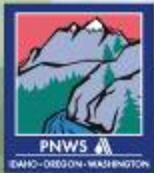
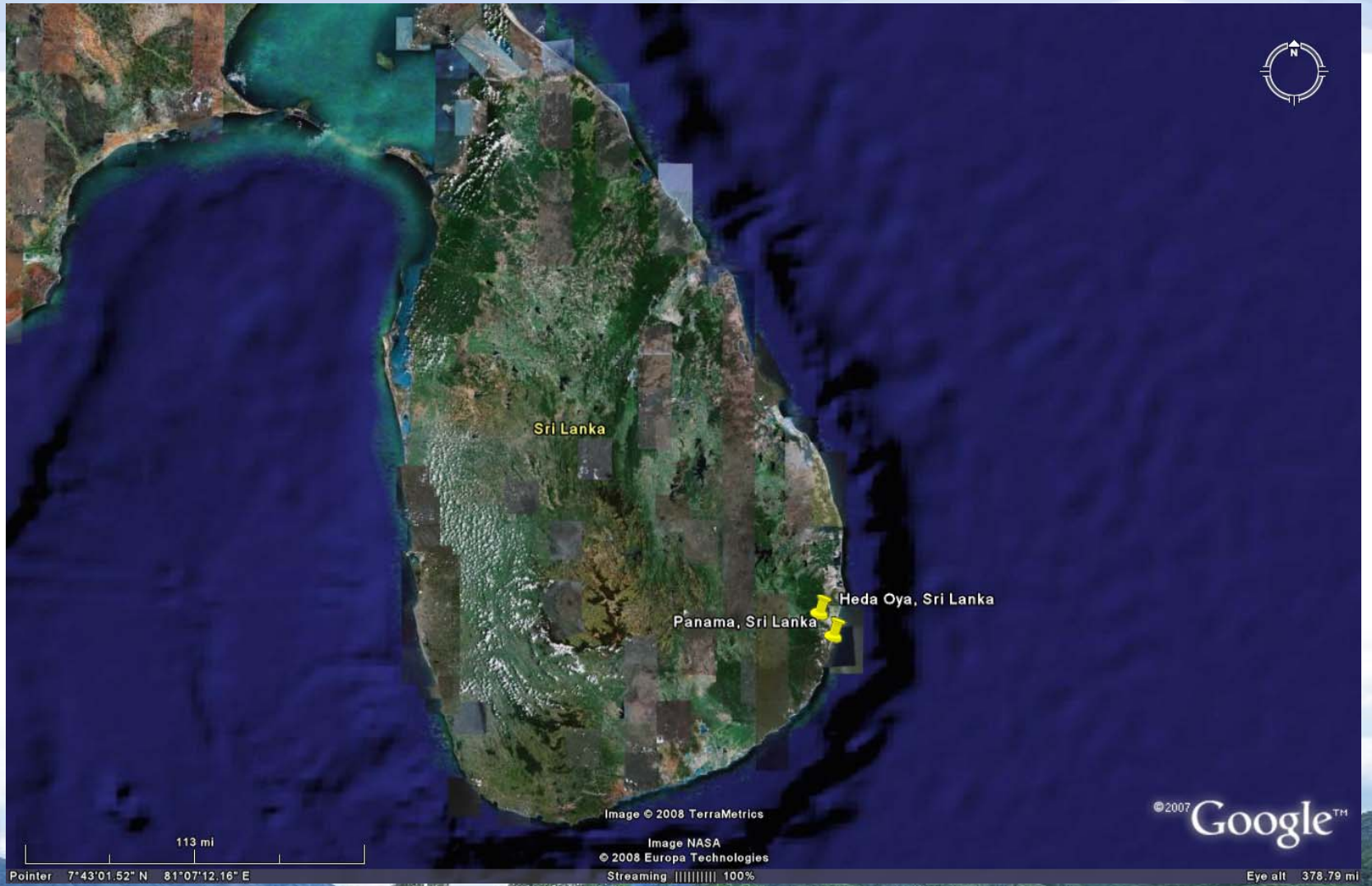
- Arugum Bay Water Supply Project, Sri Lanka
 - US AID – Sri Lanka Tsunami Reconstruction Program
- Jefferson County, WA
 - PUD No. 1 of Jefferson County – Sparling Well WTP Upgrade
- Fairbanks Alaska
 - Alaska Department of Fish and Game – Ruth Burnett Sport Fish Hatchery Influent Treatment



Sri Lanka Tsunami Reconstruction



Sri Lanka Tsunami Reconstruction



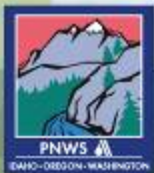
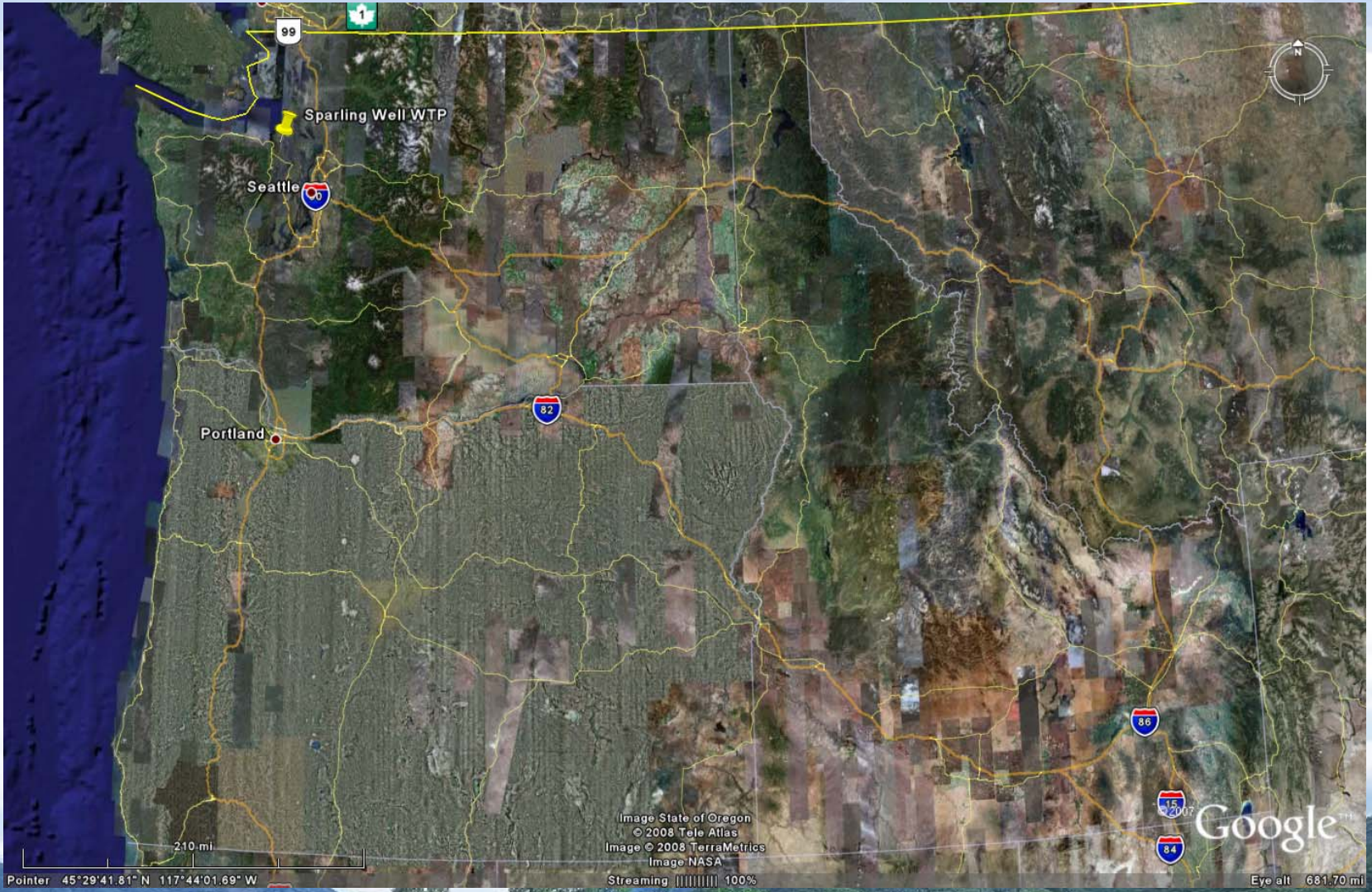
©2007 Google™

Image © 2008 TerraMetrics
Image NASA
© 2008 Europa Technologies
Streaming ||||| 100%

Eye alt 378.79 mi

CH2MHILL

PUD No. 1 of Jefferson County

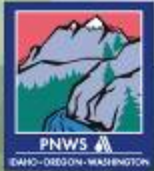
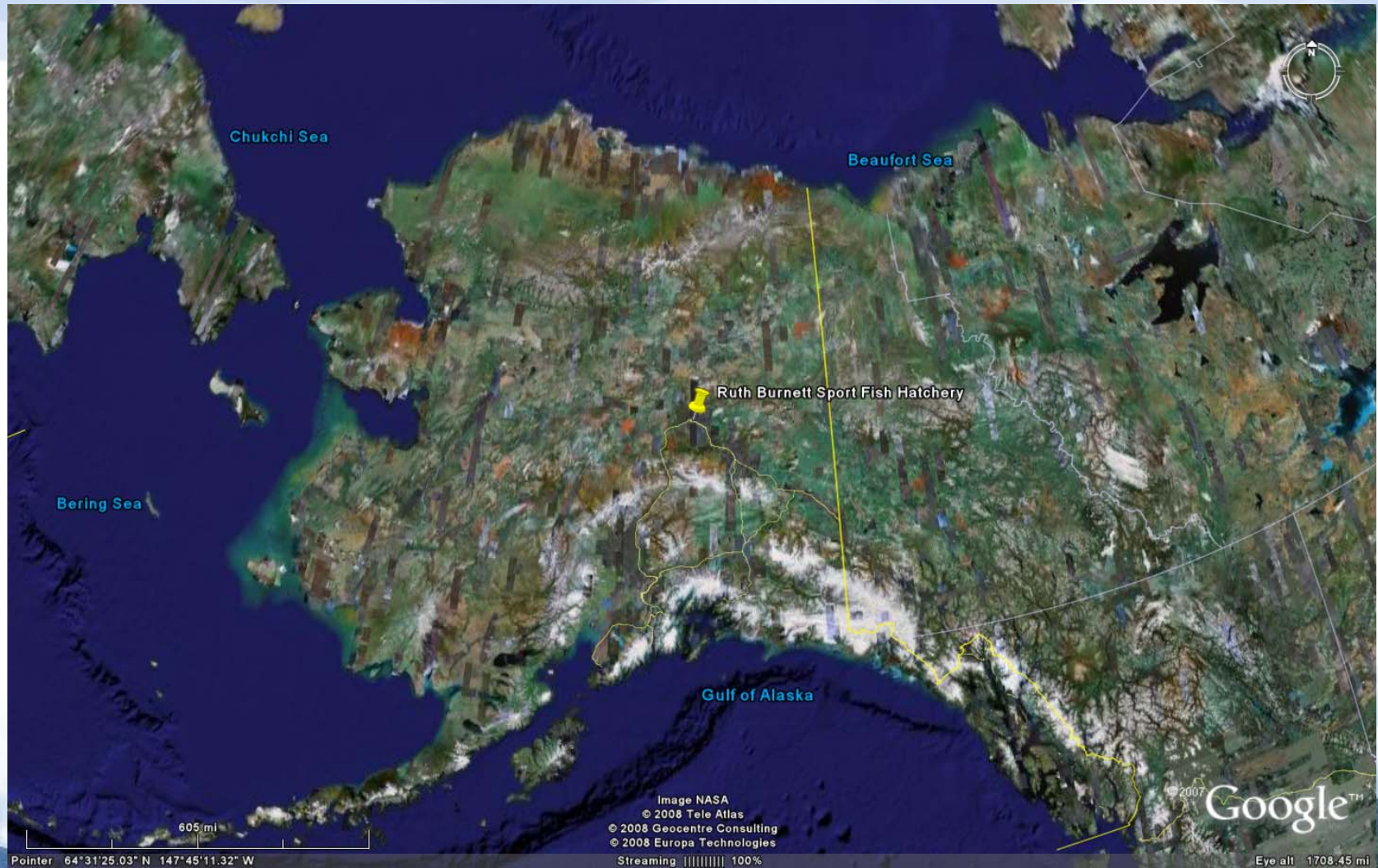


Pointer 45°29'41.81" N 117°44'01.69" W

Image State of Oregon
© 2008 Teje Atlas
Image © 2008 TerraMetrics
Image NASA
Streaming 100%

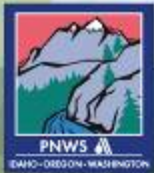
Eye alt 681.70 mi

Ruth Burnett Sport Fish Hatchery



Fe-Mn Treatment Alternatives

- Oxidation-Precipitation-Filtration
 - Aeration, precipitation, filtration
 - Chlorination, precipitation, filtration
 - Ozone, precipitation, filtration
 - Potassium permanganate, precipitation, filtration
 - Oxidation, membrane filtration
- Oxidation – Filtration/Adsorption
 - Manganese - zeolite (greensand) filtration
 - Oxide coated sand filtration
 - Pyrolusite media adsorption
- Biological removal
- Softening
 - Ion exchange (zeolite) softening
 - Lime softening

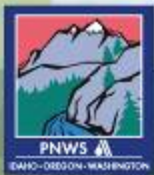


Fe-Mn Oxidation

How Much Chemical is Needed ?

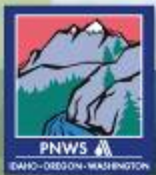
| Oxidant (mg/L) | Per mg/L of Mn | Per mg/L of Fe |
|------------------------|----------------|----------------|
| Oxygen (from aeration) | 0.29 | 0.14 |
| Ozone | 0.67 | 0.43 |
| Chlorine | 1.28 | 0.63 |
| Potassium permanganate | 1.92 | 0.94 |
| Chlorine Dioxide | 2.4 | 1.2 |

Other Oxidant Demands Include Hydrogen Sulfide & Organic Material



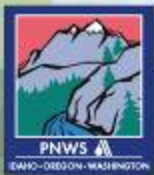
Common Treatment Approach

- Oxidation-Adsorption Process
 - Oxidation Chemicals
 - Chlorine
 - Permanganate
 - Adsorption Media
 - Manganese Dioxide
 - Greensand



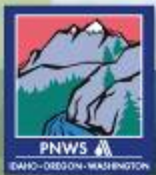
Project Goals and Concerns

| Sri Lanka | Jefferson PUD | Fairbanks |
|--|---|--|
| <ul style="list-style-type: none"> - High Iron - Minimize Operational Complexity - Dependable Treatment - Low Operating Cost - Reduce chemical dependence | <ul style="list-style-type: none"> - High Iron - Decrease Operating Costs - Improved Treatment Performance | <ul style="list-style-type: none"> - High Iron - Protect Fish - Dependable Treatment - Minimize Operational Effort - Low Operating Cost |



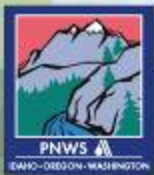
Biological Fe-Mn Filtration

- Biological Uptake from “Iron Bacteria” removes iron and manganese from water
- Facultative - Autotrophic Bacteria (needs oxygen to thrive, but only energy source is iron & manganese oxidation)
- High removal capacity
- Requires pre-aeration or pre-ozonation for groundwater

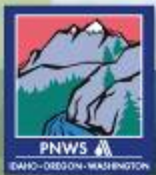
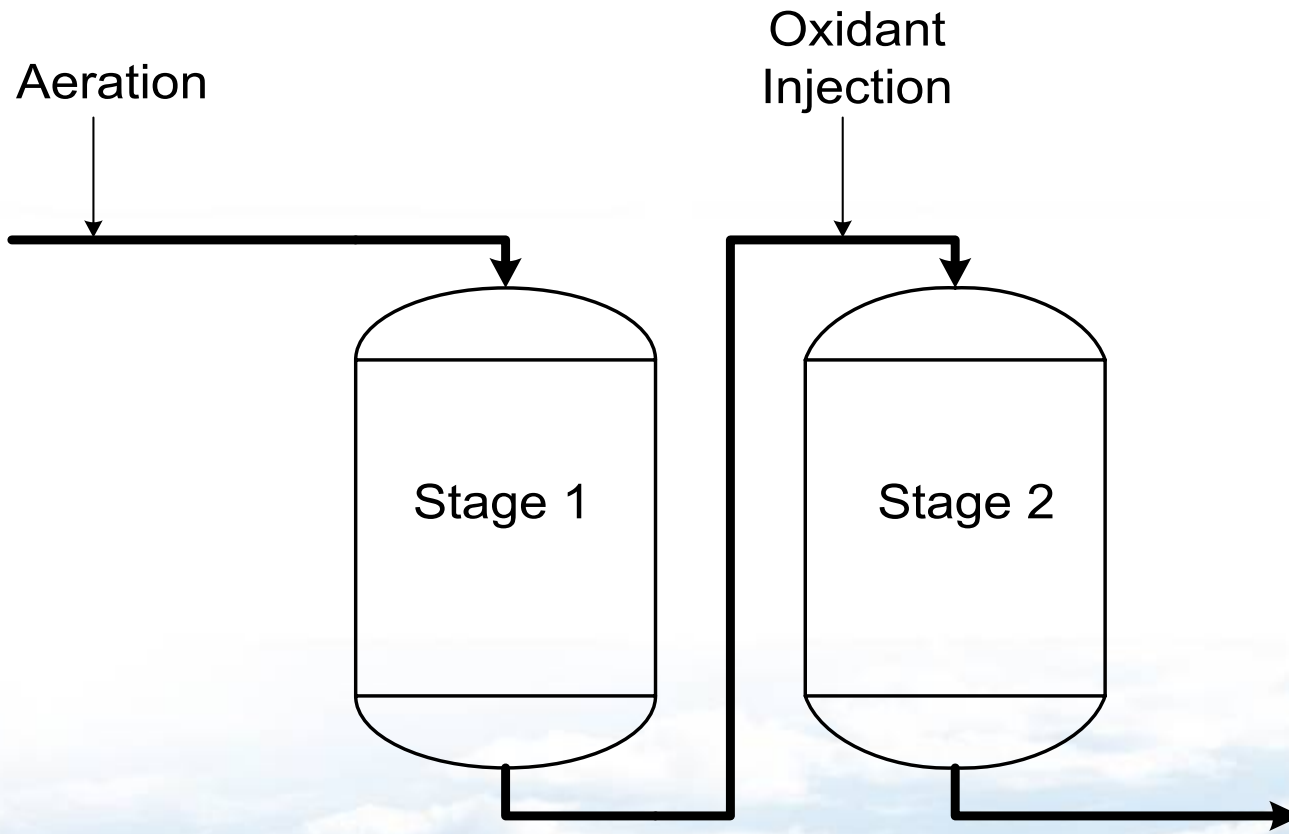


Biological Treatment Challenges

- Concerns:
 - Long start-up time while bacterial populations acclimate and grow to sustainable level
 - Potential for upsetting
- Solution:
 - Two-stage filtration with biological front end and chemical adsorptive process as second stage

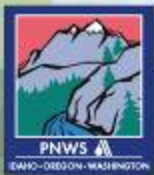


Biological Fe-Mn Flow Diagram



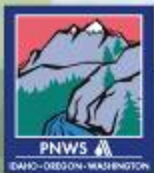
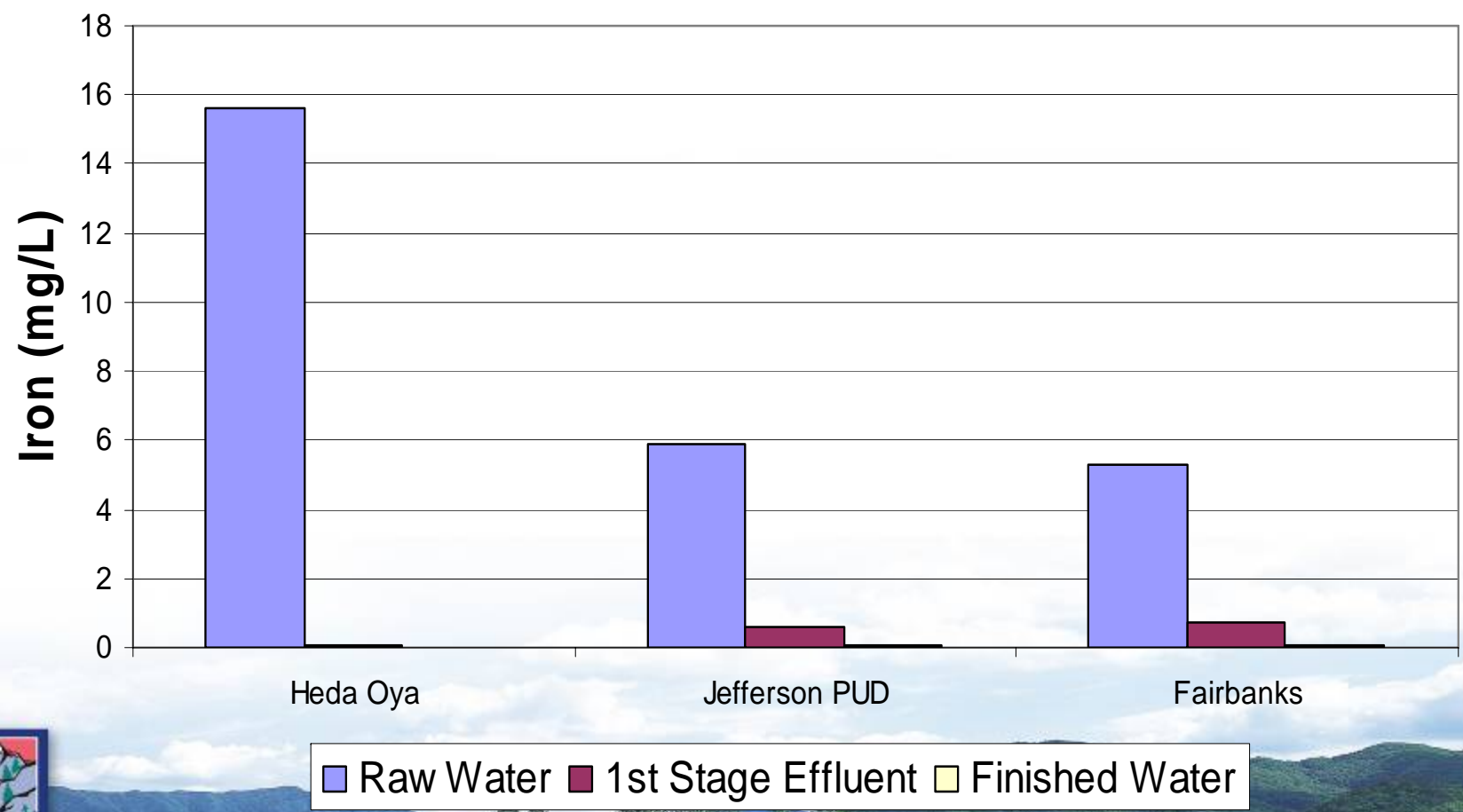
Pilot Testing Overview

| Sri Lanka | Jefferson PUD | Fairbanks |
|--|---|---|
| <ul style="list-style-type: none"> - Two days each at Heda Oya and Panama well sites - Chlorine injected between stages - 5.84 gpm/sq. ft. loading rate - 2.0 mg/L Cl₂ dose | <ul style="list-style-type: none"> - Two month acclimation period at Sparling Well - Chlorine injected between stages - 7.9 gpm/sq. ft. loading rate - 1.1 mg/L Cl₂ dose | <ul style="list-style-type: none"> - Conducted for 10 months in pilot hatchery system - KMnO₄ injection added between stages - 9.0 gpm/sq. ft. loading rate - 2.5 mg/L KMnO₄ dose |



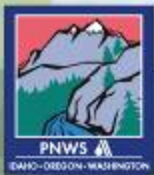
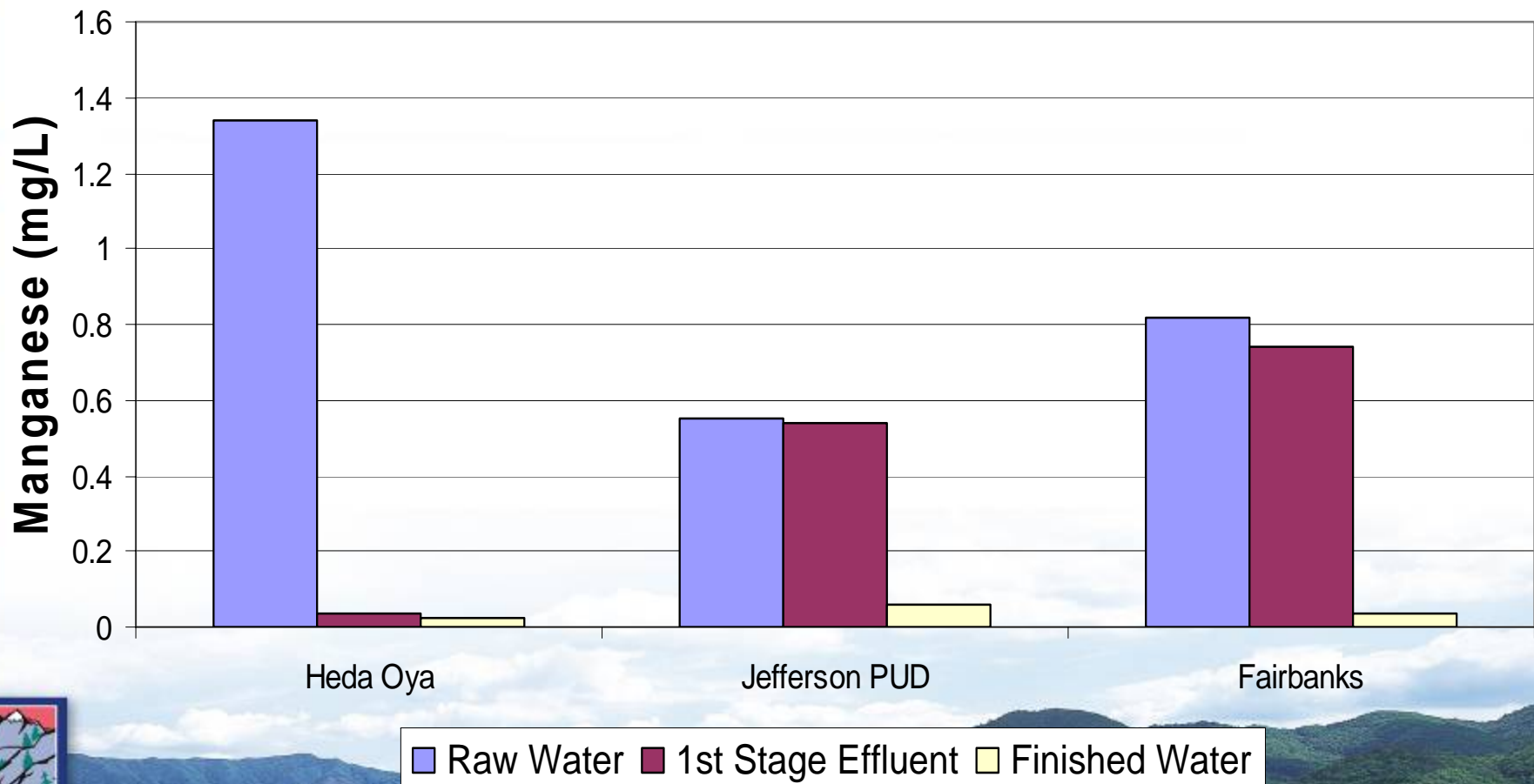
Iron Results

Iron Data



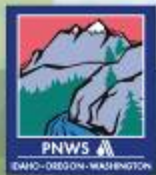
Manganese Results

Manganese Data

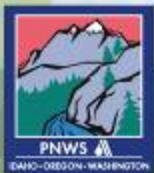
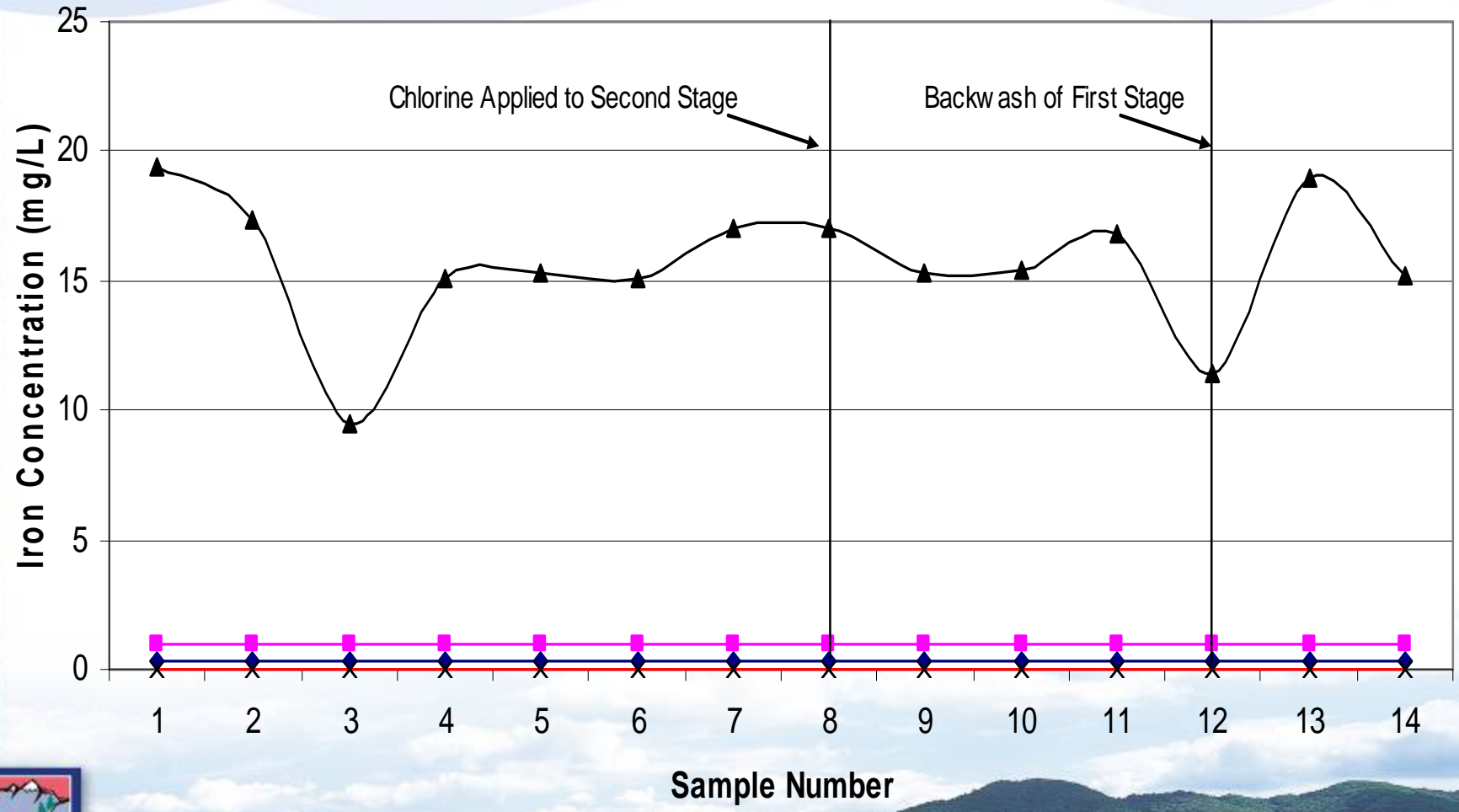


Pilot Testing Results

| Sri Lanka – Heda Oya | Jefferson PUD | Fairbanks |
|---|--|--|
| <p>- Raw Water Fe: 15.6 mg/L Mn: 1.34 mg/L</p> <p>- 1st Stage Effluent: Fe: 0.054 mg/L Mn: 0.036 mg/L</p> <p>- Finished Water: Fe: 0.014 mg/L Mn: 0.021 mg/L</p> | <p>- Raw Water Fe: 5.9 mg/L Mn: 0.55 mg/L</p> <p>- 1st Stage Effluent: Fe: 0.61 mg/L Mn: 0.54 mg/L</p> <p>- Finished Water: Fe: 0.058 mg/L Mn: 0.061 mg/L</p> | <p>- Raw Water Fe: 5.3 mg/L Mn: 0.82 mg/L</p> <p>- 1st Stage Effluent: Fe: 0.74 mg/L Mn: 0.74 mg/L</p> <p>- Finished Water: Fe: 0.077 mg/L Mn: 0.033 mg/L</p> |

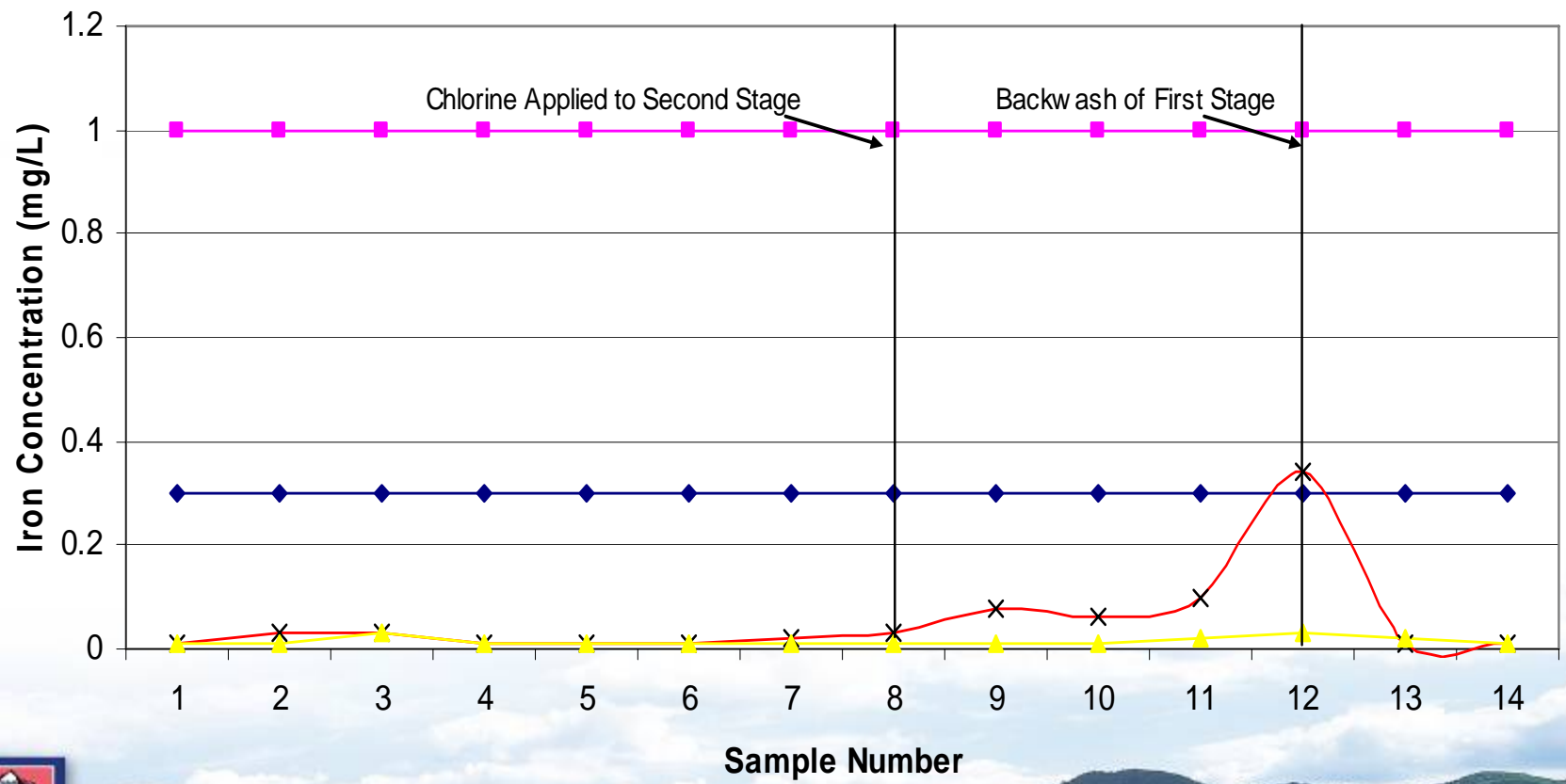


Heda Oya, Sri Lanka - Fe Results

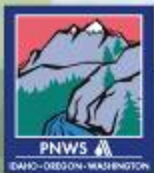


■ MCL (1 mg/L) ◆ MCLG (0.3 mg/L) ▲ Raw Water × Stage 1

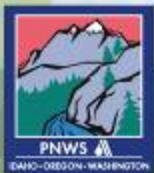
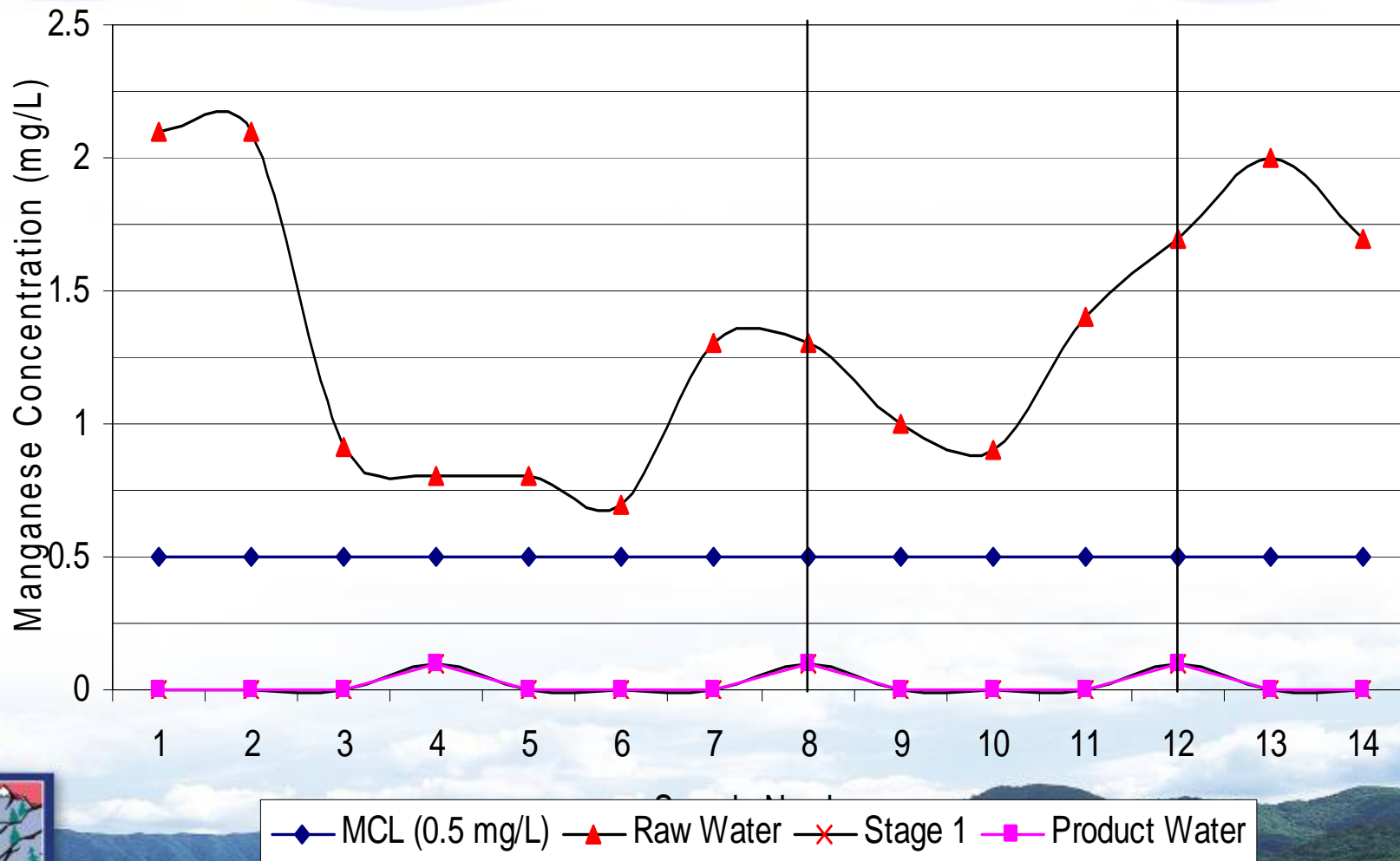
Heda Oya, Sri Lanka - Fe Results



■ MCL (1 mg/L) ◆ MCLG (0.3 mg/L) × Stage 1 ▲ Product Water

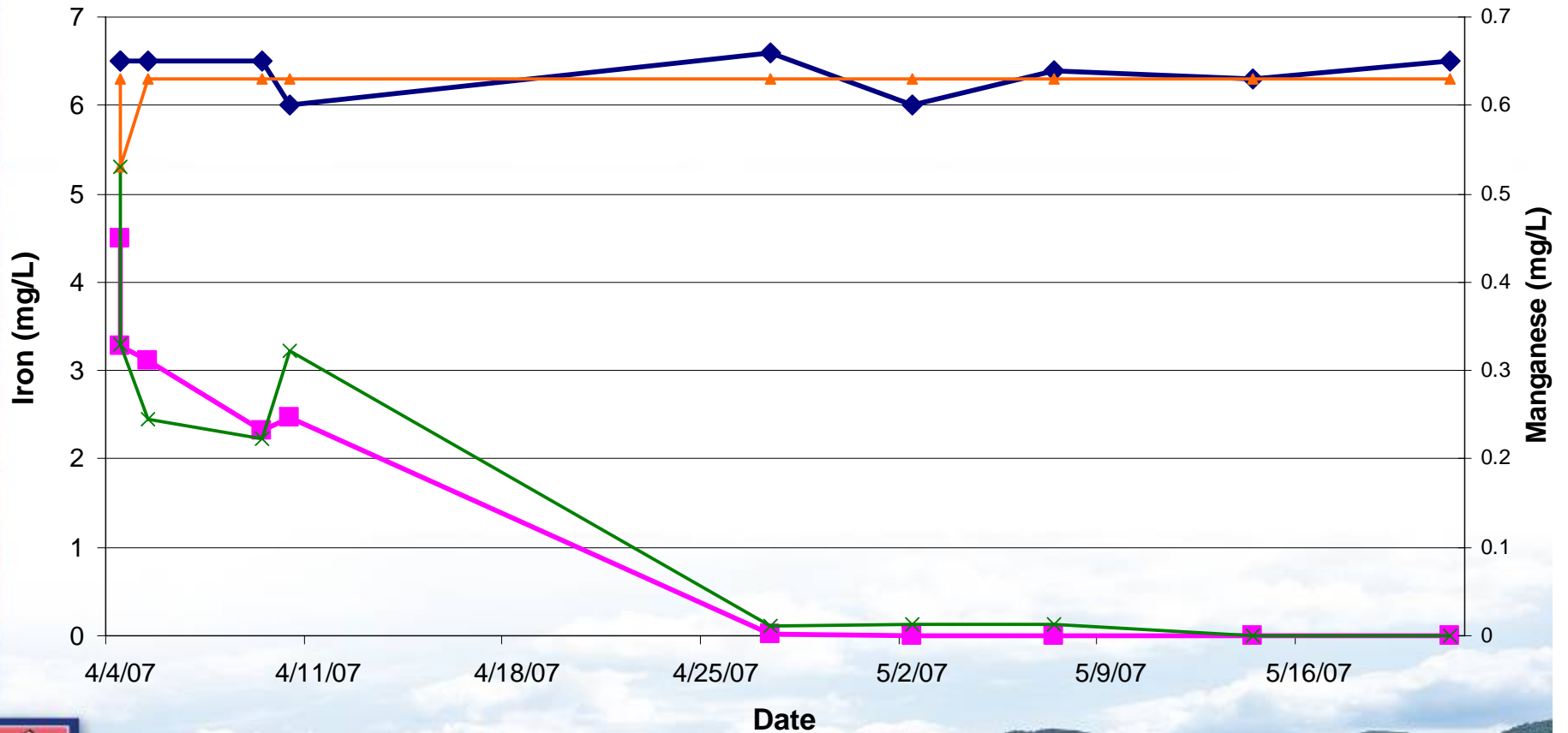


Heda Oya, Sri Lanka - Mn Results

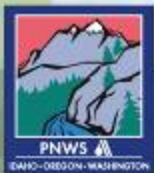


Jefferson PUD Maturation

Jefferson PUD Biological Conditioning

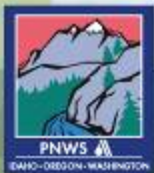
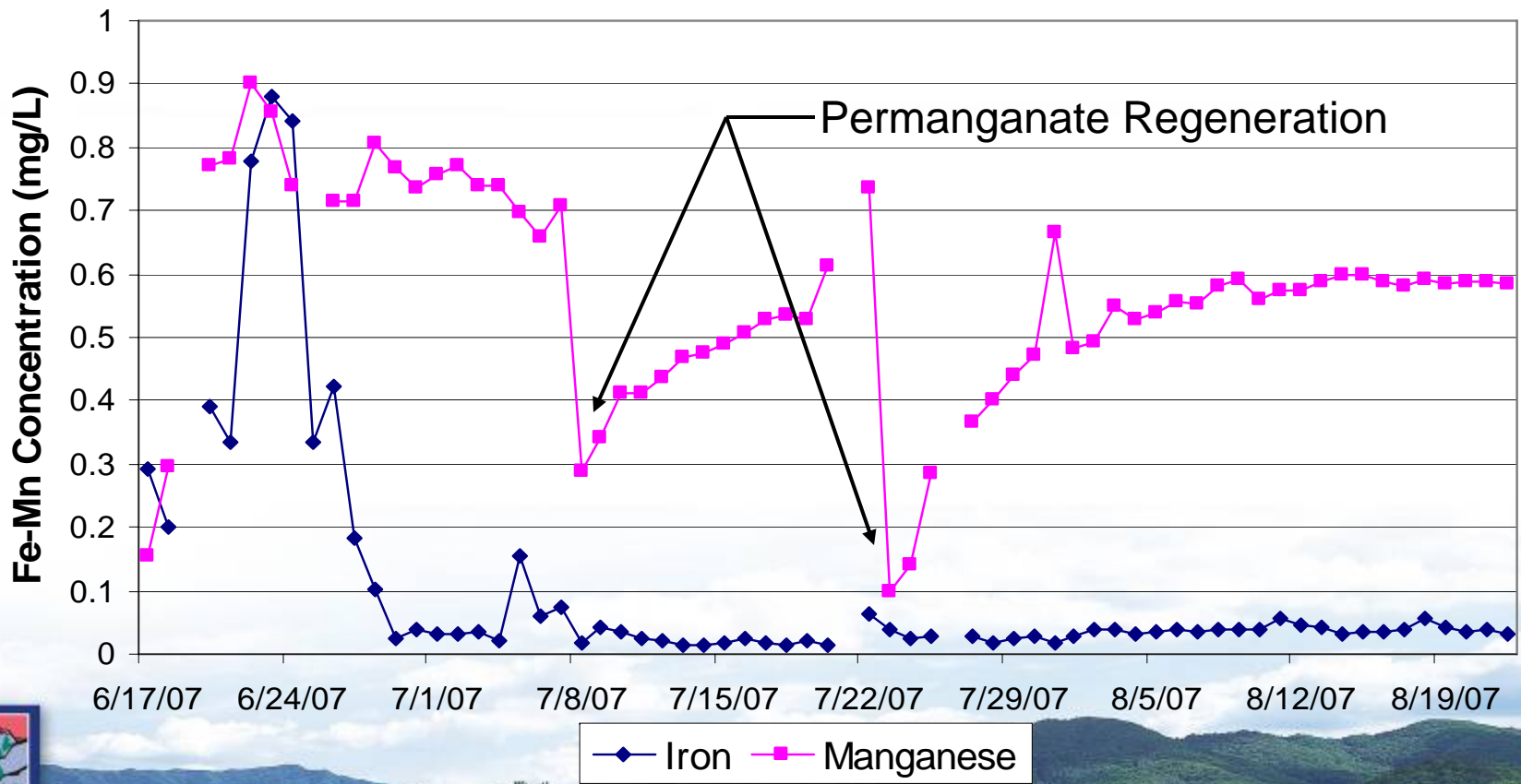


◆ Raw (Fe) ■ Finished (Fe) ▲ Raw (Mn) × Finished (Mn)



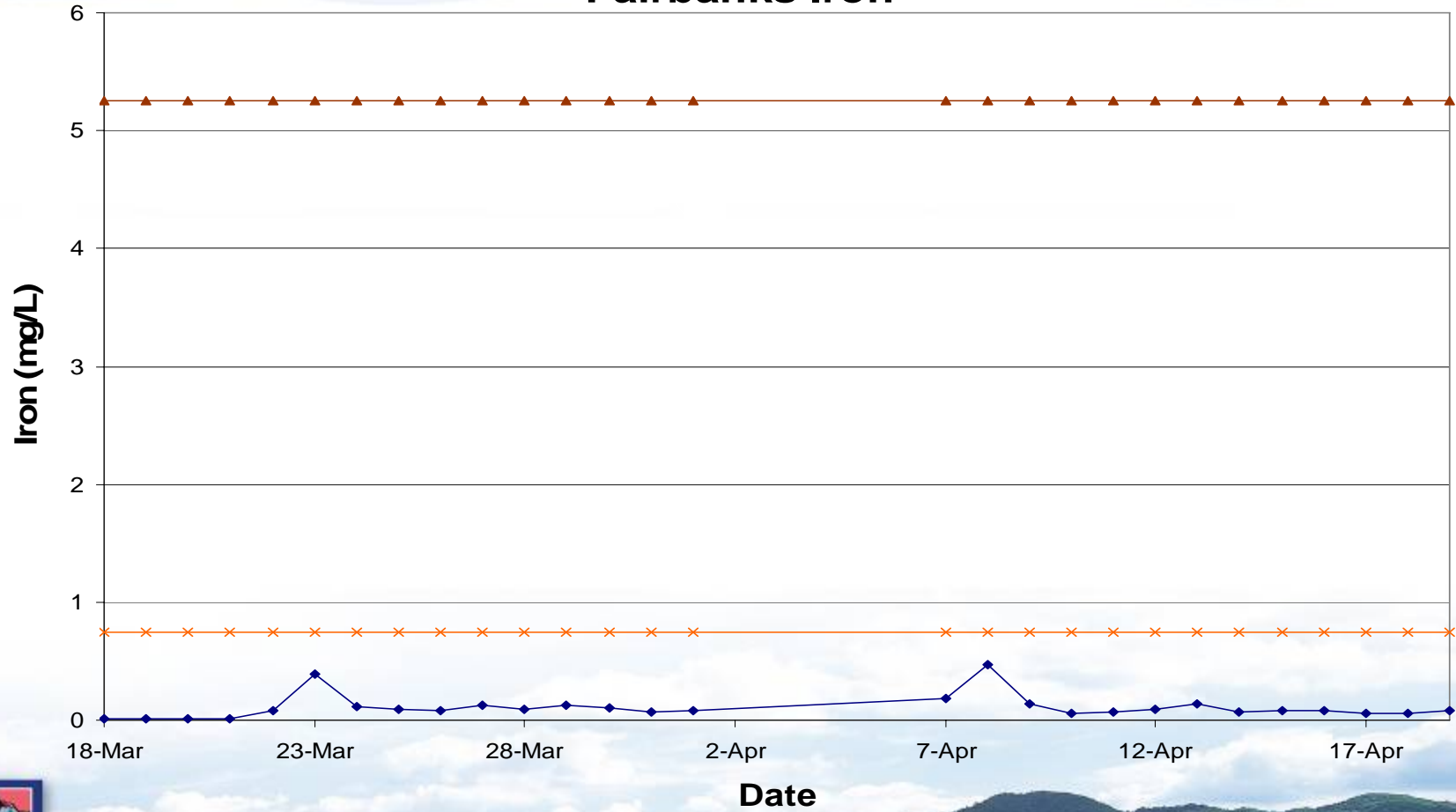
Fairbanks Startup Period

Fairbanks Iron and Manganese Following Startup of Two Stage System

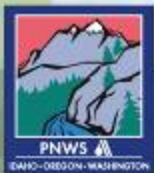


Fairbanks - Fe Results

Fairbanks Iron

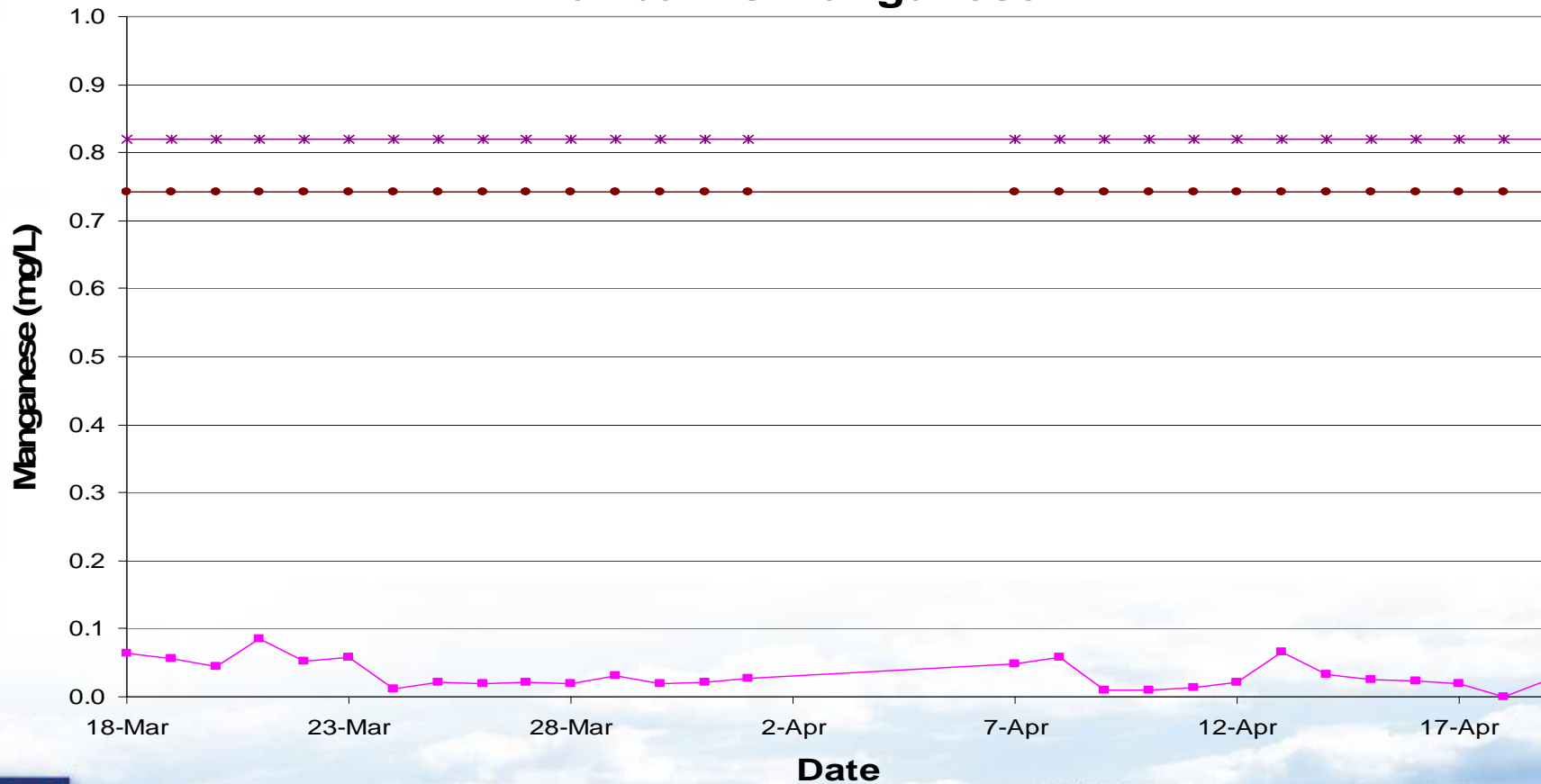


Raw Iron 1st stage Iron 2nd Stage Iron

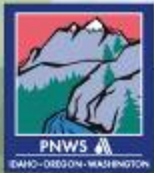


Fairbanks - Mn Results

Fairbanks Manganese

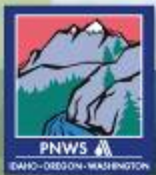


* Raw Manganese ● 1st Stage Manganese ■ 2nd Stage Manganese



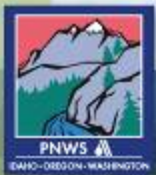
Cost Savings

- Fairbanks (Avg. Flow = 500 gpm)
 - Oxidation-Adsorption
 - Annual Chemical Costs = \$37,000/year
 - Aeration-Biological-Adsorption
 - Annual Chemical Costs = \$26,500/year
 - Annual Cost Savings
 - \$10,500/year
- Jefferson PUD (Avg. Flow = 400 gpm)
 - Oxidation-Adsorption
 - Annual Chemical Costs = \$20,000/year
 - Oxidation-Precipitation-Filtration
 - Annual Chemical Costs = \$100,000/year
 - Aeration-Biological-Adsorption
 - Annual Chemical Costs = \$7,000/year
 - Annual Cost Savings
 - \$113,000/year

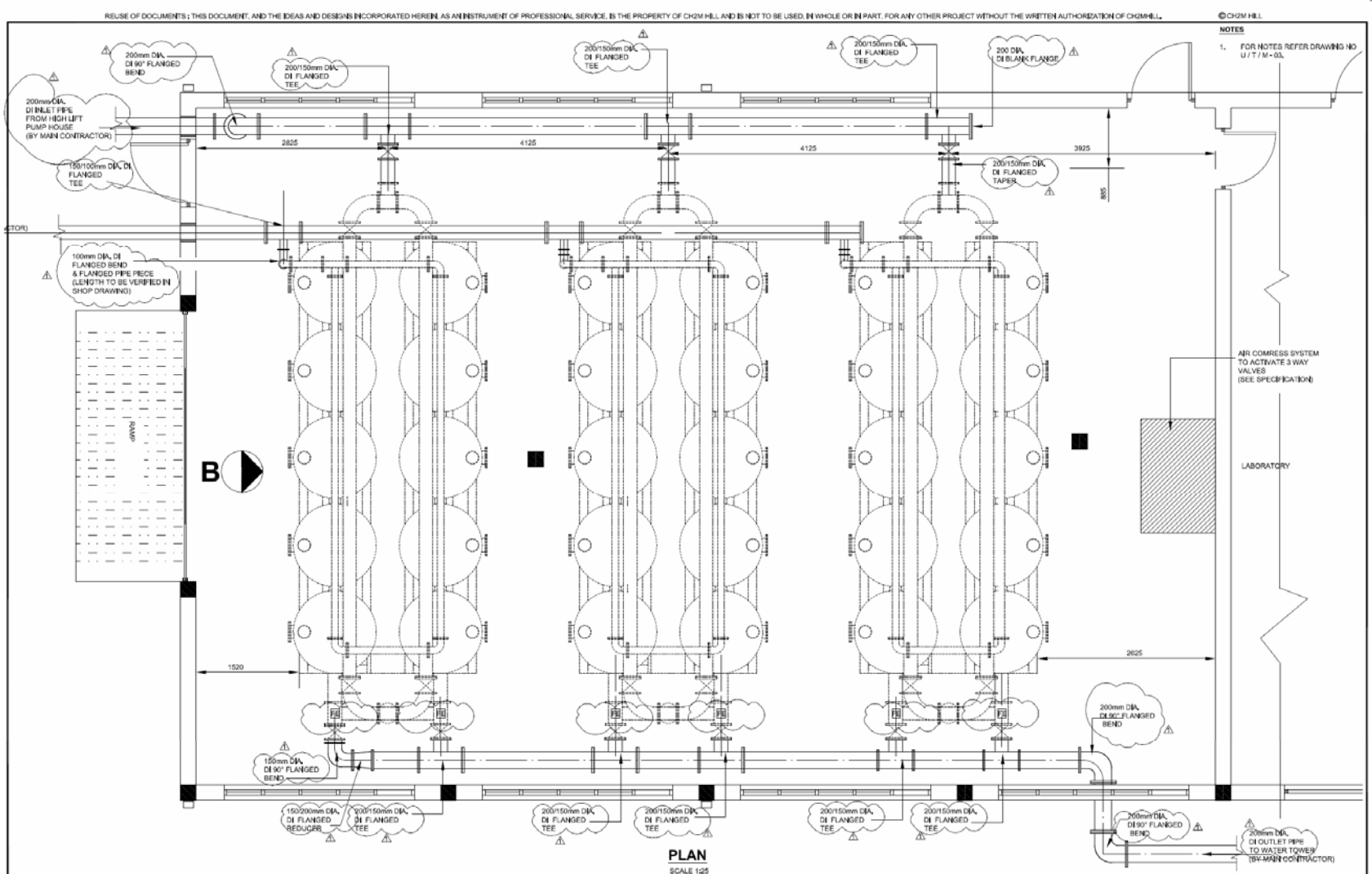


Cost Savings (Cont.)

- Fairbanks
 - Permanganate is over twice as expensive as chlorine, so even though you use far less chemical, you are using more permanganate, which costs you more money.
 - Ratio of permanganate to Fe and Mn is higher than ratio of chlorine to Fe and Mn, so more permanganate is needed than if chlorine was used after stage one instead.
 - Costs above do not include a slight additional cost savings from dechlorination. Maybe another \$1,000 per year.
- Jefferson PUD
 - Permanganate and chlorine doses are both reduced due to biological first stage filtration.
 - Biological two stage system would replace conventional filtration system that uses coagulants and oxidants for removal
 - System has other constituents in raw water that effect chlorine and permanganate dose that are removed in first stage filters and aeration.



System Designs – Sri Lanka



PLAN
SCALE 1:25

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NOTES

- FOR NOTES REFER DRAWING NO. U/T/M-03.

AIR COMPRESS SYSTEM TO ACTIVATE 3 WAY VALVES (SEE SPECIFICATION)

LABORATORY

| | |
|-------|---------------|
| SHEET | 115 OF 152 |
| DWG | U/T/M-01 |
| DATE | MAY 21st 2007 |
| PROJ | SLTRP |

| | | | | | |
|-------------------|-----------------|---------|---|-------------|----------|
| DSGD | M.H. Edwards | | | | |
| DRN | S.J. Kundelinas | | | | |
| CHKD | J.L. Navaratnam | | | | |
| APVD | Rick Robertson | 25-1-08 | PO44 - THIS DRAWING HAS BEEN REVISED TO REFLECT THE SYSTEM CHANGES MADE UP TO 28th JAN 2008 | Scale | MH |
| AUTHORITY OF DRAW | Checked | NO. | DATE | DESCRIPTION | REVISION |

VERIFY SCALE
BAR IS 25 MM ON ORIGINAL DRAWING.
IF NOT 25 MM ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

FROM THE AMERICAN PEOPLE

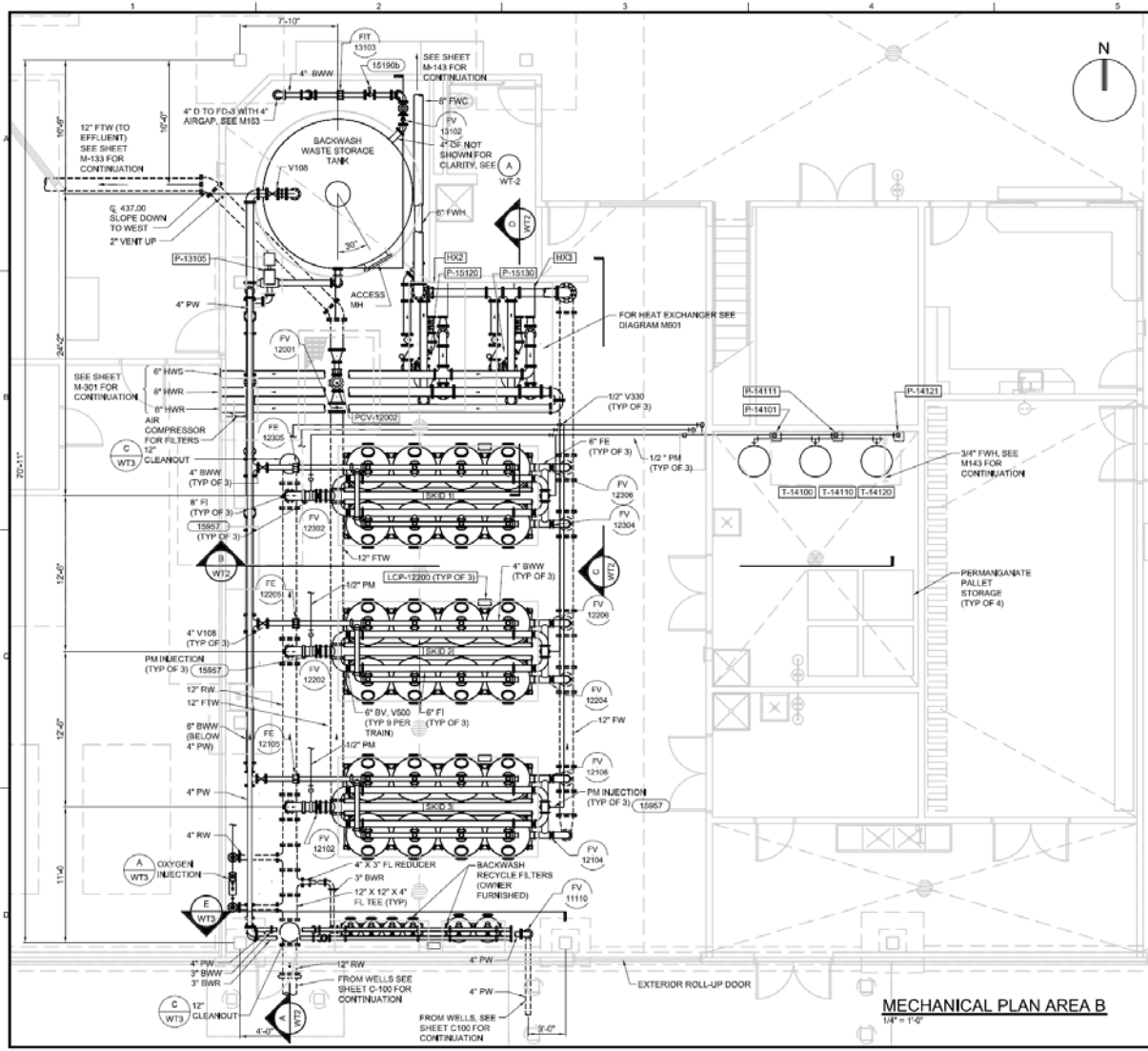
IN ASSOCIATION WITH

MINISTRY OF URBAN DEVELOPMENT & WATER SUPPLY NATIONAL WATER SUPPLY & DRAINAGE BOARD

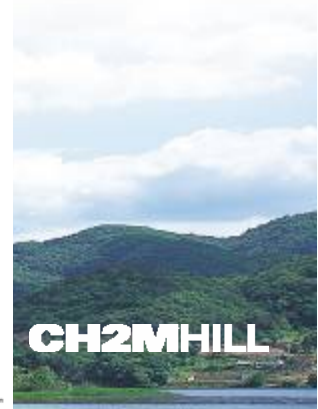
SRI LANKA TSUNAMI RECONSTRUCTION PROJECT
ARUGAM BAY WATER SUPPLY
ULLA / POTTUVIL WATER TREATMENT PLANT
TREATMENT BUILDING
FILTER LAYOUT AND PIPING DETAIL
PLAN



System Designs – Fairbanks

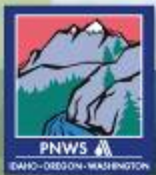


| | |
|--|--|
| RUTH BURNETT SPORT FISH HATCHERY FAIRBANKS, ALASKA STATE OF ALASKA DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES & DEPARTMENT OF FISH AND GAME | |
| PLAN DEVELOPED BY: CH2M HILL | NO. DATE 01/00 02/00 03/00 04/00 05/00 06/00 07/00 08/00 09/00 10/00 11/00 12/00 |
| INFLUENT TREATMENT INFLUENT TREATMENT PLAN | REVISION CRK A. STORBERG A. STORBERG |
| VERIFY SCALE DRAWN BY: CH2M HILL CHECKED BY: CH2M HILL DATE: DECEMBER 2007 PROJ: 336573 DWG: WT1 SHEET: | MECHANICAL PLAN AREA B 1/4" = 1'-0" |



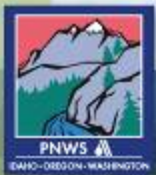
Conclusions

- Biological iron and manganese filtration:
 - provides a cost effective alternative to traditional oxidation-adsorption or oxidation-precipitation-filtration treatment in system with high iron and manganese levels
 - greatly reduces the need for chemicals and operating costs
 - provides a safe alternative in situations where chlorine exposure is not acceptable



Questions?

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enichols@ch2m.com
425.233.3259

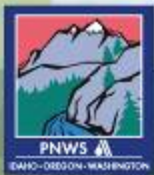


Fe-Mn Oxidation

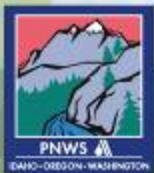
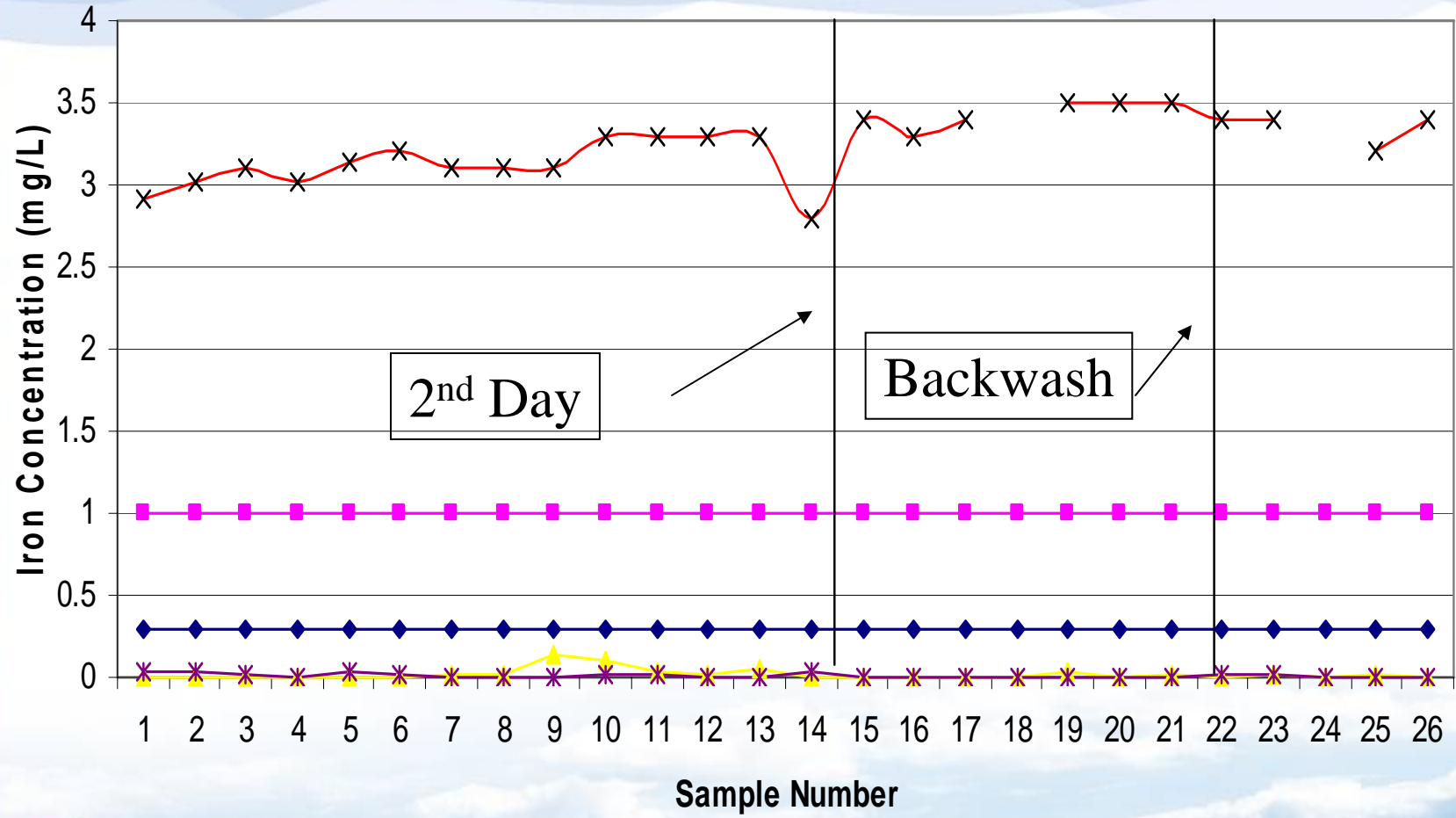
How long does it take ?

| Oxidant | Iron | Manganese |
|------------------------|--------------------|----------------------|
| Oxygen (from aeration) | <10 min. to hrs. * | 80 min. to Days * |
| Ozone | < 5 min. | < 5 min. |
| Chlorine | <1 min - <1 hr. * | 15 min. to 12 hrs. * |
| Potassium permanganate | < 5 min. | < 7 min. |
| Chlorine Dioxide | < 5 min. | < 5 min. |

* pH dependent - oxidation rate quicker at high pH

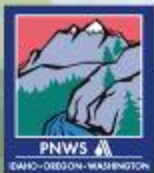
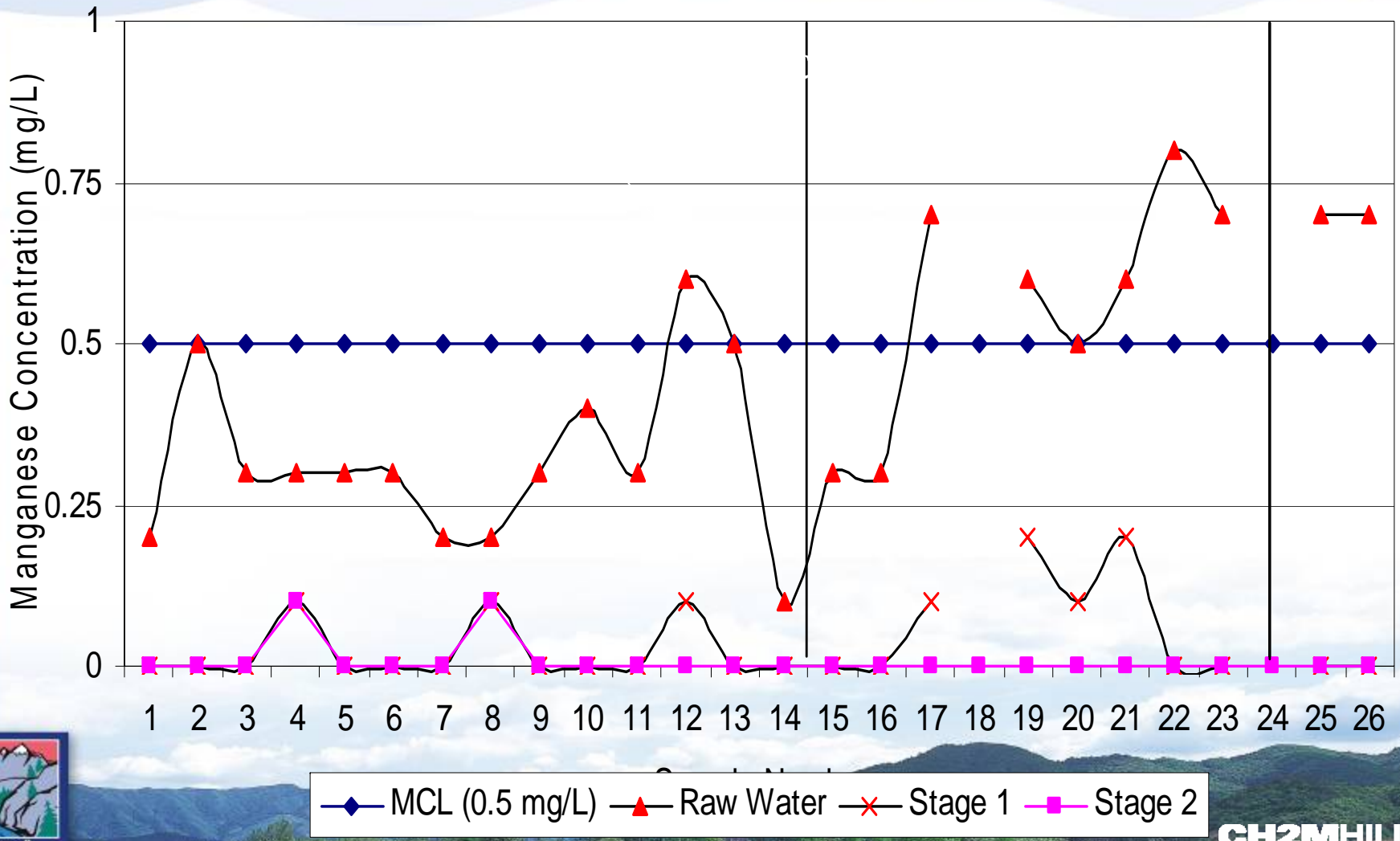


Panama, Sri Lanka – Fe Results



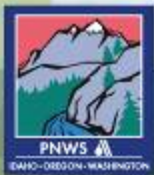
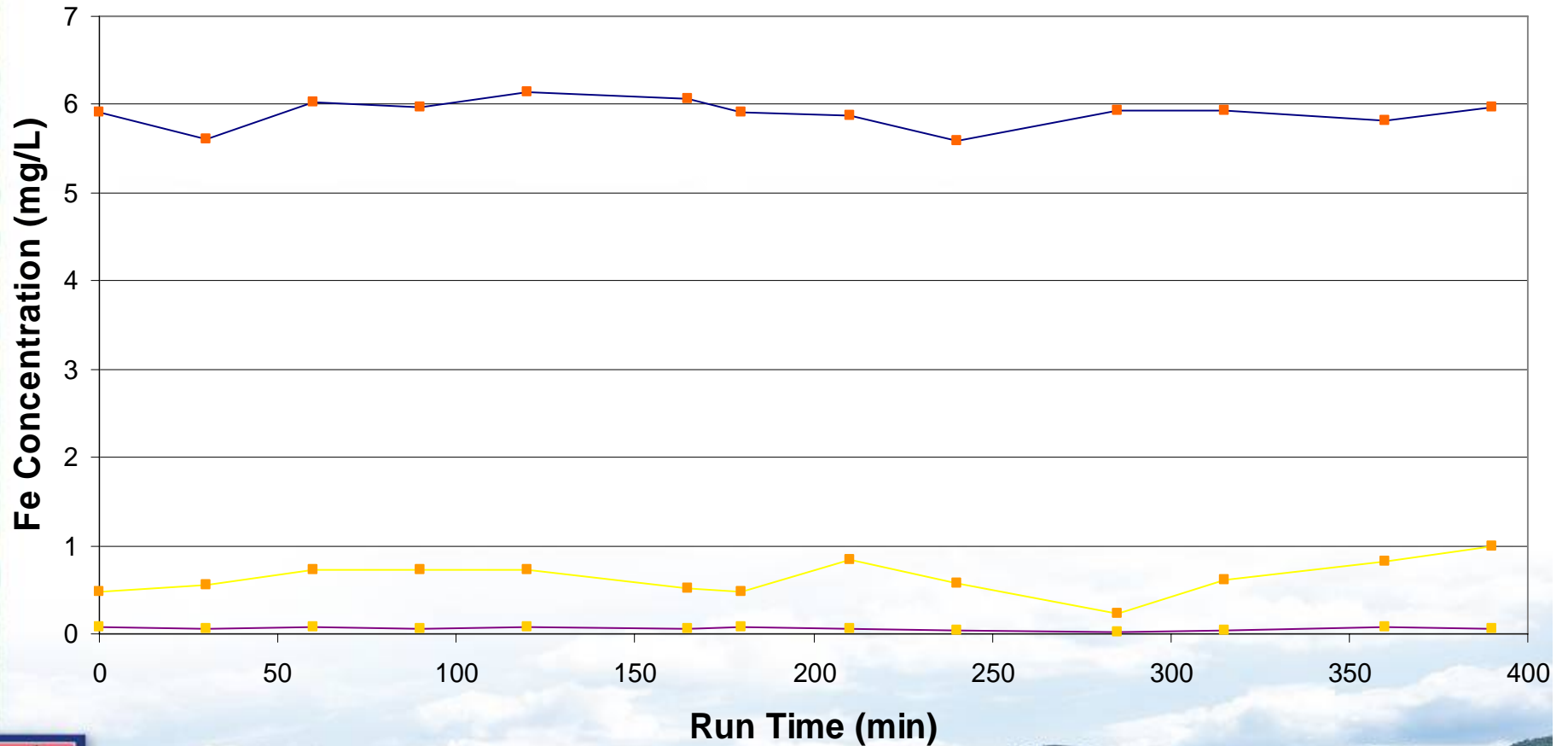
■ MCL (1 mg/L) ◆ MCLG (0.3 mg/L) × Raw ▲ Stage 1 * Stage 2

Panama, Sri Lanka - Mn Results



Jefferson PUD - Fe Results

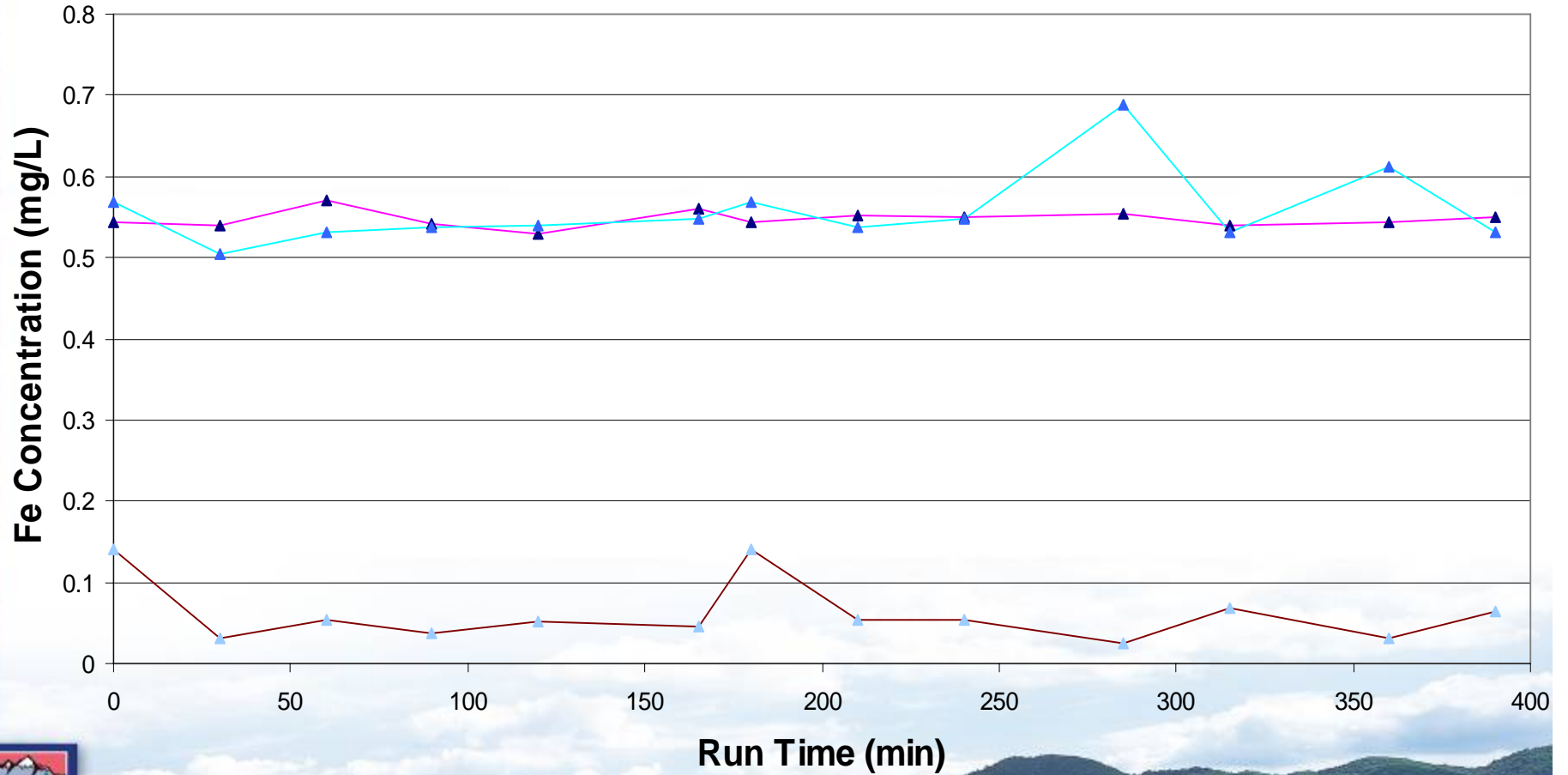
Jefferson PUD Iron



— Fe Raw — Stage 1 Fe — Stage 2 Fe

Jefferson PUD - Mn Results

Jefferson PUD Manganese



▲ Mn Raw ▲ Stage 1 Mn ▲ Stage 2 Mn

