Comparison of Aerobic and Anaerobic Biotreatments of Low-Level Vinyl Chloride

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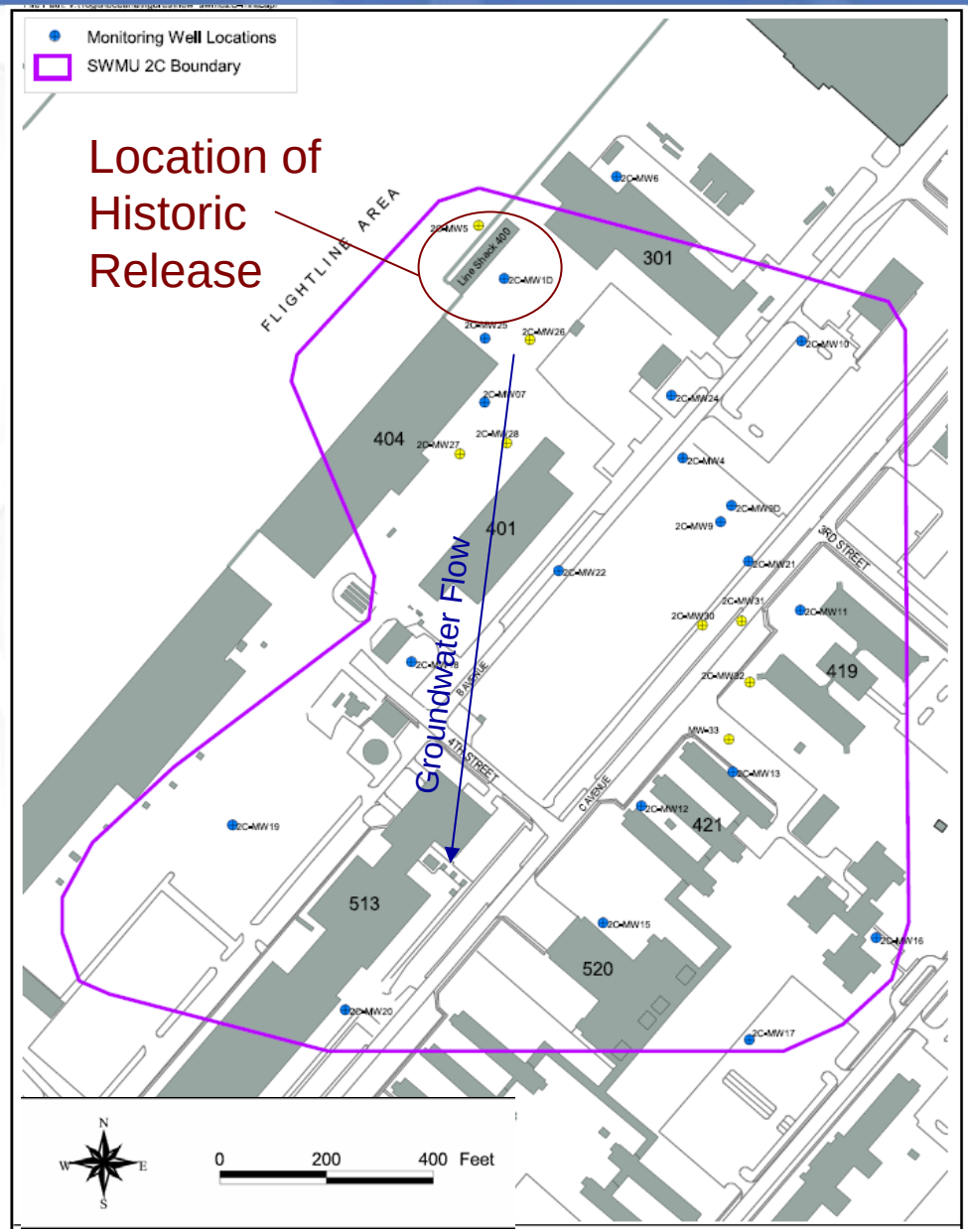
Overview

- **SWMU 2C Background and Physical Conditions**
- **Baseline Nature and Extent of Contamination**
- **Treatability Study Design and Implementation**
- **Treatability Study Results**
- **Comparison of Treatment Alternatives**
- **Conclusions**

Site History

- **SWMU 2C is located in the flight line and barracks areas of Naval Air Station Oceana in Virginia Beach, Virginia**
- **Aircraft cleaning solvents containing TCE were historically disposed south of Line Shack 400**
- **Shallow groundwater plume formed primarily through advection following groundwater flow to the SSW**
- **TCE naturally attenuated to VC in most cases [very low baseline concentrations of TCE (<6 µg/L) and cis 1,2-DCE (<30 µg/L)]**



Hydrogeologic Conditions

- **Shallow (Columbia Aquifer) geology consists of silty and clean sand and silt to a depth of 20 ft bgs where the Yorktown Confining Unit (clayey silt) is encountered.**
- **Estimated average hydraulic gradient across the site is 0.036 ft/ft**
- **Estimated groundwater flow velocity is 10 ft/year**

Baseline Nature and Extent of Contamination

- **Direct push temporary well sampling was used to refine the extent of the most contaminated areas**
- **Temporary well VC concentrations in the most contaminated areas ranged from 200 µg/L to 356 µg/L**
- **Monitoring wells in same areas ranged from 24 µg/L to 160 µg/L**
- **Design used more conservative temporary well data**

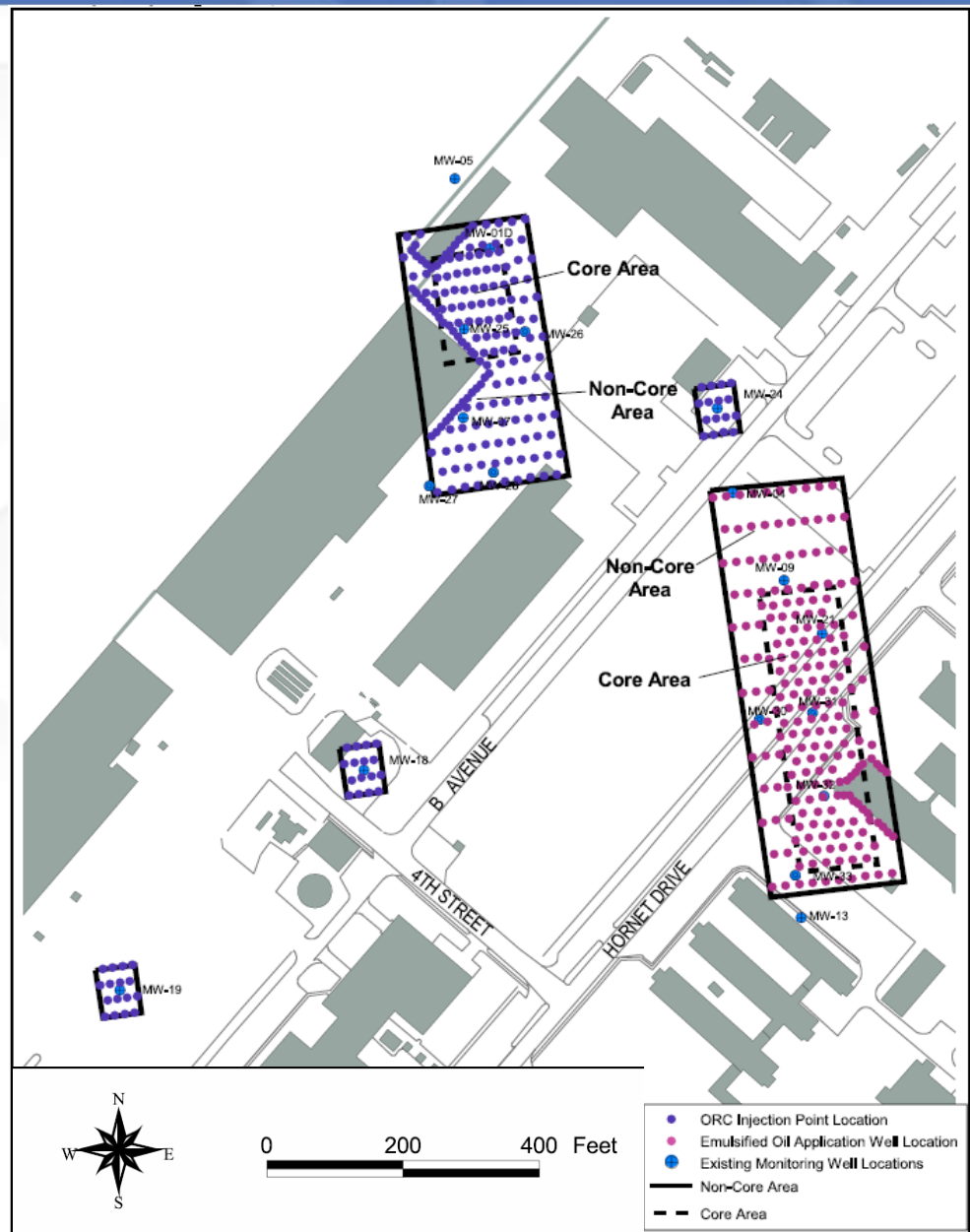
Groundwater
Vinyl Chloride Plume

Drivers for Remedial Action

- **Regulators desired unlimited use and unrestricted exposure for site groundwater**
- **The MCL of 2 µg/L was selected as the treatability study objective for VC**
- **Regulators desired to achieve the target concentration as quickly as possible**
- **This site is one of three sites preventing completion of base-wide Decision Document for NAS Oceana**

Treatability Study Design

- **Two main plume areas were treated (north and south plumes) based on areas of highest concentration**
- **North plume was injected with Oxygen Release Compound (ORC®)**
- **South plume was injected with Newman Zone emulsified vegetable oil**
- **Smaller areas of lower concentration were treated with ORC® as "hot spots"**



North Plume Grid

- **Total of 171 DPT injection points for ORC® injection**
- **Injections completed in "core" and "non-core" areas**
  - core area
    - 110 ft x 160 ft
    - injection point spacing 15 ft within cross gradient rows and 25 ft between rows (with gradient)
  - non-core area
    - 200 ft x 400 ft
    - injection point spacing 15 ft within cross gradient rows and 25 ft between rows (with gradient)

North Plume Treatment

- **A mixture of 30% ORC® and 70% potable water was injected at 3 lbs ORC® per ft at each DPT location**
- **Injection interval of 6’ to 16’ bgs**
- **Treatment cost was approximately $95,000**
- **Injections took approximately 2.5 weeks to complete**
- **Difficult to inject between 6 and 9 feet due to finer grained soils**

South Plume Grid

- **Total of 208 temporary emulsified oil application wells installed using a DPT rig**
- **Injections completed in "core" and "non-core" areas**
  - core area
    - 110 ft x 420 ft
    - injection point spacing 20 ft within cross gradient rows and 20 ft between rows (with gradient)
  - non-core area
    - 200 ft x 625 ft
    - injection point spacing 20 ft within cross gradient rows and 50 ft between rows (with gradient)

South Plume Treatment

- **Application wells were set at 18.5 feet bgs and were screened from 8.5 to 18.5 feet bgs**
- **Application was completed using a ten channel manifold system**
- **7.5 gallons of pure emulsion (375 gallons of diluted emulsion) applied to core area wells**
- **5.5 gallons of pure emulsion (275 gallons of diluted emulsion) applied to non-core area wells**
- **Treatment cost of approximately $110,000**

South Plume Treatment

- **Treatment took approximately 3 weeks to complete**
- **2” diameter wells were difficult to install using the DPT rig**
- **Injections were difficult to complete in high traffic areas because ten wells had to be complete and in place before any injection could occur**

Newman Zone Injection Well with Digital Flowmeter

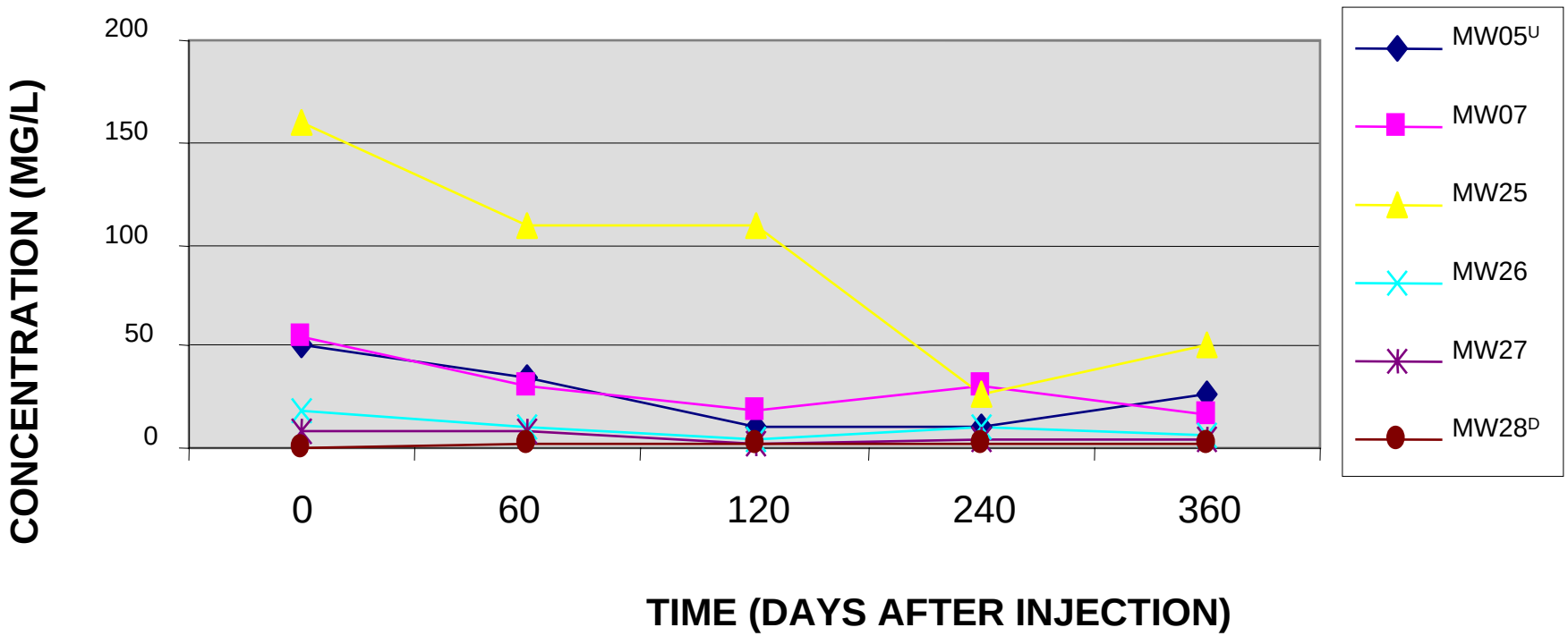
Treatability Study Monitoring

- **Five Rounds**
  - Baseline
  - 2 months post-treatment
  - 4 months post-treatment
  - 8 months post-treatment
  - 12 months post-treatment
- **Sampling network consisted of treatment area wells and upgradient wells to assess efficacy of treatment relative to natural attenuation**

North Plume (ORC®) Results

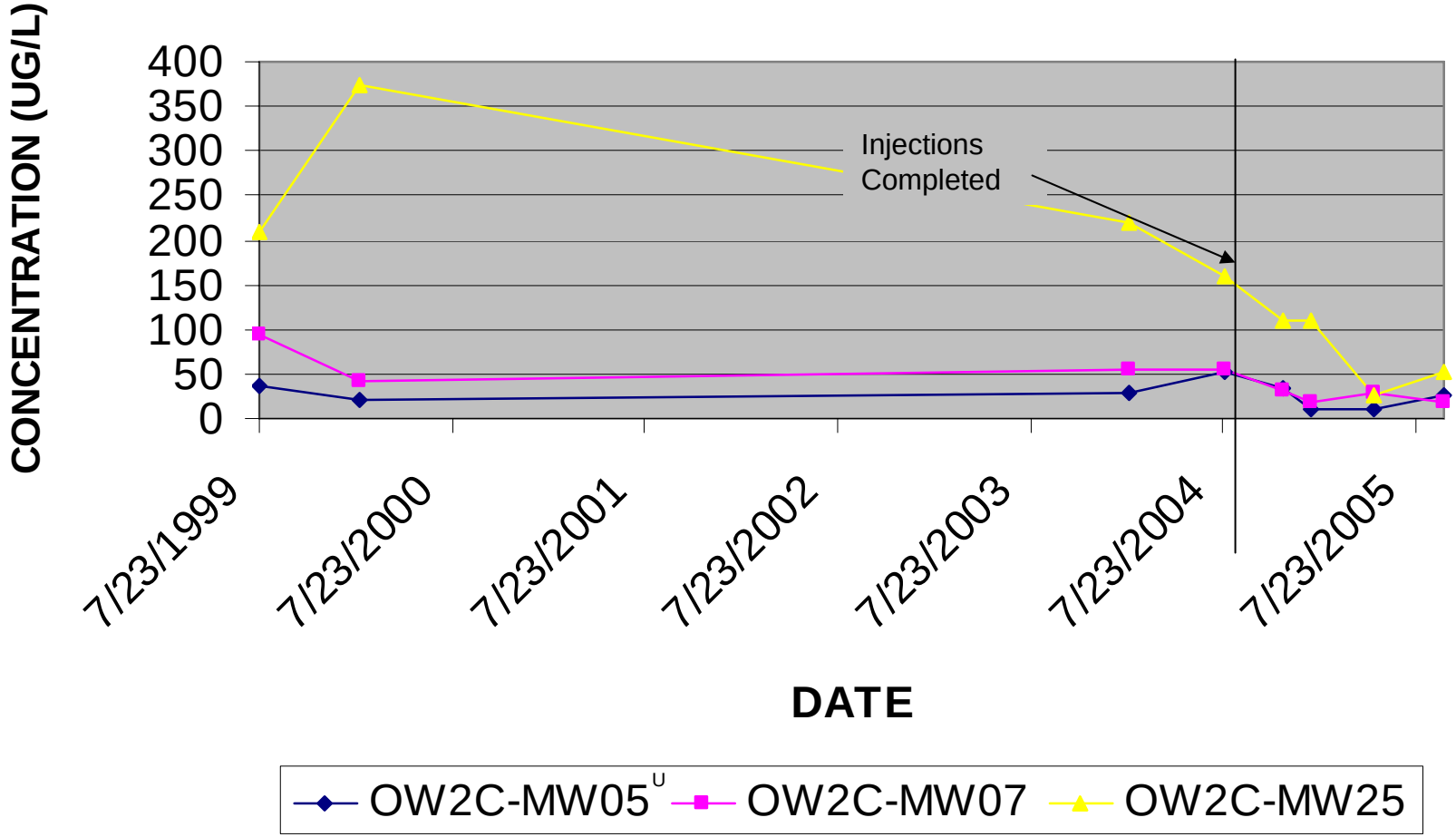
- **Treatment Area**
  - Baseline concentrations of VC
    - 9 µg/L to 160 µg/L
  - Post treatment concentrations of VC
    - 1.3 µg/L to 51 µg/L
  - Average decrease of 67%
- **Upgradient Well**
  - Baseline concentration of VC
    - 51 µg/L
  - Post treatment concentration of VC
    - 27 µg/L
  - 47% decrease

North Plume Treatment Area VC Concentrations



U: Upgradient Well
D: Downgradient Well

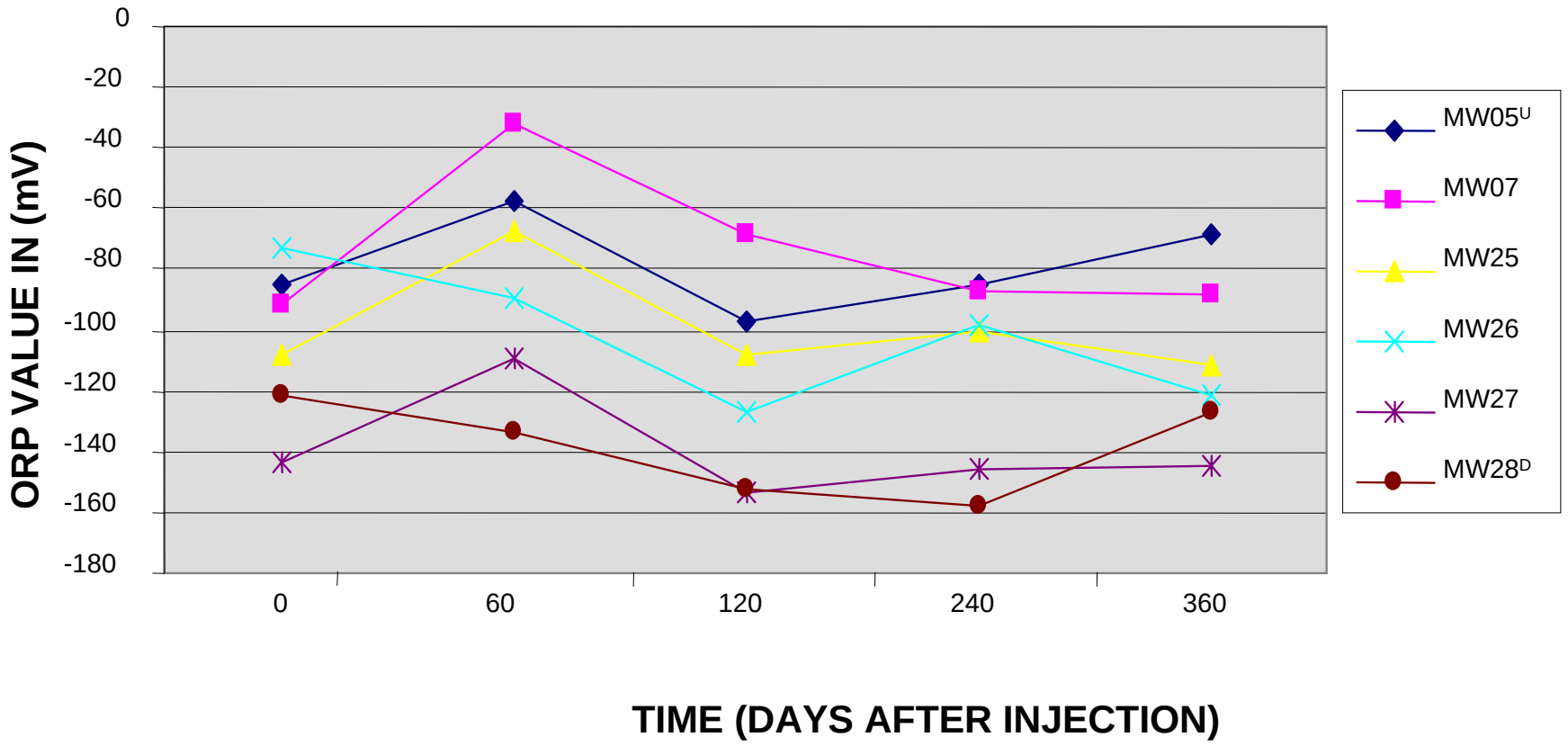
North Plume Historical VC Results



ORC® Geochemical Data

- **No notable changes in monitored geochemical parameters including: alkalinity, chloride, ferrous iron, nitrate, nitrite, sulfate and TOC**
- **Field ORP data indicates slight increase following injection and subsequent return to baseline conditions**
- **No major shift from anoxic to aerobic conditions evident**

North Plume ORP Results



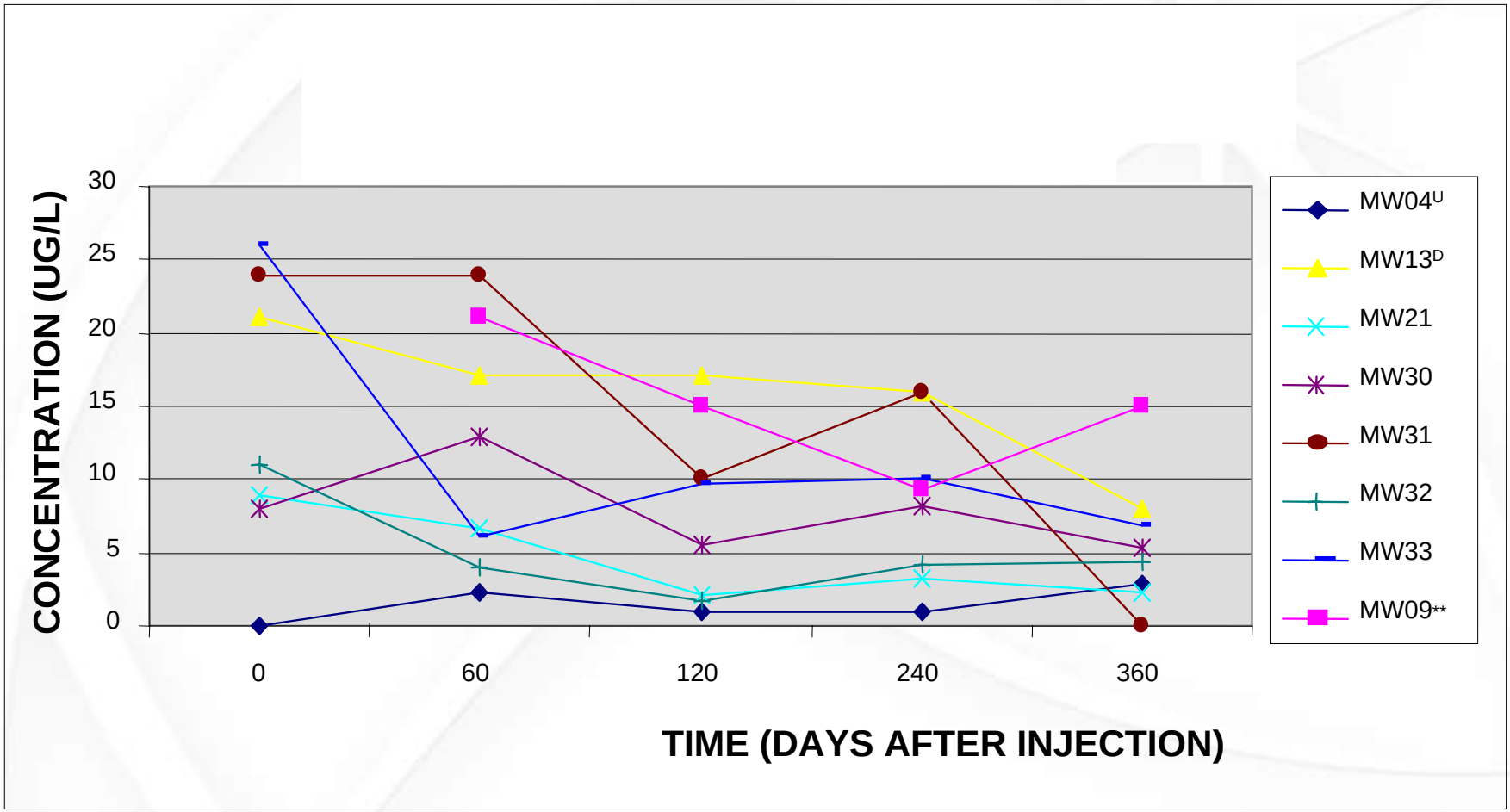
North Plume Conclusions

- **VC concentrations decreased following ORC® injection**
- **VC concentration also decreased in upgradient well**
- **Concentrations were historically decreasing**
- **Thus, some uncertainty as to the benefit of ORC® injection, although it did appear to increase the rate of decrease**
- **No geochemical indicators of ORC® presence**
- **Target MCL not reached after one year of monitoring**

South Plume (Newman Zone) Results

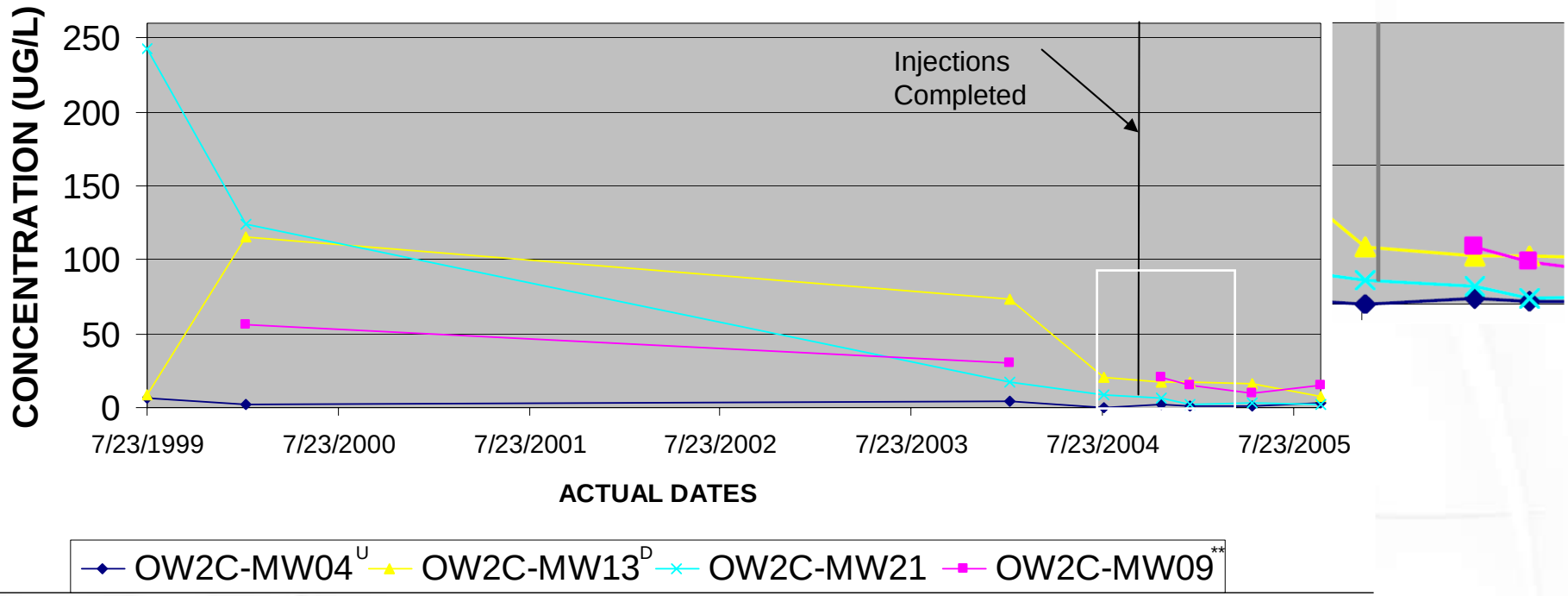
- **Treatment Area**
  - Baseline concentrations of VC
    - 8 μg/L to 26 μg/L
  - Post-treatment concentrations of VC
    - non-detect to 15 μg/L
  - Average decrease of 70%
- **Upgradient Well**
  - No appreciable change

South Plume Treatment Area VC Concentrations



U: Upgradient Well
D: Downgradient Well
** Baseline Monitoring Not Completed

South Plume Historical VC Results

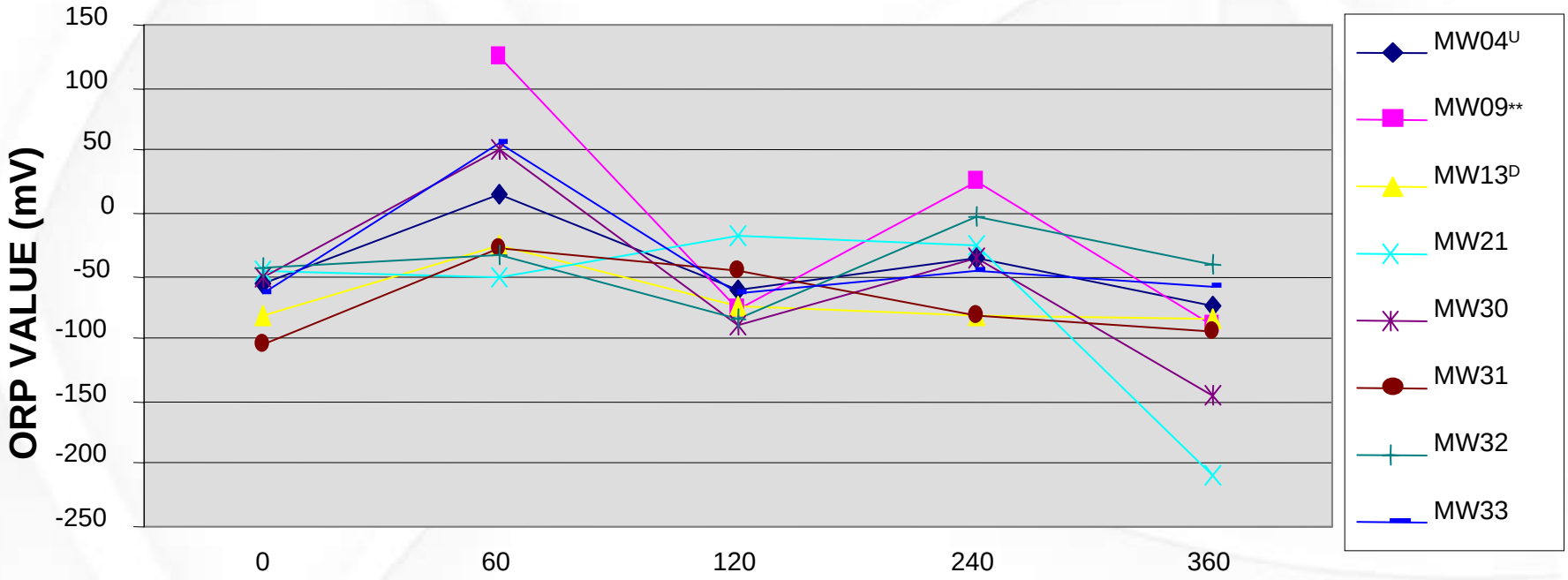


U: Upgradient Well
D: Downgradient Well
** Baseline Monitoring Not Completed

Newman Zone Geochemical Data

- **Decrease in ORP during 14-month monitoring period**
- **Methanogenesis indicates that reducing conditions were achieved**
- **Increases in VFA concentrations indicate that oil was still acting as an electron donor source 12-months following application**
- **DO and sulfate concentrations generally decreased**
- **Little ethene/ethane production was observed, but given the low initial concentrations of VC, observed increases were within the expected range**
- **Little increase in TOC was observed**

South Plume ORP Results



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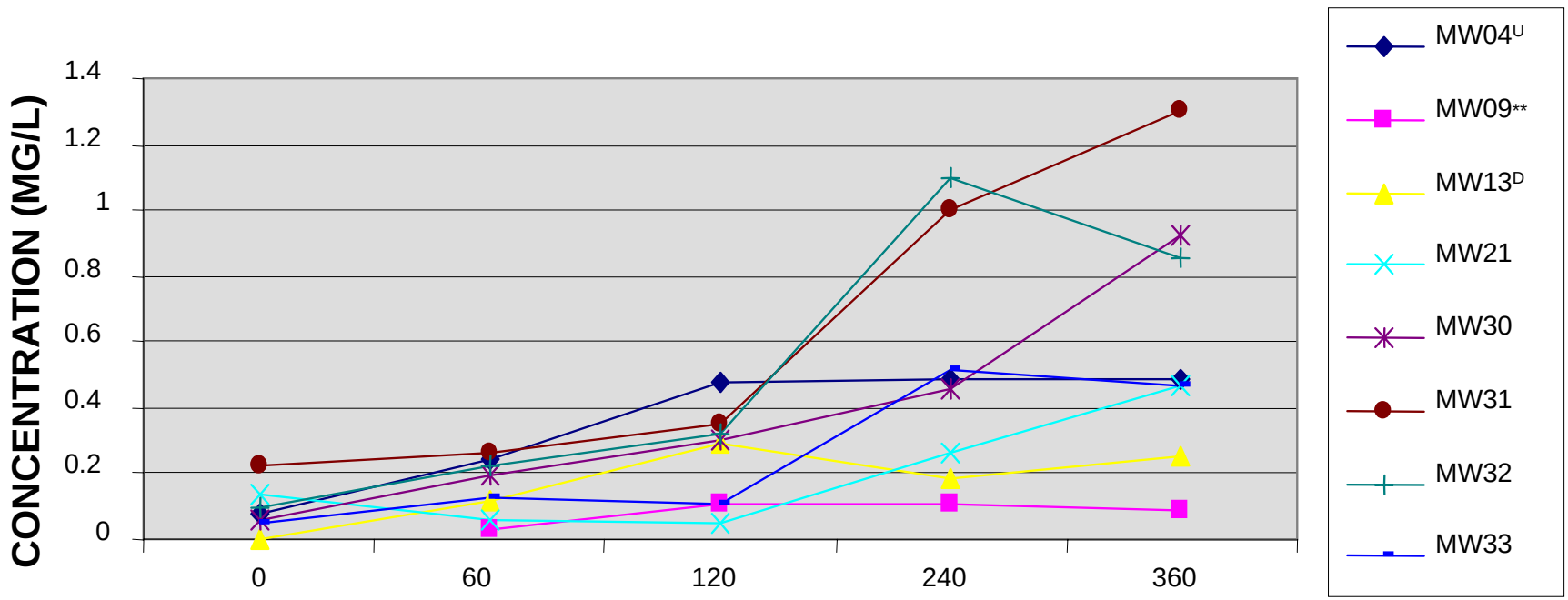
** Baseline Monitoring Not Completed

TIME (DAYS AFTER INJECTION)

South Plume Methane Results



U: Upgradient Well
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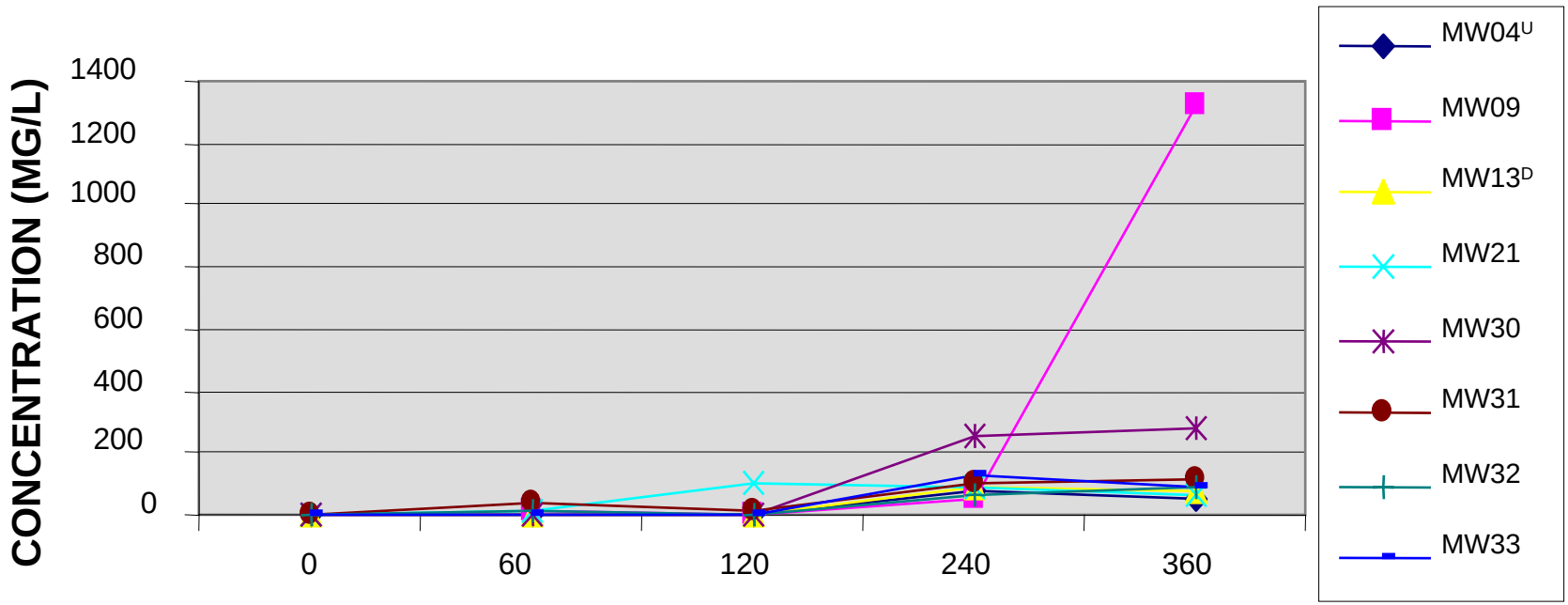
** Baseline Monitoring Not Completed

South Plume VFA Results



U: Upgradient Well
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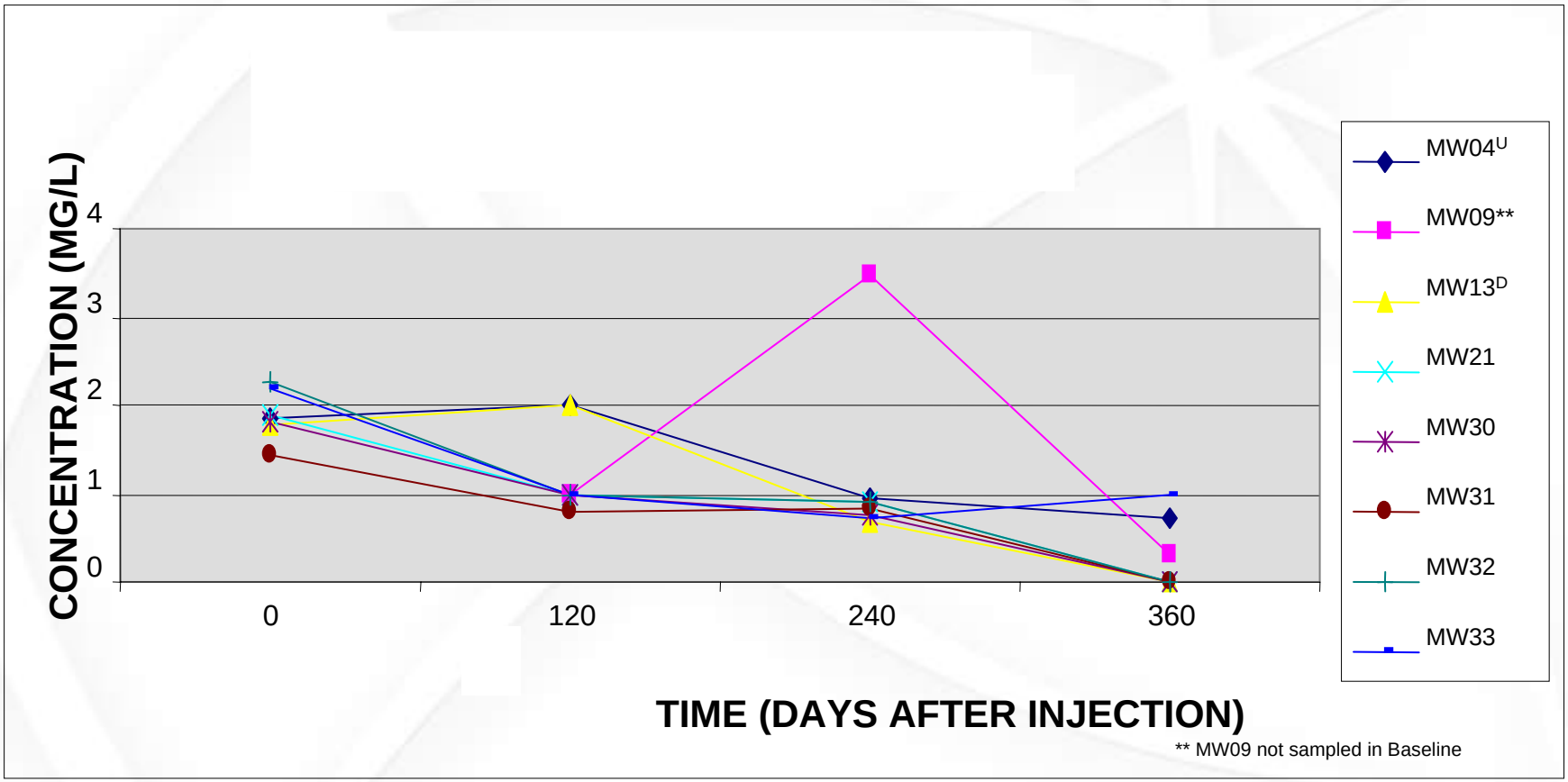
** Baseline Monitoring Not Completed

South Plume Dissolved Oxygen



U: Upgradient Well
D: Downgradient Well
** Baseline Monitoring Not Completed

South Plume Conclusions

- **VC concentrations decreased following injection**
- **Concentrations were historically decreasing**
- **Thus, some uncertainty as to the benefit of oil injection, although it did appear to increase the rate of decrease**
- **Geochemical indicators of anaerobic biodegradation were present.**
- **Geochemical indicators did not appear until about 120 days**
- **Target MCL not reached after one year of monitoring, but reducing conditions maintained**

Comparison of Treatment Alternatives

- ***Cost***: **Comparable (slightly higher for ORC®)**
- ***Ease of Implementation***: **ORC® was easier to inject in higher traffic areas**
- ***Treatment efficiency***: **Comparable (slightly greater for Newman Zone)???**
- ***Increase in rate of reduction***: **Greater for ORC®???**
- ***Geochemical Support for Efficacy***: **Greater for Newman Zone**
- ***Longevity of Treatment***: **Methane and VFA increases during the 12 month post-injection monitoring event suggest greater longevity of the Newman Zone treatment**

Overall Conclusions

- **Treatment alternatives are comparable based on results**
- **Since initial concentrations were low and natural attenuation was occurring at the site, it is difficult to quantify how much the decrease in concentrations was expedited by each treatment**

Questions?

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