WORKSHEET 1: BASELINE MASS FLUX AND REMEDIATION TIMEFRAME

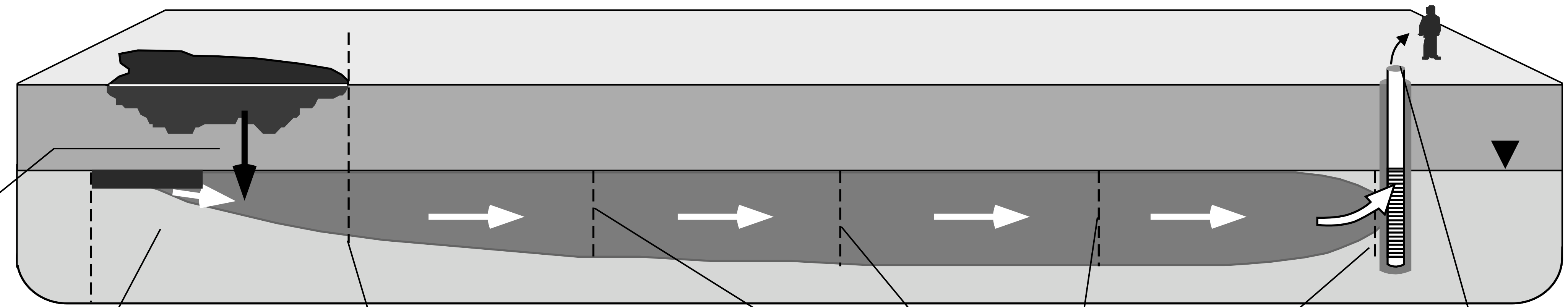
Site Name ______________________
Description ______________________
Date ____________ Constituent ____________

WORKSHEET 1
BASELINE MASS FLUX and REMEDIATION TIMEFRAME TOOL
Groundwater Remediation Strategies Tool, American Petroleum Institute

Version 2.0
Issued: 8/18/03

OBJECTIVE
Determine best way to control impacts to groundwater.

APPROACH
A. Using RBCA or other decision-making methodology, determine if there is an unacceptable impact to groundwater. If yes:
B. Calculate up to seven mass flux terms:
vadose zone-to-groundwater;
smear zone-to-groundwater;
total source-to-groundwater;
up to four "transect zone."
C. Calculate control point concentration.
D. Estimate baseline remediation timeframes for compartments that are shown.
E. Go to Worksheet 2.



Step MFB-1
VADOSE ZONE-TO-GW FLUX w_b_{vd} *(Optional)*

w_b_{vd} **VADOSE ZONE MASS FLUX (g/day)** [ ]

use methods in Section 3.5

Key Points:
w_b_{vd} is the Baseline Mass Flux prior to remediation. Compare this value to the After-Remediation Mass Flux on Worksheet 2 (w_ar_{vd}) to see how much the flux here and downgradient of this point is reduced.

The vadose zone flux calculation is *optional* , as in some cases an accurate estimation of the vadose zone flux is not possible.

Step MFB-3
SMEAR ZONE-TO-GW FLUX w_b_{sm} *(Optional)*

[ ] - [ ] = [ ]

w_b_{ts} (g/day) - w_b_{vd} (g/day) = w_b_{sm} **SMEAR ZONE MASS FLUX (g/day)**

Key Points:
w_b_{sm} is the Baseline Mass Flux prior to remediation. Compare this value to the After-Remediation Mass Flux on Worksheet 2 (w_ar_{sm}) to see how much the flux here and downgradient of this point is reduced. The smear zone flux (w_b_{sm}) is calculated indirectly by subtracting the vadose zone flux (w_b_{vd}) from the total flux from the source (w_b_{ts}). The smear zone flux calculation is *optional* .

Step MFB-2
TOTAL SOURCE-TO-GW$_{source}$ FLUX w_b_{ts}

w_b_{ts} **GROUNDWATER TOTAL SOURCE MASS FLUX (g/day)** [ ]

use methods in Section 3.1, 3.2, or 3.3

Key Points:
w_b_{ts} is the Baseline Mass Flux prior to remediation. Compare this value to the After-Remediation Mass Flux (w_ar_{ts}) on Worksheet 2 to see how much the flux here and downgradient of this point is reduced.

w_b_{ts} is the total flux in groundwater leaving the source zone. If the vadose zone and smear zone mass fluxes are not calculated, this should be the starting point of the analysis.

Step MFB-4

GROUNDWATER TRANSECT AREA FLUXES	Transect Zone 1 Mass Flux	Transect Zone 2 Mass Flux	Transect Zone 3 Mass Flux	Transect Zone 4 Mass Flux
GROUNDWATER TRANSECT ZONE MASS FLUXES (g/day)	w_b_{gw-1}	w_b_{gw-2}	w_b_{gw-3}	w_b_{gw-4}

use methods in Section 3.1, 3.2, or 3.3

Key Point:
w_b_{gw-1} through w_b_{gw-4} are the Baseline Mass Fluxes prior to remediation. Compare these values to the After-Remediation Mass Fluxes on Worksheet 2 to see how much the fluxes here and downgradient of these transects are reduced.

The intermediate transects allow you to evaluate a remedial action at a given point in the plume.

Step MFB-5
CONTROL POINT CONCENTRATION (shown as well in this worksheet, but can also be surface water)

w_{gw-4} (g/day) [ ]

÷

Control Point Flowrate (L/day) [ ]

X 1000

=

C_b_{cp} **CONTROL POINT CONCENTRATION (mg/L)** [ ]

see Section 3.4

Key Point:
C_b_{cp} is the Baseline Control Point concentration. Compare this value to the After-Remediation control point concentration (C_ar_{cp}) on Worksheet 2 to see how much the concentration has been reduced by remediation.

Step RTB-1
VADOSE ZONE MASS AND NATURAL ATTENUATION TIMEFRAME *(Optional)*

t_b_{vd} **VADOSE ZONE N.A. TIMEFRAME (yr)** [ ]

use methods in Section 4

Key Point:
t_b_{vd} is the Baseline Natural Attenuation Timeframe prior to remediation. Compare this value to the After-Remediation Vadose Zone Remediation Timeframe (t_ar_{vd}) on Worksheet 2 to see how much the timeframe is reduced by remediation.

Step RTB-2
SMEAR ZONE MASS AND NATURAL ATTENUATION TIMEFRAME *(Optional)*

t_b_{sm} **SMEAR ZONE N.A. TIMEFRAME (yr)** [ ]

use methods in Section 4

Key Point:
t_b_{sm} is the Baseline Natural Attenuation Timeframe prior to remediation. Compare this value to the After-Remediation Smear Zone Remediation Timeframe (t_ar_{sm}) on Worksheet 2 to see how much the timeframe is reduced by remediation.

Step RTB-3
TOTAL SOURCE ZONE NATURAL ATTENUATION TIMEFRAME *(Optional)*

t_b_{ts} **TOTAL SOURCE N.A. TIMEFRAME (yr)** [ ]

use maximum of t_b_{vd} *and* t_b_{sm}

Key Point:
Use the maximum of either the baseline vadose zone natural attenuation timeframe (t_b_{vd}) and the baseline smear zone natural attenuation timeframe (t_b_{sm}).

t_b_{ts} is the Baseline natural attenuation timeframe prior to remediation. Compare this value to the After-Remediation Total Source Remediation Timeframe (t_ar_{ts}) on Worksheet 2 to see how much the timeframe is reduced by remediation.

Step RTB-4

GROUNDWATER TRANSECT ZONE MASS AND NATURAL ATTEN. TIMEFRAME	Transect Zone 1	Transect Zone 2	Transect Zone 3	Transect Zone 4
Travel Time To Transect (distance from source ÷ seepage velocity) (yr)	[ ]	[ ]	[ ]	[ ]
	+	+	+	+
t_b_{ts} Total Source Natural Attenuation Timeframe (yr)	[ ]	[ ]	[ ]	[ ]
	=	=	=	=
t_b_{gw} GROUNDWATER TRANSECT ZONE NATURAL ATTENUATION TIMEFRAMES (yr)	t_b_{gw-1}	t_b_{gw-2}	t_b_{gw-3}	t_b_{gw-4}

use methods in Section 4

Key Point:
t_b_{gw-1} through t_b_{gw-4} are the Baseline Natural Attenuation Timeframes prior to remediation. Compare these values to the After-Remediation Transect Zone Remediation Timeframes on Worksheet 2 to see how much the timeframes are reduced by remediation.

WORKSHEET 2: REMEDY EVALUATION

Site Name ______________________
Description ______________________
Date ______________ Constituent ____________

WORKSHEET 2
REMEDIATION EVALUATION TOOL USING MASS FLUX and REMEDIATION TIMEFRAME
Groundwater Remediation Strategies Tool, American Petroleum Institute

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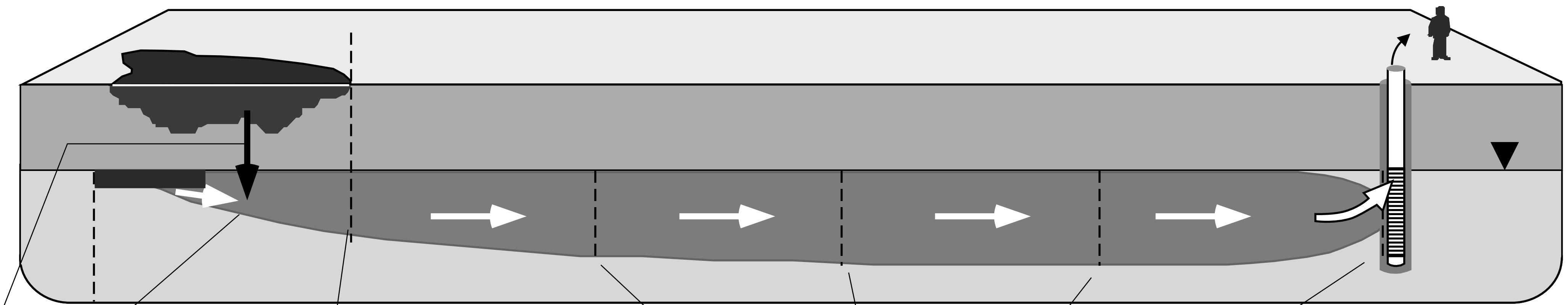
OBJECTIVE
Develop / document change of mass flux and remediation timeframe.

APPROACH
A. Calculate Baseline Mass Fluxes and Baseline Remediation Timeframes using Worksheet 1.
B. Select a candidate remedial technology or combination of technologies and:
   1. Estimate and enter the Flux Reduction Factor and Mass Reduction Factor for that remedy (see Section 5);
   2. Estimate the Mass Flux After Remediation (**ar**) (see Section 3);
   3. Estimate the After-Remediation and Remediation Timeframes (see Section 4);
   4. Evaluate how long it will take upgradient remediation activities to affect downgradient transport compartments (see Section 6).
C. Repeat this process for several remedial alternatives, and comparebased on reduction in mass flux, reduction in remediation, reliability, cost, and other factors.



Step MFAR-1
VADOSE ZONE-TO-GW FLUX w_ar_{vd} *(Optional)*

w_b_{vd} (g/day) [ ] *from WrkSht1*
Technology: [ ] X
Flux Reduction Factor (rw_{vd}) [ ]
use resources in Section 5
=
w_ar_{vd} VAD. ZONE MASS FLUX AFTER REMEDIATION (g/day) [ ]

+

Key Point:
w_ar_{vd} represents the after-remediation mass flux to groundwater. Continue the calculations to the right to determine the downgradient impact of this remedial alternative. The vadose zone flux calculation is *optional.*

Step MFAR-2
SMEAR ZONE-TO-GW FLUX w_ar_{sm} *(Optional)*

w_b_{sm} (g/day) [ ] *from WrkSht1*
Technology: [ ] X
Flux Reduction Factor (rw_{sm}) [ ]
use resources in Section 5
=
w_ar_{sm} SMEAR Z. MASS FLUX AFTER REMEDIATION (g/day) [ ]

=

Key Point:
w_ar_{sm} represents the after-remediation mass flux to groundwater. Continue the calculations to the right to determine the downgradient impact of this remedial alternative. The smear zone flux calculation is *optional.*

Step MFAR-3
TOTAL SOURCE-TO-GW$_{source}$ FLUX w_ar_{ts}

w_ar_{ts} Total Source Flux After Remediation (g/day) [ ]
÷
w_b_{ts} (g/day) [ ] *from WrkSht1*
=
FLUX REDUCTION FACTOR (rw_{ts}) [ ]

Key Point:
w_ar_{ts} is the total mass flux to groundwater from the source zone after remediation. w_ar_{ts} can also be calculated by adding $w\_ar_{vd} + w\_ar_{sm}$. Continue the calculations to the right to determine the downgradient impact of this remedial alternative.

Step MFAR-4

GROUNDWATER TRANSECT ZONE FLUXES w_ar_{gw-x}	TRANSECT ZONE 1 FLUX	TRANSECT ZONE 2 FLUX	TRANSECT ZONE 3 FLUX	TRANSECT ZONE 4 FLUX
Transect Zone Flux (g/day)	[ ] *from WrkSht1* w_b_{gw-1}	[ ] *from WrkSht1* w_b_{gw-2}	[ ] *from WrkSht1* w_b_{gw-3}	[ ] *from WrkSht1* w_b_{gw-4}
Technology: [ ]	X	X	X	X
Flux Reduction Factor (rw_{gw}) *use resources in Section 5*	[ ] rw_{gw-1}	[ ] rw_{gw-2}	[ ] rw_{gw-3}	[ ] rw_{gw-4}
	X	X	X	X
	[ ] rw_{ts}	[ ] rw_{ts} x rw_{gw-1} =	[ ] rw_{ts} x rw_{gw-1} x rw_{gw-2} =	[ ] rw_{ts} x rw_{gw-1} x rw_{gw-2} x rw_{gw-3} =
TRANSECT ZONE MASS FLUX AFTER REMEDIATION (g/day)	[ ] w_ar_{gw-1}	[ ] w_ar_{gw-2}	[ ] w_ar_{gw-3}	[ ] w_ar_{gw-4}

Key Point:
Calculate the flux reduction factor for each transect zone being used. Add any flux reduction factors that have occurred in the source zone to reflect upstream remediation efforts. Note that the final flux being reported is the long-term flux after the system has reached equilibrium with the new, remediated transport compartments located upstream. To determine how long it might take to reach the after-remediation fluxes, use the charts in Section 6.

Step MFAR-5
CONTROL POINT CONCENTRATION (shown as well in this worksheet, but can also be surface water)

w_ar_{gw-4} (g/day) [ ]
X
Control Point-of-Use (POU) Flux Reduction Factor (rw_{pou}) [ ]
=
w_ar_{cp} Control Point Mass Flux After Remediation (g/day) [ ]
÷
Control Point Flowrate (L/day) [ ]
X 1000
=
C_ar_{cp} CONTROL POINT CONCENTRATION AFTER REMEDIATION (mg/L) [ ]
see Section 3.4

Key Point:
The control point flux reduction factor can be used if point-of-use treatment such as carbon adsorption or air stripping is being used as part of the remedy.

This calculation shows the estimated concentration at the control point after remediation.

How Long Does it Take?
Use the charts in **Section 6 and Appendix A** to estimate how long upstream changes in mass flux will take to affect the mass flux downgradient.

Step RTAR-1
VADOSE ZONE REMEDIATION TIMEFRAME t_ar_{vd} *(Optional)*

VADOSE ZONE REMEDIATION TIMEFRAME AFTER REMEDIATION (yr) [ ]
use methods in Section 4

Key Point:
t_ar_{vd} represents the after-remediation remediation timeframe for the vadose zone. This calculation is *optional* .

Step RTAR-2
SMEAR ZONE REMEDIATION TIMEFRAME t_ar_{sm} *(Optional)*

SMEAR ZONE REM. TIMEFRAME AFTER REMEDIATION (yr) [ ]
use methods in Section 4

Key Point:
t_ar_{sm} represents the after-remediation remediation timeframe for the smear zone. This calculation is *optional* .

Step RTAR-3
SELECT MASS FLUX CURVE FROM APPENDIX B *(Optional)*

Is source mass flux vs. time during adn after remediation represented better by:
☐ Decaying Source?
☐ Step Function Source?

Which mass flux curve in Appendix A best represents source mass flux during and after remediation? [ ]

Key Point:
Use results from Step RTAR-1 and RTAR-2 and the methods shown in Section 6 and Appendix A to select a mass flux curve that best represents this source during and after remediation.

Step RTAR-4

GROUNDWATER TRANSECT ZONE REMEDIATION TIME-FRAMES	TRANSECT ZONE 1 Timeframe	TRANSECT ZONE 2 Timeframe	TRANSECT ZONE 3 Timeframe	TRANSECT ZONE 4 Timeframe
TRANSECT ZONE REMEDIATION TIMEFRAME (yr) *use methods in Section 6*	[ ] t_ar_{gw-1}	[ ] t_ar_{gw-2}	[ ] t_ar_{gw-3}	[ ] t_ar_{gw-4}

Key Point:
Method 1: If there is no active remediation in the Transect Zones, use the methods shown in Section 6 and Appendix A to evaluate the timing of upgradient remediation activities on the transect zones. This calculation is *optional* .
Method 2: If there is active remediation in the Transect Zones (such as pump-and-treat), use the methods shown in Section 4 and 6 to estimate the remediation timeframe. This calculation is *optional* .