| Case study ID | Reference | Site | Constituents | Use | Mass flux/discharge measurement method | Benefits of mass flux/mass discharge estimates | Method used to estimate specific discharge |
|---|---|---|---|---|---|---|---|
| 1 | Annable et al. 2005 | CFB Borden, Ontario | PCE and TCE | Site characterization—Evaluated depth-specific mass flux and specific discharge using PFM. | Pumping well, passive flux meter (PFM) | Not applicable (n/a) | n/a |
| | | | MtBE | Site characterization—Evaluated depth-specific mass flux and specific discharge using transect method (TM) with PFM and TM with multilevel sampling (MLS) wells and identified increasing mass discharge with distance from initial source due to transient conditions. | TM, PFM | n/a | n/a |
| 2 | Barbaro and Neupane 2006 | Dover AFB, Delaware | VOCs | Site characterization—Used $M_d$ values calculated from two transects to evaluate natural attenuation along the flow path. | TM | Detailed three-dimensional plume delineation improved conceptual site model (CSM) and provided more reliable determination of plume attenuation rate between two transects. | Used a uniform specific discharge across both transects based on relatively uniform head distribution, lithology, and aquifer thickness in the vicinity of the two transects. |
| 3 | RTDF 1998 | Dover AFB, Delaware | Total chlorinated organics | Site characterization—Used multiple transects to evaluate the degree to which natural attenuation was occurring downgradient of a source zone. | Indirect—synthetic transect from contours | n/a | n/a |

| Case study ID | Reference | Site | Constituents | Use | Mass flux/discharge measurement method | Benefits of mass flux/mass discharge estimates | Method used to estimate specific discharge |
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| 4 | Basu et al. 2006 | Former electronic parts manufac-turing plant, midwestern United States | TCE | Site characterization and evaluation of remediation alternatives— Measured mass flux and mass discharge to characterize (a) site hydrogeology, (b) source strength, (c) vertical delineation of specific discharge and contaminant flux at well locations, and (d) degradation rates. Isoconcentration contours and depth-specific Darcy flux were used to estimate mass discharge at three transects transverse to groundwater flow for the purpose of calculating a biodegradation rate. Depth- integrated mass flux was calculated at various locations along a cross section parallel to groundwater flow. | PFM and isoconcentration contour transects | Depth-discrete flux monitoring indicates that the zone of higher permeability and lower concentrations needs to be considered as a target zone for remediation because it represents a relatively large portion of the source strength, which shows that focusing remediation only in the zone of high concentrations may be “suboptimal.” Detailed contaminant flux vertical profiles revealed valuable information about the upgradient source distribution that could not be determined using conventional monitoring well data. High-resolution profiles of specific discharge versus depth determined using the PFM provide valuable information about variability in hydraulic conductivity that may affect the distribution of injected solutions during remediation. | PFM was used to quantify specific discharge at approximately 0.3 m intervals. The average specific discharge determined using the PFM for shallow, intermediate, and deep zones were compared to specific discharge estimates based on average single-well response tests for monitoring wells completed in corresponding horizons. |

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|---|---|---|---|---|---|---|---|
| 5 | Basu et al. 2009 | Former manufac-turing site, Australia | TCE | Site characterization—Used $M_d$ values to compare mass discharge from source zone to $M_d$ in plume about 175 m downgradient to evaluate potential for natural attenuation of TCE. Determined that higher $M_d$ in plume relative to smaller source zone $M_d$ is because of declining source concentrations and six-year travel time between the source and plume control plane transects. | Transects using PFMs | Flux-based site management approach in heterogeneous aquifer resulted in improved CSM, which will lead to improved effectiveness of site remediation measures. Mass flux and specific discharge measurements were used to demonstrate that residual DNAPL mass was present in low-permeability zones and that source treatment was unwarranted. | PFMs were used to quantify specific discharge at approximately 0.3 m intervals over different periods of time to allow for assessment of seasonal fluctuations. |

| Case study ID | Reference | Site | Constituents | Use | Mass flux/discharge measurement method | Benefits of mass flux/mass discharge estimates | Method used to estimate specific discharge |
|---|---|---|---|---|---|---|---|
| 6 | Bauer et al. 2004 | Linz, Austria | PCE, TCE | Risk prioritization based on regional characterization of relative strengths of multiple source zones at different sites—Used the integral pumping test (IPT) method to evaluate mass discharge at three transects. Purpose was to quantify the relative strength of multiple source zones contributing to a dissolved plume. Two to five pumping wells were used on each transect. Water generated during pumping tests was disposed to the sewer system without treatment. Source zones between transects were identified as being stronger than upgradient sources. | IPT | Basin-wide mass discharge analysis determined which source zones should be targeted for further characterization and remediation and identified which portions of the aquifer could be excluded from further investigation and remediation. | n/a |
| 7 | Beckett, Stanley, and Walsh 2005 | Fuel release site, Morro Bay, California | MtBE | Mass discharge framework used to evaluate potential threat of MtBE plume to nearby water supply wells. | n/a | n/a | n/a |

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|---|---|---|---|---|---|---|---|
| 8 | Bockelmann, Ptak, and Teutsch 2001 | Former manufac-turing site near Stuttgart, Germany | BTEX, polycyclic aromatic hydrocarbons (PAHs) | Site characterization—Evaluated natural attenuation between two transects situated at distances of 140 and 280 m downgradient of the source zone. Mass discharges at each transect were used to estimate first-order biodegradation rates. Each transect included four pumping wells, and the average travel time between the two transects under static conditions is 70 days. | IPT based on wells along transects | Mass discharge estimated using the IPTs facilitated the estimation of natural attenuation rates in a highly heterogeneous aquifer with a curvilinear flow path. Changes in mass discharge of electron acceptors and metabolic by-products between transects was also evaluated to provide additional lines of evidence for biodegradation. | n/a |

| **Case study ID** | **Reference** | **Site** | **Constituents** | **USE** | **Mass flux/discharge measurement method** | **Benefits of mass flux/mass discharge estimates** | **Method used to estimate specific discharge** |
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| 9 | Bockelmann et al. 2003 | Former manufac-turing site near Stuttgart, Germany | BTEX, PAH | Site characterization—Compared the mass discharge across two transects using two approaches: (a) integrating mass flux estimated at each well based on point-source concentrations and (b) IPT method. Also estimated plume attenuation rates for BTEX and PAH species between three transects using three methods: (a) conventional concentration vs. distance attenuation estimates along the flow path, which was determined based on a natural gradient tracer test; (b) mass discharge at each transect based on integrated mass flux; and (c) mass discharge based on IPTs. Transects are 30, 140, and 280 m downgradient of the source zone. Each transect incorporated four monitoring wells with approximate spacing of 30–40 m between. Investigators determined that mass discharge estimates using monitoring well concentrations and well spacing of 30–40 m at this site resulted in significantly different discharge estimates than the IPT method (up to 159% difference). | TM | Evaluated uncertainty when using large spacing between wells along transect for estimating mass flux. | n/a |

| Case study ID | Reference | Site | Constituents | Use | Mass flux/discharge measurement method | Benefits of mass flux/mass discharge estimates | Method used to estimate specific discharge |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 10 | Borden et al. 1997 | Sampson County, North Carolina | MtBE, BTEX | Site characterization—Installed four transects up to 177 m downgradient of the source zone to delineate vertical and horizontal contamination and to facilitate estimation of biodegradation rates along the flow path. Five to six clusters of monitoring wells were installed along each transect. At each location, typically three wells were installed at different elevations, each having a 1.5 m screen length. The well screen length was selected to facilitate a flux-averaged evaluation over 1.5 m. The use of mass discharge to estimate biodegradation rates reduced uncertainty by eliminating the effect of vertical and transverse dispersion and mitigating the effect of nonideal well placement. Temporal variations in mass discharge were also evaluated over a two-year period. | TM | Using mass discharge to estimate plume attenuation rates between transects overcame previous limitations in estimating a biodegradation rate along the nonlinear flow path. Used medium-resolution vertical sampling with flux-averaged concentrations in 1.5 m well screens to estimate mass discharge and plume attenuation at each transect. Further vertical delineation was not required for this study. | n/a |

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| 11 | Brooks et al. 2008 | Hill AFB, Utah | TCE and cis-1,2-DCE | Remediation performance monitoring—Compared the mass discharge at a transect approximately 10–15 m downgradient of the source zone before and after remediation to assess performance efficiency. Multiple methods were used for mass discharge estimates to reduce uncertainty. Ten monitoring wells situated on the transect with approximate spacing of 3 m. | PFM, modified integral pump test (MIPT), TM | Demonstrated that source treatment resulted in a significant reduction in mass discharge from the source. Multiple methods were used to estimate mass discharge to reduce the uncertainty of the remediation performance assessment. High-resolution mass flux delineation indicates a potential reduction in source zone permeability due to stimulated biodegradation that occurred as a result of source treatment. | PFM and IPT |

| **Case study ID** | **Reference** | **Site** | **Constituents** | **Use** | **Mass flux/discharge measurement method** | **Benefits of mass flux/mass discharge estimates** | **Method used to estimate specific discharge** |
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| 12 | Brooks et al. 2008 | Fort Lewis, Washington | TCE and cis-1,2-DCE | Remediation performance monitoring—Compared the mass discharge at a transect approximately 6 m downgradient of the source zone before and after remediation to assess performance efficiency. Multiple methods were used for mass discharge estimates to reduce uncertainty. Ten monitoring wells situated on the transect with approximate spacing of 5 m. | PFM, MIPT, TM | Demonstrated that source treatment resulted in a significant reduction in mass discharge from the source. Multiple methods were used to estimate mass discharge the reduce the uncertainty of the remediation performance assessment. High- resolution mass flux delineation indicates a potential reduction in source zone permeability due to stimulated biodegradation that occurred as a result of source treatment. | PFM and IPT |

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| 13 | Brusseau et al. 2007 | Tucson Internation-al Airport area, Arizona | TCE | Remediation performance monitoring—Used mass removal data from an operating pump-and-treat system to confirm the presence of NAPL in the source zone and evaluated the transient relationship between mass flux reduction and source mass depletion. | n/a | Mass removed by the pump-and- treat system over 19 years was reported to be higher than the initial estimate of dissolved-phase mass, suggesting that NAPL is present in the source zone. Partitioning interwell tracer testing to measure source mass indicates that a 90% reduction in mass flux occurred with only a 50% reduction in source mass. This detailed characterization helps to improve the effectiveness of site management decisions. | n/a |
| 14 | Burton et al. 2002 | Beach Point, Maryland | Chlorinated solvents and heavy metals | Risk assessment—Evaluated potential risks associated with discharge of chlorinated solvents and heavy metals from the Beach Point surficial aquifer to Bush River, a tributary of Chesapeake Bay. | n/a | Groundwater discharge was used to evaluate dilution in the surface water body and the applicability of a Maryland “regulatory mixing zone,” i.e., a localized discharge zone in which local water quality standards may be exceeded. | n/a |

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| 15 | Buscheck, Nijhawan, and O’Reilly 2003 | Gas station, Tahoe City, California | MtBE | Mass discharge used to evaluate potential impact to downgradient river. | n/a | n/a | n/a |

| Case study ID | Reference | Site | Constituents | Use | Mass flux/discharge measurement method | Benefits of mass flux/mass discharge estimates | Method used to estimate specific discharge |
|---|---|---|---|---|---|---|---|
| 16 | Buscheck, Nijhawan, and O’Reilly 2003 | Fuel terminal, San Jose, California | MtBE | Mass flux measured to select optimal rate of dissolved oxygen addition to PRB with diffusive emitters. | n/a | n/a | n/a |
| 17 | Buscheck, Nijhawan, and O’Reilly 2003 | Unnamed site | MtBE | Mass discharge measured at three transects to evaluate natural attenuation of plume. | n/a | n/a | n/a |
| 18 | Buscheck, Nijhawan, and O’Reilly 2003 | 10 fuel release sites in California | MtBE | Mass discharge values used to prioritize remediation. Shows sites with high $M_d$ values are not necessarily the sites with the highest concentrations. | n/a | n/a | n/a |


| Case study ID | Reference | Site | Constituents | Use | Mass flux/discharge measurement method | Benefits of mass flux/mass discharge estimates | Method used to estimate specific discharge |
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| Case study ID | Reference | Site | Constituents | Use | Mass flux/discharge measurement method | Benefits of mass flux/mass discharge estimates | Method used to estimate specific discharge |
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| 19 | USEPA 2009 | Well 12A Superfund Site, Tacoma, Washington | Chlorinated solvents | Remedial action objectives and remediation performance monitoring —Based on computer modeling results, it was determined that a future reduction in mass discharge from the source zone of 90% would be sufficient to meet MCLs at the compliance wells, allowing for a future transition from active source remediation to MNA in the plume. Based on this work, an RAO developed for the site is a 90% reduction in mass discharge from the source zone. A transect of monitoring wells will be used to evaluate changes to mass discharge during active remediation and to assess changes in mass flux at other wells closer to the source zone. The compliance transect includes six horizontal locations with approximate spacing of 400 ft between locations, and each location includes two to three nested wells. The distribution of mass flux changes over time will be used to optimize the active remediation of the source zone. The PFM will be used to assess mass flux in monitoring wells. | TM using PFM | Use of a mass discharge reduction as an interim remediation goal provides a single metric for evaluating the integrated effect of source treatment and is directly related to the source strength that affects plume response to remediation. A mass discharge reduction goal can also be readily compared to the range of mass discharge reductions documented as being achievable for various technologies under site-specific conditions. | PFM |

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| 20 | Chapman and Parker 2005 | Industrial site, Connecticut | TCE | Site characterization and remediation performance monitoring—Measured the mass discharge across a transect of MLS wells to evaluate the distribution of mass in the plume and assess the influence of source zone isolation conducted six years earlier. | TM | High-resolution vertical sampling resulted in an important refinement to the CSM because the zone of concentrated source strength in the aquifer is thinner than what was apparent based on conventional monitoring well data. A mass balance demonstrated that 3,000 kg of TCE was stored in the aquitard over a distance of 280 m downgradient from the source. Based on a conservative comparison to mass discharge across the plume transect after the DNAPL source had been isolated, the authors determined that it would take longer than 80 years for TCE mass stored in the aquitard to be removed. The measured mass discharge at the transect was also used in a mass balance to demonstrate that substantial mass depletion had occurred in the source zone due to natural dissolution over four decades prior to source zone isolation. | Specific discharge was applied as a uniform value along the transect because the variability of *K* in the mildly heterogeneous aquifer was much smaller than the variability in TCE concentrations. |

| **Case study ID** | **Reference** | **Site** | **Constituents** | **Use** | **Mass flux/discharge measurement method** | **Benefits of mass flux/mass discharge estimates** | **Method used to estimate specific discharge** |
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| 21 | Chapman et al. 2007 | Industrial site, Connecticut | TCE, cis-1,2-DCE | Site characterization—Evaluated processes contributing to natural attenuation of chlorinated solvents across three transects situated between the DNAPL source zone and a river. The three transects were located 280–700 m downgradient from the source zone. The mass discharge investigation was conducted to facilitate the characterization of processes causing the natural attenuation of TCE and by-products along the groundwater flow path and to support a detailed mass balance assessment. | TM | A detailed mass discharge assessment significantly improved the CSM for contaminant transport pathways and the relative quantitative contribution of multiple attenuation processes. The mass balance included quantitative prediction of the relative mass discharged to local drainage streams versus the mass discharged from groundwater to a downgradient river. The mass balance also included quantification of mass loss through volatilization in local surface-water ponds. | Specific discharge was applied uniformly across all three transects. |

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| 22 | Chapman et al. 1997 | Former gasoline station, Ontario | BTEX | Remediation performance monitoring—Three transects were installed using MLS wells along each transect. The purpose of the transects was to evaluate the reduction in BTEX mass flux downgradient of a treatment zone consisting of passive wells containing oxygen-releasing compound between the first and second transect. Several monitoring events were conducted to evaluate changes to source mass discharge and treatment efficiency in the biobarrier over time. | TM | Mass discharge estimated at transects 2 and 3 was used to evaluate the degree to which natural attenuation was occurring downgradient of the biobarrier. The mass discharge calculations indicated that other organic and inorganic species represented significant sinks of oxygen which reduced the efficiency of BTEX treatment. | Specific discharge was applied as a uniform value along both transects. “Given the relatively small variation in flow velocity observed and the number of other unknowns, the assumption of a uniform velocity field is justified for these first-approximation estimates. The assumption of a uniform velocity field is not expected to significantly bias the conclusions drawn from these mass flux estimates, since the conclusions are based on differences between Fences 1 and 2.” |
| 23 | Einarson et al. 2005 | MtBE release site, Calistoga, California | MtBE | Mass discharge calculations suggest release from one site responsible for chemical impacts detected in supply well. | n/a | n/a | n/a |

| **Case study ID** | **Reference** | **Site** | **Constituents** | **Use** | **Mass flux/discharge measurement method** | **Benefits of mass flux/mass discharge estimates** | **Method used to estimate specific discharge** |
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| 24 | Einarson and MacKay 2001 | Port Hueneme, California | MtBE | Transect of MLS wells. | TM | n/a | n/a |
| 25 | Einarson and MacKay 2001 | Site 1, Alameda Naval Air Station | cis-1,2-DCE | Transect of MLS wells. | TM | n/a | n/a |
| 26 | Einarson and MacKay 2001 | Unnamed | MtBE | Transect of MLS wells. | TM | n/a | n/a |
| 27 | Einarson and MacKay 2001 | Vandenberg AFB, California | MtBE | Transect of MLS wells. | TM | n/a | n/a |
| 28 | Guilbeault, Parker, and Cherry 2005 | Florida | TCE | Site characterization—Measured the mass discharge across a transect downgradient of a source zone. | TM | High-resolution sampling improved the CMS with respect to hot-spot locations. Three distinct local high-concentration zones were identified with concentrations ranging 4%–15% of solubility. Approximately 60% of the source mass discharge was in <5% of the transect area, and 80% of the mass discharge was in <10% of the transect area. | Specific discharge was applied as a uniform value along the transect because the variability of *K* in the mildly heterogeneous aquifer was much smaller than the variability in concentrations. |

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| 29 | Parker et al. 2008 | Florida | TCE | Remediation performance monitoring—Estimated the change in mass discharge across a transect due to the implementation of a hydraulic control remedy downgradient of the source zone. The estimate of mass discharge change due to the source zone containment system was based on temporal changes in groundwater concentrations at multilevel wells along the transect, assuming that there was no change in groundwater specific discharge across the transect. | TM | The estimated mass discharge occurring in the plume after the source zone had been hydraulically isolated was used to demonstrate that the mass stored in a thin clay layer is much higher than the mass discharge rate. This comparison was used to illustrate that back-diffusion from a thin clay represents a long-term process likely to sustain concentrations in the plume above MCLs. | n/a |

| **Case study ID** | **Reference** | **Site** | **Constituents** | **Use** | **Mass flux/discharge measurement method** | **Benefits of mass flux/mass discharge estimates** | **Method used to estimate specific discharge** |
|---|---|---|---|---|---|---|---|
| 30 | Guilbeault, Parker, and Cherry 2005 | Ontario | PCE | Site characterization—Measured the mass discharge from the source zone across a transect. | TM | High-resolution sampling improved the CSM with respect to hot-spot locations. Four distinct local high-concentration zones were identified with concentrations as high as 16% of solubility. Approximately 60% of the source mass discharge was in <5% of the transect area, and 80% of the mass discharge was in <10% of the transect area. | Specific discharge was applied as a uniform value along the transect because the variability of *K* in the mildly heterogeneous aquifer was much smaller than the variability in concentrations. |

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| 31 | Guilbeault, Parker, and Cherry 2005 | New Hampshire | PCE | Site characterization—Measured the mass discharge from the source zone across a transect. | TM | High-resolution sampling improved the CSM with respect to hot-spot locations. Fifteen distinct local high-concentration zones were identified with concentrations 1%–62% of solubility. Approximately 60% of the source mass discharge was in <5% of the transect area, and 80% of the mass discharge was in <10% of the transect area. | Used two specific discharge zones: one above and one below a clay layer. The hydraulic conductivity of the clay layer is orders of magnitude less than the sand layers, so the clay layer was ignored in the mass flux and mass discharge calculations, and the thickness of the clay was subtracted in the areal elements where it was present. |
| 32 | D'Affonseca et al. 2008 | Coal tar site near Hamburg, Germany | Naphthalene | Site characterization—Used a transect with three well clusters over a total width of 60 m, with three vertical well screens at each cluster location. Also used the IPT with one extraction well having a capture zone width of 15 m. The purpose was to evaluate DNAPL architecture in the source zone. Two- and three-dimensional modeling of multicomponent DNAPL depletion was conducted, and simulated mass discharge was compared to estimated values based on field data. | TM, IPT | Vertical delineation of mass flux confirmed that one portion of the source zone was contributing a majority of the discharge making up the total source strength. Modeling illustrated that the mass flux of naphthalene has likely reached its peak and will begin to decline over time. Field and model data were used to evaluate the potential benefits and limitations of partial mass removal on downgradient mass discharge trends. | Specific discharge was applied uniformly across the transect. |

| Case study ID | Reference | Site | Constituents | Use | Mass flux/discharge measurement method | Benefits of mass flux/mass discharge estimates | Method used to estimate specific discharge |
|---|---|---|---|---|---|---|---|
| 33 | DiFillippo and Brusseau 2008 | Several sites, North America | Various | Remediation performance assessment—Evaluated the relationship between mass discharge reduction and source mass depletion for 21 remediation projects. | Various | n/a | n/a |
| 34 | Ellis, Mackat, and Rivett 2007 | River Tame, U.K. | Inorganic parameters | Regional characterization—Estimated mass discharge of various inorganic parameters from the Birmingham Aquifer to River Tame. | n/a | Provided a quantitative comparison of the degree of base flow loading to the river relative to contributions from other sources of surface water. | n/a |
| 35 | Ford, Wilklin, and Hernandez 2006 | Superfund site, Massachu-setts | Arsenic | Site characterization—Used arsenic mass flux calculations to compare the relative contribution of groundwater discharge and sediment dissolution/desorption to arsenic in surface water. | Synoptic sampling | n/a | n/a |
| 36 | Goltz et al. 2009 | Test site, New Zealand | Bromide and nitrate | Measurement method validation— Used an artificial aquifer with dimensions of 9.5 × 4.7 × 2.6 m to validate TCW methods and to compare to the MIPT method. | TCW, MIPT | n/a | n/a |

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| 37 | Imbrigiotta et al. 1997 | Picatinny Arsenal, New Jersey | TCE | Conducted a detailed mass balance to assess relative contributions of various processes representing gains and losses for plume mass. The mass discharge to a brook downgradient from the source zone was included in the mass balance assessment. | Hand calculations | n/a | n/a |
| 38 | Johnson, Truex, and Clement 2006 | Unidenti-fied site | Unknown | Remedial design—Demonstrated an example application where RT3D was used to estimate the plume mass discharge corresponding to different remedial alternatives. | Modeled | n/a | n/a |

| **Case study ID** | **Reference** | **Site** | **Constituents** | **Use** | **Mass flux/discharge measurement method** | **Benefits of mass flux/mass discharge estimates** | **Method used to estimate specific discharge** |
|---|---|---|---|---|---|---|---|
| 39 | Kao and Wang 2001 | Gasoline spill site, Garysburg, North Carolina | BTEX | Site characterization—Used mass discharge estimates from three transects at distances of 8, 48, and 88 m downgradient of the source zone to estimate natural biodegradation rates. | TM | Plume attenuation rates were estimated based on declines in mass discharge between transects, independent of transverse horizontal and vertical dispersivity estimates. | Specific discharge was applied uniformly across all transects. |

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| 40 | Landmeyer et al. 2001 | Gasoline station near Beaufort, South Carolina | MtBE | Site characterization—Used mass discharge estimates across three transects adjacent to a creek receiving groundwater discharge. Results showed that MtBE was undergoing extensive biodegradation in a small oxic zone caused by mixing of groundwater and surface water adjacent to the creek. | TM | n/a | n/a |
| 41 | Pitz 1999 | South Puget Sound, Washington | Nitrate | Site characterization—Estimated nitrate mass loading to South Puget Sound by groundwater discharge. | Recharge zone method | Nitrate mass discharge estimates facilitate tracking of annual changes in nutrient loading to South Puget Sound. | n/a |
| 42 | Ricker 2008 | Former wood treating site, Louisiana | Naphthalene | Site characterization—Estimated temporal changes to dissolved plume mass and the potential for downgradient migration of the plume center of mass, as part of a plume stability evaluation. | n/a | Analysis of plume stability based on individual well trends can be challenging when some wells show a decreasing trend and other wells show an increasing or stable trend. This study demonstrated the application of plume dissolved mass and the center of mass location over time to demonstrate that the naphthalene plume is shrinking over time. | n/a |

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| 43 | Semprini et al. 1995; Weaver Wilson, and Kampbell 1997 | St. Joseph, Michigan | Total ethenes | Site characterization—Used multiple transects to evaluate natural attenuation rates along the groundwater flow path. | TM | Estimated natural attenuation rates based on mass discharge are independent of dispersivity estimates and less susceptible to transient fluctuations in groundwater flow direction and uncertainty in the location of the plume centerline. | Not specified |

| **Case study ID** | **Reference** | **Site** | **Constituents** | **Use** | **Mass flux/discharge measurement method** | **Benefits of mass flux/mass discharge estimates** | **Method used to estimate specific discharge** |
|---|---|---|---|---|---|---|---|
| 44 | Thomson, Hood, and Farquhar 2007 | CFB Borden, Ontario | TCE, PCE | Remediation performance assessment—Used a transect of MLS wells to compare pre- and post-treatment mass flux distribution and mass discharge. | TM | n/a | n/a |

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| 45 | Thomson, Hood, and Farquhar 2007 | Coal tar creosote source, Borden, Ontario | PAHs, BTEX | Remediation performance assessment—Conducted a mass balance to evaluate efficiency of permanganate injections and evaluated changes to mass discharge associated with source treatment. | n/a | A detailed mass balance involving permanganate and contaminated species was critical to evaluating the efficiency of remedial injections. Temporal fluctuations in mass discharge and plume mass provided valuable information regarding the effectiveness of source treatment and the corresponding influence on downgradient plume response. | n/a |
| 46 | Thuma, Kremesec, and Kolhatkar 2001 | Long Island | MtBE | Site characterization—Calculated mass flux across several transects downgradient from the source zone using monitoring well concentration data and compared these data to calculations from a solute transport model to validate the model calibration. | TM, solute transport model | Mass flux data were used to demonstrate natural attenuation due to biodegradation was occurring along the groundwater flow path. Using mass discharge as a model calibration target provides an important metric that may help to improve the representativeness of the calibrated model. | n/a |
| 47 | Kingston 2008 (Table 5.5) | Thermal Treatment Site 1 | Total VOCs | Remediation performance assessment. | TM | n/a | n/a |
| 48 | Kingston 2008 (Table 5.5) | Thermal Treatment Site 2 | Total VOCs | Remediation performance assessment. | TM | n/a | n/a |
| 49 | Kingston 2008 (Table 5.5) | Thermal Treatment Site 3 | Total VOCs | Remediation performance assessment. | TM | n/a | n/a |
| 50 | Kingston 2008 (Table 5.5) | Thermal Treatment Site 4 | Total VOCs | Remediation performance assessment. | TM | n/a | n/a |

| Case study ID | Reference | Site | Constituents | Use | Mass flux/discharge measurement method | Benefits of mass flux/mass discharge estimates | Method used to estimate specific discharge |
|---|---|---|---|---|---|---|---|
| 51 | Kingston 2008 (Table 5.5) | Thermal Treatment Site 5 | Total VOCs | Remediation performance assessment. | TM | n/a | n/a |
| 52 | Kingston 2008 (Table 5.5) | Thermal Treatment Site 6 | Total VOCs | Remediation performance assessment. | TM | n/a | n/a |
| 53 | Kingston 2008 (Table 5.5) | Thermal Treatment Site 7 | Total VOCs | Remediation performance assessment. | TM | n/a | n/a |
| 54 | Kingston 2008 (Table 5.5) | Thermal Treatment Site 9 | Total VOCs | Remediation performance assessment. | TM | n/a | n/a |
| 55 | Kingston 2008 (Table 5.5) | Thermal Treatment Site 11 | Total VOCs | Remediation performance assessment. | TM | n/a | n/a |
| 56 | Kingston 2008 (Table 5.5) | Thermal Treatment Site 12 | Total VOCs | Remediation performance assessment. | TM | n/a | n/a |
| 57 | Kingston 2008 (Table 5.5) | Thermal Treatment Site 14 | Total VOCs | Remediation performance assessment. | TM | n/a | n/a |
| 58 | Kingston 2008 (Table 5.5) | Thermal Treatment Site 15 | Total VOCs | Remediation performance assessment. | TM | n/a | n/a |
| 59 | Kingston 2008 (Table 5.5) | Thermal Treatment Site 16 | Total VOCs | Remediation performance assessment. | TM | n/a | n/a |
| 60 | Kingston 2008 (Table 5.5) | Thermal Treatment Site 18 | Total VOCs | Remediation performance assessment. | TM | n/a | n/a |

| Case study ID | Reference | Site | Constituents | Use | Mass flux/discharge measurement method | Benefits of mass flux/mass discharge estimates | Method used to estimate specific discharge |
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| 61 | Troldborg et al. 2008 | Naerum Supply Well Field, Denmark | | Risk prioritization and forensic evaluation—A model decision support tool is applied to evaluate the site(s) causing contamination at a water supply well field. Estimated source mass discharge from multiple sites are input to a regional groundwater model to evaluate the relative risks and contribution to pollution at the water supply wells. | Groundwater flow and transport models | Prioritization of site cleanup is based on a quantitative assessment of relative risks to the downgradient receptors for multiple sites. This method also identified the sites most likely to be contributing to pollution at the water supply wells. | n/a |

## Table A-2. Mass flux/discharge methods and configuration

| Case study ID | Reference | Sample collection device for mass flux estimation | Method used to estimate specific discharge | # transects perpen-dicular to ground-water flow | Width of transect(s) (m) | # transects parallel to ground-water flow | Horizontal spacing along transects | # vertical wells on transects | Vertical well screen lengths (m) | Vertical interval between screens (m) |
|---|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Barbaro and Neupane 2006 | Direct-push rig used to vibrate drill rods to deepest sampling depth (12– 15 m bgs). Stainless steel well screen was then exposed to aquifer. Samples extracted with peristaltic pump using Teflon tubing. Then drill rod with exposed screen was pulled up to next sampling depth. Stability of drill string indicated that borehole collapsed below sampling depth, which “minimized cross contamination.” | Used a uniform specific discharge across both transects based on relatively uniform head distribution, lithology, and aquifer thickness in the vicinity of the two transects. | 7 | 130–380 | Not applicable (n/a) | 40–45 m | 3–4 | 1.2 | 2.4 |

| **Case study ID** | **Reference** | **Sample collection device for mass flux estimation** | **Method used to estimate specific discharge** | **# transects perpen-dicular to ground-water flow** | **Width of transect(s) (m)** | **# transects parallel to ground-water flow** | **Horizontal spacing along transects** | **# vertical wells on transects** | **Vertical well screen lengths (m)** | **Vertical interval between screens (m)** |
|---|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | Basu et al. 2009 | *Longitudinal transect along plume centerline:* PFMs installed in wells for time-integrated mass flux measurements for periods of 6 and 72 days. *Source and plume transects perpendicular to flow:* PFMs installed in wells for time-integrated mass flux measurement over 20 days. PFMs also deployed in a two-screen well nest during three flux sampling periods described above to measure seasonal variability in groundwater flux distribution. | PFMs were used to quantify specific discharge at approximately 0.3 m intervals over different periods of time to allow for assessment of seasonal fluctuations. | 2 | 13–40 | 1 | *Source transect:* 3–6 m spacing, p*lume transect:* 15–21 m spacing | Total of 2–3 screens in each well nest over two aquifers separated by a 1–2-m-thick clay confining unit | 2–6 | 2–5 |
| 9 | Bockelmann et al. 2003 | Groundwater samples from permanent wells | Not specified | 3 | n/a | n/a | 30–39 | 1 | n/a | n/a |
| 10 | Borden et al. 1997 | Groundwater samples from permanent wells | Not specified | 4 | n/a | n/a | 10–16 | 3 | 1.5 m well screens to provide flux-averaged concentra-tions across screen, for purpose of estimating mass discharge at the transect | 0–1 m on cross section parallel to ground-water flow |

| Case study ID | Reference | Sample collection device for mass flux estimation | Method used to estimate specific discharge | # transects perpen-dicular to ground-water flow | Width of transect(s) (m) | # transects parallel to ground-water flow | Horizontal spacing along transects | # vertical wells on transects | Vertical well screen lengths (m) | Vertical interval between screens (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| 11 | Brooks et al. 2008 | PFM sorbent was silver-impregnated granular activated carbon. PFMs were constructed to match the saturated thickness in each well, and multiple PFMs (1.5 m long) were deployed as needed in wells to cover well screen intervals longer than 1.5 m. Each PFM sock was divided into 25-cm- long segments separated using Norprene rubber washers to prevent vertical water flow in the PFM and section the device upon retrieval. | PFM, IPT | 1 | n/a | n/a | 3 | 1 | 3-m-long screens completed across the entire saturated thickness of the aquifer | n/a |
| 12 | Brooks et al. 2008 | PFM, IPT | 1 | n/a | 10 | 6.1 | 1 | 7.5 | n/a | |
| 19 | USEPA 2009 | Passive flux meters | PFM | 1 | 500 | n/a | 100 | 2 | n/a | n/a |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | Chapman and Parker 2005 | "Groundwater samples were collected using a peristaltic pump and dedicated sampling tubes. After purging at least two tubing volumes, the pump was shut off (maintaining the vacuum at surface), the sample tube withdrawn from the multilevel point, the pump reversed or suction released, and groundwater in the sample tube pumped or drained into a 25-mL VOA vial………………" | Specific discharge was applied as a uniform value along the transect because the variability of *K* in the mildly heterogeneous aquifer was much smaller than the variability in TCE concentrations. | 1 | 485 | n/a | Average: 24 m, minimum: 7 m, maximum: 47 m | 4–8 | 0.10–0.15 | 0.3–1 |

| Case study ID | Reference | Sample collection device for mass flux estimation | Method used to estimate specific discharge | # transects perpen-dicular to ground-water flow | Width of transect(s) (m) | # transects parallel to ground-water flow | Horizontal spacing along transects | # vertical wells on transects | Vertical well screen lengths (m) | Vertical interval between screens (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| 21 | Chapman et al. 2007 | | Specific discharge | 3 | 485–590 | n/a | Average | MLSs: 4– | MLSs: | MLSs: |
| | | was applied uniformly | | | | spacing on | 8, | 0.10–0.15, | 0.3–1, | |
| | | across all three | | | | transects | Waterloo | Waterloo | Waterloo | |
| | | transects. | | | | ranged | profiler: | profiler: | profiler: | |
| | | | | | | from 24 m | varied, | depth- | 0.15–0.6, | |
| | | | | | | upgradient | piezo- | discrete, | piezo- | |
| | | | | | | to 41 m | meters: 3– | piezometers: | meters: 3– | |
| | | | | | | down- | 5 | 0.10–0.15 | 4 screens | |
| | | | | | | gradient | | | over 3 m | |
| | | | | | | | | | thickness | |
| | | | | | | | | | or 3–5 | |
| | | | | | | | | | screens | |
| | | | | | | | | | over 2 m | |
| | | | | | | | | | thickness | |

| Case study ID | Reference | Sample collection device for mass flux estimation | Method used to estimate specific discharge | # transects perpen-dicular to ground-water flow | Width of transect(s) (m) | # transects parallel to ground-water flow | Horizontal spacing along transects | # vertical wells on transects | Vertical well screen lengths (m) | Vertical interval between screens (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| 22 | Chapman et al. 1997 | Groundwater samples from permanent wells | Specific discharge was applied as a uniform value along both transects. “Given the relatively small variation in flow velocity observed and the number of other unknowns, the assumption of a uniform velocity field is justified for these first-approximation estimates. The assumption of a uniform velocity field is not expected to significantly bias the conclusions drawn from these mass flux estimates, since the conclusions are based on differences between Fences 1 and 2.” | 3 | 2 | n/a | 0.3 | 6 | n/a | 0.15 |
| 28 | Guilbeault, Parker, and Cherry 2005 | Waterloo profiler (temporary) and permanent multilevel wells | Specific discharge was applied as a uniform value along the transect because the variability of *K* in the mildly heterogeneous aquifer was much smaller than the variability in concentrations. | 1 | 40 | n/a | Average of 3 m | Average of 25 vertical samples per profile location | Depth-discrete | Varies, minimum spacing of 0.15 |

| Case study ID | Reference | Sample collection device for mass flux estimation | Method used to estimate specific discharge | # transects perpen-dicular to ground-water flow | Width of transect(s) (m) | # transects parallel to ground-water flow | Horizontal spacing along transects | # vertical wells on transects | Vertical well screen lengths (m) | Vertical interval between screens (m) |
|---|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | Guilbeault, Parker, and Cherry 2005 | Waterloo profiler (temporary) and permanent multilevel wells | Specific discharge was applied as a uniform value along the transect because the variability of *K* in the mildly heterogeneous aquifer was much smaller than the variability in concentrations. | 1 | 72 | n/a | Average of 5 m | Average of 10 vertical samples per profile location | Depth-discrete | Varies, minimum spacing of 0.15 m |
| 31 | Guilbeault, Parker, and Cherry 2005 | Waterloo profiler (temporary) | Used two specific discharge zones: one above and one below a clay layer. The hydraulic conductivity of the clay layer is orders of magnitude less than the sand layers, so the clay layer was ignored in the mass flux and mass discharge calculations, and the thickness of the clay was subtracted in the areal elements where it was present. | 1 | 27 | n/a | Average of 2 m | Average of 12 vertical samples per profile location | Depth-discrete | Varies, minimum spacing of 0.15 m |
| 32 | D’Affonseca et al. 2008 | Groundwater samples from permanent wells | Specific discharge was applied uniformly across the transect. | 1 | 60 | n/a | 30 | 3 | 3.7 | 9 |
| 39 | Kao and Wang 2001 | Groundwater samples from permanent wells | Specific discharge was applied uniformly across all transects. | 3 | 32 | n/a | 8 | 4 | 0.6 | 1.2 |

| Case study ID | Reference | Sample collection device for mass flux estimation | Method used to estimate specific discharge | # transects perpen-dicular to ground-water flow | Width of transect(s) (m) | # transects parallel to ground-water flow | Horizontal spacing along transects | # vertical wells on transects | Vertical well screen lengths (m) | Vertical interval between screens (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| 43 | Semprini et al. 1995; Weaver, Wilson, and Kampbell 1997 | Auger with 5 ft well screen, collected samples at continuous 5 ft intervals | Not specified | 4 | 115–200 | 1 | 19–50 | Various | 1.5 | 0 (contin-uous 5 ft sample intervals using a slotted auger) |

**Table A-3. Mass flux/discharge estimates pre- and post-treatment**

| Case study ID | Constituents | Treatment process | Pretreatment mass discharge (kg/y) | Post-treatment mass discharge (kg/y) | % reduction pre vs. post |
|---|---|---|---|---|---|
| 41 | Nitrate | | Nitrate: 160,000–190,000 | Not applicable (n/a) | n/a |
| 8 | BTEX, PAH | Natural attenuation between transects due to | Chloride: 38,832 | Chloride: 37,588 | Chloride: 3% |
| | | biodegradation. Pre- and post-treatment represent | Total BTEX: 0.7 | Total BTEX: 0.04 | Total BTEX: 94% |
| | | mass discharge values from transects at distances | Total PAH: 12 | Total PAH: 5 | Total PAH: 58% |
| | | of approximately 140 m (pretreatment) and 280 m | $NO_3$: 88 | $NO_3$: 274 | $NO_3$: –211% |
| | | (post-treatment) downgradient from the source | Mn(II): 254 | Mn(II): 161 | Mn(II): 37% |
| | | zone. | Fe(II): 770 | Fe(II): 1,142 | Fe(II): –48% |
| | | | $SO_4$: 79,351 | $SO_4$: 77,468 | $SO_4$: 2% |
| 51 | Total VOCs | Thermal treatment. | 680 | 82 | 88% |
| 37 | TCE | Natural attenuation via biodegradation and | *Gains:* | n/a | n/a |
| | | volatilization. | Desorption: 550 | | |
| | | | Infiltration: <1 | | |
| | | | DNAPL dissolution: unknown | | |
| | | | *Losses:* | | |
| | | | Biodegradation: 360 | | |
| | | | Discharge to surface water: 50 | | |

| | | | | | |
|---|---|---|---|---|---|
| | | | Volatilization: 50 | | |
| | | | Dispersion: <1 | | |
| | | | Sorption: <1 | | |

| **Case study ID** | **Constituents** | **Treatment process** | **Pretreatment mass discharge (kg/y)** | **Post-treatment mass discharge (kg/y)** | **% reduction pre vs. post** |
|---|---|---|---|---|---|
| 20 | TCE | A sheet pile enclosure was installed around the DNAPL source zone. Mass discharge was estimated across the transect at a distance of 280 m downgradient from the source zone six years after source isolation. The investigators estimated that the mass discharge prior to source zone isolation was 10 times higher than the post-isolation mass discharge, based on the observed magnitude of changes in TCE concentrations in monitoring wells over this time period. | 360 (estimated) | 36 (measured) | 90% (Complete restoration was not obtained due to back- diffusion from the silt aquitard to the aqueous plume outside the isolated source zone.) |
| 43 | Total ethenes | Natural attenuation via biodegradation. Pre- and post-treatment mass discharge values represent calculations for transects situated 130 and 855 m downgradient of the source zone (i.e., separation distance of 745 m over which natural attenuation was evaluated). | TCE: 120 DCE: 130 Vinyl chloride: 17 Ethene: 7.6 Total ethenes: 280 Methane: 66 Chloride: 1,500 | TCE: 0.95 DCE: 10 Vinyl chloride: 1.7 Ethene: 0.16 Total ethenes: 13 Methane: 47 Chloride: 5,300 | TCE: 99.2% DCE: 92% Vinyl chloride: 90% Ethene: 98% Total ethenes: 95% Methane: 29% Chloride: –250% |
| 12 | TCE | Thermal treatment and multiphase extraction. | PFM: 240 MIPT: 170 TM: 220 Average: 210 | PFM: 0.84 MIPT: 0.55 TM: 0.69 Average: 0.69 | PFM: 99.6% MIPT: 99.7% TM: 99.7% Average: 99.7% |
| 4 | TCE | Natural attenuation between transects due to reductive dechlorination. Pre- and post-treatment represent mass discharge values from transects at distances of approximately. 0 m (pretreatment) and 31 m (post-treatment) downgradient from the source zone. | MW8-99 (x = 0): 201 MW2-98 (x = 12m): 133 | MW-13I (x = 31m): 100 | 50% over 31 m downgradient from source zone |
| 32 | Naphthalene | n/a | 176 | n/a | n/a |
| 3 | Total chlorinated organics | n/a | 100 | n/a | n/a |

| | | | | | |
|---|---|---|---|---|---|
| 12 | cis-1,2-DCE | Thermal treatment and multiphase extraction. | PFM: 49 MIPT: 82 TM: 92 Average: 74 | PFM: 1.4 MIPT: 0 TM: 0 Average: 0.47 | PFM: 97% MIPT: 100% TM: 100% Average: 99.4% |

| Case study ID | Constituents | Treatment process | Pretreatment mass discharge (kg/y) | Post-treatment mass discharge (kg/y) | % reduction pre vs. post |
|---|---|---|---|---|---|
| 46 | MtBE | Natural attenuation via biodegradation. Pre- and post-treatment mass discharge values represent the calculated flux at transects situated approximately 1000 and 4400 feet downgradient of the source zone. | 91 | 4 | 95.6% |
| 48 | Total VOCs | Thermal treatment. | 60 | 4.9/21 | 65%/92% |
| 24 | MtBE | n/a | 55 | n/a | n/a |
| 47 | Total VOCs | Thermal treatment. | 52 | 0.19 | 99.63% |
| 49 | Total VOCs | Thermal treatment. | 49 | 0.13 | 99.73% |
| 28 | TCE | n/a | 31–45 | n/a | n/a |
| 21 | TCE, cis-1,2-DCE | Natural attenuation in via biodegradation and discharge to the on-site pond and drainage creeks where dilution and volatilization occurred. Mass discharge values represent Transects 1 and 3, separated by a distance of 420 m and a travel time of several years. | TCE: 36 cis-1,2-DCE: 0.84 | TCE: 0.07 cis-1,2-DCE: 0.11 | TCE: 99.80% cis-1,2-DCE: 86.96% |
| 50 | Total VOCs | Thermal treatment. | 32 | 2.1 | 93% |
| 11 | TCE | Surfactant-enhanced aquifer restoration (SEAR). | PFM: 28 MIPT: 28 TM: 28 Average: 28 | PFM: 2.2 MIPT: 1.4 TM: 2.6 Average: 2.1 | PFM: 92% MIPT: 95% TM: 91% Average: 93% |
| 39 | BTEX | Natural attenuation via biodegradation. Mass discharge values for pre- and post-treatment represent transects at distances of 8 and 88 m downgradient of the source zone. | Benzene: 11 Toluene: 5.2 Ethylbenzene: 1.5 m- and p-xylene: 1.9 o-xylene: 1.7 1,2,4-trimethylbenzene (TMB): 1.1 Total BTEX: 22.3 | Benzene: 1.6 Toluene: 0.064 Ethylbenzene: 0.29 m- and p-xylene: 0.16 o-xylene: 0.080 1,2,4-TMB: 0.56 Total BTEX: 2.8 | Benzene: 85% Toluene: 98.8% Ethylbenzene: 81% m- and p-xylene: 92% o-xylene: 95% 1,2,4-TMB: 48% Total BTEX: 88% |
| 30 | PCE | n/a | 20.5 | n/a | n/a |
| 31 | PCE | n/a | 15 | n/a | n/a |
| 25 | cis-1,2-DCE | n/a | 11 | n/a | n/a |
| 53 | Total VOCs | Thermal treatment. | 9.4 | 0.027 | 99.71% |

| | | | | | |
|---|---|---|---|---|---|
| 59 | Total VOCs | Thermal treatment, | 9.3 | 0.017 | 99.82% |
| 6 | PCE, TCE | n/a | PCE: 8.2 TCE: 0.82 | n/a | n/a |
| 52 | Total VOCs | Thermal treatment. | 4.6 | 0.073 | 98.41% |
| 27 | MtBE | n/a | 0.44–2.5 | n/a | n/a |

| Case study ID | Constituents | Treatment process | Pretreatment mass discharge (kg/y) | Post-treatment mass discharge (kg/y) | % reduction pre vs. post |
|---|---|---|---|---|---|
| 5 | TCE | n/a | Source: 1.1 Plume (x = 175 m): 2.1 | n/a | n/a |
| 54 | Total VOCs | Thermal treatment. | 1.7 | 0.6 | 65% |
| 26 | MtBE | n/a | 1.5 | n/a | n/a |
| 11 | cis-1,2-DCE | SEAR | DCE below level of quantification | PFM: 1.1 MIPT: 0.73 TM: 1.4 Average: 1.1 | n/a |
| 60 | Total VOCs | Thermal treatment. | 1.3 | 2.8 | –115% |
| 58 | Total VOCs | Thermal treatment. | 1.2 | 0.054 | 96% |
| 2 | VOCs | Natural attenuation between transects (possibly oxidation of cis-DCE under iron-reducing conditions). Pre- and post-treatment represent mass discharge values from transects at 91 m (pretreatment) and 335 m (post-treatment) downgradient from the source zone. | PCE: 0.19 TCE: 0.35 cis-DCE: 0.20 | PCE: 0.20 TCE: 0.38 cis-DCE: 0.07 | PCE: n/a TCE: n/a cis-DCE: 65% |
| 44 | TCE, PCE | In situ chemical oxidation with potassium permanganate recycling for 485 days followed by 180 days of enhanced flushing in the source zone via groundwater extraction. | TCE: 0.31 PCE: 0.32 | TCE: 0.0026 PCE: 0.036 | TCE: 99.2% PCE: 89% |
| 40 | MtBE | Natural attenuation via biodegradation. Mass discharge values for pre- and post-treatment represent transects separated by less than 6.5 m adjacent to the creek. | 0.51 | 0.019 | 96% |
| 55 | Total VOCs | Thermal treatment. | 0.40 | 0.03 | 93% |
| 57 | Total VOCs | Thermal treatment. | 0.097 | 0.061 | 37% |
| 56 | Total VOCs | Thermal treatment. | 0.019 | $1.80 \times 10^{-7}$ | 100.00% |

| | | | | | |
|---|---|---|---|---|---|
| 29 | TCE | n/a | n/a | n/a | 90%–99% (Complete restoration was not obtained due to back-diffusion from the silt and clay lenses to the aqueous plume outside the contained source zone.) |

| Case study ID | Constituents | Treatment process | Pretreatment mass discharge (kg/y) | Post-treatment mass discharge (kg/y) | % reduction pre vs. post |
|---|---|---|---|---|---|
| 10 | MtBE, BTEX | Natural attenuation via biodegradation and volatilization. Mass discharge reduction efficiency volatilization. Mass discharge reduction efficiency represent the difference in mass discharge between the source zone and a transect located 88 m downgradient of the source zone. | n/a | n/a | Toluene: >99%<br>Ethylbenzene: >99%<br>m- and p-xylene: >99%<br>o-xylene: 89%<br>Benzene: 87%<br>MtBE: 74% |

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