Table A-5.A. Multi-phase extraction

Technology	Fluid recovery (multi-phase extraction, vacuum-enhanced dual pump)	MPE technology employs vacuum-enhancement and sometimes up to two dedicated pumps to extract liquids (LNAPL through a pneumatic pump and groundwater typically through a submersible pump) from an extraction well simultaneously. It is also known as total fluids extraction or dual-phase extraction. See illustrations for potential configurations. MPE single-pump technology employs a single pump to extract fluids (e.g., a downhole pneumatic pump that removes groundwater and LNAPL, or a high-vacuum stinger tube to remove groundwater, LNAPL, and vapor). MPE will emulsify LNAPL and requires LNAPL/water separation. MPE using two pumps is more applicable to cases where LNAPL is recovered at a rate sufficient to require the continuous operation of a dedicated LNAPL pump or where minimization of emulsification is desired and cycling of the LNAPL recovery pump is feasible. The cycling of the LNAPL pump allows LNAPL exhibiting lower recovery rates to build up substantial LNAPL thickness in the well, which can then be pumped off during a pump cycle. The vapor and groundwater extraction induces additional drawdown into the well over and beyond what skimming alone can induce. This additional drawdown in turn results in increased LNAPL recovery. Because each fluid can be recovered by an exclusive pump, emulsification of LNAPL is limited to that which may occur in the formation as a result of LNAPL weathering and dissolved-phase impacts within groundwater.	
Remediation process	Physical mass recovery	Yes	Removes mobile LNAPL at the groundwater surface.
	Phase change	Yes (secondary)	Vacuum induces volatilization, which changes the LNAPL constituent composition.
	In situ destruction	No	N/A
	Stabilization/ binding	No	N/A
Objective applicability	LNAPL saturation	Yes	LNAPL recovery reduces LNAPL saturation toward residual saturation; does not typically improve dissolved-phase concentrations due to residual LNAPL mass left behind.
		Example performance metrics	Direct analysis of soil to indicate changes in formation LNAPL saturations, LNAPL transmissivity/LNAPL conductivity, LNAPL/water ratio, asymptotic recovery.
	LNAPL composition	Yes	
		Example performance metrics	Removal of VOC concentrations in extracted vapor to a concentration end point; vapor-phase or dissolved-phase concentrations meet regulatory standard at compliance point; reduced volatile or soluble LNAPL constituent mass fraction.
Applicable LNAPL type	All LNAPL types; however, lower-viscosity LNAPL (0.5–1.5 cP) is much more recoverable than high-viscosity LNAPL (>6 cP).		
Geologic factors	Unsaturated zone	Permeability	More effective in higher-permeability materials where vapor flow is easier but can also be applied in lower-permeability materials through the use of stronger vacuum.
		Grain size	More applicable to sands and gravels but can also be applied in silts and clays.
		Heterogeneity	In heterogeneous soils, vacuum extracts LNAPL from preferential pathways, possibly short-circuiting remediation coverage, but LNAPL is often also in preferential pathways.
		Consolidation	Not typically a factor.
	Saturated zone	Permeability	Soil permeability is proportional to LNAPL recovery rate; higher LNAPL recovery and saturation reduction in higher-permeability soils. Permeability affects the ROI of a recovery well. A low-permeability setting maximizes drawdown, exposing the LNAPL smear zone for LNAPL recovery via vapor extraction, and reduced groundwater recovery minimizes groundwater treatment costs. The higher the permeability (or conductivity), the greater the water production will be to dewater the smear zone.
		Grain size	LNAPL in fine-grained soils may not be feasible to remove by MPE.

		Heterogeneity	Moderately sensitive to heterogeneity; affects the ROI of a recovery well. Focuses on LNAPL at the groundwater surface and LNAPL that can drain with a depressed groundwater surface. MPE is not applicable to thin, perched LNAPL layers, from which drawdown is limited; moderately applicable to unconfined LNAPL conditions; however, in low-permeability settings, smearing could occur due to excessive drawdowns. Excellent applicability for confined LNAPL since little to no additional smearing will occur. Well screen location and submersible pump depth can help overcome heterogeneities.
		Consolidation	Not typically a factor.
Cost	Per well, the capital costs of MPE dual-pump wells are higher than skimming. However, fewer wells are required to achieve the same goal within the same time frame as skimming. The costs of aboveground oil/water separation should be considered over and above the dual-pump aboveground fluid treatment.		