**Table 1 • Evaluation of Process Options**
Feasibility Study
Pall Life Sciences, Ann Arbor, Michigan

| General Response Actions and Process Options | Description | Effectiveness | Engineering Practices | | | Retain as Possible Alternative Component |
|---|---|---|---|---|---|---|
| | | | Feasibility | Applicability | Reliability | |
| **NO ACTION** | None | Does not directly reduce contaminant mass or concentration. | Not pertinent. | Unacceptable to regulators and the public. | Not pertinent. | No |
| **MONITORED NATURAL ATTENUATION** | Contaminant levels and parameters, indicative of contaminant degradation through natural chemical, physical, and biological processes, are monitored. | Contaminant mass and concentration reduction is long-term. | 1) Readily implemented; some monitoring wells exist. 2) Biodegradation rate unknown. All other attenuation process rates can be measured or predicted. | Applicable | Natural attenuation will proceed without fail though rates may be slow. | Yes |
| **Institutional Controls** | | | | | | |
| Deed Restriction | Restrictions prevent access to the subsurface and/or use of groundwater. | Prevents access to impacted media. Does not directly reduce contaminant mass or concentration. | Readily enacted for Pall owned parcels; expensive or impossible for non Pall owned parcels. | Applicable | Existence of deed restrictions may be forgotten. | Yes |
| City Ordinance | Ordinance prohibits access to the subsurface and/or use of groundwater. | Prevents access to impacted media if enforced by local government. Does not directly reduce contaminant mass or concentration. | Action by local governmental units required. | Applicable | Enforcement may become low priority over time. | Yes |
| **GROUNDWATER RECOVERY** | | | | | | |
| Vertical Well | Groundwater is pumped from vertical wells. | Well-positioned screens maximize plume control and contaminant. | 1) Well suited to sand and gravel geology. 2) Access to well locations may be problematic. 3) Construction methods are well proven. 4) Qualified contractors are readily available. | Applicable | Well maintenance involves chemical treatment of wells. | Yes |
| Horizontal Well | Groundwater is pumped from a long well screen (>100' long) positioned along the long axis of the plume. | Well-positioned screens maximize contaminant capture. | 1) Well suited to sand and gravel geology. 2) Access to well locations may be problematic. 3) Construction methods are well proven. 4) Specialty contractors are available. | Applicable | Well maintenance is more difficult and expensive than for vertical wells. | No |
| **Ex-Situ Groundwater Treatment** | | | | | | |
| Ultra-Violet Light & Hydrogen Peroxide Oxidation | Water, with dissolved contaminants, is passed near a UV-lamp. The light energy excites the electrons of one or more atoms of the contaminant molecule, causing bonds to break. Dissolved chloride ions, carbon dioxide, water, and/or smaller organic molecules are formed. | Can reduce 1,4-dioxane to concentrations suitable for discharge into surfacewater or groundwater. | 1) Transport and storage of two strong oxidizers. 2) High electrical demand, sufficient service may not be available at some locations. | Regulatory agencies accept chemical oxidation with proper operational controls and monitoring. Significant chemical and electrical demands make use of this technology at remote sites very difficult. | 1) Above grade treatment is controllable and verifiable. 2) Inspection and maintenance of equipment is routine. | Yes |
| Ozone & Hydrogen Peroxide Oxidation | A combination of powerful oxidants (ozone and hydroxyl radicals) is formed. The addition of hydrogen peroxide increases the production of hydroxyl radicals. | Can reduce 1,4-dioxane to concentrations suitable for discharge into surfacewater or groundwater. | 1) Transportation and storage of one strong oxidizer. 2) Low to medium electrical demand 3) bromate generation is a potential concern. | Regulatory agencies accept chemical oxidation with proper operational controls and monitoring. Generation of bromate may not allow for low level 1,4-dioxane treatment and groundwater injection. | 1) Above grade treatment is controllable and verifiable. 2) Inspection and maintenance of equipment is routine 3) has not been tested long-term. | Yes |
| **Treatment Location** | | | | | | |
| Pall, Wagner Road | Treatment of extracted groundwater occurs at Pall-Wagner Road facility. | The effectiveness of treatment is not impacted by the location. | 1) Buildings and storage facilities can be large, improving vibration, ventilation, and heat control during system operations versus trailers or small buildings. 2) Reagents could be received and stored in larger quantities. | Applicable | 1) Movement of large quantities of untreated water over long distances increases the likelihood of secondary release. 2) Vibration control, ventilation, and cooling will be optimized at Wagner Road. | Yes |
| Maple Road Area (East of I-94) | Treatment of extracted groundwater occurs on Pall or Non-Pall owned property in the Maple Road area. | The effectiveness of treatment is not impacted by the location. | 1) Space constrains building or trailer size, thus making it more difficult to operate. Increased frequency of oxidant deliveries due to smaller space. 2) Electrical supplies may be limited. 3) Large quantities of reagents must be received and stored in a commercial or residential area creating health and safety issues. 4) Minimizes movement of untreated water and the probability of secondary release. | Applicable | Vibration control, ventilation, and cooling will be more difficult than at Wagner Road thus making the system less reliable. Staff would not be stationed at system thus relying on remote monitoring and response to system upsets. | Yes |
| Huron River | Treatment would be at a suitable location near to the Huron River. | The effectiveness of treatment is not impacted by the location. | 1) Buildings and storage facilities can be large, improving vibration, ventilation, and heat control during system operations versus trailers or small buildings. 2) Reagents could be received and stored in larger quantities. | Applicable | Not pertinent. | No (except for contingency situation) |
| **Transfer Options** | | | | | | |
| New pipeline to Pall Facility | Extracted groundwater is pumped through a new pipeline to the Wagner Road facility for treatment. | Not pertinent. | 1) Will likely require a court order for access 2) Subsurface transmission minimizes interference with surface activities. 3) Access to critical construction locations is likely to be problematic. | Applicable | A properly engineered pipeline is reliable. The pipeline will require constant maintenance due to encrustation. Construction specifications will exceed anticipated project life. | Yes |
| New Pipeline to Maple Road Area | Extracted water is treated and pumped through pipelines to injection wells. | Not pertinent. | 1) Will likely require a court order for access 2) Subsurface transmission minimizes interference with surface activities. 3) Access to critical construction locations is likely to be problematic. | Applicable | A properly engineered pipeline is reliable. The pipeline will require constant maintenance due to encrustation. Construction specifications will exceed anticipated project life. | Yes |
| Tanker truck | Extracted groundwater is shipped by tanker truck to the Wagner Road facility for treatment. | Not pertinent. | Extremely high number of trucks required increases probability of traffic accidents and road wear. | Applicable | The probability of a traffic accident given the large number of trucks is likely higher than the probability of leaks from a pipeline. | No |
| Existing Montgomery Well Pipeline | The existing Montgomery Well pipeline is used to transfer water to the Huron River for discharge. | Not pertinent. | The existing pipeline is fully utilized. | Applicable | Pipeline is fully utilized. | No (Pipeline is fully utilized.) |

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| General Response Actions and Process Options | Description | Effectiveness | Engineering Practices | | | Retain as Possible Alternative Component |
|---|---|---|---|---|---|---|
| | | | Feasibility | Applicability | Reliability | |
| **Treated Water Discharge** | | | | | | |
| Above Grade Discharge | | | | | | |
| County Drain (Allen Drain) | Treated water is discharged to the County Drain (Allen Drain) under NPDES permit. | Not pertinent. | Discharge point is nearby. | Prohibited by local government. | A properly engineered discharge line will be reliable. Construction specifications will exceed anticipated project life. | No (unacceptable to local government) |
| Sanitary Sewer (Publicly Owned Treatment Works) | Treated water is discharged to the Sanitary Sewer (Publicly Owned Treatment Works) under permit. | Not pertinent. | Discharge point is nearby. Capacity may not be available to handle discharge volume. | Prohibited by local government. | A properly engineered discharge line will be reliable. Construction specifications will exceed anticipated project life. | No (unacceptable to local government) |
| Huron River | Treated water is discharged to the Huron River under NPDES permit. | Not pertinent. | Huron River flow far exceeds treatment stream flow. 2) Pipeline construction to the Huron River will be disruptive and access will be very difficult. | Applicable | A properly engineered pipeline is reliable. The pipeline will require constant maintenance due to encrustation. Construction specifications will exceed anticipated project life. | Yes |
| Honey Creek (Tributary) | Treated water is discharged to Honey Creek under an NPDES permit. | Not pertinent. | PLS is currently permitted to discharge upto 1,300 gpm into Honey Creek. This limit has been contested for various reasons. This discharge rate could be be increased, which would require a permit modification and associated uncertainties. Future reductions in the flow contribution from other systems may allow for Unit E water to be discharged without an increase in the current discharge limit. | Applicable | A properly engineered discharge line will be reliable. Construction specifications will exceed anticipated project life. | Yes |
| First Sister Lake (Honey Creek) | Treated water is discharged to First Sister Lake under an NPDES permit. First Sister Lake is hydraulically connected to the Honey Creek. | Not pertinent. | PLS is currently permitted to discharge upto 1,300 gpm into Honey Creek. This limit has been contested for various reasons. This discharge rate could be be increased, which would require a permit modification and associated uncertainties. Future reductions in the flow contribution from other systems may allow for Unit E water to be discharged without an increase in the current discharge limit. Discharge into First Sister Lake is complicated due to access (the lake area is a City of Ann Arbor park), and potential ecological uncertainties changes in lake area hydrological conditions. | Applicable | A properly engineered discharge line will be reliable. Construction specifications will exceed anticipated project life. | No |
| Below Grade Discharge | | | | | | |
| Unit E, >85 ug/L of 1,4-dioxane | Treated water injected into Unit E, inside 85 ug/L plume under MDEQ Part 22 permit | Discharging within the plume may interfere with the ability to capture the plume. | Access to critical, off-Pall construction locations is likely to be problematic. | Applicable Injection back into the plume, especially in areas toward the leading edge, may not allow for containment of the plume. | Injection wells are prone to plugging. Maintenance frequencies are often high in order to keep the wells operating at original design capacities. | Yes |
| Unit E, >1 and <85 ug/L of 1,4-dioxane | Treated water injected into Unit E, in a portion of the plume where 1,4-dioxane concentrations are between 1 and 85 ug/L plume under MDEQ Part 22 permit. | Discharging within the plume may interfere with the ability to capture the plume. | Access to critical, off-Pall construction locations is likely to be problematic. | Applicable | Injection wells are prone to plugging. Maintenance frequencies are often high in order to keep the wells operating at original design capacities. | Yes |
| Unit E, <1 ug/L of 1,4-dioxane. | Treated water injected into Unit E, in an area of the plume where 1,4-dioxane concentrations are below 1 ug/L under MDEQ Part 22 permit | Not pertinent. | Access to critical, off-Pall construction locations will be problematic. | Applicable | Injection wells are prone to plugging. Maintenance frequencies are often high in order to keep the wells operating at original design capacities. | Yes |
| **Untreated Water Discharge Options** | Treated water is injected into the Mt. Simon, a deep (>5,000 feet below grade) geologic formation, under US EPA UIC permit. | | | | | |
| Pall, Wagner Road | The deep injection well would be at the Pall, Wagner Road facility. | Not pertinent. | Injection capacity is unknown | Applicable | Injection wells are prone to plugging. Maintenance frequencies are often high in order to keep the wells operating at original design capacities. | Yes |
| Pall, Maple Village Area | The deep injection well would be on Pall-owned property in or near Maple Village. | Not pertinent. | Injection capacity is unknown. | Applicable | Injection wells are prone to plugging. Maintenance frequencies are often high in order to keep the wells operating at original design capacities. | No |
| **IN-SITU GROUNDWATER TREATMENT (with insitu chemical oxidation technologies)** | | | 1) Oxygen or carbon dioxide released during contaminant destruction can reduce aquifer hydraulic conductivity. 2) Iron, manganese and other inorganics can react with (consume) oxidant. Inorganics may precipitate as a result, reducing the efficiency of treatment equipment and groundwater flow in the aquifer. Application over a large scale (such as the volume of the Unit E plume) may not be practical. Not capable of containing the plume. | Applicable | Changes in contaminant levels will require frequent monitoring of treatment results and adjustment of treatment system operations. | |
| Recirculating Ozone Wells | Oxidants are released into a large diameter treatment well which has two screened sections, one near the lower end and another, higher but beneath the water table. Water circulation is induced in the well. Water flows one direction in the well, the opposite in the aquifer, which spreads the oxidant and draws untreated water into the treatment well. | Ability to degrade 1,4-dioxane to below Part 201 goals depends on oxidant used and dosage. | 1) Feasible as treatment zone technology 2) Numerous remedial well locations required due to small radius of influence of each. Property access at critical locations may be problematic. 3) Transport, storage, and mixing of strong oxidants required. | Applicable to situation within regulations. | 1) System specifications will protect against potential damage from reagents or oxidants. 2) Precipitation of inorganics within or on the walls of the treatment well must be addressed or system performance and capacity will decline. | No (Lack of influence and increased maintenance relative to methods that oxidize contaminants in the aquifer. |
| Fenton's reagent (hydrogen peroxide and ferrous iron) | Hydrogen peroxide and dissolved iron are injected into the aquifer separately. They react to form hydroxyl radicals, a powerful oxidant. | Can likely reduce 1,4-dioxane to below Part 201 goals. | 1) Feasible as treatment zone technologies 2) Numerous injection wells needed due to short life span of hyroxyl radicals, which limits migration distance. Access to critical locations may be problematic. 3) Groundwater pH must be lowered to | Applicable to situation within regulations. | 1) System specifications will protect against potential damage from reagents or oxidants. 2) Precipitation of inorganics near the treatment wells may reduce system performance. 3) Mixing and injection of strong oxidants is inherently difficult and | No ( Handling and storage or large quantities of strong oxidants in congested areas.) |
| Ozone-Rich Water Injection | Ozone gas is sparged or reverse-air-stripped into water. The ozone-enriched water is then injected below grade through a well screen within the contaminant plume. | Can likely reduce 1,4-dioxane to below Part 201 goals. | 1) Feasible as treatment zone. 2) Spacing of wells greatest in this option, due to tendency of injected ozone-rich water to remain near the depth of injection. 3) Handling of large quantities of water rather than gas is more difficult and cost than with ozone sparging. 4) Specialized construction materials, able to withstand ozone, are available. 5) Bromate production a concern. | Not applicable due to scale of plume. | 1) System specifications will protect against potential damage from reagents or oxidants. 2) Precipitation of inorganics near the treatment wells may reduce system performance. 3) Above grade equipment will be more complex than for ozone sparging; therefore, relatively less reliable. | No (More complex than ozone sparging.) |

**Table 1 • Evaluation of Process Options**

Feasibility Study

Pall Life Sciences, Ann Arbor, Michigan

| General Response Actions and Process Options | Description | Effectiveness | Engineering Practices | | | Retain as Possible Alternative Component |
|---|---|---|---|---|---|---|
| | | | Feasibility | Applicability | Reliability | |
| Ozone Sparging | Oxygen gas is passed through an ozone generator. The gas stream is then injected into the groundwater. As the air rises, ozone, which is 10-15 times more soluble that oxygen, dissolves into the groundwater and destroys dissolved contaminants directly, or forms hydroxyl radicals that destroy the contaminants more quickly. | Can reduce 1,4-dioxane to below Part 201 goals. | 1) Feasible as a treatment zone technology 2) Oxidant risk low because oxygen and ozone is generated on-site and distributed with minimal storage 3) Bromate production above USEPA MCL is a concern. | Not applicable due to scale of plume. | 1) System specifications will protect against potential damage from reagents or oxidants. 2) Precipitation of inorganics near the treatment wells may reduce system performance. | No |
| Ozone Sparging and Hydrogen Peroxide | Ozone gas is sparged or reverse-air-stripped into water. The ozone-enriched water is then injected below grade through a well screen within the contaminant plume. Hydrogen peroxide is added to enhance the reaction and reduce bromate formation. | Can reduce 1,4-dioxane to below Part 201 goals. | Potentially feasible as a treatment zone technology. | Not applicable due to scale of plume. | 1) System specifications will protect against potential damage from reagents or oxidants. 2) Precipitation of inorganics near the treatment wells may reduce system performance. | No |
| Hydrogen Peroxide Injection | Hydrogen peroxide is injected into the aquifer. Bromate is not produced in the reaction. | Uncertain if technology can reduce 1,4-dioxane to below Part 201 goals. | Potentially feasible as a treatment zone technology. | Unknown | 1) System specifications will protect against potential damage from reagents or oxidants. 2) Precipitation of inorganics near the treatment wells may reduce system performance. | No |

**Table 2 • Initial Screening of Draft Remedial Alternatives**
Feasibility Study
Pall Life Sciences, Ann Arbor, Michigan

| | | | | | | Treatment Location | | | | Treatment Method | | | Discharge Point: Huron River | Discharge Point: Honey Creek | Discharge Point: Unit E (GW Inj.) | | | Discharge Point: Mt. Simon Formation (or other) | Initial Screening Criteria: Effect. | Initial Screening Criteria: Engineering Practices | | | Initial Screening Criteria: Cost | | Initial Screening Criteria: Time | Other Considerations | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alternative | No Action | Monitored Natural Attenuation | Institutional Controls (City Ordinance) | Groundwater Pumping | Pipeline to Wagner Road Facility | Pall, Wagner Road Facility | Pall/Non-Pall Maple Road Area | Downgradient of Current Plume Boundary (Contingency) | Near Huron River | Ozone Oxidation | Ozone and Hydrogen Peroxide | Ultra-violet Light & Hydrogen Peroxide | Huron River | Honey Creek | >85 ug/L | >1 <85 ug/L | Non-detect | Pall, Wagner Road Facility | Effectiveness | Feasibility for Location and Condition of Release | Applicability to Problem | Reliability | Cost (Capital) | Cost (O&M) | Time | Other Considerations | Retain for Detailed Analysis? |
| 2 | | X | X | | | | | | | | | | | | | | | | M | H | H | H | Low | Low | L | | Y |
| 3a-1 | | | | X | X | X | | | | | X | | X | | | | | | H | M | H | H | High | Mod. | M | | Y |
| 3a-2 | | | | X | X | X | | | | | | X | X | | | | | | H | M | H | H | High | Very High | M | | Y |
| 3b-1 | | | | X | X | X | | | | | X | | | | X | | | | L | L | L | M | High | Mod. | M | Would distort and/or dilute plume; extend duration. | N |
| 3b-2 | | | | X | X | X | | | | | | X | | | X | | | | L | L | L | M | High | Very High | M | | N |
| 3c-1 | | | | X | X | X | | | | | X | | | | | X | | | M | M | M | M | High | High | M | | Y |
| 3c-2 | | | | X | X | X | | | | | | X | | | | X | | | M | M | M | M | High | Very High | M | | Y |
| 3d-1 | | | | X | X | X | | | | | X | | | | | | X | | H | L | L | L | High | High | M | Routine Treatment to Non-Detect is Uncertain | N |
| 3d-2 | | | | X | X | X | | | | | | X | | | | | X | | L | L | L | L | High | Very High | M | | N |
| 3e-1' | | | | X | X | X | | | | | X | | | X | | | | | H | M | H | H | High | Mod. | M | | Y |
| 3e-2' | | | | X | X | X | | | | | | X | | X | | | | | M | H | H | H | High | Very High | M | | Y |
| 4a | | | | X | | | X | | | | X | | X | | | | | | H | M | H | H | High | Mod. | M | | Y |
| 4b | | | | X | | | X | | | | X | | | | X | | | | L | L | L | M | High | High | M | Would distort and/or dilute plume; extend duration. | N |
| 4c | | | | X | | | X | | | | X | | | | | X | | | H | M | H | M | High | High | M | | Y |
| 4d | | | | X | | | X | | | | X | | | | | | X | | H | L | M | L | High | Mod. | M | Routine treatment to Non-Detect is Uncertain | N |
| 5 | | | | X | | X | | | | | | | | | | | | X | H | M | M | M | High | Mod. | M | | Y |
| 6 | | | | X | | | | | X | | X | | X | | | | | | H | H | H | H | Mod. | High | M | | Y |

X - Indicates the components of each alternative.
H - Criteria is judged highly beneficial to the project as a whole.
M - Criteria is judged moderately beneficial to the project.
L - Criteria is judged of little benefit to the project.

COST RANGES (in Millions of Dollars):

| | Capital | Operations, Maintenance, and Monitoring |
|---|---|---|
| Very High | >$10 | >$30 |
| High | $5-10 | $20-$30 |
| Moderate | $2-$5 | $10-$20 |
| Low | <$2 | <$10 |

**Table 3 • Detailed Evaluation of Remedial Alternatives**
Feasibility Study
Pall Life Sciences, Ann Arbor, Michigan

| | | | | | Treatment | | | | | Discharge Point | | | | Detailed Evaluation Criteria | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Location | | | Method | | Huron River | Honey Creek | Unit E | Deep Well | | | Cost | | Engineering | | | | | | | | | |
| Alternative | Monitored Natural Attenuation | Institutional Controls (City Ordinance) | Groundwater Pumping | Pipeline to Wagner Road Facility | Pall, Wagner Road Facility | Pall/Non-Pall Maple Road Area (east of I-94) | Huron River | UV/Hydrogen Peroxide | Ozone and Hydrogen Peroxide | Huron River | Honey Creek | >1 <85 ug/L | Mt. Simon Formation | Protection of human health and the environment | Refinement and specification of alternatives in detail | Capital | O&M | Implementability | Reliability | Constructability | Feasibility | Recycling/Minimization & Innovative | Adverse Impacts | Remaining Risks | Compliance with Objectives | Protection of Public Welfare and Public Perspective | TOTAL RANKING |
| 2 | x | x | | | | | | | | | | | | NI | NI | 4 | 4 | 3 | 3 | 3 | 3 | NI | 3 | NI | NI | 3 | 26 |
| 3a-1 | | | x | x | x | | | | x | x | | | | NI | NI | 2 | 3 | 1 | 3 | 1 | 1 | NI | 2 | NI | NI | 1 | 14 |
| 3a-2 | | | x | x | x | | | x | | x | | | | NI | NI | 2 | 1 | 1 | 3 | 1 | 1 | NI | 2 | NI | NI | 1 | 12 |
| 3c-1 | | | x | x | x | | | | x | | | x | | NI | NI | 2 | 2 | 2 | 1 | 2 | 1 | NI | 2 | NI | NI | 1 | 13 |
| 3c-2 | | | x | x | x | | | x | | | | x | | NI | NI | 2 | 1 | 2 | 1 | 2 | 1 | NI | 2 | NI | NI | 1 | 12 |
| 3e-1 | | | x | x | x | | | | x | | x | | | NI | NI | 2 | 3 | 2 | 3 | 2 | 1 | NI | 2 | NI | NI | 1 | 16 |
| 3e-2 | | | x | x | x | | | x | | | x | | | NI | NI | 2 | 1 | 2 | 3 | 2 | 1 | NI | 2 | NI | NI | 1 | 14 |
| 4a | | | x | | | x | | | x | x | | | | NI | NI | 2 | 3 | 1 | 3 | 1 | 1 | NI | 2 | NI | NI | 1 | 14 |
| 4c | | | x | | | x | | | x | | | x | | NI | NI | 2 | 2 | 1 | 2 | 1 | 1 | NI | 2 | NI | NI | 1 | 12 |
| 5 | | | x | | | | | | | | | | x | NI | NI | 2 | 3 | 1 | 2 | 2 | 1 | NI | 2 | NI | NI | 1 | 14 |
| 6 | | | x | | | | x | | x | x | | | | NI | NI | 3 | 2 | 3 | 3 | 2 | 2 | NI | 2 | NI | NI | 2 | 19 |

Criteria Ranking
1 - Criteria judged to be of little benefit to project.
2 - Criteria judged to be moderately beneficial to project.
3 - Criteria judged to be highly beneficial to project.
NI - Not included. To improve discrimination among alternatives, those criteria judged equal among alternatives are not ranked or included in numerical totals.

COST RANGES (in Millions of Dollars):

| Criteria Ranking | Project Benefit | Capital | Operations, Maintenance, and Monitoring |
|---|---|---|---|
| 1 | Very High | >$10 | >$30 |
| 2 | High | $5-10 | $20-$30 |
| 3 | Moderate | $2-$5 | $10-$20 |
| 4 | Low | <$2 | <$10 |