ERO Resources Corp.

September 5, 2018

**To:** Chad Howell, City of Thornton

**From:** Jack Denman and Brian Olmsted, ERO Resources Corporation (ERO)

**Re:** Thornton Shopping Center Corrective Action Plan (CAP) Review

This memorandum provides ERO's high-level review and professional opinions regarding the 2017 Second Corrective Action Plan (CAP) Modification (collectively "2017 CAP Mod") prepared by LT Environmental (LTE) that describes the proposed remedial actions to address the tetrachloroethylene (PCE) release at the Thornton Shopping Center (the "property"). The Thornton Shopping Center is located northeast of East 88th Avenue and North Washington Street, with the area of release and associated soil and groundwater contamination generally in the southeast corner of the facility. ERO's review is based on publicly available information maintained by the Colorado Department of Public Health and Environment (CDPHE) and is organized in the following manner:

- *Site Summary* – Provides an overall background of the site
- *Data Uncertainty* – Evaluates data gaps within existing characterization information
- *CAP Implementation* – Evaluates LTE's November 2017 CAP Mod
- *CDPHE's CAP Approval Letter* – Discusses CDPHE's response to the 2017 CAP Mod
- *Cost Assessment of Current CAP* – Provides ERO's order of magnitude cost estimate for anticipated implementation of the 2017 CAP Mod
- *Conclusion* – Provides ERO's professional opinions regarding costs and proposed remediation

## Site Summary

Numerous reports and previous investigations have identified up to six former dry cleaners in the southeast portion of the property as a source of a PCE release to soil and groundwater on the property (Freedom Environmental Consultants [FEC] 2006; LTE 2017a). Historical information indicates that dry cleaning activities started on the property when the Thornton Shopping Center first opened in 1957 and have been ongoing on an almost continuous basis ever since. Site characterization activities started in 2005 after a site assessment identified PCE concentrations in soil and groundwater indicative of a release in locations adjacent to a unit with a long history of use for a dry cleaner (8866 North Washington Street) and near a then (2005) operating dry cleaner (8946 North Washington Street) (FEC 2006). Site

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characterization activities have continued to date, often concurrent with remediation activities, which started in 2008. To date, the primary remedial strategy has consisted of the injection of a treatment solution of BOS-100, a proprietary reductive dechlorination material, into the soil and groundwater to dechlorinate the PCE to inert compounds. To date, 9,078 pounds of BOS-100 have been injected in and immediately downgradient of the source area over three injection events conducted in 2008, 2009, and 2014. The injections used direct push technology (DPT), a drilling technology that uses a hydraulically powered hammer to drive a hollow drill rod into the subsurface. Through the hollow drill tube, soil cores can be extracted, monitoring wells installed, and injections can be conducted into the subsurface. Because of the hydraulically-powered nature, the depth of the technology is often limited by tighter, clay-rich and bedrock conditions encountered typically encountered along the Denver Front Range.

Prior to the start of injections in 2008, site characterization was limited to soil and groundwater samples collected using DPT or traditional auger drilling techniques. In August 2016, a membrane interface probe (MIP) [1] was used to investigate 32 locations primarily within the source area and immediately downgradient on the shopping center building (LTE 2017a). The MIP borings were conducted using DPT, which limited the depth of characterization to between 16 and 30 feet below ground surface (bgs) due to bedrock conditions in the subsurface that resulted in mechanical refusal of the DPT rig. As soil sampling is not possible with an MIP, a follow up drilling program using DPT was conducted at 18 locations to confirm and quantify the MIP characterization results.

In October 2016, characterization of contamination at depths greater than that achieved with DPT was conducted by drilling and installing deep soil borings up to 74 feet bgs at two locations - MW-22 in the source area and MW-23 at the downgradient property boundary. Nested wells were installed within the borings, permitting the sampling of groundwater at different depths within the subsurface. The highest PCE groundwater concentrations from MW-22 were from 55 to 60 feet bgs, and as LTE noted, at concentrations indicative of non-aqueous phase liquid, or NAPL[2]. At MW-23, PCE concentrations exceeding standards were detected in groundwater at depths of 64 to 74 feet bgs. It was noted by LTE that deeper well samples required extracting groundwater from the wells until the wells went dry and groundwater recharge took several hours to a few days. These characteristics are indicative of contamination located in very low permeability rock that does not convey groundwater

[1] The MIP is a high-resolution sensor tool that attaches to DPT drill rods and produces real-time continuous chemical and physical logs of the vadose and saturated zones. The system detects total volatile organic compounds (VOCs) in the subsurface and shows where the contaminants occur relative to geologic and hydrologic units.

[2] NAPL is a phrase used to describe relatively pure PCE which is in contrast to dissolved PCE which is water with PCE dissolved in it. Water can only dissolve a limited amount of PCE so when concentrations are relatively high (i.e. greater than about 10,000 micrograms per liter), it is reflective of groundwater that is close to its solubility with PCE.

readily. Given the very high PCE concentrations found in source area wells, LTE notes several times throughout documents that the potential exists that pure PCE product (i.e. NAPL) exists at depth.

## Data Uncertainty

***On-Site Characterization.*** Based on the characterization information available to date, shallow groundwater contamination appears reasonably well characterized on-site, however deep groundwater impacts have extremely limited information, especially given the elevated PCE concentrations documented at the only two wells with data, MW-22 and MW-23. Deep groundwater contamination up to 72,800 micrograms per liter (µg/L) at MW-22 have been measured but the deep investigations have been limited to two locations, MW-22 near the source area and the second well near the southern property boundary (MW-23) (LTE 2017a). Data from these wells appear to delineate the vertical extent of the deep contamination, however even the deepest PCE groundwater concentration detected at MW-23 was still above the regulatory standards of 17 ug/L. In addition, the horizontal extent has not been defined with other deeper borings. More critical to the site characterization and ultimate remedial planning, other similarly deep borings to delineate the lateral extent of the deep zones is lacking.

Despite this lack of deep zone characterization, the current, 2017 CAP Mod provides a discussion and figure showing proposed BOS-100 injection points associated with remediation of this deep contamination. There are several concerns with this approach –

First, without data to show the lateral extents of the deep contamination, it is unknown whether the area planned to be treated is adequate.

Second, based on the slow recharge rates noted for the deep wells during sampling, it is unknown whether the deeper formation will readily accept treatment chemicals at rates that would be sufficient to treat the contaminants.

Finally, there is a significant data gap with respect to the deep contamination's downgradient extent. Maps produced by LTE for this deeper zone are based on two data points (MW-22 and MW-23), with the deep extent appearing to arbitrarily end at the property boundary as illustrated in LTE's reports. Given the elevated PCE concentrations within well MW-23 (up to 2,090 ug/L at 52 feet bgs), it is ERO's opinion that the artificial "termination" of the plume at the southern property boundary is unlikely. At a minimum, better characterization of the deeper zone will be needed in the future as remediation activities proceed.

As discussed above, with the very high PCE concentrations found in source area wells, both shallow and deep, the potential exists that pure PCE product (i.e. NAPL) exists at depth. Since BOS-100 treats PCE dissolved in groundwater, it is unknown whether the selected injection product will be effective if NAPL is indeed present. It is ERO's opinion that NAPL is

likely present in isolated pockets and will complicate remediation efforts as currently planned.

***Off-Site Characterization.*** Based on the review of information, it appears that the off-site areas of the groundwater plume are not fully characterized within the hydraulically downgradient neighboring properties to the same extent as on-site areas. This has resulted in the CDPHE recently requesting four new wells installed on downgradient properties (CDPHE 2018 and noted below). Three of the four wells recently requested by the CDPHE are to be located directly downgradient of the proposed off-site BOS-100 remediation zones and are likely being requested to help assess the remediation efforts planned. Based on the limited number of well locations on downgradient properties, it is ERO's opinion that it is likely that additional wells will be requested by the CDPHE based on the new well results to be collected.

In addition to groundwater characterization, only one round of off-site indoor air assessment has been conducted by EPA in 2012. This provides a very limited data set for the evaluation of off-site soil vapor intrusion exposure pathway. As noted in CDPHE's response (discussed below), additional sampling and assessment of the residential buildings is going to be required as part of the 2017 CAP Mod implementation.

***Cost Implications*.** The gaps within site characterization, primarily the deep zone and off-site areas will increase the uncertainty of costs projected for the ultimate remediation because treating the deeper zone can be expected to be greater on a point by point basis than treating the shallow groundwater where DPT can be utilized. As noted throughout site characterization report, use of DPT at the site is limited to a depth of 16 to 30 feet bgs. To achieve injection within the deeper zone, the Second CAP Mod indicates auger drilling and a packer assembly may be necessary. Although one of the highest PCE concentrations was measured in the deeper zone at MW-22 at 55 to 60 feet bgs, the remediation design for the deeper zones calls for injection spacing to be on 25-foot centers in contrast to the shallow zone being designed at 10- to 15-foot centers. The rationale for this difference is not provided and, in ERO's opinion, underscores the limited design plan for the deeper zone and the lack of assessing whether treatment of this zone is even possible based on the technology chosen.

## CAP Implementation

Within the 2017 CAP Mod, LTE specifically states that Thornton LLC's ability to implement the designed CAP is contingent on another entity assuming liability for the contamination and funding the 2017 CAP Mod evaluation and implementation. The indication that the 2017 CAP Mod, as written, still needs to be evaluated, suggests limited design evaluation has been performed and the 2017 CAP Mod may not be as sound as suggested. For example, the plan describes extensive remedial injections throughout the contaminant plume, but no discussion of injection volumes, phasing, or challenges that may be encountered, such as

foundation lifting encountered during previous interior injections and how these impacts may affect injection success, mobilize contaminant mass outside of the treatment areas, or the practicality of the implementation.

Practically speaking, it extremely difficult to design a CAP (or significant modification as proposed) that will achieve full compliance and closure with one iteration of design. In reality, the 2017 CAP Mod, as written, should be considered a step in the iterative process of design, treatment, objective evaluation of results, revision of the conceptual site model, and implementation of a refined remedial approach based on new data as it is gathered. This process is not explicitly stated in the 2017 CAP Mod, but suggestions of this approach are alluded to :

- First, LTE notes the likelihood that alternative concentration limits may need to be considered. This means the remedial approach would seek an allowed increase in the state groundwater standards for areas that do not get treated to below standards. It has been ERO's experience that this is not something that occurs with regularity and, even if granted, is unlikely to increase the current state groundwater standards by a significant amount. The state views groundwater as a current and future state resource and groundwater standards are the measure by which the state evaluates or determined injury to the resource and potential exposure for the public. The 2017 CAP Mod assumes that the current exposure risks are indicative of future exposure, regardless of future development. This is a broad assumption that, in ERO's opinion, CDPHE is unlikely to make. Finally, there is no guarantee the CDPHE would grant site-specific standards by which to close a site. Assuming such a closure scenario is, in ERO's opinion, unfoundedly wishful and impracticable.
- Second, as discussed earlier, all groundwater concentrations measured reflect the dissolved concentration of PCE in groundwater and treatment is only designed to treat the groundwater. Sites with extremely high PCE groundwater concentrations take such extended times to meet standards partially due to the equilibrium that exists between groundwater and the surrounding aquifer matrix. Dissolved contaminant concentrations measured in a well are reflective of a chemical equilibrium between the contamination adsorbed and/or trapped in the sediments/rock comprising the aquifer matrix and the groundwater in contact with those sediments/rock. Aqueous treatment fluids that are injected into an area of contamination treat the contaminants that are contacted by the treatment fluids, but only compounds currently dissolved in the groundwater (not adsorbed or trapped within the matrix).

  Once the contaminants are removed (treated) from the groundwater, the balance (i.e. equilibrium) between the matrix and the groundwater is shifted to the matrix (i.e. the matrix still contains the contaminants while the groundwater temporarily does not). In response, equilibrium is restored by diffusion of the contaminants still present in the matrix back into the groundwater, thereby increasing groundwater concentrations. This process is typically referred to as rebound or back-diffusion and explains why an initial decrease in concentration

is typically observed followed by an increase over time as the equilibrium between the groundwater and matrix contamination is restored.

- When extrapolated to a site-wide remediation approach, numerous practical variables combine to work against rapid site closure. The process of groundwater treatment decreases the overall amount (i.e. mass) of contamination present so that the new rebounded concentration is typically less than the pre-treatment concentration, but groundwater concentrations may still not be low enough to close the site. Incomplete distribution of the treatment fluid in areas that cannot be directly accessed due to buildings or roads limits the effectiveness and efficiency of the original injection design. Aquifer materials containing mudstones and sandstones that are difficult to inject into and higher clay content increases the contaminant adsorption within the aquifer matrix. The presence of NAPL which slowly dissolves and releases contamination over a long period can lead to the underestimation of the contaminant mass that requires treatment. Finally, slow groundwater velocities typical of claystone and mudstone aquifers increase performance monitoring and trend reporting timelines.

It has been ERO's experience, both first hand as well as part of review of other site data, that sites in locations like the Thornton Shopping Center, where high contaminants concentrations exist in low permeability bedrock, rarely get remediated to closure in a short period of time without a significant expenditure of resources. More typically, an iterative process using various treatment technologies occurs that allows for a refinement of the conceptual site model that leads to a better understanding of the extent of contamination as progress is achieved. It is also not uncommon for high levels of contamination to remain in certain areas following treatments only to be indicative of other areas of contamination not initially known or preferential flow paths in the bedrock not initially understood.

Although only briefly alluded to in the 2017 CAP Mod, alternative treatment methods could be evaluated to either replace, or more efficiently, be combined with those currently proposed. The only complete treatment method available is excavation, but due to the depth of the source area, the hard bedrock, and the large area that the plume occupies, this is not a very realistic option. An alternative treatment option for the source area is thermal treatment which involves heating the ground to the boiling point of water. This method effectively treats NAPL and both the matrix and the groundwater it is in contact with thereby eliminating rebounding. However, a significant amount of energy is needed to heat the ground and typical costs for a small treatment area usually begin in the millions of dollars due to the extensive infrastructure needed.

## CDPHE's CAP Approval Letter

Based on ERO's review of the 2017 CAP Mod produced by LTE and the subsequent response by CDPHE (CDPHE 2018), it is ERO's opinion that the current CAP was hastily put together after a series of delays to temporarily satisfy the CDPHE's desire to move the site towards

treatment. The CDPHE's CAP Mod "approval" letter is revealing and points to some of the short comings of the proposed Second CAP Mod.

First, the CDPHE notes that during a previous meeting concerning the site, it was noted that excavation might be possible but only BOS-100 treatments are currently proposed. As discussed above, excavation is the only treatment method that assures complete treatment, but is limited to the accessible areas able to be excavated. If in fact excavation remains an option, it is something that should be done prior to injections for practical reasons, but is not discussed as an option within the 2017 CAP Mod.

Second, the CDPHE's request to require implementation of the off-site areas first is an indication of their initial goals and primary concerns. The CDPHE's first and foremost goal is to protect human health, which is the presumed rationale behind their initial requests for installation of additional monitoring wells and additional indoor air sampling in the off-site areas. The requirement that off-site treatments proceed on downgradient properties by a specified date is indicative of a human health focus.

Third, CDPHE rejects several assertions and conditions within the CAP Mod including:

- Reliance on alternative concentration limits for closure is premature and not a substitute for remediation;
- Closure for uncontaminated parcels within the larger complex may be considered, but data would be required to make the determination;
- Should another party purchase the property, that new entity would be the owner and operator of the RCRA site, subject to the corrective action and responsibility for the cleanup; and
- Expressly rejects the statement that remediation is contingent on "what-ifs" and "potential-but-yet-to-materialize agreements" that may fund the remediation.

Finally, CDPHE also recognizes the likelihood that closure of the site may not be completed if the CAP Mod was implemented. The CDPHE oversees hundreds of sites throughout the state and has seen numerous attempts made to cleanup sites but only rarely issues site closure letters. The CDPHE's note that they reserve the right to require additional remediation even if the current plan was implemented is, in our experience, standard language from a regulatory agency, but it underscores the reality that sites like the Thornton Shopping Center do not cleanup to standards based on implementation of a single remediation plan. It also reasserts CDPHE's position that the owner/operator of the property and facility are ultimately responsible to meet cleanup requirements regardless of the complexity or cost of the remedial plan.

## Cost Assessment of Current CAP

Although it is ERO's opinion that implementation of the current 2017 CAP Mod is unlikely to result in site closure, it is nevertheless informative to assess the cost of the plan as proposed as a significant step toward closure. Although no costs were provided by LTE, ERO was able to extrapolate and estimate approximate costs based on data, process descriptions, and experience with similar technologies. Data gaps within the technical design of the plan require several assumptions to be made. For example, LTE document makes no mention of how much product would be, or could be, injected at each location, only the location of each injection point and a general figure showing multiple vertical injections at each point. ERO used conservative assumptions to fill these gaps within the conceptual workplan, a range of schedules, and cost estimates based on previous experience to develop a conceptual cost estimate.

| **Conceptual Redevelopment Preparation Costs** | | |
|---|---|---|
| **Item** | ***Low Estimate*** | ***High Estimate*** |
| **Remediation Plan** | | |
| *Implementation Timeframe (years)* | *4* | *10* |
| *Shallow Treatment Boring Injections On-Site* | *$1,707,000* | *$3,983,000* |
| *Shallow Treatment Boring Injections Off-Site* | *$ 740,000* | *$1,295,000* |
| *Deep Treatment Boring Injection* | *$490,000* | *$735,000* |
| *Semi-annual Groundwater Monitoring (23 wells)* | *$92,000* | *$230,000* |
| *Additional Wells (6)* | *$24,000* | *$24,000* |
| *Indoor Air Sampling (14 locations, 2 per location)* | *$56,000* | *$56,000* |
| *Reporting (per year)* | *$20,000* | *$100,000* |
| ***Total Conceptual Remediation Costs*** | ***$3,129,000*** | ***$6,423,000*** |
| **Site Preparation** | | |
| *Asbestos Abatement* | *$496,557* | *$676,563* |
| *Site Demolition* | *$1,141,429* | *$1,342,201* |
| *Source Area Excavation (7,385 CY scoped in 2013)* | *$612,955* | *$812,350* |
| ***Total Estimate*** | ***$5,379,941*** | ***$9,254,114*** |
| *Roofing Abatement (Unlikely to be required)* | *$943,280* | *$1,297,010* |

Remediation plan costs differences due to timeframe of implementation and varied success associated with injection treatment.
Site preparation costs are based on non-competitive consultation with industry representatives familiar with the site, type of work, and local regulations.
Asbestos abatement based on 2016 LT Environmental ACM Inspection report and industry order of magnitude costs.
Source Area Excavation estimates from a 2013 conceptual design for partial excavation of source area soils presented to a local construction contractor for order of magnitude estimating.

## Conclusion

As noted previously, it is ERO's opinion that even with implementation of the currently approved 2017 CAP Mod, site closure is highly unlikely and speculative. Because the grid of injections proposed would likely compromise the current monitoring well network, it is likely that the CDPHE would want several additional wells installed downgradient of the injection points to assess the contaminant levels not directly influenced by the BOS-100 that entered

current wells used for monitoring. This coupled with numerous additional years of groundwater monitoring, additional characterization of the deep zone, and at least two additional rounds of treatment borings albeit at a reduced number of injection points focused on residual contamination, it is not unrealistic to anticipate the cost for remediation of this site to greatly exceed conceptual estimates.

## References

Colorado Department of Public Health and Environment (CDPHE). 2018. Second Corrective Action Plan Modification; Second Semi-Annual 2017 Groundwater Monitoring Report, Thornton Shopping Center, Northwest Corner 88th and Corona, Thornton, CO. March 5.

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