Conceptual Leachate Treatment Scoping Study for New England Waste Services of Vermont (NEWSVT) Landfill

Prepared for

Casella Waste Systems, Inc., Hyde Park, Vermont

October 11, 2019

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1855 Vermont Route 100
Hyde Park, Vermont 05655

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P.E.'s Clarification: Cost estimates provided in Section 6 are provided for Casella's use but are not engineering instruments of service and are therefore excluded from my responsible charge.

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AACE	Association for the Advancement of Cost Engineering
AOP	Advanced Oxidation Processes
BDD	Boron-Doped Diamond
BC	Brown and Caldwell
BOD	Biochemical Oxygen Demand
CapEx	Capital Expenditure
CIP	Clean-In-Place
COD	Chemical Oxidation Demand
DSW	Discharge to Surface Water
EC	Electrocoagulation
EO	Electrochemical oxidation
EDR	Electrodialysis Reversal
EQ	Equalization
EREF	Environmental Research and Education Foundation
GAC	Granular Activated Carbon
gpd	Gallons Per Day
HA	Health Advisory
IX	Ion Exchange
LFG	Landfill Gas
LTP	Leachate Treatment Plant
µm	Micron
MBBR	Moving Bed Bioreactors
MBR	Membrane Bioreactors
mg/L	Milligrams Per Liter
MGD	Million Gallons Per Day
NEWSVT	New England Waste Services of Vermont
NF	Nanofiltration
ng/L	Nanograms Per Liter
OpEx	Operational Expenditure
PAL	Preventive Action Levels
PFAS	Per- and Polyfluoroalkyl Substances
PFHpA	Perfluoroheptanoic Acid
PFHxS	Perfluorohexane Sulfonate
PFNA	Perfluorononanoic Acid
PFOA	Perfluorooctanoic Acid
PFOS	Perfluorooctanesulfonic Acid
POTW	Publicly Owned Treatment Works
PPCP	Pharmaceuticals and Personal Care Products
ppt	Parts Per Trillion
RL	Regulatory Limit
RO	Reverse Osmosis
SBR	Sequencing Batch Reactor
SCFM	Standard Cubic Feet Per Minute
SPLP	Synthetic Precipitation Leaching Procedure
SVOC	Semi-Volatile Organic Compounds
T&D	Transportation and Disposal
TCLP	Toxicity Characteristic Leaching Procedure
UF	Ultrafiltration
VFD	Variable Frequency Drive
VOC	Volatile Organic Compound
VTDEC	Vermont Department of Environmental Conservation
WET	Whole Effluent Toxicity
WRRF	Water Resource Recovery Facility
WWTP	Wastewater Treatment Plant
ZLD	Zero Liquid Discharge

Executive Summary

This report summarizes and presents the findings of the evaluation prepared by Brown and Caldwell (BC) to evaluate, at a conceptual level, two on-site and two off-site treatment and pretreatment technologies for removal of per- and polyfluoroalkyl substances (PFAS) compounds at New England Waste Services of Vermont's (NEWSVT) landfill in Coventry, Vermont. This evaluation was conducted as requested and described in the Responsiveness Summary prepared by the Vermont Agency of Natural Resources Department of Environmental Conservation (VTDEC) dated October 12, 2018 and the Facility Certification dated October 12, 2018, specific condition #86. In addition to an evaluation of benefits and limitations associated with particular disposal and technology alternatives, the results of a preliminary economic analysis of the on-site and off-site treatment and disposal options are included. The various technologies discussed were evaluated and selected based on commercial availability, proven treatment of leachate and effectiveness at PFAS removal for application in each of the associated disposal options as part of conceptual integrated treatment systems. This evaluation considered only those that are currently proven with leachate, can remove PFAS and are commercially available. Given the rapidly evolving development of PFAS treatment technologies, Casella will continue to consider and evaluate new technologies that are consistent with the foregoing as they become available.

Based on the results of this study, there are several core technical and regulatory challenges related to treating landfill leachate for PFAS at NEWSVT:

1. The lack of promulgated PFAS treatment or discharge standards makes the process of selecting a specific treatment approach and technology problematic. Without established performance limits as a basis of a system performance design, design engineers will not be able to specify appropriate processes or equipment for supply by technology vendors, nor will an accurate economic analysis be possible. This is particularly problematic since PFAS consists of thousands of compounds, the vast majority of which have not been evaluated for health risks nor treatment. Accordingly, this evaluation is limited to removal of PFAS compounds that currently have regulatory health advisories (HA) and preventive action limits (PAL) in the State of Vermont (PFOA. PFOS, PFNA, PFHxS and PFHpA), rather than PFAS as a class, with a primary focus on PFOA and PFOS given the greater availability of information. Identified treatment technologies may be less effective at removing other PFAS compounds that are not currently regulated or as well studied.
2. The primary focus for research conducted on PFAS removal has been on comparatively clean liquid matrices (compared to leachate) such as drinking water and groundwater due to their potential for human contact and ingestion. Additionally, the vast majority of the evaluations have focused on PFOA and PFOS. There is limited information available regarding treatment of PFAS in a complex matrix such as leachate.
3. There is very limited data available on PFAS concentrations as well as other leachate and POTW effluent characteristics that may have significant impacts on technology and leachate disposal selection and costs. Additional characterization and treatability testing are required to validate the results of this evaluation.
4. The chemical nature of PFAS compounds and the very low concentrations present in leachate, coupled with the complex chemical matrix of leachate makes 'front end' selective treatment of PFAS in landfill leachate technically infeasible for most standard waste water treatment processes. Therefore, significant 'front end' pretreatment of the leachate is required before

PFAS removal can be accomplished at the 'back end' of a standard treatment system process. This makes most on-site treatment options complex with multiple processing steps required before PFAS removal can be accomplished. Removal to single parts per trillion concentrations is challenging in a clean (e.g., drinking water) matrix and is further complicated by the matrix presented by leachate.

5. Because of the chemically stable nature of PFAS compounds and complex chemical matrix of leachate, all of the PFAS treatment processes commercially available for a leachate application ultimately either concentrate or capture PFAS compounds into a liquid concentrate, solid residual or spent media form. These residuals still must be either stabilized (to ensure that the compounds don't get re-entrained in the leachate) and then landfilled on site or shipped off site for either disposal or incineration at another disposal facility. There are also many unknowns associated with disposal of residuals such as formation of secondary compounds through incomplete destruction. Therefore, the management of treatment process residuals containing PFAS compounds is a significant part of the challenge and must be considered carefully in terms of technical and economic viability as well as secondary environmental impacts for any currently available treatment scenario selected. There is limited information available regarding the availability and effectiveness of currently available final disposal/destruction options.
6. On-site treatment options will require multi-media (water, air, solid waste) permitting coordination by VTDEC for project advancement. As noted above, promulgated limits have not been established by Vermont for any media at this time thus complicating the potential application of on-site options in a timely manner. Additionally, effective residuals management solutions are largely unproven. Confirmation of the status of leachate derived PFAS residuals as hazardous or non-hazardous waste is needed to understand final residual management requirements.
7. On-site options for residuals management result in negative impacts on landfill capacity and operational costs due to leachate treatment and stabilization and landfill placement of residuals. The landfill effectively becomes a terminal sequestration point for PFAS associated with any PFAS containing waste (e.g., POTW sludge, municipal solid waste and industrial/special wastes) with an associated public benefit. This public benefit should be acknowledged and reflected both economically and through permitting approaches.
8. Implementation of PFAS removal for off-site options offers several significant challenges that must be addressed including leachate treatment capacity limitations at Montpelier and Newport, PFAS removal system confirmation testing and design, permitting, contractual and financial aspects, possible residuals management impact on landfill capacity, and project funding. There are undefined sources of PFAS to POTWS. For example, a review of data in the Weston and Sampson report "Wastewater Treatment Facility and Landfill Leachate PFAS Sampling Various Locations, Northern Vermont" dated May 3, 2018 indicates <25 percent of PFOA and PFOS is associated with NEWSVT leachate. Treatment of POTW effluent will remove the non-leachate associated PFAS offering a substantial environmental benefit to the public complex. Contractual arrangements to secure long-term disposal rights and fair rates would be needed to assure the long-term viability of this approach. Note that these off-site options still have limitations as summarized in bullet 1 above and treatment may be less effective at removing many of the other PFAS compounds that are not currently regulated.

Analysis of the various options to treat leachate for PFAS removal consisted of the elements below. Technical memorandums summarizing the results of preceding steps of the evaluation are provided in the listed appendices. This report summarizes information on treatment technologies, on- and off-site options, residuals and preliminary costs.

- Leachate Characterization (Appendix A)
- Regulatory Review (Appendix B)
- Leachate Strategy Review (Ranking; weighted economic, environmental, technology factors), (Appendix C)
- GAC and IX Resin Isotherm Testing of POTW Effluents (Appendix D)
- Capacity Evaluation for Leachate Treatment of Montpelier POTW (Appendix E)
- Capacity Evaluation for Leachate Treatment of Newport POTW (Appendix F)

Results Summary

Based on the results of this study and analysis, the preferred on-site treatment approach is to direct discharge to surface water (DSW) after on-site treatment via a Rochem Reverse Osmosis (RO) leachate treatment system. Most of the on-site treatment system processes reviewed can treat the leachate to, or near to, applicable and anticipated surface water quality standards in the process of removing PFAS compounds. Therefore, it makes sense to discharge the clean treatment effluent directly rather than haul otherwise clean effluent to a publicly owned treatment works (POTW) for discharge. The Rochem RO process removes the overwhelming majority of Vermont regulated PFAS compounds from the wastewater stream to below health advisory levels for drinking water (surface water quality limits for PFAS have not been promulgated at this time). The Rochem RO technology also requires fewer front-end processes to accomplish PFAS treatment than many of the other technology options reviewed and has a proven industry track record in treating landfill leachate.

The principal challenge with this technology option is in the management of RO treatment residuals, which will concentrate contaminants removed in the process (including PFAS compounds) into concentrated liquid residual volume of approximately 10 to 25 percent of the original total influent leachate volume. The removed contaminants are thus concentrated by a factor of 4-10 times in the RO concentrate residual. Therefore, there is a significant residuals management process at the back end to allow placement of residuals in the landfill without re-entrainment of contaminants into the leachate. This will require liquids minimization (via evaporation) and then stabilization of the concentrated waste to mitigate the potential that landfilled residuals allow re-entrained PFAS compounds back into the landfill leachate. Stabilization technologies to provide effective long-term sequestration of PFAS are under development and not yet proven as technically attainable or cost effective. Off-site disposal and destruction of residuals via incineration at adequate temperatures (>1,000°C) is currently limited due to few available facilities and there is uncertainty regarding production and long-term liability associated with incineration byproducts. Other technology and regulatory challenges include effluent discharge permitting, air emissions permitting (odor and emissions from evaporation), regulatory classification of residuals (haz/non-haz) and reliable stabilization and sequestration of the residual PFAS and other concentrated compounds. The permitting challenges will require focused VTDEC support of this approach to be successful. This treatment option has a relatively higher upfront capital cost but will have a lower operating cost than the preferred off-site leachate management option but provides NEWSVT with more control of the process.

For off-site leachate management options, the preferred approach is to continue hauling raw leachate to either the Newport or Montpelier POTWs (for conventional leachate treatment) and upgrading of one of these facilities to treat for PFAS compounds at the back end of their existing treatment process, prior to discharge. Such an approach would require a potentially complex contractual agreement with the selected facility to address a host of issues including project funding, disposal fees, compliance considerations, long-term disposal assurance and back-up disposal outlets.

This approach results in removal of PFAS associated with leachate as well as PFAS associated with undefined sources in the POTW influent. Upgrades would include additional raw leachate storage and equalization tanks at the front end of the POTW process and granular activated carbon (GAC) and/or ion exchange (IX) resin treatment at the backend. Modifications to the existing POTW facilities including increased aeration capacity would be needed at either Montpelier or Newport to accommodate all current and future leachate volumes. GAC and/or IX treatment for PFAS in a (relatively) clean waste water stream is a well-established method of PFAS removal for longer chain PFAS compounds that are currently regulated. Shorter chain compounds, if regulated, would likely require additional treatment such as PFAS specific resins. POTW effluents will contain a broad suite of other constituents that will adsorb to carbon (or resins) and compete for adsorption of PFAS compounds. Note that back end GAC and/or IX treatment would need to be sized to treat all of the POTW effluent for PFAS, not just leachate. It should also be noted that carbon or IX treatment would not be selective to just PFAS compounds, therefore media loading (i.e., expenditure rate) will also be a function of both PFAS and some non-PFAS constituents present in the POTW discharge, albeit present at concentrations within the currently allowable discharge standards. Although it is an environmentally attractive benefit that non-landfill sources of PFAS are also treated (along with some other compounds), this beneficial impact is not well quantified and is a significant risk in terms of GAC/resin operating cost (i.e., carbon/resin media usage). It should be noted that the recovered PFAS would be ultimately destroyed when the GAC media (if used) is reactivated at an off-site GAC recovery facility provided the facility operates at required temperatures and residence times. Note that carbon reactivation at a temperature of >1,000°C is reported to be required for PFAS destruction. Research is ongoing regarding the required conditions for destruction and the potential for generation of combustion byproducts. Spent resins would either be landfilled after stabilization, incinerated or regenerated (with the regenerate requiring disposal similar to that of RO concentrate). Operating costs associated with this option include GAC/resin media usage, leachate hauling and leachate disposal fees, which will still remain, and resin residuals disposal. GAC reactivation is included in the GAC media cost.

This option has the benefit of a continuation of the business-as-usual approach of hauling and disposal of leachate, relying on the POTW facilities to manage treatment processes. There are also qualitative benefits and challenges of this option associated with 'partnering' on this problem with local municipal POTWs including items mentioned previously. Although the capital costs associated with this option are less than the capital costs associated with the preferred on-site treatment option, overall operating expenses are expected to be higher than the on-site treatment option in part due to the greater volume of liquid being treated (e.g., entire POTW flow), lower PFAS concentrations (e.g., reduced adsorption driving force) and competing adsorption compounds in the POTW effluent. Although there is potential for capital and O&M cost sharing, transportation costs would likely not be reduced as they are volume and distance based.

One of the principal challenges is the ability of either of the two POTW facilities (Montpelier and Newport) evaluated to be able to manage all of NEWSVT's raw leachate as part of its' current treatment process, regardless of the presence of PFAS compounds. Both Montpelier and Newport are limited in leachate treatment capacity and each would require upgrades to aeration capacity and leachate receiving to allow acceptance of the full quantity of leachate currently produced at the landfill. Acceptance of the longer term anticipated leachate volume would require more substantial upgrades at the POTWs, including additional tankage at Newport and a new aeration grid and blowers at Montpelier…this will drive both capital and operating costs unfavorably. Another key challenge, which is still undetermined, is the allowable effluent discharge concentration of PFAS from the POTWs. Without established PFAS discharge limits, the design and probable operating costs of the GAC treatment system cannot be accurately determined. Costs herein are based on testing of only a single sample of pre-disinfection effluent from each POTW (Montpelier and Newport) and are therefore subject to significant variability. Other potential challenges with this management option include limitations on future control of leachate disposal cost, contractual challenges with the POTWs associated with capital expenses, disposal costs and guaranteed long-term leachate acceptance, control of operating costs managed by others, and capacity limitations at the POTW to handle increasing leachate generation due to landfill growth.

It is important to note:

- Additional characterization and treatability testing are required to refine and validate treatment process performance and economics.
- Engineering Design has not been completed for any options presented. Therefore, actual costs are expected to be within -30% to +50% of the estimates presented in this report, notwithstanding any of the indeterminate variables and risks presented.

Table ES-1. Treatment Options Comparison

	On-Site: Discharge to Surface Water	On-Site: Zero Liquid Discharge (ZLD)	Off-Site: Pretreatment at POTW (50% Reduction)	Off-Site: POTW Enhancements [3,4]	
Attribute	Option 1a – RO + GAC + Remineralization with Concentrator + Emissions Control	Option 3a – Concentrator + Emissions Control	Option 2a – RO at POTW with Concentrator + Emissions Control (at NEWSVT)	Option 4a – Filtration + GAC at POTW (Newport)	Option 4b – Filtration + GAC at POTW (Montpelier)
Benefits	• Control of own destiny • Removes virtually all contaminants • All contaminants remain on-site • Forward looking for new contaminants • Small concentrate volume relative to others • Should not require propane supplement • Provides a greater overall environmental benefit (for leachate only) through greater overall contaminant removal as compared to Options 2a, 4a and 4b • Does not require siting concentrator at energy plant for waste heat • Capacity can be increased easily • Adequate waste heat and LFG for current and future capacity	• Control of own destiny • Single treatment process • Removes virtually all contaminants • All contaminants remain on-site • Forward looking for new contaminants • No liquid disposal to environment • Capacity can be increased easily	• Removes virtually all contaminants in treated liquid • Forward looking for new contaminants • Does not require siting concentrator at energy plant for waste heat • Capacity can be increased easily • Adequate waste heat and LFG for current and future capacity	• No on-site treatment • Removes other PFAS source contributions • Removes a broad suite of organic contaminants • Largest overall environmental benefit due to reduction of leachate and non-leachate related contaminants • Good public perception • PFAS destroyed with GAC regeneration • No impact to site air-space • No additional permitting by Casella	• Higher flow system (greater dilution) • No on-site treatment • Removes other PFAS source contributions • Removes a broad suite of organic contaminants • Largest overall environmental benefit due to reduction of leachate and non-leachate related contaminants • Good public perception • PFAS destroyed with GAC regeneration • No impact to site air-space • No additional permitting by Casella
Limitations	• Air emissions from concentrator (if used), odor concerns and PFAS • Public perception • Permitting challenges (NPDES, air) • Concentrate requires sequestration/solidification or off-site disposal • Concentrate impact on airspace • Does not eliminate PFAS at site unless concentrate disposed off-site via incineration/cement kiln/deep well or alternative disposal site	• Air emissions concerns (odor, PFAS) and permitting • Public perception • Requires significant supplemental propane and associated cost • Requires siting at energy plant for waste heat utilization • High concentrate volume • Concentrate requires sequestration/solidification or off-site disposal • Concentrate impact on airspace • Does not eliminate PFAS at site unless concentrate disposed off-site via incineration/cement kiln/deep well or alternative disposal site • Insufficient waste heat and LFG for current and future capacity	• Limited control of own destiny • Sized for partial treatment (allows more to environment) • Contract challenges • Reliance on others for operation (e.g., PFAS pass-through) • Long-term commitment • Continued hauling to POTW and concentrate to NEWSVT • Potential long lead time for implementation (P3 project) • Air emissions from concentrator (if used for residuals), odor concerns and PFAS • Public perception (Concentrator) • Permitting challenges (air) • Concentrate requires sequestration/solidification or off-site disposal • Concentrate impact on airspace • Does not eliminate PFAS at site unless concentrate disposed off-site via incineration/cement kiln/deep well or alternative disposal site)	• Limited control of own destiny • Contract challenges • Reliance on others for compliance (e.g., PFAS pass-through) • Long-term commitment • Continued hauling • Less effective on short chain compounds (IX can be added) • Potential long lead time for implementation (P3 project) • Requires increased disposal volume allowance from VTDEC • May become capacity limited in the future	• Farther distance (higher hauling cost) • Limited space for improvements at POTW • Limited control of own destiny • Contract challenges • Reliance on others for compliance (e.g., PFAS pass-through) • Long-term commitment • Continued hauling • Less effective on short chain compounds (IX can be added) • Potential long lead time for implementation (P3 project) • Requires increased disposal volume allowance from VTDEC • May become capacity limited in the future
CapEx Range (Low-Mid-High) ($)	13,700,000-17,100,000-34,200,000	9,600,000-11,900,000-23,900,000	9,000,000-11,300,000-33,600,000	13,400,000-16,800,000-33,600,000	12,500,000-15,700,000-31,300,000
Total 20-year cost Range (Low-Mid-High) incl. CapEx, OpEx, T&D ($)	32,000,000-40,000,000-80,000,000	157,800,000-197,200,000-394,400,000	51,400,000-64,300,000-128,600,000	52,600,000-65,700,000-131,400,000	70,400,000-88,000,000-176,000,000
Factored Disposal Rating Total[2]	56.25	49.0	64.25	56.5	56.5
Combined Rating Total	120	124	132	109	109
Leachate Application (PFAS removal)	RO proven, Air emission uncertainty for concentrator. but expected to be minor	Air emission uncertainty for concentrator but expected to be minor	RO proven, Air emission uncertainty for concentrator. but expected to be minor	Less proven for treated wastewater to low PFAS levels	Less proven for treated wastewater to low PFAS levels
Process Performance Risk	Low RO. Moderate for concentrator (Air emissions and odor concerns)	Moderate (Air emissions and odor concerns)	Low RO. Moderate for concentrator (Air emissions and odor concerns)	Moderate (operational)	Moderate (operational)
Health and Safety	Moderate	Moderate	Moderate	Low	Low
Chemical Use	High	High	High	Low	Low
Energy Use	High	Extreme	High	Low	Low
Generation of On-site Concentrate	Moderate	High	Moderate	None	None

Notes:

1. *20-year costs calculated based on straight line amortization of equipment CapEx and 2.5% inflation for OpEx and T&D. Based on 50,000 gpd flow.*
2. *Refer to Appendix C (Leachate Management Strategy Review Tech Memo) for complete table. Lower ratings are preferred.*
3. *The cost estimate includes Newport WWTF upgrades to treat 50,000 gpd leachate at Newport WWTF average loading conditions. Additional $4,550,000 capital cost is required for Newport WWTF upgrades to treat 100,000 gpd leachate at Newport WWTF at average loading conditions.*
4. *The cost estimate includes Montpelier WRRF upgrades to treat 50,000 gpd leachate at Montpelier WRRF average loading conditions. Additional $1,015,000 capital cost is required for Montpelier WRRF upgrades to treat 100,000 gpd leachate at Montpelier WRRF at average loading conditions.*

Section 1

Introduction

This report summarizes and presents the findings of the evaluation prepared by BC to evaluate, at a conceptual level, the leachate disposal alternatives and associated on-site and off-site treatment and pretreatment technologies to assist Casella's NEWSVT landfill in Coventry, Vermont with developing a long-term leachate management plan. This evaluation has been conducted as requested and described in the Responsiveness Summary prepared by the Vermont Agency of Natural Resources Department of Environmental Conservation dated October 12, 2018 for at least two on-site and two off site treatment options for leachate management. In addition to an evaluation of benefits and limitations associated with particular disposal and technology alternatives the results of an economic analysis of the preferred on-site and off-site treatment and disposal options are included. The various technologies discussed were evaluated and selected for application in each of the associated disposal options as part of conceptual integrated treatment systems.

First, an evaluation of leachate characterization data was conducted to determine the design basis (leachate flow and characteristics) to form the basis of evaluation (see Appendix A). Second, an evaluation of regulatory requirements associated with disposal options was conducted (see Appendix B). Next, an evaluation of potential leachate disposal options was conducted to establish specific leachate quality requirements based on discharge requirements associated with each option (see Appendix C). Supplemental evaluations were conducted to refine specific areas of uncertainty with off-site options that could significantly impact feasibility and costs. This consisted of carbon adsorption testing to estimate carbon usage for treatment of POTW effluent (Appendix D) and desk-top capacity evaluations for the Montpelier (Appendix E) and Newport (Appendix F) POTWs to determine current leachate acceptance capacity and potential upgrades required to provide adequate capacity to treat all of the current and future leachate volume produced by NEWSVT.

There is a broad universe of technologies available for wastewater treatment in the marketplace. These technologies generally fall into two broad categories:

1. **Concentrating Technologies:** These technologies remove constituents from the liquid stream via adsorption, filtration or partitioning (e.g., activated carbon, ion exchange resins, membranes, electrocoagulation (EC), precipitation, foam fractionation, concentrator, electrodialysis reversal (EDR). A residual with leachate concentrate is produced that requires final disposal. The leachate constituents are concentrated and not destructed.
2. **Destruction Technologies:** These technologies remove constituents from the liquid stream via biological, chemical, or thermal reactions that alter the molecular structures of the constituent of interest. Example technologies include aerobic or anaerobic biological treatment, advanced oxidation processes (AOP), electrochemical oxidation (EO), or incineration.

Within each of these broad categories there are a plethora of technologies variants with a smaller subset demonstrated for leachate treatment with efficacy for treatment of typical leachate constituents such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pharmaceuticals and personal care products (PPCPs), PFAS, nitrogen compounds, and 1,4-Dioxane. Due to the diverse suite of constituents found in leachate, multiple technologies may be required to achieve a particular set of treatment requirements (depending on concentration targets).

Technologies found to be effective for treating leachate include:

- **Biological treatment:** Particularly SBRs, MBBRs, and MBRs for organics and nitrogen
- **Chemical precipitation:** primarily for metals
- **Membranes:** ultrafiltration (UF), nanofiltration (NF), reverse osmosis (RO) for solids, colloids, salts, organics, metals, and virtually all other constituents. Specific membrane type depends on target constituents
- **Electrochemical oxidation:** ammonia and COD/BOD
- **Activated carbon:** trace organics and PFAS
- **IX resins:** ammonia, metals and other inorganics, and PFAS.
- **Concentrator:** Volume reduction of leachate or concentrates

It is important to note that adequate leachate storage and equalization are critical to the operation of any of the processes noted above. Both flow and concentration dampening through equalization are needed to maintain consistent performance (effluent quality) and to avoid oversizing of the treatment process to manage temporary fluctuations in volume and concentrations of constituents. The site currently has a 438,000-gallon leachate storage tank and plans to install a second identical tank. These two tanks would provide up to approximately 18 days of storage at a daily leachate flow of 50,000 gallons per day (gpd). Equalization residence time would be approximately five days if the tanks are operated at a 30 percent full operating level. This volume provides adequate flow and concentration dampening based on experience with other leachate treatment facilities.

Future leachate flows are projected to increase to approximately 100,000 gpd with peak wet weather flows potentially approaching 1.0 million gallons per day (MGD). Future average conditions would result in approximately 9 days of storage (2.5 days if tanks are operated at 30 percent full). This is marginal for typical operations and additional tankage may be needed in the future. During a wet weather event, a combination of storage and disposal will be required to mitigate leachate retention within the landfill. However, it is typical that landfill leachate retention occurs for short durations during transient wet weather events. Approaches to mitigate leachate production have been successfully implemented at the site and should be aggressively applied in the future.

1.1 Report Organization

This Report is organized as follows:

- Section 2: Emerging Contaminants
- Section 3: Applicable Treatment Technologies
- Section 4: Technology Application for Disposal Options
- Section 5: Leachate Concentrate
- Section 6: Class 5 Opinion of Probable Capital Cost and O&M Cost Comparison
- Section 7: Results
- Section 8: References

Section 2

Emerging Contaminants

As the terminology implies, emerging contaminants are those that traditionally have not been regulated and have not required treatment. Regulators are in the process of establishing rulemaking to potentially regulate emerging contaminants due to concerns regarding potential impacts to human health and the environment. Current examples relevant to leachate include PFAS compounds (particularly perfluorooctanoic acid [PFOA] and perfluorooctanesulfonic acid [PFOS]), 1,4-Dioxane, and PPCPs. PFAS and 1,4-Dioxane have been identified as present in various leachate samples nationally; as have PPCPs. Thus far, no regulatory limits or goals for PPCPs have been established while the United States Environmental Protection Agency and individual states have established health advisories and action limits for PFAS and 1,4-Dioxane.

Of special interest and focus for this evaluation is PFAS (i.e., PFOA and PFOS). Vermont has established health advisories for five PFAS compounds (PFOA, PFOS, perfluorononanoic acid [PFNA], perfluorohexane sulfonate [PFHxS], and perfluoroheptanoic acid [PFHpA] at 20 nanograms/liter [ng/L]) and preventive action levels (PAL) of 10 ng/L. There are thousands of PFAS compounds, as well as related compounds such as Gen-X, that are under evaluation by regulators.

As with typical leachate constituents, technologies that are applicable for removal of emerging contaminants are either concentrating or destructive in their mechanism for removal. The primary focus for research conducted on PFAS removal has been on comparatively clean liquid matrices (compared to leachate) such as drinking water and groundwater due to their potential for human contact and ingestion. There is limited information available regarding treatment of PFAS in a complex matrix such as leachate. Many of the advanced technologies that have been applied, or are in the research stage, for treatment of PFAS in groundwater or drinking water are not directly applicable to leachate due to the presence of interfering constituents (e.g., solids, COD, salts, metals) that are not present in a clean matrix. Pretreatment of leachate can be applied to improve the efficacy of technologies targeting PFAS.

Given the objective of identifying treatment systems to comply with various disposal option treatment requirements, the universe of available technologies for removal of typical leachate constituents as well as emerging contaminants can be reduced to those that have been proven for treatment of leachate and those that have been proven for emerging contaminant (particularly PFAS) removal and that are compatible with either raw or pretreated leachate and are at a maturity level for full-scale implementation. Examples of technologies that have been identified for potential removal of PFAS that were not considered for this application due to the level of technology maturity or incompatibility with leachate include:

- **Foam fractionation** - Not demonstrated with leachate or PFAS treatment to low parts per trillion (ppt) concentrations
- **Immobilized fungi degradation of PFAS** - Not demonstrated with leachate or PFAS treatment to low ppt concentrations
- **Direct treatment with GAC** - GAC fouling and premature breakthrough
- **Biochar adsorption** - Less effective than GAC or resins, non-regenerable
- **Direct treatment with IX resins** - Resin fouling and premature breakthrough

- **Boron-Doped Diamond (BDD) anode EO** - Not demonstrated with leachate nor at full scale; Anode production challenges
- **Titanium Dioxide anode EO** - Not demonstrated with leachate nor at full scale; Anode production challenges
- **EC** - PFAS removal not demonstrated with leachate
- **Sonolysis** - Not demonstrated with leachate nor at full scale.
- **AOP** - Not applicable due to high concentrations of competing oxidizable organic material in leachate coupled with limited proven effectiveness on PFAS compounds; By-product formation such as perchlorate and bromate.
- **Reductive defluorination** - Not applicable due to high concentrations of competing organic material in leachate coupled with limited proven effectiveness on PFAS compounds
- **Anaerobic defluorination** - Not demonstrated with leachate or proven to be effective with PFAS compounds
- **Carbon nanotubes** - Not proven with leachate and not commercially available
- **Thermal distillation** - Not proven with leachate or for PFAS removal
- **Plasma arc thermal destruction** - High energy, not suitable for high volumes, not commercially proven
- **Incineration** - Not feasible for significant volumes of leachate. Air emission issues; Hydrofluoric acid and other by-products formation in emissions; Requires up to 30-minute contact time at >1,000 degrees Celsius for destruction.
- **Electrodialysis** - Not demonstrated with leachate for PFAS removal

Section 3

Applicable Treatment Technologies

This Section summarizes the list of treatment technologies that have been identified as applicable for leachate treatment. Table 1 presents information on technology suppliers that were contacted. Table 2 present a comparison of the leachate treatment technologies.

3.1 Membrane Bioreactor (MBR)

The MBR process consists of a standard activated sludge configuration except that a UF membrane is used for solids/liquid separation rather than gravity separation using a clarifier. Biomass (microorganisms) are used to biodegrade organic components in the leachate. Inorganics such as nitrogen, phosphorus, and metals, are removed via sorption or through biological nitrification of ammonia. The biomass is continually recirculated in the system and excess biomass is periodically removed (wasted) for disposal as a sludge. The system operates aerobically. The UF membranes prevent suspended solids and biomass from passing through to the effluent, thus producing a high-quality effluent that is suitable for further treatment via physical–chemical processes. The MBR can operate at higher (two to three times) biomass concentrations as compared to conventional activated sludge or SBR systems. MBRs have been used successfully in numerous leachate applications. Biological treatment will have little impact on removal of PFAS compounds as they are essentially non-biodegradable. There may be some removal via sorption to biomass. However, aerobic treatment will result in oxidation of PFAS precursor compounds which may otherwise pass through other technologies. Effluent concentrations of PFOA and PFOS have been higher than influent concentrations in POTWs in some instances due to transformation of precursor compounds through aerobic biological treatment. The MBR process is considered a potential technology for either a DSW or pretreatment disposal option when coupled with other technologies targeted towards PFAS removal.

3.2 Granular Activated Carbon (GAC)

GAC is a proven technology for removal of organic compounds in wastewater. Note that some inorganics, such as heavy metals, may also be removed incidentally. GAC removes constituents through adsorption and is not selective on the constituents removed. GAC is established as an effective technology for removal of PFAS (particularly long-chain compounds such as PFOA and PFOS). GAC is less effective for short-chain PFAS compounds (e.g., less than six carbon atoms). PFAS removal efficiency and the rate of carbon usage are impacted by other constituents (e.g., COD) that compete for adsorption sites. GAC is not suitable for direct treatment of raw leachate due to the high concentration of organic material present in leachate that would reduce adsorption efficiency of PFAS and other emerging constituents that are present at comparatively low concentrations. Additionally, the high organic content of raw leachate will quickly exhaust available adsorption capacity resulting in frequent carbon replacement. GAC is suitable only as a polishing step after pretreatment for removal of organic material. The GAC must be replaced when capacity is exhausted. Batch isotherm testing was conducted on POTW effluents from Montpelier and Newport to estimate the carbon usage rate and costs for GAC polishing of POTW effluent for PFAS removal (see Appendix D). Expected GAC usage (and associated costs) are based on testing of only a single sample from each POTW (Montpelier and Newport) and are therefore subject to significant wastewater and leachate variability and uncertainty for long-term operations. The exhausted GAC can either be disposed onsite or off-site or reactivated off-site. The thermal regeneration process results in PFAS destruction if conducted at temperatures of approximately 1,000 degrees Celsius or higher (1,300 degrees Celsius has been reported). Thermal regeneration byproducts are of continued interest and concern and require further investigation. Research is ongoing regarding the required conditions for destruction and the potential for generation of combustion byproducts. Pretreatment prior to GAC could consist of biological processes (e.g., MBR or activated sludge), RO, or EO. GAC is suitable as an effluent polishing process for POTW effluent but would also likely require a pre-filtration process to prevent fouling.

3.3 Ion Exchange (IX) Resins

IX resins function by preferentially exchanging anions or cations (depending on the resin) for target compounds. Resins tailored to PFAS removal are anion exchange type. Resin adsorption capacity for PFAS can be reduced by other competing anions such as chloride and sulfate that are found in leachate at elevated concentrations. Depending on the resin, the exhausted media may be regenerated, or the exhausted resin may be disposed. If regenerated, the regenerate solution containing the target constituents must be disposed. The target constituent concentrations in the regenerate are typically 20 to 100 times those in the wastewater applied to the resin; thus, the resin serves to only concentrate leachate constituents. Some resins are intended for single use and are disposed and replaced after capacity is exhausted. Resin disposal may consist of incineration or stabilization and placement in a landfill.

Resins have been developed that specifically target PFAS compounds and have greater adsorption capacity (approximately 10 times that of GAC) compared to GAC along with higher media cost. Resins are also adversely impacted by dissolved ions. As with GAC, these resins are intended for comparatively clean wastewaters to avoid fouling and therefore are only applicable for final polishing after significant pretreatment to remove other constituents that interfere with resin functions. Resins developed for PFAS removal are more typically single use type and are disposed after adsorption capacity is exhausted although regenerable resins are available. The regenerate solution containing the PFAS that is desorbed from the resin would require final disposal. Resins can be used effectively on effluent from GAC to further reduce PFAS concentrations and can be more effective on short chain compounds.

3.4 Ultrafiltration (UF)

UF can be operated as a standalone process as well as part of an MBR system. In a standalone configuration the UF serves to remove solids and some larger molecular weight organic material (e.g., oils and grease) that may interfere with downstream systems such as RO, GAC, or IX. The UF system results in a leachate concentrate stream that requires disposal in this configuration. As part of an MBR process, UF provides solids/liquid separation in lieu of a gravity clarifier. The UF would not remove PFAS, ammonia, COD, VOCs, SVOCs, metals, or other emerging compounds other than those sorbed to solids but is applicable as a pretreatment step prior to other advanced processes or as part of an MBR system. Conventional RO can be used directly following UF without additional pretreatment.

3.5 Reverse Osmosis (RO)

RO is a separation (filtration) process that uses a membrane to separate and concentrate constituents at the molecular level from water via high pressure. RO is effective at removing PFAS and most other leachate constituents by concentrating contaminants into a side-stream that must be subsequently managed (e.g., via destruction or sequestration of contaminants). RO has reduced efficacy with lower molecular weight compounds such as VOCs and short chain PFAS. In most cases, RO requires a very clean influent to prevent membrane fouling. In a leachate application, conventional RO membranes (e.g., spiral wound) require prefiltration by UF, and perhaps NF, as well as removal of most organic material to reduce/prevent fouling. As such, conventional membranes are suitable as a final polishing step only when coupled with other technologies for pretreatment such as MBR. Conventional RO has been used successfully with pretreated leachate (e.g., after MBR) with a typical leachate concentrate volume of 30 percent of the feed volume. Thus, the leachate concentrate has about three times the concentration of constituents of the RO influent and must be disposed. Conventional RO has been shown to remove PFAS to below about 5 ng/L and in some cases below detection limits (less than 2 ng/L) but effluent (permeate) concentrations vary depending on the specific compound and overall liquid matrix characteristics. Permeate concentrations are dependent, in part, on influent concentrations since compound rejection percentage is relatively constant. Hence, increased influent concentrations result in increased effluent concentrations although the percent removal is similar. Accordingly, it is important that constituents in the RO leachate concentrate be effectively sequestered prior to disposal to avoid re-entrainment into the leachate and subsequent increases in raw leachate concentrations if the leachate concentrate is to be placed back in the landfill for disposal.

A variant of RO is NF, which is often termed a “loose” RO membrane (i.e., with slightly larger pores). NF has been shown to partially (approximately 90-99%) remove long-chain PFAS compounds (e.g., PFOA/PFOS) but is less effective with lower molecular weight long-chain compounds and short-chain compounds. The removal efficiency of PFOA/PFOS is also less than RO which may make this technology applicable for pretreatment disposal options although it may not address future regulatory requirements satisfactorily. It would likely not be efficient at removal of 1,4-dioxane as compared to RO but may remove some PPCPs (those with high molecular weights).

A different RO configuration is offered by Rochem Americas (Rochem) that has been demonstrated to operate effectively on raw leachate (with preliminary filtration at 10 microns [µm]). The Rochem system uses an alternative membrane construction with a high crossflow velocity to reduce fouling coupled with higher operating pressures than conventional membranes (up to about 1,800 pounds per square inch). Rochem reports achieving PFAS concentrations for a broad list of PFAS compounds, including those detected at NEWSVT, to below detection limits (less than 2 ng/L) in raw leachate applications using a two-stage system (>99.9% removal). Removals to about 5 ng/L can be achieved with a single stage system. Rochem also offers a three-stage system that improves permeate recovery, thus potentially reducing leachate concentrate to approximately 12-15 percent of RO feed volume.

3.6 Electrochemical Oxidation (EO)

EO utilizes an electric charge distributed to the leachate via submerged anodes and cathodes and addition of oxidizing agents or catalysts to produce hydroxyl radicals, and to change the chemical structure of constituents (loss of electrons in one chemical, to create a gain of electrons in another), ozone, and hydrogen peroxide. These oxidizing species mineralize organic and some inorganic (e.g., ammonia) species. The process may serve as part of an overall treatment train for pretreatment prior to advanced processes targeting PFAS or other emerging contaminants. EC has generally not been demonstrated to provide significant and sustainable removal of PFAS in a complex matrix at large scale. Complex anode formulations (e.g., BDD) have shown promise at bench scale but are not demonstrated or available at a commercial level. One supplier (Xogen) claims to achieve high removal of organics (e.g., COD) and ammonia in leachate. The EO process may be applicable as a pretreatment process upstream of the technologies targeting PFAS.

3.7 Electrocoagulation (EC)

EC is similar to EO in that it uses an electric charge to change the charge properties of dissolved and suspended material to allow for agglomeration (coagulation) into solids that can be removed from the liquid. An anode and cathode are typically used, and the anode materials can be customized depending on the target constituents. EC has not been demonstrated for PFAS removal in leachate as a stand-alone process. No oxidizing agents are typically added. EC often precedes EO.

One supplier (HTX) claims to achieve complete PFAS removal although they also employ GAC as a polishing step. Their system also produces a concentrated PFAS residual that requires disposal. E2metrix offers an EC unit but does not have data for PFAS removal. This would be considered a pretreatment technology upstream of a PFAS removal technology.

3.8 Concentrator

Concentrator technology consist of concentrating constituents in the leachate by removal of water using thermal processes. The leachate is heated sufficiently to form water vapor which is vented to the atmosphere. Some constituents, such as ammonia and VOCs, in the leachate are also partially emitted with the water vapor depending on their specific properties. Odor compounds such as mercaptans and reduced sulfides may also be emitted. Accordingly, thermal oxidation of concentrator emissions is required to eliminate potential odor concerns. Air permitting would be required as well.

At a landfill, energy for heating the leachate can be obtained from waste heat (e.g., from a flare or engines used for generation of electricity), directly from combustion of LFG, or alternative fuels such as propane, natural gas, or fuel oil. The NEWSVT has up to 900 standard cubic feet per minute (SCFM) of excess LFG (approximately 46 percent methane) available that can be used for evaporation. Additionally, there are five (5) Cat 3520 engines that can supply waste heat. The LFG can also be supplemented with propane to provide adequate heat for the concentration of the required liquid volume or for thermal oxidation of air emissions.

A concentrator technology provided by Heartland Technologies was reviewed as it can operate on waste heat. This technology uses indirect combustion heating where LFG is combusted in a flare and the combustion product (exhaust) is directed to a concentrator where the volume reduction occurs. The concentrator can reduce the leachate volume by approximately 95 percent, resulting in a 20-fold increase in constituent concentrations in the resulting leachate concentrate. Assuming the leachate concentrate is to be placed back in the landfill, it would likely require sequestration or solidification to prevent re-entrainment into the waste mass and leachate.

Lastly, the concentrator process has the potential to emit constituents to the atmosphere. Concentrator technology is widely used for leachate management, and air permitting has not been problematic in most jurisdictions. Air emission testing of a concentrator (not by Heartland) evaluated non-methane organics, carbon monoxide, nitrogen oxides, arsenic, and total chromium. The reported emissions were deemed satisfactory for release without additional air emission controls. The combustion product emissions (NO_x, CO, SO_2) will not be greater than those from the current flare unless supplemental fuel (propane) is used. VOC emission will be on the order of 0.7 tons/year at a leachate flow of 50,000 gpd.

Emissions of PFAS has not been determined for leachate concentrators based on a cursory review of the literature and discussions with Heartland. Based on the physical properties of PFAS compounds, emission rates are expected to be low (e.g., less than one percent of concentrator feed) given their low volatility and high solubility in water. However, it is likely some PFAS compounds will be emitted and the associated risks should be considered. Also, note that there will be a visible water vapor plume. A thermal oxidation, or similar, process would be required to address potential odor concerns as well as other possible emissions (e.g., PFAS and VOCs). Air emission controls will increase CapEx, and OpEx costs and operational complexity.

An alternative concentrator technology (Mechanical Vapor Recompression) that produces a distillate could be considered to significantly reduce potential odor and PFAS emissions. However, this technology is significantly more complex, is not routinely used on leachate, has a higher cost, does not operate on waste heat, and produces a liquid stream that may require additional treatment prior to discharge. This technology would likely only be considered in the event that air emission concerns could not be resolved with a conventional leachate concentrator. Other innovative technologies such as vacuum membrane distillation may be of potential interest but are not proven with a leachate concentrate.

Section 4

Technology Application for Disposal Options

This section describes the selected treatment options for each disposal route.

4.1 Scenario 1 – Discharge to Surface Water

The DSW disposal scenario requires a high level of treatment for compliance with anticipated discharge limits. There are a number of challenges and uncertainties associated with a discharge to surface water including:

- Negative public perception associated with discharge to surface water
- Permitting approval challenges (National Pollutant Discharge Elimination System, air)
- No limits established for PFAS
- Concentrate requires sequestration/solidification or off-site disposal
- Does not eliminate PFAS at site unless concentrate is disposed off-site via incineration/cement kiln/deep well or alternative disposal site
- Concentrate impact on airspace thus reducing landfill life
- Air emissions from concentrator (if used), odor concerns
- Capital and O&M costs

Based on experience with leachate treatment and the need to achieve a high-quality effluent with PFAS concentrations effluent with PFAS concentrations less than 20 ng/L, three treatment options have been identified:

- **Option 1a:** Standalone RO with GAC (and/or IX) with or without leachate concentrate volume reduction
- **Option 1b:** MBR plus RO and IX, with or without leachate concentrate volume reduction
- **Option 1c:** EO plus UF, RO, and IX, with or without leachate concentrate volume reduction

The selected treatment trains reflect the need to produce a high-quality effluent suitable for direct discharge. Options 1a, 1b, and 1c incorporate RO and Options 1b, and 1c incorporate IX for final polishing for PFAS removal. Option 1a consists of a Rochem RO system while Options 1b and 1c consist of a conventional RO system due to lower cost compared to the Rochem RO system and associated pretreatment. GAC and/or IX is provided for polishing after RO in the event that some regulated PFAS compounds and VOCs are not adequately removed by RO alone. IX would be incorporated should short-chain PFAS compounds that may not be adequately removed by RO alone become regulated in the future since GAC is not as effective on short chain compounds. All the options with RO will require a remineralization step to make the final effluent suitable for discharge to comply with whole effluent toxicity (WET) limits. Thermal leachate concentration would be provided with each alternative to reduce final leachate concentrate volumes and associated sequestration/solidification volumes and impacts on the landfill. Thermal concentration would include a thermal oxidizer, or similar, for odor mitigation in all cases.

To provide additional assurance for continuous compliance, routine monitoring of select operational and performance parameters would be conducted. Note that each process employs a “belt and suspenders” approach where the primary treatment process is backed up by a secondary process to remove constituents that may have not been adequately removed in the primary process. The secondary treatment step is selected depending on the type of constituents most likely to pass through the primary process. GAC provides removal of a broad spectrum of contaminants (both organics, including PFAS, and, to a lesser extent inorganics) while IX is targeted towards PFAS.

Option 1a. This approach uses the Rochem RO system and does not require biological pretreatment. The raw leachate feed would be pumped through inlet strainers to a feed tank. The pH in the feed tank would be adjusted to approximately 5.5-6 to optimize ammonia removal. Then, the pH-adjusted feed would be processed through media filters and cartridge filters for gross solids removal and to minimize membrane fouling. The media filters are installed in parallel with designated retention of particles 10 µm and larger. The media filters are backwashed with raw feed and an air scour system to minimize the backwash flow. The backwash from the filters is combined with the Rochem RO leachate concentrate stream. The cartridge filters are double open-end units constructed of propylene and are 20 inches long with a nominal rating of 10 microns and installed in two parallel filter housings. Media filter effluent is dosed with an antiscalant to minimize scaling of the downstream RO membranes.

The Rochem RO system would be configured as a three-stage RO unit to minimize leachate concentrate volume combining a 1st stage RO to treat the raw leachate, a 3rd stage RO to treat the leachate concentrate from the first stage for higher recovery, and a second stage permeate polishing system to treat the permeate from the first and third stages for improved quality. A variable frequency drive (VFD)-controlled high-pressure positive displacement pump delivers feed flow to the feed/leachate concentrate manifold, where recirculation pumps feed parallel banks of RO membranes connected in series. It is anticipated that the RO system can achieve a recovery of up to approximately 88 percent, which results in a leachate concentrate flow of about 6,000 gpd at a raw leachate flow of 50,000 gpd. A leachate concentrate volume of 10,000 gpd (80 percent recovery) has been assumed due to unknowns that could impact long-term recovery. The RO leachate concentrate from the third stage can be further concentrated by a concentrator followed by sequestration/solidification prior to landfill disposal. The concentrator can provide approximately 90-95 percent volume reduction. Due to the small volume of leachate concentrate, available LFG at the site can provide both volume reduction as well as concentrator off-gas combustion for odor destruction.

The RO permeate (from second stage) would be treated through liquid-phase GAC to remove low molecular weight compounds such as VOCs and residual PFAS that may pass through the RO membranes. IX could be added or substituted for GAC if additional PFAS compound removal was required.

Final effluent undergoes remineralization so that it’s suitable for discharge to comply with WET limits. A simple block flow diagram for Option 1a is represented in Figure 1.

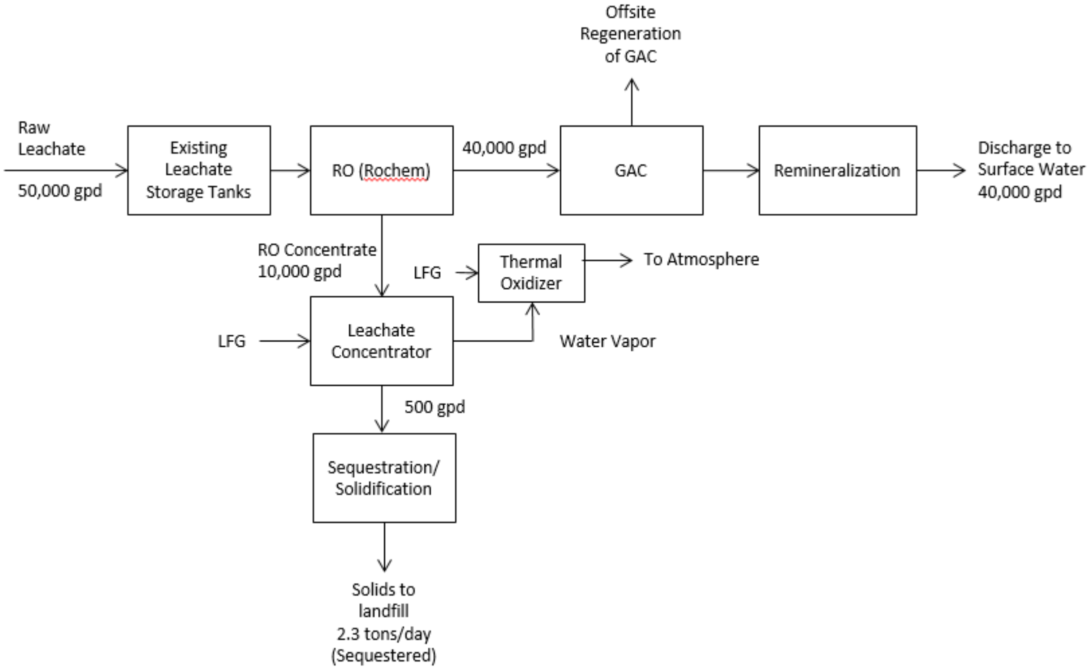

Figure 1. Block Flow Diagram for Option 1a

Option 1b. Under this approach, organics such as VOCs are degraded biologically in the MBR system. Similarly, other compounds such as BOD and ammonia-nitrogen are treated through the MBR system. The MBR system consists of an activated sludge (aerobic) tank and a UF system. The aerobic tank is a 100,000-gallon bolted steel tank equipped with a jet aeration system, jet mix manifold, nozzles, and two positive displacement blowers. Odors are not typically encountered when treating leachate with complete mix biological treatment systems since the contents in the aeration tank are the same quality as the effluent (other than biomass solids) due to oxidation and biodegradation of contaminants and odor compounds. The tank would be covered for heat conservation and the off-gas could be vented to a biofilter for preventative odor control.

The UF membranes are 8-inch diameter by 4 meters long, tubular-type membranes. Each membrane housing contains eight-millimeter (mm) diameter membrane tubes. The unit has three modules installed with the ability to add two additional membranes for additional (e.g., future) capacity. UF membrane pore sizes between 0.03 to 0.05 µm are commonly used to achieve suspended and colloidal solids removal. Mixed liquor would be recirculated through the UF membrane system and returned to the aeration tank. Excess sludge would be wasted from the process periodically to maintain biomass inventory. The system has a clean-in-place (CIP) system for fouling that accumulates in the membrane walls. Typically, CIP cleaning sequences are conducted using an acidic solution, an alkaline solution, and sodium hypochlorite. Air-operated diaphragm pumps are provided to deliver the cleaning chemicals to the make-down tanks.

UF permeate would be subsequently treated through a conventional RO system. The RO system components include 8-inch diameter RO membranes, pressure vessels, VFD-controlled feed pumps, and a CIP system. Conventional RO will result in a leachate concentrate volume of about 30 percent of the influent volume, or about 15,000 gpd at a leachate flow of 50,000 gpd. A simple block flow diagram for Option 1b is represented in Figure 2.

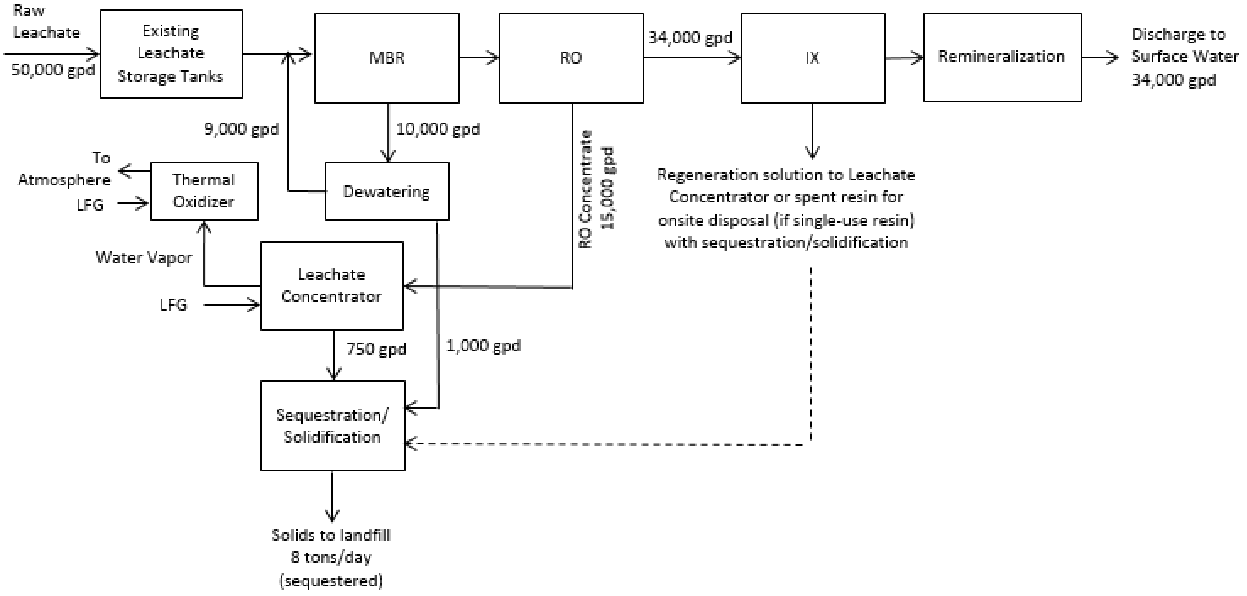

Figure 2. Block Flow Diagram for Option 1b

Option 1c. Under this approach, Organics are oxidized, and ammonia-nitrogen is destroyed in the EO process. Gases resulting from the EO process include hydrogen, oxygen, nitrogen, and carbon dioxide. An EC process may be used in conjunction with EO to improve treated water quality.

A simple block flow diagram for Option 1c is represented in Figure 3.

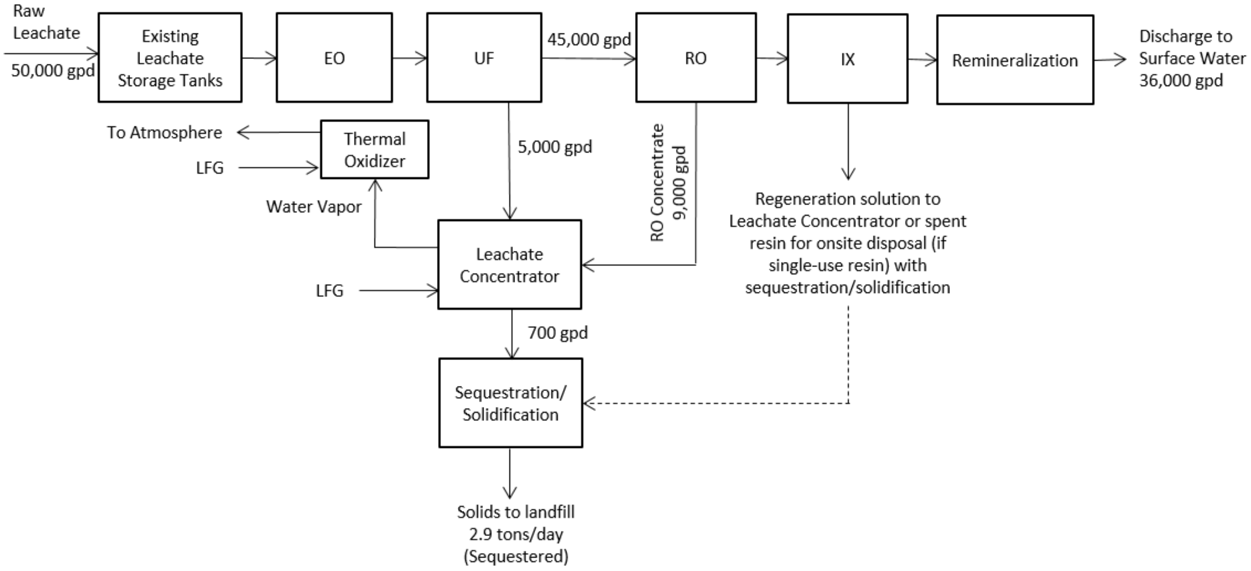

Figure 3. Block Flow Diagram for Option 1c

4.2 Scenario 2 – Pretreatment for POTW Disposal

Three options were identified for pretreatment to reduce PFAS loadings to POTWs. These options could be implemented either at the landfill or at a POTW. Adequate space would be required at the POTW for the pretreatment system and tank storage. This may limit future POTW expansion or upgrades. This scenario has a number of challenges and limitations:

- Casella would be fully dependent on POTWs for leachate disposal thus limiting the ability to control costs
- Only partial pretreatment for PFAS is practical. Full PFAS treatment results in discharge of clean water to the POTW
- Contract challenges to establish ownership, maintenance and operations responsibilities and liabilities
- Reliance on others for operation (e.g., PFAS pass-through)
- Long-term commitment requirement
- Requires continued hauling to POTW and return hauling of concentrate to NEWSVT
- Potential long lead time for implementation (P3 project)
- Air emissions from concentrator (if used for residuals) including odor concerns and PFAS
- Public perception due to air emissions
- Permitting challenges (air)
- Concentrate requires sequestration/solidification or off-site disposal
- Concentrate impact on airspace
- Does not eliminate PFAS at site unless concentrate disposed off-site via incineration/cement kiln/deep well or alternative disposal site)

If implemented at a POTW the leachate concentrate would be returned to the landfill for final processing (e.g., concentrator and/or sequestration/solidification). For purposes of this evaluation, it was assumed that pretreatment to achieve a 50 percent reduction in PFAS loadings would be required. In practice, the percent reduction can be modified as needed to comply with regulatory or other requirements by adjusting treatment process capacity.

- **Option 2a:** Standalone RO with or without leachate concentrate volume reduction
- **Option 2b:** EO plus UF and RO with or without leachate concentrate volume reduction
- **Option 2c:** MBR plus GAC

Option 2a. This option uses the Rochem NF or RO process to reduce approximately 50 percent of the leachate PFAS load. Additional polishing steps, such as IX, could be added if needed for new or more stringent limits. The leachate concentrate (3,000 gpd) would be sequestered/solidified for on-site disposal. A concentrator could be used to reduce the leachate concentrate volume to approximately 300 gpd. Due to the small volume of leachate concentrate, available LFG at the site can provide both volume reduction as well as concentrator off-gas combustion for odor destruction.

A simple block flow diagram for Option 2a is represented in Figure 4.

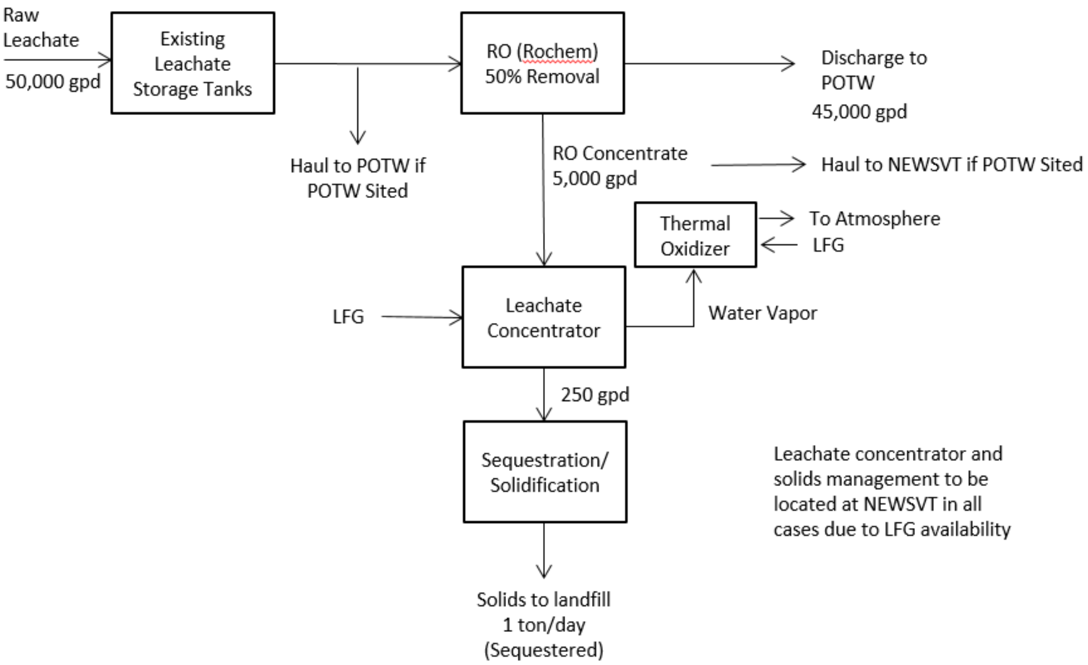

Figure 4. Block Flow Diagram for Option 2a

Option 2b. This option utilizes EO to remove organics and ammonia as well as oxidize PFAS precursors. The EO unit would be followed by UF for removal of solids and a final polishing step of GAC, IX, or RO depending on the efficacy of PFAS-removal by the EO system. One vendor (HTX) claims to remove PFAs to below detection limits with their process (which includes a GAC step). Other EO providers do not claim PFAS removal and require effluent polishing for PFAS removal. The system would be designed to provide approximately 50 percent removal of PFAS and precursor compounds.

A simple block flow diagram for Option 2b is represented in Figure 5.

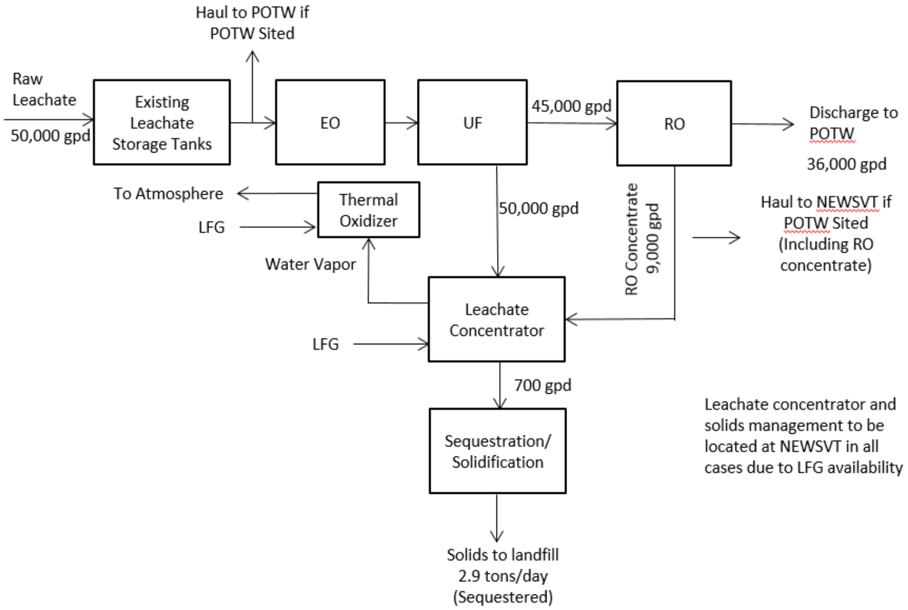

Figure 5. Block Flow Diagram for Option 2b

Option 2c. In this process an MBR is used to remove organics and ammonia such that liquid phase GAC adsorption capacity is not rapidly consumed by organic material. The MBR will also provide oxidation of PFAS precursors such that they are removed and not passed on to the POTW. The GAC would provide polishing of organics and target PFAS compounds as well as other non-biodegradable emerging contaminants such as 1,4 Dioxane and PPCPs. The IX resin also provides removal of PFAS compounds. Waste sludge from the MBR would be dewatered and placed in the landfill. GAC would be regenerated off site which would result in destruction of adsorbed PFAS compounds and other constituents. IX resin (e.g., single use) would be disposed on site (with sequestration/solidification) or off site.

A simple block flow diagram for Option 2c is represented in Figure 6.

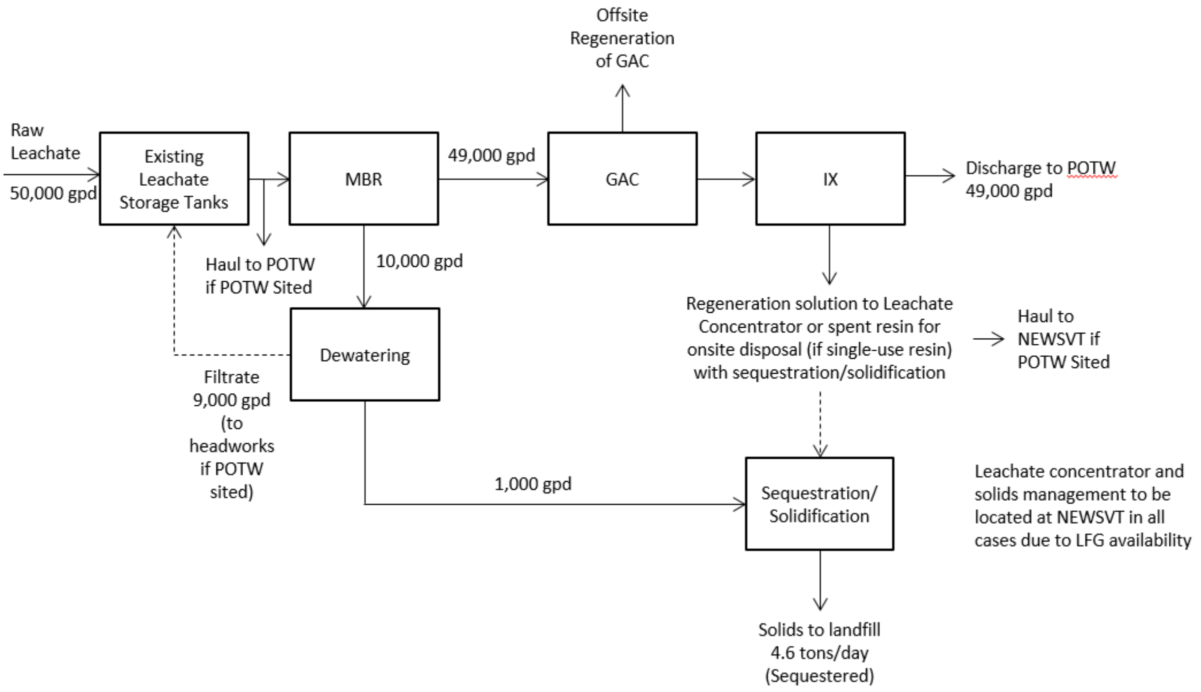

Figure 6. Block Flow Diagram for Option 2c

4.3 Scenario 3 – Zero Liquid Discharge

Option 3a. The ZLD option would use a concentrator (Heartland Technologies) to reduce leachate volume. Leachate concentrate would contain concentrated constituents and would require disposal via sequestration/solidification. This Scenario has a number of significant challenges and uncertainties:

- Air emissions concerns (odor, PFAS) and permitting
- Public perception due to air emissions
- Requires significant supplemental propane and associated cost
- Requires siting at energy plant for waste heat utilization
- High concentrate volume
- Concentrate requires sequestration/solidification or off-site disposal.

- Does not eliminate PFAS at site unless concentrate is disposed off-site via incineration/cement kiln/deep well or alternative disposal site
- Concentrate impact on airspace thus reducing landfill life
- Insufficient waste heat and LFG for current and future capacity
- Capital and O&M costs

The leachate concentrate volume at a leachate flow of 50,000 gpd would be approximately 2,500 gpd. The leachate concentrate would be solidified using a solidifying agent such as fly ash or Portland cement (or other materials developed for PFAS) or otherwise sequestered to prevent re-entrainment of PFAS into the landfill mass and leachate. The actual solidification agent for PFAS solidification would need to be validated as there is currently no information available. Non-porous geotubes or bulk bags could also be used to sequester the leachate concentrate. Operations would require periodic cleaning of certain concentrator components and management of leachate concentrate. Supplemental fuel (e.g., propane) may be required for thermal oxidation for odor control since the currently available LFG volume of 900 SCFM, is only adequate to concentrate approximately 50,000 gpd of leachate if waste heat is not used.

The concentrator system consists of an enclosed flare, hot gas transfer system and the concentrator with a thermal oxidizer. The concentrator would require approximately 843 SCFM of LFG (at 48 percent methane) to process 50,000 gpd. The Site generates approximately 900 SCFM of excess LFG (46 percent methane), which is sufficient to concentrate approximately 50,000 gpd of leachate. The concentrator would need to be supplemented with other waste heat or propane gas to treat the off-gas via thermal oxidation. The concentrator can reduce the leachate volume by approximately 90-95 percent, resulting in about 2,500 gpd of leachate concentrate. Assuming the leachate concentrate is to be placed back in the landfill, it would likely require sequestration/solidification to prevent re-entrainment into waste mass and leachate.

A simple block flow diagram for Option 3a is represented in Figure 7.

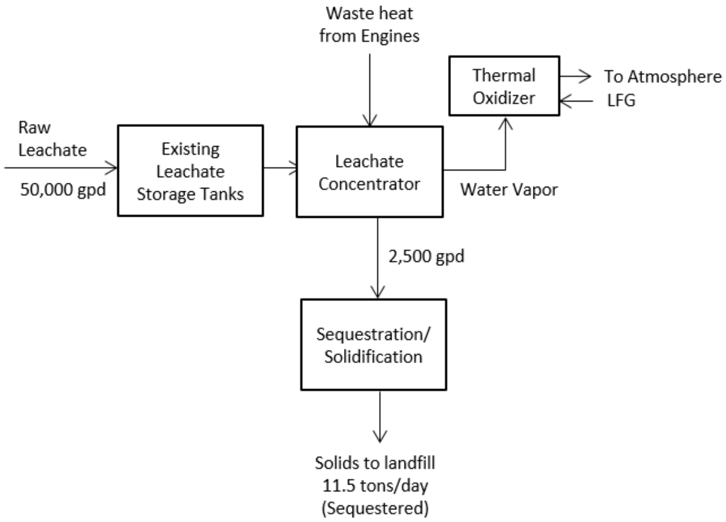

Figure 7. Block Flow Diagram for Option 3a

4.4 Scenario 4 – POTW Enhancements

Options 4a and 4b. These options would consist of adding PFAS removal capability at a designated POTW that receives leachate from NEWSVT. This approach consolidates PFAS management at POTWs rather than the landfill but has a number of challenges and limitations:

- Limited space for improvements at POTW both near-term for PFAS treatment and long-term for other POTW improvements or expansion
- Casella would be fully dependent on POTWs for leachate disposal thus limiting the ability to control costs
- Contract challenges associated with project funding
- Reliance on others for compliance (e.g., PFAS pass-through)
- Long-term commitment for treatment
- Continued leachate hauling is required
- Potential long lead time for implementation (P3 project)
- Requires increased disposal volume allowance from VTDEC. Upgrades are required at either Newport or Montpelier to accept all NEWSVT leachate
- POTWs may become capacity limited in the future

This would likely consist of filtration and GAC treatment of current POTW effluent for removal of PFAS. Exhausted GAC would be reactivated off-site at a temperature sufficient to result in destruction of PFAS and other adsorbed constituents. IX effluent polishing may also be required or used in lieu of GAC depending on final discharge requirements and POTW effluent quality. IX would either be a single use type requiring disposal via incineration or stabilization/landfilling or a regenerable type that would produce a regenerate solution requiring similar disposal. GAC was chosen at this time as it provides a greater breadth of contaminant adsorption and is not affected by dissolved ions commonly found in leachate and domestic wastewater. This approach would also provide removal of PFAS not associated with leachate that is present from undefined sources in POTW influent.

The system would be sized to handle the design average daily POTW flow which results in significant CapEx and OpEx costs, although the apportionment of both to NEWSVT could be negotiated. For this evaluation we have assumed NEWSVT's contribution would be the full capital cost and current disposal (transportation and disposal) cost. In practice, it is possible that cost sharing with the municipality could be negotiated to reduce capital and/or disposal costs. It is not possible to estimate these reductions given available information. Option 4a is identified for enhancements to the Newport POTW while Option 4b is for enhancements to the Montpelier POTW.

Contractual arrangements to secure long-term disposal rights and competitive rates would be needed to assure the long-term viability of this approach. Our experience is that these negotiations can be complex and require an extended time period. This option effectively eliminates the need for on-site treatment.

A simple block flow diagram for Options 4a and 4b is represented in Figure 8.

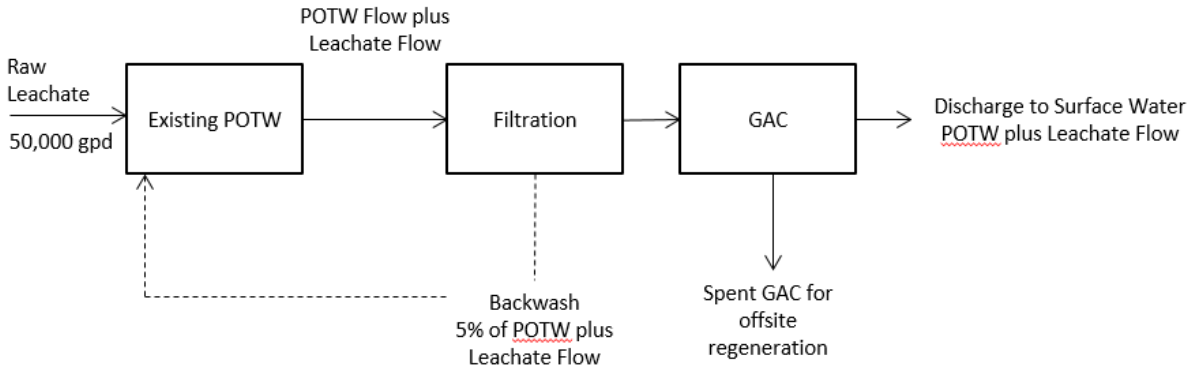

Figure 8. Block Flow Diagram for Options 4a and 4b.

Section 5

Leachate Concentrate

Due to the refractory nature of PFAS compounds, their removal results in a concentrated product that must be managed appropriately to mitigate the potential for re-entrainment to the leachate if the material is to be placed back into the landfill. Offsite disposal options for concentrate are limited (e.g., incineration, deep well injection, physicochemical destruction, or disposal at another landfill). These other disposal options are costly or infeasible as compared to on-site management.

5.1 Sequestration/Solidification

Residuals sequestration/solidification is anticipated as a method for improving the ease of handling and for mitigating re-entrainment of constituents from leachate concentrate resulting from treatment (e.g., RO leachate concentrate, concentrator leachate concentrate, used ion exchange resins, or sludges). There are varying anecdotal and published information on the potential for re-entrainment of constituents from RO and evaporation leachate concentrate if placed back into the landfill. Information suggests that the method of placement of leachate concentrate into the waste mass may have a significant impact on re-entrainment. Waste mass composition and the particular constituents of interest as well as the composition and characteristics of the concentrate material each also are factors.

There is insufficient information to identify a successful blend of solidification agents as the particular blend will depend on specific leachate concentrate characteristics and characteristics of the agent(s) (e.g., fly ash or Portland cement) as well as specific leaching characteristics of the constituents of interest. Research is underway to develop PFAS specific sequestering agents for leachate treatment residuals but commercially proven products are not currently available.

The report “Disposal of Aqueous Wastes in MSW Landfills, Utilization and Effectiveness of Bulking and Stabilization Strategies” (Environmental Research and Education Foundation [EREF], October 2018) provides helpful information on this topic. For example, fly ash, lime, cement kiln dust, or Portland cement are common solidification agents, but effectiveness and proportions can vary significantly depending on the chemical composition of the fly ash and the material to be solidified. Treatability testing is required to identify the preferred mix of solidification agents and liquid (e.g., leachate concentrate). Testing should include evaluation of leaching potential in a landfill environment (e.g., toxicity characteristic leaching procedure [TCLP], synthetic precipitation leaching procedure [SPLP], or multiple extraction procedure).

Typical ranges of solidification additives (on a mass basis) reported by EREF are:

- Portland Cement – 5 to 15 percent
- Fly ash – 15 to 80 percent

Testing of different materials and blends would be needed to identify the preferred approach in terms of cost, structural aspects, and leaching characteristics. For purposes of this evaluation and based on guidance from Casella, we have assumed a cost of $200/ton for materials, blending, and disposal in the landfill and to account for lost airspace.

The physical solidification process can be conducted in a variety of ways including mixing in a lined pit or tank with excavation equipment to processing through a device such as a pug mill. The actual method to be employed would be dependent upon NEWSVT preferences.

However, given the daily volume of leachate concentrates and local weather considerations, we recommend a dedicated system to blend the leachate concentrate and solidification materials. A duplex pug mill or similar equipment has been assumed. The blended material would be transported to the landfill for placement in roll-offs.

An alternative approach would be to sequester the leachate concentrate in a container such as non-porous geotubes or supersacks for placement in the landfill. In this way the material would be segregated from other waste material and leachate.

5.1.1 Classification of Final Concentrate Product

Due to the concentrating nature of several technologies such as RO and concentrators (evaporators), concentrations of contaminants in the leachate concentrate are increased by the factor of the volume reduction. This can increase concentrations to above hazardous waste regulatory limits under the Resource Conservation and Recovery Act. However, the determination of whether the leachate concentrates are hazardous is dependent on TCLP results. Note that leachate and associated sludges that contain PFAS are exempted as hazardous waste under VT 7-203(cc). Arsenic concentrations in leachate concentrate that would be solidified/sequestered could possibly be above the regulatory limit of 5 mg/L based on the projected average influent leachate arsenic concentration of 0.66 mg/L, depending on the factor of concentration. However, hazardous classification is based on the TCLP results rather than the concentration in the residual material. Solidification, as described previously, would be conducted to stabilize materials such as arsenic, PFAS and other compounds prior to TCLP analysis and transportation to the landfill. Sequestration as noted above would be an alternate approach applied if the leachate concentrate passed the TCLP test. It should be noted that there is no published information on full-scale immobilization of PFAS compounds in leachate concentrate or through solidification although it is known that research in this regard is underway with successful results reported anecdotally.

5.1.2 Potential Regulatory Requirements

If the concentrate/residue is shown to be a hazardous waste, the facility will be classified as a generator of hazardous waste and will need to conform to certain portions of the federal and Vermont hazardous waste regulations, including the generator regulations at 40 CFR 262. Section 262 incorporates some portions of the Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR 264). Portions of those rules that will be most applicable are design and operation of short-term storage and treatment units. On-ground tanks are recommended (see 40 CFR 260 for definition). Note that there is an exclusion from 40 CFR 264 for totally enclosed treatment facilities at 40 CFR 264(g)(5) which may be applicable to Casella. Solidified material that is in conformance with regulations would be disposed of in the landfill. As an alternate approach, sequestered material would be exempt from the hazardous waste regulations as per VT 7-203(cc) and would be transported to the landfill.

Section 6

Class 5 Opinion of Probable Capital Cost and O&M Cost Comparison

A planning level capital cost opinion was developed for the preferred on- and off-site options described in Section 4. These consisted of Options 1a, 2a, 3a, 4a, and 4b. These options were selected based on an evaluation of risks, benefits, and limitations. This capital cost opinion is considered an AACE International Class 5 estimate. A Class 5 estimate is performed when engineering is conceptual and is used to prepare planning level cost scopes or to evaluate alternatives in design conditions. The expected accuracy for a Class 5 estimate typically ranges from -50 percent to +100 percent but may have a lower range given the extent of cost and project definition. Several major assumptions have been made for the development of the cost estimate and are listed below:

- Site is the existing NEWSVT Landfill site located in Coventry, Vermont.
- Cost associated with additional equalization (EQ) Tank(s) is not included.
- Cost is based on a design flow of 50,000 gpd. Does not include additional equipment for future projected flow (Phase VI expansion).
- Costs do not include a sewer discharge line for on-site pretreatment options.
- Cost does not include yard piping from EQ Tanks to the future on-site leachate treatment plant (LTP) building, and from LTP building to surface water discharge point.
- Cost does not include working capital investment.
- Site will not need to be cleared and no significant site preparation is required (e.g., major earthwork, blasting, dewatering, or stormwater management).
- Site has adequate space for construction, staging, and lay-down, and no off-site storage is required.
- Non-unionized local labor and contractor are assumed. Prevailing union wage rates are not applicable.
- Contractor performs work during normal daylight hours, Monday through Friday, and in normal eight-hour shifts. No allowance has been included for night or weekend work.
- Contractor markup is based on conventionally accepted values.
- Site has sufficient electrical power for new process equipment. Additional power distribution or transformers are outside the scope of this estimate.
- Existing area has sufficient structural integrity to accommodate new process equipment (e.g., no piling or special subsurface improvements required).
- Process equipment pricing is based on budgetary vendor quotes. Quotes have not been collected for all equipment at this conceptual stage, and prices for these items (not supported by vendor quotes) are based on prices factored from previous projects.
- GAC usage costs for Options 4a and 4b are based on estimates of 160,000 and 300,000 pounds of media usage per year, respectively (based on $2 per pound including media fill and spent media reactivation). This usage is based on results of carbon isotherm testing conducted

on one sample each of Montpelier and Newport effluents (Appendix D). Carbon isotherm testing provides an approximation of carbon usage but is subject to error given it is a batch test conducted on a single sample. More sophisticated testing is required to refine carbon usage and reflect typical wastewater variability that will be encountered over long-term operation.

- Propane gas usage cost based on $2.50 per gallon for options with concentrators where insufficient LFG is available. All concentrators assumed to use thermal oxidation for odor destruction.
- Onsite pretreatment Option 2a and Offsite option 4b include T&D cost of pretreated liquids to the Montpelier and Newport POTW. Both facilities would need upgrades to allow treatment of all the current and future leachate volume produced by the site (50,000 gpd and 100,000 gpd, respectively, see Appendices D and E)

The following allowances were made in the development of this estimate for known but undefined work:

- Purchased equipment installation (6 to 14 percent of total equipment cost)
- Instrumentation and controls equipment and installation (20 to 36 percent of total equipment cost)
- Process piping (16 to 40 percent of total equipment cost)
- Electrical systems and installation (15 to 35 percent of total equipment cost)
- Pre-engineered metal building for treatment and electrical equipment; and concrete slab-on-grade for outdoor equipment (e.g., concentrator)
- Structural (e.g., building foundations and footings, housekeeping pads, pipe supports, stairs) (18 to 25 percent of total equipment cost)
- Site civil work (5 to 10 percent of total equipment cost)
- Service utility piping and installation (20 to 50 percent of total equipment cost)

The following exclusions were assumed in the development of this estimate:

- Hazardous materials remediation or disposal
- Utility agency costs for incoming power modifications
- Permits beyond those normally needed for this type of project and project conditions. Site planning and/or zoning approvals not included.
- Costs associated with production shutdowns required to complete the work, if any
- Consumables and laboratory equipment

To the extent the assumptions and exclusions noted above are correct, we would expect that the cost opinion will range from -20 percent to +100 percent. BC's cost opinion of pretreatment options capital cost, including contingency, and cost opinion for annual O&M costs are summarized in Table 3.

Construction cost estimates, financial analyses, and feasibility projections are subject to many influences including, but not limited to, price of labor and materials, unknown or latent conditions of existing equipment or structures, and time or quality of performance by third parties. Such influences may not be precisely forecasted and are beyond the control of BC. Actual costs incurred may vary from the estimate prepared by BC based on these conditions and influences beyond our control. BC does not warrant or guarantee the accuracy of construction or development cost estimates.

Section 7

Evaluation Results

Budgetary quotes were obtained from 10 vendors for equipment as described previously. Based on this information, conceptual designs were assembled reflecting the treatment train alternatives discussed in Section 4. Each treatment train was then evaluated resulting in a combined weighted ranking as shown in Table 4. The rating considerations and weighting factors were reviewed with Casella for alignment with corporate and project objectives. Each treatment train alternative was rated by BC based on experience and information provided by each vendor. The ranking system above should be interpreted as a guide but does not necessarily reflect the full granularity that is required for final selection. Also, note that the ranking system represents averages, and that items or options with higher risk potential can have a wider range of scores and those with lower risk can have a narrower range of scores. The ratings were structured such that lower rankings were preferred. The ranking process is based on currently available information and is subject to considerable potential variability due to the current uncertainty regarding PFAS regulations and other subjective factors and unknowns.

Based on the weighted ratings, the Scenario 1 DSW Option 1a (RO plus GAC with concentrator plus emissions control), Scenario 3 ZLD Option 3a (concentration plus emissions control) were the preferred on-site options with ratings of 120 and 124 respectively. Note that Scenario 2 Option 2a can be located at the site or the POTW. Together with Option 2a, Scenario 4 Options 4a and 4b are the preferred off-site options with a rating of 132 for Option 2a and 109 for Options 4a and 4b. Option 2a is preferred over Option 2c due to significantly lower long-term cost.

The evaluation considered multiple cost and non-cost factors to identify the two preferred on-site options and two preferred off-site options. For on-site treatment, discharge to surface water after treatment via RO offers the best overall rating but has a higher CapEx cost compared to the ZLD option however the OpEx costs are significantly lower providing much lower long-term costs and better value. There may be permitting challenges with the DSW approach that may delay implementation without focused VTDEC support.

For off-site options, the approach of continuing hauling to either Newport or Montpelier POTWs and upgrading their facility (one or the other) is attractive given CapEx costs and the potential for cost sharing. OpEx costs may be more significant due to hauling and disposal fees. It is foreseeable that more favorable disposal rates could be negotiated, however, transportation costs would likely not be reduced as they are volume and distance based. Upgrades at a POTW is also attractive in that non-landfill sources of PFAS are also treated thus providing a greater overall environmental benefit. Additionally, the recovered PFAS would be expected to be destroyed when the GAC media is regenerated.

Section 8

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Tables

TABLE 1
KEY TECHNOLOGY SUMMARY
NEWSVT LANDFILL

	Units	Technology Vendor												
Vendor		Heartland Water Technology, Inc.	E2Metrix	Rochem Americas		Dynatec Systems	Xogen Technologies, Inc.	Calgon Carbon	Desalitech	HTX Solutions, LLC	Clark Technology		PuroLite	Magna Imperio Systems
Technology		Concentrator w/ Thermal Oxidizer	Electrocoagulation (EC)	Reverse Osmosis (RO) - Three-stage	RO - Three-stage with concentrator and thermal oxidizer	Membrane Bioreactor (MBR)	Electrooxidation (EO)	Granular Activated Carbon (GAC)	UF and RO	EC	RO	UF	Ion Exchange (IX)	Electrodialysis Reversal (EDR)
Application		Full Treatment	Partial treatment	Full treatment	Full treatment	Full treatment	Partial treatment	Polishing	Polishing	Partial treatment	Full treatment	Partial treatment	PFAS polishing	RO Concentrate
Demonstrated with leachate		Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	No
Effluent Volume	gpd	0		44,000 (88% recovery)	44,000 (88% recovery)				45,000 (90% recovery)		40,000	40,000		
BOD Removal	mg/L	Complete	Partial	Complete	Complete	Complete			Complete		99% removal	90% removal		
Ammonia Removal	mg/L	Complete	Remove 100 mg/L	Complete	Complete	Complete	Complete		Complete		95% removal	70% removal		
PFOA Removal	ng/L	Complete	None	ND (< 1.9)	ND (< 1.9)	50%	(Literature only) Bench-scale and/or pilot recommended			Bench-scale and/or pilot recommended	99% removal	90% removal	ND (< 1.9)	
PFOS Removal	ng/L	Complete	None	ND (< 1.9)	ND (< 1.9)	50%					99% removal	90% removal	ND (< 1.9)	
Total PFAS Removal	ng/L	Complete	None	ND (< 1.9)	ND (< 1.9)	50%							ND (< 1.9)	
Air Emissions as VOCs	tons/yr	0.7	None	None	0.7	0.07	None	None	None				None	
Air Emissions as PFAS	lb/yr	Unknown	None	None	Unknown	Negligible	None	None	None				None	
Residuals	cy/d	12.4	9.9	29.7	8.0	2.5	Off-gases (mainly H, O2 and N)	Spent media	25		10,000	10,000	Spent media	
LFG Requirement	cfm	843	0	0	166	0	0		0		0	0	0	
Chemicals	$/yr	45,000	3,100	108,000	120,000		480,000 to 720,000		13,000		15,000	12000	0	
Electricity[1]	kwh/d	3,120	49	1,726	1,726		incl. with Chemicals		215		489	274		
Labor[2]	hours/d	8	2	8	12		1.1		1		3	3		
Parts/Consumables	$/yr	15,000	60,000	57,000	57,000		215,000		10,000		32,000	25,000		
Maintenance	$/yr			91,000	117,250		incl. in Parts/Consumables							
Equipment footprint	sq ft	5,000	500	2,500	2,500 for RO; 1,600 pad for evap.	500 (UF Skid and Permeate Tank)	2,500	60	150	modular units housed in 40 ft shipping containers; 6,000 to 8,000 nominal footprint	800	800	60	
Additional Trt Needed		Solidification	Bio pretreat/dewatering	Dewatering/solidification	Solidification	Dewatering/solidification	Filtration, solidification		Dewatering/solidification		Dewatering/solidification	Dewatering/solidification		
OpEx[3]	$/yr	345,000	155,000	469,000	601,000	550,000[5]	835,000		44,000	1,460,000	111,000	90,000	$14,000 (Option 1a); $55,000 (Option 2c)	
OpEx	$/gal	0.019	0.008	0.026	0.033	0.30			0.002	0.03 to 0.12 (excludes electricity and catalyst; depends on volume treated, contract duration, operating hrs/d, # of treatment trains)	0.006	0.005	0.001 (Option 1a); 0.003 (Option 2c)	
Vendor Equipment CapEx[3]	$	2,587,000	200,000	2,600,000	3,610,000	1,140,000	4,600,000	35,000	500,000 (+/- 15%)	Equipment cost not provided	2,100,000	984,000	105,500	
Total 20 year cost[4]	$	13,590,000	4,420,000	16,860,000	22,090,000	16,410,000	29,960,000		2,040,000		6,610,000	4,090,000	550,000 (Option 1a); 1,600,000 (Option 2c)	
Total 20 year cost	$/gal	0.037	0.012	0.046	0.061	0.045	0.082		0.006		0.018	0.011	0.002 (Option 1a); 0.0044 (Option 2c)	
Additional Notes		Does not include residuals solidification equipment, building, supplemental gas supply and misc. equipment.	Only includes base equipment package. Requires tanks, electrical, building etc.	Includes: influent pH adj, duplex MMF and cartridge filtration before 1st-stage RO; effluent pH adjustment; recirc pumps; influent, effluent, permeate tanks, and 3rd-stage working tank. Option with concentrator includes Heartland concentrator for RO concentrate.		Pretreatment needed incudes removal of large solids and equalization. Includes: Aerobic tank jet aeration system, UF; Assumes GAC media regenerated offsite.	Does not include tanks, pumps and ancillary equipment	Includes two 4-ft diameter skid-mounted GAC vessels with interconnecting piping. Includes pre-filtration for POTW effluent treatment (Option 4a).	Includes: UF and RO membranes, CIP system and antiscalant feed system and tanks. Would require upstream pretreatment (e.g., filtration, MBR, EO, etc.)	Includes: filtration, tanks, pump, heating skid, pH adjustment. Vendor only provides services on a contract $ per treated gallon basis.	Includes: membranes (LB-L9 system; 0.006 microns), modules, electrical, PLC, HMI, pumps, piping, CIP, shipping.	Includes: membranes (LB-L1 system; 0.02 microns), modules, electrical, PLC, HMI, pumps, piping, CIP, shipping..	Includes: Two 2.5 ft diameter resin vessels with interconnecting piping and valves, incl. initial media fill	Vendor equipment information not provided.

Notes:

(1) Labor based on $50/hr raw labor rate

(2) Electricity cost based on $0.14/kWh (approximated based on Vermont Electric Cooperative, Inc. invoices dated December 2018).

(3) Process equipment pricing and operating costs are based on budgetary vendor quotes and equipment information. Quotes are for 50,000 gpd systems and do not include costs for equipment installation, balance of plant equipment, freight, tax and associated indirect costs.

(4) Calculated based on straight line amortization of equipment capital cost, including 2.5% inflation for OpEx and 4% of CapEx for annual maintenance cost.

(5) Operating cost for the MBR system calculated based on $0.03 per gallon.

TABLE 2
LEACHATE TREATMENT TECHNOLOGY COMPARISON
NEWSVT LANDFILL

Attribute	Biological Treatment	Adsorption (GAC)	Ion Exchange (Resin)	Reverse Osmosis (RO)	Electrocoagulation	Electrooxidation (EO)	Evaporation
Benefits	• Advanced activated sludge treatment (Membrane Bioreactor) • Produces effluent suitable for effluent polishing treatment processes • Removes biodegradable compounds including biodegradable emerging contaminants • Provides removal for nutrients • Proven technology with leachate	• Most commonly used technology • Simple to operate • Residuals are managed off-site and constituents destructed • Minimal operator requirements • Removes a broad suite of constituents including PFAS, and many PPCPs. 1,4 Dioxane may be sparingly adsorbed	• Can be designed for selective removal of PFOA and PFOS • Smaller footprint • Minimal operator requirements	• Nearly complete removal of all organic and inorganic material • Removal of PFAS and other emerging contaminants to near or below ND • 90%-98% TDS Removal • RO performs a separation without a phase change • RO systems are compact • Due to their modular design, maintenance is easy. Scheduled maintenance can be performed without shutting down the entire plant	• Relatively simple • Small footprint • Removal of inorganics (e.g. metals) , organics and solids	• Ammonia removal as well as other constituents such as Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Volatile Organic Compounds (VOCs), Pharmaceutical and Personal Care Products (PPCPs), and Pathogens such as E-coli, coliforms and non-coliforms, and color. • Small footprint • Relatively simple	• On average 95% water reduction by evaporation • Largely mechanical operations • Insensitive to variations in influent leachate quality • Process can be turned on/off rapidly to respond to significant changes in flows • Can be applied for raw leachate or concentrate reduction • Produces minimal volume of residuals • No liquid discharge
Limitations	• Requires larger footprint. • Does not remove PFAS and some other emerging contaminants • Process performance is temperature and pH dependent	• Limited with sorbent capacity, sorbent needs to be regenerated or replaced • Requires pretreatment of solids and organics • Generates backwash stream that requires subsequent treatment and disposal • Low adsorption capacity for PFAS compared to resins	• The presence of organics, suspended solids, calcium, or iron can cause fouling of ion exchange resin • Requires pretreatment of solids • Larger regenerate volume may require volume reduction treatment • Resin targeted for PFAS removal may require backwashing provisions • Does not remove other emerging contaminants	• Recovery is limited by TDS concentration • Requires routine membrane cleaning due to fouling. • Pretreatment required. Type and extent dependent on membrane type. • Produces a concentrate (about 20% v/v) that requires disposal. Concentrate contains all constituents at elevated concentrations	• Technology not new but experience with leachate is limited and relatively new, including PFAS • Not proven at full-scale with PFAS	• Technology not new but experience with leachate is limited and relatively new, including PFAS • Not proven at full-scale with PFAS • The reaction consumes alkalinity, so Recovery is limited based on TDS, pH is affected (e.g., decreased)	• Usually 75%-80% uptime due to cleaning of the precipitated solids. • Highly labor intensive due to cleaning of the precipitated solids • The control of air emissions from the process may be required • Potential odors • Potential PFAS emissions • Concentrates only requiring residuals sequestration and disposal
Leachate Application	• Proven in multiple applications	• Proven in multiple applications	• Not applied for leachate	• Proven in multiple applications	• Proven in multiple applications, primarily outside United States	• Proven in multiple applications, primarily outside United States	• Proven in multiple applications
Process Performance	• Process requires relatively constant hydraulic and mass loading • Not able to respond to rapid and significant changes in the influent characterization • Requires biological treatment operations expertise	• Proven and known treatment/technology for removal and polishing of organics including PFAS and PPCPs	• Competition for the exchange ion can reduce the effectiveness of ion exchange • Can achieve ND concentrations for PFOA and PFOS	• Separate treatment step • May require chemical addition to reduce membrane fouling • Requires membrane cleaning cycles • Requires membrane replacement about every 5 years • Requires concentrate treatment equipment if volume reduction is desired	• Not demonstrated for PFAS or other emerging contaminants at full scale • Requires periodic replacement of electrodes • Cost and effectiveness depend on power settings, capacity, and retention time	• Not demonstrated for PFAS or other emerging contaminants at full scale • Requires periodic replacement of electrodes • Cost and effectiveness depend on power settings, capacity, and retention time	• Bulk liquid in the leachate is evaporated using high temperatures; pollutants concentrated in residual • Vapor is emitted to atmosphere • Residual concentrated brine is produced • Operation is relatively labor-intensive
Health and Safety	• No significant issues beyond general safety concerns	• No significant issues beyond general safety concerns	• May require occupational health and safety measures as it may require storage and handling of regeneration chemical reagents (unless resin is single-use)	• Requires sodium hypochlorite and citric acid (or similar) for membrane cleaning • Other chemicals (e.g., antiscalants) may be required for pretreatment to reduce fouling	• Not demonstrated for PFAS or other emerging contaminants at full scale	• Not demonstrated for PFAS or other emerging contaminants at full scale •	• General use of chemicals for cleaning • Possible entry into a confined space during major cleaning events
Chemical Use	• Antifoam anticipated to be significant • Methanol for carbon source requirement for denitrification	• Minimal to none	• Acid, caustic or other chemical is required for resin regeneration (if not single-use resin which is replaced)	• Increased chemical use for membrane cleaning • Additional chemicals may be needed for pretreatment to reduce membrane fouling potential	• Some chemicals may be added to improve coagulation	• Sodium chloride may be added to increase water conductivity which improves ammonia removal and reduces electricity consumption	• Acid cleaning used to remove scale and other deposits from the unit • Antifoam addition required
Energy Use	• High energy requirement for aerobic removal processes	• Low compared to all other technologies	• Low compared to all other technologies	• Increased since feed pumps are high horsepower for pressures required • Brine evaporators for residuals volume reduction have very high energy requirements	• High energy requirement for electric charge delivery	• High energy requirement for electric charge delivery	• Electricity consumption. and costs of heat energy will vary, depending on availability of local waste heat sources and LFG quantity

TABLE 2
LEACHATE TREATMENT TECHNOLOGY COMPARISON
NEWSVT LANDFILL

Attribute	Biological Treatment	Adsorption (GAC)	Ion Exchange (Resin)	Reverse Osmosis (RO)	Electrocoagulation	Electrooxidation (EO)	Evaporation
Generation of Residuals	• Sludge cake production after dewatering process • Incineration or landfill disposal required for sludge cake	• None if carbon is regenerated off-site	• Increase residual disposal volumes for single use resin • Requires treatment of residuals prior to disposal; may be hazardous if highly concentrated	• Clean-in-place liquids will require management with concentrate or separate disposal • RO concentrate requires disposal. May be 20% v/v of treated water volume unless volume reduction is applied • Concentrate will require disposal either as a liquid or solid suitable for disposal; may be hazardous if highly concentrated	• Off-gases (e.g., nitrogen gas, oxygen, carbon dioxide) • Solids will be formed requiring handling and disposal	• Off-gases (e.g., nitrogen gas, oxygen, carbon dioxide) • Solids may be formed requiring handling and disposal	• Concentrate will require disposal and likely solidification
Applicability	• Successfully applied to leachate treatment of readily biodegradable compounds, which contribute to BOD and COD concentrations • Ammonia is easily removed under aerobic conditions via uptake as a nutrient in BOD removal and via biological nitrification • Foaming is typical for leachate aeration • Heating and cooling of the wastewater may be required • Due to use of UF, the system can be operated at higher mixed liquor concentration resulting in smaller aeration tank. UF provides superior solids separation and effluent quality.	• This process can be applicable for this site as a post-treatment (e.g., organics polishing)	• This process can be applicable for this site as a post-treatment (e.g., PFAS polishing)	• Conventional RO membranes are not considered to be a stand-alone or primary treatment technology as use is intended to target biologically recalcitrant or non-biologically degradable constituents such as chlorides, etc. • RO membranes designed for leachate service can be applied and provide nearly complete removal of virtually all constituents • Leachate has high membrane fouling potential and will require pretreatment of solids removal and organics removal, depending on membrane type	• Pretreatment prior to PFAS removal technologies such as conventional RO, GAC or IX • Technology not new; experience with leachate is limited and relatively new. .	• Pretreatment prior to PFAS removal technologies such as conventional RO, GAC or IX • Technology not new; experience with leachate is limited and relatively new. .	• The evaporation system require air permitting and engineering design for installation. • The evaporation system would require a heat source (e.g., propane) to supplement available LFG for raw leachate treatment • There is adequate LFG for evaporation of RO concentrate • Odor and PFAS destruction in air emissions requires significant additional energy input • Foaming and scaling are typical issues for leachate evaporation. • Residuals disposal could also be challenging and expensive. • The evaporators should be sized to accommodate maintenance downtime.

TABLE 3
CLASS 5 OPINION OF PROBABLE COST AND ANNUAL O&M COST COMPARISON
NEWSVT LANDFILL

	Option 1a	Option 3a	Option 2a	Option 4a	Option 4b
	Discharge to Surface Water	Zero Liquid Discharge	Pretreatment at POTW	POTW Enhancements	
	RO+GAC+Remin w/ Conc. + Emissions Control	Conc. + Emissions Control	RO (Partial Volume)	Filtration+GAC (Newport)	Filtration+GAC (Montpelier)
Estimated Total Installed Cost (CapEx)	$ 17,100,000	$ 11,900,000	$ 11,300,000	$ 16,800,000	$ 15,700,000
Estimated Total Installed Cost Range (CapEx)	$13,700,000-$34,200,000	$9,600,000-$23,900,000	$9,000,000-$22,500,000	$13,400,000-$33,600,000	$12,500,000-$31,300,000
Annual OpEx ($/yr)	$ 871,000	$ 7,074,000	$ 449,000	$ 711,000	$ 1,187,000
Annual OpEx Range ($/yr)	$700,000-$1,700,000	$5,700,000-$14,100.000	$400,000-$900,000	$600,000-$1,400,000	$900,000-$2,400,000
Transportation and Disposal (T&D) ($/yr)	NA	NA	$ 1,572,000	$ 1,154,000	$ 1,572,000
Total Annual OpEx incl. T&D ($/yr)	$ 871,000	$ 7,074,000	$ 2,021,000	$ 1,865,000	$ 2,759,000
Total Annual OpEx Range incl. T&D ($/yr)	$700,000-$1,700,000	$5,700,000-$14,100.000	$1,900,000-$2,500,000	$1,700,000-$2,600,000	$2,500,000-$3,900,000

Notes:

a. Calculations and opinions of probable costs presented herein are conceptual level estimates prepared without benefit of a thorough engineering evaluation and include an allocation for repair and replacement costs over a 20 yr period.. As such, this information should not be considered definitive and should be validated after proper engineering evaluations are completed.

b. In accordance with the Association for the Advancement of Cost Engineering International (AACE) criteria, this is a Class 5 estimate. A Class 5 estimate is defined as a Conceptual Level or Project Viability Estimate. Typically, engineering is from 0 percent to 2 percent complete. Class 5 estimates are used to prepare planning level cost scopes or evaluation of alternative schemes, long range capital outlay planning and can also form the base work for the Class 4 Planning Level or Design Technical Feasibility Estimate. **The expected accuracy for this Class 5 estimate is -20 percent to +100 percent.** In unusual circumstances, ranges could exceed those shown.

c. Construction cost estimates, financial analyses, and feasibility projections are subject to many influences including, but not limited to, price of labor and materials, unknown or latent conditions of existing equipment or structures, and time or quality of performance by third parties. Such influences may not be precisely forecasted and are beyond the control of BC. Actual costs incurred may vary from the estimate prepared by BC based on these conditions and influences beyond our control. BC does not warrant or guarantee the accuracy of construction or development cost estimates.

d. 30 to 40 percent contingency used.

e. Option 3a annual OpEx includes approx. $5.7M in propane gas annual usage costs for the concentrator thermal oxidizer; Propane gas cost based on $2.50 per gallon.

f. Based on current POTW T&D costs provided by Casella.

g. The cost estimate includes Newport WWTF upgrades to treat 50,000 gpd leachate at Newport WWTF average loading conditions. Additional $4,550,000 capital cost is required for Newport WWTF upgrades to 100,000 gpd leachate at Newport WWTF average loading conditions.

h. The cost estimate includes Montpelier WRRF upgrades to treat 50,000 gpd leachate at Montpelier WRRF average loading conditions. Additional $1,015,000 capital cost is required for Montpelier WRRF upgrades to 100,000 gpd leachate at Montpelier WRRF average loading conditions.

TABLE 4
TREATMENT OPTIONS COMPARISON
NEWSVT LANDFILL

	On-Site: Discharge to Surface Water	On-Site: Zero Liquid Discharge (ZLD)	Off-Site: Pretreatment at POTW (50% Reduction)	Off-Site: POTW Enhancements [3,4]	
Attribute	Option 1a – RO + GAC + Remineralization with Concentrator + Emissions Control	Option 3a – Concentrator + Emissions Control	Option 2a – RO at POTW with Concentrator + Emissions Control (at NEWSVT)	Option 4a – Filtration + GAC at POTW (Newport)	Option 4b – Filtration + GAC at POTW (Montpelier)
Benefits	• Control of own destiny • Removes virtually all contaminants • All contaminants remain on-site • Forward looking for new contaminants • Small concentrate volume relative to others • Should not require propane supplement • Provides a greater overall environmental benefit (for leachate only) through greater overall contaminant removal as compared to Options 2a, 4a and 4b • Does not require siting concentrator at energy plant for waste heat • Capacity can be increased easily • Adequate waste heat and LFG for current and future capacity	• Control of own destiny • Single treatment process • Removes virtually all contaminants • All contaminants remain on-site • Forward looking for new contaminants • No liquid disposal to environment • Capacity can be increased easily	• Removes virtually all contaminants in treated liquid • Forward looking for new contaminants • Does not require siting concentrator at energy plant for waste heat • Capacity can be increased easily • Adequate waste heat and LFG for current and future capacity	• No on-site treatment • Removes other PFAS source contributions • Removes a broad suite of organic contaminants • Largest overall environmental benefit due to reduction of leachate and non-leachate related contaminants • Good public perception • PFAS destroyed with GAC regeneration • No impact to site air-space • No additional permitting by Casella	• Higher flow system (greater dilution) • No on-site treatment • Removes other PFAS source contributions • Removes a broad suite of organic contaminants • Largest overall environmental benefit due to reduction of leachate and non-leachate related contaminants • Good public perception • PFAS destroyed with GAC regeneration • No impact to site air-space • No additional permitting by Casella
Limitations	• Air emissions from concentrator (if used), odor concerns and PFAS • Public perception • Permitting challenges (NPDES, air) • Concentrate requires sequestration/solidification or off-site disposal • Concentrate impact on airspace • Does not eliminate PFAS at site unless concentrate disposed off-site via incineration/cement kiln/deep well or alternative disposal site	• Air emissions concerns (odor, PFAS) and permitting • Public perception • Requires significant supplemental propane and associated cost • Requires siting at energy plant for waste heat utilization • High concentrate volume • Concentrate requires sequestration/solidification or off-site disposal • Concentrate impact on airspace • Does not eliminate PFAS at site unless concentrate disposed off-site via incineration/cement kiln/deep well or alternative disposal site • Insufficient waste heat and LFG for current and future capacity	• Limited control of own destiny • Sized for partial treatment (allows more to environment) • Contract challenges • Reliance on others for operation (e.g. PFAS pass-through) • Long-term commitment • Continued hauling to POTW and concentrate to NEWSVT • Potential long lead time for implementation (P3 project) • Air emissions from concentrator (if used for residuals), odor concerns and PFAS • Public perception (Concentrator) • Permitting challenges (air) • Concentrate requires sequestration/solidification or off-site disposal • Concentrate impact on airspace • Does not eliminate PFAS at site unless concentrate disposed off-site via incineration/cement kiln/deep well or alternative disposal site)	• Limited control of own destiny • Contract challenges • Reliance on others for compliance (e.g. PFAS pass-through) • Long-term commitment • Continued hauling • Less effective on short chain compounds (IX can be added) • Potential long lead time for implementation (P3 project) • Requires increased disposal volume allowance from VTDEC • May become capacity limited in the future	• Farther distance (higher hauling cost) • Limited space for improvements at POTW • Limited control of own destiny • Contract challenges • Reliance on others for compliance (e.g. PFAS pass-through) • Long-term commitment • Continued hauling • Less effective on short chain compounds (IX can be added) • Potential long lead time for implementation (P3 project) • Requires increased disposal volume allowance from VTDEC • May become capacity limited in the future
CapEx Range (Low-Mid-High) ($)	13,700,000-17,100,000-34,200,000	9,600,000-11,900,000-23,900,000	9,000,000-11,300,000-33,600,000	13,400,000-16,800,000-33,600,000	12,500,000-15,700,000-31,300,000
Total 20-year cost Range (Low-Mid-High) incl. CapEx, OpEx, T&D ($)	32,000,000-40,000,000-80,000,000	157,800,000-197,200,000-394,400,000	51,400,000-64,300,000-128,600,000	52,600,000-65,700,000-131,400,000	70,400,000-88,000,000-176,000,000
Factored Disposal Rating Total[2]	56.25	49.0	64.25	56.5	56.5
Combined Rating Total	120	124	132	109	109
Leachate Application (PFAS removal)	RO proven, Air emission uncertainty for concentrator. but expected to be minor	Air emission uncertainty for concentrator but expected to be minor	RO proven, Air emission uncertainty for concentrator. but expected to be minor	Less proven for treated wastewater to low PFAS levels	Less proven for treated wastewater to low PFAS levels
Process Performance Risk	Low RO. Moderate for concentrator (Air emissions and odor concerns)	Moderate (Air emissions and odor concerns)	Low RO. Moderate for concentrator (Air emissions and odor concerns)	Moderate (operational)	Moderate (operational)
Health and Safety	Moderate	Moderate	Moderate	Low	Low
Chemical Use	High	High	High	Low	Low
Energy Use	High	Extreme	High	Low	Low
Generation of On-site Concentrate	Moderate	High	Moderate	None	None

<u>*Notes:*</u>

1. *20-year costs calculated based on straight line amortization of equipment CapEx and 2.5% inflation for OpEx and T&D. Based on 50,000 gpd flow.*
2. *Refer to Appendix C (Leachate Management Strategy Review Tech Memo) for complete table. Lower ratings are preferred.*
3. *The cost estimate includes Newport WWTF upgrades to treat 50,000 gpd leachate at Newport WWTF average loading conditions. Additional $4,550,000 capital cost is required for Newport WWTF upgrades to treat 100,000 gpd leachate at Newport WWTF at average loading conditions.*
4. *The cost estimate includes Montpelier WRRF upgrades to treat 50,000 gpd leachate at Montpelier WRRF average loading conditions. Additional $1,015,000 capital cost is required for Montpelier WRRF upgrades to treat 100,000 gpd leachate at Montpelier WRRF at average loading conditions.*

Appendix A: Data Review Technical Memorandum

Brown AND Caldwell

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Technical Memorandum

Prepared for: Casella Waste Systems, Inc.

Project Title: NEWSVT Leachate Treatment Options Engineering Evaluation

Project No.: 152990

Technical Memorandum

Subject: Data Review and Estimated Leachate Loading Conditions

Date: January 18, 2019

To: Ken Robbins

From: Brown and Caldwell

Copy to: Jeremy Labbe and Joe Gay – Casella

Steve Giese and Alan Kirschner – Brown and Caldwell

Prepared by: Anthony A. Andrews

Reviewed by: Kevin D. Torrens

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5/31/2019
NO. 134331
ENVIRONMENTAL

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Limitations:

This document was prepared solely for Casella Waste Systems, Inc. (Casella) in accordance with professional standards at the time the services were performed and in accordance with the contract between Casella and Brown and Caldwell dated December 17, 2018. This document is governed by the specific scope of work authorized by Casella; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Casella and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

Section 1: Introduction

This technical memorandum (TM) summarizes Brown and Caldwell's (BC) review of site background information and data for Casella's New England Waste Systems landfill in Coventry, VT (NEWSVT), including leachate flow, characteristics, and per- and polyfluoroalkyl substances (PFAS) analytical data. BC also reviewed permitting documentation, including NEWSVT's currently applicable pretreatment discharge permit and air permit as well as publicly owned treatment works (POTW) discharge permits.

This TM also summarizes the estimated mass loads developed based on the reviewed raw leachate data (e.g., 2015 through 2018 flow data and constituent concentrations) as well as projected future flows and loads for the Phase VI expansion. These data will be used for developing and comparing technologies and disposal options. This TM was prepared under Task 2 of the scope of work.

Section 2: Background Information and Data Review

BC conducted a review of available and requested information for NEWSVT provided by Casella, including:

- Daily and monthly leachate flow (2015 through 2018)
- Combined leachate analytical data (metals, volatile organic compounds [VOCs], and semi-volatile organic compounds [SVOCs])
- Site drawings (Existing Conditions, Leachate Gravity Main Plan and Profile, Site Development Plan, and Phase VI Leachate Generation Table)
- PFAS analytical results for leachate samples collected at five landfills, including NEWSVT (sampled by Weston & Sampson on January 10, 2018)
- NEWSVT water quality sampling and trends report (prepared by Waite – Heindel Environmental Management dated July 16, 2018)
- Leachate Generation Summary by Cell and Stage for the Phase VI Landfill Expansion

The total combined monthly flow data collected from January 2015 to August 2018 was evaluated to estimate the average and maximum flow rates. This data includes the flow from the four (4) currently constructed phases of the landfill. The quarterly analytical data collected from the combined above ground leachate storage tank from 2015 through 2018 (quarterly samples) was used to estimate loads for various parameters, as described further in Section 3. In addition, the limited PFAS analytical data from the sampling event on January 10, 2018 was used to calculate corresponding loads. Data reported using Method MLA-110 was selected as it is less prone to matrix interferences as it is intended for wastewater matrices as compared to Method 537 which is only certified for drinking water.

Section 3: Leachate Loading – Current Flow and Loads

This Section summarizes the concentrations, flows and corresponding estimated mass loadings under for raw leachate.

Flows: The landfill currently consists of Phases I through IV. The average and 95th percentile flows calculated are as follows:

- Average Leachate Flow: 26,300 gallons per day (gpd) (approx.)
- 95th Percentile Flow: 37,600 gpd (approx.)

Characteristics and Estimated Loads: Leachate characterization data were provided by Casella. Leachate samples for analysis were collected from the aboveground storage tank on the west side of the landfill on a quarterly basis. Mass loadings were calculated for several parameters including metals, VOCs, SVOCs, PFAS (PFAS from one sampling event on January 10, 2018), and select inorganics. Two scenarios were calculated for maximum loadings:

- Load 1: Calculated from average concentration and the 95th percentile flow
- Load 2: Calculated from 95th percentile concentration and the average flow

The constituent concentrations and calculated mass loads are provided in Attachment A. The higher of the two loadings is used as the estimated load for evaluation. Attachment B provides plots for key parameters over the duration of the available data. The plots show average, maximum and minimum flows and concentrations by year. Overall, the data suggest relatively consistent leachate volume and quality and, therefore, the entire data set was used to develop loads. The data are consistent with a typical mid-strength leachate.

A summary of key parameter loads is provided in Table 1.

Table 1. Current Raw Leachate Estimated Loads

Parameter	Maximum Loading (lbs/day)
BOD_5	340
COD	984
Total Kjeldahl Nitrogen	367
Total Chloride	592
Total Suspended Solids	--
Total Dissolved Solids	--
Arsenic	0.26
Zinc	0.12
Acetone	0.83
t-Butanol	0.57
2-Butanone (MEK)	0.93
Total Cresol	0.24
Phenol	0.05
PFOA	5.8×10^{-4}
PFOS	7.65×10^{-5}

Section 4: Leachate Loading – Future Flow and Load Projections

Flows: Casella provided estimated leachate generation rates for the Phase VI expansion in addition to leachate flow from existing Phases I, II, III, and IV. Phase VI flows are provided for the cells and stages, as shown in “Table 1, Leachate Generation Summary by Cell and Stage, Phase VI Landfill Expansion”, included in Attachment C. Based on the 2015 to 2018 flow data, the ratio of maximum flow to average flow is 1.94, herein referred to as the peaking factor. The average and maximum flows calculated are as follows:

- Future Projected Average Flow: 45,200 gpd (approx.)
- Future Projected Maximum Flow: 87,700 gpd (approx.; product of the Projected Average Flow and Peak Factor)

Table 2 provides a summary of the current and future projected flows.

Table 2. Current and Future Projected Flows

Flow	Current – Phases I through IV (gpd)	Future Projection – Phases I through VI (gpd)
Average	26,300	45,200
Maximum	37,600*	87,700

**95th percentile flow*

Estimated Load Projection: Mass loadings were calculated for the same parameters. Two scenarios were calculated for maximum loadings: Similarly, two scenarios were calculated for maximum loadings:

- Load 1: Calculated from average concentration and the maximum flow
- Load 2: Calculated from 95th percentile concentration and the average flow

A summary of key parameter loads is provided in Table 3.

Table 3. Raw Leachate Estimated Projected Loads

Parameter	Maximum Loading (lbs/day)
BOD_5	621
COD	2,297
Kjeldahl Nitrogen	847
Total Chloride	1,341
Total Suspended Solids	--
Total Dissolved Solids	--
Arsenic	0.49
Zinc	0.21
Acetone	1.93
t-Butanol	1.29
2-Butanone (MEK)	2.18
Total Cresol	0.41
Phenol	0.08
PFOA	1.35×10^{-3}
PFOS	1.79×10^{-4}

Section 5: Additional Data

Additional characterization data are being collected to test for analytical parameters necessary to evaluate specific technologies that are not available in the current data base. Placeholders are included in Attachment A, and these data will be added to the current information when available. Additionally, quarterly leachate monitoring data will be collected in early February. These data are representative of leachate after initiation of Gas Well Liquid (GWL) pumping, which began in December 2018. These data will be compared to recent data collected before initiation of GWL pumping to determine potential impacts on leachate quality associated with the GWL. The estimated loadings may be modified if significant impacts are identified.

Attachment A: Estimated Raw Leachate Loads

NEWSVT LANDFILL
CASELLA WASTE SYSTEMS, INC.
ESTIMATED RAW LEACHATE LOADS

	gpd	Notes
Current Flow		
Average Flow	26,300	Based on 2015-2018 flow data provided by Casella (Phases I-IV)
Maximum Flow	51,000	
95th Percentile Flow	37,600	
Future Projected Flow		
Average Flow	45,200	Based on Phase VI Expansion estimated flow plus Phases I-IV
Maximum Flow	87,700	Based on 1.94 peak factor (2015-2018 flow data)

			Current Scenario (Phases I-IV)			Future Projection Scenario (Phase I-VI)		
Parameter	Average Concentration	95th Percentile Conc.	Load 1	Load 2	Higher of Loading 1 and 2	Load 1	Load 2	Higher of Loading 1 and 2
	mg/L	mg/L	95th Percentile Flow x Avg. Conc. (lbs/day)	Average Flow x 95th Percentile Conc. (lbs/day)	Estimated Loading (lbs/day)	Maximum Flow x Avg. Conc. (lbs/day)	Average Flow x 95th Percentile Conc. (lbs/day)	Estimated Loading (lbs/day)
BOD_5	849	1,550	266	340	340	621	584	621
COD	3,138	4,425	984	971	984	2,295	1,668	2,295
Total Chloride	1,831	2,700	574	592	592	1,339	1,018	1,339
Kjeldahl Nitrogen	1,157	1,675	363	367	367	846	631	846
Total Sodium	1,588	2,025	498	444	498	1,161	763	1,161
Alkalinity (as CaCO3)								
Total Suspended Solids								
Total Dissolved Solids								
Ammonia Nitrogen								
Magnesium								
Metals								
Antimony								
Antimony	0.02	0.04	0.01	0.01	0.01	0.0164	0.0156	0.0164
Arsenic	0.66	1.17	0.21	0.26	0.26	0.49	0.44	0.49
Barium	0.20	0.22	0.06	0.05	0.06	0.14	0.08	0.14
Boton								
Beryllium	0.01	0.01	0.0021	0.0022	0.0022	0.005	0.004	0.005
Cadmium	0.01	0.03	0.0045	0.0055	0.0055	0.011	0.009	0.011
Chromium	0.31	0.50	0.098	0.109	0.11	0.229	0.188	0.23
Cobalt	0.14	0.20	0.043	0.044	0.044	0.099	0.075	0.099
Copper	0.15	0.25	0.046	0.055	0.055	0.11	0.09	0.11
Cyanide								
Iron	22.3	46.7	7.0	10.2	10.2	16.31	17.60	17.60
Lead	0.07	0.25	0.02	0.05	0.05	0.05	0.09	0.09
Manganese	1.82	3.57	0.57	0.78	0.78	1.33	1.35	1.35

NEWSVT LANDFILL
CASELLA WASTE SYSTEMS, INC.
ESTIMATED RAW LEACHATE LOADS

			Current Scenario (Phases I-IV)			Future Projection Scenario (Phase I-VI)		
Parameter	Average Concentration	95th Percentile Conc.	Load 1	Load 2	Higher of Loading 1 and 2	Load 1	Load 2	Higher of Loading 1 and 2
	mg/L	mg/L	95th Percentile Flow x Avg. Conc. (lbs/day)	Average Flow x 95th Percentile Conc. (lbs/day)	Estimated Loading (lbs/day)	Maximum Flow x Avg. Conc. (lbs/day)	Average Flow x 95th Percentile Conc. (lbs/day)	Estimated Loading (lbs/day)
Mercury	0.00	0.00	0.0001	0.0004	0.0004	0.0003	0.001	0.001
Molybdenum	0.13	0.25	0.04	0.05	0.05	0.10	0.09	0.10
Nickel	0.47	0.66	0.15	0.14	0.15	0.34	0.25	0.34
Selenium	0.01	0.02	0.0042	0.0044	0.0044	0.010	0.008	0.010
Silver	0.12	0.20	0.037	0.044	0.044	0.09	0.08	0.09
Strontium								
Thallium	0.01	0.02	0.0028	0.0036	0.0036	0.007	0.006	0.007
Vanadium	0.12	0.20	0.0374	0.0439	0.0439	0.09	0.08	0.09
Zinc	0.25	0.55	0.08	0.12	0.12	0.18	0.21	0.21
VOCs								
Acetone	2.63	3.54	0.83	0.78	0.83	1.92	1.33	1.92
Benzene	0.004	0.00	0.0011	0.0010	0.0011	0.003	0.002	0.003
t-Butanol	1.76	2.59	0.55	0.57	0.57	1.29	0.98	1.29
2-Butanone (MEK)	2.98	4.08	0.93	0.89	0.93	2.18	1.54	2.18
Diethyl Ether	0.03	0.04	0.0103	0.0092	0.0103	0.024	0.016	0.024
1,2 Dichloroethane	0.003	0.00	0.0011	0.0009	0.0011	0.002	0.001	0.002
Ethyl Benzene	0.01	0.01	0.0038	0.0032	0.0038	0.009	0.006	0.009
2-Hexanone	0.06	0.06	0.0180	0.0126	0.0180	0.04	0.02	0.04
4-Isopropyl toluene	0.01	0.01	0.0019	0.0015	0.0019	0.004	0.003	0.004
4-Methyl 2-Pentanone	0.08	0.10	0.0246	0.0221	0.0246	0.06	0.04	0.06
Naphthalene	0.02	0.02	0.0058	0.0049	0.0058	0.014	0.008	0.014
Tetrachloroethene	0.003	0.00	0.0008	0.0005	0.0008	0.002	0.001	0.002
Tetrahydrofuran	2.02	2.38	0.63	0.52	0.63	1.48	0.90	1.48
1,2,4 Trimethy benzene	0.01	0.01	0.0019	0.0014	0.0019	0.004	0.002	0.004
Toluene	0.03	0.05	0.0086	0.0101	0.0101	0.020	0.017	0.020
Total Xylenes	0.03	0.04	0.0093	0.0083	0.0093	0.02	0.01	0.02
Unidentified	0.01	0.01	0.0024	0.0022	0.0024	0.01	0.00	0.01
SVOCs								
Total Cresol	0.52	1.09	0.165	0.240	0.24	0.38	0.41	0.41
2 Methyl phenol	0.02	0.02	0.006	0.005	0.006	0.013	0.009	0.013
3&4 Methylphenol	0.52	1.07	0.162	0.235	0.24	0.377	0.404	0.40
Naphthalene	0.01	0.01	0.0033	0.0031	0.0033	0.008	0.005	0.008
Phenol	0.11	0.21	0.035	0.046	0.05	0.082	0.078	0.082
Unidentified Peaks	0.01	0.01	0.003	0.002	0.0031	0.007	0.004	0.007

NEWSVT LANDFILL
CASELLA WASTE SYSTEMS, INC.
ESTIMATED RAW LEACHATE LOADS

			Current Scenario (Phases I-IV)			Future Projection Scenario (Phase I-VI)		
Parameter	Average Concentration	95th Percentile Conc.	Load 1	Load 2	Higher of Loading 1 and 2	Load 1	Load 2	Higher of Loading 1 and 2
	mg/L	mg/L	95th Percentile Flow x Avg. Conc. (lbs/day)	Average Flow x 95th Percentile Conc. (lbs/day)	Estimated Loading (lbs/day)	Maximum Flow x Avg. Conc. (lbs/day)	Average Flow x 95th Percentile Conc. (lbs/day)	Estimated Loading (lbs/day)
PFAS (Method MLA 110, sample collected 1/10/18)								
	ng/L							
Perfluorobutanoic acid (PFBA)	10,300	--	3.23E-03	--	3.23E-03	7.53E-03	--	7.53E-03
Perfluoropentanoic acid (PFPeA)	2,020	--	6.33E-04	--	6.33E-04	1.48E-03	--	1.48E-03
Perfluorohexanoic acid (PFHxA)	2,890	--	9.06E-04	--	9.06E-04	2.11E-03	--	2.11E-03
Perfluoroheptanoic acid	748	--	2.35E-04	--	2.35E-04	5.47E-04	--	5.47E-04
Perfluorooctanoic acid (PFOA)	1,850	--	5.80E-04	--	5.80E-04	1.35E-03	--	1.35E-03
Perfluorononanoic acid (PFNA)	125	--	3.92E-05	--	3.92E-05	9.14E-05	--	9.14E-05
Perfluorodecanoic acid (PFDA)	129	--	4.05E-05	--	4.05E-05	9.44E-05	--	9.44E-05
Perfluoroundecanoic acid (PFUnA)	16.0	--	5.02E-06	--	5.02E-06	1.17E-05	--	1.17E-05
Perfluorododecanoic acid (PFDoA)	17.0	--	5.33E-06	--	5.33E-06	1.24E-05	--	1.24E-05
Perfluorotridecanoic acid (PFTrDA)	3.36	--	1.05E-06	--	1.05E-06	2.46E-06	--	2.46E-06
Perfluorotetradecanoic acid (FTeDA)	3.12	--	9.78E-07	--	9.78E-07	2.28E-06	--	2.28E-06
Perfluorobutanesulfonic acid (PFBS)	3,520	--	1.10E-03	--	1.10E-03	2.57E-03	--	2.57E-03
Perfluoropentanesulfonic acid (PFPeS)	50	--	1.56E-05	--	1.56E-05	3.64E-05	--	3.64E-05
Perfluorohexanesulfonic acid (PFHxS)	397	--	1.24E-04	--	1.24E-04	2.90E-04	--	2.90E-04
Perfluoroheptanesulfonic acid (PFHpS)	ND	--	--	--	--	--	--	--
Perfluorooctanesulfonic acid (PFOS)	244	--	7.65E-05	--	7.65E-05	1.78E-04	--	1.78E-04
Perfluorononanesulfonic acid (PFNS)	ND	--	--	--	--	--	--	--
Perfluorodecanesulfonic acid (PFDS)	ND	--	--	--	--	--	--	--
Perfluorododecanesulfonic acid (PFDoS)	ND	--	--	--	--	--	--	--
4:2 FTS	NQ	--	--	--	--	--	--	--
6:2 FTS	2,090 D	--	6.55E-04	--	6.55E-04	1.53E-03	--	1.53E-03
8:2 FTS	122	--	3.83E-05	--	3.83E-05	8.92E-05	--	8.92E-05
Perfluorooctanesulfonamide (PFOSA)	14.9	--	4.67E-06	--	4.67E-06	1.09E-05	--	1.09E-05
N-Methylperfluorooctanesulfonamide (N-MeFOSA)	9.5	--	2.97E-06	--	2.97E-06	6.93E-06	--	6.93E-06
N-EtFOSA	34.3	--	1.08E-05	--	1.08E-05	2.51E-05	--	2.51E-05
MeFOSAA	82.0	--	2.57E-05	--	2.57E-05	6.00E-05	--	6.00E-05
EtFOSAA	49.4	--	1.55E-05	--	1.55E-05	3.61E-05	--	3.61E-05
N-MeFOSE	287	--	9.00E-05	--	9.00E-05	2.10E-04	--	2.10E-04
N-EtFOSE	110	--	3.45E-05	--	3.45E-05	8.05E-05	--	8.05E-05

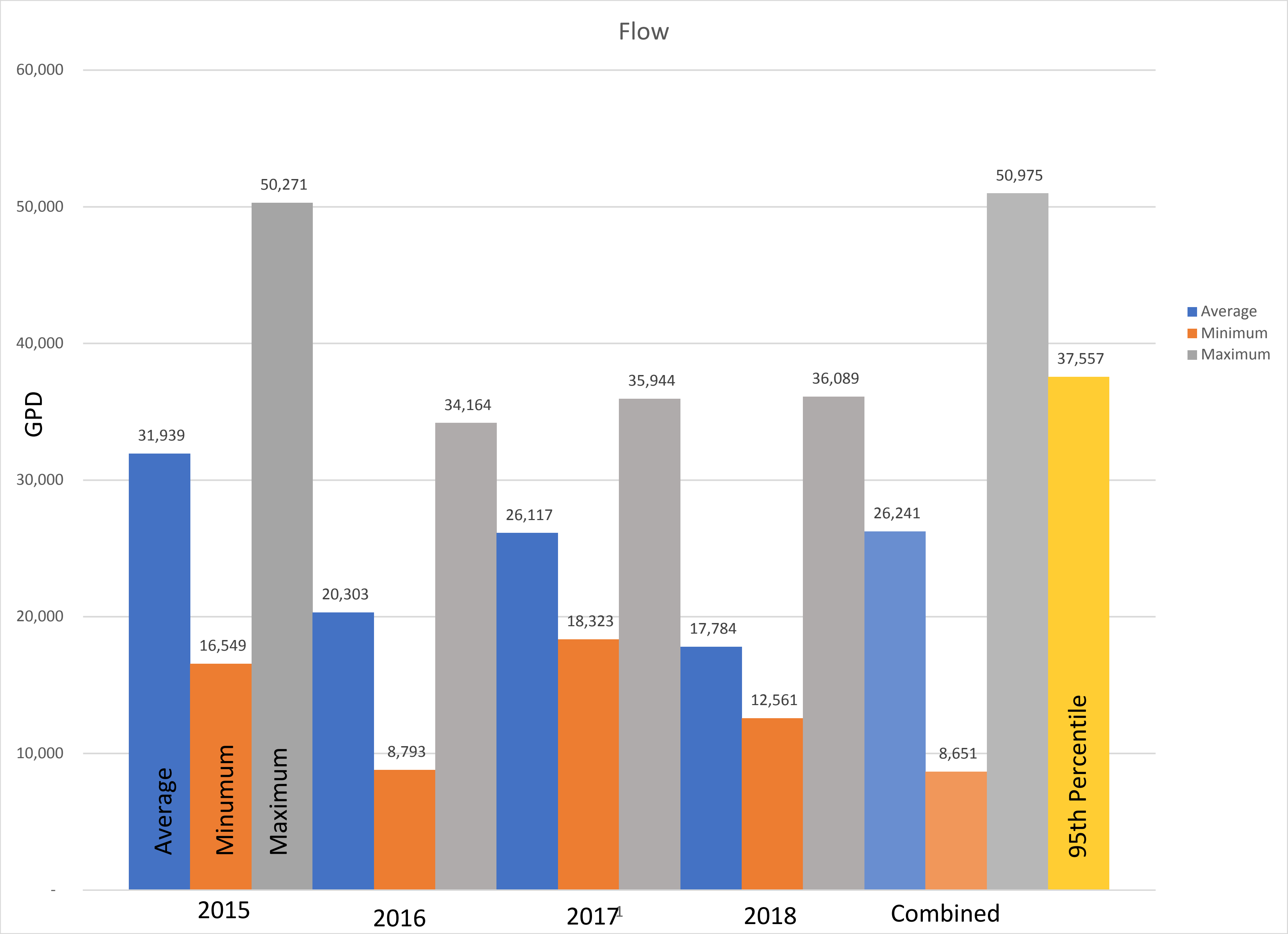
🟨 Selected Loading

ND = non-detect

D = diluted sample

Attachment B: Flow and Concentration Plots

Flow, BOD, Specific Conductivity, Total Chloride, TKN, Arsenic, Acetone, MEK


Flow
GPD
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50,000
40,000
30,000
20,000
10,000
-
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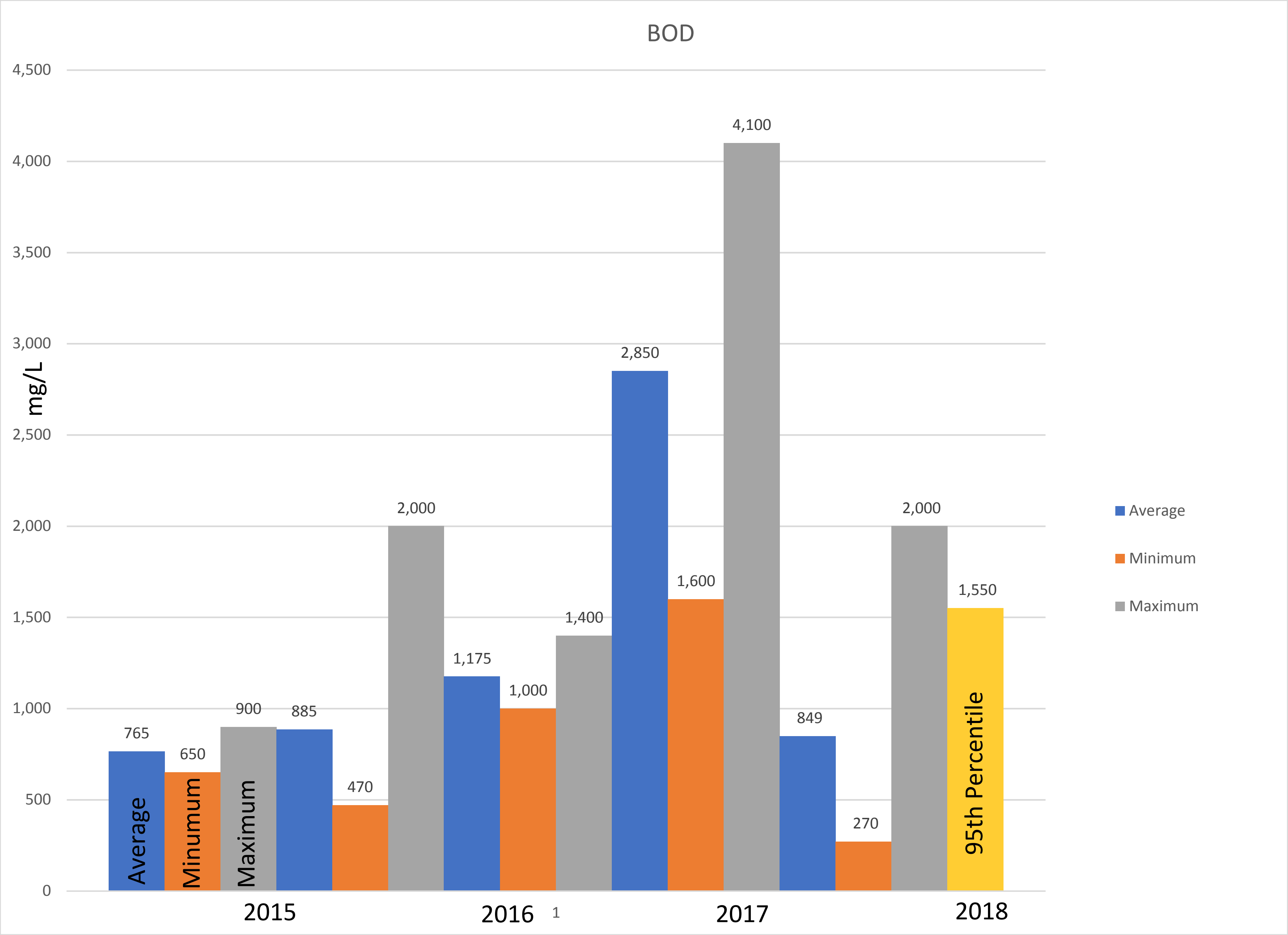
16,549
50,271
20,303
8,793
34,164
26,117
18,323
35,944
17,784
12,561
36,089
26,241
8,651
50,975
37,557
Average
Minumum
Maximum
95th Percentile
2015
2016
2017
1
2018
Combined
Average
Minimum
Maximum


BOD
mg/L
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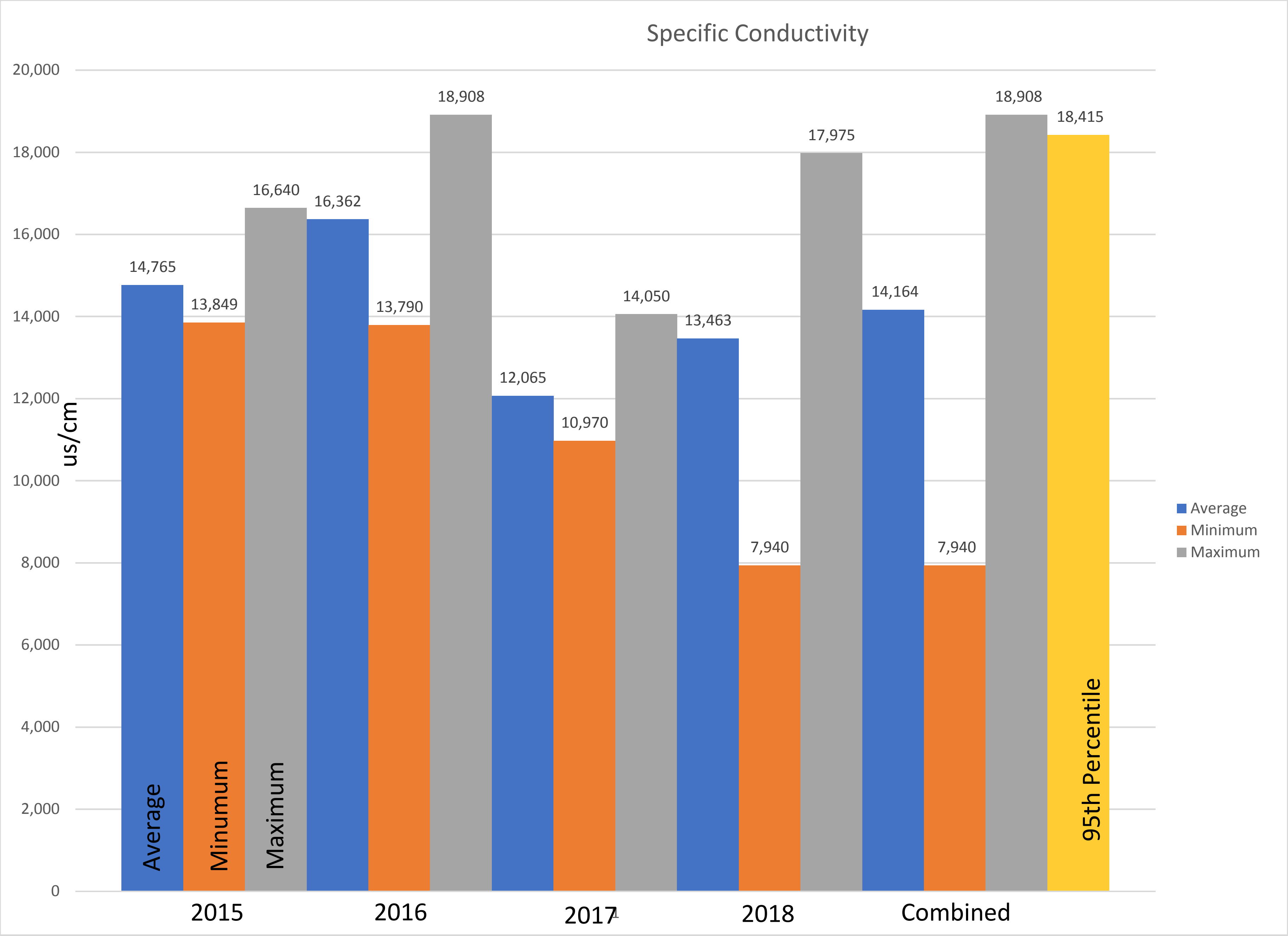
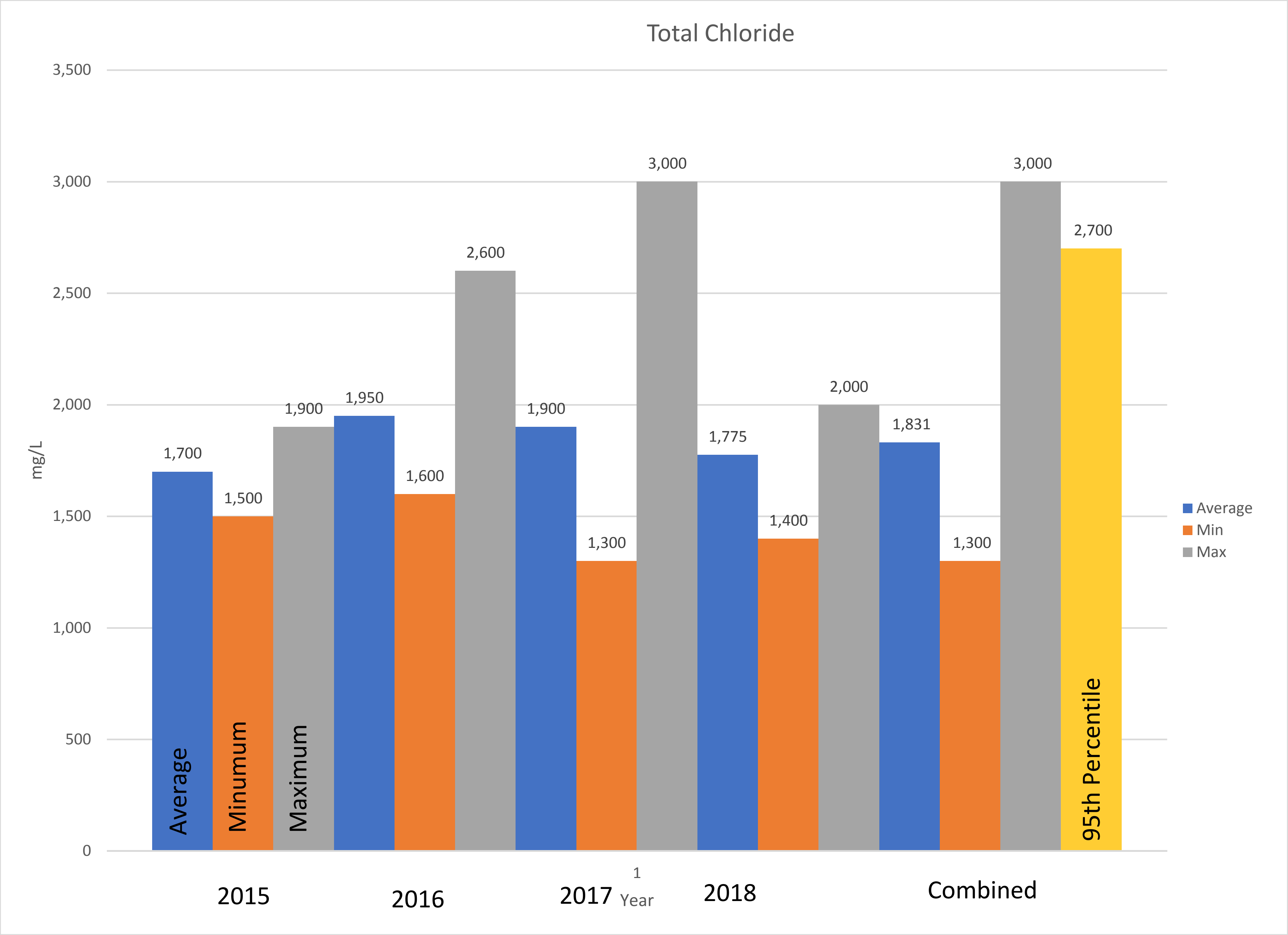
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
765
650
900
885
470
2,000
1,175
1,000
1,400
2,850
1,600
4,100
849
270
2,000
1,550
Average
Minumum
Maximum
95th Percentile
2015
2016
2017
2018
Average
Minimum
Maximum


Specific Conductivity
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
us/cm
14,765
13,849
16,640
16,362
13,790
18,908
12,065
10,970
14,050
13,463
7,940
17,975
14,164
7,940
18,908
18,415
Average
Minumum
Maximum
95th Percentile
2015
2016
2017
2018
Combined
Average
Minimum
Maximum


Total Chloride
mg/L
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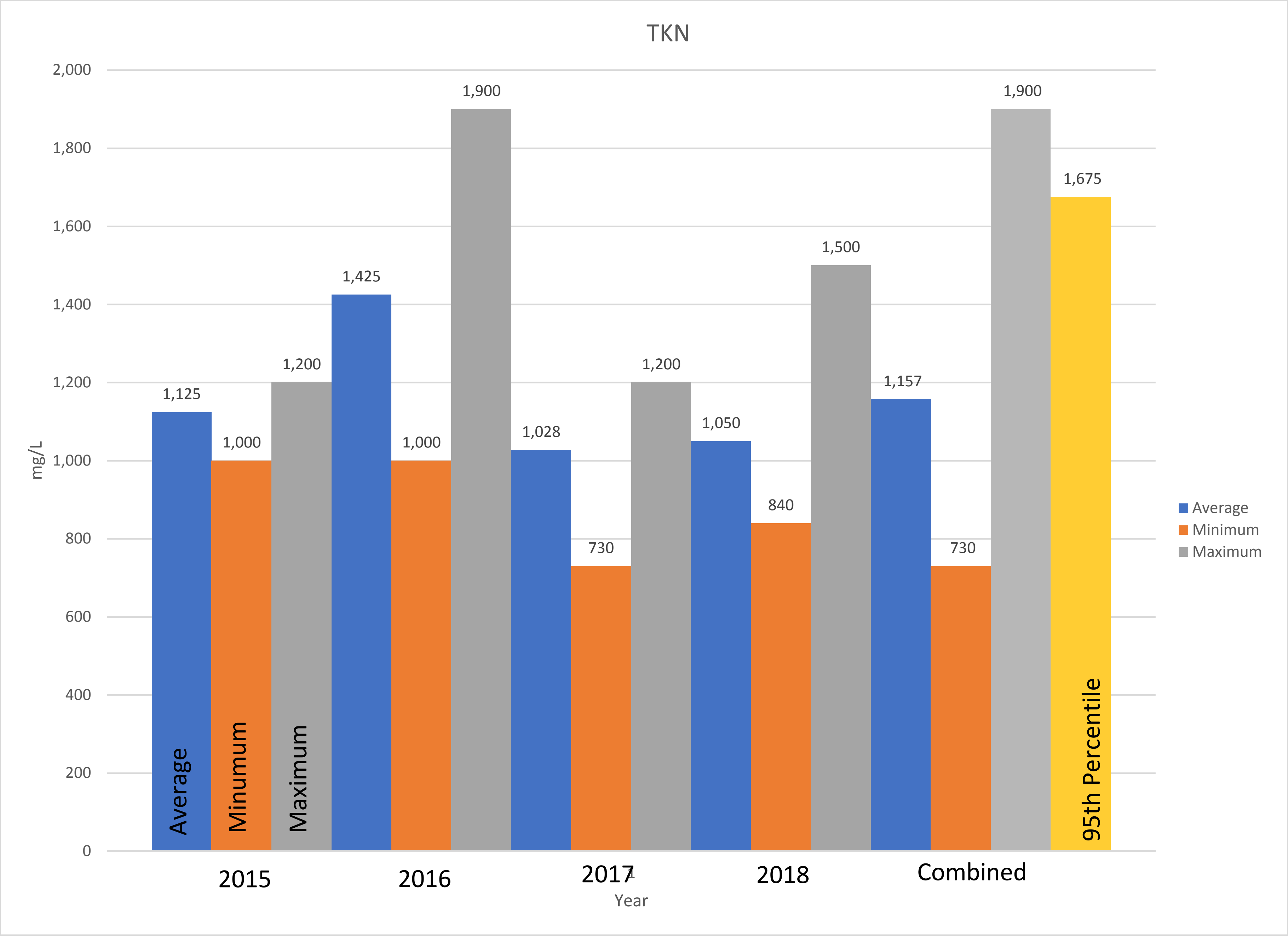
3,000
2,500
2,000
1,500
1,000
500
0
1,700
1,500
1,900
1,950
1,600
2,600
1,900
1,300
3,000
1,775
1,400
2,000
1,831
1,300
3,000
2,700
Average
Minumum
Maximum
95th Percentile
1
Year
2015
2016
2017
2018
Combined
Average
Min
Max


TKN
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1,800
1,600
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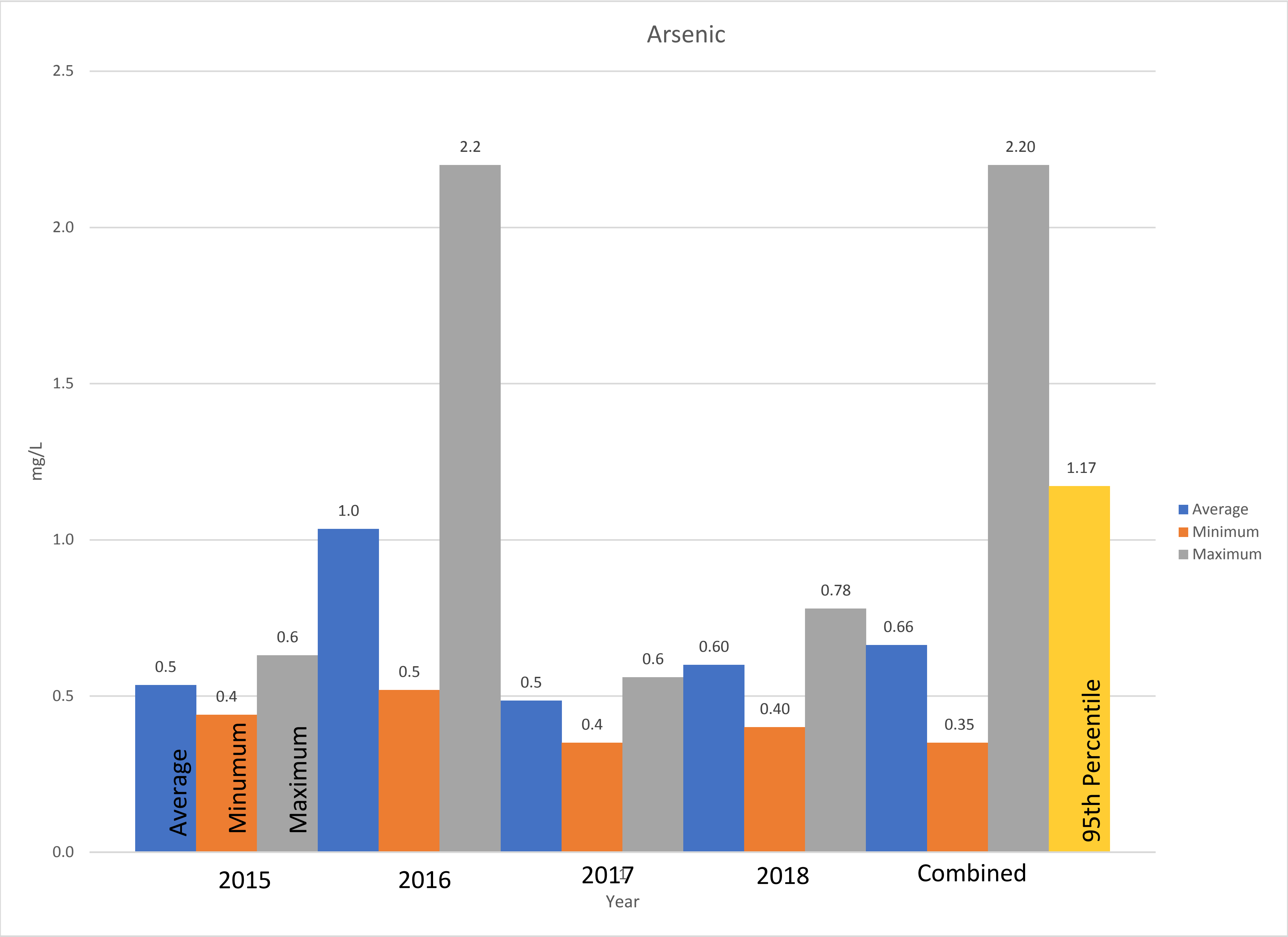
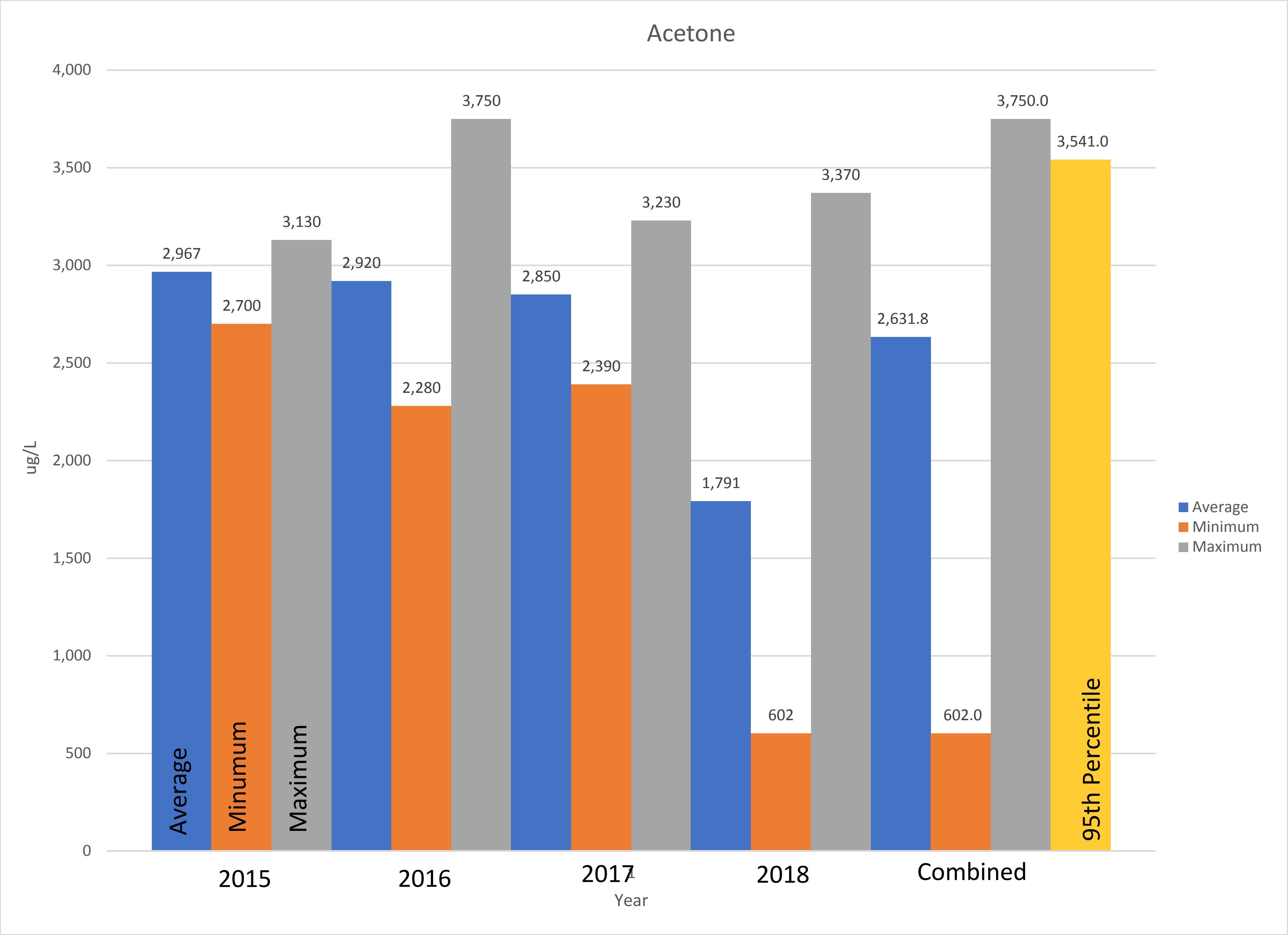
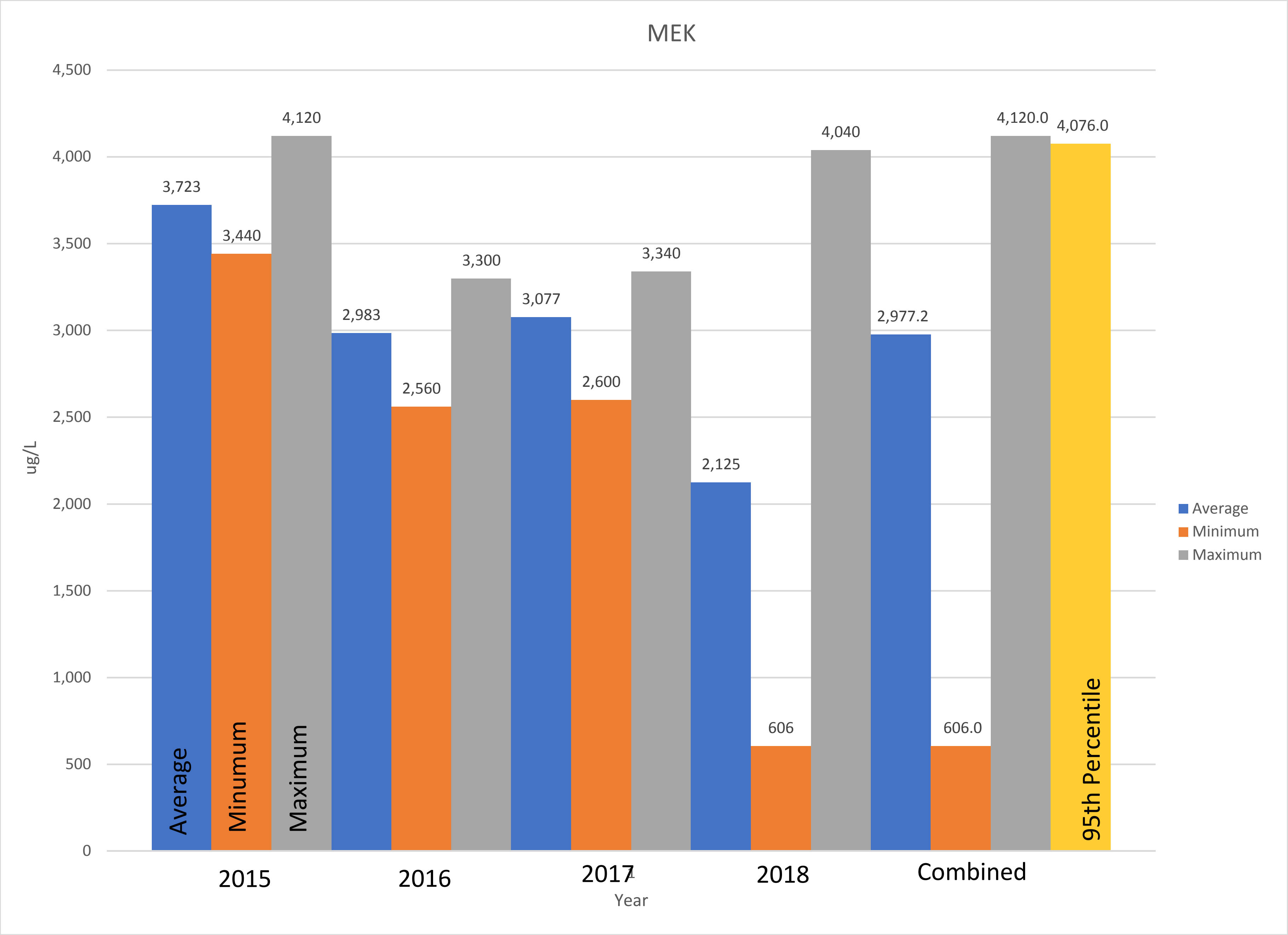
1,200
1,000
800
600
400
200
0
mg/L
1,125
1,000
1,200
1,425
1,000
1,900
1,028
730
1,200
1,050
840
1,500
1,157
730
1,900
1,675
Average
Minumum
Maximum
95th Percentile
2015
2016
2017
2018
Combined
Year
🟦 Average
🟧 Minimum
⬜ Maximum


Arsenic
2.5
2.0
1.5
1.0
0.5
0.0
mg/L
0.5
0.4
0.6
1.0
0.5
2.2
0.5
0.4
0.6
0.60
0.40
0.78
0.66
0.35
2.20
1.17
Average
Minumum
Maximum
95th Percentile
2015
2016
2017
2018
Combined
Year
🟦 Average
🟧 Minimum
⬜ Maximum


Acetone
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
ug/L
2,967
2,700
3,130
2,920
2,280
3,750
2,850
2,390
3,230
1,791
602
3,370
2,631.8
602.0
3,750.0
3,541.0
Average
Minumum
Maximum
95th Percentile
2015
2016
2017
2018
Combined
Year
Average
Minimum
Maximum


MEK
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
ug/L
3,723
3,440
4,120
2,983
2,560
3,300
3,077
2,600
3,340
2,125
606
4,040
2,977.2
606.0
4,120.0
4,076.0
Average
Minumum
Maximum
95th Percentile
2015
2016
2017
2018
Combined
Year
Average
Minimum
Maximum

Attachment C: Phase VI Expansion Leachate Summary

Table 1 – Leachate Generation Summary by Cell and Stage, Phase VI Landfill Expansion

Attachment D

Table 1 - Leachate Generation Summary By Cell and Stage
Phase VI Landfill Expansion

Phase VI Cell No. (in order of Construction)	**Cell 1A**		**Cell 1B**	**Cell 2A/1C**			**Cell 2B/1D**		**Cell 1E**	
Phase VI Cell Stage	**Stage 1**	**Stage 2**		**Stage 1**		**Stage 2**			**Stage 1**	**Stage 2**
Cell Sump Receiving Leachate	**Cell 1**	**Cell 1**	**Cell 1**	**Cell 1**	**Cell 2**	**Cell 2**	**Cell 1**	**Cell 2**	**Cell 1**	**Cell 1**
Geomembrane Lined Area (acres)	10.5	3.7	6.2	1.9	8.7	5.8	3.6	4.4	3.6	5
Geomembrane Lined Area (square feet)	457,380	161,172	270,072	82,764	378,972	252,648	156,816	191,664	156,816	217,800
Additional Tributary Area (acres)	0	2.9	5.1	1.3	0	2.5	0	2.1	3.1	14.1
Additional Tributary Area (square feet)	0	126,324	222,156	56,628	0	108,900	0	91,476	135,036	614,196
Leachate Generation[1] (gallons) (25yr-24hr Storm Event = 4.14 inches)	1,180,473	497,485	840,384	250,148	978,106	722,337	404,733	553,698	491,864	958,431
Leachate Pump Rate Required to Remove Leachate Generated from 25yr-24hr Storm Event from New Cell Within 5 days (gpm)[2]	**164**	69	117	35	**136**	100	56	77	68	133
Average Daily Leachate Generated by Phases I through IV combined with constructed Phase VI Cells (at 359 gal/acre/day)[2]	27,787	31,556	32,884	35,110		38,916	40,998		40,100	45,162
Leachate Volume Generated Generated by Phases I through IV combined with constructed Phase VI Cells Over a 5-Day Period (gallons)	138,933	157,781	164,422	175,550		194,578	204,989		200,502	225,811
Leachate Generation after 25yr-24hr Storm Event with Daily Generation from Constructed Cells Over a 5-day Period (gallons)	1,319,406	655,265	1,004,806	1,403,804		916,915	1,163,420		692,365	1,184,242
Leachate Volume Remaining After Existing On-Site Storage Capacity has been Exhausted (gallons) (Assumed Existing Capacity = 412,200 gallons)[3]	907,206	243,065	592,606	991,604		504,715	751,220		280,165	772,042
Additional Leachate Volume Required After Considering Leachate to be Removed by Truck over 5-Day Period (gallons), (landfill can remove 120,000 gallons/day)[4]	307,206	-356,935	-7,394	391,604		-95,285	151,220		-319,835	172,042
Greatest Required Leachate Storage (gallons)				**391,604**						

Comments:

1) Assumes 25% of additional tributary area contributes to total volume *(Goldman, et.al., Erosion and Sediment Control Handbook).* Tabulated values based on 25-year, 24-hour storm event (approximately 4.14 inches of precipitation).

2) Leachate produced by existing landfill areas during 5 day pumping period assuming an average generation rate of 359 gallons/acre/day. Note that the quantity of leachate generated increases as cells/subcells of Phase VI are developed.

3) On-site storage capacity: UST = 20,000 gallons, AST = 438,000 gallons (Assume NEWSVT will pump out storage structures so that 90 percent of capacity is available when a new cell is constructed. Therefore, use 412,200 gallons of available capacity).

4) Assumes 20 truck loads per day at 6,000 gallons per truck load (120,000 gallons). Removal capacity provided by Lenny Wing of NEWSVT.

Appendix B: Regulatory Review Technical Memorandum

Brown AND Caldwell

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Upper Saddle River, NJ 07458

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Technical Memorandum

Prepared for: Casella Waste Systems, Inc.

Project Title: NEWSVT Leachate Treatment Options Engineering Evaluation

Project No.: 152990

Technical Memorandum

Subject: Regulatory Review

Date: January 16, 2019

To: Ken Robbins

From: Brown and Caldwell

Copy to: Jeremy Labbe and Joe Gay – Casella
Steve Giese, Anthony Andrews and Alan Kirschner – Brown and Caldwell

Prepared by: Steven W. Giese

Steven W Giese

Reviewed by: Kevin D. Torrens

Kevin D. Torrens

Reviewed by: Stephen J. McGuire

STATE OF VERMONT
STEPHEN JOHN MCGUIRE
5/31/2019
NO. 134331
ENVIRONMENTAL
LICENSED PROFESSIONAL ENGINEER

Stephen J. McGuire, PE
VT PE# 018.0134331

Limitations:

This document was prepared solely for Casella Waste Systems, Inc. (Casella) in accordance with professional standards at the time the services were performed and in accordance with the contract between Casella and Brown and Caldwell dated December 17, 2018. This document is governed by the specific scope of work authorized by Casella; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Casella and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

Introduction

This technical memorandum (TM) summarizes regulatory requirements in Vermont for potential leachate management approaches at Casella's New England Waste Systems landfill in Coventry, Vermont (NEWSVT). These include permit requirements for pretreatment, direct discharge to surface water and air permitting for on-site treatment options. We have also included an outlook on the current regulatory landscape for emerging contaminants and potential impacts on regulatory permits. The outlook is a general overview of current trends and is not meant to be fully predictive, nor have we conducted an exhaustive review of all regulatory actions. This TM was prepared under Task 3 of the scope of work.

The following key points summarize the detailed discussion herein:

- Per- and polyfluoroalkyl substances (PFAS) and 1,4-dioxane are currently of high interest to federal and state regulators. Much of this focus is on drinking water and contamination of drinking water sources. Some states have established surface water quality limits for these compounds.
- Vermont has established health advisories for PFAS in drinking water, similar to other states in the Northeast and nationwide. These advisories are more stringent than the current federal advisory. Select states (New Hampshire and New York) are looking at establishing maximum contaminant levels (MCLs) in drinking water, which are enforceable standards.
- Many states have established groundwater or drinking water guidelines for 1,4-dioxane, Vermont has a health advisory of 300 ppt. New Jersey and New York are looking at establishing an MCL for 1,4-dioxane.
- Few states have established surface water quality standards (SWQS) for PFAS or 1,4-dioxane. Although Vermont does not have an established SWQS for PFAS, the Vermont Department of Environmental Conservation (VTDEC) has referenced Minnesota SWQS for PFOA and PFOS in presentations and correspondence regarding NEWSVT. VTDEC has indicated that it is evaluating a SWQS for PFOA and PFOS. Vermont does not have a SWQS for 1,4-dioxane.
- VTDEC will likely include limits for PFOA, PFOS and select metals, such as arsenic, in a renewed pretreatment permit.
- VTDEC will likely require that an effluent discharge to the Black River under a National Pollutant Discharge Elimination System (NPDES) permit meet SWQS at end of pipe. The Black River is a high-quality waterbody, where no dilution is allowed per Vermont regulations. However, this may be negotiable. Permit limits will likely be included for general chemistry, metals, volatile organic compounds, semi-volatile organic compounds, pesticides, PCBs, phosphorus, PFOS, PFOA and effluent toxicity. The NPDES permit application will be considered high-profile and will include multiple public meetings.
- The existing Title V air permit may require modification depending on on-site treatment. Treatment processes for direct discharge to surface water do not typically require an air permit modification based on our experience. Evaporation technology may trigger air emissions monitoring and perhaps control requirements for odors based on vendor experience.

Section 1: Outlook on Regulatory Environment for PFAS and Other Emerging Contaminants

The USEPA Contaminant Candidate List (CCL) is a list of contaminants that are currently not subject to any proposed or promulgated national primary drinking water regulations but are known or anticipated to occur in public water systems. Contaminants listed on the CCL may require future regulation under the Safe Drinking Water Act (SDWA). The Final CCL 4 includes 97 chemicals or chemical groups. The list includes, among others, chemicals used in commerce, pesticides, disinfection byproducts and pharmaceuticals. Of particular current interest on this list are PFOA, PFOS, and 1,4-dioxane. Many of the other compounds on the list including pharmaceuticals and insecticides may be present in leachate as well although they are typically not analyzed for.

It is important to note that inclusion on the CCL list does not mean regulation is imminent. At least five compounds are selected from the list and a determination made as to whether regulation is required. If regulation is determined as not required, the compound is removed from the CCL list. If regulation is required, the regulatory process for establishing limits is initiated. Note that limits are for drinking water and not for wastewater discharges (although drinking water standards may be used as a basis for establishing discharge limits in some cases). Compounds not selected for evaluation remain on the CCL for future consideration. The CCL is updated every five years.

The VTDEC is looking closely at PFAS, as Casella is aware. States often look to federal standards or other states for guidance before determining their own standards. The federal health advisory for total PFOA and PFOS in drinking water is 70 parts per trillion (ppt). The VTDEC recently established a total advisory level of 20 ppt for five PFAS (PFHpA, PFHxS, PFNA, PFOA, and PFOS) in drinking water. Connecticut and Massachusetts each have an advisory level of 70 ppt for the same five PFAS compounds. Advisory levels are not enforceable or regulatory, but instead provide guidance for agencies to take further action (e.g., monitoring, point-of-use treatment, etc.). In December 2018, the New York State Drinking Water Quality Board (DWQB) recommended MCLs of 10 ppt each for PFOA and PFOS. New Hampshire is proposing to establish MCLs and Ambient Groundwater Quality Standards (AGQS) of 38 ppt for PFOA, 70 ppt for PFOS, 70 ppt for total PFOA and PFOS (based on federal health advisory), and 85 ppt for PFHxS, and 23 ppt for PFNA. New Hampshire state law requires that AGQS be the same or more stringent than federal or health advisory under the Safe Drinking Water Act (SDWA). Thus, PFAS compounds are a significant focus for state health and environmental agencies in the Northeast (and nationwide) and could eventually include next generation PFAS (e.g., Gen-X, ADOVA, fluorotelomers, etc.) and PFAS precursors. There are thousands of PFAS compounds and there is ongoing work to understand their environmental and health-based risks. It is unclear at this time as to whether any additional compounds will be regulated. Many states are implementing monitoring programs to track sources, distribution, and variability of PFAS. The Interstate Technology Regulatory Council (ITRC) issues a fact sheet (Table 4-1) containing standards and guidance values for PFAS in groundwater, drinking water, and surface water, which is included in Attachment A. ITRC updates Table 4-1 periodically as the guidance values are subject to change. The updates to Table 4-1 are also included in Attachment A.

Some states have established SWQS for PFAS; no federal standard currently exists. Table 1 summarizes known state surface water standards for PFAS. Note that these are in-stream concentrations and impacted waters may have lower discharge limits depending on background concentrations. Supporting documents are included in Attachment B.

Table 1. State Surface Water Quality Standards for PFAS

State	PFOA (ppt)	PFOS (ppt)
Michigan (Drinking Water Sources)	420	11
Michigan (Non-Drinking Water Sources)	12,000	12
Minnesota	610	6.1

The values shown for Minnesota are the most stringent of site-specific criteria for Lake Calhoun and the Mississippi River. VTDEC has indicated it is “coordinating with other regulatory agencies” regarding a surface water standard for PFAS[1]. SWQS will have a direct impact on discharges to surface water, whether via publicly owned treatment works (POTWs) or direct discharge from industrial or commercial dischargers, since they are used in determining limits in NPDES permits.

Vermont is focusing on other emerging contaminants (EC) in drinking water in addition to PFAS, such as 1,4-dioxane, 1,2,3-trichloropropane, pharmaceuticals, and personal care products. The Vermont Department of Health has advisory levels (Vermont Health Advisories, or VHAs) for ECs, which can be applied as limits to drinking water sources under Vermont’s Water Supply Rule (Chapter 21 of the VWSR, 2010). Table 2 shows VHAs for select ECs.

Table 2. Vermont Health Advisory Levels for Emerging Contaminants

Compound	Advisory Level (ppt)
1,4-Dioxane	300
1,2,3-Trichloropropane	20
PFHpA	20*
PFHxA	20*
PFNA	20*
PFOA	20*
PFOS	20*

** Total PFAS limit is 20 ppt.*

In December 2018, the New York State DWQB proposed establishing an MCL of 1,000 ppt for 1,4-dioxane. New Jersey is looking at establishing an MCL for 1,4-dioxane in drinking water. The state published notice on December 21, 2018 seeking public input for information on health effects, analysis, and treatment to aid in development of the MCL.

Other states have established drinking water and groundwater guidelines for 1,4-dioxane, as presented in Table 3 below.

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[1] Per Public Education Meeting Presentation prepared by VTDEC dated November 27, 2018.

Table 3. State Guidelines for 1,4-dioxane

State	Guideline (µg/L)	Source
Alaska	77	AL DEC 2016
California	1.0	Cal/EPA 2011
Colorado	0.35	CDPHE 2017
Connecticut	3.0	CTDPH 2013
Delaware	6.0	DE DNR 1999
Florida	3.2	FDEP 2005
Indiana	7.8	IDEM 2015
Maine	4.0	MEDEP 2016
Massachusetts	0.3	MADEP 2004
Mississippi	6.09	MS DEQ 2002
New Hampshire	0.25	NH DES 2011
New Jersey	0.4	NJDEP 2015
North Caroline	3.0	NCDENR 2015
Pennsylvania	6.4	PADEP 2011
Texas	9.1	TCEQ 2016
Washington	0.438	WA ECY 2015
West Virginia	6.1	WV DEP 2009

No federal SWQS for 1,4-dioxane exists. In October 2018, Connecticut established a NPDES permit limit for 1,4-dioxane of 43.3 ppb for an industrial discharge to a surface water body that is a non-drinking water source. The limit was derived based on human-health criteria since no state SWQS exists. Pennsylvania has a site-specific standard for one waterbody of 3 ppb based on human health criteria. Vermont currently has a guideline of 300 ppt and will likely review limits set in other states when considering SWQS for these ECs.

Section 2: Pretreatment Discharge Permit

Casella's current pretreatment discharge permit (Permit No. 3-1406) from the VTDEC Wastewater Management Division expired in 2016. VTDEC is waiting to renew the permit until the review of leachate management options is completed. The current permit includes limits for flow, biochemical oxygen demand (BOD) and pH for select POTWs in Vermont (Barre, Burlington North, Essex Junction, Montpelier, and Newport) where leachate may be disposed.

Vermont developed action levels of 120,000 ppt for PFOA and 1,000 ppt for PFOS for leachate disposed at POTWs. These values were determined to be maximum allowable concentrations at which POTW effluent discharge to surface water would not exceed Minnesota SWQS and/or Vermont VHAs, assuming no treatment of PFAS in the POTW. This is a reasonable assumption, as most POTWs are not designed to remove PFAS. In some cases, PFAS concentrations in POTW effluent can be higher than the influent, possibly due to biological or chemical oxidation of precursor compounds. This phenomenon was noted for select PFAS at the Barre and Randolph POTWs and for many PFAS at the Newport POTW according to the data from the "Water Treatment Facility and Landfill Leachate PFAS Sampling" report dated May 3, 2018 and prepared by Weston and Sampson.

It is unclear whether the VTDEC will revise existing limits in the renewed pretreatment permit. However, it is reasonable to assume PFAS limits will be established that are similar to the action levels mentioned above. Metals, such as arsenic, may also be added.

Section 3: NPDES Permit

An NPDES permit would be required to discharge wastewater to surface water. The Black River is the closest surface water body to NEWSVT. Vermont is a delegated authority under the NPDES and, as such, issues NPDES permits for discharges to surface water within Vermont. An industrial applicant would be required to fill out Permit Application Form WR-82 and Schedule B. Both forms are included in Attachment C for reference. Leachate characterization would be required for general chemistry, metals, and USEPA priority pollutants (listed in 40 CFR Part 423. Appendix A). The permit application fee would be approximately $420 assuming a permitted capacity of 60,000 gallons per day (gpd). An annual fee of $200 would apply while the permit is in effect.

The VTDEC would consider the application as a high-profile project, resulting in significant public engagement. A pre-application meeting with VTDEC is recommended. The VTDEC would consider the application a Type 1 permit and "large and complex project", which triggers certain requirements. These include a public pre-application meeting before submittal of the application, public notifications, and 30-day public comment period for the draft permit. The public may request an informational meeting once the VTDEC issues a fact sheet and draft decision on the permit application, and the public comment period would not end until 7 days after the informational meeting.

Vermont has SWQS for general parameters and toxics that would be compared to the projected in-stream concentration in the Black River receiving the effluent discharge. The Black River is a Class A(2) water body, or a high-quality water that could be used as a drinking water source. The VTDEC does not allow a mixing zone (dilution) in Class A(1) or A(2) waterbodies, but this may be negotiable. The in-stream concentration is calculated using the annual minimum 7-day average streamflow with a 10-year recurrence interval, or the 7Q10 flow. This flow is 37 cubic feet per second (cfs) which is sizable in comparison to the sites' maximum leachate volume of about 50,000 gpd (0.08 cfs) offering a potential full dilution factor of 460:1. If the state determines that the in-stream concentration could potentially exceed SWQS, the permit would include a limitation for that parameter. Some parameters are allowed dilution, while others (e.g., carcinogens, total maximum daily loads or TMDLs) are not. For example, no dilution would likely be allowed for arsenic because it is a carcinogen. If the VTDEC will not allow a mixing zone, then SWQS must be met at end of pipe.

Per Chapter 29A-303, Part (7)(D) of the Vermont Environmental Protection Rule, the State can develop standards for parameters present in the effluent if no federal or state SWQS exists by using human-health risk criteria. Since the Black River could be used as a drinking water source, the VTDEC has the authority to develop permit limits for ECs such as PFAS.

Permit limits for discharge to surface water will likely include metals, volatile and semi-volatile organics, pesticides, Aroclor polychlorinated biphenyls (PCBs), pH, temperature, turbidity, dissolved oxygen, ammonia-nitrogen, nitrate, chloride, phosphorus, PFOA, PFOS, and whole effluent toxicity (acute and chronic). Monitoring will likely be included for 1,4-dioxane.

Section 4: Air Permit

NEWSVT has a current operating Title V air permit for the site (Permit No. AOP-17-018). Limits are included for particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, volatile organic compounds, and hazardous air pollutants. Based on the type of pretreatment technologies under consideration and discussions with Casella, it is assumed that on-site wastewater treatment equipment will not be significant contributors to emissions from the site. Our experience is that Water9 modeling can be used to estimate air emissions for liquid treatment processes. This is a USEPA model and has been accepted by regulatory agencies as a basis for a Request for Determination (RFD) to identify if the Title V air permit requires modification. In our experience the RFDs have been accepted and no permit modifications or emission controls were required.

Evaporation technology may trigger air emissions monitoring and perhaps control requirements. According to discussions with Heartland, emissions from their evaporation system are limited to pass-through of combustion byproducts from the thermal energy source and some volatile organic compounds (e.g., acetone). Odors are a consideration and may necessitate controls. These conclusions are based on Heartland's air permit experience and stack testing of their installed evaporation systems for leachate treatment.

Attachment A: ITRC Table 4-1 and Table 4-1 Updates

Standards and Guidance Values for PFAS in groundwater, drinking water, and surface water/effluent (wastewater)

November 2018

Table 4-1. Standards and guidance values for PFAS in groundwater, drinking water, and surface water/effluent (wastewater).

This Table 4.1 belongs with the ITRC PFAS Regulations, Guidance and Advisories Fact Sheet. The values included here reflect values we are aware of as of November 15, 2018. These values are changing rapidly. The ITRC intends to update this table periodically as new information is gathered. The fact sheet user is encouraged to visit the ITRC PFAS web page (http://pfas-1.itrcweb.org) to access the current version of this file. Please see ITRC Disclaimer http://pfas-1.itrcweb.org/about-itrc/#disclaimer

							PFAS Analyte Concentration (µg/L) and CAS RN													
Location	Agency / Dept	Year First Listed	Standard / Guidance	Type	Promulgated Rule (Y/N/O)	Footnote	PFOA	PFOS	PFNA	PFBA	PFBS	PFHxS	PFHxA	PFPeA	PFHpA	PFOSA	PFDA	PFDS, PFUnA, PFDoA, PFTrDA, PFTeDA	6:2 FTS	Gen-X
							335-67-1	1763-23-1	375-95-1	375-22-4	375-73-5	355-46-4	307-24-4	2706-90-3	375-85-9	754-91-6	335-76-2	2058-94-8, 307-55-1, 72629-94-8,	27619-97-2	3252-13-6
U.S. Environmental Protection Agency																				
USEPA	Office of Water	2016	HA	DW	N	a	0.07	0.07												
	Regions	2014	RSL	GW	N	b					400									
	Regions	2018	RSL Calculation	GW	N	c	0.4	0.4												
U.S. States																				
Alaska (AK)	DEC	2016	CL	GW	Y		0.40	0.40												
	DEC	2018	Action Level	DW/GW/SW	N	e	0.07	0.07	0.07		2	0.07			0.07					
California (CA)	SWRCB	2018	NL	DW	N		0.014	0.013												
Colorado (CO)	DPHE	2018	GQS	GW	Y	d	0.07	0.07												
Connecticut (CT)	DPH	2016	AL	DW/GW	N	e	0.07	0.07	0.07			0.07			0.07					
Delaware (DE)	DNREC	2016	RL	GW	N	a	0.07	0.07												
	DNREC	2016	SL	GW	N	a	0.07	0.07			38									
Iowa (IA)	DNR	2016	Statewide Standards	Protected GW	Y	a	0.07	0.07												
	DNR	2016		Non-protected GW	Y			1												
Maine (ME)	CDC	2016	Health-based MEG	DW	N	a	0.07	0.07												
	DEP	2018	RAG	GW	N		0.4	0.4			400									
	CDC	2016	Screening Level	GW	N		0.12	0.12			140									
	CDC	2016	Screening Level	SW/RW	N		0.17	0.3			7,914									
Massachusetts (MA)	DEP	2018	Guidance Values	DW	O	e	0.07	0.07	0.07		2	0.07			0.07					
Michigan (MI)	DEQ	2015	HNV	SW	Y		0.42	0.011												
	DEQ	2018	GCC	DW/GW	Y	a	0.07	0.07												
Minnesota (MN)	MDH	2017	short-term HBV	DW/GW	O/N	f	0.035	0.027		7	3	0.027								
	MDH	2017	subchronic HBV	DW/GW	O/N	f	0.035	0.027		7	3	0.027								
	MDH	2017	chronic HBV	DW/GW	O/N	f	0.035	0.027		7	2	0.027								
Nevada (NV)	DEP	2015	BCL	DW	N		0.667	0.667			667									
New Hampshire (NH)	DES	2016	AGQS	GW	Y	a	0.07	0.07												
New Jersey (NJ)	DEP	2018	GWQS	GW	Y				0.013											
	DEP	2018	MCL	DW	Y				0.013											
	DWQI	2017	MCL	DW	O		0.014													
	DWQI	2018	MCL	DW	O			0.013												
North Carolina (NC)	DEQ	2006	IMAC	GW	Y		2													
	DHHS	2017	Health Goal	DW	N															0.14
Oregon (OR)	DEQ	2011	IL	SW	Y		24	300	1						300	0.2				
Pennsylvania (PA)	DEP	2016	MSC	GW	N	a	0.07	0.07												
Rhode Island	DEM	2017	Groundwater Quality Standard	DW/GW	Y	a	0.07	0.07												
Texas (TX)	CEQ	2016	Tier 1 PCL	GW	Y		0.29	0.56	0.29	71	34	0.093	0.093	0.093	0.56	0.29	0.37	0.29		
Vermont (VT)	DEC/DOH	2018	HA	DW/GW	Y	e	0.02	0.02	0.02			0.02			0.02					

November 2018

Table 4-1. Standards and guidance values for PFAS in groundwater, drinking water, and surface water/effluent (wastewater).

This Table 4.1 belongs with the ITRC PFAS Regulations, Guidance and Advisories Fact Sheet. The values included here reflect values we are aware of as of November 15, 2018. These values are changing rapidly. The ITRC intends to update this table periodically as new information is gathered. The fact sheet user is encouraged to visit the ITRC PFAS web page (http://pfas-1.itrcweb.org) to access the current version of this file. Please see ITRC Disclaimer http://pfas-1.itrcweb.org/about-itrc/#disclaimer

							PFAS Analyte Concentration (μg/L) and CAS RN													
Location	Agency / Dept	Year First Listed	Standard / Guidance	Type	Promulgated Rule (Y/N/O)	Footnote	PFOA	PFOS	PFNA	PFBA	PFBS	PFHxS	PFHxA	PFPeA	PFHpA	PFOSA	PFDA	PFDS, PFUnA, PFDoA, PFTrDA, PFTeDA	6:2 FTS	Gen-X
International																				
Australia	DOH	2017	health-based	DW		g	0.56	0.07				0.07								
		2017	health-based	RW		g	5.6	0.7				0.7								
British Columbia, Canada		2018	water standard	DW/GW			0.2	0.3			80									
Canada	HC	2016 & 2018	screening value	DW			0.2	0.6	0.02	30	15	0.6	0.2	0.2	0.2					
Denmark	EPA	2015	health-based	DW/GW		h	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.1	
Germany	GMH	2006	health-based	DW			0.3	0.3												
			administrative	DW		i	0.1	0.1												
		2018	GFS	GW			0.1	0.1	0.06	10	6	0.1	6							
Italy		2017	health-based	DW			0.5			7	3		1	3						
		2017	screening value	FW		j	0.1			7	3		1	3						
Netherlands	EPA	2011	health-based	DW				0.53												
		2011	administrative	DW				0.0053												
Norway		2014	EQS	SW			9.1	0.00065												
		2014	EQS	CW			9.1	0.00013												
Sweden		2014	health-based	DW				0.09												
		2014	administrative	DW		k	0.09	0.09			0.09	0.09	0.09	0.09	0.09					
UK	DWI	2009	health-based	DW			10	0.3												
		2009	admin. Level 1	DW			0.3	0.3												
		2009	admin. Level 2	DW			10	1.0												
		2009	admin. Level 3	DW			90	9												

Notes:

The following states use the EPA Health Advisories: Alabama (AL), Arizona (Az), Colorado (CO), and West Virginia (WV).

Promulgated (Yes/No/Other)- Values are considered promulgated Rule if they have been finalized into law or if the table of values is referenced in supporting law. Values are not considered promulgated when they are not finalized into law but are considered final guidance. Values identified as "other" include those that are proposed, considered draft, or recommended but not yet finalized.

Year First Listed is the year the value became effective. References are provided for the most recent publication of the values.

a Applies to the individual results for PFOA and PFOS, as well as the sum of PFOA + PFOS.

b Regional Screening Level (RSL) as presented in the USEPA Regional Screening Level (RSL) Summary Table (TR=1E-06, HQ=1) November 2014 through May 2018.

c As of June 2018, calculated by the USEPA RSL calculator using USEPA OW RfDs, HQ of 1, and residential exposure assumptions. Note: RSL users screening sites with multiple contaminants should consult the USEPA (2018) RSL User's Guide and USEPA (1989) Risk Assessment Guidance.

d The 2018 Colorado Site-specific Groundwater Quality Standard was adopted to provide a cleanup goal for the contaminated aquifer in El Paso County only.

e Applies to the individual results for PFOA, PFOS, PFHpA, PFNA, and PFHxS as well as the sum of concentrations of these 5 PFAS.

f HRLs for PFBA (7 ug/L) published in 2011 are promulgated. The MN values for PFOA, PFOS, and PFBS are unpromulgated HBVs. The PFHxS value is an interim surrogate based on the PFOS HBV.

g The Australian Government Department of Health values for PFOS/PfHxS are combined value when both are present.

h Applies to the individual results for PFOA, PFOS, PFNA, PFBA, PFBS, PFHxS, PFHxA, PFPeA, PFHpA, PFOSA, PFDA, AND 6:2 FTS as well as the sum of concentrations of these 12 PFAS.

i The GMH administrative guidance value of 0.1 μg/L is a composite precautionary value for both PFOA and PFOS for long term exposure in drinking water.

j Annual Average - Environmental Quality Standards. PFOA AA-EQS based on secondary poisoning of wildlife.

k Administrative value is for the sum of seven PFAS found in drinking water: PFOS, PFOA, PFHxS, PFBS, PFHpA, PFHxA, and PFPeA. PFOS is considered to be the most toxic. Water can still be used at up to 0.09 μg/L.

November 2018

Table 4-1. Standards and guidance values for PFAS in groundwater, drinking water, and surface water/effluent (wastewater).

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Regulatory Agency
CDC= Center for Disease Control & Prevention
CEQ = Commission on Environmental Quality
DEC = Dept. of Environmental Conservation
DEM = Dept. of Environmental Management
DEP = Dept. of Environmental Protection
DEQ = Dept. of Environmental Quality
DES = Dept. of Environmental Services
DHHR = Dept. of Health and Human Resources
DHHS = Dept. of Health and Human Services
DNR = Dept. of Natural Resources
DNREC = Dept. of Natural Resources and Environmental Control
DOH = Dept. of Health
DPH = Division or Department of Public Health
DPHE = Department of Public Health and Environment
DWI = Drinking Water Inspectorate
DWQI = NJ Drinking Water Quality Institute
EPA = Environmental Protection Agency
GMH = German Ministry of Health
MDH = Minnesota Department of Health
OEHS = Office of Environmental Health Services
SWRCB = California State Water Resources Control Board

Standard or Guidance
AGQS = ambient groundwater quality standard
AL = private well action level
BCL = basic comparison level
CL = groundwater cleanup level
CW = Coastal Water
ES = environmental standard
EQS = environmental quality standard
GCC = Generic Cleanup Criteria
GFS = significance thresholds
GQS = Site-Specific Groundwater Quality Standard
HA = lifetime health advisory
HNV = human noncancer value for surface drinking water
HBV = health-based value
HRL = health risk limit
IL = initiation level
IMAC = interim maximum allowable standard
MCL = maximum contaminant level
MEG = maximum exposure guideline
MSC = medium-specific concentration
NL = Notification Level
PCL = protective concentration level
PGWES = primary groundwater enforcement standard
PHG = public health goal
RAG = remedial action guideline
RL = reporting level
RSL = regional screening level
SL = screening Level

Per- and polyfluoroalkly substances
PFAS = per- and polyfluroalkyl substances
PFOA = perfluorooctanoic acid (C8)
PFOS = perfluorooctane sulfonic acid (C8)
PFNA = perfluorononanoic acid (C9)
PFBA = perfluorobutyric acid (C4)
PFBS = perfluorobutane sulfonic acid (C4)
PFPeA = perfluoropentanoic acid (C5)
PFHxS = perfluorohexane sulfonic acid (C6)
PFHxA = perfluorohexanoic acid (C6)
PFHpA = perrfluoroheptanoic acid (C7)
PFOSA = perfluorooctane sulfonamide (C8)
PFDA = perfluorodecanoic acid (C10)
PFDS = perfluorodecane sulfonate (10)
PFUnA = perfluoroundecanoic acid (C11)
PFDoA = perfluorododecanoic acid (C12)
PFTrDA = perfluorotridecanoic acid (C13)
PFTeDA = perfluorotetradecanoic acid (C14)
6:2 FTS = 6:2 Fluorotelomer sulfonate

Type of Medium
DW = drinking water
FW = fresh water
GW = groundwater
RW = recreational water
SW = surface water and/or effluent

November 2018

Table 4-1. UPDATES Standards and guidance values for PFAS in groundwater, drinking water, and surface water/effluent (wastewater).

Table 4.1 belongs with the ITRC PFAS Regulations, Guidance and Advisories Fact Sheet. The values included here reflect values we are aware of as of November 15, 2018. These values are changing rapidly. The ITRC intends to update the table periodically as new information is gathered. The fact sheet user is encouraged to visit the ITRC PFAS web page (http://pfas-1.itrcweb.org) to access the current version of this file. Please see ITRC Disclaimer http://pfas-1.itrcweb.org/about-itrc/#disclaimer

November 2018 Update: What's New

Date	State/Country	Chemical	Update
August 2016	Maine	PFOA/PFOS/PFBS	Added screening levels for select PFAS in groundwater and surface water.
October 2018	Maine	PFOA/PFOS/PFBS	Added remedial action goals (RAGs) for select PFAS in groundwater.

September 2018 Update: What's New

Date	State/Country	Chemical	Update
September 2018	**Alaska**	PFOA/PFOS/PFNA/PFHxS/PFHpA	Adopted action levels for select PFAS in groundwater (consistent with Massachusetts approach).
September 2018	New Jersey	PFNA	Adopted Maximum Contaminant Level (MCL) for PFNA (0.013 µg/L).
2018	Germany	PFOA/PFOS/PFNA/PFBA/PFBS/PFHxS/PFHxA	Established signficance thresholds (GFS) for select PFAS in groundwater.
2014	Norway	PFOA/PFOS	Established environmental quality standards (EQS) for PFOA and PFOS

July 2018 Update: What's New

Date	State/Country	Chemical	Update
July 2018	California	PFOA/PFOS	Adopted Notification Levels for PFOA (0.014 µg/L) and PFOS (0.013 µg/L).
July 2018	Colorado	PFHpA	Dropped PFHpA from the state's drinking water health advisory.
July 2018	Vermont	PFNA/PFHxS/PFHpA	Adopted health advisory (HA) of 0.02 µg/L for PFNA, PFHxS and PFHpA in addition to previous HA of 0.02 µg/L for PFOA and PFOS.
July 2018	British Columbia	PFOA/PFOS/PFBS	Adopted groundwater remediation standards for PFOA (0.2 µg/L), PFOS (0.3 µg/L) and PFBS (80 µg/L).
July 2018	Canada	PFNA	Adopted drinking water screening value for PFNA (0.02 µg/L).

June 2018 Update: What's New

Date	State/Country	Chemical	Update
May 2018	USEPA	PFOA/PFOS	Values developed using the RSL calculator replaced consistent with November 2017 version of Section 4 Tables.
June 2018	AL, AZ, CO, MA, WV	PFOA/PFOS	States that have adopted the USEPA HA are now included in the table. Previously identified in a note only.
April 2018	Colorado	PFOA/PFOS	CDPHE Site-specific Groundwater Quality Standard for El Paso County added.
June 2018	Iowa	PFOA	Removed non-protected GW value for PFOA of 0.7 µg/L per request from Iowa DNR.
June 2018	Massachusetts	PFOA/PFOS/PFNA/PFHxS/PFHpA	MassDEP interim recommendation to adopt EPA HA (0.07 µg/L) for 5 PFAS.
June 2018	New Jersey	PFOS	Recommended MCL for PFOS.
June 2018	Pennsylvania	PFOA/PFOS	Adopted USEPA Health Advisories of 0.07 µg/L
October 2017	Rhode Island	PFOA/PFOS	Adopted USEPA Health Advisories of 0.07 µg/L

April 2018 Update: What's New

Date	State/Country	Chemical	Update
May 2017	Minnesota	PFHxS	Adopted PFHxS value as an interim surrogate based on the PFOS HBV.
December 2017	Minnesota	PFBA	Published Health-Based Values (HBVs) for PFBS: 2 µg/L (chronic) and 3 µg/L subchronic
January 10, 2018	Michigan	PFOA/PFOS	Adopted USEPA Health Advisories of 0.07 µg/L
January 16, 2018	New Jersey	PFNA	Adopted PFNA Ground Water Quality Standard of 0.01 µg/L
April 2018	USEPA	PFOA/PFOS	Values developed using the RSL calculator were removed

Attachment B: State Water Quality Standards for PFAS

Rule 57 Water Quality Values, Michigan Department of Environmental Quality

Aquatic Life Criteria and Water Quality Standards for PFAS, Minnesota Pollution Control Agency

NOTES:
All chemical specific values are in ug/L and expressed as total unless otherwise indicated
EXP = exponent in log base e
H = hardness (in mg/L)
ID = insufficient data to derive value
NLS = no literature search has been conducted
NA = not applicable
@ = Bioaccumulative Chemical of Concern
# = carcinogen
* = the lowest HNV, WV, HCV or FCV given for this chemical will
adequately protect the uses identified with an ID* or *
CFa = acute conversion factor for cadmium = 1.136672-[(lnH)(0.04184)]
CFb = chronic conversion factor for cadmium = 1.101672-[(lnH)(0.04184)]
CFc = acute and chronic conversion factor for lead = 1.46203-[(lnH)(0.14571)]
D = value is expressed as dissolved
Modifications/additions to this spreadsheet compared to the previous one dated 10/21/2016 are shaded.

Rule 57 Water Quality Values
Surface Water Assessment Section
Michigan DEQ

3/15/2018

		HNV Drink		HNV Non-drink		WV		HCV Drink		HCV Non-drink		FCV		AMV		FAV	
CAS #	PARAMETER NAME	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date
50000	Formaldehyde	5000	1200906	390000	1200906	NA		NA		NA		180	2201305	790	2201305	1600	2201305
50293	DDT # @	0.002	1199707	0.002	1199707	0.000011	1199707	0.00015	1199707	0.00015	1199707	0.0032	2199708	0.029	2199708	0.057	2199708
50328	Benzo(a)pyrene #	NLS		NLS		NA		NLS		NLS		ID	201003	ID	201003	ID	201003
51285	2,4-Dinitrophenol	55	1199707	2800	1199707	NA		NA		NA		19	2200301	130	2200301	270	2200301
53703	Dibenz(a,h)anthracene #	NLS		NLS		NA		NLS		NLS		ID	199712	ID	199712	ID	199712
56235	Carbon tetrachloride #	18	1201709	140	1201709	NA		4.7	1201709	38	1201709	77	2201709	690	2201709	1400	2201709
56382	Parathion	NLS		NLS		NA		NA		NA		0.013	1199707	0.065	1199707	0.13	1199707
56553	Benzo(a)anthracene	NLS		NLS		NA		NLS		NLS		ID	201501	ID	201501	ID	201501
57125	Cyanide, free	600	1199707	48000	1199707	NA		NA		NA		5.2	1199707	22	1199707	44	1199707
57410	Phenytoin #	790	1201004	11000	1201004	NA		6.1	1201004	89	1201004	120	2200606	1100	2200606	2200	2200606
57556	Propylene glycol	580000	1200202	47000000	1200202	NA		NA		NA		290000	2200203	1000000	2200203	2100000	2200203
57749	Chlordane # @	0.0014	1199707	0.0014	1199707	NLS		0.00025	1199707	0.00025	1199707	0.029	2199705	0.27	2199705	0.53	2199705
58899	Lindane # @	0.47	1199707	0.5	1199707	0.026	1199809	0.025	2199809	0.027	2199809	0.07	2199706	0.95	1199707	1.9	1199707
58902	2,3,4,6-Tetrachlorophenol	120	2200301	150	2200301	NA		NA		NA		1.2	2200301	11	2200301	22	2200301
59507	4-Chloro-3-methylphenol	6900	1200103	39000	1200103	NA		NA		NA		7.4	2200103	67	2200103	130	2200103
60297	Ethyl ether	14000	1199707	1000000	1199707	NA		NA		NA		ID	201310	ID	201310	ID	201310
60571	Dieldrin # @	0.00041	1199707	0.00041	1199707	0.000071	1199704	0.0000065	1199707	0.0000065	1199707	0.056	1199707	0.24	1199707	0.48	1199707
62533	Aniline #	190	1199809	13000	1199809	NA		21	1199809	1500	1199809	3	2201412	10	2201412	21	2201412
62737	Dichlorvos	NLS		NLS		NA		NA		NA		0.0040	2201708	0.038	1201708	0.076	1201708
63252	Carbaryl	NLS		NLS		NA		NA		NA		0.52	2201704	2.3	2201704	4.5	2201704
64175	Ethanol	1500000	1199810	120000000	1199810	NA		NA		NA		NLS		NLS		NLS	
64186	Formic acid	38000	1199905	3100000	1199905	NA		NA		NA		ID	199905	ID	199905	ID	199905
64197	Acetic acid (includes acetate)	16000	2199807	1300000	2199807	NA		NA		NA		EXP(0.2732*(pH) + 7.0362)	2200506	EXP(0.2732*(pH) + 9.2333)	2200506	EXP(0.2732*(pH) + 9.9265)	2200506
67561	Methanol	14000	1199810	1100000	1199810	NA		NA		NA		590000	2200307	1300000	2200307	2700000	2200307
67630	2-Propanol	28000	1200202	2200000	1200202	NA		NA		NA		57000	2200203	500000	2200203	1000000	2200203
67641	Acetone	5600	1199710	450000	1199710	NA		NA		NA		1700	2199711	15000	1199711	30000	1199711
67663	Chloroform #	350	1201509	11000	1201509	NA		*	201509	*	201509	630	2201509	5700	1201509	11000	1201509
67685	Dimethylsulfoxide	830000	1199807	67000000	1199807	NA		NA		NA		190000	2199709	1700000	2199709	3400000	2199709
67721	Hexachloroethane #	6	1199707	7.6	1199707	NA		5.3	1199707	6.7	1199707	13	2200512	110	2200512	210	2200512
71363	n-Butanol	3500	1201107	250000	1201107	NA		NA		NA		9800	2201108	88000	2201108	180000	2201108
71432	Benzene #	19	1199707	510	1199707	NA		12	1199707	310	1199707	200	2201511	950	2201511	1900	2201511
71501	Acetate (includes acetic acid)	16000	2199807	1300000	2199807	NA		NA		NA		EXP(0.2732*(pH) + 7.0362)	2200407	EXP(0.2732*(pH) + 9.2333)	2200407	EXP(0.2732*(pH) + 9.9265)	2200407
71556	1,1,1-Trichloroethane	62000	1201208	1300000	1201208	NA		NA		NA		89	2201709	800	2201709	1600	2201709
72208	Endrin	NLS		NLS		NA		NA		NA		0.036	1199707	0.086	1199707	0.172	1199707
74839	Bromomethane	39	1199708	2600	1199708	NA		NA		NA		4.2	2201401	38	2201401	75	2201401
74873	Chloromethane #	3500	1201005	240000	1201005	NA		110	1201005	7300	1201005	ID	201011	ID	201011	ID	201011
74895	Methylamine	ID	199805	ID	199805	NA		NA		NA		ID	199807	ID	199807	ID	199807
74931	Methylmercaptan	140	1200107	11000	1200107	NA		NA		NA		ID	200107	ID	200107	ID	200107
74975	Bromochloromethane	1000	1200108	59000	1200108	NA		NA		NA		ID	201010	ID	201010	ID	201010
75003	Chloroethane #	500000	1201310	27000000	1201310	NA		170	1201310	9400	1201310	1100	2201310	10000	2201310	20000	2201310
75014	Vinyl chloride #	83	1201610	4400	1201610	NA		0.25	1201610	13	1201610	930	2201511	8400	2201511	17000	2201511
75047	Ethylamine	740	1199712	60000	1199712	NA		NA		NA		ID	199807	ID	199807	ID	199807
75058	Acetonitrile	5600	1201404	450000	1201404	NA		NA		NA		13000	2201401	120000	2201401	230000	2201401
75070	Acetaldehyde	1200	2200107	93000	2200107	NA		NA		NA		130	2200107	1200	2200107	2400	2200107
75092	Methylene chloride #	1600	1199707	90000	1199707	NA		47	1199707	2600	1199707	1500	2201510	8500	2201510	17000	2201510
75150	Carbon disulfide	1000	1199809	34000	1199809	NA		NA		NA		ID	200511	ID	200511	ID	200511
75252	Bromoform #	470	1199801	8100	1199801	NA		52	1199801	890	1199801	ID	199712	ID	199712	ID	199712
75274	Dichlorobromomethane #	170	1201509	4500	1201509	NA		6.8	1201509	180	1201509	ID	201509	ID	201509	ID	201509
75343	1,1-Dichloroethane	9800	1201511	400000	1201511	NA		NA		NA		740	2201511	6600	2201511	13000	2201511
75354	1,1-Dichloroethylene	1200	1201209	33000	1201209	NA		NA		NA		130	2201709	1200	2201709	2300	2201709
75434	Dichlorofluoromethane	2500	2199910	130000	2199910	NA		NA		NA		150	2199910	1300	2199910	2600	2199910
75569	Propylene oxide #	ID*	199711	ID*	199711	NA		2.3	1199711	180	1199711	220	2199709	2000	2199709	4000	2199709
75718	Dichlorodifluoromethane	2900	1201408	90000	1201408	NA		NA		NA		ID	201408	ID	201408	ID	201408
76131	1,1,2-Trichloro-1,2,2-trifluoroethane	444000	1200007	1834000	1200007	NA		NA		NA		32	2201206	280	2201206	570	2201206
76448	Heptachlor #	0.071	2200007	0.072	2200007	NA		0.0017	2200007	0.0018	2200007	0.07	2200012	0.42	1200012	0.85	1200012
77474	Hexachlorocyclopentadiene	140	1199904	450	1199904	NA		NA		NA		ID	199904	ID	199904	ID	199904
77769	2,2-Dimethoxypropane	ID	199810	ID	199810	NA		NA		NA		ID	199812	ID	199812	ID	199812
78591	Isophorone #	4100	1199811	110000	1199811	NA		310	1199811	8200	1199811	1300	2200207	4600	2200207	9200	2200207

CAS #	PARAMETER NAME	HNV Drink Value	verif date	HNV Non-drink Value	verif date	WV Value	verif date	HCV Drink Value	verif date	HCV Non-drink Value	verif date	FCV Value	verif date	AMV Value	verif date	FAV Value	verif date
78875	1,2-Dichloropropane #	12000	1200309	380000	1200309	NA		9.1	1200309	290	1200309	230	2200309	2000	2200309	4000	2200309
78933	Methyl ethyl ketone	17000	1201005	1300000	1201005	NA		NA		NA		2200	2201001	20000	2201001	40000	2201001
79005	1,1,2-Trichloroethane #	110	1201709	3000	1201709	NA		12	1201709	330	1201709	730	2201709	3200	2201709	6400	2201709
79016	Trichloroethylene #	44	1199709	550	1199709	NA		29	1199707	370	1199707	200	2201507	1800	2201507	3500	2201507
79061	Acrylamide #	28	1200506	2200	1200506	NA		0.12	1200506	10	1200506	590	2200808	5300	2200808	11000	2200808
79094	Propionic acid	50000	1199807	3900000	1199807	NA		NA		NA		ID	199709	ID	199709	ID	199709
79210	Paracetic acid	NLS		NLS		NA		NA		NA		9.3	2201401	19	2201401	39	2201401
79345	1,1,2,2-Tetrachloroethane #	180	1200709	4300	1200709	NA		3.2	1200709	78	1200709	200	2200707	910	2200707	1800	2200707
79390	Methacrylamide	NLS		NLS		NA		NLS		NLS		ID	201011	ID	201011	ID	201011
80057	Bisphenol A	NLS		NLS		NLS		NLS		NLS		20	2200212	180	2200212	350	2200212
80466	Dimethylpropyl phenol	ID	199707	ID	199707	NA		NA		NA		ID	199710	ID	199710	ID	199710
83329	Acenapthene	580	2199903	890	2199903	NA		NA		NA		38	1201406	100	1201406	200	1201406
84662	Diethyl phthalate	14000	1200101	40000	1200101	NA		NA		NA		110	2200101	980	2200101	2000	2200101
84742	Di-n-butyl phthalate	640	2199808	690	2199808	NA		NA		NA		9.7	2199809	38	2199809	75	2199809
84764	Dinonyl phthalate	ID*	200501	ID*	200501	NA		NA		NA		140	2200501	1200	2200501	2500	2200501
85018	Phenanthrene	ID*	199706	ID*	199706	NA		NA		NA		1.7	2201411	5.7	2201411	11	2201411
85687	Butyl benzyl phthalate	6.9	1199902	160	1199902	NA		NA		NA		67	2200207	310	1200207	630	1200207
86737	Fluorene	140	2199901	160	2199901	NA		NA		NA		12	2201411	110	2201411	220	2201411
86748	Carbazole#	ID*	199809	ID*	199809	NA		19	1200001	41	1200001	4	2199905	36	2199905	72	2199905
87616	1,2,3-Trichlorobenzene	55	1200609	73	1200609	NA		NA		NA		ID	200609	ID	200609	ID	200609
87683	Hexachlorobutadiene # @	0.093	1199704	0.098	1199704	0.053	1199906	0.33	2199704	0.35	2199704	1	2199904	7	2199904	15	2199904
87821	Hexabromobenzene	81	1199903	6500	1199903	NA		NA		NA		ID	199903	ID	199903	ID	199903
87865	Pentachlorophenol #	300	1199710	450	1199710	NA		1.8	1199710	2.8	1199710	EXP(1.005*(pH)-5.134)	1199707	EXP(1.005*(pH)-4.869)	1199707	(EXP(1.005*(pH)-4.869))*2	1199707
88062	2,4,6-Trichlorophenol #	1900	1200612	14000	1200612	NA		41	1200612	290	1200612	5	2200609	39	2200609	79	2200609
88697	2-Isopropylphenol	ID	200212	ID	200212	NA		NA		NA		36	2200212	320	2200212	650	2200212
88755	2-Nitrophenol	ID	201005	ID	201005	NA		NA		NA		56	2200911	510	2200911	1000	2200911
88857	Dinoseb	28	1200006	1900	1200006	NA		NA		NA		0.48	2200005	4.8	2200005	9.5	2200005
90120	1-Methylnaphthalene #	740	2201509	1200	2201509	NA		34	2201509	54	2201509	ID	201412	ID	201412	ID	201412
91203	Naphthalene	1100	1201709	2300	1201709	NA		NA		NA		11	2201709	100	2201709	200	2201709
91576	2-Methylnaphthalene	600	2200911	1000	2200911	NA		NA		NA		19	2200909	170	2200909	340	2200909
91941	3,3'-Dichlorobenzidine #	650	2199709	950	2199709	NA		0.14	2199709	0.2	2199709	4.5	2199710	41	2199710	81	2199710
92524	Biphenyl	460	1200108	690	1200108	NA		NA		NA		13	2200110	54	2200110	110	2200110
92875	Benzidine #	74	1201003	3700	1201003	NA		0.0015	1201003	0.073	1201003	2.7	2200902	25	2200902	49	2200902
93721	Silvex	83	2200301	140	2200301	NA		NA		NA		30	2200301	270	2200301	540	2200301
93765	2,4,5-T	490	1200301	1200	1200301	NA		NA		NA		ID	200301	ID	200301	ID	200301
94757	2,4-D	240	1199804	1900	1199804	NA		NA		NA		220	2199802	1400	2199802	2900	2199802
95487	2-Methylphenol	1400	1199802	44000	1199802	NA		NA		NA		76	2201109	690	2201109	1400	2201109
95498	o-Chlorotoluene	360	1200010	970	1200010	NA		NA		NA		ID	200010	ID	200010	ID	200010
95501	1,2-Dichlorobenzene	2000	1200609	11000	1200609	NA		NA		NA		13	2200609	120	2200609	240	2200609
95512	2-Chloroaniline	91	1200809	3100	1200809	NA		NA		NA		ID	199906	ID	199906	ID	199906
95578	2-Chlorophenol	190	2200703	400	2200703	NA		NA		NA		18	2200806	160	2200806	320	2200806
95636	1,2,4-Trimethylbenzene	190	2200101	330	2200101	NA		NA		NA		17	2200102	150	2200102	310	2200102
95658	3,4-Dimethylphenol	37	1201109	580	1201109	NA		NA		NA		25	2201108	230	2201108	460	2201108
95943	1,2,4,5-Tetrachlorobenzene	2.8	1199902	2.9	1199902	ID		NA		NA		3	2199905	23	2199905	46	2199905
96128	1,2-Dibromo-3-chloropropane #	ID*	200908	ID*	200908	NA		0.24	1200908	4.9	1200908	ID	200908	ID	200908	ID	200908
98066	tert-Butylbenzene	ID	200109	ID	200109	NA		NA		NA		ID	200109	ID	200109	ID	200109
98668	4-Chlorobenzenesulfonic acid	28000	2200908	2200000	2200908	NA		NA		NA		ID	200908	ID	200908	ID	200908
98828	Cumene	1700	1201103	3800	1201103	NA		NA		NA		28	2200807	250	2200807	500	2200807
98862	Acetophenone	ID	200108	ID	200108	NA		NA		NA		ID	200109	ID	200109	ID	200109
98953	Nitrobenzene #	26	1201005	990	1201005	NA		4.7	1201005	180	1201005	230	2201002	1000	2201002	2100	2201002
99876	p-Isopropyltoluene	ID	200011	ID	200011	NA		NA		NA		ID	200010	ID	200010	ID	200010
99898	4-Isopropylphenol	ID	200212	ID	200212	NA		NA		NA		20	2200212	180	2200212	360	2200212
100027	4-Nitrophenol	680	1200906	18000	1200906	NA		NA		NA		200	2200806	940	2200806	1900	2200806
100414	Ethylbenzene #	2100	1199704	8900	1199704	NA		25	1200409	110	1200409	18	2200309	160	2200309	320	2200309
100425	Styrene #	4200	1199809	18000	1199809	NA		20	1199809	80	1199809	160	2199802	1400	2199802	2900	2199802
100618	N-methylaniline	ID	200607	ID	200607	NA		NA		NA		ID	200607	ID	200607	ID	200607
101848	Diphenyloxide	44	2200109	78	2200109	NA		NA		NA		2.9	2200109	26	2200109	52	2200109
102829	Tributylamine	ID	199707	ID	199707	NA		NA		NA		ID	199710	ID	199710	ID	199710
103231	Di(2-ethylhexyl)adipate	ID	200201	ID	200201	NA		ID	200201	ID	200201	4.6	2200404	41	2200404	83	2200404
103333	Azobenzene #	ID*	201004	ID*	201004	NA		3.7	2201004	6.0	2201004	ID	201004	ID	201004	ID	201004
103651	N-propyl benzene	ID	200011	ID	200011	NA		NA		NA		ID	200609	ID	200609	ID	200609
103695	N-ethylaniline	ID	199902	ID	199902	NA		NA		NA		1.8	2199709	16	2199709	32	2199709
104518	n-Butylbenzene	ID	200011	ID	200011	NA		NA		NA		ID	200010	ID	200010	ID	200010
104767	2-Ethylhexanol #	8700	1200201	68000	1200201	NA		86	1200408	660	1200408	130	2200402	1100	2200402	2300	2200402
105679	2,4-Dimethylphenol	450	1199707	8700	1199707	NA		NA		NA		380	2199909	1300	1199909	2700	1199909
106445	4-Methylphenol	1400	1199802	45000	1199802	NA		NA		NA		25	2201310	230	2201310	450	2201310
106467	1,4-Dichlorobenzene #	1100	1201512	11000	1201512	NA		24	1201512	240	1201512	17	2201511	100	2201511	210	2201511
106478	4-Chloroaniline #	39	1200805	1400	1200805	NA		2	1200805	72	1200805	ID	200804	ID	200804	ID	200804
106489	4-Chlorophenol	880	2201005	14000	2201005	NA		NA		NA		30	2201010	270	2201010	530	2201010
106934	1,2-Dibromoethane #	250	1200607	8200	1200607	NA		0.17	1200607	5.7	1200607	15	2200607	140	2200607	280	2200607
107062	1,2-Dichloroethane #	6900	1201709	420000	1201709	NA		6.0	1201709	360	1201709	2000	2201709	8200	2201709	16000	2201709
107131	Acrylonitrile #	58	1200708	320	1200708	NA		0.21	1200708	1.2	1200708	66	2201010	590	2201010	1200	2201010
107211	Ethylene glycol	56000	1200003	4500000	1200003	NA		NA		NA		190000	2200003	1700000	2200003	3400000	2200003
108101	4-Methyl-2-pentanone	ID	201003	ID	201003	NA		NA		NA		ID	200906	ID	200906	ID	200906
108112	4-Methyl-2-pentanol	ID	201209	ID	201209	NA		NA		NA		ID	201208	ID	201208	ID	201208
108203	Diisopropylether	7300	1201511	390000	1201511	NA		NA		NA		ID	200008	ID	200008	ID	200008
108394	3-Methylphenol	2700	1199912	89000	1199912	NA		NA		NA		71	2199912	636	2199912	1271	2199912
108601	Bis(2-chloroisopropyl)ether #	990	1199711	47000	1199711	NA		6	1199711	290	1199711	ID	199709	ID	199709	ID	199709

		HNV Drink		HNV Non-drink		WV		HCV Drink		HCV Non-drink		FCV		AMV		FAV	
CAS #	PARAMETER NAME	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date
108678	1,3,5-Trimethylbenzene	2000	1200101	4200	1200101	NA		NA		NA		45	2200102	410	2200102	810	2200102
108872	Methylcyclohexane	ID	200910	ID	200910	NA		NA		NA		ID	200910	ID	200910	ID	200910
108883	Toluene	5600	1199707	51000	1199707	NA		NA		NA		270	2201307	1300	1201307	2600	1201307
108907	Chlorobenzene	470	1199707	3200	1199707	NA		NA		NA		25	2201511	220	2201511	450	2201511
108952	Phenol	1100	2200310	1200	2200310	NA		NA		NA		450	2200303	3400	1200303	6800	1200303
109739	Butylamine	ID	199805	ID	199805	NA		NA		NA		57	2199805	510	2199805	1000	2199805
109897	Diethylamine	310	1199712	24000	1199712	NA		NA		NA		20	2199807	180	2199807	350	2199807
109999	Tetrahydrofuran	350	2199802	26000	2199802	NA		NA		NA		11000	2199806	74000	2199806	150000	2199806
110816	Diethyl disulfide	ID	199710	ID	199710	NA		NA		NA		ID	199710	ID	199710	ID	199710
110827	Cyclohexane	ID	200607	ID	200607	NA		NA		NA		ID	200607	ID	200607	ID	200607
111444	Bis(2-chloroethyl)ether #	ID*	200012	ID*	200012	NA		0.79	2200012	15	2200012	ID*	200012	ID	200012	ID	200012
111466	Diethylene glycol	170000	1199708	14000000	1199708	NA		NA		NA		ID	199801	ID	199801	ID	199801
111922	Dibutylamine	ID	199712	ID	199712	NA		NA		NA		ID	199802	ID	199802	ID	199802
112265	1,2-Bis(2-chloroethoxy)ethane	ID	200012	ID	200012	NA		NA		NA		1500	2200012	13000	2200012	26000	2200012
115297	Endosulfan	85	1200103	170	1200103	NA		NA		NA		0.029	2200107	0.13	1200107	0.27	1200107
117817	Bis(2-ethylhexyl)phthalate #	120	1199711	160	1199711	NA		14	1201402	18	1201402	ID*	199809	285	2199809	285	2199809
117840	Di-n-octyl phthalate	240	2199902	300	2199902	NA		NA		NA		ID	199808	ID	199808	ID	199808
118741	Hexachlorobenzene # @	0.046	1199707	0.046	1199707	0.0003	1199704	0.00045	1199707	0.00045	1199707	ID*	199801	ID	199801	ID	199801
120127	Anthracene	1900	2199901	2400	2199901	NA		NA		NA		ID	201411	ID	201411	ID	201411
120821	1,2,4-Trichlorobenzene	80	1201002	99	1201002	NA		NA		NA		130	2201006	420	1201006	850	1201006
120832	2,4-Dichlorophenol	220	1200609	1100	1200609	NA		NA		NA		11	2200807	92	2200807	180	2200807
120956	2,4-Di-tert-pentylphenol	ID	199712	ID	199712	NA		NA		NA		NLS		NLS		NLS	
121448	Triethylamine	4000	1199708	230000	1199708	NA		NA		NA		260	2199710	1100	2199710	2100	2199710
121824	RDX #	83	1199908	6100	1199908	NA		5.8	1199908	420	1199908	85	2199908	400	2199908	790	2199908
122349	Simazine	140	1200604	4000	1200604	NA		NA		NA		17	2200604	160	2200604	310	2200604
123911	1,4-Dioxane #	890	1201611	72000	1201611	NA		3.5	1201611	280	1201611	22000	2199806	200000	2199806	390000	2199806
124174	Diethylene glycol butyl ether acetate	330	1200501	13000	1200501	NA		NA		NA		260	2200501	2300	2200501	4600	2200501
124481	Dibromochloromethane #	570	1201408	12000	1201408	NA		6.8	1201408	150	1201408	ID	201408	ID	201408	ID	201408
126727	Tris(2,3-dibromopropyl)phosphate #	ID*	200908	ID*	200908	NA		0.31	1200908	13	1200908	ID	200908	ID	200908	ID	200908
126863	2,4,7,9-Tetramethyl-5-decyne-4,7-diol	ID	200112	ID	200112	NA		NA		NA		350	2200410	3100	2200410	6200	2200410
127184	Tetrachloroethylene #	320	1199705	1800	1199705	NA		11	1199705	60	1199705	190	2201510	1400	1201510	2900	1201510
127195	N,N-dimethylacetamide	700	1199711	57000	1199711	NA		NA		NA		4100	2199709	37000	2199709	74000	2199709
128370	4-Methyl-2,6-di-T-butylphenol #	3	2199805	3	2199805	NA		0.25	2199805	0.25	2199805	ID	199803	ID	199803	ID	199803
129000	Pyrene	15	2199807	15	2199807	NA		NA		NA		ID	201411	ID	201411	ID	201411
132649	Dibenzofuran #	ID*	199902	ID*	199902	NA		NA		NA		4	2199902	36	2199902	72	2199902
135988	sec-Butylbenzene	ID	200011	ID	200011	NA		NA		NA		ID	201007	ID	201007	ID	201007
140669	Octylphenol	NLS		NLS		NA		NA		NA		2	2199708	13	2199708	26	2199708
140807	N,N-diethyl-1,4-pentanediamine	ID	199807	ID	199807	NA		NA		NA		ID	199801	ID	199801	ID	199801
140932	Sodium isopropyl xanthate	ID	201408	ID	201408	NA		NA		NA		150	2201408	1400	2201408	2800	2201408
144627	Oxalic acid	4500	1199906	360000	1199906	NA		NA		NA		250	2200008	2300	2200008	4600	2200008
149735	Trimethylorthoformate	ID	199710	ID	199710	NA		NA		NA		ID	199709	ID	199709	ID	199709
156592	cis-1,2-Dichloroethylene	880	1200809	36000	1200809	NA		NA		NA		620	2200007	5500	2200007	11000	2200007
156605	trans-1,2-Dichloroethylene	470	1200809	19000	1200809	NA		NA		NA		1500	2200007	14000	2200007	28000	2200007
191242	Benzo(g,h,i)perylene	ID	201009	ID	201009	NA		NA		NA		ID	201006	ID	201006	ID	201006
193395	Indeno (1,2,3-cd) pyrene #	NLS		NLS		NA		NLS		NLS		ID	199712	ID	199712	ID	199712
205992	Benzo(b)fluoranthene #	NLS		NLS		NA		NLS		NLS		ID	199712	ID	199712	ID	199712
206440	Fluoranthene	18	2199901	18	2199901	NA		NA		NA		1.6	2201411	14	1201411	28	1201411
208968	Acenaphthylene	ID	199803	ID	199803	NA		NA		NA		ID	201411	ID	201411	ID	201411
218019	Chrysene #	ID	199903	ID	199903	NA		ID	199903	ID	199903	ID	201401	ID	201401	ID	201401
288324	Imidazole	ID	201003	ID	201003	NA		NA		NA		ID	201003	ID	201003	ID	201003
302012	Hydrazine #	42	1201201	3400	1201201	NA		0.094	1201201	7.6	1201201	1.8	2201201	16	2201201	32	2201201
309002	Aldrin #	0.00012	1200011	0.00012	1200011	NA		0.0000087	1200011	0.0000087	1200011	0.017	2200011	0.15	2200011	0.3	2200011
319846	alpha-Hexachlorocyclohexane #	19	1200910	21	1200910	ID*	200910	0.016	1200910	0.017	1200910	ID	200910	ID	200910	ID	200910
319857	beta-Hexachlorocyclohexane # @	0.091	1200011	0.098	1200011	ID*	200011	0.024	2200011	0.026	2200011	ID	200011	ID	200011	ID	200011
319868	delta-Hexachlorocyclohexane @	ID	200011	ID	200011	ID	200011	NA		NA		ID	200011	ID	200011	ID	200011
333415	Diazinon	12	1200408	37	1200408	NA		NA		NA		0.004	2200410	0.064	1200410	0.13	1200410
335671	Perfluorooctanoic acid	0.42	1201105	12	1201105	NA		NA		NA		880	2201007	7700	2201007	15000	2201007
495487	Azoxybenzene	ID	199811	ID	199811	NA		NA		NA		ID	199812	ID	199812	ID	199812
526738	1,2,3-Trimethylbenzene	290	1200609	650	1200609	NA		NA		NA		ID	200609	ID	200609	ID	200609
526750	2,3-Dimethylphenol	ID	201109	ID	201109	NA		NA		NA		120	2201108	1100	2201108	2200	2201108
540590	1,2-Dichloroethylene	ID	199902	ID	199902	NA		NA		NA		1100	2200007	9600	2200007	19000	2200007
541731	1,3-Dichlorobenzene	37	2200309	65	2200309	NA		NA		NA		28	2200309	100	2200309	200	2200309
542756	1,3-Dichloropropylene #	930	1200709	39000	1200709	NA		3.3	1200709	140	1200709	9.0	2200708	81	1200708	160	1200708
575371	1,7-Dimethylnaphthalene	ID	200007	ID	200007	NA		NA		NA		ID	200007	ID	200007	ID	200007
585342	3-tert-Butylphenol	ID	200210	ID	200210	NA		NA		NA		29	2200212	260	2200212	530	2200212
591786	2-Hexanone	9700	1200409	630000	1200409	NA		NA		NA		ID	200409	ID	200409	ID	200409
594207	2,2-Dichloropropane	ID	199803	ID	199803	NA		NA		NA		ID	199802	ID	199802	ID	199802
608935	Pentachlorobenzene # @	0.38	1200206	0.38	1200206	0.019	1200206	NA		NA		1.2	2200206	11	2200206	21	2200206
611143	2-Ethyltoluene	ID	200109	ID	200109	NA		NA		NA		ID	200109	ID	200109	ID	200109
618451	3-Isopropylphenol	ID	200212	ID	200212	NA		NA		NA		26	2200212	240	2200212	470	2200212
620144	3-Ethyltoluene	ID	200109	ID	200109	NA		NA		NA		ID	200109	ID	200109	ID	200109
620235	m-Tolualdehyde	ID*	201109	ID*	201109	NA		NA		NA		34	2201108	310	2201108	620	2201108
624920	Dimethyl disulfide	480	2199707	20000	2199707	NA		NA		NA		ID	199709	ID	199709	ID	199709
625456	Methoxyacetic acid	ID	200102	ID	200102	NA		NA		NA		270	2200008	2400	2200008	4800	2200008
625503	N-ethyl acetamide	ID	199807	ID	199807	NA		NA		NA		ID	199710	ID	199710	ID	199710

		HNV Drink		HNV Non-drink		WV		HCV Drink		HCV Non-drink		FCV		AMV		FAV	
CAS #	PARAMETER NAME	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date
630206	1,1,1,2-Tetrachloroethane #	680	1200203	3500	1200203	NA		19	1200203	100	1200203	ID	200203	ID	200203	ID	200203
632224	1,1,3,3-Tetramethylurea	ID	200605	ID	200605	NA		NA		NA		ID	200605	ID	200605	ID	200605
634662	1,2,3,4-Tetrachlorobenzene @	3.9	1201006	4.1	1201006	ID	201006	NA		NA		3.4	2201007	18	2201007	35	2201007
637923	Ethyl tert-butyl ether	2500	1200703	130000	1200703	NA		NA		NA		ID	200609	ID	200609	ID	200609
685916	Diethylacetamide	ID	199707	ID	199707	NA		NA		NA		ID	199710	ID	199710	ID	199710
706785	Octachlorocyclopentene	ID	199903	ID	199903	NA		NA		NA		ID	199904	ID	199904	ID	199904
792745	Dimethyl 4,4'-biphenylcarboxylate	ID	200910	ID	200910	NA		NA		NA		ID	200910	ID	200910	ID	200910
872504	N-Methyl pyrrolidone	25000	1200402	2000000	1200402	NA		NA		NA		ID	200402	ID	200402	ID	200402
927628	N,N-dimethyl-1-butamine	ID	199805	ID	199805	NA		NA		NA		ID	199803	ID	199803	ID	199803
950107	Mephosfolan	2.5	1200103	170	1200103	NA		NA		NA		0.37	2200112	3.3	2200112	6.6	2200112
1024573	Heptachlor epoxide #	0.0075	2200008	0.0076	2200008	NA		0.0021	2200008	0.0021	2200008	ID	200008	ID	200008	ID	200008
1330207	Xylene	3800	1201509	16000	1201509	NA		NA		NA		49	2201510	440	2201510	890	2201510
1336363	PCB # @	NLS		NLS		0.00012	1199707	0.000026	1199707	0.000026	1199707	ID*	199706	ID	199706	ID	199706
1634044	Methyl tert butyl ether (MTBE) #	920	1200809	63000	1200809	NA		100	1200809	7100	1200809	32000	2200808	210000	1200808	420000	1200808
1702176	3,6-Dichloropicolinic acid	4100	1199806	200000	1199806	NA		NA		NA		ID	199809	ID	199809	ID	199809
1746016	2,3,7,8-TCDD # @	0.000000067	1199707	0.000000067	1199707	3.1E-09	1199707	8.6E-09	1199707	8.6E-09	1199707	ID*	199709	ID*	199709	ID*	199709
1763231	Perfluorooctane sulfonate @	0.011	1201403	0.012	1201403	NA		NA		NA		140	2201408	780	2201408	1600	2201408
1912249	Atrazine	880	1200309	8600	1200309	NA		NA		NA		7.3	2199712	50	2199712	100	2199712
1918021	Picloram	5500	1200301	180000	1200301	NA		NA		NA		46	2200301	290	2200301	570	2200301
2385855	Mirex # @	ID*	199904	ID*	199904	0.000016	1199904	0.000042	1199904	0.000042	1199904	ID*	199905	ID	199905	ID	199905
2691410	HMX	1400	1199908	110000	1199908	NA		NA		NA		250	2199908	2300	2199908	4600	2199908
2764729	Diquat	61	1200212	4900	1200212	NA		NA		NA		6.0	2201107	54	2201107	110	2201107
2921882	Chlorpyrifos	*		*		NA		NA		NA		0.002	2200301	0.027	1200301	0.053	1200301
3380345	Triclosan	NLS		NLS		NA		NA		NA		4.4	2201708	25	2201708	50	2201708
3383968	Temephos	NLS		NLS		NA		NA		NA		0.000075	2201111	0.00067	2201111	0.0013	2201111
4684940	6-Chloropicolinic acid	410	1199806	22000	1199806	NA		NA		NA		26	2199809	230	2199809	460	2199809
4860031	1-Chlorohexadecane	ID	200007	ID	200007	NA		NA		NA		ID	200007	ID	200007	ID	200007
7439921	Lead	14	1200709	190	1200709	NA		NA		NA		(EXP(0.9859*(LnH)-1.0967))*CFc^{D}	1201801	(EXP(0.9859*(LnH)+0.4892))*CFc^{D}	1201801	(EXP(0.9859*(LnH)+1.1823))*CFc^{D}	1201801
7439932	Lithium	720	2200602	58000	2200602	NA		NA		NA		440	2200806	910	1200806	1800	1200806
7439965	Manganese	1300	1200612	59000	1200612	NA		NA		NA		EXP(0.8784*(lnH)+3.5385)	1201208	EXP(0.8784*(lnH)+4.3075)	1201208	EXP(0.8784*(lnH)+5.0006)	1201208
7439976	Mercury @	0.0018	1199707	0.0018	1199707	0.0013	1199707	NA		NA		0.77^{D}	1199707	1.4^{D}	1199707	2.8^{D}	1199707
7439987	Molybdenum	120	1200605	10000	1200605	NA		NA		NA		3200	2200604	29000	2200604	58000	2200604
7440020	Nickel	2600	1199706	210000	1199706	NA		NA		NA		(EXP(0.846*(LnH)+0.0584))*0.997^{D}	1199707	(EXP(0.846*(LnH)+2.255))*0.998^{D}	1199707	(EXP(0.846*(LnH)+2.255))*0.998*2^{D}	1199707
7440224	Silver	130	1199705	11000	1199705	NA		NA		NA		0.06	1199710	0.54	1199710	1.1	1199710
7440246	Strontium	ID*	199808	ID*	199808	NA		NA		NA		21000	2200806	40000	1200806	81000	1200806
7440280	Thallium	1.2	1201609	3.7	1201609	NA		NA		NA		7.2	2201407	47	2201407	94	2201407
7440326	Titanium	NLS		NLS		NA		NA		NA		ID	200205	ID	200205	ID	200205
7440360	Antimony	1.7	1199807	130	1199807	NA		NA		NA		240	2200106	1100	2200106	2300	2200106
7440382	Arsenic #	10	1201009	280	1201009	NA		10	1201009	10	1201009	150	1199707	340	1199707	680	1199707
7440393	Barium	1900	1199705	160000	1199705	NA		NA		NA		EXP(1.0629*(lnH)+1.1869)	2200905	EXP(1.0629*(lnH)+2.2354)	2200905	EXP(1.0629*(lnH)+2.9285)	2200905
7440417	Beryllium	160	1201411	1200	1201411	NA		NA		NA		EXP(1.6839(LnH)-5.8575)	2201401	EXP(1.6839(LnH)-3.6603)	2201401	EXP(1.6839(LnH)-2.9672)	2201401
7440428	Boron	4000	1201511	330000	1201511	NA		NA		NA		7200	1201511	34000	1201511	69000	1201511
7440439	Cadmium	2.5	1199706	130	1199706	NA		NA		NA		(EXP(0.7852*(LnH)-2.715))*CFb^{D}	1199707	(EXP(1.128*(LnH)-3.6867))*CFa^{D}	1199707	(EXP(1.128*(LnH)-3.6867))*CFa*2^{D}	1199707
7440473	Chromium	120	1199706	9400	1199706	NA		NA		NA		(EXP(0.819*(LnH)+0.6848))*0.86^{D}	1199707	(EXP(0.819*(LnH)+3.7256))*0.316^{D}	1199707	(EXP(0.819*(LnH)+3.7256))*0.316*2^{D}	1199707
7440484	Cobalt	ID*	199807	ID*	199807	NA		NA		NA		100	2199804	370	2199804	740	2199804
7440508	Copper	470	1200512	38000	1200512	NA		NA		NA		(EXP(0.8545*(LnH)-1.702))*0.96^{D}	1199707	(EXP(0.9422*(LnH)-1.7))*0.96^{D}	1199707	(EXP(0.9422*(LnH)-1.7))*0.96*2^{D}	1199707
7440622	Vanadium	53	1200907	540	1200907	NA		NA		NA		27	2201104	79	2201104	160	2201104
7440666	Zinc	3300	1200510	16000	1200510	NA		NA		NA		(EXP(0.8473*(LnH)+0.884))*0.986^{D}	1199707	(EXP(0.8473*(LnH)+0.884))*0.978^{D}	1199707	(EXP(0.8473*(LnH)+0.884))*0.978*2^{D}	1199707
7664417	Ammonia, unionized coldwater	ID*	199711	ID*	199711	NA		NA		NA		29	1199710	160	1199710	320	1199710
7664417.1	Ammonia, unionized warmwater	ID*	199711	ID*	199711	NA		NA		NA		53	1199710	210	1199710	420	1199710
7722647	Potassium permanganate	NLS		NLS		NA		NA		NA		*	2200308	29	2200308	58	2200308
7722841	Hydrogen peroxide	ID*	199903	ID*	199903	NA		NA		NA		10	2200906	92	2200906	180	2200906
7726956	Bromine	ID*	199903	ID*	199903	NA		NA		NA		0.26	2200911	2.4	2200911	4.8	2200911
7782492	Selenium & inorganic salts	120	1199704	2700	1199704	NA		NA		NA		5	1199707	62	1199808	120	1199808
7782505	Chlorine	NLS		NLS		NA		NA		NA		*	1199709	19	1199709	38	1199709
7783064	Hydrogen sulfide	160	1200401	13000	1200401	NA		NA		NA		0.36	2200812	3.2	1200812	6.4	1200812
8001352	Toxaphene # @	0.021	1199710	0.021	1199710	0.00014	1199710	0.000068	1199707	0.000068	1199707	0.005	2199706	0.15	2199706	0.3	2199706
10028156	Ozone	NLS		NLS		NLS		NLS		NLS		0.065	2200112	0.58	2200112	1.2	2200112
10061015	*cis* -1,3-Dichloropropylene #	930	1200709	39000	1200709	NA		3.3	1200709	140	1200709	9.0	2200708	81	1200708	160	1200708
10061026	*trans* -1,3-Dichloropropylene #	930	1200709	39000	1200709	NA		3.3	1200709	140	1200709	9.0	2200708	81	1200708	160	1200708
10222012	DBNPA	ID*	199804	ID*	199804	NA		NA		NA		7.8	2199804	71	2199804	140	2199804
14797558	Nitrate	10000	1200309	NLS		NA		NA		NA		NLS		NLS		NLS	
14797730	Perchlorate	19	1200905	1600	1200905	NA		NA		NA		400	2201610	6300	2201610	13000	2201610
14998277	Chlorite	830	1200601	67000	1200601	NA		NA		NA		0.72	2200601	6.5	1200601	13	1200601
15541454	Bromate #	100	1200505	8200	1200505	NA		0.5	1200505	40	1200505	760	2200505	6900	2200505	14000	2200505
15687271	Ibuprofen	NLS		NLS		NA		NA		NA		96	2201401	860	2201401	1700	2201401
15972608	Alachlor #	270	1199802	6900	1199802	NA		3.5	1199802	91	1199802	11	2199803	150	2199803	300	2199803
16984488	Fluoride	NLS		NLS		NA		NA		NA		EXP(0.1776*(lnH)+6.9017)	2201302	EXP(0.1776*(lnH)+8.1995)	1201302	EXP(0.1776*(lnH)+8.8927)	1201302
18540299	Chromium, hexavalent	120	1199706	9400	1199706	NA		NA		NA		11^{D}	1199707	16^{D}	1199707	32^{D}	1199707
21725462	Cyanazine #	190	1199805	12000	1199805	NA		0.93	1199805	56	1199805	110	2199804	1000	2199804	2000	2119804
22204531	Naproxen	NLS		NLS		NA		NLS		NLS		96	2201510	860	2201510	1700	2201510
25154523	n-Nonylphenol (mixed isomers)	NLS		NLS		NA		NA		NA		2	1199902	7	1199902	14	1199902
25812300	Gemfibrozil	NLS		NLS		NA		NA		NA		44	2201401	400	2201401	800	2201401
26628228	Sodium azide	330	2200307	27000	2200307	NA		NA		NA		7.3	2200306	65	2200306	130	2200306
32289580	PHMB	*	201211	*	201211	NA		*	201211	*	201211	0.2	2201209	1.8	2201209	3.6	2201209

		HNV Drink		HNV Non-drink		WV		HCV Drink		HCV Non-drink		FCV		AMV		FAV	
CAS #	PARAMETER NAME	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date	Value	verif date
38836394	N-(1-methylpropylidene)-2-propanamine	ID	199805	ID	199805	NA		NA		NA		ID	199803	ID	199803	ID	199803
40360449	3,5,6-Trichloropicolinic acid	ID	199809	ID	199809	NA		NA		NA		ID	199805	ID	199805	ID	199805
40596698	Methoprene	21	2200401	21	2200401	NA		NA		NA		2.9	2200401	26	2200401	51	2200401
51207319	Tetrachlorodibenzofuran, 2,3,7,8-	NLS		NLS		NA		NA		NA		ID	199706	ID	199706	ID	199706
51218452	Metolachlor	3300	1200603	14000	1200603	NA		78	1200603	340	1200603	15	2200604	110	2200604	210	2200604
59756604	Fluridone	2200	1200212	80000	1200212	NA		NA		NA		1	2200304	3	2200304	250	2200301
64741668	Isopar C	ID	200402	ID	200402	NA		NA		NA		1.9	2200402	17	2200402	35	2200402
67774327	PBB #	0.00031	1199904	0.00031	1199904	NA		0.00013	1199904	0.00013	1199904	NLS		NLS		NLS	
84852153	4-Nonylphenol	130	2199811	200	2199811	NA		NA		NA		ID	199902	ID	199902	ID	199902
103361097	Flumioxazin	NLS		NLS		NA		NA		NA		ID	201205	ID	201205	ID	201205
168316958	Spinosad	620	1200505	7500	1200505	NA		NA		NA		60	2200507	540	2200507	1100	2200507

MINNESOTA POLLUTION CONTROL AGENCY
AQUATIC LIFE CRITERIA

Page 1 SUMMARY

A. Chemical: PFOA (Lake Calhoun)	CAS# 335-67-1	Date Aug. 16, 2007

B. Minnesota Criterion: ug/l (unless noted otherwise)

Water Class	**Use**	**CC**	**MC**	**FAV**	**Basis**[1]
1,2A	DW, Salmonid	0.61	15,346	30,692	PCA Hs
1,2Bd	DW, NonSalmonid	0.61	15,346	30,692	PCA Hs
2B, 2C, 2D	NonSalmonid	1.62	15,346	30,692	PCA Hs
	Other				

Toxicity related to water quality?: no
If yes, above criteria values determined for:
Slope: Acute:
Chronic:

Formulas:	**MPCA**	**EPA**
CC:		
MC:		
FAV:		

Notes:

C. EPA Criterion: ug/l	CCC: none	Basis:
Date:	MC: none	Basis:
	FAV: none	Basis:

D. Other Criteria ug/l	**Source**

E. Notes: The PFOA site-specific criterion for Lake Calhoun is based on BAF information from Lake Calhoun. Lake Calhoun is a class 2B water. The PFOA site-specific criterion for the Mississippi River is based on BAF information collected at Pool 3 on the Mississippi River.

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[1] Criteria basis codes for part B:
EPA = From EPA criterion
PCA = Criterion developed by Minnesota Pollution Control Agency staff
T1 = Direct aquatic life toxicity, EPA national criteria procedures used
T2 = Direct aquatic life toxicity, EPA advisory procedures used
Hs = Human health systemic effects
Hc = Human health carcinogenic effects
R = Tissue residue (bioaccumulation)
W = Wildlife effects
O = Organoleptic (taste and odor)
Other = Criterion based on other end point

Page 2 DIRECT AQUATIC LIFE TOXICITY - EPA Criterion Available

A.	Chemical: PFOA (Lake Calhoun)	CAS# 335-67-1	Date Aug. 16, 2007

B.	EPA Criterion: ug/l	CCC: none	Basis:
	Date:	MC: none	Basis:
		FAV: none	Basis:

1.	Related to water quality?: no			
2.	Toxicity:	FAV:	N:	ACR:
	ug/l	Chronic value:	N:	
3.	Residue			
	FDA action level: none			
	BCF Final: none	N total:	N used:	
	geo mean at 1% lipid:			
	% lipid:			
	geo man unadjusted for lipid:			

C. MPCA Evaluation of EPA Criterion

1. Four lowest GMAVs:

2. Commercially or recreationally important species:

3. Plant data:

4. Extrapolation of water quality effects:

5. Chronic data No. of values:
No. below criterion:

Notes:

6. ACRS	ACR used by EPA: none	N:
	Geo. mean, all ACRs:	N:
	ACR used by MPCA: 18	N: 1- generic ACR

Notes:

D. Separate Cool/Warm Water Criterion, ug/l
No. of Salmonids deleted from lowest 4 GMAVs:
N(nonsal): FAV: MC: CC:
Adjustments to FAV:

Notes:

E. Summary of changes made to EPA criterion:

Page 3 DIRECT AQUATIC LIFE TOXICITY
No EPA criterion available

A.	Chemical: PFOA (Lake Calhoun)	CAS# 335-67-1	Date Aug. 16, 2007

B. EPA National Method		
1. Data requirements:	Salmonid (2A water only):	
	Osteichthyes (fish):	Pimephales promelas
	Chordata (fish, amphibian):	
	Planktonic crustacean:	Daphnia magna
	Benthic crustacean:	
	Aquatic insect:	
	Phylum other than Arthropoda or Chordata:	
	Second insect or phylum not already rep.:	

2. GMAVs	Lowest 4(2A): see Tier II method	Lowest 4(2B,2C, 2D): see Tier II method
ug/l		
	N:	N:
3. FAV:	2A: see Tier II method	2B, 2C, 2D: see Tier II method
4. Adjustments to FAVs:		

5. Chronic data: see Table 2a	No.	Species:
mean values		
ug/l		

6. ACR Measured:	Acute value	Chronic value	ACR
	Generic		18
Generic: 18			
Final: 18			

7. Final Plant Value: NOEC of 23,900 ug/l for Northern milfoil

8. Chronic Criterion (FAV/ACR) see Tier II method

C. EPA Advisory Method		
1. Data requirements:	Fish:	Pimephales promelas
	Crustacean:	Daphnia magna
No. SMAVs: 2	Third animal:	
No. GMAVs: 2	Plant for herbicide:	
Factor: 13	Insect for pesticide:	

2. Lowest GMAV: 399,000 ug/l — Species: Daphnia magna
3. FAV: 30,692 ug/l — MC: 15,346 ug/l
4. Chronic data: See B.5.
5. ACR: 18 See B.6.
6. CC: 1705 ug/l
7. Citation for lowest GMAV: AR226-0512, AR226-0517, AR226-0508, and STS-403

D. Notes:

Page 4 HUMAN HEALTH

A. Chemical: PFOA (Lake Calhoun)	CAS# 335-67-1	Date Aug. 16, 2007

B. EPA Human Health Criterion: ug/l	DW and fish: none	fish only: none	DW only: none
ADI/Ref.dose: none mg/kg/day	Cancer Potency Slope: none $(mg/kg\text{-}d)^{-1}$		
Final BCF: none	%lipid: not applicable		
RSC: none			

C. Minnesota Human Health Criterion				
1. Ref.dose: 0.00014 mg/kg/day	Source: MDH			
RSC: 0.2	Source: MDH			
2. Cancer Potency Slope: none $(mg/kg\text{-}d)^{-1}$	Source:			
3. Measured BAFs: Species/Tissue	BAF	%lipid	Norm BAF	
1. Bluegill (fillet)	35	not applicable	35	
2. White sucker (fillet)	46	not applicable	46	
3.				
4.				
Geo mean: 40				
4. Measured BCFs: Species/Tissue	BCF	%lipid	Norm. BCF	
1. See Table 5a and Table 5b				
2.				
3.				
4.				
5.				
6.				
Geo mean:				
5. Edible portion BAF or BCF	BAF		BCF	
Cold water: 6.0 % lipid				
Warm water: 1.5 % lipid				
6. Geo mean unadjusted for lipid:				
7. log Kow: not applicable adjust. for % lipid: not applicable	meas.	QSAR:	Est. BCF:	
8. Parachor: not applicable				
9. Food Chain Multiplier: not applicable				
10. Final BAF: 2A: 40	2B,2C, 2D: 40			
11. Criteria: ug/l	2A: 0.61 * ug/l	2Bd: 0.61 * ug/l	2B/2C, 2D: 1.62 # ug/l	HRL/HBV: 0.5

D. Organoleptic: ug/l	Source:

E. Notes: BAFs mostly derived from 1/2 the detection limit of the fish tissue data.
F. * Criterion developed using 2 L/day water intake rate and 70 kg body wt. as specified in Minn. R. ch
G. 7050.
H. # Criterion developed using 0.01 L/day incidental ingestion rate and 70 kg body wt. as specified in
I. Minn. Rule ch. 7050.

MINNESOTA POLLUTION CONTROL AGENCY
AQUATIC LIFE CRITERIA

Page 1 SUMMARY

A. Chemical: PFOA (Mississippi River)	CAS# 335-67-1	Date Aug. 15, 2007

B. Minnesota Criterion: ug/l (unless noted otherwise)

Water Class	**Use**	**CC**	**MC**	**FAV**	**Basis**[1]
1,2A	DW, Salmonid	0.72	15,346	30,692	PCA Hs
1,2Bd	DW, NonSalmonid	0.72	15,346	30,692	PCA Hs
2B, 2C, 2D	NonSalmonid	2.7	15,346	30,692	PCA Hs
	Other				

Toxicity related to water quality?: no
If yes, above criteria values determined for:
Slope: Acute:
Chronic:

Formulas:	**MPCA**	**EPA**
CC:		
MC:		
FAV:		

Notes:

C. EPA Criterion: ug/l	CCC: none	Basis:
Date:	MC: none	Basis:
	FAV: none	Basis:

D. Other Criteria ug/l	**Source**

E. Notes: The Mississippi River site-specific criterion for PFOA is based on BAF information collected at Pool 3 on the Mississippi River. The site-specifc criterion for PFOA is at Lake Calhoun is based on BAF information collected at Lake Calhoun.

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[1] Criteria basis codes for part B:
EPA = From EPA criterion
PCA = Criterion developed by Minnesota Pollution Control Agency staff
T1 = Direct aquatic life toxicity, EPA national criteria procedures used
T2 = Direct aquatic life toxicity, EPA advisory procedures used
Hs = Human health systemic effects
Hc = Human health carcinogenic effects
R = Tissue residue (bioaccumulation)
W = Wildlife effects
O = Organoleptic (taste and odor)
Other = Criterion based on other end point

Page 2 DIRECT AQUATIC LIFE TOXICITY - EPA Criterion Available

A.	Chemical: PFOA (Mississippi River)	CAS# 335-67-1	Date Aug. 15, 2007

B.	EPA Criterion: ug/l	CCC: none	Basis:
	Date:	MC: none	Basis:
		FAV: none	Basis:

1.	Related to water quality?: no			
2.	Toxicity:	FAV:	N:	ACR:
	ug/l	Chronic value:	N:	
3.	Residue			
	FDA action level: none			
	BCF Final: none N total: N used:			
	geo mean at 1% lipid:			
	% lipid:			
	geo man unadjusted for lipid:			

C. MPCA Evaluation of EPA Criterion

1. Four lowest GMAVs:

2. Commercially or recreationally important species:

3. Plant data:

4. Extrapolation of water quality effects:

5. Chronic data No. of values:
No. below criterion:

Notes:

6. ACRS	ACR used by EPA: none	N:
	Geo. mean, all ACRs:	N:
	ACR used by MPCA: 18	N: 1-generic ACR

Notes:

D. Separate Cool/Warm Water Criterion, ug/l
No. of Salmonids deleted from lowest 4 GMAVs:
N(nonsal): FAV: MC: CC:
Adjustments to FAV:

Notes:

E. Summary of changes made to EPA criterion:

Page 3 DIRECT AQUATIC LIFE TOXICITY
No EPA criterion available

A. Chemical: PFOA (Mississippi River)	CAS# 335-67-1	Date Aug. 15, 2007

B. EPA National Method

1. Data requirements:	Salmonid (2A water only):	
	Osteichthyes (fish):	Pimephales promelas
	Chordata (fish, amphibian):	
	Planktonic crustacean:	Daphnia magna
	Benthic crustacean:	
	Aquatic insect:	
	Phylum other than Arthropoda or Chordata:	
	Second insect or phylum not already rep.:	

2. GMAVs	Lowest 4(2A): see Tier II method	Lowest 4(2B,2C, 2D): See tier II method
ug/l		
	N:	N:
3. FAV:	2A: see tier II method	2B, 2C, 2D:

4. Adjustments to FAVs:

5. Chronic data: see Table 2a	No.	Species:
mean values		
ug/l		

6. ACR Measured:	Acute value	Chronic value	ACR
	Generic		18
Generic: 18			
Final: 18			

7. Final Plant Value: NOEC of 23,900 ug/l for Northern milfoil

8. Chronic Criterion (FAV/ACR) see Tier II method

C. EPA Advisory Method

1. Data requirements:	Fish:	Pimphales promelas
	Crustacean:	Daphnia magna
No. SMAVs: 2	Third animal:	
No. GMAVs: 2	Plant for herbicide:	
Factor: 13	Insect for pesticide:	

2. Lowest GMAV: 399,000 ug/l Species: Daphnia magna
3. FAV: 30,692 ug/l MC: 15,346 ug/l
4. Chronic data: See B.5.
5. ACR: 18 See B.6.
6. CC: 1705 ug/l
7. Citation for lowest GMAV: AR226-0512, AR226-0517, AR226-0508, and STS-403.

D. Notes:

Page 4 HUMAN HEALTH

A. Chemical: PFOA (Mississippi River)	CAS# 335-67-1	Date Aug. 15, 2007

B. EPA Human Health Criterion: ug/l	DW and fish: none	fish only: none	DW only: none
ADI/Ref.dose: none mg/kg/day	Cancer Potency Slope: none $(mg/kg\text{-}d)^{-1}$		
Final BCF:	%lipid: not applicable		
RSC:			

C. Minnesota Human Health Criterion			
1. Ref.dose: 0.00014 mg/kg/day	Source: MDH		
RSC: 0.2	Source: MDH		
2. Cancer Potency Slope: none $(mg/kg\text{-}d)^{-1}$	Source:		
3. Measured BAFs: Species/Tissue	BAF	%lipid	Norm BAF
1. Bluegill (fillet)	24	not applicable	24
2. White Bass (fillet)	26	not applicable	26
3.			
4.			
Geo mean: 24			
4. Measured BCFs: Species/Tissue	BCF	%lipid	Norm. BCF
1. See Table 5a and Table 5b			
2.			
3.			
4.			
5.			
6.			
Geo mean:			
5. Edible portion BAF or BCF	BAF		BCF
Cold water: 6.0 % lipid			
Warm water: 1.5 % lipid			
6. Geo mean unadjusted for lipid:			
7. log Kow: not applicable adjust. for % lipid: not applicable	meas.	QSAR:	Est. BCF:
8. Parachor: not applicable			
9. Food Chain Multiplier:			
10. Final BAF: 2A: 24	2B,2C, 2D: 24		

11. Criteria: ug/l	2A: 0.721 * ug/l	2Bd: 0.721 * ug/l	2B/2C, 2D: 2.68 # ug/l	HRL/HBV: 0.5

D. Organoleptic: ug/l	Source:

E. Notes: BAFs derived from 1/2 the detection limt of the fish tissue data.
F. * Criterion developed using 2 L/day water intake and 70 kg body wt. as specified in Minn. R. ch. 7050.
G. # Criterion developed using 0.01 L/day incidental ingestion rate and 70 kg body wt. as specified in Minn.
H. Rule ch. 7050. Criterion rounded up to 2.7 ug/l.

Page 1 SUMMARY

A. Chemical/Element: Perfluorooctanesulfonic acid (PFOS)	CAS# 1763231	Dates Proposed/Promulgated /	Aquatic Tox. & Human Health
Site-specific Lake Calhoun		Developed 3Aug2007	
		Revised 12 May 2010	
		Revised	

B. Minnesota Water Quality Standards: µg/l (unless noted otherwise)

Water Class	Use	CS	MS	FAV	CS Basis[1]
1,2A	DW, Salmonid	n/a	85 µg/L	170 µg/L	PCA Hs
1,2Bd	DW, NonSalmonid	n/a	85 µg/L	170 µg/L	PCA Hs
2B, 2C, 2D	NonSalmonid	6.1 ng/L	85 µg/L	170 µg/L	PCA Hs
	Other				

CS: Chronic Standard, DW: Drinking Water, FAV: Final Acute Value, MS: Maximum Standard

Toxicity related to water quality?: no
If yes, above criteria values determined for:
Slope: Acute:
Chronic:

Formulas:	MPCA	EPA
CS:		
MS:		
FAV:		

Notes:

C. EPA Criterion: µg/l	CCC: none	Basis:
Date:	MC: none	Basis:
	FAV: none	Basis:

D. Other Criteria µg/l	Source
0.2 (based on 10 kg child and 1 L drinking water intake)	EPA Office of Water Provisional Health Advisory under the Safe Drinking Water Program at http://www.epa.gov/waterscience/criteria/drinking/

E. Notes: Lake Calhoun site –based water quality criteria are based from calculations using fish tissue data collected in 2008 and 2009, and surface waters samples collected in 2007 and 2008 from Lake Calhoun.

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[1] Criteria basis codes for part B:
EPA = From U. S. Environmental Protection Agency (EPA) criterion
PCA = Criterion developed by Minnesota Pollution Control Agency staff
T1 = Direct aquatic life toxicity, EPA national criteria procedures used
T2 = Direct aquatic life toxicity, EPA advisory procedures used
Hs = Human health systemic effects
Hc = Human health carcinogenic effects
R = Tissue residue (bioaccumulation)
W = Wildlife effects
O = Organoleptic (taste and odor)
Other = Criterion based on other end point

Page 2 DIRECT AQUATIC LIFE TOXICITY - EPA Criterion Available

A. Chemical/Element: PFOS	CAS# 1763231	

B.	EPA Criterion: µg/l	CCC: none	Basis:
	Date:	MC: none	Basis:
		FAV: none	Basis:

1. Related to water quality?: no			
2. Toxicity:	FAV:	N:	ACR:
µg/l	Chronic value:	N:	
3. Residue			
Food and Drug Administration (FDA) action level:			
BCF Final: N total: N used:			
geo mean at 1% lipid:			
% lipid:			
geo man unadjusted for lipid:			
ACR: Acute to Chronic Ratio, BCF: Bioconcentration Factor, CCC: Chronic Criterion, MC: Maximum Criterion			

C. MPCA Evaluation of EPA Criterion

1. Four lowest GMAVs (Genus Mean Acute Values):

2. Commercially or recreationally important species:

3. Plant data:

4. Extrapolation of water quality effects:

5. Chronic data No. of values:
No. below criterion:

Notes:

6. ACRS	ACR used by EPA:	N:
	Geo. mean, all ACRs:	N:
	ACR used by MPCA: 9.12	N: 3

Notes: EPA has no surface water criteria for PFOS

D. Separate Cool/Warm Water Criterion, ug/l
No. of Salmonids deleted from lowest 4 GMAVs:
N(nonsal): FAV: MC: CC:
Adjustments to FAV:

Notes:

E. Summary of changes made to EPA criterion

Page 3 DIRECT AQUATIC LIFE TOXICITY when no EPA criterion is available

A. Chemical/Element: PFOS	CAS# 1763231	

B. EPA National Method		
1. Data requirements:	Salmonid (2A water only):	Onchorynchus mykiss
	Osteichthyes (fish):	Pimephales promelas
	Chordata (fish, amphibian):	Pseudacris crucifer
	Planktonic crustacean:	Daphnia magna
	Benthic crustacean:	Hyalella azteca
	Aquatic insect:	
	Phylum other than Arthropoda or Chordata:	Unio complamatus
	Second insect or phylum not already rep.:	Lumbriculus variegatus

2. GMAVs	Lowest 4(2A): See Tier II method	Lowest 4(2B,2C, 2D): See Tier II method
µg/l		
	N:	N:
3. FAV:	2A:	2B, 2C, 2D:
4. Adjustments to FAVs:		

5. Chronic data: See Table 2a	No.	Species:
mean values		
µg/l		

6. ACR Measured:	Acute value	Chronic value	ACR
	9100	410	22.19
Generic: 18	67,200	35,350	1.9
	Generic	Generic	18
Final: 9.12			

7. Final Plant Value: NOEC = 300 µg/L, Northern milfoil
8. Chronic Criterion (FAV/ACR) see Tier II method

C. EPA Advisory Method (Tier II method)		
1. Data requirements:	Fish:	Pimephales promelas
N = 7	Crustacean:	Daphnia magna
No. SMAVs: 8	Third animal:	Lumbriculus variegatus
No. GMAVs: 7	Plant for herbicide:	
Adjustment Factor: 4.3	Insect for pesticide:	

2. Lowest GMAV: 5600 µg/L Species: Lumbriculus variegatus
3. FAV: 1302 µg/L (reduced to 170 µg/L) MC: 85 µg/L
4. Chronic data: See B.5.
5. ACR: 9.12 (See B.6)
6. CC: 18.6 µg/L (rounded up to 19 µg/L)
7. Citation for lowest GMAV: STS-334

D. Notes: FAV = GMAV ÷ Adjustment Factor; EAO staff lowered the Tier II calculated FAV of 1302 µg/L to the project EC50 of 170 µg/L to protect Chironomus tentans. The original Chironomus tentans study used the highest exposure concentration of 150 µg/L and reported the EC50 as greater than 150 µg/L. Therefore, EAO staff determined an estimated EC50 for the test at 170 µg/L.

Page 4 HUMAN HEALTH

A. Chemical/Element: PFOS	CAS# 1763231	

B. EPA Human Health Criterion (µg/l):	DW and fish: none	fish only: none	DW only: Perfluorooctane Sulfonate. Provisional short-term value 0.2 µg/L
Reference Dose: mg/kg/day	Cancer Potency Slope: (mg/kg-d)$^{-1}$		
Final BCF:	%lipid:		
Relative Source Contribution (RSC):			

C. Minnesota Human Health Criterion			
1. Ref.dose: 0.00008 mg/kg/day	Source: MDH		
RSC: 0.2	Source: MDH		
Additivity endpoint(s): Development (body weight/weight gain), Hepatic (liver) system, Thyroid	Source: MDH		
2. Cancer Potency Slope: n/a (mg/kg-d)$^{-1}$	Source:		
3. Measured BAFs: Species/Tissue	BAF	%lipid	Norm BAF
1. Bluegill/ Fillet	4516	n/a	4516
2. Black Crappie/ Fillet	5552	n/a	5552
3. Northern Pike / Fillet	4908	n/a	4908
4. Largemouth Bass/ Fillet	10418	n/a	10418
Geo mean:	6087		
4. Measured BCFs: Species/Tissue	BCF	%lipid	Norm. BCF
1.			
Geo mean:			
5. Edible portion BAF or BCF	BAF		BCF
Cold water: 6.0 % lipid	n/a		
Warm water: 1.5 % lipid	n/a		
6. Geo mean unadjusted for lipid:	n/a		
7. log Kow: adjust. for % lipid:	meas.	QSAR (7.6% lipid):	Est. BCF:
8. Parachor: n/a			
9. BCF to BAF conversion factor: n/a			

10. Final BAF: 2A (6% lipid):			2B & 2Bd,2C, 2D (1.5% lipid): 6087	
11. Criteria:	2A: n/a	2Bd: n/a	2B/2C, 2D: 6.1 ng/L *	HRL/HBV: 0.3 µg/L MDH Health Risk Limit/ Health Based Value for Groundwater

D. Organoleptic: n/a	Source:

F. * Criterion developed using 0.01 L/day water incidental ingestion and 70 kg body wt. as specified in Minn. R. Ch. 7050. Data used for calculation of fish BAF values for PFOS and PFOA were reported fish tissue and surface water samples collected from the Mississippi R, Pool 2 in 2009, and Lake Calhoun in 2007 and 2008. Methods used for calculating water quality criteria can be found in the MPCA water quality guidance manual (Maschwitz, 2000).

MINNESOTA POLLUTION CONTROL AGENCY
AQUATIC LIFE CRITERIA AND WATER QUALITY STANDARDS

Page 1 SUMMARY

A. Chemical/Element: Perfluorooctanesulfonic acid (PFOS)	CAS# 1763231	Dates Proposed/Promulgated /	Aquatic Tox. & Human Health
Site-specific Pool 2, Mississippi R.		Developed 3Aug2007	AL and HH
		Revised 30 Oct 2009	HH
		Revised 23 January 2013	HH

B. Minnesota Water Quality Standards: µg/l (unless noted otherwise)

Water Class	**Use**	**CS**	**MS**	**FAV**	**CS Basis**[1]
1,2A	DW, Salmonid	14 ng/L	85 µg/L	170 µg/L	PCA Hs
1,2Bd	DW, NonSalmonid	14 ng/L	85 µg/L	170 µg/L	PCA Hs
2B, 2C, 2D	NonSalmonid	14 ng/L	85 µg/L	170 µg/L	PCA Hs
	Other				

CS: Chronic Standard, DW: Drinking Water, FAV: Final Acute Value, MS: Maximum Standard

Toxicity related to water quality?: no
If yes, above criteria values determined for:
Slope: Acute:
Chronic:

Formulas:	**MPCA**	**EPA**
CS:		
MS:		
FAV:		

Notes:

C. EPA Criterion: µg/l	CCC: none	Basis:
Date:	MC: none	Basis:
	FAV: none	Basis:

D. Other Criteria µg/l	**Source**
0.2 (based on 10 kg child and 1 L drinking water intake)	EPA Office of Water Provisional Health Advisory under the Safe Drinking Water Program at http://www.epa.gov/waterscience/criteria/drinking/

E. Notes: Mississippi River site-specific criterion for PFOS is based on BAF information collected from Pool 2, Mississippi River.

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[1] Criteria basis codes for part B:
EPA = From U. S. Environmental Protection Agency (EPA) criterion
PCA = Criterion developed by Minnesota Pollution Control Agency staff
T1 = Direct aquatic life toxicity, EPA national criteria procedures used
T2 = Direct aquatic life toxicity, EPA advisory procedures used
Hs = Human health systemic effects
Hc = Human health carcinogenic effects
R = Tissue residue (bioaccumulation)
W = Wildlife effects
O = Organoleptic (taste and odor)
Other = Criterion based on other end point

Page 2 DIRECT AQUATIC LIFE TOXICITY - EPA Criterion Available

A. Chemical/Element: PFOS	CAS# 1763231	

B.	EPA Criterion: µg/l	CCC: none	Basis:
	Date:	MC: none	Basis:
		FAV: none	Basis:

1.	Related to water quality?: no			
2.	Toxicity:	FAV:	N:	ACR:
	µg/l	Chronic value:	N:	
3.	Residue			
	Food and Drug Administration (FDA) action level:			
	BCF Final:	N total:	N used:	
	geo mean at 1% lipid:			
	% lipid:			
	geo man unadjusted for lipid:			
ACR: Acute to Chronic Ratio, BCF: Bioconcentration Factor, CCC: Chronic Criterion, MC: Maximum Criterion				

C. MPCA Evaluation of EPA Criterion

1. Four lowest GMAVs (Genus Mean Acute Values):

2. Commercially or recreationally important species:

3. Plant data:

4. Extrapolation of water quality effects:

5. Chronic data No. of values:
No. below criterion:

Notes:

6. ACRS	ACR used by EPA:	N:
	Geo. mean, all ACRs:	N:
	ACR used by MPCA: 9.12	N: 3

Notes: EPA has no surface water criteria for PFOS

D. Separate Cool/Warm Water Criterion, ug/l
No. of Salmonids deleted from lowest 4 GMAVs:
N(nonsal): FAV: MC: CC:
Adjustments to FAV:

Notes:

E. Summary of changes made to EPA criterion

MINNESOTA POLLUTION CONTROL AGENCY
AQUATIC LIFE CRITERIA

Page 3 DIRECT AQUATIC LIFE TOXICITY when no EPA criterion is available

A. Chemical/Element: PFOS	CAS# 1763231	

B. EPA National Method		
1. Data requirements:	Salmonid (2A water only):	*Onchorynchus mykiss*
	Osteichthyes (fish):	*Pimephales promelas*
	Chordata (fish, amphibian):	*Pseudacris crucifer*
	Planktonic crustacean:	*Daphnia magna*
	Benthic crustacean:	*Hyalella azteca*
	Aquatic insect:	
	Phylum other than Arthropoda or Chordata:	*Unio complamatus*
	Second insect or phylum not already rep.:	*Lumbriculus variegatus*

2. GMAVs	Lowest 4(2A): See Tier II method	Lowest 4(2B,2C, 2D): See Tier II method
µg/l		
	N:	N:
3. FAV:	2A:	2B, 2C, 2D:
4. Adjustments to FAVs:		

5. Chronic data: See Table 2a	No.	Species:
mean values		
µg/l		

6. ACR Measured:	Acute value	Chronic value	ACR
	9100	410	22.19
Generic: 18	67,200	35,350	1.9
	Generic	Generic	18
Final: 9.12			

7. Final Plant Value: NOEC = 300 µg/L, Northern milfoil

8. Chronic Criterion (FAV/ACR) see Tier II method

C. EPA Advisory Method (Tier II method)		
1. Data requirements:	Fish:	*Pimephales promelas*
N = 7	Crustacean:	*Daphnia magna*
No. SMAVs: 8	Third animal:	*Lumbriculus variegatus*
No. GMAVs: 7	Plant for herbicide:	
Adjustment Factor: 4.3	Insect for pesticide:	

2. Lowest GMAV: 5600 µg/L Species: *Lumbriculus variegatus*
3. FAV: 1302 µg/L (reduced to 170 µg/L) MC: 85 µg/L
4. Chronic data: See B.5.
5. ACR: 9.12 (See B.6)
6. CC: 18.6 µg/L (rounded up to 19 µg/L)
7. Citation for lowest GMAV: STS-334

D. Notes: FAV = GMAV ÷ Adjustment Factor; EAO staff lowered the Tier II calculated FAV of 1302 µg/L to the project EC50 of 170 µg/L to protect Chironomus tentans. The original Chironomus tentans study used the highest exposure concentration of 150 µg/L and reported the EC50 as greater than 150 µg/L. Therefore, EAO staff determined an estimated EC50 for the test at 170 µg/L.

Page 4 HUMAN HEALTH

A. Chemical/Element: PFOS	CAS# 1763231	

B. EPA Human Health Criterion (µg/l):	DW and fish: none	fish only: none	DW only: Perfluorooctane Sulfonate. Provisional short-term value 0.2 µg/L
Reference Dose: mg/kg/day	Cancer Potency Slope: (mg/kg-d)$^{-1}$		
Final BCF:	%lipid:		
Relative Source Contribution (RSC):			

C. Minnesota Human Health Criterion			
1. Ref.dose: 0.00008 mg/kg/day	Source: MDH		
Additivity endpoint(s): Development (body weight/weight gain), Hepatic (liver) system, Thyroid	Source: MDH		
RSC: 0.2	Source: MDH		
2. Cancer Potency Slope: n/a (mg/kg-d)$^{-1}$	Source:		
3. Measured BAFs: Species/Tissue	BAF	%lipid	Norm BAF
1. Bluegill/ Fillet	2700	n/a	2700
2. Carp/ Fillet	1237	n/a	1237
3. Freshwater Drum / Fillet	3077	n/a	3077
4. Smallmouth Bass/ Fillet	2845	n/a	2845
5. White Bass/ Fillet	4618	n/a	4618
Geo mean:	2667		
4. Measured BCFs: Species/Tissue	BCF	%lipid	Norm. BCF
1.	none		
Geo mean:			
5. Edible portion BAF or BCF	BAF		BCF
Cold water: 6.0 % lipid	n/a		
Warm water: 1.5 % lipid	n/a		
6. Geo mean unadjusted for lipid:	n/a		
7. log Kow: adjust. for % lipid:	meas.	QSAR (7.6% lipid):	Est. BCF:
8. Parachor: n/a			
9. BCF to BAF conversion factor: n/a			

10. Final BAF: 2A (6% lipid): 2667			2B & 2Bd,2C, 2D (1.5% lipid): 2667	
11. Criteria: ug/l	2A: 14 ng/L *	2Bd: 14 ng/L *	2B/2C, 2D: 14 ng/L #	HRL/HBV: 0.3 µg/L MDH Health Risk Limit/ Health Based Value for Groundwater

D. Organoleptic: n/a	Source:

E. Notes: E. Notes: * Criterion developed using 2 L/day water and 70 kg body wt. as specified in Minn. R. ch.7050. F. # Criterion developed using 0.01 L/day water incidental ingestion and 70 kg body wt. as specified in Minn. R. Ch. 7050.

Data used for calculation of fish BAF values for PFOS were reported fish tissue and surface water samples collected from the Mississippi R, Pool 2 in 2012. Methods used for calculating water quality criteria can be found in the MPCA water quality guidance manual (Maschwitz, 2000).

Water Quality Criteria development for 2012 Mississippi River PFOS sample analysis

Individual fish tissue values were measured from fillets of fish captured from pool 2 in 2012 and from surface water samples collected from the same area (Table 1). Procedures and results of those measurements are reported elsewhere. Briefly, fish and water were collected from the sites throughout pool 2 segregated by four discrete sampling sections of the pool. An arithmetic average of the measured water concentrations was calculated for each section of pool 2 sampled. Field BAFs were calculated for individual fish using the measured tissue value divided by the average measured water concentration from the corresponding section of the fish collection site. These individual BAFs were used to calculate a pool-wide geometric mean BAF. Values analyzed and reported as non-detect were given the value of the reporting limit for that analysis. Presently, guidance is being developed to better serve MPCA in its use of censored data.

		Species BAF (L/Kg)					
		Blue Gill Sunfish	Carp	Freshwater Drum	Smallmouth Bass	White Bass	Section GeoMean
Section	1	4081.30	1210.32	6106.25	5092.91	8726.25	4138.21
	2	4964.34	953.26	3536.58	4823.07	9166.39	3748.31
	3	4385.94	4695.43	3969.28	3608.00	5627.30	4405.58
	4	598.29	432.09	1045.7	738.82	882.12	702.35
	Grand Geometric mean						**2632.09**

Table 1. Summary BAFs (units = L/Kg) computed using geometric mean of BAFs from individual fish tissue residue measured from fish collected in each section divided by the arithmetic average water concentration of PFOS measured from the corresponding section.

Pool-wide BAF and Water Quality Criteria equations:

$$fCC = \frac{RfD\ x\ BW\ x\ RSC}{[IW + (\ BAF\ x\ CR)]}$$

Where:

fCC = fish consumption criterion (mg/L)

RfD = reference dose = 0.00008 (mg/kg-d)

BW = standard body weight (70 kg)

RSC = Relative Source Contribution factor: exposure fraction attributed to water and fish consumption (0.2)

IW = incidental ingestion of water (0.01 L/d)

CR = fish consumption rate (0.030 kg/d)

BAF = Biological Accumulation Factor (L/Kg)

$$\textbf{fCC} = \frac{0.00008 mg/kg{-}d\ x\ 70\ kg\ x\ 0.2}{[0.01\ L/d{+}(\ 2632.09\ L/kg x\ 0.030\ kg/d)]} = 0.0000142\ mg/L$$

WQC based on fish tissue BAFs for all of Pool 2:

BAF (L/Kg) = 2632.09

fCC (ng/L) = 14

Attachment C: Vermont NPDES Permit Application Forms

Permit Application Forms WR-82 and WR-82/Schedule B

VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION
WATERSHED MANAGEMENT DIVISION
WASTEWATER PROGRAM

Permit Application Form WR-82

10 V.S.A. Chapter 47

For DEC Use:

Application #:__________ PIN:__________ Reviewer:________ Receive date:__________ Title 3: ○Y ○N

Check #: Amount: $________ Paid By: __________________

Application For: (Check one) **Attach Schedule**:

☐ Municipal Discharge Permit	A
☐ Industrial Discharge Permit	B
☐ Pretreatment Discharge Permit	B
☐ Emergency Pollution Permit	E

Action Requested: (Check one)

☐ Original Permit
☐ Renewal
☐ Amendment
☐ Transfer Permit # ____________________

Status of Discharge: (Check one)

☐ Proposed
☐ Existing

Nature of Waste: (Check one)

☐ Sanitary (domestic sewage only)
☐ Non-Sewage/Industrial

A. Applicant

1a. Name:

1b. Legal Entity (Individual, corporation, partnership, firm, state agency, municipality, etc.):

2a. Mailing Address:

2b. Town: 2c. State: 2d. Zip:

3. Phone: 4. Email:

B. Project Activity

1. Name of Activity:

2. Description of waste:

3. Type of Activity: (Residential subdivision, paper mill, state park, motel, etc.)

4. Name of Landowner:

5. Location: 6. Town:

C. Discharge Schedule

Using a separate serial number (S/N), identify each independent discharge which will result from the activity described above. Attach a separate schedule for each discharge identified below.

Use an attached sheet for additional discharges.

Discharge	Receiving Water	Latitude (optional)	Longitude (optional)
S/N 001			
S/N 002			
S/N 003			
S/N 004			
S/N 005			

D. Permit Renewal

If this application is for a permit renewal, is the previous application still valid in all respects?

○ Yes ○ No If no, document changes on a separate attachment.

(Note: appropriate Schedule must be completed regardless if changes have occurred.)

E. Application Fees

3 V.S.A. Section 2822 Fees:

email jill.draper@vermont.gov for assistance calculating the application review fee.

$240.00 Administrative Processing Fee		Does not apply to Emergency Pollution Permits
Plus Application Review Fee		Applies to all applications (except for name change)
Total Fee Enclosed		

F. Signature

I CERTIFY THAT TO THE BEST OF MY KNOWLEDGE AND BELIEF THE INFORMATION SUBMITTED ABOVE IS TRUE, ACCURATE AND COMPLETE. I RECOGNIZE THAT BY SIGNING THIS APPLICATION I AM GIVING CONSENT TO EMPLOYEES OF THE STATE TO ENTER THE SUBJECT PROPERTY FOR THE PURPOSE OF PROCESSING THIS APPLICATION.

NAME AND TITLE OF APPLICANT OR LEGALLY AUTHORIZED REPRESENTATIVE (please print)

SIGNATURE DATE

NAME AND TITLE OF CO-APPLICANT OR LEGALLY AUTHORIZED REPRESENTATIVE (please print)

SIGNATURE DATE

☐ ***By checking this box, I certify that all adjoining property owners have been sent a DEC Adjoiner form via US mail prior to submission of this application.***

This application must be signed by the applicant or an officer in the applicant's business, a municipal official, etc. The application CANNOT be signed by the applicant's attorney, engineer, contractor, etc.

Submittal of Application: Attach appropriate schedules, administrative processing and application review fees, plans, specifications and other supporting material.

Refund Policy:

- If an application is modified, withdrawn or denied after technical review has commenced; all fees are retained.
- If an application is withdrawn prior to administrative review; all fees will be refunded.
- If an application is withdrawn after administrative review but prior to commencement of technical review, deemed administratively incomplete and returned to applicant, or determined that a permit is not required; administrative fees are retained and permit application review fees will be refunded.

Send completed application to:

VT Department of Environmental Conservation
Watershed Management Division
One National Life Drive, Main Bldg, 2nd Floor
Montpelier VT 05620-3522

VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION
WATERSHED MANAGEMENT DIVISION
WASTEWATER PROGRAM

SCHEDULE B: INDUSTRIAL/COMMERCIAL/INSTITUTIONAL WR-82B

10 V.S.A. Chapter 47

1. Name:

2. Activity:

3. Discharge:

4. S/N Designation: For each discharge point, enter a S/N designation (001, 002, 003, etc)

5. Exact location on receiving water (describe and locate on map) or receiving wastewater treatment facility:

6. Nature of Activity:

7. Point source category (EPA)		40 CFR Sub-part	
SIC		Sub category	
Product			
Production Process			
Production Ton/Day			

7b. If the discharge is regulated by either 40 CFR Part 423 OR CFR Part 433 (metal finishing or electroplating), include a toxic organic management plan ☐ Attached

8. Describe wastes to be discharged:

9a. Existing discharge? ☐ Yes ☐ No If "yes", are wastes being treated? ☐ Yes ☐ No

9b. Explain and describe any less than full time operation of treatment facilities:

9c. If "no", give the date the discharge will commence:

9d. Will wastes be treated prior to discharge? ☐ Yes ☐ No

9e. Explain and describe any less than full time operation of treatment facilities:

10a. Are new treatment facilities or modifications to existing facilities in design or under construction? ☐ Yes ☐ No

10b. If "yes", describe and provide schedule for attainment of operational level:

10c. If design of proposed treatment facility requires a period for data collection, how much time is required?

11. Have modifications to the production process or treatment facilities occurred during since the previous application was submitted? ☐ Yes ☐ No

12. If “yes”, please describe:

13. Describe flow sequence of discharge, including source of intake water, operations contributing wastewater to the effluent and treatment facilities. Attach line drawing showing the water flow through the facility.

14. Volumes of wastes, after treatment, if any, to be discharged

(A) Sanitary Wastes				
Weekdays average		GPD		
Weekends average		GPD		
(B) All other wastes				
Weekdays average		GPD		
Weekends average		GPD		

15. Will discharges in (B) above be essentially uniform over a 12 month period? ☐ Yes ☐ No

15b. If “No”, provide monthly or seasonal breakdown:

16. Is the person who is, or will be, responsible for operation and maintenance of the treatment facility certified by the Office of Professional Regulation as a Treatment Plant Operator? ☐ Yes ☐ No

17. Describe the procedures used for the disposal of all solids, sludges, filter backwash or other pollutants removed in the course of treatment or control of wastewaters. Include disposal site or location:

18. Describe the effluent characteristics of wastes, (B-12(a) and (B)) to be discharged which you know or have reason to believe are present. Provide maximum concentrations or range of concentrations. If no constituent of the type indicated is added, enter "none added". If constituent is present in unknown or uncertain amount enter "present" and describe in an attachment of the circumstances relating to its presence, including amounts of known constituents.

Biochemical and physical characteristics

Constituent	Amount	Unit	Constituent	Amount	Unit
BOD5		Mg/l	Total Dissolved Solids		Mg/l
COD		Mg/l	Total Phosporus AS P		Mg/l
TSS		Mg/l	Total Kjeldahl Nitrigen (TKN)		Mg/l
Turbidity		NTU	Color		
Settleable Solids		Mg/l	Materials affecting taste and Odor		
Oil and Grease		Mg/l	Temperature Range		°F
Floatable Solids		Mg/l	pH Range		SU

Chemical Constituents

Constituent	Amount	Unit	Constituent	Amount	Unit
Arsenic		Mg/l	Mercury		Mg/l
Cadmium		Mg/l	Nickel		Mg/l
Chlorine (free)		Mg/l	Selenium		Mg/l
Chromium (+6)		Mg/l	Silver		Mg/l
Chromium (+3)		Mg/l	Zinc		Mg/l
Copper		Mg/l	OTHERS (including any other pollutant identified as a priority pollutant by EPA in the NRDC vs. Train consent decree of July 8, 1976).[1]		
Cyanide		Mg/l	Other:		
Iron		Mg/l	Other:		
Lead		Mg/l	Other:		
Maganese		Mg/l	Other:		

[1] Existing discharges regulated by 40 CFR Part 413 or 40 CFR Part 433 are required to perform an analysis for Total Toxic Organics from a grab sample and submit the results as part of this application. Contact the Department for the list of Total Toxic Organics.

Attach additional information relating to the presence and amounts of other known constituents (instructions attached below)

Send completed application to:

VT Department of Environmental Conservation
Watershed Management Division
One National Life Drive, Main Bldg, 2nd Floor
Montpelier VT 05620-3522

Appendix C: Leachate Management Strategy Review Technical Memorandum

Brown AND Caldwell

2 Park Way, Suite 2A
Upper Saddle River, NJ 07458

T: 201.574.4700
F: 201.236.1607

Technical Memorandum

Prepared for: Casella Waste Systems, Inc.
Project Title: NEWSVT Leachate Treatment Options Engineering Evaluation
Project No.: 152990

Technical Memorandum

Subject: Leachate Management Strategy Review
Date: April 3, 2019
To: Ken Robbins
From: Brown and Caldwell
Copy to: Jeremy Labbe and Joe Gay – Casella
Steve Giese, Anthony Andrews and Alan Kirschner – Brown and Caldwell

Prepared by: Kevin D. Torrens

Kevin D. Torrens

Reviewed by: Steven J. McGuire

STEPHEN JOHN MCGUIRE
5/31/2019
NO. 134331
ENVIRONMENTAL

Stephen J. McGuire, PE
VT PE# 018.0134331

Limitations:

This document was prepared solely for Casella Waste Systems, Inc. (Casella) in accordance with professional standards at the time the services were performed and in accordance with the contract between Casella and Brown and Caldwell dated December 17, 2018. This document is governed by the specific scope of work authorized by Casella; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Casella and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

Introduction

Leachate that is produced at Casella's New England Waste Systems landfill in Coventry, Vermont (NEWSVT) is currently pumped to a 20,000-gallon underground storage tank and then to a 438,000-gallon above ground storage tank (AGST). The AGST is a covered, double wall tank providing secondary containment. The tank is mixed with a small recirculation pump. Tank contents are removed on a regular basis via pumping to tank trucks at a dedicated indoor load-out station. Leachate is disposed at any of seven publicly-owned treatment works (POTWs). Five of the POTWs are in Vermont, one is in New York State, and one is in New Hampshire. Currently, approved disposal locations are:

- Barre, Vermont
- Burlington North, Vermont
- Essex Junction, Vermont
- Montpelier, Vermont
- Newport, Vermont
- Plattsburg, New York
- Concord, New Hampshire

Leachate Management Option

The potentially relevant leachate management options for NEWSVT include the following:

- Flow reduction
- Source segregation
- On-site treatment and discharge to surface water (DSW)
- Hauling to POTW(s) with no additional treatment
- Hauling to POTW(s) with additional pre or post treatment at the POTW
- On-site pretreatment and hauling to POTWs
- Hauling to third party facilities (e.g., Centralized Waste Treatment [CWT] facilities)
- On-site pretreatment and hauling to CWT
- Zero liquid discharge (ZLD)

Flow Reduction

Leachate flow reduction often provides an economical leachate management strategy by reducing the overall leachate volume. This is particularly beneficial where advanced treatment processes (e.g., reverse osmosis) are applied due to both initial capital cost, energy consumption, and concentrate disposal requirements. It is also beneficial where leachate hauling is conducted rather than direct or indirect discharge.

It appears that NEWSVT has implemented appropriate and effective leachate generation reduction strategies based on a relatively average leachate generation rate of 392 gallons/acre (as compared to typical values of 200 to 600 gpd for facilities in the Northeast). Sections of the landfill are covered with exposed geomembrane covers (EGC). If not currently employed, the use of other reduction strategies such as rain flaps on open cells and open cell size minimization can be considered.

Based on the aforementioned information a significant reduction in leachate volume through application of additional leachate reduction practices is not anticipated.

Source Segregation

Source segregation can be beneficial if certain sections of landfill or specific liquid sources, such as gas well liquids (GWL) or gas condensate (GC), are problematic from a treatment or disposal perspective. Based on discussions with Casella and a review of available data, there are not significant differences in leachate quality between cells or phases that would justify segregation. All leachate and GWL is conveyed to the leachate storage tank through a combined leachate collection and conveyance system that limits segregation opportunities. The current GWL contribution is estimated to be approximately 14,000 gpd based on a pumping rate of 2 gpm from each of 5 wells. Recent (sample collected February 7, 2019) leachate data from the storage tank were compared to 2018 data for key parameters as shown in Table 1. No GWL pumping was conducted until December of 2018 so a comparison of the February 2019 data to pre-December 2018 data provides an indication of the impact of GWL. The data indicate a substantial impact on organic loading (BOD and COD) and on some semi-volatile compounds (cresols and phenols) which is not unexpected. Interestingly acetone and MEK (2-butanone) were not impacted compared to long-term average although they are considerably higher than the previous round of sampling in October 2018. These compounds are often significantly elevated in GWL. They are both highly soluble so volatilization/stripping in the storage tank would not be expected to be significant.

These significantly higher organic loadings would impact off-site disposal given current loading limits. Segregation could be used to manage this through targeted pretreatment of GWL. Assuming the pumping rates mentioned of about 10 gpm in total (5 wells at 2 gpm), this is about 50% of current daily flow. It is not known what the PFAS concentrations are in the GWL so treatment approach for PFAS in off-site liquids to achieve a target reduction is uncertain (e.g. can a 50% PFAS reduction be achieved by only pretreating GWL).

Table 1. Raw Leachate Comparison

		2018					2019
Parameter	Units	Feb	Mary	August	October	Average	2/07/19[1]
BOD_5	mg/L	1,200	490	270	320	570	2,500
COD	mg/L	3,200	1,600	4,100	2,500	2,850	6,600
Total Cresol	µg/L	1,180	65.2	--	42.7	429	2,050
3&4-Methylphenol	µg/L	1,160	52.2	--	31.2	414	2,020
Phenol	µg/L	190	55.8	--	45.3	97	453

1. Raw leachate sample collected 2/07/19.

Segregation of condensate collected from the third-party landfill gas (LFG) energy facility is technically feasible. The volume of condensate is estimated to be approximately 2,500-3,000 gallons per day (gpd). GC is often characterized by elevated concentrations of acetone, methyl ethyl ketone (MEK), and arsenic. No data are available for the site GC. If these compounds were identified as potentially problematic from a treatment discharge perspective, the GC could be segregated for alternative management such as dedicated pretreatment or offsite disposal. Note that arsenic is often present in GWL and GC as an organic arsenic species that can be difficult to remove.

At this time, segregation of any site-derived liquids does not appear to be practical or beneficial to leachate treatment opportunities.

Treatment and Discharge to Surface Water

Discharge to surface water (DSW) would consist of performing required leachate treatment to meet applicable discharge limits prior to discharging to a nearby waterbody, in this case the Black River. The Black River is designated as a Class A(2) waterbody, which precludes the use of mixing zones. If the Vermont Department of Environmental Conservation (VTDEC) will not allow a mixing zone, then Surface Water Quality Standards must be met at end of pipe.

Accordingly, discharge limits would likely be based on the lower of technology-based effluent limits (TBELs) or water quality-based effluent limits (WQBELs). TBELs and WQBELs would be implemented at end of pipe for parameters where dilution is not allowed (e.g., carcinogens). Further discussion is provided in BC's Technical Memorandum "Leachate Treatment Evaluation – Regulatory Review" dated January 16, 2019.

The Black River ultimately discharges to Lake Memphremagog, which serves as a potential drinking water source for communities downstream.

Given this and the classification of the Black River, it is reasonable to assume that low discharge limits for regulated constituents, including per- and polyfluoroalkyl substances (PFAS), will be implemented for discharge. Additionally, permitting may take an extended period of time due to the fact that the high-quality nature of the Black River will likely result in a cautionary approach by the VTDEC, as well as public scrutiny.

A direct DSW offers several key considerations to NEWSVT including:

- Control of own destiny regarding leachate disposal
- Elimination of hauling and associated costs and risks (e.g., spills, termination of disposal sites, changing discharge limits that impact treatment)
- Control of fate of PFAS

Disposal at POTWs or Third-Party Facilities

Disposal of leachate at POTWs or third-party facilities (e.g. CWTs) is a preferred alternative for many landfills, including NEWSVT. Disposal may be via connection to a sewer line, dedicated pipeline or hauling. Disposal may be with or without pretreatment, depending on leachate quality and disposal site regulations or disposal criteria. Disposal at POTWs could consist of the following:

- Hauling to POTW(s) with no additional treatment
- Hauling to a POTW with additional pretreatment at the POTW
- Hauling to a POTW with upgrades to the POTW (likely post-treatment)
- On-site (at NEWSVT) pretreatment and hauling to POTW(s)

For leachate disposal at POTWs within the State of Vermont, VTDEC issues a single discharge permit that allows disposal of leachate only at specific POTWs within the State. However, leachate can also be disposed at POTWs not within Vermont in accordance with facility specific discharge facilities.

The current Vermont POTW pretreatment discharge permit (Permit No. 3-1406) (Attachment A) was issued in November 4, 2011 (effective January 1, 2012) and expired in December 31, 2016. Although expired, the permit provisions remain in-force until a permit renewal is issued. VTDEC is currently evaluating the permit requirements for renewal. The current permit specifies limits only for pH and BOD loading. The disposal volume is also limited but may be increased above the specified value if the BOD loading limit is not exceeded. Given current emphasis on emerging contaminants (e.g. PFAS) as well as nutrients (e.g. nitrogen and phosphorus) as well as other constituents such as metals and pesticides, there is a potential for additional limits to be included in the next permit issued by VTDEC. It is recommended that discussions with VTDEC be held to identify the potential for additional permit limits as this may have a significant impact on disposal options and the need for, and type of, pretreatment.

Out of State POTWs and CWT facilities will have specific permit limits associated with leachate acceptance. CWTs are regulated both by the Federal Effluent Limit Guidelines (ELGs) for the CWT category (40 CFR Part

437) and the POTW to which they discharge. Out of State POTW limits are typically based on the POTW's pretreatment ordinance which is established to prevent potential impacts from constituents on worker health and safety, sludge quality, plant upset or pass-through to the effluent.

Use of POTWs or third-party facilities for disposal offers the following considerations to NEWSVT:

- Reduction or elimination of leachate treatment by NEWSVT
- Reduced CapEx (third party facilities)
- Reduced control of own destiny
- Complex contractual terms for POTW treatment enhancements
- Reduced control of PFAS fate

Zero Liquid Discharge

This option consists of collecting all landfill liquids and removing sufficient liquids such that residuals may be disposed of as a solid (e.g., pass paint filter test) resulting in elimination of liquids disposal. Functionally, this consists of evaporation of liquids using thermal processes. This approach is attractive in that only solid residuals must be disposed (typically on site) although air emissions and odors must also be considered. A thermal oxidation, or similar, process would be required to address potential odor concerns as well as other possible emissions (e.g., PFAS, VOCs).

This approach offers the benefit of eliminating liquid discharge to the environment, thus negating potential concerns with aqueous discharge of regulated constituents. This approach is energy intensive, however, the site has approximately 500 cubic feet per minute (cfm) of LFG available.

Evaporation (concentrator) technology does not destroy constituents but rather concentrates them for final disposal. Of additional consideration is the potential for release of odors and airborne emissions of constituents and associated dispersion to the environment. A detailed evaluation of potential air emissions is recommended for this approach with particular emphasis on PFAS constituents and odors.

Residuals management is of concern due to the potential for re-entrainment of constituents into the leachate from placed residuals. There are differing opinions on the potential constituent re-entrainment, however, data demonstrate that constituent re-entrainment does occur. Given the uncertainty associated with contaminant re-entrainment and the high-profile nature of PFAS, it is recommended that residuals be managed using one of the following approaches:

- Offsite disposal via incineration or deep-well injection
- Onsite stabilization to permanently immobilize constituents (e.g., Portland cement or similar)
- Monofilling residuals in a dedicated cell to prevent contamination of bulk leachate. Note that this approach may result in a concentrated leachate stream (of low volume) that requires additional management such as stabilization, treatment, or offsite disposal.

A ZLD approach offers several key considerations to NEWSVT including:

- Eliminates liquids disposal
- Control of own destiny regarding leachate disposal
- Elimination of hauling and associated costs and risks (e.g., spills, termination of disposal sites, changing discharge limits that impact treatment)
- Control of fate of PFAS
- Generates residuals that must be appropriately managed to prevent future impacts to leachate and gas production
- Air emission and odor uncertainties and public perceptions

Leachate Management Strategy Review

Seven leachate management strategies were identified based on the above: 1) Discharge to Surface Water (DSW with On-site leachate treatment for all regulated constituents including PFAS); Disposal of leachate to POTW: 2) with no pretreatment; 3) with upgrade of POTW for PFAS treatment, 4) with leachate Pretreatment for PFAS at the POTW; 5) with leachate pretreatment for PFAS and other constituents as needed at NEWSVT; 6) Haul to private facility for disposal without pretreatment; 7) Zero Liquid discharge (ZLD). Each leachate strategy noted above was evaluated based on key considerations as summarized in Table 2. Each consideration was weighted based on relative importance to Casella. Considerations were grouped by three categories: Environmental related, Technology related and Economic related with each category assigned a contributory allocation (percentage) to the overall weighted total. The weighting given to each consideration can be subjective, hence these were discussed with Casella for alignment. The assigned ratings for each consideration are based on experience and site-specific considerations. Lastly, the weighted values were summed to provide an overall weighted score to allow for option comparison. In this case, the lowest score provides the preferred overall approach to the identified considerations.

The results provide information that is useful in evaluating different disposal options based on specific considerations, categories or as a whole. The preferred disposal approach for each category and on a category weighted basis are summarized below. The complete table is included in Attachment B.

Table 2. Disposal Options Summary

	DSW	Disposal to POTW				Haul to Private Facility	Zero Liquid Discharge
Category	Onsite Treatment	No Pretreatment	Upgrade POTW	Pretreat at POTW	Pretreat at Landfill	No Pretreatment	No Pretreatment
Environmental	36.5	55	35	37.5	31.5	43	28.5
Technology	5.75	3.75	5.75	9	7.5	2.25	5
Economical	14	12.75	15.75	17.75	19	13.75	15.5
Combined*	**56.25**	**71.5**	**56.5**	**64.25**	**58**	**59**	**49**

* Category factors used: 50% for environmental, 25% for technology and 25% for economical. Refer to Attachment B.

The disposal approaches with the lowest weighted score for each category and combined (with and without category factors applied) are highlighted in yellow. The ZLD option at NEWSVT landfill results in the preferred approach for the Environmental category. On-site pretreatment (at NEWSVT) with POTW disposal and no pretreatment and disposal to upgraded POTW as the following options with lowest scores. For the Technology category, the option of hauling to a private facility without pretreatment results in the preferred approach, with no pretreatment and disposal to POTW and ZLD as the following options with lowest scores. The option of no pretreatment and disposal to POTW is the preferred option for the Economical category, with hauling to a private facility without pretreatment and DSW as the following options with lowest scores. Lastly, with preferred options based on the combined categories is the ZLD option, followed by DSW, no pretreatment and disposal to upgraded POTW, and on-site pretreatment and disposal to POTW.

The no pretreatment option can be considered a baseline condition that reflects current status, and it has the least environmental benefit. Note that hauling to a private facility will likely incur greater costs over the long term since the hauling distance will be greater (e.g., several hundred miles) and these facilities may be impacted by PFAS pretreatment regulations in the future. The nearest potential third-party facilities located (Clean Harbors) in South Portland, ME, and Bristol, CT, which are located approximate 170 miles and 266 miles from NEWSVT, respectively. The ranking system above should be interpreted as a guide but does not necessarily reflect the full granularity that is required for final selection. Also, note that the ranking system represents averages, and that items or options with higher risk potential can have a wider range of scores and those with lower risk can have a narrower range of scores. Given specific site and corporate objectives as well as the evolving regulatory climate, the private facility alternative may not be the overall preferred option. Of the remaining options ZLD, DSW and pretreatment at the landfill with POTW disposal offer the overall best combined rankings (with or without category weighting). The ZLD option may present some additional risk due to uncertainty regarding air emissions. That said, the pretreatment at the landfill option will result in residuals management requirements that may benefit from application of an evaporation technology with similar concerns. However, alternate residuals disposal such as solidification or off-site incineration can be substituted for evaporation if the risk is unacceptable. Lastly, on site treatment with direct discharge to surface water is slightly less attractive but offers complete control by Casella. As with the other options, residuals management will be a key consideration. The benefits and limitations of each disposal route are summarized in Attachment C. These factors will be important in identifying the preferred overall approach in conjunction with technology screening.

Attachment A: VTDEC Pretreatment Discharge Permit

Pretreatment Discharge Permit No. 3-1406

VERMONT

State of Vermont
Department of Environmental Conservation
Wastewater Management Division
103 South Main St – The Sewing Bldg
Waterbury VT05671-0405
www.anr.state.vt.us/dec/ww/wwmd.cfm

[phone] 802-241-3822
[fax] 802-241-2596

Agency of Natural Resources

November 4, 2011

John Gay
New England Waste Services, Inc.
PO Box 976 220 Avenue B
Williston, VT 05495

RE: Pretreatment Discharge Permit No. 3-1406 & Response Summary

Dear Mr. Gay,

Enclosed is your copy of Discharge Permit No. 3-1406 which has been signed on behalf of the Commissioner of the Department of Environmental Conservation. This permit authorizes the discharge of municipal landfill leachate from your solid waste disposal facilities to the City of Montpelier, City of Burlington "North",Village of Essex Junction, City of Barre, and City of Newport wastewater treatment facilities.

Please review the permit carefully and note the effluent limitations, monitoring requirements, and other special conditions.

Numerous comments were received on the draft of this permit during the public notice period. Enclosed is a Response Summary which addresses these comments. Any changes to the final permit due to comments are noted is the Response Summary.

Please note that this permit does not become effective until January 1, 2012 and if there are any questions regarding this permit please contact Randy Bean at our office.

Sincerely,
Christine Thompson
Christine Thompson, Director
Wastewater Management Division

Attachments
cc
Robert Fisher, City of Montpelier
James Jutras, Village of Essex Junction
Laurie Adams, City of Burlington
Steve Micheli, City of Barre
Dave Parenteau, City Newport
Liz Dickson, VT DEC WWMD
Jeff Fehrs, VT DEC WWMD
Don Hendrich, Memphremagog Watershed Association
Gisele Lacasse Benoit, Memphremagog Conservation, Inc

AGENCY OF NATURAL RESOURCES
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
WASTEWATER MANAGEMENT DIVISION
103 SOUTH MAIN STREET
WATERBURY, VERMONT 05671-0405

Permit No.: 3-1406
File No.: 12-11
PIN: WY06-0020

PRETREATMENT DISCHARGE PERMIT

In compliance with the provisions of the Vermont Water Pollution Control Act, as amended, (10 V.S.A. Chapter 47 §1251 et. seq),

New England Waste Services
PO Box 976 220 Avenue B
Williston, VT 05495

(hereinafter referred to as the "permittee") is authorized, by the Secretary, Agency of Natural Resources, to discharge to the:

City of MontpelierWastewater Treatment Facility

and the
City of Burlington "North" Wastewater Treatment Facility

and the
Village of Essex Junction Wastewater Treatment Facility

and the
City of Barre Wastewater Treatment Facility

and the
City of Newport Wastewater Treatment Facility

in accordance with effluent limitations, monitoring requirements, and other conditions set forth in Parts I, II, III hereof.

This permit shall become effective on January 1, 2012

This permit and the authorization to discharge shall expire on December 31, 2016.

Signed this 3rd day of November, 2011.

David K. Mears, Commissioner
Department of Environmental Conservation

By Christine Thompson
Christine Thompson, Director
Wastewater Management Division

PART I

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1. From January 1, 2012 through December 31, 2016, the permittee is authorized to discharge solid waste landfill leachate from its Coventry, VT and the Bethlehem, NH, and the "Central Vermont" facilities to **the Montpelier Wastewater Treatment Facility.** Such discharges shall be limited by the permittee as specified below:

	Discharge Limitations		**Monitoring Requirements**	
Effluent Characteristic	**Daily Maximum**	**Weekly Maximum**	**Measurement Frequency**	**Sample Type**
Flow	23,000 gpd (1)		Daily	Total Volume
Biochemical Oxygen Demand (BOD)	1,200 lbs (1)	7,200 lbs	Weekly (2)	Grab
pH	Range: 5.0 - 9.5 SU		Daily	Grab

(1) The Daily Maximum leachate flow may exceed 23,000 gpd only if the Biochemical Oxygen Demand (BOD) of the leachate discharged on that day does not exceed **1,200 pounds**.

On days when the flow exceeds **23,000 gallons**, the permittee shall sample and analyze a representative sample(s) of the entire volume of leachate discharged to the facility and report the **total** pounds of BOD discharged to the WWTF for that day to verify that less than **1,200 pounds** of BOD was discharged.

(2) BOD shall be sampled at a **minimum** of weekly, even if the daily flows during the week have not reached or exceeded **23,000 gpd**.

2. From January 1, 2012 through December 31, 2016, the permittee is authorized to discharge: solid waste landfill leachate from its Coventry, Vermont and Bethlehem, New Hampshire facilities to the **Burlington "North" Wastewater Treatment Facility**. Such discharges shall be limited by the permittee as specified below:

	Discharge Limitations		**Monitoring Requirements**	
Effluent Characteristic	**Weekly Average**	**Daily Maximum**	**Measurement Frequency**	**Sample Type**
Flow		23,000 gpd (1)	Daily	Total Volume
BOD		900 lbs (1)	Weekly (2)	Grab
pH	Range: 5.0 - 9.5 SU		Daily	Grab

(1) The Daily Maximum leachate discharged to the "Day Leachate Storage Tank" shall not exceed 23,000 gpd **or 900 pounds per day of Biochemical Oxygen Demand, whichever is more restictive**. The permittee may deliver additional leachate to the wastewater treatment facility for storage in the unused aeration tanks at the discretion of the City of Burlington.

(2) BOD shall be sampled at a minimum of weekly, even if the daily flows during the week have not reached 23,000 gpd.

3. From January 1, 2012 through December 31, 2016, the permittee is authorized to discharge: solid waste landfill leachate from its Coventry, Vermont and Bethlehem, New Hampshire facilities to the **Essex Junction Wastewater Treatment Facility**. Such discharges shall be limited by the permittee as specified below:

	Discharge Limitations		**Monitoring Requirements**	
Effluent Characteristic	**Weekly Average**	**Daily Maximum**	**Measurement Frequency**	**Sample Type**
Flow		30,000 gpd (1)	Daily	Total Volume
BOD		1,200 lbs (1)	Weekly (2)	Grab
pH	Range: 5.0 - 9.5 SU		Daily	Grab

(1) The Daily Maximum leachate discharged to the wastewater treatment facility shall not exceed 30,000 gpd **or 1,200 pounds per day of Biochemical Oxygen Demand, whichever is more restrictive.**

(2) BOD shall be sampled at a minimum of weekly, even if the daily flows during the week have not reached 30,000 gpd.

4. From January 1, 2012 through December 31, 2016, the permittee is authorized to discharge: solid waste landfill leachate from its Coventry, Vermont and Bethlehem, New Hampshire facilities to the **City of Barre Wastewater Treatment Facility**. Such discharges shall be limited by the permittee as specified below:

	Discharge Limitations		**Monitoring Requirements**	
Effluent Characteristic	**Weekly Average**	**Daily Maximum**	**Measurement Frequency**	**Sample Type**
Flow		7,000 gpd (1)	Daily	Total Volume
BOD		117 lbs (1)	Weekly (2)	Grab
pH	Range: 5.0 - 9.5 SU		Daily	Grab

(1) The Daily Maximum leachate discharged to the wastewater treatment facility shall not exceed 7,000 gpd **or 117 pounds per day of Biochemical Oxygen Demand, whichever is more restrictive.**

(2) BOD shall be sampled at a minimum of weekly, even if the daily flows during the week have not reached 7,000 gpd.

5. From January 1, 2012 through December 31, 2016, the permittee is authorized to discharge: solid waste landfill leachate from its Coventry, Vermont and Bethlehem, New Hampshire facilities to the **City of Newport Wastewater Treatment Facility**. Such discharges shall be limited by the permittee as specified below:

	Discharge Limitations		**Monitoring Requirements**	
Effluent Characteristic	**Weekly Average**	**Daily Maximum**	**Measurement Frequency**	**Sample Type**
Flow		15,000 gpd (1)	Daily	Total Volume
BOD		450 lbs (1)	Weekly (2)	Grab
pH	Range: 5.0 - 9.5 SU		Daily	Grab

(1) The Daily Maximum leachate discharged to the wastewater treatment facility shall not exceed 15,000 gpd **or 450 pounds per day of Biochemical Oxygen Demand, whichever is more restrictive.**

(2) BOD shall be sampled at a minimum of weekly, even if the daily flows during the week have not reached 15,000 gpd.

B. SPECIAL CONDITIONS:

1. Leachate shall be discharged into holding tanks or into the receiving stations at the wastewater treatment facilities or in a manner as specified by the chief operator or other authorized City or sewer department representative. The discharge of leachate into the Montpelier Wastewater Treatment Facility's collection system shall not occur during storm events, snow melt, or when a storm event is imminent.

2. Leachate samples collected in accordance with the monitoring requirements of this permit shall be taken **from the holding tank(s) at the landfills**, and the samples shall be well mixed and representative of the leachate discharged to the wastewater treatment facilities.

3. This permit constitutes authorization by the Vermont Agency of Natural Resources to discharge leachate to the wastewater treatment facilities specified in Part I.A.1, 2, 3, 4, and 5 above. This permit does not constitute authorization by the City of Montpelier, the City of Burlington, Village of Essex Junction, the City of Barre or the City of Newport to discharge leachate to their wastewater treatment facilities. The municipalities have the right to restrict the discharge of leachate to a lesser volume than is specified in Part I.A.1, 2, 3, 4, and 5 of this permit or to refuse acceptance of the discharge.

4. Leachate shall not be introduced into the treatment process at the Montpelier Wastewater Treatment Facility on any day in which the maximum rate of influent flow to the facility exceeds the facility's peak design flow of 8.0 MGD.

5. Leachate shall not be introduced into the Newport Wastewater Treatment Facility in a manner that would cause or contribute to a combined sewer overflow event.

6. If the monitoring results indicate the presence of substances in such concentrations as may interfere with or are otherwise incompatible with the Montpelier Wastewater Treatment Facility, the Burlington North Wastewater Treatment Facility, the Village of Essex Junction Wastewater Treatment Facility, the City of Barre Wastewater Treatment Facility or City of Newport Wastewater Treatment Facility or may pass through without treatment and cause a violation of Vermont Water Quality Standards in the receiving stream, the Department may reopen this permit and modify effluent limitations, monitoring requirements, or other permit conditions as required. The Department may also require the cessation of this discharge until such time as the discharge will not interfere with or cause an adverse effect on the Facility or receiving stream.

C. REAPPLICATION

If the permittee desires to continue to discharge after the expiration of this permit, the permittee shall reapply on the application forms then in use at least 180 days before this permit expires.

Reapply for a Discharge Permit by: **June 30, 2016**

D. OPERATING FEES

This discharge is subject to operating fees. The permittee shall submit the operating fees in accordance with the procedures provided by the Secretary.

D. MONITORING AND REPORTING

1. Metal, Organic, and Inorganic Sampling

In addition to the monitoring required in Condition I.A. above, the permittee shall monitor and record the quality and quantity of discharge(s) to the Montpelier, Burlington "North", Essex Junction, Barre, and the Newport wastewater treatment facilities, according to the following schedule and other provisions.

Until December 31, 2016:

Parameter	Minimum Frequency of Analysis	Sample Type
Metals (Total) (1,2)	1 x Quarterly	Grab
Chemical Oxygen Demand (1)	1 x Quarterly	Grab
Chloride (1)	1 x Quarterly	Grab
Total Kjeldahl Nitrogen (1)	1 x Quarterly	Grab
Volatile Organic Compounds (1,3)	1 x Annually	Grab
Acid and Base/Neutral Extractable (1,4)	1 x Annually	Grab

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(1) Leachate samples collected in accordance with the monitoring requirements of this permit shall be taken **from the holding tank(s) at the landfills**, and the samples shall be well mixed and representative of the leachate discharged to the wastewater treatment facilities.

(2) Samples shall be analyzed for the following total metals: arsenic, cadmium, chromium, copper, lead, molybdenum, mercury, nickel, selenium, and zinc.

(3) Volatile Organic Compounds shall be analyzed by EPA Method 8260.

(4) Acid and Base/Neutral Extractable shall.be analyzed by EPA Method 8270.

2. Sampling and Analysis

The sampling, preservation, handling, and analytical methods used shall conform to regulations published pursuant to Section 304(g) of the Clean Water Act, under which such procedures may be required. Guidelines establishing these test procedures have been published in the Code of Federal Regulations, Title 40, Part 136 (Federal Register, Vol. 56, No. 195, July 1, 1999 or as amended).

If applicable, *Escherichia coli* shall be tested using one of the following methods:

a. "Most Probable Number" (MPN) method 9223B found in Standard Methods for the Examination of Water and Wastewater, 18th or subsequent approved edition(s). Premade formulations are available as Colilert and Colilert 18 from IDEXX Labs Inc., Westbrook, ME;

b. EPA "membrane filtration" (MF) method 1603 using modified mTEC; or

c. A single step membrane filtration (MF) method using mColiBlue 24 available from Hach Company, Loveland, CO.

Samples shall be representative of the volume and quality of effluent discharged over the sampling and reporting period. All samples are to be taken during normal operating hours. The permittee shall identify the effluent sampling location used for each discharge.

3. Reporting

The Permittee is required to submit monitoring results as specified on a Discharge Monitoring Report (Form WR-43). Reports are due on the 15th day of each month, beginning with the month following the effective date of this permit.

If, in any reporting period, there has been no discharge, the permittee must submit that information by the report due date.

Signed copies of these, and all other reports required herein, shall be submitted to the Secretary at the following address:

Agency of Natural Resources
Department of Environmental Conservation
Wastewater Management Division
103 South Main Street, The Sewing Building
Waterbury, Vermont 05671-0405

and the:

Montpelier Wastewater Treatment Facility
Attn: Robert Fisher

and the

Burlington Department of Public Works
Attn: Laurie Adams

and the

Village of Essex Junction Wastewater Treatment Facility
Attn: James Jutras

and the

City of Barre
Attn: Steve Micheli

and the

City of Newport Wastewater Treatment Facility
Attn: David Parenteau

All reports shall be signed:

a. In the case of corporations, by a principal executive officer of at least the level of vice president, or his/her duly authorized representative, if such representative is responsible for the overall operation of the facility from which the discharge described in the permit form originates;

b. In the case of a partnership, by a general partner;

c. In the case of a sole proprietorship, by the proprietor;

d. In the case of a municipal, State, or other public facility, by either a principal executive officer, ranking elected official, or other duly authorized employee.

4. Recording of Results

The permittee shall maintain records of all information resulting from any monitoring activities required including:

a. The exact place, date, and time of sampling;
b. The dates and times the analyses were performed;
c. The person(s) who performed the analyses;
d. The analytical techniques and methods used including sample collection handling and preservation techniques;
e. The results of all required analyses.
f. The records of monitoring activities and results, including all instrumentation and calibration and maintenance records;
g. The original calculation and data bench sheets of the operator who performed analysis of the influent or effluent pursuant to requirements of Section I.(A) of this permit.

The results of monitoring requirements shall be reported (in the units specified) on the Vermont reporting form WR-43 or other forms approved by the Secretary.

5. Additional Monitoring

If the permittee monitors any pollutant at the location(s) designated herein more frequently than required by this permit, using approved analytical methods as specified above, the results of such monitoring shall be included in the calculation and reporting of the values required in the Discharge Monitoring Report Form WR-43. Such increased frequency shall also be indicated.

PART II

A. MANAGEMENT REQUIREMENTS

1. Facility Modification / Change in Discharge

All discharges authorized herein shall be consistent with the terms and conditions of this permit. Such a violation may result in the imposition of civil and/or criminal penalties as provided for in Section 1274 and 1275 of the Vermont Water Pollution Control Act. Any anticipated facility expansions, production increases, or process modifications which will result in new, different, or increased discharges of pollutants must be reported by submission of a new permit application or, if such changes will not violate the effluent limitations specified in this permit, by notice to the permit issuing authority of such changes. Following such notice, the permit may be modified to specify and limit any pollutants not previously limited.

2. Noncompliance Notification

In the event the permittee is unable to comply with any of the conditions of this permit due, among other reasons, to:

a. breakdown or maintenance of waste treatment equipment (biological and physical-chemical systems including, but not limited to, all pipes, transfer pumps, compressors, collection ponds or tanks for the segregation of treated or untreated wastes, ion exchange columns, or carbon absorption units),

b. accidents caused by human error or negligence, or

c. other causes such as acts of nature,

the permittee shall notify the Secretary within 24 hours of becoming aware of such condition or by the next business day and shall provide the Secretary with the following information, in writing, within five (5) days:

i. cause of non-compliance

ii. a description of the non-complying discharge including its impact upon the receiving water;

iii. anticipated time the condition of non-compliance is expected to continue or, if such condition has been corrected, the duration of the period of non-compliance;

iv. steps taken by the permittee to reduce and eliminate the non-complying discharge; and

v. steps to be taken by the permittee to prevent recurrence of the condition of non-compliance.

3. Operation and Maintenance

All waste collection, control, treatment, and disposal facilities shall be operated in a manner consistent with the following:

a. The permittee shall, at all times, maintain in good working order and operate as efficiently as possible all treatment or control facilities or systems installed or used by the permittee to achieve compliance with the terms and conditions of this permit.

b. The permittee shall provide an adequate operating staff which is duly qualified to carry out the operation, maintenance, and testing functions required to insure compliance with the conditions of this permit.

4. Quality Control

The permittee shall calibrate and perform maintenance procedures on all monitoring and analytical instrumentation at regular intervals to ensure accuracy of measurements, or shall ensure that both activities will be conducted.

The permittee shall keep records of these activities and shall provide such records upon request of the Secretary.

The permittee shall analyze any additional samples as may be required by the Agency of Natural Resources to ensure analytical quality control.

5. Records Retention

All records and information resulting from the monitoring activities required by this permit including all records of analyses performed, calibration and maintenance of instrumentation, and recordings from continuous monitoring instrumentation shall be retained for a minimum of three (3) years, and shall be submitted to Department representatives upon request. This period shall be extended during the course of unresolved litigation regarding the discharge of pollutants or when requested by the Secretary.

6. **Duty to Mitigate**

The permittee shall take all reasonable steps to minimize or prevent any adverse impact to the receiving wastewater treatment facility resulting from non-compliance with any condition specified in this permit, including accelerated or additional monitoring as necessary to determine the nature and impact of the non-complying discharge.

7. **Bypass**

The diversion or bypass of facilities, necessary to maintain compliance with the terms and conditions of this permit, is prohibited, except where authorized under terms and conditions of an emergency pollution permit issued pursuant to 10 V.S.A. Section 1268.

8. **Solids Management**

Collected screenings, sludges, and other solids removed in the course of treatment and control of wastewaters shall be stored, treated and disposed of in accord with 10 V.S.A., Chapter 159 and with the terms and conditions of any certification, interim or final, transitional operation authorization or order issued pursuant to 10 V.S.A., Chapter 159 that is in effect on the effective date of this permit or is issued during the term of this permit.

9. **Emergency Pollution Permits**

Maintenance activities, or emergencies resulting from equipment failure or malfunction, including power outages, which result in an effluent which exceeds the effluent limitations specified herein, shall be considered a violation of the conditions of this permit, unless the permittee immediately applies for, and obtains, an emergency pollution permit under the provisions of 10 V.S.A., Chapter 47, Section 1268. The permittee shall notify the Department of the emergency situation by the next working day.

10 V.S.A., Chapter 47, Section 1268 reads as follows:

"When a discharge permit holder finds that pollution abatement facilities require repairs, replacement or other corrective action in order for them to continue to meet standards specified in the permit, he may apply in the manner specified by the secretary for an emergency pollution permit for a term sufficient to effect repairs, replacements or other corrective action. The permit may be issued without prior public notice if the nature of the emergency will not provide sufficient time to give notice; provided that the secretary shall give public notice as soon as possible but in any event no later than five days after the effective date of the emergency pollution permit. No emergency pollution permit shall be issued unless the applicant certifies and the secretary finds that:

(a) there is no present, reasonable alternative means of disposing of the waste other than by discharging it into the waters of the state during the limited period of time of the emergency;

(b) the denial of an emergency pollution permit would work an extreme hardship upon the applicant;

(c) the granting of an emergency pollution permit will result in some public benefit;

(d) the discharge will not be unreasonably harmful to the quality of the receiving waters;

(e) the cause or reason for the emergency is not due to wilful or intended acts or omissions of the applicant."

Application shall be made to the Secretary of the Agency of Natural Resources, Department of Environmental Conservation, 103 South Main Street, Waterbury, Vermont 05671-0405.

10. Power Failure

In order to maintain compliance with the effluent limitations and prohibitions of this permit, the permittee shall either:

a. Provide an alternative power source sufficient to operate the wastewater control facilities, or if such alternative power source is not in existence,

b. Halt, reduce, or otherwise control production and/or all discharges upon the reduction, loss, or failure of the primary source of power to the wastewater control facilities.

B. RESPONSIBILITIES

1. Right of Entry

The permittee shall allow the Secretary or authorized representative, upon the presentation of proper credentials:

a. to enter upon the permittee's premises in which an effluent source or any records required to be kept under terms and conditions of the permit are located;

b. to have access to and copy any records required to be kept under the terms and conditions of the permit;

c. to inspect any monitoring equipment or method required in the permit; or

d. to sample any discharge of pollutants.

2. Transfer of Ownership or Control

This permit is not transferable without prior written approval of the Secretary. All application and operating fees must be paid in full prior to transfer of this permit. In the event of any change in control or ownership of facilities from which the authorized discharges emanate, the permittee shall provide a copy of this permit to the succeeding owner or controller and shall send written notification of the change in ownership or control to the Secretary. The permittee shall also inform the prospective owner or operator of their responsibility to make an application for transfer of this permit.

This request for transfer application must include as a minimum:

a. A properly completed application form provided by the Secretary and the applicable processing fee.

b. A written statement from the prospective owner or operator certifying:

   i. The conditions of the operation that contribute to, or affect, the discharge will not be materially different under the new ownership.

   ii. The prospective owner or operator has read and is familiar with the terms of the permit and agrees to comply with all terms and conditions of the permit.

   iii. The prospective owner or operator has adequate funding to operate and maintain the treatment system and remain in compliance with the terms and conditions of the permit.

c. The date of the sale or transfer.

The Secretary may require additional information dependent upon the current status of the facility operation, maintenance, and permit compliance.

3. Confidentiality

Pursuant to 10 V.S.A. 1259(b):

"Any records, reports or information obtained under this permit program shall be available to the public for inspection and copying. However, upon a showing satisfactory to the secretary that any records, reports or information or part thereof, other than effluent data, would, if made public, divulge methods or processes entitled to protection as trade secrets, the secretary shall treat and protect those records, reports or information as confidential. Any records, reports or information accorded confidential treatment will be disclosed to authorized representatives of the state and the United States when relevant to any proceedings under this chapter."

4. Permit Modification

After notice and opportunity for a hearing, this permit may be modified, suspended, or revoked in whole or in part during its term for cause including, but not limited to, the following:

a. violation of any terms or conditions of this permit;

b. obtaining this permit by misrepresentation or failure to disclose fully all relevant facts; or

c. a change in any condition that requires either a temporary or permanent reduction or elimination of the permitted discharge.

5. Toxic Effluent Standards

That if a toxic effluent standard or prohibition (including any schedule of compliance specified in such effluent standard or prohibition) is established under section 307(a) of the Federal Act for a toxic pollutant which is present in the permittee's discharge and such standard or prohibition is more stringent than any limitation upon such pollutant in the permit, the secretary shall revise or modify the permit in accordance with the toxic effluent standard or prohibition and so notify the permittee.

6. Civil and Criminal Liability

Except as provided in, "Bypass" (Part II.A., paragraph A.7.), "Power Failure" (Part II.A., paragraph 10.), and "Emergency Pollution Permits" (Part II, paragraph A.9.), nothing in this permit shall be construed to relieve the permittee from civil or criminal penalties for noncompliance. Civil penalties, as authorized under 10 V.S.A. §1274 and 10 V.S.A. §8010, shall not exceed $10,000 a day for each day of violation. Criminal penalties, as authorized under 10 V.S.A. §1275, shall not exceed $25,000 for each day of violation, imprisonment for up to six months, or both.

7. Oil and Hazardous Substance Liability

Nothing in this permit shall be construed to preclude the institution of legal action or relieve the permittee from any responsibilities, liabilities, or penalties to which the permittee is or may be subject under 10 V.S.A. §1281.

8. State Laws

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties established pursuant to any applicable State law or regulation under authority preserved by Section 510 of the Clean Water Act.

9. Property Rights

Issuance of this permit does not convey any property rights in either real or personal property, or any exclusive privileges, nor does it authorize any injury to private property or any invasion of personal rights, nor any infringement of Federal, State, or local laws or regulations.

10. Severability

The provisions of this permit are severable, and if any provision of this permit, or the application of any provision of this permit to any circumstance, is held invalid, the application of such provision to other circumstances, and the remainder of this permit, shall not be affected thereby.

11. Authority

This permit is issued under authority of 10 V.S.A. §1259 which states that: "No person shall discharge any waste, substance, or material into waters of the State, nor shall any person discharge any waste, substance, or material into an injection well or discharge into a publicly owned treatment works any waste which interferes with, passes through without treatment, or is otherwise incompatible with those works or would have a substantial adverse effect on those works or on water quality, without first obtaining a permit for that discharge from the Secretary", and under the authority of Section 402 of the Clean Water Act, as amended.

PART III

A. OTHER REQUIREMENTS

This permit shall be modified, or alternatively, revoked and reissued, to comply with any applicable effluent standard or limitation issued or approved under Sections 301(b) (2) (C), and (D), 304(b) (2), and 307 (a) (2) of the Clean Water Act, if the effluent standard or limitation so issued or approved:

1. Contains different conditions or is otherwise more stringent than any effluent limitation in the permit; or

2. Controls any pollutant not limited in the permit.

The permit as modified or reissued under this paragraph shall also contain any other requirements of the Vermont Water Pollution Control Act then applicable.

B. DEFINITIONS

For purposes of this permit, the following definitions shall apply.

The Act - The Vermont Water Pollution Control Act, 10 V.S.A. Chapter 47

Annual Average - The highest allowable average of daily discharges calculated as the sum of all daily discharges (mg/l, lbs or gallons) measured during a calendar year divided by the number of daily discharges measured during that year.

Average - The arithmetic means of values taken at the frequency required for each parameter over the specified period.

The Clean Water Act - The federal Clean Water Act, as amended.

Composite Sample - A sample consisting of a minimum of one grab sample per hour collected during a 24-hour period (or lesser period as specified in the section on Monitoring and Reporting) and combined proportionally to flow over that same time period.

Daily Discharge - The discharge of a pollutant measured during a calendar day or any 24-hour period that reasonably represents the calendar day for purposes of sampling.

For pollutants with limitation expressed in pounds the daily discharge is calculated as the total pounds of pollutants discharged over the day.

For pollutants with limitations expressed in mg/l the daily discharge is calculated as the average measurement of the pollutant over the day.

Grab Sample - An individual sample collected in a period of less than 15 minutes.

Incompatible Substance (Pollutant) - Any waste being discharged into the treatment works which interferes with, passes through without treatment, or is otherwise incompatible with said works or would have a substantial adverse effect on these works or on water quality. This includes all pollutants required to be regulated under the Federal Clean Water Act.

Instantaneous Maximum - A value not to be exceeded in any grab sample.

Major Contributing Industry - One that: (1) has a flow of 50,000 gallons or more per average work day; (2) has a flow greater than five percent of the flow carried by the municipal system receiving the waste; (3) has in its wastes a toxic pollutant in toxic amounts as defined in standards issued under Section 307(a) of the Act; or (4) has a significant impact, either singly or in combination with other contributing industries, on a publicly owned treatment works or on the quality of effluent from that treatment works.

Maximum Day (maximum daily discharge limitation) - The highest allowable "daily discharge" (mg/l, lbs or gallons).

Mean - The mean value is the arithmetic mean.

Monthly Average - (Average monthly discharge limitation) - The highest allowable average of daily discharges (mg/l, lbs or gallons) over a calendar month, calculated as the sum of all daily discharges (mg/l, lbs or gallons) measured during a calendar month divided by the number of daily discharges measured during that month.

NPDES - The National Pollutant Discharge Elimination System.

Secretary - The Secretary of the Agency of Natural Resources

State Certifying Agency Agency of Natural Resources
Department of Environmental Conservation
Wastewater Management Division

103 South Main Street
Waterbury, Vermont 05671-0405

Weekly Average - (Average weekly discharge limitation) - The highest allowable average of daily discharges (mg/l, lbs or gallons) over a calendar week, calculated as the sum of all daily discharges (mg/l, lbs or gallons) measured during a calendar week divided by the number of daily discharges measured during that week.

07/2000; u. 4/2007

STANDARD OPERATING PROCEDURE

LEACHATE SAMPLING AT NEWSVT LANDFILL
USING DEDICATED BAILERS
OR
SAMPLING FROM THE TOP OF TANKER TRUCKS

The following procedure shall be used for collecting a leachate sample from the holding tanks or directly out of a trailer used to transport leachate. Prior to sampling, calibrate the pH meter with a 2 or 3 point calibration procedure. The calibration points will correspond with the pH buffers of 4, 7 and 10 pH.

- Don nitrile or thick rubber gloves to sufficiently limit exposure to leachate.
- Fill out sample labels or adequately identify bottles prior to filling. Ensure an adequate supply of preservatives is available if necessary.
- Lower the bailer down the access hole to the leachate holding tank. (If sampling from the top of a tanker truck, collect a sample from the top of the truck).
- Remove the bailer from the holding tank and fill the sample bottles. Add required preservative as necessary. Cap bottles. Note sample time.
- Collect pH readings and record time. Make sure pH measurements are done within 15 minutes of sample time. Readings collected from pH meters must include 2 decimal places.
- Put samples on ice and arrange for transportation to Endyne as quickly as possible.
- Information on all samples must be recorded on Chain of Custody (COC), showing project name, sample location, type and number of sample containers, analysis required and signature of relinquishing personnel (sampler). Note the sample time and time of pH collection on the COC. Retain copies of the COC in the project file.

Attachment B: Disposal Options

ATTACHMENT B

DISPOSAL OPTIONS

Category Factor	Considerations by Category	Consideration Weighting	Discharge to Surface Water (DSW)		Disposal to POTW (50% Reduction)								Haul to Private Facility		Zero Liquid Discharge	
			On-Site Treatment		No Pretreatment		Upgrade POTW		Pretreat at POTW		Pretreat at Landfill		No Pretreatment		No Pretreatment	
			Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
	Environmental															
	Permitting/Agreement Complexity/Time	4	5	20	5	20	5	20	5	20	2	8	1	4	3	12
	Changing Treatment Standards Impact	2	4	8	5	10	3	6	3	6	3	6	4	8	2	4
	Regulatory Compliance Challenge	3	5	15	5	15	3	9	3	9	3	9	3	9	2	6
	Risk of PFAS Pass-through	5	1	5	5	25	2	10	2	10	2	10	5	25	2	10
	Overall Environmental Impact	5	2	10	5	25	3	15	3	15	3	15	5	25	2	10
	Air/odor emissions	5	3	15	3	15	2	10	3	15	3	15	3	15	3	15
	Subtotal	24	20	73	28	110	18	70	19	75	16	63	21	86	14	57
50%	**Factored Subtotal**		**10**	**36.5**	**14**	**55**	**9**	**35**	**9.5**	**37.5**	**8**	**31.5**	**10.5**	**43**	**7**	**28.5**
	Technology															
	Treatment Technology Complexity	3	5	15	0	0	3	9	4	12	4	12	0	0	4	12
	Potential Impacts to Outside Facility Operations	3	0	0	5	15	2	6	4	12	2	6	3	9	0	0
	Unproven Technology	4	2	8	0	0	2	8	3	12	3	12	0	0	2	8
	Subtotal	10	7	23	5	15	7	23	11	36	9	30	3	9	6	20
25%	**Factored Subtotal**		**1.75**	**5.75**	**1.25**	**3.75**	**1.75**	**5.75**	**2.75**	**9**	**2.25**	**7.5**	**0.75**	**2.25**	**1.5**	**5**
	Economical															
	Outside Dependency	3	0	0	5	15	5	15	5	15	4	12	5	15	0	0
	Hauling/Disposal Costs (no sewer connection)	4	0	0	5	20	3	12	4	16	4	16	5	20	0	0
	Residuals Disposal Complexity/Costs	4	3	12	0	0	4	16	3	12	3	12	0	0	5	20
	CapEx	4	5	20	0	0	3	12	4	16	4	16	0	0	4	16
	OpEx (including disposal of residuals)	4	4	16	4	16	2	8	3	12	3	12	5	20	5	20
	On-site Footprint	2	4	8	0	0	0	0	0	0	4	8	0	0	3	6
	Subtotal	21	16	56	14	51	17	63	19	71	22	76	15	55	17	62
25%	**Factored Subtotal**		**4**	**14**	**3.5**	**12.75**	**4.25**	**15.75**	**4.75**	**17.75**	**5.5**	**19**	**3.75**	**13.75**	**4.25**	**15.5**
	Total	55	43	152	47	176	42	156	49	182	47	169	39	150	37	139
	Factored Total		**15.75**	**56.25**	**18.75**	**71.50**	**15.00**	**56.50**	**17.00**	**64.25**	**15.75**	**58.00**	**15.00**	**59.00**	**12.75**	**49.00**
	Weighting and Rating: 0-5 (Least to Most)															

🟨	1st
🟧	2nd
🟥	3rd
🟥	4th

Brown AND Caldwell

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5/31/2019

Attachment C: Disposal Options Attributes

Attachment C. Disposal Options Attributes

	DSW	Disposal to POTW				Haul to Private Facility	Zero Liquid Discharge
Attribute	Onsite Treatment	No Pretreatment (Current Practice)	Upgrade POTW	Pretreat at POTW	Pretreat at Landfill	No Pretreatment	No Pretreatment
Benefits	• Control of own destiny regarding leachate disposal • Removes virtually all contaminants • Elimination of hauling and associated costs and risks • Control of fate of PFAS • Perhaps the highest environmental benefit	• No additional CapEx • No additional OpEx • No change to current practices	• Environmental benefit to the community • PFAS destroyed with GAC regeneration • Presumably achieve a long-term agreement with favorable rate structure • Positive public perception • Operations by others • No onsite footprint	• Operations by others • No onsite footprint • Presumably achieve a long-term agreement • No impact to site air space	• Overall best combined ranking (with or without category weighting) • Control of fate of PFAS	• Reduction or elimination of leachate treatment by NEWSVT • No additional CapEx	• Eliminates liquid disposal • Control of own destiny regarding leachate disposal • Elimination of hauling and associated costs and risks • Control of fate of PFAS • Overall best combined ranking (with or without category weighting)
Limitations	• Increased CapEx (fifth least economical benefit) • Lower discharge limits for regulated constituents • OpEx costs • Self-operation and regulatory compliance • Land requirement (onsite footprint) • Permitting challenges • Potential adverse public perception • Potential for air emissions and odors	• Reduced control of own destiny regarding leachate disposal • Does not address PFAS • Adverse public perception • Lowest overall environmental benefit/ranking	• High capital although potentially mitigated with grant funding • No longer in control of own destiny regarding leachate disposal • Treatment efficacy dependent on others • Highest residual volume for disposal • Complicated contract negotiations • Potential loss of asset depreciation	• Treatment efficacy dependent on others • Complicated contract negotiations • Potential loss of asset depreciation • Sized for partial treatment (allows more to environment) • Long-term commitment • Air emissions from concentrator (if sued for residuals)	• Requires handling and disposal of pretreated liquids • Residuals management may need volume reduction (e.g., evaporation, solidification or off-site incineration)	• Likely incur greater costs over the long term due to longer hauling distance • Potentially impacted by future PFAS pretreatment regulations • Second least environmental benefit/ranking • Reduced control of own destiny regarding leachate disposal	• Uncertainty on air emissions • Residuals management to prevent future impacts to leachate and gas production • Odor risk • Public perception • Concentrate impact on air space • Does not eliminate PFAS at site • Requires significant supplemental propane

Appendix D: GAC and IX Resin Isotherm Testing of POTW Effluents

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Technical Memorandum

Prepared for: Casella Waste Systems, Inc.

Project Title: NEWSVT Leachate Treatment Options Engineering Evaluation

Project No.: 152990

Technical Memorandum

Subject: Bench-Scale GAC and IX Batch Isotherm Treatability Testing – PFAS Removal from POTW Effluent

Date: August 30, 2019

To: Ken Robbins

From: Brown and Caldwell

Copy to: Jeremy Labbe and Joe Gay – Casella
Alan Kirschner – Brown and Caldwell

Prepared by: Steven Shiokari

Reviewed by: Kevin D. Torrens

Kevin D. Torrens

Reviewed by: Stephen J. McGuire

STEPHEN JOHN McGUIRE
8-30-19
NO. 134331
ENVIRONMENTAL

Stephen J. McGuire, P.E.
VT PE# 018.0134331

Limitations:

This document was prepared solely for Casella Waste Systems, Inc. (Casella) in accordance with professional standards at the time the services were performed and in accordance with the contract between Casella and Brown and Caldwell dated December 17, 2018. This document is governed by the specific scope of work authorized by Casella; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Casella and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Introduction

This technical memorandum (TM) presents a summary of the test procedures and results of bench-scale granular activated carbon (GAC) and ion exchange (IX) resin isotherm batch treatability testing to evaluate GAC and IX performance with respect to per- and polyfluoroalkyl substances (PFAS) removal from municipal wastewater effluent. Treatment of effluents (prior to disinfection) from the Montpelier, Vermont and/or Newport, Vermont publicly-owned treatment works (POTWs) is of consideration for reduction of PFAS concentrations associated with leachate and other sources of PFAS to the POTWs. The testing results provides further refinement of initial cost projections for off-site treatment options (e.g., effluent polishing for PFAS removal at the Montpelier and/or Newport POTW.

The State of Vermont has established health advisory (HA) levels for five PFASs: PFOA, PFOS, PFNA, PFHxS, and PFHpA. Each individual compound, as well has the sum of the five compounds ($PFAS_5$) has a HA level of 20 nanograms per liter (ng/L).

Proven treatment technologies for PFAS removal in water matrices are adsorption by GAC or IX media, alone or in combination. The treatment performance of both GAC and IX adsorbates is highly dependent on the specific target compounds and adsorptive competitors in the water matrix. Batch isotherm tests for the removal of PFAS in Montpelier and Newport effluents were conducted to evaluate the adsorptive capacity of GAC and IX media for PFAS removal.

Test Procedures

Secondary effluent samples (prior to disinfection), from Montpelier and Newport POTWs were collected and shipped by the respective POTWs via overnight courier to Brown and Caldwell's (BC) Treatability Lab in Nashville, Tennessee. Raw samples were analyzed for bulk water quality parameters (Table 1) and stored in a cold room at 4 °C until testing commenced.

Table 1. Raw Water Quality

Sample Source	TOC	DOC	UV_{254}	SUVA	TSS	pH
	mg/L	mg/L	cm^{-1}	M-L/mg	mg/L	S.U.
Newport	15.4	13.8	0.248	1.8	5.7	8.4
Montpelier	8.2	7.9	0.124	1.6	0.7	8.0

Batch isotherm tests were conducted on May 27 through June 7, 2019. Isotherm tests were conducted with Calgon F300 GAC which is a bituminous based activated carbon and anion exchange resin Purolite PFA694E IX media. Sequential (GAC treatment followed by IX) batch isotherm testing of GAC and IX was also conducted on the Newport sample to evaluate the impact of GAC pretreatment on IX adsorption. Batch isotherm test parameters (e.g., media dose and contact time) were selected based on literature and are presented in Table 2. UV_{254} and dissolved organic carbon (DOC) were analyzed to identify potential surrogate parameters for PFAS removal.

Table 2. Isotherm Testing Design Parameters

Test No.	Sample Source	Media Type	Adsorbate Dose (mg/L)	Contact time to Equilibrium Days
1	Newport	GAC	5, 25, 50, 100	7
2	Newport	IX	5, 10, 20, 40	2
3	Newport	(GAC) + IX	(25)[a] 5, 10, 20, 40	(7) 2
4	Montpelier	GAC	5, 25, 50, 100	7
5	Montpelier	IX	5, 10, 20, 40	2

[a] *Test no. 3 was pretreated with 25 mg/L GAC prior to IX batch tests.*

Batch isotherm tests were conducted in 1-liter polypropylene bottles which are acceptable for PFAS sampling. The GAC media was crushed with a mortar & pestle and separated through a U.S. Standard No. 100 and 200 sieves. The GAC media retained on the No. 200 sieve was used to create a concentrated GAC slurry. Aliquots of the GAC slurry were used to accurately dose GAC for isotherm experiments. Dilution impacts from the slurry addition are insignificant (<0.5percent) and do not measurably affect the initial PFAS concentration. IX resin was carefully weighed on an analytical balance to apply the specified mass for IX isotherm experiments. After GAC and IX media were dosed, sample bottles were placed onto a shaker table for GAC and IX equilibrium contact time durations of 7 and 2 days, respectively. Once study samples reached equilibrium, samples were filtered using a 0.45 micron (μm) nominal pore size filter and analyzed for PFAS, UV_{254}, and DOC. PFAS analysis was conducted by Pace Analytical Services, LLC using EPA Method 537m.

Results

Both the Newport and Montpelier secondary effluent samples detected 12 of 21 analyzed PFAS compounds prior to treatment with GAC or IX. The results for the five PFAS compounds with HA values in Vermont ($PFAS_5$) in the raw Newport and Montpelier samples are summarized in Table 3. Both samples exceed the HA levels for the sum $PFAS_5$ with PFOA representing the highest concentrations of the five regulated compounds. Of note is that PFOA is less efficiently removed by GAC as compared to PFOS (in part due to its lower molecular weight).

Table 3. Sample Water $PFAS_5$ Concentrations

Source Water	PFHpA (7 Carbons) ng/L	PFHxS (7 Carbons) ng/L	PFOA (8 Carbons) ng/L	PFNA (9 Carbons) ng/L	PFOS (8 Carbons) ng/L	Sum $PFAS_5$ ng/L
Newport	11.7	3.2	28.8	3.4	3.7	50.7
Montpelier	7.1	2.5	20.0	2.4	3.8	35.8

Note. Analysis results are an average of three (n = 3) filtered raw water samples.

GAC was shown to provide more significant removal of $PFAS_5$ compared to IX (Figure 1). At GAC doses of 50 and 25 mg/L, respectively, for Newport and Montpelier, samples were treated to below HA levels. IX provided minimal removal of $PFAS_5$, which may be attributed to the presence of only long-chain PFAS compounds (>6 carbons) in the $PFAS_5$, or a high concentration of IX adsorption competitors present in both water matrices. For both Newport and Montpelier waters, PFOA had the highest concentrations and would drive treatment objectives.

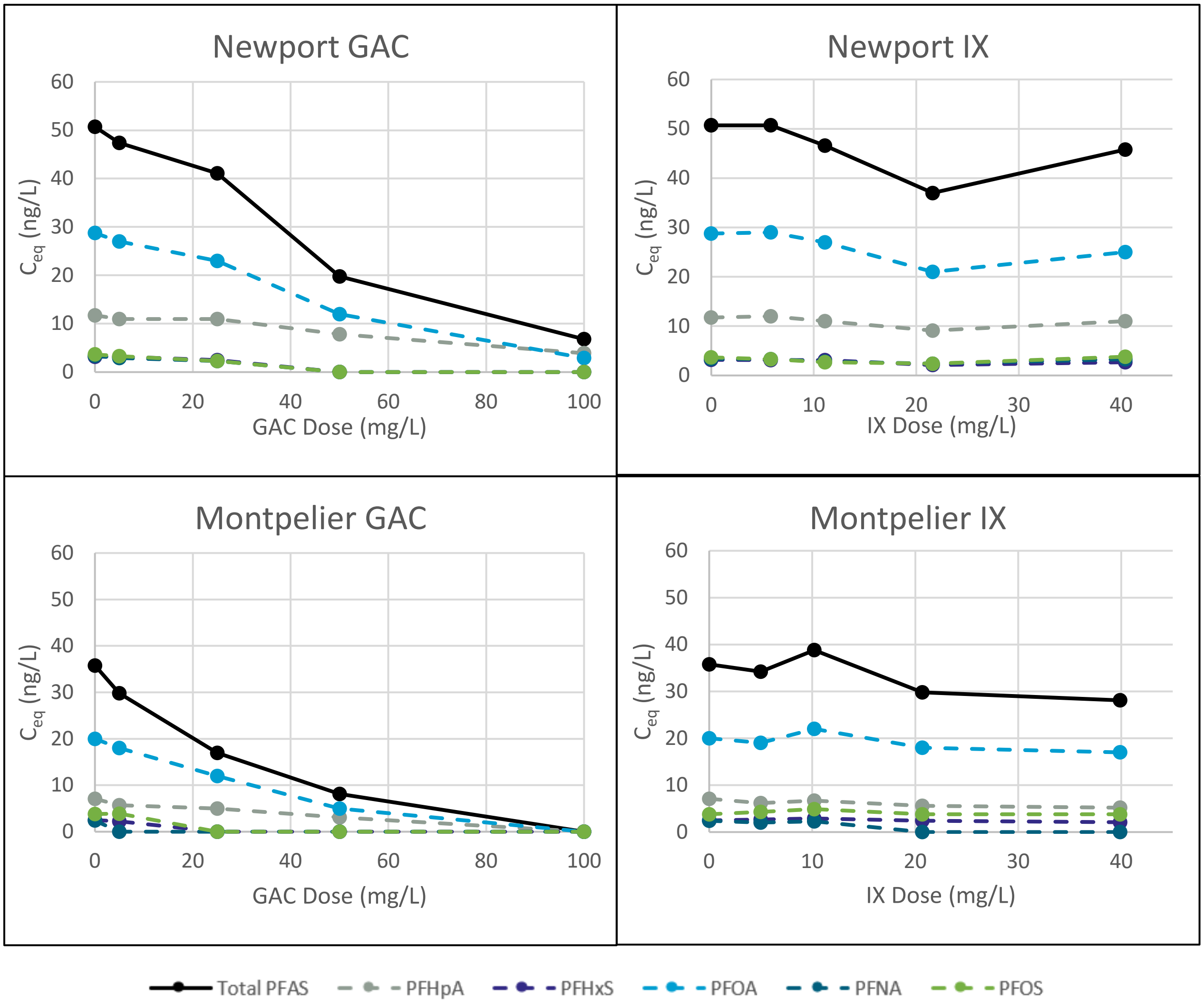
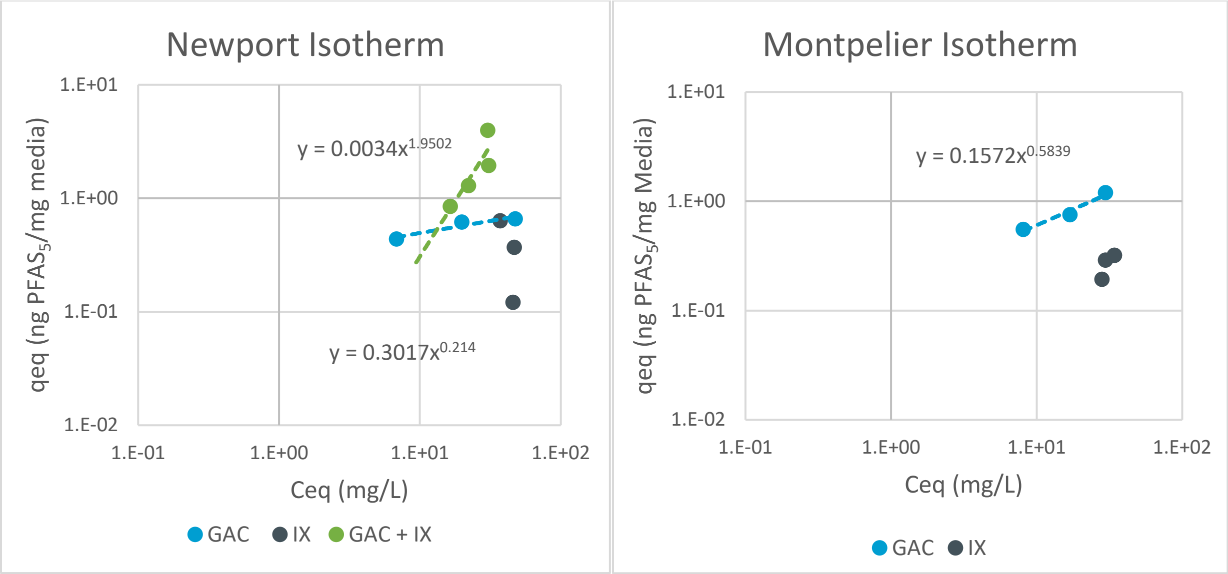


Figure 1. GAC and IX Isotherms

To estimate the capacity of GAC to remove the PFAS compounds, solid-phase concentrations (q_{eq}) for each batch test were calculated using a mass balance and fit to a Freundlich isotherm model. Solid-phase concentrations provide the mass of compound(s) removed per mass of adsorbate media at equilibrium. At a total $PFAS_5$ treatment target of 10 ng/L (1/2 the HA), the GAC solid phase adsorption capacity for Newport and Montpelier are estimated to be 0.49 and 0.60 ng $PFAS_5$/mg GAC, respectively (Figure 2).



Note. IX isotherm tests results were not able to fit the Freundlich Isotherm model. GAC + IX isotherm was extrapolated to our treatment target and should be interpreted with care.

Figure 2. Freundlich Isotherm Models

Based on Newport and Montpelier average daily flows and assuming consistent raw water PFAS concentrations as measured in this study, carbon usage rates (CUR) and IX resin usage rate (RUR) based on equilibrium concentrations can be calculated (Table 4).

Table 4. GAC and IX Resin Isotherm Projected Usage Rates

	Flow[a]	Sum of $PFAS_5$	q_{eq}	K_f	1/n	R^2	CUR		IX RUR	
Source Water	MGD	ng/L	ng / mg	$(ng\ mg^{-1})/(ng\ L^{-1})$	-	-	lb GAC/Day	lb/gallon	lb resin/day	lb resin/gallon
Newport (GAC)	0.6	50.7	0.49	0.3017	0.214	0.90	412.6	0.00069	n/a	n/a
Newport (GAC + IX)				0.30	2.0	0.78	125.2[b]	--	672.1	0.0011
Montpelier (GAC)	2.0	35.8	0.60	0.1572	0.5839	0.96	714.0	0.00036	n/a	n/a

[a] *Based-on flow data provided in 2018 and 2019 POTW WR-43 reports.*

[b] *CUR for pretreatment is an approximation based on the GAC dosage rate of 25 mg/L prior to IX batch tests.*

n/a = not applicable

Although these calculations provide a general estimate about media usage rate, they should not be used for full-scale design of GAC contactors.

DOC and UV_{254} concentrations were analyzed for each GAC isotherm sample. Plotting DOC vs $PFAS_5$ removals, a linear trend can be observed in Figure 3 (Newport DOC $R^2 = 0.93$, Newport UV $R^2 = 0.96$, Montpelier DOC $R^2 = 0.98$, Montpelier UV $R^2 = 0.99$). This suggest DOC or UV_{254} may be potential surrogate parameters for tracking GAC $PFAS_5$ removals and GAC replacement. However, these trends were only established for equilibrium concentrations and may not hold for non-steady state conditions.

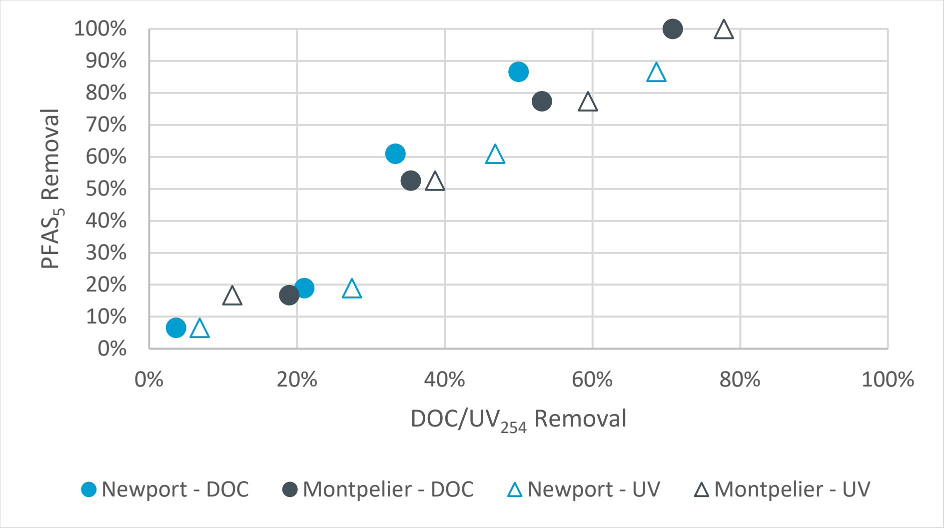


Figure 3. GAC removal of DOC and PFAS$_5$

GAC pretreatment had a significant positive impact on IX adsorption of PFAS. The results illustrated in Figure 4 show pretreatment with 25 mg/L GAC improved IX removal of PFAS by an average of 40 percent although a target PFAS$_5$ concentration of 10 ng/L was not achieved. These results suggest the GAC pretreatment is providing significant IX adsorption competitor control. Although GAC alone still provided greater equilibrium adsorptive capacity at the treatment target of 10 ng/L PFAS$_5$, a dual media contactor may be of interest when GAC and IX adsorption kinetics are considered. Further testing through column studies would be needed to assess potential benefits of an integrated GAC and IX system.

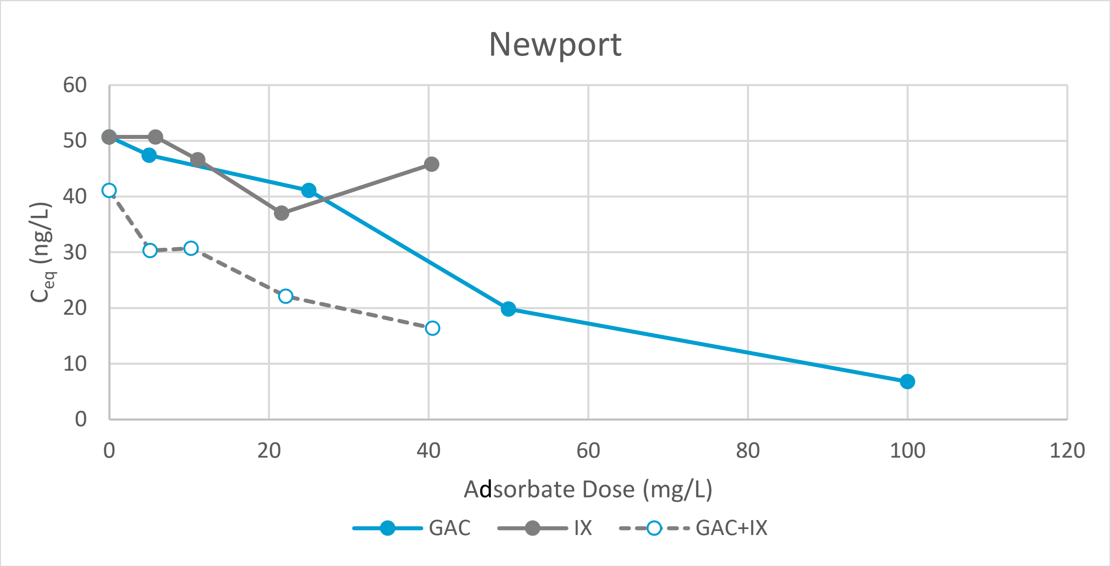


Figure 4. GAC Impact on IX Adsorption

As noted in Table 4, the estimated CUR for Newport and Montpelier is 413 lbs GAC per day (160,000 lbs GAC per year or an annual usage cost of approximately $320,000 per year) and 714 lbs of GAC per day (300,000 lbs GAC per year or an annual usage cost of approximately $600,000 per year), respectively, based on a bulk delivered carbon cost of $2.00/lb and the PFAS$_5$ concentrations measured in the treatability study. The annual CUR and IX RUR for Newport is rounded up to the nearest factor of 40,000 to account for simultaneous media changeout of both lead vessels (based on two trains of lead/lag vessels, 20,000 lbs each). Similarly, the annual CUR for Montpelier is rounded up to the nearest factor of 60,000 to account for simultaneous media changeout of all three lead vessels (based on three trains of lead/lag vessels, 20,000 lbs each). The resulting annual GAC usage costs based on the GAC isotherm tests are different than the for Newport and Montpelier, respectively, provided in the "Wastewater in the "Leachate Treatment and Disposal Alternatives Evaluation for NEWSVT" prepared by BC dated May 31, 2019.

The "Wastewater Treatment Facility and Landfill Leachate PFAS Sampling" report prepared by Weston & Sampson (W&S) dated May 3, 2018 provided PFAS_5 concentrations of 130.2 ng/L and 76.1 ng/L for Newport and Montpelier effluent, respectively, using the MLA 110 test method. The samples were collected on January 9 and 10, 2018. For comparison purposes, the resulting projected annual GAC usage cost based on these initial concentrations and a treatment target of 10 ng/L for Newport and Montpelier is approximately \$960,000 per year and \$1,440,000 per year, respectively. Note that this estimate is based on the Freundlich isotherm model constants (K_f and 1/n) developed based on the POTW effluent samples collected for the GAC isotherm tests. Projected GAC and IX resin usage and costs for each PFAS_5 concentrations based on the results from samples collected for the GAC isotherm treatability tests and W&S's report are summarized in Table 5.

Table 5. Projected GAC and IX Resin Usage Costs

Sum of PFAS_5 Concentrations Data Source		Sum of PFAS_5	GAC Usage[b] (System)	IX Resin Usage (System)	Total GAC and IX Resin (System)		O&M Cost (NEWSVT Flow)[e]
	Source Water (Test)	ng/L	\$/yr[c]	\$/yr[d]	\$/yr	\$/gallon	\$/gallon
GAC Isotherms Treatability Test	Newport (GAC)	50.7	320,000	n/a	320,000	0.00073	0.009
	Newport (GAC + IX)		160,000	1,710,000	1,950,000	0.0082	0.098
	Montpelier (GAC)	35.8	600,000	n/a	600,000	0.00038	0.015
W&S Report	Newport (GAC)	130.2	960,000	n/a	960,000	0.0022	0.026
	Montpelier (GAC)	76.1	1,440,000	n/a	1,440,000	0.0010	0.039

[a] *Based-on flow data provided in 2018 and 2019 POTW WR-43 reports; 0.6 MDG Newport and 2.0 MGD Montpelier.*

[b] *Newport (GAC) based on two trains of lead/lag vessels (20,000 lbs ea.); Montpelier (GAC) based on three trains of lead/lag vessels (20,000 lbs ea.)*

[c] *Based on bulk delivered GAC cost of \$2.00/lb.*

[d] *Based on a bulk delivered IX resin cost of \$6.11/lb (\$400/cubic foot, S.G. = 1.05), incl. replacement and incineration.*

[e] *Based on NEWSVT raw leachate flow of 50,000 gallons per day.*

An integrated system combining GAC and IX may offer reduced operational costs although initial capital costs could be higher. However, as noted previously, IX was less effective than GAC in removing the PFAS_5 compounds and thus may not be suitable for this application.

Next Steps

The next steps for Casella's consideration are conducting rapid small-scale column testing or pilot testing to further evaluate and confirm GAC and IX resin usage rates through more comprehensive testing that will also provide information required for design (e.g. system sizing and configuration based on contaminant breakthrough characteristics). This testing would utilize multiple samples of POTW effluent such that effluent variability is considered and contaminant breakthrough curves can be developed. The duration of this testing would be approximately 3 to 4 months.

Appendix E: Capacity Evaluation for Leachate Treatment of Montpelier POTW Technical Memorandum

Brown AND Caldwell

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Technical Memorandum

Prepared for: Casella Waste Systems, Inc.

Project Title: New England Waste Services of Vermont (NEWSVT) Landfill-Leachate Evaluation

Project No.: 152990.009

Technical Memorandum

Subject: Capacity Evaluation of the Montpelier Wastewater Resource Recovery Facility

Date: September 5, 2019

To: Ken Robbins, Casella Waste

From: Brown and Caldwell

Prepared by: Everett Gill

Everett Gill

Reviewed by: Kevin D. Torrens

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Reviewed by: Stephen J. McGuire

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Stephen J. McGuire, PE
VT PE# 018.0134331

PE's Clarification: Cost estimates provided in Section 3.1 are provided for Casella's use but are not engineering instruments of service and are therefore excluded from my responsible charge.

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Section 1: Background

Brown and Caldwell (BC) is assisting Casella Waste Systems, Inc. (Casella) with an evaluation of leachate disposal alternatives and treatment technologies at the New England Waste Services of Vermont (NEWSVT) Landfill in Coventry, Vermont. As part of that evaluation, the City of Montpelier wastewater resource recovery facility (WRRF) was evaluated in order to determine the ability of this WRRF to receive additional leachate from NEWSVT.

Table 1-1 provides a summary of the leachate characteristics from NEWSVT.

Table 1-1. NEWSVT Leachate Characteristics

Parameter	Current	Projected
Flow, gpm	50,000	100,000
BOD_5, lbs/day	340	621
COD, lbs/day	984	2,295
Total Kjeldahl Nitrogen, lbs/day	367	846

Section 2: Montpelier WRRF

The potential capacity and limiting factors for the Montpelier WRRF (herein referred to as WRRF) to accept additional leachate was evaluated.

2.1 Treatment Facility Summary

The WRRF consists of screening, grit removal, primary clarification, activated sludge treatment, Ultraviolet (UV) disinfection, and solids handling. Leachate treatment is provided by the activated sludge process which is comprised of the following major equipment:

- Four 39 ft x 39 ft x 18 ft aeration tanks
  - 240 Sanitaire Silver Series II LP Diffusers per tank (960 diffusers total)
  - Main blower = 75 horsepower (HP)
  - Backup blower = 40 HP
  - Maximum air flow = 1265 standard cubic feet per minute (SCFM)
- Two 76-foot diameter peripheral feed secondary clarifiers

2.2 Influent Loading and Operational Data

The WRRF provided influent flows and loading, as well as operational data for January 1, 2018 to February 28, 2019. Winter operating data were selected since winter conditions control activated sludge treatment capacity for most parameters. The 7-day average low temperature in the activated sludge treatment process was 8.1°C. A statistical analysis was performed to evaluate influent flows and loadings. A probability plot was prepared that displays the biochemical oxygen demand (BOD) loading values on a log scale on the Y-axis versus the standard deviation of the mean on the X-axis. The value of 0 standard deviations from the mean is the median of the data set, i.e., 50 percent of the values are less than or equal to this value. A line was fit to the data with the assumption that the data followed a lognormal distribution, as is typically the case for environmental data.

As shown in Figure 2-1, there was a good fit to the data, indicating that the data were in fact lognormally distributed. The equation for the best fit line was used to calculate the 50th and 95th percentile values for the historical data. The value that represents the 50th percentile was chosen as the average value in the design basis. The value that represents the 95th percentile was chosen as the representative daily maximum value.

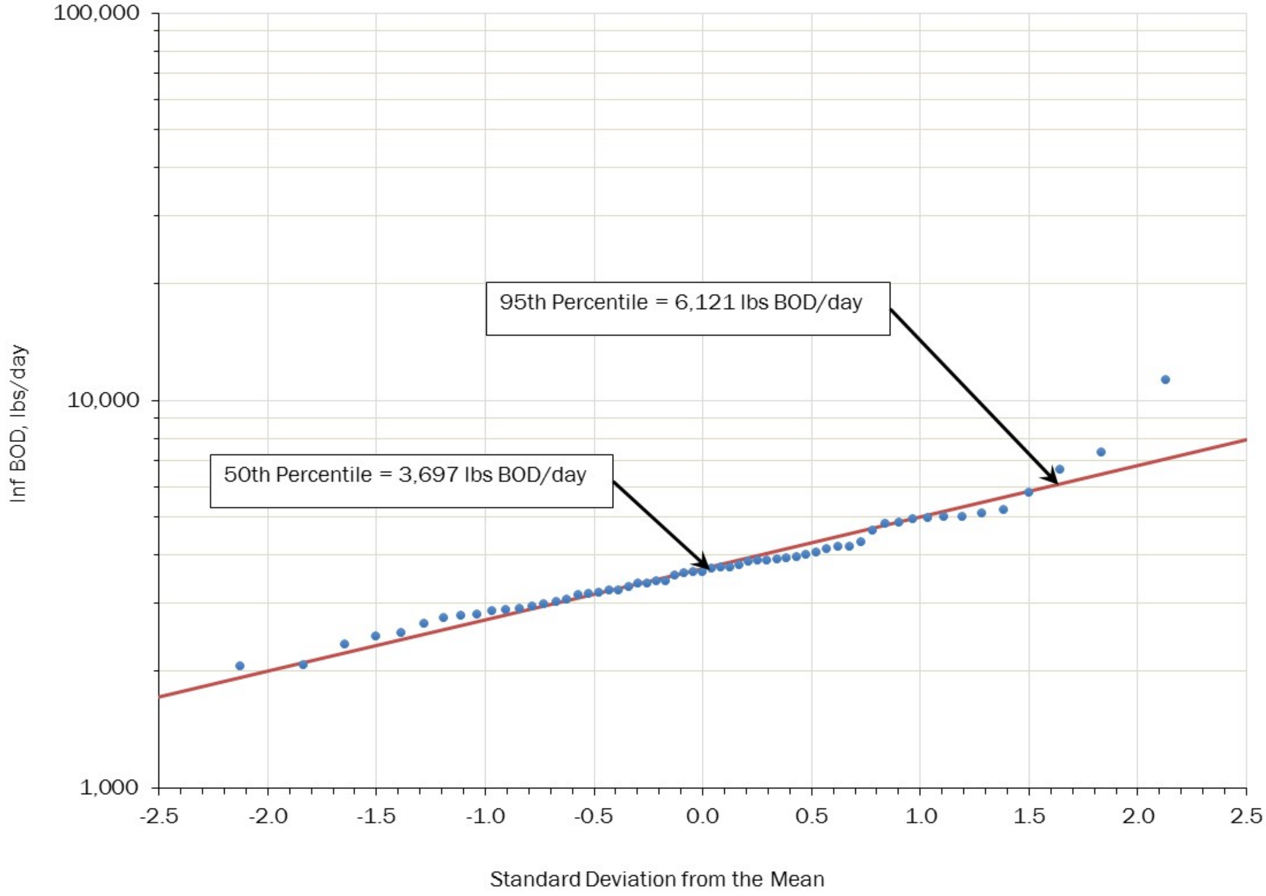

Figure 2-1. Influent BOD Loading at WRRF

The same statistical analysis was performed on influent and effluent BOD, total suspended solids (TSS), basin mixed liquor suspended solids (MLSS), sludge wasting, leachate flow, and leachate BOD. Note that these data reflect the contribution of leachate disposed at WRRF which includes Casella, as well as the Moretown landfill. Table 2-1 provides the results of that analysis.

Table 2-1. WWRF Influent and Effluent Flows and Loading

Parameter	50th Percentile	95th Percentile
WRRF Influent		
Flow, MGD	1.90	3.18
BOD, lbs/day	3,697	6,121
TSS, lbs/day	2,276	3,156
WRRF Effluent		
BOD, lbs/day	98.5	326
TSS, lbs/day	67.8	138
WRRF Operation		
MLSS, mg/L	2,276	3,156
Waste Sludge, lbs/day	3,333	8,151
Influent Leachate to WRRF		
Flow, gal/day	20,971	60,852
BOD, lbs/day	367	3,241

The WRRF receives leachate from two facilities, Casella and Moretown Landfills. The Moretown facility is a closed landfill. The current 50th percentile total leachate flow consists of 20,971 gallons per day from the two sources. The Moretown landfill leachate discharged to Montpelier totaled 1,836,000 gallons over the 12-month period of July 2018 to June 2019. Therefore, the average leachate flow from Moretown was 5,030 gallons per day (gpd), indicating an average of 15,941 gpd from Casella, or 0.8 percent of the 50th percentile daily flow. Table 2-2 provides the flow fraction to WRRF from Casella at current flows, 50,000 gpd, and 100,000 gpd assuming no increase in flow from other contributors to the WRRF.

Table 2-2. Flows to WRRF and Casella Fraction

Parameter	Casella Fraction of Total Flow Average WRRF Flow	Casella Fraction of Total Flow Peak WRRF Flow
	(%)	(%)
Current Casella Flow of 15,941 gpd	0.8%	0.5%
Casella Flow of 50,000 gpd	2.6%	1.6%
Casella Flow of 100,000 gpd	5.0%	3.1%

2.3 Oxygen Transfer

The WRRF has four aeration basins. Currently there are three blowers at the facility, the main blower is 75 HP. A second 40 HP blower will turn on automatically if the dissolved oxygen decreases below a preset condition. A third 40 HP is used as a backup. The current reported maximum airflow is 1,265 SCFM, which was assumed to be with the 75 HP blower. The diffusers are Sanitaire Silver Series II LP Diffusers. Oxygen transfer calculations were performed in order to evaluate oxygen transfer capacity. The following assumptions were made in this evaluation:

- Maximum airflow with 75 hp blower operation = 316.3 SCFM/basin (1,265 SCFM total)
- Number of air diffusers = 240/basin (960 total)
- SCFM/diffuser = 1.32

- Alpha = 0.50
- Beta = 0.95
- Residual DO = 1.5 mg/L
- Oxygen Transfer = 834 lbs O2/day/basin (3,337 lbs/day total)

With the additional 40 HP blower, the oxygen transfer will increase to 1,337 lbs O2/day/basin (5,348 lbs O2/day total). The operable air flow per air diffuser is 0.5 to 4.5 SCFM, indicating the diffusers can handle additional air flow. If the current diffuser system is operated at the maximum allowable air flow per diffuser (4,320 SCFM total), the oxygen transfer could be as high as 2,850 lbs/day per basin (11,400 lbs/day total). This will require approximately 230 HP total of blower horsepower as compared to the current average operating blower of 75 HP.

2.4 Plant Capacity

Eckenfelder activated sludge modeling was used to evaluate plant capacity. The 50th percentile influent loading listed in Table 2-1 was used to calibrate the model.

2.4.1 Sludge Age

The 50th percentile MLSS concentration was 2,276 mg/L. With 0.819 MG total aeration volume, the total biomass in the system is 15,550 lbs MLSS. With a waste sludge of 3,360 lbs/day and an effluent TSS of 68 lbs/day, the average sludge age is 4.6 days.

2.4.2 Eckenfelder Parameters

Table 2-3 demonstrates the activated sludge kinetic and stochiometric parameters used in the process calculations. These values were selected based on calibration with operational data, published values, BC's experience, and engineering judgment. Since the facility does not completely nitrify nor is required to nitrify at all, nitrification parameters were not evaluated. If nitrification was required in the future to comply with ammonia or total nitrogen discharge limits, the noted plant capacity would be significantly reduced.

Table 2-3. Activated Sludge Kinetic and Stochiometric Parameters

Parameter	Description	Unit	Value
a_H	Sludge yield from heterotrophic cell synthesis	mg $VSS_{Heterotrophs}$/mg $COD_{Removed}$	0.46
a'_H	Oxygen required for substrate oxidation	mg O_2/mg $COD_{Removed}$	0.36
T	Mixed liquor temperature	°C	14.1
$b_{H,20}$	Endogenous heterotrophic decay coefficient at 20°C	day^{-1}	0.10
Θ_b	Temperature correction coefficient for b_H and b_N	unit less	1.04
$K_{COD,20}$	Aerobic COD biodegradation rate at 20°C	mg/day COD per mg $VSS_{Heterotrophs}$	15.0
Θ_{KH}	Temperature correction coefficient for K_{COD}	unit less	1.065
$f_{VSS\ Deg}$	Fraction of influent VSS that is degradable	unit less	0.97
$K_{P,20}$	Influent solids biodegradation rate at 20°C	day^{-1}	0.10

2.4.3 Leachate Treatment Availability

Table 2-4 provides the current average and peak oxygen demand at Montpelier assuming complete nitrification occurred while accepting the average 15,941 gpd from Casella. Also provided is the available oxygen delivery with the existing 75 HP blower and the additional 40 HP blower.

Table 2-4. Oxygen Demand at WRRF

Parameter	Average	Peak
Total Oxygen Demand, lbs O_2/day	5,210	9,670
Total Oxygen Delivery (average with 75 HP Blower, peak with additional 40 HP)	3,340	5,350

The current 15,941 gpd leachate from Casella is providing the following process oxygen demand:

- 108 lb BOD/day (based on the current disposal volume of 15,941 gpd) of the average 3,697 lbs BOD/day (2.9 percent). Estimated oxygen demand from Casella BOD is 91 lbs/day
- 117 lb total kjeldahl nitrogen (TKN)/day (based on the current disposal volume of 15,941 gpd) of the average 768 lbs TKN/day (15.2 percent). Estimated oxygen demand from Casella TKN is 318 lbs/day

The total oxygen demand exerted by the Casella wastewater under varying loadings is estimated in Table 2-5.

Table 2-5. Oxygen Demand with Increased Casella Loading

Parameter	Average Oxygen Demand	Casella Fraction of Total Demand	Peak Oxygen Demand	Casella Fraction of Total Demand
	(lbs O_2/day)	(%)	(lbs O_2/day)	(%)
WRRF Oxygen Demand at Current Casella flow of 15,941 gpd	5,210	7.9%	9,670	4.2%
WRRF Oxygen Demand with Casella flow of 50,000 gpd	6,080	21.1%	10,540	12.2%
WRRF Oxygen Demand with Casella flow of 100,000 gpd	7,620	37.0%	12,080	23.4%

A blower upgrade to maximize oxygen transfer to 11,400 lbs O_2/day is sufficient to provide the oxygen demand for the current peak WRRF loading (9,670 lbs O_2/day which includes 409 lbs O_2/day from Casella). With the blower upgrade, peak loading with 50,000 gpd of Casella wastewater would have an oxygen demand of 10,540 lbs O_2/day, less than the available transfer of 11,400 lbs O_2/day. With this blower upgrade, up to 76,000 gpd of Casella wastewater can be discharged even while processing the peak day loading from other sources. This same blower upgrade at WWRF would allow up to 100,000 gpd from Casella during average WRRF loading from other sources. An upgrade to the diffused aeration system in all four basins and 245 HP of aeration will be required to discharge 100,000 gpd from Casella during peak WRRF loading.

2.5 Secondary Clarification

The facility has two 76-foot secondary clarifiers. The 50th and 95th percentile sludge volume indices (SVIs) values are 131 and 260 mL/g, respectively. Solids separation via two conventional secondary clarifiers was evaluated. The empirical model developed for predicting settling as a function of SVI and MLSS was determined by Wahlberg[1]. Settling characteristics developed for a one-liter unstirred graduated cylinder was used for this evaluation. The average and peak return activated sludge (RAS) flow was recorded as 0.92 and 1.0 MGD, respectively. A RAS flow of 0.92 MGD was used for this evaluation.

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[1] Wahlberg, E.J., and Keinath, T.M., Development of Settling Flux Curves Using SVI: An Addendum, Water Environment Federation.

Each of the 76-foot clarifiers will have a surface area of 4,563 ft². The effective clarifier surface area (e.g., available are for clarification through discounting area for launders, etc.) was calculated by downgrading the surface area by 16.8 percent to 3,775 ft² using Figure 2-2[2].

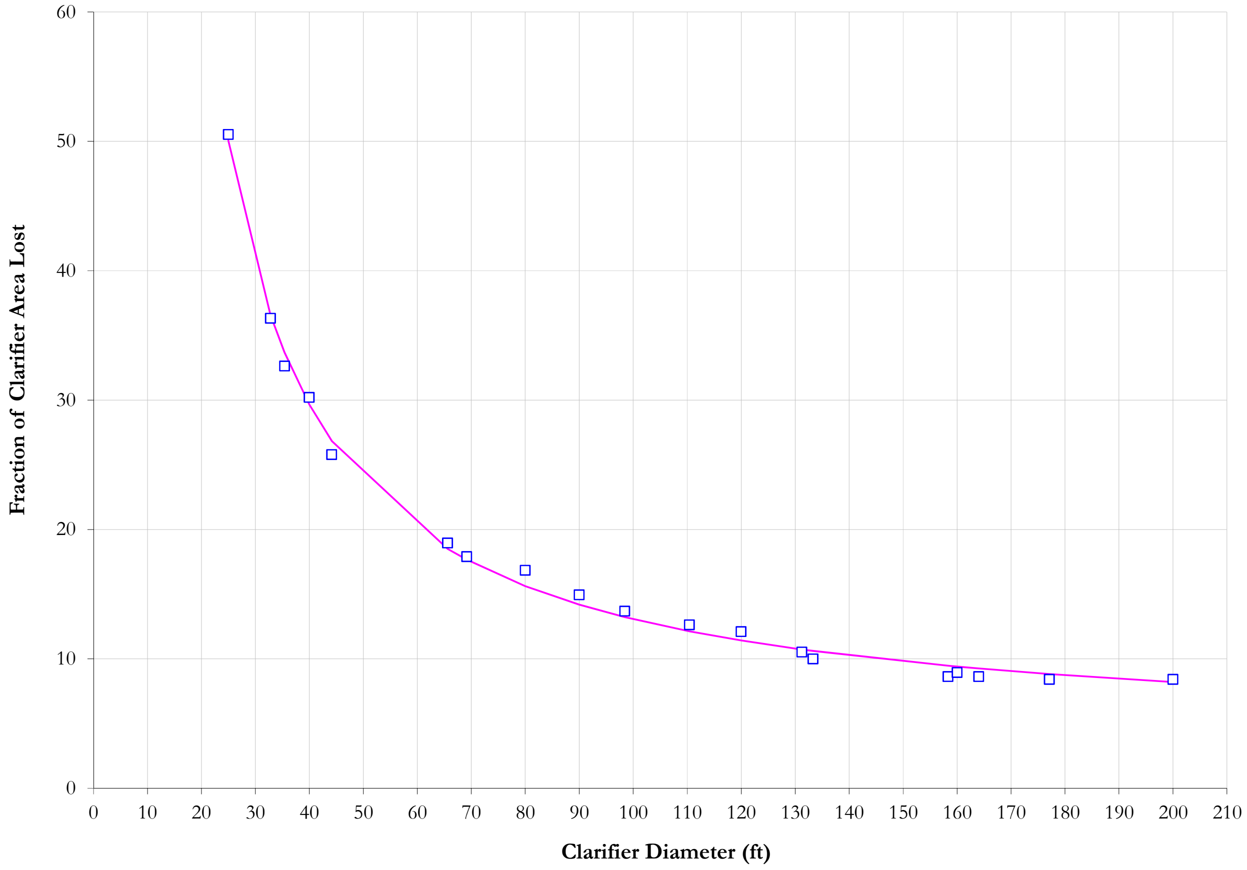

Figure 2-2. Effect of Clarifier Diameter on the Fraction of Surface Area Lost

Figure 2-3 presents a state point analysis generated for the following average conditions.

- Effluent Flow = 1.9 MGD (50th percentile)
- RAS flow = 0.92 MGD (50th percentile)
- Number of clarifiers in service = 2
- SVI = 131 mL/g (50th percentile)
- Clarifier diameter = 76 ft
- Total surface area per clarifier = 4,563 ft²
- Fraction of clarifier that is effective = 83.2 percent
- Effective surface area per clarifier = 3,775 ft²
- 2,276 mg/L MLSS concentration (50th percentile)

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[2] *Clarifier Design, Manual of Practice*, Water Pollution Control Federation, 1985.

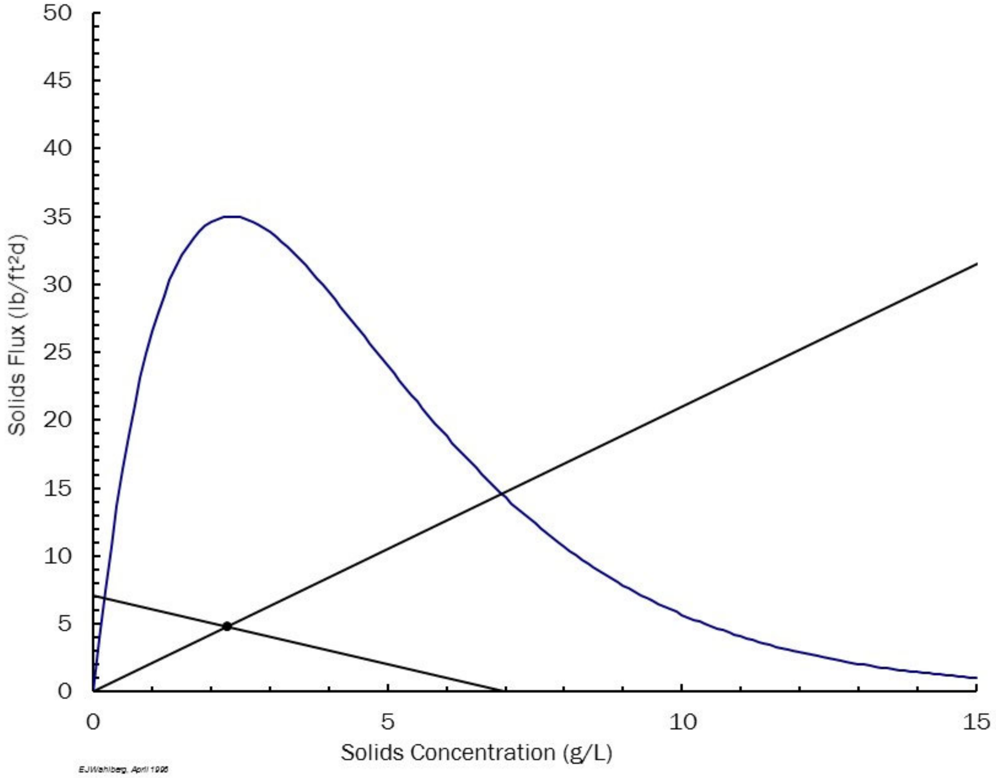

Figure 2-3. State Point Analysis for Two Clarifiers and Average Loading

This state point analysis indicates the clarifiers are capable of separating the solids at the average design flow, SVI, and MLSS concentration assuming the RAS can concentrate to 7,000 mg/L. During average conditions, the SVI can deteriorate to the peak value of 260 mL/g (95th percentile) and remain within the capacity of the clarifiers.

Figure 2-4 presents a state point analysis generated for the peak flow and MLSS concentrations but average SVI:

- Effluent Flow = 3.18 MGD (95th percentile)
- RAS flow = 0.92 MGD (50th percentile)
- Number of clarifiers in service = 2
- SVI = 131 mL/g
- Clarifier diameter = 64 ft
- Total surface area per clarifier = 3,219 ft^2
- Fraction of clarifier that is effective = 81 percent
- Effective surface area per clarifier = 2,590 ft^2
- 3,156 mg/L MLSS concentration (95th Percentile)

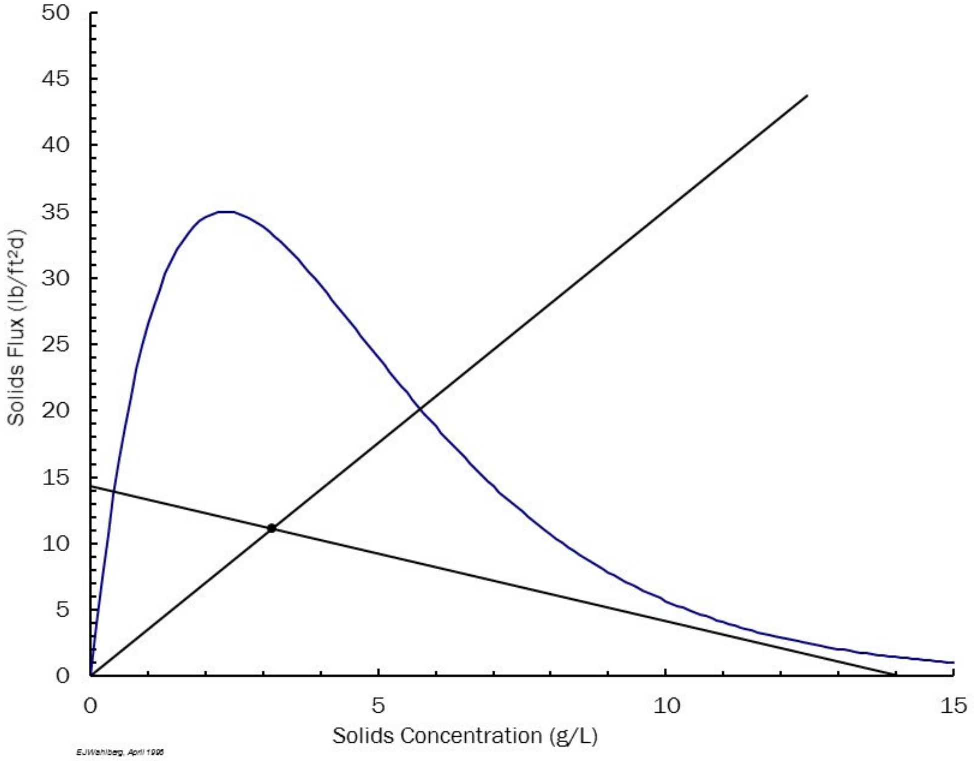

Figure 2-4. State Point Analysis for Two Clarifiers in Service, and Peak Flow, MLSS, and Average SVI

This state point analysis indicates the clarifiers are capable of separating the solids at the peak design flow and peak historical MLSS concentration assuming the RAS can concentrate to 14,000 mg/L. If the SVI deteriorates to 150 mL/g (the 69th percentile SVI), the system will overload the existing clarifiers while operating at peak loading.

At the peak flow, MLSS, and SVI, the system can continue to use the existing clarification system (without upgrades) if the sludge recycle is increased from 0.92 MGD to at least 2.0 MGD. Design documents indicate a RAS capacity of 3.17 MGD indicating sufficient RAS capacity is available. Figure 2-5 presents the state point for that condition.

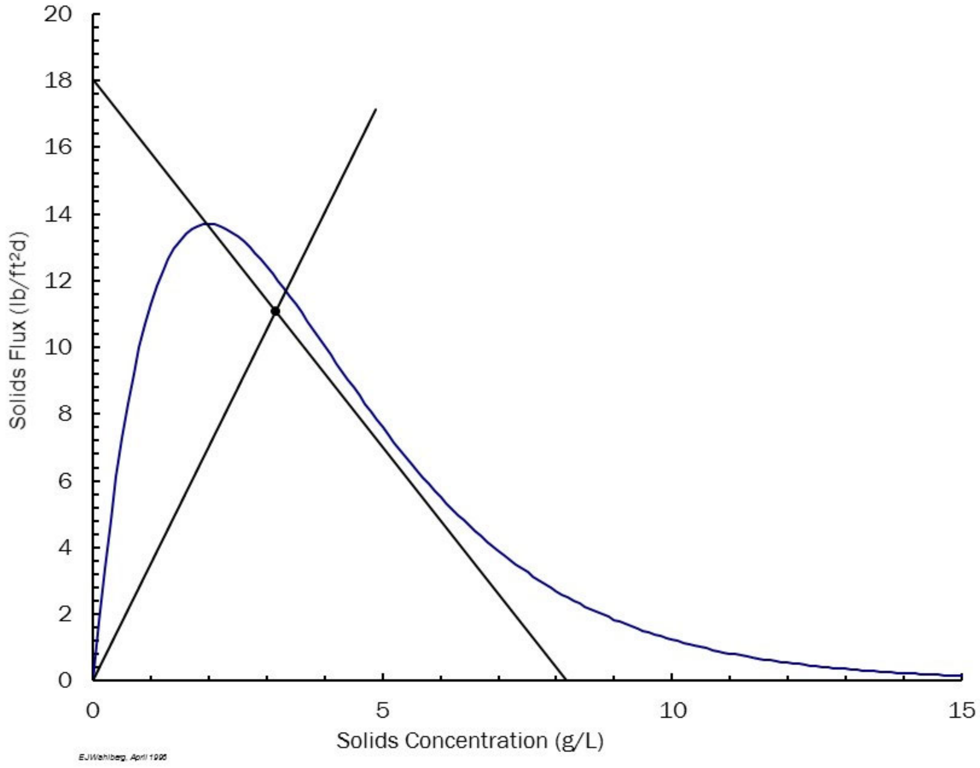

Figure 2-5. State Point Analysis for Two Clarifiers in Service, Peak Loading, Peak SVI, and Increased RAS

Figure 2-6 presents the state point analysis at the following peak conditions:

- Peak Effluent Flow = 3.27 MGD (Includes 100,000 gpd Casella flow)
- RAS flow = 2.0 MGD
- Number of clarifiers in service = 2
- Peak SVI = 260 mL/g
- Clarifier diameter = 64 ft
- Total surface area per clarifier = 3,219 ft^2
- Fraction of clarifier that is effective = 81 percent
- Effective surface area per clarifier = 2,590 ft^2
- Peak MLSS concentration = 3,156 mg/L

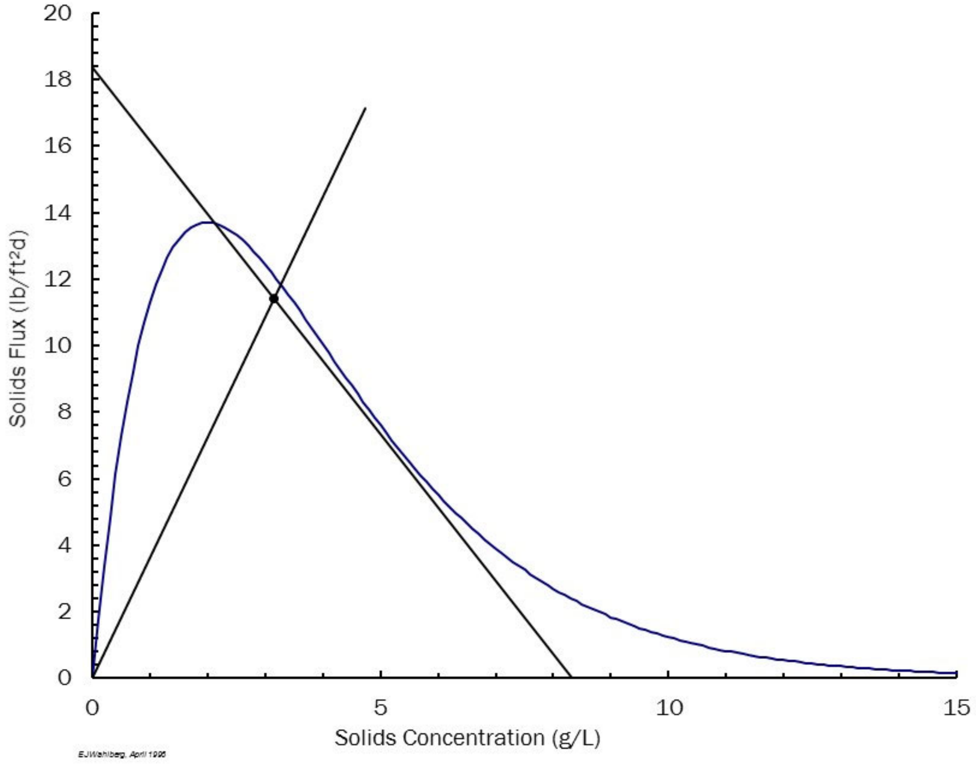

Figure 2-6. State Point Analysis for Two Clarifiers in Service, Peak Loading, Peak SVI, and Peak Casella

The state point model indicates the system can handle 100,000 gpd Casella wastewater while operating at peak flow and peak SVI, assuming a RAS rate of 2.0 MGD.

2.6 Solids Handling

The impact on solids handling would be minor and accommodated within the Organics to Energy project currently under construction at the WRRF.

2.7 Disinfection

Montpelier uses UV disinfection. UV disinfection effectiveness can be adversely impacted by leachate due to reduced UV transmittance associated primarily with humic and fulvic acids. Research has shown that the target UV transmittance required for effective disinfection of 65% can be impacted at leachate volumes of 1% to 5% of total wastewater flow. The percent by volume (based on existing average Montpelier flows) at 50,000 gpd of leachate is 2.6% volume/volume (v/v) and would be 5.2% v/v at 100,000 gpd of leachate. The future leachate volume of 100,000 gpd would likely be associated with increased base wastewater flow at Montpelier, thus decreasing the leachate contributory volume. The impact of leachate on UV disinfection is variable and dependent on leachate characteristics with higher organic strength leachates often having a greater impact on UV disinfection due to high humic and fulvic acid content. The actual impact on the disinfection process would require batch treatability testing to discern.

Section 3: Conclusions

BC evaluated the activated sludge treatment capacity at the Montpelier WRRF and evaluated increasing leachate discharge from Casella. Based on the evaluation;

- Treatment capacity is limited by oxygen transfer.
- Clarification capacity is adequate to accommodate current and future leachate volumes. Impacts on UV disinfection are expected to be minimal, if any, based on the volumetric contribution of leachate.
- The impact on solids handling would be minor and accommodated within the Organics to Energy project currently under construction at the WRRF.
- The impact on UV disinfection would require batch treatability testing to discern.

Table 3-1 demonstrates required upgrades for additional treatment capacity to accommodate additional leachate discharge assuming no increase in loading at the WRRF from other sources.

Table 3-1. Leachate Treatment Capacity at WRRF

Upgrade	Leachate Capacity at Average WRRF Loading	Leachate Capacity at Peak WRRF Loading	Description
	(gpd)	(gpd)	
Current Operation	19,580	0	No upgrades.
Blower Upgrade	50,000	28,850	Increase total blower capacity to 120 HP.
Blower Upgrade	>100,000	50,000	Increase total blower capacity to 210 HP.
Blower Upgrade	>100,000	76,000	Maximize current diffuser system. Increase total firm blower capacity to 230 HP.
Blower and Aeration Grid Upgrade	>100,000	100,000	Increase diffuser system. Increase total firm blower capacity to 245 HP.

3.1 Class 5 Opinion of Probable Costs

The opinion of probable costs to implement the upgrades noted in Table 3-1 are summarized in Table 3-2. The opinion of cost consists of a Class 5 estimate with an expected accuracy range of -50 percent to +100 percent around the opinion of probable cost and is based on experience from other facilities. A Class 5 estimate is performed when engineering is conceptual and is used to prepare planning level cost scopes or to evaluate alternatives in design conditions.

Table 3-2. Class 5 Opinion of Probable Cost

Upgrade	Leachate Treatment Capacity	Total Equipment Cost	Direct Cost Subtotal	Indirect Cost Subtotal[1]	Opinion of Probable Cost
	gpd	($)	($)	($)	($)
Current Operation	19,580	--	--	--	--
Blower Upgrade	50,000 gpd at Average WRRF Loading	95,000	230,000	375,000	605,000
Blower Upgrade	76.000 gpd at Peak WRRF Loading and 100,000 gpd at Average WRRF Loading	125,000	310,000	510,000	820,000
Blower and Aeration Grid Upgrade	100,000 gpd at Peak WRRF Loading	415,000	845,000	775,000	1,620,000

[1] *Indirect cost includes contingency.*

The following assumptions have been made for the development of the opinion of probable cost and are listed below:

- The location for proposed equipment does not require significant site preparation (e.g., major earthwork, blasting, dewatering, or stormwater management) and has sufficient structural integrity to accommodate the proposed equipment (e.g., no piling or special subsurface improvements required).
- The facility has adequate space for construction of the proposed equipment.
- The facility has sufficient electrical power for new process equipment. Additional power distribution, transformers, or substations are outside the scope of this estimate.
- Standby or spare blowers are not included in addition to those that the facility may already have.
- The existing aeration pipe size is adequate for increased air flow rate.
- Aeration grid upgrade includes demolition of existing aeration diffusers, lateral and header piping.
- Process equipment pricing is based on budgetary quotes. Quotes have not been collected for all equipment at this conceptual stage, and prices for these items (not supported by vendor quotes) are based on prices factored from previous projects.
- A building or structure to house the proposed equipment is not included.
- Site and civil improvements are not required for the proposed equipment; and service utilities such as potable water, instrument air, plant air, and electricity are not required.
- Includes a 30 percent contingency.

The following allowances were made in the development of this estimate for known but undefined work:

- Purchased equipment installation (6 to 14 percent of total equipment cost)
- Instrumentation and controls equipment and installation (18 to 36 percent of total equipment cost)
- Process piping (16 to 60 percent of total equipment cost)
- Electrical systems and installation (10 to 35 percent of total equipment cost)
- Structural (e.g., housekeeping pads, pipe supports, stairs) (18 to 25 percent of total equipment cost)

Appendix F: Capacity Evaluation for Leachate Treatment of Newport POTW Technical Memorandum

Brown AND Caldwell

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Technical Memorandum

Prepared for: Casella Waste Systems, Inc.

Project Title: New England Waste Services of Vermont (NEWSVT) Landfill-Leachate Evaluation

Project No.: 152990.009

Technical Memorandum

Subject: Capacity Evaluation of the City of Newport Wastewater Treatment Facility

Date: October 3, 2019

To: Ken Robbins, Casella Waste

From: Brown and Caldwell

Prepared by: Everett Gill

Everett Gill

Reviewed by:

Kevin Torrens

Reviewed by: Stephen J. McGuire

STEPHEN JOHN MCGUIRE
10-3-19
NO. 134331

Stephen J. McGuire, PE
VT PE# 018.0134331

PE's Clarification: Cost estimates provided in Section 3.1 are provided for Casella's use but are not engineering instruments of service and are therefore excluded from my responsible charge.

Table of Contents

List of Tables

Section 1: Background

Brown and Caldwell (BC) is assisting Casella Waste Systems, Inc. (Casella) with an evaluation of leachate disposal alternatives and treatment technologies at the New England Waste Services of Vermont (NEWSVT) Landfill in Coventry, Vermont. As part of that evaluation, the City of Newport wastewater treatment facility (WWTF) was evaluated in order to determine the ability of this facility to receive additional leachate from NEWSVT.

Table 1-1 provides a summary of the leachate characteristics from NEWSVT and used in this evaluation.

Table 1-1. NEWSVT Leachate Characteristics

Parameter	Current	Projected
Flow, gpm	50,000	100,000
BOD_5, lbs/day	340	621
COD, lbs/day	984	2,295
TKN, lbs/day	367	846

BOD_5 = 5-day biochemical oxygen demand

COD = chemical oxygen demand

TKN = Total Kjeldahl Nitrogen

gpm = gallons per minute

lbs/day = pounds per day

Section 2: Newport Wastewater Treatment Facility

The potential capacity and limiting factors for the City of Newport WWTF (herein referred to as Newport WWTF) to accept additional leachate were evaluated.

2.1 Treatment Facility Summary

The Newport WWTF consists of screening, grit removal, two primary clarifiers, activated sludge treatment basins, secondary clarifiers, chlorine disinfection, and solids handling (gravity thickening and anaerobic digestion). Leachate treatment is provided by the activated sludge process which is comprised of the following major equipment:

- Four 92,400-gallon aeration tanks (369,600 gallons total)
  - Fine bubble diffusers
  - Three centrifugal blowers (one capable of supplying 800 standard cubic feet per minute [SCFM] and two capable of supplying 950 SCFM each)
- Two 54-foot diameter secondary clarifiers with 13-foot side water depth

2.2 Influent Loading

Newport WWTF provided influent flows and loading data for June 1, 2018 to February 28, 2019. Table 2-1 provides a summary of the data. The evaluation is based on this limited available data that was provided and considers the existing treatment plant design basis capacity as the point of reference for determining additional available capacity.

Table 2-1. Newport Influent and Effluent Flows and Loading (June 1, 2018 to February 28, 2019)

Parameter	Average	95th Percentile	Maximum
Newport Influent			
Flow, MGD	0.54	0.69	1.18
BOD_5, lbs/day	1,220	1,570	1,660
TSS, lbs/day	1,405	2,635	2,640
Newport Effluent			
BOD_5, lbs/day	22.6	49.2	107
TSS, lbs/day	27.8	70.1	79.9

MGD = million gallons per day

TSS = total suspended solids

2.3 Effluent Limits

The National Pollutant Discharge Elimination System effluent limitations for the Newport WWTF are provided in Table 2-2.

Table 2-2. Newport Effluent Limits

Parameter	Monthly Average	Weekly Average	Maximum Day	Instantaneous Max
Flow, MGD	1.3	--	--	--
BOD_5, lbs/day	300	450	--	--
BOD_5, mg/L	30	45	50	--
TSS, lbs/day	300	450	--	--
TSS, mg/L	30	45	50	--
Settleable Solids, mL/L	--	--	--	1.0
Total Residual Chlorine, mg/L	--	--	--	0.1
Escherichia coli, count/mL	--	--	--	77/100

mg/L = milligrams per liter

count/mL = counter per milliliter

The Newport WWTF effluent BOD_5 and TSS effluent is currently well below the allowable discharge permit loading.

2.4 Plant Capacity

The Newport WWTF provided documentation of the plant capacity in the document “City of Newport Wastewater Treatment Facility Upgrade/Expansion, Basis for Final Design, October 2004” prepared by Forcier Aldrich & Associates. The plant capacity for influent hydraulics and organic loading are listed in Table 2-3.

Table 2-3. Newport Influent Hydraulic and Organic Loading Basis of Design

Parameter	Design
Flow (Average Daily), MGD	1.30
Flow (Peak Daily), MGD	2.71
Flow (Peak Hourly)	3.25
BOD_5, lbs/day	3,253
TSS, lbs/day	2,927
Total Phosphorus, lbs/day	65

This design influent loading is before the primary clarifiers where 33 percent of the influent BOD_5 and 66 percent of the influent TSS is expected to be removed. Therefore, the BOD_5 capacity in the activated sludge basin is 2,180 lbs/day and TSS capacity is 966 lbs/day.

2.4.1 BOD Removal Capacity

The Newport WWTF has four, 0.37 million-gallon aeration basins. A fine bubble aeration system, which includes 165 diffusers, is installed in each tank. There are two 75 horsepower (HP) and one 60 HP centrifugal blowers. The reported oxygen supply is 1.2 lbs oxygen (O_2) per pound of BOD_5 removed at a reported 2,180 lbs BOD_5/day after primary treatment for a total oxygen transfer capacity of 2,616 lbs O_2/day. The design organic loading rate is 44 lbs BOD_5/1,000 cubic feet (ft^3) of aeration volume (close to that of a typical design standard of 40 lbs BOD_5/1,000 ft^3).

An increase in treatment capacity beyond the design values would likely require the construction of additional aeration basins or an increase in current oxygen transfer in the existing basins. However, an increase in aeration in the existing basins will further increase the design loading beyond the equivalent of 40 lbs BOD/1,000 ft^3. Each aeration basin currently can provide 654 lbs O_2/day (total of 2,616 lbs O_2/day). This is enough oxygen to treat 40,800 gallons per day (gpd) leachate and influent wastewater from other sources under average Newport WWTF influent loading conditions and up to 22,100 gpd leachate under Newport WWTF peak day loading conditions.

2.4.2 Clarification Capacity

The Newport WWTF has two 54-foot clarifiers that have a 13-foot side water depth. The reported clarification capacity is provided in Table 2-4.

Table 2-4. Clarification Capacity of the Newport WWTF

Parameter	Design
Surface Overflow Rate	
Design Average Surface Overflow Rate, gpd/ft^2	284
Design Peak Surface Overflow Rate, gpd/ft^2	710
Design Basis Overflow Rate, gpd/ft^2	<900
Solids Overflow Rate	
Design Peak Solids Loading Rate, lbs/day/ft^2	34
Design Basis Solids Loading Rate, lbs/day/ft^2	<50

gpd/ft^2= gallons per day per square foot

lbs/day/ft^2= pounds per day per square foot

The facility design peak hydraulic and solids loading rates are less than the design flows and loading. With 100,000 gpd of leachate, the HLR and SLR will still be below design capacity indicating clarification capacity will not limit loading at the facility.

2.4.3 Solids Handling

The solids handling processes consist of gravity thickening and anaerobic digestion. The solids handling system has sufficient capacity since the facility is designed for the provided oxygen demand for complete BOD_5 removal based on the loads evaluated. Sludge production is primarily tied to removal of BOD_5. Because biomass that provides nitrification exhibits a lower sludge yield compared to the same oxygen demand for BOD_5 removal, the total solids generated would be less than the design capacity.

2.4.4 Disinfection

The impact on the disinfection process is expected to be minimal due to the use of chlorination (in lieu of ultraviolet disinfection as used at the Montpelier WRRF). Accordingly, leachate will not adversely impact disinfection efficiency since UV disinfection is not used at Newport. If complete nitrification of the ammonia in the leachate does not occur, the chlorine demand will increase approximately 7.6 milligrams per milligram of ammonia in the effluent.

2.5 Leachate Capacity

Leachate treatment capacity at the Newport WWTF is limited by oxygen transfer rather than other potential bottlenecks including clarification, sludge dewatering or disinfection. The oxygen demand of the leachate is based on leachate characteristics, BOD_5 removal, and nitrification of ammonia. The oxygen demand was developed during the Montpelier wastewater resource recovery facility (WRRF) evaluation and determined to be 28.2 lbs O_2/1,000 gallons leachate. The total oxygen demand exerted by the current average and peak Newport WWTF loading, as well was the additional leachate volume to reach the maximum available oxygen transfer capacity at Newport WWTF is estimated in Table 2-5. The available oxygen transfer is 2,616 lbs O_2/day.

Table 2-5. Oxygen Demand and Available Casella Leachate Volume

Parameter	Average Newport Loading	Peak Newport Loading
Current Newport WWTF Oxygen Demand, lbs O_2/day	1,464	1,992
Casella Leachate Flow to Reach 2,616 lbs O_2/day Oxygen Demand, gpd	40,800	22,100

As provided in the table, based on current flows and loadings, the Newport WWTF can currently provide treatment of up to 40,800 gpd of Casella leachate during average loading at the Newport WWTF and 22,100 gpd Casella leachate during peak loading at the Newport WWTF. In order to treat 50,000 gpd of leachate, another aeration basin of 92,400 gallons will be required to meet oxygen transfer needs at the current average Newport loading and aeration basins with a capacity of 184,800 gallons would be required at current peak Newport loading. In order to treat 100,000 gpd of leachate, 277,200 gallons of additional aeration basin capacity will be required for current average Newport loading and 369,600 gallons of additional aeration basin capacity would be required for current peak Newport loading. Note that additional aeration system including aeration header, diffusers, and blower is required to provide oxygen to each additional aeration basin. The estimated additional oxygen demand requirement and corresponding blower sizes is summarized in Table 2-6.

Table 2-6. Leachate Treatment Capacity at Newport WWTF

Leachate Treatment Capacity at WWTF, gpd	Additional Oxygen Transfer Required, lb O_2/day	Estimated Additional Blower Capacity, HP
50,000 gpd at Average WWTF Loading	260	40
50,000 gpd at Peak WWTF Loading	787	80
100,000 gpd at Average WWTF Loading	1,670	120
100,000 gpd at Peak WWTF Loading	2,197	160

Section 3: Conclusions

BC evaluated the activated sludge treatment capacity at the Newport WWTF based on the City of Newport Basis for Final Design and current loading. That review indicated treatment capacity for receiving additional leachate is limited by oxygen transfer as noted above. Table 3-1 demonstrates the currently available leachate treatment capacity at the Newport WWTF based on the current loadings.

Table 3-1. Leachate Treatment Capacity at Newport WWTF

	Leachate Flow
	(gpd)
Leachate Capacity at Average Newport Loading	40,800
Leachate Capacity at Peak Newport Loading	22,100

In order to treat 50,000 gpd of leachate, another aeration basin of the same size as the existing aeration basins (92,400 gallons) with approximately 40 HP additional blower capacity will be required to meet oxygen transfer needs at the current average Newport WWTF loading and twice that volume (184,800 gallons) with approximately 80 HP additional blower capacity would be required at current peak Newport WWTF loading. In order to treat 100,000 gpd of leachate, three times that volume (277,200 gallons) with approximately 120 HP additional blower capacity will be required for current average Newport WWTF loading and four times that volume (369,600 gallons) with approximately 160 HP additional blower capacity would be required for current peak Newport WWTF loading. Note that there may be limited space available to expand the plant for acceptance of additional leachate volume above that identified in Table 3-1. It may be possible to increase the aeration in the existing basins, resulting in fewer required new basins. However, the capacity of the existing aeration transfer equipment was not provided so this option was not able to be evaluated.

Existing clarification, solids handling, and disinfection facilities are adequate to handle the maximum allowable leachate volume as defined by available aeration capacity. These processes are also adequate to accommodate the full current leachate volume of 50,000 gpd or the future leachate volume of 100,000 gpd.

Table 3-2 demonstrates required upgrades for additional treatment capacity to accommodate additional leachate discharge assuming no increase in loading at the Newport WWTF from other sources.

Table 3-2. Required Upgrades at Newport WWTF to Treat Casella's Leachate

Leachate Treatment Capacity at WWTF, gpd	Upgrades
50,000 gpd at Average WWTF Loading	One additional 92,400 gal aeration basin and 40 HP additional blower capacity
50,000 gpd at Peak WWTF Loading	Two additional 92,400 gal aeration basins and 80 HP additional blower capacity
100,000 gpd at Average WWTF Loading	Three additional 92,400 gal aeration basins and 120 HP additional blower capacity
100,000 gpd at Peak WWTF Loading	Four additional 92,400 gal aeration basins and 160 HP additional blower capacity

3.1 Class 5 Opinion of Probable Costs

The opinion of probable costs to implement the upgrades noted in Table 3-1 are summarized in Table 3-3. The opinion of cost consists of an AACE Class 5 estimate with an expected accuracy range of -50 percent to +100 percent around the opinion of probable cost and is based on experience from other facilities. A Class 5 estimate is performed when engineering is conceptual and is used to prepare planning level cost scopes or to evaluate alternatives in design conditions.

Table 3-3. AACE Class 5 Opinion of Probable Cost

Upgrade	Leachate Treatment Capacity	Total Equipment Cost	Direct Cost Subtotal	Indirect Cost Subtotal[1]	Opinion of Probable Cost
	gpd	($)	($)	($)	($)
One additional aeration basin and 40 HP blower	50,000 gpd at Average WWTF Loading	265,000	333,000	972,000	1,570,000
Two additional aeration basin and 80 HP blower	50,000 gpd at Peak WWTF Loading	530,000	665,000	1,945,000	3,140.000
Three additional aeration basin and 120 HP blower	100,000 gpd at Average WWTF Loading	795,000	1,000,000	2,795,000	4,590,000
Four additional aeration basin and 180 HP blower	100,000 gpd at Peak WWTF Loading	1,060,000	1,330,000	3,730,000	6,120,000

[1] *Indirect cost includes contingency.*

The following assumptions have been made for the development of the opinion of probable cost and are listed below:

- The location for proposed equipment does not require significant site preparation (e.g., major earthwork, blasting, dewatering, or stormwater management) and has sufficient structural integrity to accommodate the proposed equipment (e.g., no piling or special subsurface improvements required).
- The facility has adequate space for construction of the proposed equipment.
- The facility has sufficient electrical power for new process equipment. Additional power distribution, transformers, or substations are outside the scope of this estimate.
- Standby or spare blowers are not included in addition to those that the facility may already have.
- The existing aeration pipe size is adequate for increased air flow rate.
- Process equipment pricing is based on budgetary quotes. Quotes have not been collected for all equipment at this conceptual stage, and prices for these items (not supported by vendor quotes) are based on prices factored from previous projects.
- A building or structure to house the proposed equipment is not included.

- Site and civil improvements are not required for the proposed equipment; and service utilities such as potable water, instrument air, plant air, and electricity are not required.
- Includes a 30 percent contingency.

The following allowances were made in the development of this estimate for known but undefined work:

- Purchased equipment installation (6 to 14 percent of total equipment cost)
- Instrumentation and controls equipment and installation (18 to 36 percent of total equipment cost)
- Process piping (16 to 60 percent of total equipment cost)
- Electrical systems and installation (10 to 35 percent of total equipment cost)
- Structural (e.g., housekeeping pads, pipe supports, stairs) (18 to 25 percent of total equipment cost)